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Bureau of Economic Geology

E. H. Sellards, Director

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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of Democracy, and while guided and controlled by virtue, the noblest attribute of man. It is the only dictator that freemen acknowledge, and the only security which freemen desire.

Mirabeau B. Lamar

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CONTRIBUTIONS TO GEOLOGY, 1939

Part 1

CRINOIDS FROM THE UPPER CARBONIFEROUS AND PERMIAN STRATA IN TEXAS

R. C. Moore and F. B. Plummer

INTRODUCTION

It was initially the intention of the authors of this report to prepare descriptions and accompanying illustrations for a small number of Pennsylvanian crinoids, evidently new to science, that in the course of several years of general collecting of fossils had been found in Texas and Kansas. The total number of these specimens, including examples of already described species, was less than one hundred, and, of course, the number of species represented was considerably smaller—probably less than twenty. As careful studies of the specimens and of the literature on crinoids were undertaken, special efforts were made to collect additional material. Largely as a result of personal field work, but also in some instances aided very importantly by other collectors, the available paleontological material has been expanded almost unbelievably in two years. At the present time (March, 1939), upwards of 6,000 dorsal cups and crowns of Upper Carboniferous and Lower Permian crinoids have come into our hands. This fact indicates that crinoids are much more common in rocks of this age than has been generally recognized. The great abundance and variety of fragmentary crinoidal remains in marine rocks of late Paleozoic age in the central United States, and the known value of crinoids as guide fossils in Lower Carboniferous and other horizons, leads to the expectation that this group of fossils, when adequately known, may have much value in stratigraphic correlation of Pennsylvanian and Permian beds. The original plan of publication of a paper dealing with Texas and Kansas crinoids has been abandoned. The large number of newly acquired specimens from Kansas and adjoining states remains largely untouched, although some of this material is utilized in connection with the present study. Work on the Texas crinoids has had the objective of finding new lines

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of paleontologic comparison with deposits of the northern Mid-Continent region and more distant districts.

Acknowledgment is made gratefully to many friends and co-workers who have contributed directly and indirectly to the development of the present study. In several instances this aid has been of such outstanding importance, that a simple statement of indebtedness seems hardly sufficient, yet to the persons who have thus helped in large degree, as to all who have aided, we can merely express very sincere appreciation.

Specimens that furnish basis for descriptions and illustrations in this report, aside from those collected by ourselves, include, first, the notable collection of dorsal cups and crowns of crinoids from the Millsap Lake formation of Parker and Hood counties belonging to Mrs. G. D. Harris, of Waco, Texas, and the similarly fine collection from the same beds belonging to Mrs. W. R. Marrs, of Austin, Texas. To the kindness of these friends in loaning specimens for our study, and to Dr. Gayle Scott, of Texas Christian University, Fort Worth, who discovered the Kickapoo Falls crinoid zone near the Parker-Hood county line and who generously donated several fine crinoid cups and crowns, is due knowledge of this especially interesting assemblage of Texas crinoids, containing several genera and species that are not yet known elsewhere. Other specimens of Texas crinoids made available to us were collected by Dr. Charles Laurence Baker, College Station, Texas; Mr. I. J. Broman, Austin, Texas; Mr. Monroe G. Cheney, of Coleman, Texas; Dr. Robert Cuyler, of The University of Texas, Austin; Mr. Gordon Fisher, of The University of Texas, Austin; Mr. Ralph King, of Wichita Falls, Texas; Mr. Carl Chelf, of the Texas Memorial Museum, Austin, Texas; Mr. Wallace Lee, of Lawrence, Kansas; Prof. L. A. Nelson, of the College of Mines and Metallurgy, El Paso, Texas; Mr. W. T. O'Gara, of Texas Christian University, Fort Worth, Texas; Mr. John Skinner, of Midland, Texas; and Mr. Hugo Wolfe, of Stephenville, Texas. Aiding Mr. Moore on a trip to outcrops of the Cibolo limestone in Presidio County, west Texas, in April, 1938, crinoids were collected by Mrs. Lilian B. Moore, Mr. John Skinner, and three University of Kansas students, Mr. John D. Ewers, Mr. Fred Holden, and Mr. Bruce Latta. Also, several specimens of Marble Falls limestone crinoids from the Rough Creek locality, southeast of San Saba, recorded as collected by Charles Schuchert, A. W. McCoy, and D. K. Greger, were furnished by Dr. Carl O. Dunbar, of Peabody Museum, Yale University. We are thankful to all of these who have contributed to the essential materials of our study.

Hardly less important than the Texas crinoids, which constitute the special object of this study, is availability of as complete and reliable information as possible concerning already described genera and species of crinoids that correspond more or less closely to the Texas forms. Through the coöperation of various colleagues, opportunity has been afforded for study of the type specimens of almost all the Upper Carboniferous and Permian crinoid species; the types of a few species have been lost, or we have been unable to locate them. Much the most important single group of crinoid types, loaned for our study, is that of Walker Museum, at the University of Chicago; besides numerous species of Miller and Gurley, those described by Stuart Weller from the Lower Permian rocks of west Texas are represented in the Walker Museum types. We are grateful to Dr. Carey Croneis, of the University of Chicago, for the privilege of access to these specimens and opportunity to re-study the west Texas crinoids, which were collected by Dr. J. A. Udden, for many years Director of the Bureau of Economic Geology at The University of Texas. Type specimens in the Springer collection of crinoids at the U.S. National Museum have been studied, and through kindness of Dr. Ray S. Bassler, plastotypes of many species have been procured. Similar facilities at the Harvard Museum of Comparative Zoology, at Cambridge, Massachusetts, have been given by Dr. Percy E. Raymond. Dr. A. H. Sutton, of the University of Illinois, and Dr. M. M. Leighton, Chief of the Illinois Geological Survey, have aided in securing loan of types from the University of Illinois, Geological Survey, and Illinois State Natural History Museum. Other type specimens have been loaned by Dr. I. P. Tolmachoff, of the Carnegie Museum, Pittsburgh, Pennsylvania; Mr. Edward Butts, of the Public Library Museum, Kansas City, Missouri; Dr. A. K. Miller, of Iowa State University, Iowa City, Iowa; Dr. L. R. Laudon, University of Tulsa, Tulsa. Oklahoma; and Dr. J. E. Carman, of Ohio State University, Columbus, Ohio.

Many Upper Carboniferous and Permian crinoids from localities outside of Texas have been studied in connection with work on the Texas crinoid faunas, and some of these Oklahoma, Kansas, and

Missouri forms are included in this report because of their bearing on the Texas study. Persons who have collected or made available varying numbers of specimens that have been included directly or indirectly in the present work should be acknowledged, and we give them sincere thanks. This group of friends includes: Dr. G. E. Abernathy, of the Kansas Geological Survey, Pittsburgh, Kansas; Mr. E. L. Banion, Marcelline, Missouri; Dr. J. W. Beede, Spencer, Indiana; Dr. C. C. Branson, Providence, Rhode Island; Mr. Arthur Bridwell, Baldwin, Kansas; Dr. H. A. Buehler, State Geologist of Missouri, Rolla, Missouri; Mr. A. C. Carpenter, Ottawa, Kansas; Dr. G. E. Condra, State Geologist of Nebraska, Lincoln, Nebraska; Mr. John D. Ewers, Caney, Kansas; Mr. C. L. Foster, Norman, Oklahoma; Mr. Allen Graffham, Ottawa, Kansas; Mr. Frank C. Greene, of the Missouri Geological Survey, Kansas City, Missouri; Mr. J. M. Jewett, of the University of Kansas, Lawrence, Kansas; Dr. J. Harlan Johnson, of the Colorado School of Mines, Golden, Colorado; Dr. Don B. Gould, of Colorado College, Colorado Springs, Colorado; Mr. J. B. Kleihege, Kansas City, Missouri; Dr. L. R. Laudon, of the University of Tulsa, Tulsa, Oklahoma; Mr. A. R. Loeblich, of the University of Chicago, Chicago, Illinois; Mr. Paul McGuire, Fairfax, Oklahoma; Mr. Vernon May, Lawrence, Kansas; Dr. N. D. Newell, of the University of Wisconsin, Madison, Wisconsin; Mr. H. C. Price, Ottawa, Kansas; Mr. Frank Replogle, Topeka, Kansas; Mr. Ralph Rose, Havre, Montana; Mr. Bob Stevens, Gorham, Kansas; Mr. Ben Taylor, Tulsa, Oklahoma; Mr. Lyman Terry, Lawrence, Kansas; Mr. John Waugh, Kansas City, Missouri; Dr. J. M. Weller, of the Illinois Geological Survey, Urbana, Illinois; and Mr. James Wright, Edinburgh, Scotland.

A great deal of painstaking labor in editorial handling of the manuscript has been contributed by Mrs. Helen Jeanne Plummer, and this, together with aid in attack on certain taxonomic problems, is very much appreciated. Mr. Gyles Mulliken photographed most of the specimens that are illustrated, some being photographed by Mr. Moore with aid of Mr. Oren Bingham.

Dr. E. H. Sellards, Director of the Bureau of Economic Geology, has encouraged the preparation of this study because of appreciation of its prospective usefulness in application to practical stratigraphic problems, as well as interest in adding to knowledge of a group of Texas fossils that has previously been almost unknown.

Thanks are expressed to him for stenographic and other aid furnished by the Bureau, and for facilitating publication. Acknowledgment is also made to the graduate research fund of the University of Kansas for assistance of several sorts in carrying forward studies of fossil crinoids.

The photographic illustrations have been retouched by Mr. Moore, and he has personally prepared most of the drawings.

GENERAL CHARACTER OF CRINOIDS

Crinoids are invertebrate animals that have existed in the sea from Cambrian times to the present. Like their close relatives, the sea-urchins and star-fishes, they live only in salt water, but unlike these free-moving dwellers on the sea bottom, most crinoids are fixed by a stalk and thus superficially resemble a rooted plant. The name crinoid is derived from the Greek word *crinon,* a lily, and denotes the rather striking resemblance of these interesting animals to a delicate lily. A popular name that is sometimes used instead of sea-lily, is feather-star, which calls attention to the radiating main arms and their innumerable branchlets, each main arm or ray suggesting the structure of a feather. Most Carboniferous crinoids consisted of a cup-like body or calyx about three-quarters of an inch in diameter, having five or more flexible arms resembling somewhat the petals of a lily, and a long slender stem or stalk having a root-like base, which served to anchor the animal to the sea bottom (fig. 1). A few Carboniferous crinoids were not attached to a stem and were free to float or swim through the water.

Modern crinoids have a cup, made up of a series of plates and covered by a calcareous or leathery cover known as the tegmen, and slender, flexible, feather-like arms. The part covered by the tegmen is known as the upper, or ventral, surface, and the part attached to the stem is the lower, or dorsal, surface. The mouth is at the center of the upper surface and may open through the tegmen or lie beneath it. Five food grooves, radiating from the mouth, extend to the arms and continue along their upper or inner surface as branching canals that reach to all their extremities. The food grooves in some crinoids are covered by small plates, which serve as protective coverings. Food passes down the grooves, through the mouth, into an esophagus, and thence to the stomach, which is located within the cup. Waste products pass out through an intestine and are expelled through an anal opening which may be located in an inter-radius within the circle of the arms, or elevated on a tube or proboscis that rises from the tegmen and that may extend above the arms. The side of the cup on which the anal vent is located, or on which one or more extra plates are introduced in the upper circlet, is designated as posterior, and the opposite side is anterior. If the posterior side of a crinoid cup is held so that it is toward the observer, the left and right sides of the cup correspond in position to his own left and right. Individual plates may be specified according to occurrence in a particular circlet, of which there are three in most Carboniferous crinoids, and according to their position in the circlet, as for example, left anterior basal, or right posterior radial.

PRINCIPAL PARTS OF FOSSIL CRINOIDS

The hard parts of a crinoid, which are preserved as fossil remains, consist of the root system, the stem, the calyx (dorsal cup and tegmen, including the anal tube, if one is present), and the arms (fig. 1). The calyx and arms, which together form the crown, constitute the frame work, body, and food-gathering system of the crinoid. The dorsal cup of most Carboniferous crinoids consists of three circlets of plates, in upward order from the stem attachment, called the infra-basals (IBB), basals (BB), and radials (RR), arranged as shown in figure 2. Additional plates, known as anal plates, may be intercalated between the radials, partly separating the basals. The anal plates vary in number up to three or more in different genera; in some crinoid cups no anal plates are present. Depending chiefly on their relative positions, the anal plates are designated as radianal (RA), first tube plate or anal x, right tube plate (rt), and left tube plate (lt), as illustrated in figure 2.

The arms also are made up of a series of plates, termed brachials (Br), which are given individual names (fig. 3), as follows:

Primibrachs (IBr)—all plates from the radials to and including the first plate that functions to form the base of two branching arms.

Secundibrachs (IIBr)—all plates above the primibrachs up to and including the plate that functions to form the base of a second branching of arms.

Tertibrachs (IIIBr)—all plates above the secundibrachs, although quartibrach (IVBr) and higher divisions may be differentiated in occasional descriptions.

Arm plates are arranged either uniserially or biserially, as illustrated in figure 3.

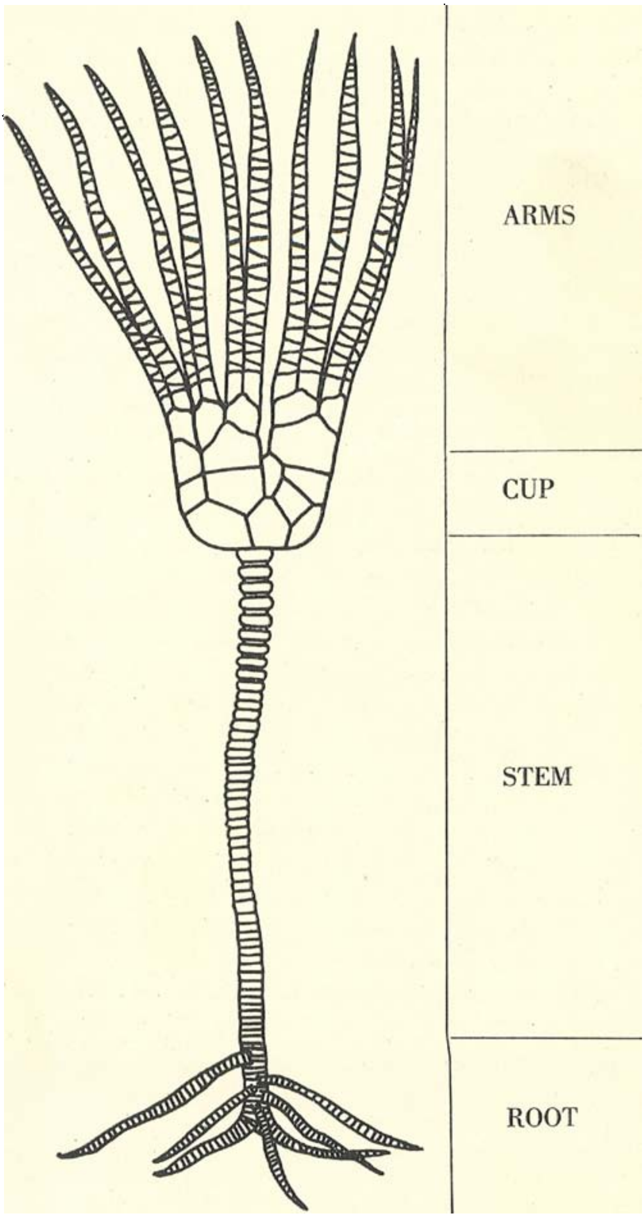

Fig. 1. Diagrammatic sketch of an Upper Carboniferous crinoid illustrating the major parts of its structure.

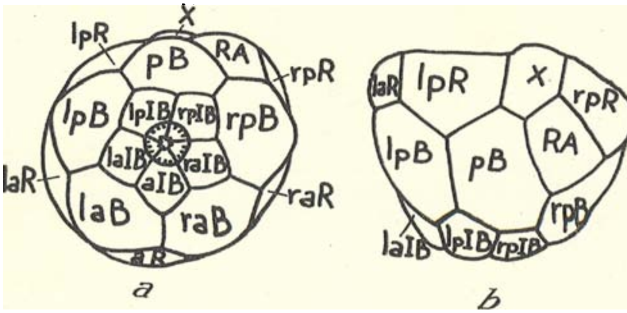

Fig. 2. Diagrammatic views of the dorsal cup of a Carboniferous crinoid showing the terminology of the plates. *a*, Dorsal view; *b*, posterior view.

lpIB, left posterior infrabasal	raB, right anterior basal
rpIB, right posterior infrabasal	lpR, left posterior radial
raIB, right anterior infrabasal	rpR, right posterior radial
laIB, left anterior infrabasal	laR, left anterior radial
aIB, anterior infrabasal	raR, right anterior radial
pB, posterior basal	aR, anterior radial
rpB, right posterior basal	x, anal x
lpB, left posterior basal	RA, radianal
laB, left anterior basal	

TERMINOLOGY IN CRINOID DESCRIPTIONS

A large number of terms have been used in descriptions of crinoids in addition to the principal ones already mentioned. Most of these terms are to be found in the textbooks on paleontology by Zittel,[1] Berry,[2] Davies,[3] Shimer,[4] Swinnerton,[5] Twenhofel and Shrock,[6] and Clark.[7] The more useful terms have been arranged alphabetically and defined below for the convenience of readers who do not have textbooks available. The terms that are most commonly needed in descriptions of Carboniferous crinoids and used in this report are printed in heavy type. For some of the most

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[1]Zittel, K. A., Text book of paleontology: English Ed., translated and edited by C. R. Eastman, The Macmillan Co., New York, pp. 124–177, 1900, 2d edition. pp. 173–243, 1913.

[2]Berry, E. W., Paleontology: McGraw-Hill Book Co., New York, pp. 60–69, 1929.

[3]Davies, A. Morley, An introduction to paleontology: Thos. Murby and Co., London, pp. 240–255, 1920.

[4]Shimer, H. W., An introduction to the study of fossils: The Macmillan Co., New York, pp. 206–210, 1933.

[5]Swinnerton, H. H., Outlines of paleontology: Edward Arnold and Co.. London, pp. 129–145, 1923.

[6]Twenhofel, W. H., and Shrock. R. R., Invertebrate paleontology: McGraw-Hill Book Co., New York, pp. 172–190, 1935.

[7]Clark, A. H., Sea-lilies and feather-stars: Smithsonian Misc. Coll., vol 72, no. 7, pp. 4–10, 1921.

common terms, it is both convenient and economical of space to use a standard set of letter symbols that has been devised. These are included in the list.

GLOSSARY OF DESCRIPTIVE TERMS

Adsutural platform—see Interfacet area.

Adsutural slope—see Interfacet area.

Ambulacra—grooves on arms and pinnules, lined with cilia, by aid of which food is conveyed to the mouth.

Ambulacral plates—small plates in two rows along the ambulacral groove.

Ambulacral grooves—see ambulacra.

Anal plates—extra plates introduced between the arms, the radials, or the basals, or all three and associated with the anal sac. See Radianal (RA), Anal x, Right tube plate (rt).

Anal sac—an outgrowth of rounded, tubelike, conical or mushroom-like form from the tegmen of a crinoid that encloses part of the gut and that generally carries the anal vent at its top or side. It may be formed partly of plates that are bordered by prominent pores or slits.

Anal tube—see Anal sac.

Anal x—the lowest tube plate of the anal series, generally, but not in every species, occurring in the dorsal cup between the two posterior radials and resting against the tip of the posterior basal (fig. 2). Where the radianal plate (RA) is present, anal x occurs above it at the left.

Anterior (a)—refers to position in the crown or dorsal cup; the side opposite to the posterior, which is that where the anal vent in the cup or anal plates occur; for example, anterior radial (aR), or in combination with right (r) or left (l), as right anterior radial (raR).

Arms—the movable rows of articulated plates extending outward or upward from the rim of the dorsal cup, carrying food grooves (fig. 1). They may be branched or unbranched.

Axial canal—central vertical tube extending through the columnals or stem segment; the cross-section of the canal may be circular, pentagonal, or stellate in form.

Axillaries (Ax)—bifurcating plates of the arms which give rise to the successive orders of branches. An axillary primibrach (IAx) is the first plate above a radial that is followed immediately by two branches; an axillary secundibrach (IIAx) is the first plate above an axillary primibrach that is followed immediately by two branches; and an axillary tertibrach (IIIAx) is the first plate above an axillary secundibrach that is followed immediately by two branches.

Basals (BB)—plates that adjoin the radials in the next lower circlet of the dorsal cup, alternating with them, in interradial position (fig. 2). An individual basal plate (B) may be designated by indicating its relative position in this circlet, as posterior basal (pB) or right anterior basal (raB).

Basal plane—the plane that is tangent to the base of the dorsal cup. Measurements of the height of a dorsal cup or crown are vertical distances upward from this plane.

Base—that part of the dorsal cup adjacent to the column. It may be composed of one or two rings of plates.

Biserial—an arrangement of the arm segments in which the plates or joints interlock from opposite sides (fig. 3). Biserial arms are generally uniserial in their lowest few plates.

Brachials (Br)—plates making up the dorsal or outer side of the arms (fig. 3); a convenient collective term for arm segments generally.

Calyx—the hard parts of a crinoid exclusive of the arms and stem. It includes the dorsal cup and the tegmen, together with the anal or ventral sac, if present. The principal parts of the calyx of a crinoid, of a type such as occurs in the Upper Carboniferous and Permian rocks of Texas, are illustrated in figures 2 and 3.

Central pit—see Facet.

Cirri—small branches attached to the stalk or stem. They are similar in form to the stem but smaller.

Column—the stem.

Columnal—stem segment.

Costals—a term sometimes used for the first brachial plates following the radials; equivalent to primibrachs, which is a preferred term.

Cover plates—a paired series of plates which cover and protect the food grooves.

Crinoid—name of a class of echinoderms, meaning lily-like. The word is derived from the Greek *crinon,* lily, and *eidos,* form.

Crown—crinoid without the stem, that is, the calyx and arms.

Cup—see Dorsal cup.

Dicyclic—crinoids that have two circlets of plates in the base, that is, below the radials. These circlets are called basals (BB) and infrabasals (IBB), the latter being lowermost.

Distal—in a direction away from the center of the stem impression at the base of a crinoid cup, which means outward and upward as regards plates of the dorsal cup and arms, and downward as regards segments of the stem. This term is the opposite of proximal.

Distichals—arm plates or brachials of the second order, secundibrachs.

Dorsal cup—the part of the calyx below the free arms (fig. 1).

Dorsal surface—lower or outer surface of the crinoid cup and arms.

Endotomous—a type of branching in crinoid arms in which two diverging main arms of each ray give off lesser branches only toward the inner side of the ray.

Exotomous—a type of branching in crinoid arms that is opposite to endotomous, the main arms being located centrally in each ray and giving off lesser branches toward the two sides.

Facet—the articulating surface, with straight or curved margins, between the radial and brachial plates; they are variously marked by grooves and ridges. Terms that apply chiefly to the facets of radial plates in a majority of Upper Carboniferous and Permian crinoids are illustrated in figure 4 and defined below, in groups corresponding to the three main subdivisions of the facet.

1. **Outer ligament area**—portions of the facet lying on the outer, or dorsal, side of the transverse ridge. It is generally depressed in a furrow and is wide but short, containing the following:
   - **Ligament pit**—a relatively deep, sharply bounded excavation centrally located at the inner border of this area, next to the transverse ridge.
   - Ligament pit furrow—the shallow groove between the median ridge and transverse ridge, its mid-portion containing the ligament pit.
   - Marginal furrow—the shallow furrow between the median ridge and outer marginal ridge.
   - **Marginal ridge**—the outer edge of the outer ligament area, separating the facet from the nonarticular surface of the radial plate.
   - Median ridge—a faint elevation that divides the outer ligament area into two subequal parts, subparallel to the transverse ridge.
2. **Transverse ridge**—the prominent, generally sharp-crested elevation that extends from one lateral margin of the facet to the other near its outer edge. It is commonly marked by minute teeth, or denticles, normal to its axis.
3. **Inner ligament area**—the part of the facet lying between the transverse ridge and the edge of the body cavity, containing the following:
   - **Central pit**—a shallow depression, commonly subtriangular in outline, located at mid-length of the transverse ridge on its inner side.
   - **Intermuscular furrow**—a narrow groove with trend normal to that of the transverse ridge, dividing the areas of muscle attachment.
   - **Intermuscular notch**—a V-shaped indentation of the inner edge of the facet dividing the muscular areas.
   - Intermuscular ridge—in some crinoids a ridge, instead of a furrow, divides the muscular areas.
   - Lateral lobe—the inward projection of the edge of the facet in form of a rounded point adjacent to the sutures between the plates.
   - **Lateral ridge**—an elevation trending nearly parallel to the sutures along lateral margins of the facet.
   - **Muscular area**—a subtriangular space, sometimes marked by parallel furrows, for muscle attachment, located near the inner margin on each side of the intermuscular furrow or ridge.
   - **Oblique furrow**—a groove trending slightly oblique to the transverse ridge from each of the outer angles of the inner ligament area toward the central portion; these furrows are for attachment of ligaments, and frequently they are marked by denticles.
   - **Oblique ridge**—an elevation parallel to each oblique furrow on its inner side.

First anal plate—see Anal x.

Food grooves—trough-like depressions on the upper or ventral surface of the arm plates.

Fossa—a term equivalent to furrow or groove, most commonly used for designation of the portions of the facet.

Heterotomous—Crinoid arms having unequal branches.

Infraradial—lower half of a radial plate that is bisected transversely.

Infrabasals (IBB)—plates of the lowest circlet in the dorsal cup (fig. 2) of crinoids having three circlets in the cup (dicyclic); an individual infrabasal plate (IB) may be indicated by referring to its position, as right posterior infrabasal (raIB).

Inner ligament area—see Facet.

Interbrachials (iBr)—plates between the arms, confined chiefly to camerate and flexible crinoids.

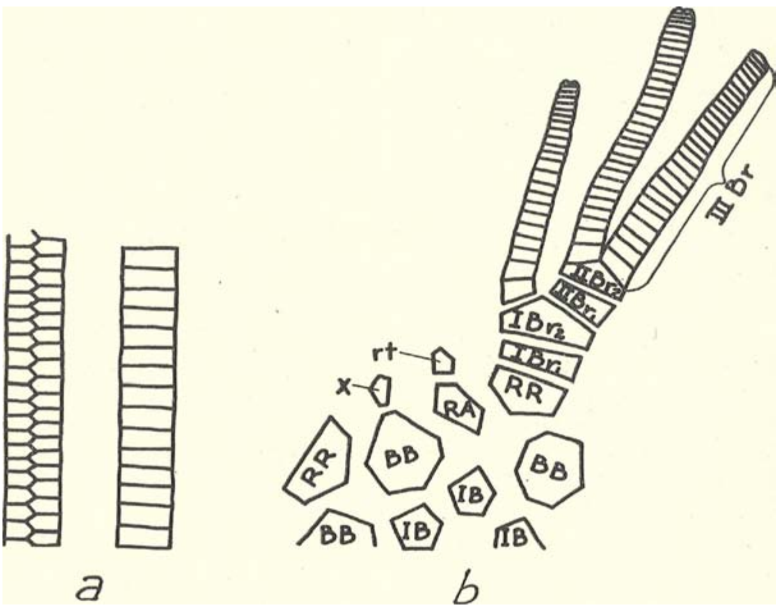

Fig. 3. Diagrammatic sketches showing: *a,* Two types of crinoid arm structure (biserial and uniserial). *b,* An arm and adjoining plates of the dorsal cup of a Pennsylvanian crinoid, with indication of terminology. The arm segments here shown are uniserial in arrangement, and the branching in the ray is of the heterotomous (unequal division) type. This is only one of the several types of arm structures that are seen in Pennsylvanian and Permian crinoids. IB, infrabasal; B, basal: R, radial: x, anal x, rt, right tube plate; IBr$_1$, IBr$_2$, first and second primibrachs; IIBr$_1$, IIBr$_2$, first and and second secundibrachs; IIIBr, tertibrachs.

Interfacet area—a space, generally narrow, along sutures at the top of radial plate between adjacent facets. In some forms this represents an inward extension of the outer face of the radial plate, but in others, though excluded as part of the facet, it is not exposed to the exterior. An interfacet area, where present, may be less than the length of the interradial suture at the top of these plates and it may include the following:

Adsutural platform—a relatively low, flat space of varying width, next to the interradial suture.

Adsutural slope—the inclined surface, generally speaking, between the crest of the lateral ridge and the edge of the adsutural platform or the suture between radial plates.

Intermuscular furrow—see Facet.

Intermuscular notch—see Facet.

Intermuscular ridge—see Facet.

Interradials—supplementary plates between radials and succeeding rays.

Interradii—radii halfway between the center lines of each ray.

Isotomous—crinoid arms that divide in branches of equal size; branching evenly.

Lateral lobe—see Facet.

Ligament area—see Facet.

Ligament pit—see Facet.

Lumen—central cavity in the stem segments.

Marginal furrow—see Facet.

Marginal ridge—see Facet.

Median ridge—see Facet.

Monocyclic—having only a single row of basal plates intervening between the radials and the stem.

Muscular area—see Facet.

Oblique furrow—see Facet.

Oblique ridge—see Facet.

Orals—five plates in interradial position that surround or cover the mouth.

Ossicles—calcareous segments or plates of which the crinoid skeleton is composed.

Outer ligament area—see Facet.

Palmars—arm plates of the third order; see tertibrachs.

Patina—the three circlets of plates in the dorsal cup, including radials, basals, and infrabasals.

Perradial—situated along the median line of the rays.

Perradii—radii drawn through the middle of each ray.

Pinnulate—arms having pinnules, each brachial generally bearing one pinnule.

Pinnules—minute branchlets at the sides of arms.

Posterior—the side of a crinoid which is marked by presence in the dorsal cup of the anal vent or by a plate or plates of the anal series.

Post-palmars—arm plates of the fourth and higher orders. Branches: quartibrachs, quinquebrachs, etc.

Primibrachs (IBr)—the brachial plates immediately above the radials up to the first bifurcation (figs. 2, 3).

Proximal—in a direction toward the center of the stem impression at the base of a crinoid cup, which means inward and downward as regards plates of the dorsal cup and arms, and upward as regards segments of the stem. This term is the opposite of distal.

Radials (RR)—the lowermost plates in direct succession of the rays, the five plates from which the arms arise (figs. 2, 3). They alternate in position with the basals and their upper face generally carries a facet for articulation with the first brachial. Any individual radial plate (R) can be designated by its position in the circlet, as, left anterior radial (laR).

Radianal (RA)—the plate which, if present, rests in the reëntrant angle of two adjoining basal plates to the right of the anal x plate (figs. 2, 3).

Rami—individual branches of an arm or ray, referring particularly to arms that branch only once.

Ray—a radial plate, together with all the structures which it bears.

Secundibrachs (IIBr)—brachials above the axillary primibrach plate (IAx) up to and including a second axillary plate (IIAx), if present, or otherwise to the end of the branch (figs. 2, 3).

Stalk—see Stem.

Stem—the elongate means of attachment of a crinoid, round, elliptical, or pentagonal in cross-section; same as stalk or column (fig. 1).

Stereom—cribwork of calcite composing the plates of crinoids.

Summit plane—the plane tangent to the transverse ridges of the three anterior radial plates, generally also tangent to the transverse ridges of posterior radials but not in all forms.

Superradial—upper half of a radial that is bisected transversely.

Suture—union of two adjacent plates or segments by connective tissue. It is termed a loose suture if the tissue lacks any calcareous deposit and there is room for some play between the plates; it is called a close suture if calcareous deposits serve to unite the plates immovably.

Tegmen—the cover above the dorsal cup, inside the bases of the free arms; sometimes also called *ventral disc, vault, dome* or *summit.*

Tertibrachs (IIIBr)—Brachials above the secundibrachs (fig. 3).

Transverse ridge—see Facet.

Uniserial—arrangement of segments in a crinoid arm in a single series, the joints or plates extending through to both sides of the arm (fig. 3).

Ventral sac—an upward prolongation of the posterior side of the tegmen in the form of a rounded dome, pyramid, tube, or mushroom-like structure; same as anal sac or tube.

Ventral surface—upper or oral surface.

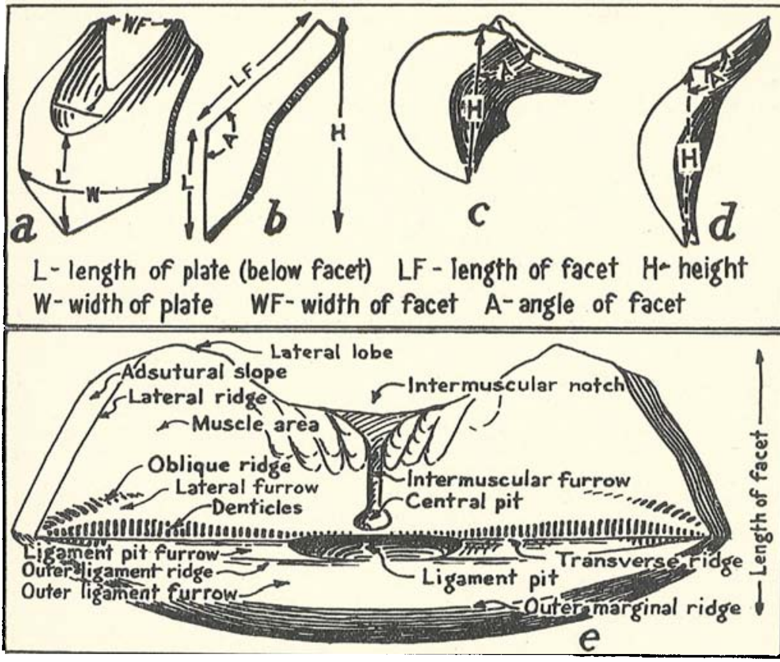

Fig. 4. Drawings showing the morphologic features of radial plates, especially the facet.

SIGNIFICANT MEASUREMENTS IN THE STUDY OF CRINOIDS

The size of fossil crinoid cups, like that of most other organisms, is to some extent of value in recognition of different species. More important than mere size, however, are relative dimensions and proportions such as may be determined from accurate measurement. Experience shows that comparative measurements are very useful in dealing with certain types of crinoid cup but not very significant in others. In any case uniformity of results or reliability in application of measurements demands that the manner in which a measurement is taken shall be uniform and clearly understood. For example, if the height of a dorsal cup is measured from the lowest point to the highest tip of a highly inclined facet or perhaps to the elevated summit of an anal series, the measurement is very different from that which is made to the margin of a radial facet, as must generally be the method where arms are in place above the radial plates. One set of measurements of the length and width of a basal plate may be obtained if a ruler is laid against the plate and its edges projected against the scale for reading; another slightly different set of measurements may be obtained with the use of calipers; and still other and materially larger results are obtained if the linear distance along the surface is measured in such a way as to include the curvature. Accurate illustrations at a given scale are the best records of many features, but some can not be given satisfactorily in this way, and then it is necessary to resort to measurements.

A general lack of precision and consistency in the definition of measurements of crinoids, recorded by previous authors, makes it worth while to include here explicit statements concerning the different elements of a crinoid cup that may be worthy of measurement, and of use, either directly or in terms of ratios, in comparative study. The following notes give such definitive statements concerning important measurements:

Basal plane (bp)—the plane tangent to the lowermost plates of the dorsal cup; defined by contact points of the cup (in normal position with the stem impression downward) as it rests on a flat surface. This plane may be tangent to the infrabasals (IBB), the basals (BB), or to the radials (RR).

Facet angle of radial plate (Fa)—vertical angle between horizontal plane tangent to transverse ridge and plane intersecting tips of lateral lobes of facet and transverse ridge, measured counterclockwise from horizontal plane for outward-sloping facets and regarded as positive, or clockwise from horizontal plane for inward-sloping facets and regarded as negative.

Facet length of radial plate (FL)—distance from lateral lobe or other innermost margin of facet to line paralleling transverse ridge tangent to outer marginal ridge of the facet and measured in the plane of the slope of the facet.

Facet length of inner ligament area of radial facet (FLia)—distance from lateral lobe or other innermost margin of facet to transverse ridge measured in the plane of slope of the facet in a direction normal to the transverse ridge.

Facet length of outer ligament area of radial facet (FLoa)—distance from transverse ridge to outer marginal ridge of facet at point of their widest separation, measured normal to the transverse ridge.

Facet width of radial plate (FW)—distance between lateral extremities of the transverse ridge.

Height of cup (H)—vertical distance between basal plane and summit plane of the dorsal cup.

Height of anal plate series (HA)—vertical distance from lowermost part of lowest anal plate to summit of uppermost plate of anal series in dorsal cup. In some forms, as in *Zeacrinus* and the hydreionocrinids, where additional plates of the anal series typically remain attached to the dorsal cup, although they are entirely above the cup, it may be deemed useful to record the height of the entire series (HA'), but a statement is then required to show the number of such additional plates included.

Height of anal plates below summit plane of cup (HA")—in some crinoids it is useful to designate the height of anal plate or plates below the summit plane of the cup. This may be defined as the vertical distance between the lowermost point of the lowest plate of the anal series and the transverse ridge of rpB.

Height of inner ligament area of facet (HFi)—vertical distance between transverse ridge and highest point of inner ligament area.

Height of outer ligament area of facet (HFo)—vertical distance between transverse ridge and lowest point of outer ligament area.

Height of anal sac (HAS)—vertical distance from summit plane of dorsal cup to summit of anal sac.

Height of basal plate (HB)—vertical distance from lowermost part of plate to uppermost part; height of posterior basal (HpB) is commonly slightly different from that of other basals (BB).

Height of proximal tip of basal (B) above basal plane of cup, (HB_1)—generally measured on the right anterior basal (raB).

Height of distal tip of basal (B) above basal plane of cup, (HB_2)—generally measured on the right anterior basal (raB). In a majority of Upper Carboniferous crinoids HB_2=HB.

Height of basal concavity (HBC)—vertical distance from basal plane of cup to base of stem impression. Designation of this feature as height rather than depth is preferred.

Height of crown (HC)—vertical distance from basal plane of cup to summit of arms. Height of arms and of arm segments is not regarded as needful of indication as distinct from length.

Height of facet (HF)—vertical distance from lowest point on facet (generally on outer marginal ridge) to highest point on facet (generally at lateral lobe on inner margin of facet).

Height of infrabasal plate (HIB)—vertical distance from lowermost part of plate to uppermost part. In down-flaring infrabasal circlets this vertical distance may be designated as negative height.

Height of radial plate (HR)—vertical distance from lowermost part of plate (generally the proximal tip) to summit plane of cup; generally measured on anterior radials (RR).

Height of proximal tip of radial (R) *above basal plane of cup,* (HR_1)—generally measured on the anterior radial (aR).

Height of greatest lateral bulge of radial (R) *above basal plane of cup,* (HR_2)—generally measured on the anterior radial (aR). Frequently this is the same as HR_3.

Height at midpoint of outer margin of outer ligament area of radial (R) *above basal plane of cup,* (HR_3)—generally measured on the anterior radial (aR). Commonly $HR_3 - HR_1 = HR$.

Height of line connecting lateral lobes of radial articular facet above basal plane of cup, (HR_1)—generally measured on the anterior radial (aR).

Height of stem impression (HS)—vertical distance from base of stem impression to adjacent surface of cup outside of this impression; a significant feature in some hydreionocrinids and other genera. From the standpoint of consistency this distance is better designated as height rather than depth.

Height of greatest width of cup (HW)—vertical distance of line of greatest width above basal plane of the cup. This may be significant character in bowl-shaped cups.

Length of basal plate (LB)—distance from proximal tip of basal plate to distal tip, measured to include curvature; this measurement refers to basals other than the posterior basal (pB) which, because of variation, is commonly specified separately (LpB).

Length of interbasal suture (LBB)—distance along suture between two adjoining basal plates. Because of asymmetry in the posterior part of a cup, measurement is generally based on basal plates other than posterior basal (pB) or the right posterior basal (rpB).

Length of basal-infrabasal suture (LBIB)—distance along suture between a basal plate and one of the adjoining infrabasal plates.

Length of infrabasal plate (LIB)—distance from center of stem canal to distal tip of infrabasal plate, measured to include angulation or curvature.

Length of interinfrabasal suture (LIBB)—distance along suture between any two adjoining infrabasal plates.

Length of radial plate (LR)—distance from proximal tip of radial plate to outer edge of outer ligament area, measured to include curvature.

Length of radial-basal suture (LRB)—distance along suture between a radial plate and one of the adjoining basal plates; one of the three anterior radials is used unless otherwise stated.

Length of interradial suture (LRR)—distance along suture between two radial plates from distal tip of a basal plate to edges of articular facets at their upper angles. In genera with facets less than width of radials, the interradial suture is regarded as continuing to the border of the body cavity.

Width of cup (W)—horizontal distance through widest part of the cup. Unless otherwise stated, this is measured along a line transverse to the antero-posterior axis, passing through or near the center of the stem impression.

Width of basal plate (WB)—greatest distance across basal plate, measured to include curvature, transverse to proximal-distal axis. This measurement refers to basals other than the posterior basal (pB) which, because of variation, is commonly specified separately (WpB).

Width of basal circlet (WBB)—greatest horizontal distance across the basal circlet (except through the right posterior basal). For convenience this is measured between distal extremities of the left posterior basal (lpB) and the right posterior basal (rpB).

Width of cup at points of contact with basal plane (Wbp)—unless otherwise stated, measured through radius of the right anterior basal (raB).

Width of infrabasal plate (WIB)—greatest distance across infrabasal plate transverse to proximal-distal axis.

Width of infrabasal circlet (WIBB)—greatest horizontal distance across infrabasal circlet. For convenience this is measured between distal extremities of the left anterior infrabasal (laIB) and the right anterior infrabasal (raIB).

Width of radial plate (WR)—greatest distance across radial plate, measured to include curvature, transverse to proximal-distal axis. This measurement, unless otherwise indicated, refers to anterior radials because the two posterior radials are frequently somewhat smaller than the others.

Width of radial circlet (WRR)—greatest horizontal distance across the radial circlet. Except in a few forms, such as *Dinocrinus,* this is the same as width of the cup (W.).

Width of stem impression (WS)—diameter of stem impression.

Width of cup at summit plane (Wsp)—horizontal distance across widest part of cup at summit plane; measured between points on transverse ridges of radial facets.

CLASSIFICATION OF CRINOIDS

General Discussion

Fossil crinoids are extremely varied. The dorsal cup may be the most prominent part of the organism, or only a small, seemingly unimportant assemblage of plates that serves to unite the arms and stem. The shape of the dorsal cup is almost spherical in some crinoids, like a deep bowl or a shallow basin in others, and low-, medium-, or high-conical in still others; also, the cup may be a very flat, discoidal structure, with a base that is convex or slightly to strongly concave. The upper (ventral) side of the cup may be solidly roofed with plates or roofed only by a leathery cover that disappears on fossilization of calcified parts of the skeleton. The upper surface is strongly elevated in some forms, as a rounded vault, tube, or mushroom-like growth that may rise even higher than the tips of the arms. The arms, too, exhibit wide variation in plan, although almost all are arranged in some sort of five-fold symmetry. They may fork in several ways, or not fork at all. The component segments of the arms may be quadrangular or wedge-shaped pieces arranged in a single row (uniserial), or they may appear as an interlocking double row (biserial) of plates. Small branchlets (pinnules) are present in some crinoids, but lacking in others. The stem may be round, elliptical, or pentagonal in cross-section and composed of thick or thin segments that are fairly uniform in character, or that consist of alternating dissimilar forms; at intervals there may be a stem segment that carries slender side branches (cirri), or these may be lacking. Also, there is a variation in the shape and relative size of the central canal that perforates the stem segments. Some types of crinoids are stemless, at least in the adult stage. Finally, ornamentation of many different sorts may be developed.

The almost endless differences in crinoid form and structure present a difficult but interesting problem from the standpoint of classification. It is not scientifically acceptable to base classification on arbitrarily selected characters that lack meaning as to real relationship. For example, a division of crinoids on the basis of shape of the stem, of the uniserial or biserial arrangement of the arm segments, or of the number of anal plates in the dorsal cup, would almost certainly lead to placing together types that are not related closely, and in separating many forms that actually have close kinship. The object of biologic classification in any class of organism is to be natural, in contrast to arbitrary and artificial, and this signifies an arrangement in groups that reflect genetic relationships. Divisions of different rank must define the greater and smaller groups that have developed in the course of evolutionary change during the life history of the whole assemblage. The geologic age of each different crinoid is a significant element to be considered in making effort to determine ancestral stocks and descendant lineages. If the course of evolution among crinoids can be traced correctly, and if characters of structure that are truly significant of this evolution are the basis of classification, the defined groups of different rank (species, genera, families, orders), will be natural, and the classification will be a phylogenetic one.

Knowledge of fossil crinoids is yet far from sufficient to permit classification that is entirely along demonstrable phylogenetic lines. Comprehensive classifications published by authorities such as

Wachsmuth and Springer,[8] Springer,[9] Bather,[10] Jaekel,[11] and Wanner[12] show agreement in many features but wide divergence in others. It is beyond the scope of this paper to discuss phylogenetic classification in a detailed or critical manner. Ability for such a task without much more study is lacking. It is desirable, however, to outline the character of the recognized main divisions of crinoids, to indicate the basis for definition of groups among Texas crinoids from Upper Carboniferous and Permian rocks, and to show the general classificatory position of these crinoids.

Main Divisions of Crinoids

Fossil and living crinoids can be divided into five groups that appear to define major lines of descent. The characters that distinguish each group are chiefly (a) the structure of the dorsal cup and (b) the nature of the union between the cup and the arms. Similarities in these features within the respective groups indicate a common origin of the crinoids so constituted, but considerable uncertainty exists as to the mode of origin of younger groups out of older ones. The five groups, or orders, are: Camerata, Adunata, Flexibilia, Inadunata, and Articulata.

1. The Camerata, or camerate crinoids, are characterized by the relatively large size of the dorsal cup, plates that are morphologically part of the arms, or rays, being incorporated in the cup, often with addition of interradial plates. Also, the cup is solidly covered above by a tegmen, consisting generally of many irregularly arranged plates. These crinoids thus resemble rather strikingly the undoubtedly more primitive, many-plated, sac-like class of echinoderms known as Cystoidea, which is probably the ancestral

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[8]Wachsmuth, Charles, and Springer, Frank, Revision of the Palæocrinoidea: Acad. Sci. Philadelphia, Proc. for 1879. The North American Crinoidea Camerata: Mus. Comp. Zool. (Harvard College), Mem., vols. 21, 22, 1897.

[9]Springer, Frank, Unusual forms of fossil crinoids: U. S. Nat. Mus., Proc., vol. 67, art. 9, pp. 1–137, pls. 1–26, 1926.

[10]Bather, F. A., A phylogenetic classification of the Pelmatozoa: British Assoc. Adv. Sci., Rept. for 1898, pp. 916–923, 1899. The Crinoidea: in Lankester's *Treatise on Zoology*, pp. 94–202, text figs. 1–127, 1900.

[11]Jaekel, Otto, Phylogenie und System der Pelmatozoen: Palaeont. Zeitschr., Bd. 3, pp. 1–128, 1918.

[12]Wanner, J., Die permischen Echinodermen von Timor, I: Paläontologie von Timor, Lief. 6, Teil II, pp. 1–329, pls. 96–114 (1–19), text figs. 1–88, 1916. Die permischen Krinoiden von Timor, II: Jaarb. Mijnw. Ned.-Indië, Verh. 1921 Gedeelte 3, pp. 1–348, pls. 1–22, text figs. 1–61, 1924. Neue Beiträge zur Kenntnis der permischen Echinodernen von Timor, VIII–XIII: Palaeontographica, Suppl., Bd. 4, Lief. 2, pp. 57–212, pls. 5–14, text figs. 1–32, 1937.

stock of all crinoids. The camerates are more regularly symmetrical than cystoids and they have more highly developed arms. The oldest known camerate crinoids have been found in Ordovician rocks. They attained maximum variety and numbers in early Carboniferous time and were represented by a few stragglers in late Carboniferous and Permian seas.

2. The Adunata comprise forms that are clearly derivatives of the camerates, with which it has been classed by some authors. The adunates, first known from Silurian beds, are distinguished from camerates by the fact that the arms are almost, but not quite, withdrawn as structural components of the dorsal cup and as immovably joined attachments of the tegmen. This group, like the camerates, was most abundant in early Carboniferous time, and was represented by only a few survivors in late Carboniferous and Permian time.

3. The Flexibilia, or flexible crinoids, are characterized by the ligamentous union between plates of the dorsal cup and by the freely mobile nature of the articulation of arm segments. Resemblance to the camerates is seen in the lack of sharp differentiation between dorsal cup and arms, for the lower parts of the arms are commonly joined together, often with accessory interradial plates, as in the camerates. The Flexibilia are an off-shoot of the Camerata, or perhaps of the Inadunata, that became differentiated in the direction of mobility of the test. Specialization is shown in the reduction of the number of plates in the lowest circlet (infrabasals) from the primitive complement of five to three, also in special features of the articulation between brachials. Flexible crinoids occur as fossils in Ordovician rocks and are found somewhat sparingly in each of the succeeding Paleozoic systems but not in younger rocks.

4. The Inadunata comprise a rather heterogeneous assemblage of crinoids that has in common a well-marked separation between the arms and the dorsal cup, that is, the arms are attached by articulation on the radial plates of the cup, without forming any part of the cup itself or being joined rigidly to the tegmen. One group of inadunates, called Larviformia, because of their small size and larviform appearance, is separated from the remainder, termed Fistulata. The order Inadunata is well represented by Ordovician fossils, and it includes much the largest number of known Upper Carboniferous and Permian crinoids. Except for

three Triassic genera this group disappeared at the close of Paleozoic time. It is not yet determined definitely whether the Inadunata or Camerata is the more primitive group.

5. The Articulata include all known Mesozoic and Cenozoic crinoids, omitting the lone surviving inadunates in Triassic strata just mentioned. The articulates resemble the inadunates most closely, but some of their features, such as the exposed mouth and food grooves, correspond to characters of the Flexibilia. The cup is almost perfectly pentamerous in symmetry, and the arms, composed of uniserial segments, are entirely free above the radials, to which they are joined by complete muscular and ligamentous articulation. This order is thought to have descended from the Inadunata. Crinoids of this order are found in rocks ranging in age from Triassic to Recent.

Subdivisions of Upper Carboniferous and Permian Crinoids

Nine-tenths of the genera and species of crinoids found in Upper Carboniferous and Permian rocks belong to the Inadunata, although each of the four Paleozoic orders of crinoids is represented. Taking account of all known crinoids of this age throughout the world, more than two-thirds belong to a single family of inadunates, called Poteriocrinitidae. Among Texas crinoids, the preponderance of this family is even more striking, for it includes nearly all the forms that are yet known. The number of poteriocrinitid genera is, moreover, so large that subdivision is urgently needed in order to form groups that are less unwieldy and that bring together genera having certain significant features in common. The characters to be used in such a subdivision should serve to mark out, in so far as possible, the lines of important evolutionary differentiation leading to recognition of subfamilies, and perhaps also to assemblages of genera that are lower in rank than a subfamily. It is not improbable that the so-called poteriocrinitids will ultimately be broken apart into a number of separate, though related, families, and some of these may be divided into subfamilies. The characters that are useful for recognition of related groups of poteriocrinitid genera are discussed in following paragraphs.

Significance of anal plates in the dorsal cup.—The number of anal plates in the dorsal cup is a character that has been used chiefly for subdivision of poteriocrinitids by some authors, and on this basis the following subfamilies have been proposed: (a) Poteriocrinitinae Wachsmuth and Springer, having three or two anal plates in the dorsal cup; (b) Graphiocrininae Bather, having one anal plate in the dorsal cup; and (c) Encrininae Austin, having no anal plate in the dorsal cup. It is easy to determine the number of anal plates in any poteriocrinitid cup, but there is now hardly room to doubt the conclusion that this character signifies merely the stage in an evolutionary trend witnessed in all branches of these crinoids. Indeed, Wanner[13] has shown that not only in certain genera but within the limits of certain single species the number of anal plates in the dorsal cup varies. Because of the presence in these genera and species of distinctive characters of other sorts, there can be no reasonable question as to their identification as natural assemblages of the rank indicated. Reduction in the number of anal plates belonging to the dorsal cup is a clearly recognizable evolutionary trend among widely divergent groups of crinoids. To use this as a basis of subdivision of the poteriocrinitids may be compared to cutting a tree into parts that include, respectively, the lower branches, the intermediate branches, and the terminal twigs. In order to simulate accurately the divergent orders, suborders, families, subfamilies, and genera of crinoids, it would be necessary to suppose that the tree, just mentioned, has no exactly similar main branches and that the lesser branches, twigs, and leaves differ among themselves. Classification on genetic lines would seek to divide this tree so that each main branch, with all attached lesser branches and twigs, is separated from its neighbors. The fact that neighboring main branches show similar sorts of change outward from the trunk means simply that different main stocks undergo a similar general nature of development.

Significance of number of infrabasal and radial plates.—Reduction in the number of infrabasal plates, ranging from five to three, or to one, and in some cases, reduction of radial plates, are valid features for differentiation of genera among poteriocrinitids. Such changes, however, are evidently not related to other characters, such as shape of the dorsal cup, nature of the ventral sac, or structure of the arms. A crinoid having five infrabasal plates is certainly less specialized in one type of evolutionary trend than

[13]Wanner, J., Die permischen Echinodermen von Timor: Palaeontologie von Timor, Lief. 6, Teil II, pp. 150, 208, 220, 1916. Die permischen Krinoiden von Timor: Jaarb. Mijnw. Ned.-Indie, Verh. 1921, Gedeelte 3, pp. 193, 254, 1924.

another having three infrabasals, and the latter is less advanced than a third form in which the infrabasal circlet is fused into a single plate. These three crinoids may have such similarity of form and other peculiarities as to establish very strong indication that they are genetically rather closely related, and thus to show that they mark successive evolutionary steps within a single subdivision of the poteriocrinitids. On the other hand, appearance of reduced number of infrabasals in different crinoids that have little resemblance except for this feature, may be regarded as demonstrating merely a similarity of trend in structural change that belongs to different subdivisions of poteriocrinitids. Unless associated with, and supported by, other structural evidences of relationship, reduction in numbers of infrabasals or radials is not to be accepted as a basis for definition of families or subfamilies.

Significance of arms and their articulation.—The Poteriocrinitidae are separated from other Inadunata mainly on the basis of evidence of the muscular articulation of the arms, since the radial facets bear a transverse ridge and paired muscle and ligament fossae, such as do not appear in other families of the order (except partly in the Glossocrinidae). Among the characters of the poteriocrinitids, the nature of the articular facets and the structure of the arms seem to furnish the soundest approach to a classification that has genetic significance. It is difficult briefly to demonstrate this in a satisfactory manner, but the conclusion is supported by observation of the persistence of these characters even though other features change, by judgment of relationships between different genera, and by study of the possibilities in evolutionary change. Attention is directed especially to characters of the articular facet on the radial plates, because such features as relative width and angle of slope appear to be rather definitely associated with certain forms of the dorsal cup that are deemed significant of membership in a given group. The facets have importance also because it is possible to observe them on most dorsal cups, or even on dissociated radials that are generically identifiable, whereas characters of the arms are yet unknown in many genera. Features of the facets and arms now appear to be the most useful as a basis for primary subdivision of the poteriocrinitids.

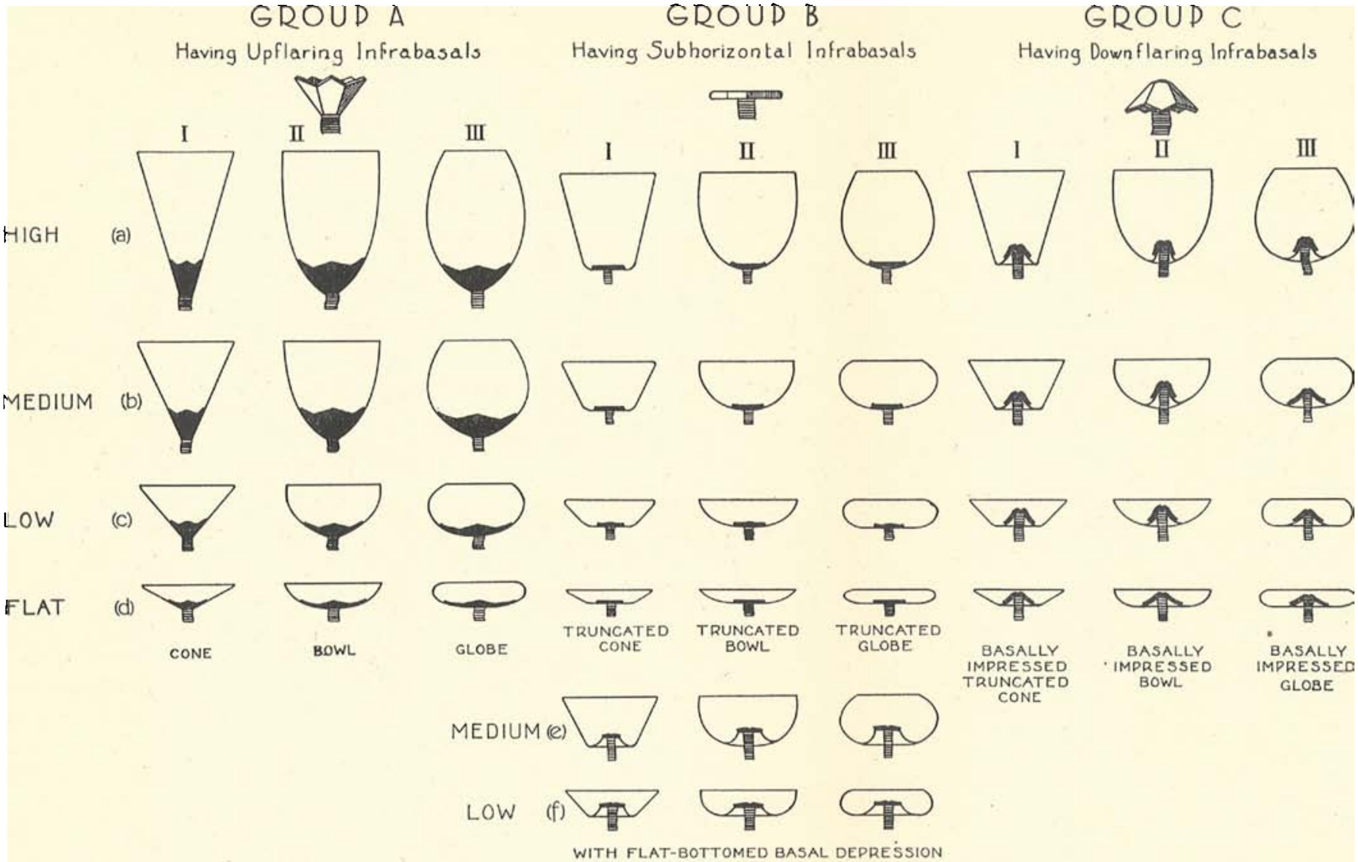
Significance of the form of the dorsal cup.—Designation of the form of the dorsal cup of a crinoid is generally made in terms of comparison to some object, such as cone, globe, bowl, basin, urn, or disc, that presumably is familiar to everyone. Obviously, most of these objects vary considerably in shape, and the words have a somewhat different significance to different people. One must find an illustration of the described fossil in order to learn exactly what is meant by terms that denote form. An effort has been made to classify the terms that signify forms of inadunate crinoids and to find a satisfactorily simple means of designating them. The relationship between form and the attitude of certain structural elements of the dorsal cup is also equally, or more, important in describing a crinoid than the shape, and an attempt has been made to analyze the relationship between shape and structure (fig. 5). Results of this study are as follows:

Subdivision of crinoid cups according to form

I. Base of cup convex, infrabasal plates (IBB) flaring upward, visible in side view of the cup.
  - A. Cone-shaped. Sides of cup flaring upward with essentially uniform slope from stem attachment; greatest width at summit of cup.
  - B. Bowl-shaped. Sides of cup flaring upward with slope near summit distinctly steeper than near stem attachment; greatest width at summit of cup.
  - C. Globe-shaped. Like bowl except that sides of cup curve distinctly inward near summit; greatest width below summit of cup.

II. Base of cup flat or concave, infrabasal plates (IBB) subhorizontal or flaring downward, not visible in the side view of cup.
  - A. Truncate cone-shaped. Side view of cup showing subhorizontal profile of base that is wider than stem, and regular upward-flaring sides; greatest width at summit of cup. If base is concave, the form may be designated as truncated cone with basal concavity.
  - B. Truncate bowl-shaped. Side view of cup showing subhorizontal profile of base that is wider than stem, and sides flaring upward with increased steepness near summit; greatest width at summit of cup. If base is concave, the form may be designated as truncated bowl with basal concavity.
  - C. Truncate globe-shaped. Side view of cup showing subhorizontal profile of base that is wider than stem, and sides flaring npward, then curving inward near summit; greatest width below summit of cup. If base is concave the form may be designated as truncated globe with basal concavity.

An examination of described genera of poteriocrinitids, supplemented by the study of some 6,000 specimens that have been available for study, shows that certain types of dorsal cups are



GROUP A—

I. Ascocrinus (b), Bursacrinus (c), Culmicrinus (c), Jahnocrinus (c), Moscovicrinus (b), Nassovicrinus (a), Ophiurocrinus (b), Poteriocrinites (a), Roemerocrinus (a), Spaniocrinus (c), Synyphocrinus (a), Springericrinus (b), Logocrinus (b), Catactocrinus (b), Glossocrinus (b), Liparocrinus (b), Charientocrinus (b), Corematocrinus (b), Morrowcrinus (b).

II. Agassizocrinus (a), Hydreionocrinus (c) Hydriocrinus (a), Scytalocrinus (a), Sinocrinus (c), Stuartwellercrinus (c), Ulocrinus (b), Ulrichicrinus (b), Woodocrinus (c).

III. Basleocrinus (b), Cromyocrinus (c), Indocrinus (b), Mollocrinus (b), Strongylocrinus (c), Sundacrinus (c), Tribrachiocrinus (b), Trimerocrinus (a).

GROUP B—

I. Abrotocrinus (e), Aulocrinus (b), Decadocrinus (b), Erisocrinus (a–e), Graphiocrinus (f), Thuringocrinus (c).

II. Sciadiocrinus (f), Aesiocrinus (e), Cibolocrinus (b), Lopadiocrinus (f), Malaiocrinus (e), Pachylocrinus (b), Parabursacrinus (f), Paraplasocrinus (f), Protencrinus (f), Stachyocrinus (f), Stemmatocrinus (b), ?Timorechinus (f), Zeacrinites (f), *Apollocrinus, (f), *Laudonocrinus (c), *Schistocrinus (c), Plaxocrinus (f), Xystocrinus (f).

III. Cadocrinus (b), Dicromyocrinus (b), Ethelocrinus (e, f), Eupachycrinus (e, ?b), Notiocrinus (f), Phanocrinus (f).

GROUP C—

I. (At present no known Upper Carboniferous genera in this group.)

II. Delocrinus (e, d), Paradelocrinus (c).

III. ?Delocrinus (c, d), Dinocrinus (b), Diphuicrinus (c), Paradelocrinus (c).

Fig. 5. Diagrams illustrating the different forms of dorsal cups in Upper Carboniferous crinoids. In Group A: High includes cups whose H/W = 1–0.5; Medium includes cups whose H/W = 1; Low includes cups whose H/W = 0.5–1; Flat includes cups whose H/W = 0.25–0.5. The asterisk (*) before generic names indicates new genera.

associated constantly with more or less clearly differentiated characters of articular facets on the radial plates. This seems to give basis for subdivision of the group along lines of genetic significance. Because many genera are yet imperfectly known, however, and because many that must exist have not been discovered, any present classification is to be regarded as very tentative.

The crinoids described in this report are arranged in order of their place among the major divisions, such as Camerata, Adunata, Flexibilia, and Inadunata, and according to families in each of these. Treatment of representatives of the family Poteriocrinitidae is arranged according to subdivisions on the basis of (a) nature of articular facets, (b) shape of the basal part of the dorsal cup, and subordinately (c) general form of the dorsal cup, and (d) number of anal plates in the dorsal cup. Structure of the arms, number of infrabasal plates, and number of arm-bearing radial plates are additional features of classificatory value in treatment of the family as a whole, but do not affect the plan of organization for the systematic part of this paper. The divisions of poteriocrinitids are indicated in the following tabulation that shows the distribution of Texas crinoids of Upper Carboniferous and Permian age in an abbreviated general classification.

CLASSIFICATORY POSITION OF TEXAS UPPER CARBONIFEROUS AND PERMIAN CRINOIDS

The following annotated table, based mainly on the classification of Wachsmuth and Springer, shows the chief divisions of crinoids, their geologic occurrence, and the place of genera that are known to be represented (marked by **) or likely to be found (marked by *) in the Upper Carboniferous or Permian formations in Texas.

Annotated list of crinoid divisions, indicating classificatory position of Texas Upper Carboniferous and Permian genera

Class CRINOIDEA Miller

I. Order CAMERATA Wachsmuth and Springer—Crinoids with dorsal cup composed partly of brachial plates (in line with radial plates and next above them), and generally of interradial plates, including an anal plate or series of plates at the posterior side; often termed "box crinoids" because of their relatively large, many-plated, subglobular or boxlike dorsal cup. *Ordovician to Permian.*

   1. Family CLIOCRINIDAE Wachsmuth and Springer—*Lower Ordovician.*

2. Family RETEOCRINIDAE Wachsmuth and Springer—*Middle and Upper Ordovician.*
3. Family DIMEROCRINITIDAE Bather—*Ordovicion to Devonian.*
4. Family RHODOCRINITIDAE Roemer—*Ordovician to Lower Carboniferous.*
5. Family MELOCRINITIDAE Zittel—*Ordovician to Devonian.*
6. Family EUCALYPTOCRINITIDAE Angelin—*Silurian and Devonian.*
7. Family BATOCRINIDAE Wachsmuth and Springer—*Ordovician to Lower Carboniferous.*

*8. Family ACTINOCRINIDAE Wachsmuth and Springer—Camerate crinoids with only three basals below circlet of radials, which are laterally in contact except at posterior side where an anal plate intervenes. Abundant in *Lower Carboniferous* of North America and Europe, and reported with several species from *Permian* of Timor, in the East Indies, but not known in Upper Carboniferous.

II. Order ADUNATA Bather—Crinoids with lower arm plates (brachials) so united to calyx as to prevent their mobility, but without definite incorporation of these plates in the dorsal cup, as in the camerates. *Silurian to Permian.*

**1. Family PLATYCRINITIDAE Roemer—Dorsal cup composed of three unequal basal plates and five large radials, laterally in contact all around. First known in *Silurian* rocks; some genera restricted to the *Devonian;* most abundant and characteristic in *Lower Carboniferous* deposits which have been thought generally to contain the last surviving members of the family. Wanner (1916, 1924, 1937) has described five genera of platycrinids from the *Permian* of Timor, however, and stem fragments that on the basis of distinctive elliptical cross-section are identified as belonging to this family are contained in available collections from *Upper Carboniferous* beds of the Mid-Continent region and the *Permian* of western Texas.

**a. Genus PLATYCRINITES Miller—Stem segments from the Wolfcamp formation, *Lower Permian,* western Texas; also from different horizons in the Pennsylvanian *(Upper Carboniferous)* of north-central Texas, Oklahoma, and Kansas. About nine other genera are included in the family, but none of these have yet been identified in post-Mississippian rocks in North America.

*2. Family HEXACRINITIDAE Wachsmuth and Springer—Essentially like the Platycrinitidae except that a large anal plate occurs between the posterior radials. Includes about eight genera, restricted to *Devonian* and *Lower Carboniferous* rocks except for reported occurrence of two genera in *Permian* strata of Timor; may possibly be represented in post-Mississippian beds of the Mid-Continent region.

*a. Genus CAMPTOCRINUS Wachsmuth and Springer—*Lower Carboniferous,* North America and Europe; *Permian,* Timor.

*3. Family ACROCRINIDAE Wachsmuth and Springer—Peculiarly retrogressive crinoids characterized by presence of a variable number of plates, sometimes very numerous, between the circlet of radials and the two basals.

*a. Genus ACROCRINUS Yandell—represented by a number of *Mississippian* species and at least three species from *Pennsylvanian* beds (Morrow and Des Moines) in Oklahoma, Arkansas, and Illinois.

III. Order FLEXIBILIA Zittel—Crinoids with plates of the calyx joined by muscular or ligamentous union, never rigidly connected; lower brachial segments generally incorporated in the dorsal cup; all known types have three unequal infrabasals; stem round, generally with very thin segments of greater diameter than lower parts of the stem occurring next to the dorsal cup. *Ordovician* to *Permian.*

A. Suborder SAGENOCRINOIDEA Springer—Flexibilia having a strong calyx, anal plates, when present, being partly or wholly incorporated in the calyx.

**1. Family LECANOCRINIDAE Springer—Infrabasal plates more or less upflaring, forming essential part of dorsal cup; crown generally short, rotund. Includes about 20 genera, ranging in age from *Silurian* to *Permian,* of which those occurring in post-Mississippian rocks are here listed.

**a. Genus CIBOLOCRINUS Weller—This genus was defined on the basis of specimens from the *Lower Permian* of western Texas. It has been emended recently (Moore and Plummer, 1938) to include only forms that correspond closely to the genotype species. The genus is now known to be represented by three species from *lower Pennsylvanian* (Morrow) rocks of northeastern Oklahoma, northwestern Arkansas, and Texas, as well as by undescribed species from *middle* and *upper Pennsylvanian* (Missouri, Virgil) in Oklahoma and Kansas. It is almost certain that specimens of *Cibolocrinus* will be found in middle and upper Pennsylvanian rocks of Texas, but none are present in the collections available for study.

*b. Genus LOXOCRINUS Wanner—*Permian,* Timor.

*c. Genus PETROCRINUS Wanner—*Permian,* Timor.

*d. Genus SYNTOMOCRINUS Wanner—*Permian,* Timor.

*e. Genus CALYCOCRINUS Wanner—*Permian,* Timor.

*f. Genus PLAGIOCRINUS Wanner—*Permian,* Timor.

*g. Genus PROPHYLLOCRINUS Wanner—*Permian,* Timor.

*h. Genus PROAPSIDOCRINUS Wanner—*Permian,* Timor.

*i. Genus ANCISTROCRINUS Wanner—*Permian,* Timor.

*j. Genus PALAEOHOLOPUS Wanner—*Permian,* Timor.

2. Family SAGENOCRINITIDAE Angelin—*Silurian to Lower Carboniferous.*

**3. Family ICHTHYOCRINIDAE Wachsmuth and Springer—Infrabasal plates horizontal, concealed by stem, in some forms absent because of resorption; crown generally elongate. Includes 11 genera, *Silurian* to *Permian*. Those occurring in post-Mississippian rocks are listed below.

*a. Genus AMPHICRINUS Springer—Typically developed in upper *Lower Carboniferous* rocks but represented at several horizons in *Upper Carboniferous* deposits of Oklahoma and Kansas.

**b. Genus SYNEROCRINUS Jaekel—*Lower Carboniferous* of Russia and *Upper Carboniferous* (Des Moines) of Texas.

*c. Genus TALANTEROCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous,* Russia and southern Oklahoma.

*d. Genus RUMPHIOCRINUS Wanner—*Permian,* Timor.

B. Suborder TAXOCRINOIDEA Springer—Flexibilia having a weak calyx; all anal plates separated from adjacent brachials.

1. Family TAXOCRINIDAE Angelin—*Ordovician to Lower Carboniferous.*

IV. Order INADUNATA Wachsmuth and Springer—Crinoids with arms freely mobile above the radials, no arm plates being incorporated in the dorsal cup; plates of the cup united by close suture. *Ordovician* to *Triassic.*

A. Suborder LARVIFORMIA Wachsmuth and Springer—Dorsal cup generally composed only of radials and basals, without anal plates; arms simple, each formed of a single row of quadrangular segments, lacking pinnules.

1. Family STEPHANOCRINIDAE Wachsmuth and Springer—*Ordovician* and *Silurian.*
2. Family PISOCRINIDAE Angelin—*Silurian* and *Devonian.*
3. Family ANAMESOCRINIDAE Goldring—*Devonian.*
4. Family HAPLOCRINITIDAE Roemer—*Devonian.*

*5. Family ALLAGECRINIDAE Etheridge and Carpenter—Calyx almost microscopic, with five basals and five irregular radials, some of which support two arms. Contains four genera. *Lower* and *Upper Carboniferous.*

**a. Genus ALLAGECRINUS Etheridge and Carpenter—Species of this genus are not uncommon in *Lower Carboniferous* beds, are known from at least three horizons in middle *Pennsylvanian* (Upper Carboniferous) (Des Moines, Missouri) rocks of Oklahoma and Kansas, and are found in the *Permian* of Timor. Specimens belonging to this genus have been collected from Cisco beds in Wise County, Texas, but they were found too late for inclusion in this paper.

*b. Genus CALLIMORPHOCRINUS J. M. Weller—*Lower Carboniferous* of Scotland and lower *Upper Carboniferous* of Indiana, Illinois, and Missouri; not yet reported from Kansas, Oklahoma, or Texas.

*6. Family SYNBATHOCRINIDAE Wachsmuth and Springer—Dorsal cup small, composed of three unequal basals and five nearly equal radials, which have upper edges evenly beveled to form straight articular facets. Contains four genera. *Devonian* to *Permian.*

*a. Genus SYNBATHOCRINUS Phillips—Well represented in *Devonian* and *Lower Carboniferous* beds and by a few species in the *Permian* of Timor.

7. Family CUPRESSOCRINITIDAE Roemer—*Devonian.*

B. Suborder FISTULATA Wachsmuth and Springer—Dorsal cup with or without infrabasals, anal plates generally present below summit of radials and commonly extending into a strong tube or sac that rises ventrally between the arms; arms simple or branching in various ways, composed of a single or double row of segments that bear or lack pinnules.

1. Family HYBOCRINIDAE Zittel—5 genera. *Lower Ordovician.*
2. Family HETEROCRINIDAE Zittel—16 genera. *Ordovician* and *Silurian.*
3. Family EUSTENOCRINIDAE Ulrich—1 genus. *Devonian.*
4. Family HOMOCRINIDAE Kirk—8 genera. *Devonian.*
5. Family ANOMALOCRINIDAE Wachsmuth and Springer—3 genera. *Ordovician.*
6. Family CALCEOCRINIDAE Meek and Worthen—6 genera. *Ordovician* to *Lower Carboniferous.*

*7. Family CATILLOCRINIDAE Wachsmuth and Springer—Contains 8 genera ranging from *Devonian to Permian,* of which 4 occur in the Permian but no representatives of the family have been reported from post-Mississippian rocks of North America. Undescribed representatives of this group have been found in the Morrow series, *Lower Pennsylvanian,* Arkansas.

8. Family BELEMNOCRINIDAE Wachsmuth and Springer—2 genera. *Lower Carboniferous.*
9. Family DENDROCRINIDAE Bather—11 genera. *Ordovician* and *Silurian.*
10. Family CROTALOCRINITIDAE Angelin—4 genera. *Silurian.*
11. Family CARABOCRINIDAE Bather—9 genera. *Ordovician* to *Devonian.*
12. Family PALAEOCRINIDAE Bather—5 genera. *Ordovician* to *Devonian.*
13. Family BOTRYOCRINIDAE Bather—25 genera. *Ordovician* to *Lower Carboniferous.*
14. Family GLOSSOCRINIDAE Goldring—4 genera. *Devonian.*

15. Family LECYTHOCRINIDAE Kirk—2 genera. *Devonian.*
16. Family GASTEROCOMIDAE Roemer—9 genera. *Devonian.*
*17. Family CYATHOCRINITIDAE Roemer—11 genera. *Silurian* to *Permian.* Dorsal cup with 3 or 5 infrabasals; articular facets on radials relatively narrow and horseshoe-shaped, without transverse ridge; only one anal plate which is in line with radials, or anal lacking.
    *a. Genus LECYTHIOCRINUS White—A rather rare crinoid but represented by more than 70 specimens from different horizons in the *Pennsylvanian (Upper Carboniferous)* rocks of Kansas and Oklahoma; also known from Illinois and is likely to be found in Texas.
    *b. Genus PILIDIOCRINUS Wanner—*Permian,* Timor.
**18. Family POTERIOCRINITIDAE Roemer—Dorsal cup containing infrabasal plates, with or without anal plate or plates, upper part of calyx commonly extended into a ventral sac; articular facets on radial plates containing a transverse ridge and depressions for muscles and ligaments; arms generally branching and bearing pinnules, composed of a single or double row of pinnule-bearing segments. This family, which contains by far the greatest number of Upper Carboniferous and Permian crinoids, contains genera ranging from *Devonian* to *Triassic.* The subdivisions of this large family, as here presented, may or may not prove to have taxonomic value, but they will serve for arrangement of descriptions in the systematic part of the report.

Section A. Poteriocrinitidae with articular facets very distinctly narrower than the width of the radials, the non-articular outer surface of the radials being extended on both sides of the facet to its inner edge.

Subsection A-1. Facets sloping very steeply outward, horseshoe-shaped.

Group a. Infrabasals flaring upward, visible from side.

Subgroup α. Cup cone-shaped; 3 anals in cup.

*a. Genus POTERIOCRINITES Miller—*Devonian* to *Permian.*

b. Genus SPRINGERICRINUS Jaekel—*Lower Carboniferous.*

Subgroup β. Cup globe-shaped; 1 or 2 anals in cup.

*a. Genus MOLLOCRINUS Wanner—2 anals; *Permian,* Timor.

*b. Genus STRONGYLOCRINUS Wanner—1 anal; *Permian,* Timor.

Group b. Infrabasals not flaring upward, not visible from side; cup truncate bowl-shaped; 1 to 3 anals in cup.

**a. Genus MALAIOCRINUS Wanner — 3 anals; *Upper Carboniferous* in Texas, *Permian* in Timor.

**b. Genus APOLLOCRINUS Moore and Plummer, n.gen.—3 anals; *Upper Carboniferous,* central United States.

*c. Genus CERATOCRINUS Wanner — 1 anal; *Permian,* Timor.

Subsection A-2. Facets sloping gently outward.

Group a. Infrabasals flaring upward, visible from side; cup cone-shaped; 1 to 3 anals in cup.

**a. Genus HAERETOCRINUS Moore and Plummer, n.gen.—3 anals; *Upper Carboniferous,* central United States.

b. Genus ROEMEROCRINUS Wanner—1 anal; *Permian,* Timor.

Group b. Infrabasals not flaring upward, not visible from side; cup truncate cone-shaped; 3 anals in cup.

*a. Genus DEPAOCRINUS Wanner—*Upper Carboniferous,* Oklahoma, and *Permian,* Timor.

Subsection A-3. Facets subhorizontal or sloping inward.

Group a. Infrabasals flaring upward, visible from side; cup angulated globular, 1 anal, 3 infrabasals, 3 or 4 arm-bearing radials.

*a. Genus INDOCRINUS Wanner — *Permian,* Timor.

*b. Genus PARINDOCRINUS Wanner — *Permian,* Timor.

Group b. Infrabasals not flaring upward, not visible from side; cup truncate bowl-shaped; 1 anal in cup.

**a. Genus APOGRAPHIOCRINUS Moore and Plummer, n.gen.—*Upper Carboniferous,* Texas, Oklahoma, Kansas. Missouri.

Section B. Poteriocrinitidae with articular facets equal or nearly equal to width of radials, the non-articular outer surface of radials extending only slightly, if at all, inward beyond transverse ridge of facet.

Subsection B-1. Facets sloping distinctly outward, either as a whole, or at least in the area of the lateral ridges bounding the facets.

Group a. Infrabasals flaring upward, visible from the side.

Subgroup α. Cup cone-shaped; 3 anals in cup.

a. Genus ALSOPOCRINUS Tansey—*Middle Devonian.*
b. Genus CERCIDOCRINUS Kirk—*Lower Carboniferous.*
c. Genus COREMATOCRINUS Goldring—*Upper Devonian.*
d. Genus COELIOCRINUS White—*Lower Carboniferous.*
e. Genus CULMICRINUS Jaekel—*Lower Carboniferous.*
f. Genus GILMOCRINUS Laudon—*Lower Carboniferous.*
g. Genus LOGOCRINUS Goldring—*Upper Devonian.*
*h. Genus MORROWCRINUS Moore and Plummer—*Upper Carboniferous* (Morrow series), Oklahoma.
*i. Genus MOSCOVICRINUS Jaekel—*Upper Carboniferous*, Russia.
*j. Genus OPHIUROCRINUS Jaekel—*Upper Carboniferous.*
**k. Genus SCYTALOCRINUS Wachsmuth and Springer—*Devonian* to *Upper Carboniferous;* represented by one species in the Marble Falls limestone of Texas.
*l. Genus ULRICHICRINUS Springer—*Upper Carboniferous* (Morrow series), Oklahoma.
*m. ?Genus MELBACRINUS Strimple—*Upper Carboniferous* (Missouri series), Oklahoma.

Subgroup β. Cup cone-shaped; 1 anal in cup.

a. Genus BURSACRINUS Meek and Worthen—*Lower Carboniferous.*
*b. Genus PHILOCRINUS de Koninck—*Permian,* India.
*c. Genus SYNYPHOCRINUS Trautschold—*Upper Carboniferous,* Russia, and *Permian,* Timor.

Subgroup γ. Cup truncate cone-shaped; no anal in cup.

*a. Genus SPANIOCRINUS Wanner—*Permian,* Timor, and (?) Texas.

Subgroup δ. Cup bowl-shaped; 3 anals in cup.

a. Genus HYDREIONOCRINUS de Koninck—*Lower Carboniferous.*

b. Genus WOODOCRINUS de Koninck—*Lower Carboniferous.*

Subgroup ϵ. Cup bowl-shaped; no anal in cup.

a. Genus JENAICRINUS Jaekel—*Triassic.*

*b. Genus SINOCRINUS Tien—*Upper Carboniferous,* China.

Group b. Infrabasals not flaring upward, not visible from side.

Subgroup α. Cup truncate cone-shaped; 3 anals in cup.

a. Genus ABROTOCRINUS Miller and Gurley—*Lower Carboniferous.*

b. Genus AULOCRINUS Wachsmuth and Springer—*Lower Carboniferous.*

c. Genus DECADOCRINUS Wachsmuth and Springer—*Lower Carboniferous.*

d. Genus LINOCRINUS Kirk—*Lower Carboniferous.*

**e. Genus PACHYLOCRINUS Wachsmuth and Springer—*Lower Carboniferous* to *Permian,* North America; includes new species from Texas.

**f. Genus TEXACRINUS Moore and Plummer, n. gen.—*Upper Carboniferous,* Texas.

Subgroup β. Cup truncate cone-shaped; 1 anal in cup.

**a. Genus BRYCHIOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous,* Texas.

*b. Genus SPHENISCOCRINUS Wanner—*Permian,* Timor.

*c. Genus EUERISOCRINUS Strimple—*Upper Carboniferous* (Missouri series), Kansas.

Subgroup γ. Cup truncate cone-shaped; no anal in cup.

**a. Genus ERISOCRINUS Meek and Worthen—*Upper Carboniferous* and *Permian*, North America and Timor.

Subgroup δ. Cup truncate bowl-shaped; 3 anals in cup.

**a. Genus AATOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous*, Texas, Oklahoma, and Kansas.

*b. Genus ADINOCRINUS Kirk—*Lower* and *Upper Carboniferous*, North America.

*c. Genus ALCIMOCRINUS Kirk—*Upper Carboniferous* (Morrow series) Oklahoma.

**d. Genus ATHLOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous*, Texas, Oklahoma, and Kansas.

e. Genus ERATOCRINUS Kirk—*Lower Carboniferous*.

**f. Genus LASANOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous* (Morrow series), Texas and Oklahoma.

**g. Genus LAUDONOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous*, Mid-Continent region, United States.

**h. Genus MARATHONOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous*, Texas.

**i. Genus NEOZEACRINUS Wanner—*Upper Carboniferous* of Kansas and Texas, *Permian*, Timor, and western Texas.

**j. Genus PERIMESTOCRINUS Moore and Plummer—*Upper Carboniferous*, Mid-Continent region, United States.

k. Genus PHANOCRINUS Kirk—*Lower Carboniferous*.

**l. Genus PIRASOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous* (Des Moines series), Texas.

**m. Genus PLAXOCRINUS Moore and Plummer—*Upper Carboniferous*, Mid-Continent region, United States.

**n. Genus SCHISTOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous,* Missouri, Kansas, Oklahoma. Texas.

**o. Genus SCIADIOCRINUS Moore and Plummer—*Upper Carboniferous,* Illinois and Mid-Continent region, United States.

p. Genus XYSTOCRINUS Moore and Plummer—*Lower Carboniferous.*

**q. Genus ZEACRINITES Troost—*Lower Carboniferous,* North America and Europe; *Upper Carboniferous,* Texas.

Subgroup ε. Cup truncate bowl-shaped; 1 anal in cup.

*a. Genus BENTHOCRINUS Wanner—*Permian,* Timor.

**b. Genus DELOCRINUS Miller and Gurley—*Upper Carboniferous* and *Permian,* United States and Timor.

**c. Genus ENDELOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous* and *Permian,* United States.

*d. Genus DIPHUICRINUS Moore and Plummer—*Upper Carboniferous* (Morrow series), Oklahoma.

**e. Genus GRAPHIOCRINUS de Koninck —*Lower Carboniferous* to *Permian.*

*f. Genus PARABURSACRINUS Wanner —*Permian,* Timor.

*g. Genus PARAPLASOCRINUS Moore and Plummer—*Permian,* Timor.

*h. Genus PROLOBOCRINUS Wanner—*Permian,* Timor.

*i. Genus TIMORECHINUS Wanner—*Permian,* Timor.

Subgroup ζ. Cup truncate bowl-shaped, no anal in cup.

a. Genus ENCRINUS Schultze—*Triassic.*

*b. Genus LOPADIOCRINUS Wanner—*Permian,* Timor.

*c. Genus NOTIOCRINUS Wanner—*Permian,* Timor.

**d. Genus PARADELOCRINUS Moore and Plummer—*Upper Carboniferous,* Mid-Continent region, United States.

e. Genus PARENCRINUS Wanner—*Triassic.*

*f. Genus PROTENCRINUS Jaekel—*Lower Carboniferous* to *Permian,* Europe and Timor.

*g. Genus STACHYOCRINUS Wanner—*Permian,* Timor.

*h. Genus STEMMATOCRINUS Trautschold—*Upper Carboniferous,* Russia.

Subsection B-2. Facets horizontal, including area of lateral ridges, generally broad and nearly plane.

Group a. Infrabasals flaring upward, visible from the side.

Subgroup α. Cup cone-shaped; 3 anals in cup.

*a. Genus HYDRIOCRINUS Trautschold—*Upper Carboniferous,* Russia.

Subgroup β. Cup cone-shaped; 1 anal in cup.

**a. Genus STUARTWELLERCRINUS Moore and Plummer—*Permian,* Texas.

Subgroup γ. Cup bowl-shaped; 2 or 3 anals in cup.

a. Genus AGASSIZOCRINUS Owen and Shumard—*Lower Carboniferous.*

**b. Genus ULOCRINUS Miller and Curley—*Upper Carboniferous,* Mid-Continent region, United States, and *Permian,* western Texas.

Subgroup δ. Cup bowl-shaped; 1 anal in cup.

**a. Genus PARAGASSIZOCRINUS Moore and Plummer, n. gen.—*Upper Carboniferous,* Mid-Continent region, United States.

*b. Genus PETSCHORACRINUS Yakovlev—*Permian,* Russia.

Subgroup ε. Cup globe-shaped; 3 anals in cup.

*a. Genus CROMYOCRINUS Trautschold—*Lower* and *Upper Carboniferous,* Russia and United States.

*b. Genus TRIBRACHIOCRINUS McCoy—*Upper Carboniferous,* Australia.

Subgroup ζ. Cup globe-shaped; 1 anal in cup.

*a. Genus BASLEOCRINUS Wanner—*Permian,* Timor.

*b. Genus PARAGRAPHIOCRINUS Wanner—*Permian,* Timor; *?Lower Carboniferous,* North America.

*c. Genus SUNDACRINUS Wanner—*Permian,* Timor.

Group b. Infrabasals not flaring upward, not visible from the side.

Subgroup α. Cup truncate globe-shaped; 2 or 3 anals in cup.

*a. Genus DICROMYOCRINUS Jaekel—3 anals; *Lower Carboniferous,* North America; *Upper Carboniferous,* North America, Russia.

**b. Genus EUPACHYCRINUS Meek and Worthen—3 anals; *Lower Carboniferous; Upper Carboniferous* (Morrow) of Texas.

**c. Genus SELLARDSICRINUS Moore and Plummer, n. gen.—3 anals; *Upper Carboniferous,* Texas.

**d. Genus ETHELOCRINUS Kirk—2 anals; *Upper Carboniferous,* United States.

**e. Genus PARULOCRINUS Moore and Plummer, n. gen.—2 anals; *Upper Carboniferous,* central United States.

Subsection B-3. Facets sloping inward.

Group a. Infrabasals flaring upward, visible from the side.

Subgroup α. Cup globe-shaped; 3 anals in cup.

*a. Genus TRIMEROCRINUS Wanner—*Permian,* Timor.

Subgroup β. Cup angulated globe-shaped; 1 anal in cup.

*a. Genus DINOCRINUS Wanner—*Permian,* Timor.

Group b. Infrabasals not flaring upward, not visible from the side.

Subgroup α. Cup truncate bowl-shaped; 1 anal in cup.

**a. Genus AESIOCRINUS Miller and Gurley—*Upper Carboniferous,* Mid-Continent region, United States.

Subgroup β. Cup truncate globe-shaped; 1 anal in cup.

*a. Genus CADOCRINUS Wanner—*Permian,* Timor.

Section C. Poteriocrinitidae uncertainly placed because dorsal cup unknown.

*a. Genus JONKEROCRINUS Wanner—*Permian,* Timor.

*b. Genus STEREOBRACHICRINUS Mather—*Upper Carboniferous* (Morrow series), Arkansas and Oklahoma.

**19. Family HYPOCRINIDAE Wanner—Mostly very small crinoids with 1 to 3 infrabasals, and in several genera a reduced number of radials, facets round and narrow, anal vent commonly through side of dorsal cup; represented by 26 genera ranging from *Lower Carboniferous* to *Permian,* of which only one is yet reported from Texas.

**a. Genus COENOCYSTIS Girty—*Permian,* Texas and Timor.

V. Order ARTICULATA Miller—Crinoids characterized by nearly perfect pentamerous symmetry, with open mouth and food grooves, arms composed of uniserial segments, joined to dorsal cup by complete muscular articulation. *Triassic* to *Recent.* Includes all modern crinoids.

STRATIGRAPHIC OCCURRENCE OF TEXAS UPPER CARBONIFEROUS AND PERMIAN CRINOIDS

Complete specimens of crinoids are extremely rare in the Upper Carboniferous and Permian strata in Texas. During twenty years of collecting by the authors less than fifty complete crinoid specimens from Texas have been found or seen in the collections of others. Dorsal cups are somewhat more common, although by no means plentiful. Diligent search for two or three hours in the better localities will generally bring to light two or three crinoid cups. The specimens on which this report is based, obtained partly through the aid of interested friends, includes some two hundred examples only of complete cups or crowns. The variety of the forms represented, however, indicates that the Texas crinoid faunas are probably as rich as those of the northern Mid-Continent area, from which the Upper Carboniferous and Lower Permian specimens available for study are nearly five thousand in number. Extensive field work in Texas directed especially towards search for additional crinoid material, will not fail to add to numbers of already known species, probably giving needed information concerning stratigraphic distribution, and it is likely that many other new forms will be found. In referring to the material now obtained from Texas, particular mention is to be made of a collection of Lower Permian specimens from Presidio County in west Texas, gathered some thirty-five years ago by Dr. J. A. Udden, former director of the Bureau of Economic Geology. These were described by Dr. Stuart Weller,[14] and the types, made available through the courtesy of Dr. Carey Croneis, University of Chicago, have given invaluable aid to this study. Not only does this collection furnish chief information concerning Lower Permian crinoids, but some of these fossils have helped in the understanding of Pennsylvanian species.

The systematic portion of this paper contains descriptions of three genera and five species of flexible crinoids, including one new genus, three new species, and one renamed species. Of inadunate crinoids, all referred to the family Poteriocrinitidae, there are 32 genera, of which 15 are new, 97 species, all but 13 new. This makes a total of 35 genera and 102 species. The genera and species occurring in Texas number 34 and 93, respectively. The stratigraphic distribution of these is shown in the following tabulation:

Stratigraphic distribution of Upper Carboniferous and Permian crinoids from Texas

Permian—
- Wolfcamp formation (including Cibolo limestone)—
  - Cibolocrinus typus Weller
  - Cibolocrinus regalis Moore and Plummer, n. sp.
  - Apographiocrinus wolfcampensis Moore and Plummer, n. sp.
  - Spaniocrinus? trinodus (Weller)
  - Erisocrinus propinquus Weller
  - Neozeacrinus uddeni (Weller)
  - Perimestocrinus excavatus (Weller)
  - Delocrinus major Weller
  - Delocrinus quadratus Moore and Plummer, n. sp.
  - Endelocrinus texanus (Weller)
  - Stuartwellercrinus turbinatus (Weller)
  - Stuartwellercrinus texanus (Weller)
  - Stuartwellercrinus symmetricus (Weller)
  - Ulocrinus americanus (Weller)
- Putnam formation—
  - Delocrinus puebloensis Moore and Plummer, n. sp.
- Moran formation—
  - Delocrinus abruptus Moore and Plummer, n. sp.

[14]Weller, Stuart, Description of a Permian crinoid fauna from Texas: Jour. Geol., vol. 17, pp. 623–635, pl. 1, 1909.

Pennsylvanian?—

Harpersville formation—

Delocrinus vulgatus Moore and Plummer, n. sp.

Pennsylvanian—

Graham formation—

Delocrinus wolforum Moore and Plummer, n. sp.

Brad formation—

Parulocrinus compactus Moore and Plummer, n. sp.

Graford formation—

Apographiocrinus calycinus Moore and Plummer, n. sp.
Pachylocrinus ogarai Moore and Plummer, n. sp.
Erisocrinus typus Meek and Worthen
Athlocrinus clypeiformis Moore and Plummer, n. sp.
Plaxocrinus parilis Moore and Plummer, n. sp.
Sciadiocrinus disculus Moore and Plummer, n. sp.
Zeacrinites? sellardsi Moore and Plummer, n. sp.
Delocrinus pictus Moore and Plummer, n. sp.
Delocrinus graphicus Moore and Plummer, n. sp.
Delocrinus papulosus Moore and Plummer, n. sp.
Endelocrinus grafordensis Moore and Plummer, n. sp.
Endelocrinus bifidus Moore and Plummer, n. sp.
Paradelocrinus protensus Moore and Plummer, n. sp.
Paradelocrinus obovatus Moore and Plummer, n. sp.
Paradelocrinus subplanus Moore and Plummer, n. sp.
Paragassizocrinus tarri (Strimple)
Aesiocrinus barydactylus (Keyes)

Palo Pinto limestone—

Apographiocrinus typicalis Moore and Plummer, n. sp.
Erisocrinus typus Meek and Worthen
Erisocrinus elevatus Moore and Plummer, n. sp.
Erisocrinus erectus Moore and Plummer, n. sp.
Plaxocrinus obesus Moore and Plummer, n. sp.
Perimestocrinus formosus Moore and Plummer, n. sp.
Delocrinus verus Moore and Plummer, n. sp.
Delocrinus paucinodus Moore and Plummer, n. sp.
Parulocrinus beedei Moore and Plummer, n. sp.

Canyon group (?), horizon uncertain—

Parulocrinus marquisi Moore and Plummer, n. sp.

Gaptank formation—

Delocrinus? perexcavatus Moore and Plummer, n. sp.

Haymond formation—

Marathonocrinus bakeri Moore and Plummer, n. sp.

Mineral Wells formation (Missouri[15] series)—
- Apographiocrinus exculptus Moore and Plummer, n. sp.
- Apographiocrinus facetus Moore and Plummer, n. sp.
- Apographiocrinus decoratus Moore and Plummer, n. sp.
- Pachylocrinus uddeni Moore and Plummer, n. sp.
- Erisocrinus typus Meek and Worthen
- Athlocrinus nitidus Moore and Plummer, n. sp.
- Plaxocrinus omphaloides Moore and Plummer, n. sp.
- Plaxocrinus lobatus Moore and Plummer, n. sp.
- Perimestocrinus impressus Moore and Plummer, n. sp.
- Delocrinus bispinosus Moore and Plummer, n. sp.
- Delocrinus subcoronatus Moore and Plummer, n. sp.
- Graphiocrinus kingi Moore and Plummer, n. sp.
- Paradelocrinus subplanus Moore and Plummer, n. sp.
- Endelocrinus parvus Moore and Plummer, n. sp.
- Parulocrinus pustulosus Moore and Plummer, n. sp.
- Aesiocrinus barydactylus (Keyes)

Mineral Wells formation (Des Moines[15] series)—
- Laudonocrinus cucullus Moore and Plummer, n. sp.
- Laudonocrinus arrectus Moore and Plummer, n. sp.
- Plaxocrinus aplatus Moore and Plummer, n. sp.
- Plaxocrinus omphaloides Moore and Plummer, n. sp.
- Perimestocrinus impressus Moore and Plummer, n. sp.
- Perimestocrinus calyculus Moore and Plummer, n. sp.
- Sciadiocrinus disculus Moore and Plummer, n. sp.
- Aatocrinus cavumbilicatus Moore and Plummer, n. sp.
- Delocrinus benthobatus Moore and Plummer, n. sp.
- Delocrinus granulosus Moore and Plummer, n.sp.
- Delocrinus granulosus var. moniliformis Moore and Plummer, n. var.
- Delocrinus granulosus var. zonatus Moore and Plummer, n. var.

Millsap Lake formation—
- Synerocrinus formosus Moore and Plummer, n. sp.
- Malaiocrinus parviusculus Moore and Plummer, n. sp.
- Apollocrinus florealis Moore and Plummer, n. sp.
- Haeretocrinus magnus Moore and Plummer, n. sp.
- Texacrinus gracilis Moore and Plummer, n. sp.
- Brychiocrinus texanus Moore and Plummer, n. sp.
- Neozeacrinus praecursor Moore and Plummer, n. sp.
- Laudonocrinus catillus Moore and Plummer, n. sp.
- Plaxocrinus obesus Moore and Plummer, n. sp.
- Plaxocrinus perundatus Moore and Plummer, n. sp.

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[15]Present faunal evidence indicates that the Dog Bend limestone in the Mineral Wells formation may be the base of the Missouri series. Since stratigraphic relationships in the field indicate an inconformity at the base of the Turkey Creek sandstone member, the contact of the Turkey Creek member and the underlying Keechi Creek shale member is accepted for the present as the contact of the Missouri and the Des Moines series, in this area.

Schistocrinus planulatus Moore and Plummer, n. sp.
Schistocrinus parvus Moore and Plummer, n. sp.
Schistocrinus confertus Moore and Plummer, n. sp.
Sciadiocrinus harrisae Moore and Plummer, n. sp.
Pirasocrinus scotti Moore and Plummer, n. sp.
Delocrinus bullatus Moore and Plummer, n. sp.
Endelocrinus rectus Moore and Plummer, n. sp.
Endelocrinus mitis Moore and Plummer, n. sp.
Paradelocrinus brachiatus Moore and Plummer, n. sp.
Paradelocrinus subplanus Moore and Plummer, n. sp.
Sellardsicrinus marisae Moore and Plummer, n. sp.
Ethelocrinus millsapensis Moore and Plummer, n. sp.

Marble Falls limestone—

Cibolocrinus punctatus Moore and Plummer, n. sp.
Scytalocrinus sansabensis Moore and Plummer
Lasanocrinus cornutus Moore and Plummer, n. sp.
Ethelocrinus texasensis Moore and Plummer, n. sp.

Crinoid fragments in the form of individual plates, portions of the dorsal cup, sections of stems, parts of arms, and ventral tube spines, are extremely common in nearly all stratigraphic horizons and formations where fossils occur. Indeed, in contrast to the rareness of complete crinoid cups, crinoid fragments are among the most common organic remains in many outcrops. Some thin limestone layers consist almost entirely of crinoid stem fragments cemented into a coquina-like mass.

The important crinoid horizons in Texas that have been discovered up to this time and in which crinoid remains are fairly plentiful are designated as crinoid zones and are given zonal names. The locations of the crinoid zones are shown in the stratigraphic section, figure 6. The most important zones are named and described briefly in the following paragraphs, beginning with the lowest.

1. *Ethelocrinus texasensis* zone.—The lowest Pennsylvanian crinoid zone in Texas occurs within a few feet of the base of the Marble Falls limestone, Bend group (Morrow series). It has been recognized at not less than five rather widely separated localities in San Saba County, Texas. This zone contains also *Cibolocrinus punctatus* Moore and Plummer, n. sp.

2. *Scytalocrinus sansabensis* zone.—This zone is about 100 feet below the top of the Marble Falls limestone, Bend group (Morrow series), in San Saba County, Texas. In this zone occurs also *Lasanocrinus cornutus*, n. sp.

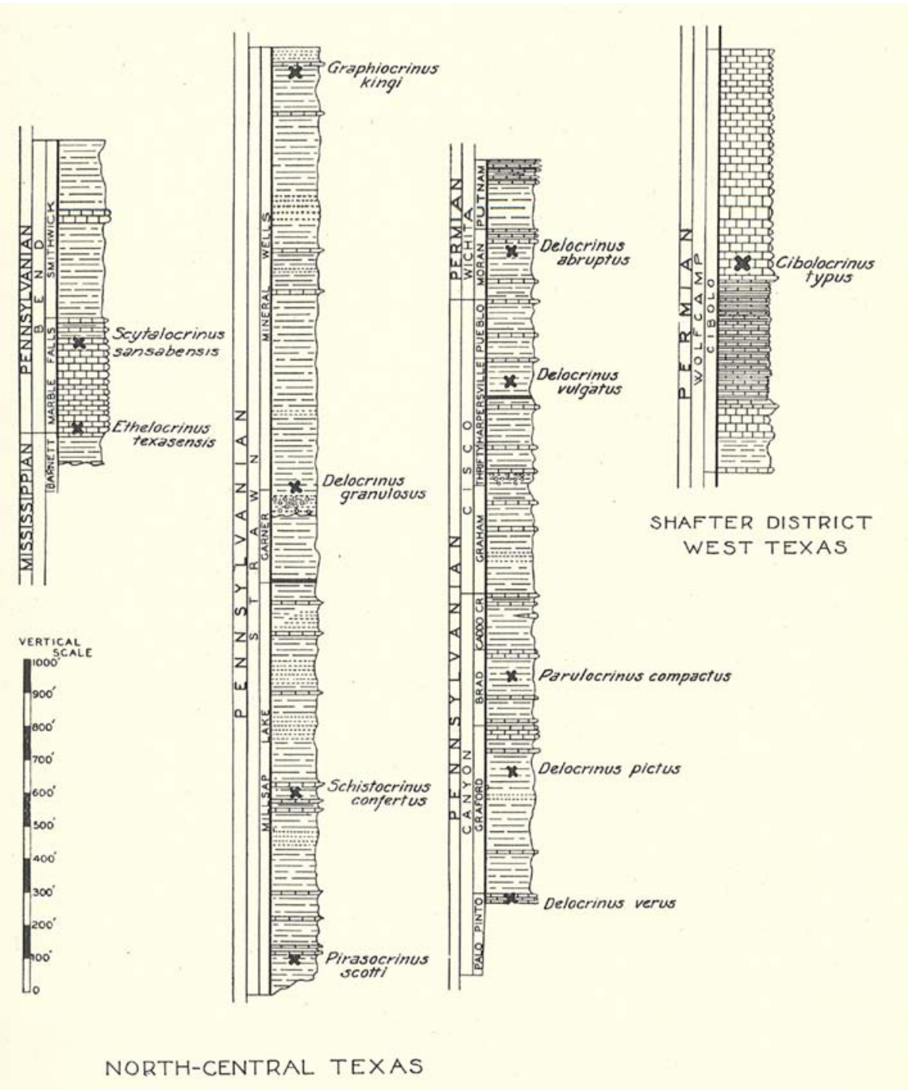

Fig. 6. Stratigraphic section of the Pennsylvanian and lower Permian formations in Texas, showing the positions of the crinoid zones.

3. *Pirasocrinus scotti* zone.—This zone occurs about 15 feet below the Kickapoo Falls limestone in the Millsap Lake formation, Strawn group (Des Moines series), and contains the following crinoids:
   - Malaiocrinus parviusculus Moore and Plummer, n. sp.
   - Plaxocrinus obesus Moore and Plummer, n. sp.
   - Plaxocrinus perundatus Moore and Plummer, n. sp.
   - Sciadiocrinus harrisae Moore and Plummer, n. sp.
   - Pirasocrinus scotti Moore and Plummer, n. sp.
   - Paradelocrinus brachiatus Moore and Plummer, n. sp.
   - Paradelocrinus subplanus Moore and Plummer, n. sp.
4. *Schistocrinus confertus* zone.—The Brannon Bridge limestone member in the middle of the Millsap Lake formation, Strawn group (Des Moines series), carries a different crinoid fauna from that observed just below the Kickapoo Falls limestone. This upper faunal zone in the Millsap Lake formation is named from its most common and characteristic species. The zone has yielded the following species:
   - Synerocrinus formosus Moore and Plummer, n. sp.
   - Apollocrinus florealis Moore and Plummer, n. sp.
   - Haeretocrinus magnus Moore and Plummer, n. sp.
   - Texacrinus gracilis Moore and Plummer, n. sp.
   - Brychiocrinus texanus Moore and Plummer, n. sp.
   - Neozeacrinus praecursor Moore and Plummer, n. sp.
   - Plaxocrinus obesus Moore and Plummer, n. sp.
   - Plaxocrinus perundatus Moore and Plummer, n. sp.
   - Schistocrinus parvus Moore and Plummer, n. sp.
   - Schistocrinus planulatus Moore and Plummer, n. sp.
   - Schistocrinus confertus Moore and Plummer, n. sp.
   - Endelocrinus rectus Moore and Plummer, n. sp.
   - Paradelocrinus subplanus Moore and Plummer, n. sp.
   - Sellardsicrinus marrsae Moore and Plummer, n. sp.
   - Ethelocrinus millsapensis Moore and Plummer, n. sp.
5. *Delocrinus granulosus zone.*—This horizon is in the lower 20 feet of the East Mountain shale of the Mineral Wells formation, Strawn group (Des Moines series), and contains the following crinoids:
   - Laudonocrinus cucullus Moore and Plummer, n. sp.
   - Laudonocrinus arrectus Moore and Plummer, n. sp.
   - Plaxocrinus aplatus Moore and Plummer, n. sp.
   - Perimestocrinus impressus Moore and Plummer, n. sp.
   - Perimestocrinus calyculus Moore and Plummer, n. sp.
   - Aatocrinus cavumbilicatus Moore and Plummer, n. sp.
   - Delocrinus benthobatus Moore and Plummer, n. sp.
   - Delocrinus granulosus Moore and Plummer, n. sp.
   - Delocrinus granulosus var. moniliformis Moore and Plummer, n. var.
   - Delocrinus granulosus var. zonatus Moore and Plummer, n. var.

6. *Graphiocrinus kingi* zone.—This zone lies in the upper part of the Mineral Wells formation, in the Keechi Creek shale, Strawn group (Missouri series). According to evidence of fusulinids and other fossils, this zone is a little above the boundary between the Des Moines and Missouri series. According to classification of the Texas Pennsylvanian, however, the horizon is included in the upper part of the Strawn group. The crinoids that are definitely recognized in this zone include the following:

   Apographiocrinus decoratus Moore and Plummer, n. sp.
   Pachylocrinus uddeni Moore and Plummer, n. sp.
   Erisocrinus typus Meek and Worthen
   Perimestocrinus impressus Moore and Plummer, n. sp.
   Delocrinus bispinosus Moore and Plummer, n. sp.
   Delocrinus subcoronatus Moore and Plummer, n. sp.
   Graphiocrinus kingi Moore and Plummer, n. sp.
   Aesiocrinus barydactylus (Keyes)

   From localities that are correlated with the upper Mineral Wells formation and which therefore may also represent this zone, the following additional species have been *found:*

   Apographiocrinus exculptus Moore and Plummer, n. sp.
   Apographiocrinus facetus Moore and Plummer, n. sp.
   Erisocrinus erectus Moore and Plummer, n. sp.
   Athlocrinus nitidus Moore and Plummer, n. sp.
   Plaxocrinus omphaloides Moore and Plummer, n. sp.
   Plaxocrinus lobatus Moore and Plummer, n. sp.
   Delocrinus benthobatus Moore and Plummer, n. sp.
   Endelocrinus parvus Moore and Plummer, n. sp.
   Paradelocrinus subplanus Moore and Plummer, n. sp.
   Parulocrinus pustulosus Moore and Plummer, n. sp.
   Aesiocrinus barydactylus (Keyes)

7. *Delocrinus verus* zone.—This zone occurs in the Palo Pinto limestone formation, basal part of the Canyon group (Missouri series). The horizon is not very far above the *Graphiocrinus kingi* zone, but the observed species of crinoids are in general unlike. The following species are recognized in this zone:

   Apographiocrinus typicalis Moore and Plummer, n. sp.
   Erisocrinus typus Meek and Worthen
   Erisocrinus erectus Moore and Plummer, n. sp.
   Erisocrinus elevatus Moore and Plummer, n. sp.
   Plaxocrinus obesus Moore and Plummer, n. sp.
   Perimestocrinus formosus Moore and Plummer, n. sp.
   Delocrinus verus Moore and Plummer, n. sp.
   Delocrinus paucinodus Moore and Plummer, n. sp.
   Parulocrinus beedei Moore and Plummer, n. sp.

8. *Delocrinus pictus* zone.—This zone lies in the Graford formation (Missouri series), from 10 to 20 feet above the Staff limestone and below the Merriman limestone. It contains the following crinoids:
    Apographiocrinus calycinus Moore and Plummer, n. sp.
    Pachylocrinus ogarai Moore and Plummer, n. sp.
    Erisocrinus typus Meek and Worthen
    Zeacrinites? sellardsi Moore and Plummer, n. sp.
    Delocrinus pictus Moore and Plummer, n. sp.
    Delocrinus graphicus Moore and Plummer, n. sp.
    Delocrinus papulosus Moore and Plummer, n. sp.
    Endelocrinus grafordensis Moore and Plummer, n. sp.
    Endelocrinus bifidus Moore and Plummer, n. sp.
    Paradelocrinus obovatus Moore and Plummer, n. sp.
    Aesiocrinus barydactylus (Keyes)

    Other crinoids identified from the Graford formation but not certainly established as belonging to the *Delocrinus pictus* zone include the following species:
    Athlocrinus clypeiformis Moore and Plummer, n. sp.
    Sciadiocrinus disculus Moore and Plummer, n. sp.
    Plaxocrinus parilis Moore and Plummer, n. sp.
    Paradelocrinus protensus Moore and Plummer, n. sp.
    Paradelocrinus subplanus Moore and Plummer, n. sp.
    Paragassizocrinus tarri (Strimple)
9. *Parulocrinus compactus* zone.—A crinoid zone in the upper part of the Canyon group (Missouri series), occurring in the Brad formation, contains abundant plates and other fragments but only a few dorsal cups. It is characterized by the species *Parulocrinus compactus* Moore and Plummer, n. sp. This zone occurs about halfway between the Merriman and Ranger limestones.
10. *Delocrinus vulgatus* zone.—The single species of *D. vulgatus* Moore and Plummer, n. sp., has been found at a number of localities in the Harpersville formation. Some typical examples of this species occur in the Brownsville limestone of northern Oklahoma, only a few feet or inches below the unconformity that is regarded as the Pennsylvanian-Permian boundary. The *Delocrinus vulgatus* zone in Texas may be classed as uppermost Pennsylvanian (Virgil series).
11. *Delocrinus abruptus* zone. So little really is known of the crinoid fauna of the Moran formation or other Lower Permian strata of north Texas, that it is hardly proper to designate a crinoid zone in this part of the section. Nevertheless the occurrence of what appears to be an identical form of *Delocrinus* in the Moran formation of Texas and the Beattie limestone of the Council Grove group in the Lower Permian of Kansas is worthy of record. The crinoid fauna of the lower Big Blue beds can be differentiated readily from that of underlying upper Virgil strata of the Pennsylvanian series.

12. *Cibolocrinus typus* zone.—The Wolfcamp formation of western Texas, to which the Cibolo limestone of Presidio County belongs, as clearly shown by fusulinids and ammonids, contains locally a very interesting crinoid fauna that has been described by Weller. This may be designated as the *Cibolocrinus typus* zone. It contains the species already listed under Wolfcamp formation.

USE OF CRINOIDS AS INDEX FOSSILS

A study by the authors of more than 5,000 crinoid specimens from the Upper Carboniferous rocks of Illinois, Iowa, Arkansas, Missouri, Kansas, Nebraska, Oklahoma, Texas, Colorado, New Mexico, and Utah, indicates clearly that many crinoid species are restricted to thin zones in the geologic section, and that many species range widely in geographic distribution throughout the Mid-Continent region. Detailed correlation of crinoidal zones will be undertaken and discussed in later papers.

The chief obstacles to the use of crinoids for stratigraphic correlation have been the comparative rarity of well-preserved complete or nearly complete cups in Upper Carboniferous formations, and lack of more than a very few published descriptions of Upper Carboniferous and Permian species in this country. Although complete crinoid cups or crowns are not at all common in these rocks in most places, fragments of crinoid skeletons consisting of stem segments, plates of the dorsal cup, elements from the tegmen, and portions of the arms, are plentiful. The majority of these remains can be distinguished according to structural position in the crinoid and a large number of them appear to be useful as guide fossils for the zones in which they occur.[16]

CORRELATION OF TEXAS UPPER CARBONIFEROUS AND PERMIAN CRINOID ZONES

It is desirable to survey the stratigraphic distribution of known crinoids from the Upper Carboniferous and Permian rocks of Texas as compared with occurrence of this group of fossils in beds of equivalent age elsewhere in North America. Such comparison should have value in correlation of the crinoid-bearing beds, and as a summary of present knowledge, it is useful as indication of the obvious gaps in knowledge. The tabular statement that is

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[16]Moore, R. C., The use of fragmentary crinoidal remains in stratigraphic paleontology: Denison Univ. Bull., Jour. Sci. Labs., vol. 33 (1938), pp. 165–250, pls. 1–5, 1939.

included with this part of the report lists all recognized species of Upper Carboniferous and Permian crinoids from North America, assignments to genera being based on study of type specimens of almost all species, excepting the microcrinoids, for which the authors' identifications are followed. Described fragmentary crinoidal remains, many of which have stratigraphic value, are also recorded. Indication of stratigraphic occurrence is given from personal field determinations or, in the case of species reported from Illinois and Indiana, from notes furnished by Harold R. Wanless and J. Marvin Weller.

Opportunity to examine type specimens of several species recently described by Strimple[16a] has been afforded. Most of this paper on Texas crinoids was completed in 1938, but delay in publication has required changes in proof to take account of Strimple's work. His new genus *Whiteocrinus*[16b] (preoccupied) does not displace *Apollocrinus*. A list of new forms described in the two papers cited is given immediately preceding the taxonomic descriptions of the species treated in this paper, but the new genera designated as *Moundocrinus* Strimple and *Pentadelocrinus* Strimple are based on dorsal cups belonging definitely to the genus *Aesiocrinus* Miller and Gurley.

The main divisions of the Upper Carboniferous rocks, classed as series, are respectively designated in upward order, Morrow, Des Moines, Missouri, and Virgil. These are typically differentiated in the northern Mid-Continent region where disconformities are found to mark boundaries between them and where fairly well developed faunal differences are recognized. The disconformities correspond to important angular unconformities in geosynclinal belts and are believed to define the most significant large stratigraphic units within the late Paleozoic systems, as these are classified. It seems most desirable to trace the lines of division between series as widely as possible, and for purposes of correlation to adopt a uniform nomenclature for the respective series that is independent of stratigraphic names applied in different

[16a]Strimple, H. L., A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, pp. 3–21, pls. 1–3, 1939. Eight species of Pennsylvanian crinoids: idem, vol. 25, no. 89, pp. 3–12, pls. 1, 2, 1939. Some new crinoid species from the Morrow subseries: Bull. Amer. Pal., vol. 25, no. 91, pp. 1–10, pl. 1, 1940. Four new crinoid species from the Wewoka and one from the Ochelata group: Bull. Amer. Pal., vol. 25, no. 92, pp. 1–10, pl. 1, 1940.

[16b]The new name *Stellarocrinus* Strimple March 7, 1940 now takes precedence over *Apollocrinus*, n.gen.

regions, such as those of north-central Texas, west Texas, or the Illinois-Indiana coal basin. A few of the faunal characteristics of each series will be noted in following paragraphs.

General survey of the crinoid fauna.—Including new genera and species of Upper Carboniferous and Permian crinoids from Texas that are described in this paper, a total number of 60 genera and 200 species of these fossils may be recorded from the post-Mississippian Paleozoic rocks of North America. As listed in the accompanying table, it is seen that the order Inadunata is strongly predominant, including 55 genera and 189 species. The Flexibilia are represented by 4 genera and 8 species, and the Camerata by 1 genus and 3 species. These figures do not include forms, such as platycrinids among the adunates that are described only from fragmentary traces consisting of stem segments or dissociated ossicles of the calyx. Additional forms described by Strimple are 3 species of Flexibilia, and 3 genera and 16 species of Inadunata.

Comparison of the Texas crinoid fauna with that of the continent as a whole shows that in rocks of the age under consideration, 6 genera and 74 species are restricted to Texas. The restricted genera are *Brychiocrinus, Marathonocrinus, Pirasocrinus, Sellardsicrinus, Stuartwellercrinus,* and *Texacrinus,* but since only 8 of the restricted species belong to these named genera, there are 66 Texas restricted species belonging to genera that occur elsewhere. Crinoids of Upper Carboniferous or Permian age found as yet only in parts of North America outside of Texas include 22 genera (1 camerate, 2 flexibles, 19 inadunates) and 105 species (3 camerates, 4 flexibles, 98 inadunates).[16b] The remaining group, which is most important in study of correlation, comprises forms that are known both from Texas and occurrences elsewhere. These include 30 genera (2 flexibles, 28 inadunates), of which 18 are represented by Texas restricted species, and there are 17 species (all inadunates), belonging to 12 of the "common" genera, that are found both in Texas and in neighboring states. It is well understood that these figures have meaning only as an approximate measure—and that, a somewhat temporary one—of the paleontological materials that are available for comparative study. Future work, both in Texas and outside of the state, will inevitably add greatly to significant data. For example, the discovery of a species of *Allagecrinus* in

[16b]Two genera and 16 species of inadunates and 3 species of flexibles, described by Strimple from Oklahoma, are to be added.

Pennsylvanian rocks in Young County, Texas, which is possibly the same as one of the two species recorded in the accompanying list from northeastern Oklahoma, requires slight modification of the numbers for genera and possibly for species as already given. It is pertinent to re-state the rather evident conclusion that only a small part of the whole Upper Carboniferous and Permian crinoid assemblage from the Mid-Continent region of the United States has been studied.

Morrow beds.—The Morrow series comprises beds between the top of the Chester series, of Mississippian (Lower Carboniferous) age, and a disconformity that marks the lower boundary of beds called Des Moines. In northwestern Arkansas and northeastern Oklahoma, which comprise the type region of the series, the lower and upper boundaries are very well marked. In north-central Texas, rocks assigned to the Morrow series include the Marble Falls limestone and the overlying Smithwick shale. Here, the disconformity between the Marble Falls limestone and the underlying Barnett shale, of Chester age, is very inconspicuous, but there is now little question as to the importance of this stratigraphic boundary. Rocks of Morrow age have been recognized in west Texas, but no crinoids have yet been collected from them.

Paleontologically, the Morrow series is characterized by its content of such Lower Carboniferous types of fossils as *Pentremites, Archimedes, Prismopora,* and simply plicated Spirifers, like *S. rockymontanus.* Plummer and Scott[17] designate this division as defined by the occurrence of the *Gastrioceras listeri* assemblage of ammonites, including especially such forms as *Gastrioceras smithwickense* Plummer and Scott, *Pronorites arkansasensis* Smith, and *Branneroceras branneri* (Smith). Fusulinids of any sort have not been found in the Morrow beds on the southwest flank of the Ozarks, but these appear in the upper part (Bostwick) of the section classed as Morrow in southern Oklahoma and are represented in part of the Marble Falls limestone of Texas. The species, *Fusiella primaeva* Skinner, which occurs in the lowest Texas zone of fusulinids, is very similar to the form from the Bostwick conglomerate of southern Oklahoma. *Pentremites* and *Archimedes* have not been observed in the Morrow rocks of Texas.

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[17]Plummer, F. B., and Scott, Gayle, Upper Paleozoic ammonites in Texas: The University of Texas Bull. 3701, pt. 1, p. 385, 1937.

Among crinoids, 24 species, representing 13 genera, are known from Morrow beds. In addition, 15 types of fragmentary crinoidal remains from these rocks have been described, as recorded in the accompanying check list. Four species of crinoids, of which three are rather closely similar to forms from Morrow strata of northeastern Oklahoma, are known from the Marble Falls limestone. Too poorly preserved for satisfactory identification is a rather large, subglobular crinoid, apparently with smooth plates (*Parulocrinus?*, sp.), from the middle part of the Marble Falls near San Saba, and specimens of a hydreionocrinid (*Sciadiocrinus?*, sp.) occurring at the top of the Marble Falls limestone. Referring to the well-preserved specimens that are useful for comparison, there can be little question as to close relationship between *Cibolocrinus punctatus*, n.sp., from the Marble Falls, and *C. tumidus* Moore and Plummer, from the Brentwood limestone, and the same may be said of *Ethelocrinus texasensis*, n.sp., from the Marble Falls, and *E. oklahomensis* Moore and Plummer, from the Brentwood. The two Texas species appear to be a little less advanced in evolutionary development than the Oklahoma forms, and, accordingly, may indicate a slightly older horizon. *Lasanocrinus cornutus*, n.sp., from a higher horizon in the Marble Falls limestone, is similar to *L. daileyi* (Strimple), from Morrow beds of northeast Oklahoma. *Scytalocrinus sansabensis* Moore and Plummer, which is the remaining well-determined Morrow crinoid from Texas, has not been found in Oklahoma or Arkansas, and it is the only species of this genus yet recognized in Upper Carboniferous rocks of North America; the genus is well represented in Devonian and Lower Carboniferous rocks. It is entirely possible that the crinoids called *Poteriocrinites lasallensis* (Worthen) and *P. macoupinensis* (Worthen), from beds of Missouri age in Illinois, may belong to *Scytalocrinus*, but these hardly need to be compared with *S. sansabensis*.

Ossicles of very distinctive character, such as *Stereobrachicrinus pustullosus* Mather and *Acantharthropterum sinum* (Moore and Plummer), which are common in Morrow rocks on the southwest flank of the Ozarks, have not been found in the Marble Falls limestone, and, likewise, no specimens of *Pentremites* appear to occur in the Morrow deposits of the Llano uplift. These observations suggest that the fossiliferous horizons in the two areas are not exactly equivalent, although they must be nearly so, as judged by various lines of evidence. The most common crinoid of the Brentwood limestone, *Paradelocrinus dubius* (Mather), is also missing from the list of crinoids known in Texas.

Des Moines beds.—The Des Moines series disconformably follows the Morrow and is separated by a disconformity from the overlying Missouri series, these relations being most clearly seen in northeastern Oklahoma and eastern Kansas. In Kansas, Missouri, and Iowa, however, the Morrow beds are absent, and the Des Moines series rests directly on Meramec or Osage beds of Mississippian age. In Texas, the Des Moines series includes all the Millsap Lake and Garner formations and all but the upper part of the Mineral Wells formation, thus comprising most of the Strawn group. The lower boundary of the series is at the well-marked unconformity between the Smithwick shale and basal Strawn beds; the upper boundary is placed at the apparent disconformity marked by the base of the Turkey Creek sandstone, for this line separates beds containing typical Des Moines fossils, below, from higher strata that lack these fossils and show presence of Missouri species.

The most characteristic guide fossils of the Des Moines series include *Mesolobus* and *Marginifera muricata*, among brachiopods, associated more or less commonly at different horizons with species of *Fusulina, Fusulinella, Wedekindellina, Chaetetes, Prismopora,* and a few restricted species of ammonites. Plummer and Scott[18] designate this as the zone of *Gastrioceras venatum* Girty. Species of *Glaphyrites, Anthracoceras, Dimorphoceras, Neoglyphioceras,* and other genera occur in beds of this series in the northern Mid-Continent.[19] Numerous species of plants that characterize upper Pottsville and Allegheny beds of the eastern United States and Westphalian deposits of Europe are found in the Des Moines series. Generally speaking, the rocks of this division are readily identified and sharply separated on faunal grounds from those of other Upper Carboniferous series.

The crinoids of Des Moines age comprise an extremely interesting and varied assemblage that includes forms having stratigraphic usefulness in correlation. Total known genera from rocks of the series number 29, of which 8 are not represented in Texas, and 5,

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[18]Idem, p. 385.

[19]Miller. A. K., and Owen, J. B., An ammonoid fauna from the Lower Pennsylvanian Cherokee formation of Missouri: Jour. Pal., vol. 13, p. 141, 1939.

including *Marathonocrinus,* of somewhat doubtful age, are restricted to Texas. There are 60 species of Des Moines crinoids, of which 26 are recorded only from localities outside Texas, 30 in Texas but not yet known elsewhere, and 4 common to Texas and outside areas. This list includes 6 genera and 17 species of microcrinoids from Missouri, Illinois, and Indiana, not known from other states. The considerable number of restricted Texas species reflects especially fortunate discoveries of rich material at three horizons and localities, whereas collections of crinoids from equivalent beds elsewhere are scanty or lacking.

Among crinoids from the shale just below the Kickapoo Falls limestone member of the Millsap Lake formation, representing the *Pirasocrinus scotti* zone, there are two species that are recognized also outside Texas. These species are *Sciadiocrinus harrisae,* n.sp., and *Malaiocrinus parviusculus,* n.sp., and it is surprising that outside of Texas these forms occur in the upper rather than in the lower part of the Des Moines series. Several excellently preserved specimens of the two species mentioned are found in a collection furnished by Bob Stevens, of the University of Tulsa, from the upper part of the Oologah limestone at Garnett quarry, a few miles northeast of Tulsa, Oklahoma. The horizon of these Oklahoma specimens is equivalent to that of the Altamont limestone of Kansas, which is next to the topmost limestone of the Des Moines series in the northern Mid-Continent area, and near Tulsa, about 300 feet below the Des Moines-Missouri boundary. The position of the Kickapoo Falls limestone in Texas is thought to be considerably lower in the Des Moines than that of the Oologah. The fairly large collection of Oologah crinoids, however, does not contain *Pirasocrinus scotti,* n.sp., *Plaxocrinus perundatus,* n.sp., or other characteristic Kickapoo Falls species, although a species of *Paradelocrinus* that is close to *P. subplanus,* n.sp., occurs in the Oologah.

One of the most remarkable of the crinoid occurrences in the Pennsylvanian rocks of Texas is that near Brock, in Parker County, at the horizon of the Brannon Bridge limestone member of the Millsap Lake formation. Many specimens of dorsal cups with attached arms have been found here, mostly by two collectors, Mrs. G. D. Harris, of Waco, and her sister, Mrs. W. R. Marrs, of Austin. None of these crinoids, however, numbering about a dozen species, are known elsewhere. It is interesting to note that *Synerocrinus formosus,* n.sp., is very closely similar to *S. incurvus* (Trautschold), from the Mjatschkowa beds, in the lower part of the Upper Carboniferous near Moscow, Russia, and that the two American and Russian species are the only ones now known belonging to the genus.

The East Mountain shale member of the Mineral Wells formation, which belongs in the upper part of the Des Moines series, contains numerous crinoids. This comprises the *Delocrinus granulosus* zone. The chief guide fossil of this zone, *D. granulosus,* n.sp., occurs in the Magdalena limestone, near Taos, New Mexico, and is found in the Wewoka formation, upper middle Des Moines, near Okmulgee, Oklahoma. The species *Perimestocrinus impressus,* n.sp., is identified in the East Mountain shale assemblage, but it appears to be most common in the Missouri series, as indicated by occurrences in Texas and in the northern Mid-Continent region.

A species that occurs both in the Millsap Lake formation, near Santo, Palo Pinto County, Texas, and in the upper part of the Oologah limestone is *Laudonocrinus catillus,* n.sp. This species is fairly distinctive, and identification of the Oklahoma specimens with the Millsap Lake form is made without question.

Missouri beds.—The Missouri series comprises the upper middle portion of the Pennsylvanian section, being separated by disconformities from the underlying Des Moines beds and the overlying Virgil series. Limestone deposits are prominent in the Missouri series of Missouri, Iowa, Nebraska, and Kansas; in Oklahoma, shale and sandstone predominate over limestone; in Texas, limestone is very prominent in that part of the section that represents the Missouri, for most, if not all the Canyon group belongs to this series. The lower boundary is drawn beneath the Turkey Creek sandstone member of the Mineral Wells formation in the Brazos River valley section, and it belongs at a position not precisely determined below the top of the Mineral Wells in the Colorado River section. The Missouri-Virgil boundary in Texas has not been satisfactorily defined, but is about equivalent to the contact between the Canyon and Cisco groups.

The Missouri fauna is marked by absence of distinctive Des Moines fossils, such as *Mesolobus, Prismopora, Chaetetes, Fusulina,* and other primitive fusulinids, and by appearance of numerous *Chonetina verneuilina, Marginifera wabashensis, Enteletes hemiplicatus,* and *Triticites irregularis.* The ammonite *Paraschistoceras* *reticulatum* (A. K. Miller) characterizes this zone, according to Plummer and Scott, together with *Prouddenites bösei* (Smith) and *Glaphyrites kansasensis* (Miller and Gurley).

A total number of 27 genera and 85 species of crinoids is listed from rocks of Missouri age, of which 13 genera and 46 species are not recorded in Texas, 3 genera and 29 species are restricted to Texas, and 11 genera and 10 species are identified both in Texas and outside of this State.[19a] In the last-mentioned group, the genus *Aesiocrinus,* until now known only from 5 species collected in the Lane shale at Kansas City, Missouri, is represented by *A. barydactylus* (Keyes), which occurs in the lower part of the Missouri series of Texas, specimens being found in the upper part of the Mineral Wells formation and in the Graford formation. One of the most common upper Missouri crinoids in southern Kansas and northern Oklahoma, represented by more than 200 specimens in collections from the Plattsburg and Stanton limestones, is *Apographiocrinus typicalis,* n.sp.; a single example of this species has been obtained from the Palo Pinto limestone in Wise County, Texas.[19b] The genus *Athlocrinus* is known at present only from rocks of Missouri age in Kansas and Texas, but the species from northern and southern localities appear to be different. Although several hundred specimens of *Delocrinus* have been obtained from Pennsylvanian rocks in Kansas, Oklahoma, Missouri, Nebraska, and Iowa, none of these correspond to the distinctive Texas new species of Missouri age, *D. pictus, D. graphicus, D. paucinodus, and D. papulosus,* all of which have decorated plates, but the smooth-surfaced form, *D. verus,* n.sp., is identified both in the Palo Pinto limestone of Texas and the Dennis limestone of southern Kansas. Two species of *Endelocrinus, E. grafordensis,* n.sp., and *E. parvus,* n.sp., that are described from the Graford formation of Texas, also occur in Kansas, the former in the Stanton limestone and the latter in the Stanton and Dennis limestones. *Erisocrinus typus* Meek and Worthen, originally described from rocks of Missouri age in Illinois, occurs also in rocks classed as belonging to this series in Texas. Fairly common remains of an interesting agassizocrinid that occurs in the Graford formation of Palo Pinto County and

[19a]Addition of the forms reported by Strimple from Oklahoma brings the total number of Missouri crinoids not recorded in Texas to 15 genera and 64 species.

[19b]Other specimens have recently been collected from lower Canyon beds at Loc. 248-T-4, Martins Lake, Wise County, Texas.

in shale of the Palo Pinto limestone in Wise County are assigned without question to *Paragassizocrinus tarri* (Strimple), which was described from upper Missouri beds at Bartlesville, Oklahoma, and which occurs in the Stanton limestone of southern Kansas. Even more certainly matched by finely preserved Kansas crinoids are the Texas types of the new species, *Parulocrinus compactus*, occurring in the Brad formation of Palo Pinto County; the Kansas specimens come from the Dennis and Iola limestones, and the species also appears to be represented in the Stanton limestone. The hydreionocrinids *Perimestocrinus impressus*, n.sp., and *Plaxocrinus parilis*, n.sp., which occur in the upper Mineral Wells shale and Graford formation, respectively, are found also in the Wyandotte limestone, in the upper middle part of the Missouri series, at Kansas City and nearby localities in eastern Kansas; *P. impressus* is a rather common and characteristic fossil of the Wyandotte horizon and is typically represented in upper Missouri beds of southern Kansas and northern Oklahoma.

This brief summary indicates correspondence of a sufficient number of species to establish reasonably the general correlation of Texas crinoid horizons assigned to the Missouri series with beds belonging to this division in the northern Mid-Continent region, but it is not possible to recognize similar zonal successions in the two areas. The lowest Texas horizon in the Missouri series (*Graphiocrinus kingi* zone), occurring in the upper part of the Mineral Wells formation, may be compared with upper Kansas City (Wyandotte limestone) and Lansing (Plattsburg and Stanton limestones) beds on the basis of occurrence of *Perimestocrinus impressus*, n.sp., and this species apparently does not occur in the lower Missouri beds of Kansas. The next higher Texas crinoid zone (*Delocrinus verus* zone), in the Palo Pinto limestone, might be correlated with the Dennis limestone, lower middle Missouri, on the basis of *D. verus*, n.sp., but this zone also appears to contain *Apographiocrinus typicalis*, n.sp., which is abundant in the Plattsburg and Stanton limestones of the upper Missouri and not observed in lower beds. The *Paragassizocrinus tarri* zone, just above the Palo Pinto limestone in Texas, appears to correspond to the Plattsburg-Stanton horizon on the basis of occurrence of this fossil in northern Oklahoma and southern Kansas, and *Aesiocrinus barydactylus* (Keyes), *Endelocrinus grafordensis*, n.sp., and *E. parvus*, n.sp., from the Graford formation may be similarly correlated with upper Missouri beds of Kansas. The highest observed Texas crinoid occurrence in beds of Missouri age, however, that of *Parulocrinus compactus*, n.sp., in the Brad formation, must be compared with horizons below the Plattsburg-Stanton beds of the north. These observations point to incompleteness of information concerning stratigraphic distribution, probably both in Texas and in Kansas.

Virgil beds.—The uppermost major division of the Carboniferous beds in the central United States is called the Virgil series. In Kansas it embraces beds between the disconformity at the top of the Missouri series and a similar disconformity that occurs just above the Brownville limestone. In southern Oklahoma the lower boundary is the pronounced angular unconformity that separates the steeply folded Hoxbar and older rocks from overlying Pontotoc deposits. Neither the lower nor upper boundary has been precisely established in Texas, but the approximate position of the base of the series coincides with the base of the Graham formation of the Cisco group and the top is thought to belong near the base of the Pueblo formation.

The Virgil series is less sharply differentiated from the Missouri beds on paleontological characters than the Missouri is separated from the Des Moines series. Most of the invertebrate species of the Upper Pennsylvanian rocks are long-ranging. Numerous species of *Triticites* occur, and this part of the section is conveniently designated as the zone of *Triticites cullomensis*. Among ammonites, occurrence of *Uddenites schucherti* Böse and *Vidrioceras irregulare* Böse is noteworthy.

Crinoids are less numerous in the Virgil formations than in lower rocks, or at least far fewer forms are known. Only 9 genera, represented by 14 species, are recorded at present, and of this number but 3 species, all belonging to *Delocrinus*, are known in Texas. These are *D.? perexcavatus*, n.sp., from the Gaptank formation of west Texas, probably, but not certainly, from beds of Virgil age, not known elsewhere and not closely similar to other described species; *D. wolforum*, n.sp., an interesting ornamented species from the lower Cisco beds that is known only from the holotype specimen; and *D. vulgatus*, n.sp., which belongs near the top of the Virgil series as represented by occurrences in Texas and by typical specimens found in the Brownville limestone, just beneath the disconformity marking the upper boundary of the Virgil in northern

Oklahoma. The observed distribution of *D. vulgatus*, in the Harpersville formation (Saddle Creek limestone) and Brownville limestone, accords with evidence of the fusulinids that has been recognized by Sellards[20] in revision of the Pennsylvanian-Permian boundary to a position beneath the Moran formation, but it is possible that the Pueblo formation, also, should be included in the Permian.

Permian beds.—According to present definition, Paleozoic rocks of the north-central Texas section above the base of the Moran formation are assigned to the Permian system. In west Texas the Permian begins with the Wolfcamp beds and continues upward through the Leonard, Word, and Capitan formations. The Hueco limestone of the Sierra Diablo and the Cibolo limestone on the flanks of the Chinati Mountains are of Wolfcamp age. Equivalents of the Leonard-Word beds are called Bone Spring and Delaware Mountain in the Sierra Diablo, Delaware Mountains, and Guadalupe Mountains.

The Wolfcamp deposits comprise the zone of *Pseudoschwagerina* and are equivalent to beds classed as the Big Blue series in the northern Mid-Continent, which also contain this fusulinid. Higher Permian zones in west Texas are characterized by the genera *Parafusulina* and *Polydiexodina*.[21] The *Pseudoschwagerina* zone, to which belong all the known Permian crinoids of North America, except one, is characterized among ammonites by occurrence of *Artinskia, Metalegoceras, Properrinites,* and several other genera[22, 23] that are observed in Lower Permian deposits of other continents.

The Lower Permian crinoid fauna of west Texas, made known almost entirely by specimens collected by J. A. Udden and described originally by Stuart Weller, comes from a single small area in Presidio County, about 3 miles north of Shafter, in beds called the Cibolo limestone. As here classified, most of Weller's species are generically re-allocated, and three additional species have been described, making 10 genera and 14 species in all, but no one of these species has yet been discovered in any other locality. Of the

[20]Sellards, E. H., The pre-Paleozoic and Paleozoic systems of Texas: The University of Texas Bull. 3232, pt. 1, p. 144, 1932.

[21]Dunbar, C. O., and Skinner, J. W., Permian Fusulinidae of Texas: The University of Texas Bull. 3701, pt. 2, p. 581, 1937.

[22]Plummer, F. B., and Scott, Gayle, Upper Paleozoic ammonites in Texas: The University of Texas Bull. 3701, pt. 1, p. 395, 1937.

[23]Miller, A. K., and Furnish, W. M., Permian ammonoids from the Guadalupe Mountain region and adjacent areas: Bull. Geol. Soc. Amer., vol. 12, p. 1918, 1938.

two additional species described from Lower Permian rocks of north-central Texas, *Delocrinus puebloensis*, n.sp., is identified only in Texas, but *Delocrinus abruptus*, n.sp., is found to occur both in the Florena shale member of the Beattie limestone of Kansas (just above the Cottonwood limestone) and in the Moran formation of Callahan County, Texas. The Kansas and Texas horizons containing *D. abruptus* appear to be about the same. Only three other Permian crinoids are known in North America: *Coenocystis richardsoni* Girty, from the Delaware Mountain formation in the southern Delaware Mountains, probably from the *Parafusulina* zone; *Delocrinus conicus* Boos from the Luta limestone of Kansas; and a form, also from the Luta of southern Kansas, described as *Erisocrinus lutana* Boos, but on the basis of the illustrations and comparison with specimens from near the same horizon and locality, this is indicated on the accompanying list as *Pachylocrinus lutanus* (Boos). Specimens of *D. conicus* have been collected from different localities in Kansas, but otherwise none of the Permian crinoids, except *D. abruptus*, is known to occur outside its type area.

List of Upper Carboniferous and Permian crinoids of North America showing stratigraphic and geographic distribution.

Geographic key—

Ark. (Arkansas, area near Fayetteville, Washington County, Arkansas).

Ill. (Illinois, counties indicated by numbers: *1*, Fayette; *2*, Fulton; *3*, Jersey; *4*, LaSalle; *5*, Macoupin; *6*, Peoria; *7*, Sangamon; *8*, Shelby).

Ind. (Indiana; counties indicated by numbers: *1*, Clay; *2*, Warren).

Iowa (Counties indicated by numbers: *1*, Mills; *2*, Parke; *3*, southwestern area).

Kans. (Kansas, counties indicated by numbers: *1*, Allen; *2*, Anderson; *3*, Chase; *4*, Cherokee; *5*, Cowley; *6*, Crawford; *7*, Douglas; *8*, Elk; *9*, Franklin; *10*, Greenwood; *11*, Jefferson; *12*, Montgomery; *13*, Shawnee; *14*, Wilson; *15*, Woodson; *16*, Wyandotte).

Mo. (Missouri, counties indicated by numbers: *1*, Boone; *2*, Jackson, containing Kansas City; *3*, Lafayette; *4*, Platte; *5*, Putnam; *6*, St. Louis).

Neb. (Nebraska, Otoe County, containing Nebraska City).

Ohio (Carbon Hill, Hocking County).

Okla. (Oklahoma, counties indicated by numbers: *1*, Carter; *2*, Cherokee; *3*, Hughes; *4*, Muskogee; *5*, Okmulgee; *6*, Osage; *7*, Tulsa; *8*, Washington).

N. M. (New Mexico, counties indicated by numbers: *1*, Santa Fe; *2*, Taos).

Pa. (Pennsylvania, vicinity of Pittsburgh, Allegheny County).

Tex. (Texas, counties indicated by numbers: *1*, Brewster; *2*, Brown; *3*, Callahan; *4*, Culberson; *5*, Hood; *6*, Jack; *7*, Kimble; *8*, McCulloch; *9*, Mason; *10*, Palo Pinto; *11*, Parker; *12*, Presidio; *13*, San Saba; *14*, Stephens; *15*, Wise; *16*, Young).

Utah (area near confluence of Green and Colorado rivers, Utah).

W. Va. (West Virginia, near Wellsburg, Brooke County).

*Indicates type specimens. ?—Doubt as to stratigraphic position.

Species	Morrow	Des Moines	Missouri	Virgil	Permian
CAMERATA—					
Acrocrinus brentwoodensis Moore and Plummer	Ark.*				
Acrocrinus pirum Moore and Plummer	Okla. 4*				
Acrocrinus wortheni Wachsmuth			?Ill. 6*		
FLEXIBILIA—					
Amphicrinus carbonarius Springer		Kans. 6* Okla. 6			

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Cibolocrinus typus Weller					Tex. 12*
C. punctatus, n.sp.	Tex. 13*				
C. regalis, n.sp.					Tex. 12*
C. regularis Moore and Plummer	Okla. 4*				
C. tumidus Moore and Plummer	Okla. 4*				
Synerocrinus formosus, n.sp.		Tex. 11*			
Talanterocrinus farishi (Laudon)	Okla. 1*				
INADUNATA—					
Aatocrinus robustus (Beede)			Mo. 2*		
A. cavumbilicatus, n.sp.		Tex. 10*			
A. mucrospinus (McChesney)			Ill. 5,* 4		
A. patulus (Girty)		Okla. 3*			
Adinocrinus pentagonus (Miller and Gurley)			Mo. 2*		
Aesiocrinus magnificus Miller and Gurley			Mo. 2*		
A. barydactylus (Keyes)			Mo. 2* Tex. 10		
A. basilicus Miller and Gurley			Mo. 2*		
A. harii Miller and Gurley			Mo. 2*		
A. lykinsi Butts			Mo. 2*		
Aidemocrinus odiosus J. M. Weller		Ind. 2*			
Alcimocrinus girtyi (Springer)	Okla. 2*				
Allagecrinus bassleri Strimple			Okla. 8*		
A. strimplei Kirk			Okla. 8*		
Amphipsalidocrinus scissurus J. M. Weller		Ind. 2*			
Apographiocrinus typicalis, n.sp.			Kans. 14,* 12 Okla. 8 Tex. 15		
A. carbonarius (Meek and Worthen)			Ill. 7*		
A. calycinus, n.sp.			Tex. 10*		
A. decoratus, n.sp.			Tex. 10*		
A. exculptus, n.sp.			Tex. 2*		

Species	Morrow	Des Moines	Missouri	Virgil	Permian
A. facetus, n.sp.			Tex. 2*		
A. wolfcampensis, n.sp.					Tex. 12*
Apollocrinus geometricus, n.sp.			Kans. 1*		
A. angulatus (Miller and Gurley)			Mo. 2*		
A. florealis, n.sp.		Tex. 11*			
A. stillativus (White)				Kans. 15*	
Athlocrinus placidus, n.sp.			Kans. 14*		
A. clypeiformis, n.sp.			Tex. 10*		
A. nitidus, n.sp.			?Tex. 8*		
Brychiocrinus texanus, n.sp.		Tex. 11*			
Callimorphocrinus astrus typicus J. M. Weller		Ind. 2*			
C. astrus intermedius J. M. Weller		Ind. 2*			
C. astrus pyramidalis J. M. Weller		Ind. 2*			
C. expansus J. M. Weller		Ill. 3*			
C. illinoisensis J. M. Weller		Mo. 6*			
C. indianensis J. M. Weller		Ind. 2*			
C. infacetus J. M. Weller		Ind. 2*			
C. knighti J. M. Weller		Mo. 6*			
C. lilius J. M. Weller		Mo. 6*			
C. piasaensis J. M. Weller		Ill. 3*			
C. pocillus J. M. Weller		Ind. 2*			
C. vanpelti J. M. Weller		Ill. 3*			
Clithrocrinus pyriformis (Kirk)		Pennsylvanian, Alaska			
Coenocystis richardsoni Girty					Tex. 4*
Cromyocrinus grandis Mather	Ark.*				
Delocrinus hemisphericus (Shumard)		Mo. 1,* 3			
D. abruptus, n.sp.					Tex. 3 Kans. 5
D. benthobatus, n.sp.		Tex. 10*	?Tex. 8		
D. bispinosus, n.sp.			Tex. 10*		
D. bullatus, n.sp.		Tex. 10*			

Species	Morrow	Des Moines	Missouri	Virgil	Permian
D. conicus Boos	—	—	—	—	Kans. 5*
D. craigii (Worthen)	—	—	Ill. 1*	—	—
D. granulosus, n.sp.	—	Tex. 10* Okla. 5	—	—	—
D. granulosus moniliformis, n.var.	—	Tex. 10*	—	—	—
D. granulosus zonatus, n.var.	—	Tex. 10*	—	—	—
D. graphicus, n.sp.	—	—	Tex. 10*	—	—
D. megalobrachius (Beede)	—	—	—	Kans. 13*	—
D. inflexus (Geinitz)	—	—	—	Neb.*	—
D. major Weller	—	—	—	—	Tex. 12*
D. matheri Moore and Plummer	Okla. 4*	—	—	—	—
D. missiouriensis Miller and Gurley	—	—	Mo. 2*	—	—
D. nodulifer (Butts)	—	—	Mo. 2*	—	—
D. paucinodus, n.sp.	—	—	Tex. 15*	—	—
D.? perexcavatus, n.sp.	—	—	—	?Tex. 1*	—
D. pictus, n.sp.	—	—	Tex. 10*	—	—
D. puebloensis, n.sp.	—	—	—	—	Tex. 3*
D. quadratus, n.sp.	—	—	—	—	Tex. 12*
D. rugosus (Shumard)	—	?Mo. 5*	—	—	—
D. papulosus, n.sp.	—	—	Tex. 10*	—	—
D. somersi (Whitfield)	—	Ohio*	—	—	—
D. subhemisphericus, n.sp.	—	—	Mo. 2*	—	—
D. subcoronatus, n.sp.	—	—	Tex. 10*	—	—
D. verus, n.sp.	—	—	Tex. 10* Kans. 12	—	—
D. vulgatus, n.sp.	—	—	—	Tex. 16,* 14 Okla. 6	—
D. wolforum, n.sp.	—	—	—	Tex. 2*	—
Dichostreblocrinus scrobiculus J. M. Weller	—	Ind. 2*	—	—	—
Diphuicrinus croneisi Moore and Plummer	Ark.* Okla. 4	—	—	—	—

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Endelocrinus fayettensis (Worthen)			Ill. 1*		
E. allegheniensis (Burke)			W.Va.* Pa.		
E. bifidus, n.sp.			Tex. 10*		
E. grafordensis, n.sp.			Tex. 10* Kans. 12		
E. mitis, n.sp.		Tex. 10*			
E. parvus, n.sp.			Tex. 2* Kans. 12		
E. rectus, n.sp.		Tex. 11*			
E. texanus (Weller)					Tex. 12*
Erisocrinus typus Meek and Worthen			Ill. 7* Tex. 10		
E. conoideus Meek and Worthen			Ill. 7*		
E. elevatus, n.sp.			Tex. 10*		
E. erectus, n.sp.			Tex. 15*		
E. propinquus Weller					Tex. 12*
Ethelocrinus magister (Miller and Gurley)			Mo. 2*		
E. bassetti (Worthen)			Ill. 1*		
E. crassus (Meek and Worthen)		Ill. 2*			
E. expansus Strimple			Okla. 8*		
E. harii (Miller)			Mo. 2*		
E. millsapensis, n.sp.		Tex. 11*			
E. monticulatus (Beede)				Kans. 13*	
E. oklahomensis Moore and Plummer	Okla. 4* Ark.				
E. sphaeralis (Miller and Gurley)			Mo. 2*		
E. texasensis, n.sp.	Tex. 13*				
E. tuberculatus (Meek and Worthen)			?Ill. 3* Iowa 2		
Graphiocrinus kingi, n.sp.			Tex. 10*		

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Haeretocrinus missouriensis, n.sp.	—	—	Mo. 2*	—	—
H. washburni (Beede)	—	—	—	Kans. 13*	—
H. magnus, n.sp.	—	Tex. 11*	—	—	—
Hydriocrinus? rosei Moore and Plummer	Okla. 4*	—	—	—	—
Lageniocrinus cassidus J. M. Weller	—	Ind. 2*	—	—	—
Lasanocrinus daileyi (Strimple)	Okla. 4*	—	—	—	—
L. cornutus, n.sp.	Tex. 13*	—	—	—	—
Landonocrinus subsinuatus (Miller and Gurley)	—	—	Mo. 2*	—	—
L. arrectus, n.sp.	—	Tex. 10*	—	—	—
L. catillus, n.sp.	—	Tex. 10* Okla. 7	—	—	—
L. cucullus, n.sp.	—	Tex. 10*	—	—	—
Lecythiocrinus olliculaeformis White	—	—	—	Kans. 15*	—
L. adamsi Worthen	—	?Ill. 6*	—	—	—
Malaiocrinus parviusculus, n.sp.	—	Okla. 7 Tex. 5*	—	—	—
Marathonocrinus bakeri, n.sp.	—	?Tex. 1*	—	—	—
Morrowcrinus fosteri Moore and Plummer	Okla. 4*	—	—	—	—
Neozeacrinus kansasensis (Weller)	—	—	—	Kans. 10*	—
N. praecursor, n.sp.	—	Tex. 11*	—	—	—
N. uddeni (Weller)	—	—	—	—	Tex. 12*
Pachylocrinus lutanus (Boos)	—	—	—	—	Kans. 5*
P. ogarai, n.sp.	—	—	Tex. 10*	—	—
P. uddeni, n.sp.	—	—	Tex. 10*	—	—
Paradelocrinus aequabilis Moore and Plummer	Okla. 4* Ark.	—	—	—	—
P. brachiatus, n.sp.	—	Tex. 5*	—	—	—
P. dubius (Mather)	Ark.* Okla. 4	—	—	—	—
P. obovatus, n.sp.	—	—	Tex. 10*	—	—

Species	Morrow	Des Moiues	Missouri	Virgil	Permian
P. planus (White)				Kans. 15*	
P. protensus, n.sp.			Tex. 10*		
P. subplanus, n.sp.		Tex. 5,* 7	?Tex. 8		
P. toddanus (Butts)			Mo. 2*		
Paragassizocrinus tarri (Strimple)			Okla. 8* Kans. 12 Tex. 10, 15		
Parulocrinus blairi (Miller and Gurley)			?Mo. 4*		
P. beedei, n.sp.			Tex. 10*		
P. compactus, n.sp.			Tex. 10* Kans. 1, 12		
P. crassus (Meek and Worthen)		Ill. 2*			
P. marquisi, n.sp.			?Tex. 9*		
P. plattsburgensis (Strimple)			Okla. 8*		
P. pustulosus, n.sp.			Tex. 2*		
P. verrucosus (White and St. John)				?Iowa 3*	
Perimestocrinus nodulifer (Miller and Gurley)			Mo. 2*		
P. calyculus, n.sp.		Tex. 10*			
P. excavatus (Weller)					Tex. 12*
P. formosus, n.sp.			Tex. 10*		
P. granulifer (Miller and Gurley)			Mo. 2*		
P. parvus (Miller and Gurley)			Mo. 2*		
P. pumilis Moore and Plummer	Okla. 4*				
P. teneris Moore and Plummer	Ark. *				
P. impressus, n.sp.		Tex. 10	Tex. 10* Mo. 2; Kans. 1, 12, 14, 16 Okla. 8		
Pirasocrinus scotti, n.sp.		Tex. 5*			

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Plaxocrinus crassidiscus (Miller and Gurley)	—	—	Mo. 2*	—	—
P. aplatus, n.sp.	—	Tex. 10*	—	—	—
P. discus (Meek and Worthen)	—	—	Ill. 7*	—	—
P. lobatus, n.sp.	—	—	?Tex. 8*	—	—
P. mooresi (Whitfield)	—	Ohio*	—	—	—
P. obesus, n.sp.	—	Tex. 5*	Tex. 10	—	—
P. parilis, n.sp.	—	—	Tex. 6* Kans. 16	—	—
P. omphaloides, n.sp.	—	—	?Tex. 8* Tex. 10	—	—
P. perundatus, n.sp.	—	Tex. 5*	—	—	—
P. strigosus Moore and Plummer	Okla. 4* Ark.	—	—	—	—
Poteriocrinites lasallensis (Worthen)	—	—	Ill. 4*	—	—
P. macoupinensis (Worthen)	—	—	Ill. 5*	—	—
Schistocrinus torquatus, n.sp.	—	—	Mo. 2*	—	—
S. confertus, n.sp.	—	Tex. 11*	—	—	—
S. parvus, n.sp.	—	Tex. 11*	—	—	—
S. planulatus, n.sp.	—	Tex. 11*	—	—	—
Sciadiocrinus acanthophorus (Meek and Worthen)	—	Ill. 2*	—	—	—
S. disculus, n.sp.	—	—	Tex. 10* ?Tex. 8	—	—
S. harrisae, n.sp.	—	Tex. 5* Okla. 7	—	—	—
S. platybasis (White)	—	?Utah*	—	—	—
Scytalocrinus sansabensis Moore and Plummer	Tex. 13*	—	—	—	—
Sellardsicrinus marrsae, n.sp.	—	Tex. 11*	—	—	—
Spaniocrinus? trinodus (Weller)	—	—	—	—	Tex. 12*
Stuartwellercrinus symmetricus (Weller)	—	—	—	—	Tex. 12*
S. texanus (Weller)	—	—	—	—	Tex. 12*
S. turbinatus (Weller)	—	—	—	—	Tex. 12*

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Synbathocrinus melba Strimple	—	—	Okla. 8*	—	—
Texacrinus gracilis, n.sp.	—	Tex. 11*	—	—	—
Tytthocrinus comptus J. M. Weller	—	Ind. 2*	—	—	—
Ulocrinus buttsi Miller and Gurley	—	—	Mo. 2*	—	—
U. americanus (Weller)	—	—	—	—	Tex. 12*
U. kansasensis Miller and Gurley	—	—	Mo. 2*	—	—
U. sangamonensis (Meek and Worthen)	—	—	Ill. 7*	—	—
Ulrichicrinus oklahomae Springer	Okla. 2*	—	—	—	—
Utharocrinus pentanodus (Mather)	Okla. 4*	—	—	—	—
Zeacrinites? sellardsi, n.sp.	—	—	Tex. 10*	—	—
OSSICLES (framentary remains)—					
Acantharthropterum acutum Moore	—	Kans. 4*	—	—	—
A. cornu Moore	—	Kans. 4*	—	—	—
A. pendens (Moore and Plummer) ("Delocrinus")	Okla. 4*	—	—	—	—
A. simum (Moore and Plummer) ("Paradelocrinus")	Ark.* Okla. 4	—	—	—	—
Aulosomphostega incisa Moore	—	Kans. 4*	—	—	—
Bunaglaopolygonum costale (Moore and Plummer) ("Ethelocrinus")	Ark.* Okla. 4	—	—	—	—
B. tuberculatum Moore	—	Kans. 4*	—	—	—
Bunarthrum septatum Moore	—	—	Kans. 12*	—	—
Coenarthropterum corrugatum Moore	—	—	Kans. 12*	—	—
Cyclocyclopa acuticarinata Moore	—	—	Kans. 12*	—	—
Cyclopentagonopa excentrica Moore	—	Kans. 4*	—	—	—
C. granulosa Moore	—	Okla. 4*	—	—	—
Ellipsellipsopa spicata Moore	—	—	Kans. 12*	—	—
Engoniarthrum granulosum Moore	—	—	Kans. 12*	—	—
E. lineatum Moore	—	Okla. 7*	—	—	—
Gisacanthostega acicularis (Moore and Plummer) ("Xystocrinus")	Okla. 4*	—	—	—	—
G. angusta Moore	—	—	Kans. 12*	—	—

Species	Morrow	Des Moines	Missouri	Virgil	Permian
G. crassacantha (Moore and Plummer) ("Sciadiocrinus")	Ark.* Okla. 4				
G. expansa Moore		Kans. 4*			
Henanobasis caliculus (Moore and Plummer) ("Agassizocrinus")	Ark.* Okla. 4				
H. carbonarius (Worthen) ("Agassizocrinus")			Ill. 8*		
H. coffeyvillensis Moore			Kans. 12*		
H. magnus (Moore and Plummer) ("Agassizocrinus")	Ark.*				
Hoplarthrum canalis Moore		Kans. 4*			
H. tenue Moore		Kans. 4*			
Liopolygonum occidentale (Miller and Gurley) ("Ulocrinus")			?Mo.?*		
Lophaglaopolygonum tenuirugosum Moore			Iowa 3*		
L. hispidum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
L. papulosum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
L. subsinuatum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
Macrocrinarthrum corrugatum Moore			Kans. 12*		
M. costale (Moore and Plummer) ("Ethelocrinus")	Ark.* Okla. 4				
M. hispidum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
M. papulosum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
M. subsinuatum (Moore and Plummer) ("Ethelocrinus")	Okla. 4*				
M. tuberculatum Moore		Kans. 4*			
Pentagonocyclopa dispar Moore			Kans. 12*		
Pentanobasis regularis Moore			Okla. 8*		
P. occidentalis (Miller and Gurley) ("Ulocrinus")			?Mo.?*		
Pentecatobasis excavata Moore					Kans. 3*

Species	Morrow	Des Moines	Missouri	Virgil	Permian
Pentexobasis glypta Moore	—	Kans. 4*	—	—	—
P. plana Moore	—	—	Kans. 12*	—	—
Schedaglaopolygonum corrugatum Moore	—	—	Kans. 12*	—	—
Stereobrachicrinus pustullosus Mather	Okla. 4* Ark.	—	—	—	—
Trianobasis bridwelli Moore	—	—	—	Kans. 7*	—
Triexobasis banioni Moore	—	—	—	Okla. 5*	—

Additional crinoids from the Missouri series of northeastern Oklahoma and southern Kansas.

Flexibilia—
- Amphicrinus oklahomaensis Strimple
- A. poundi Strimple
- Cibolocrinus robustus Strimple

Inadunata—
- Aesiocrinus typus (Strimple)
- A. osagensis (Strimple)
- Decadocrinus regularis Strimple
- Delocrinus nodosarius Strimple
- Delocrinus parinodosarius Strimple
- Endelocrinus tumidus (Strimple)
- Eucrisocrinus waysidensis Strimple
- Graphiocrinus stantonensis Strimple
- Hydreionocrinus deweyensis Strimple
- Lasanocrinus daileyi (Strimple)
- Lecythiocrinus urnaeformis Strimple
- Melbacrinus americanus Strimple
- Poteriocrinites ramonaensis Strimple
- Scytalocrinus deminutivus Strimple
- S. larvalis Strimple
- Ulocrinus convexus (Strimple)
- Utharocrinus granulosus Strimple
- Apollocrinus exculptus (Strimple)

DESCRIPTIONS OF CRINOID GENERA AND SPECIES

Order FLEXIBILIA Zittel, 1895

Suborder SAGENOCRINOIDEA Springer, 1920

Family LECANOCRINIDAE Springer, 1920

Genus CIBOLOCRINUS Weller, 1909

Cibolocrinus WELLER, 1909, Jour. Geol., vol. 17, p. 630.

Cibolocrinus Weller, emend. WANNER, 1916, Paläontologie von Timor, Lief. 6, p. 206.—1924, Jaarb. Mijn. Ned. Oost-Indië, Verh. 1921, p. 53.

Cibolocrinus Weller, emend. MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 230.

This genus, defined originally on the basis of specimens from the Cibolo limestone (now known to be equivalent to part of the Wolfcamp formation) of west Texas, was first distinguished mainly by the presence of three infrabasals (IBB) and of a single anal plate. Wanner[24] slightly modified the conception of the genus, so as to make the position of the small infrabasal (IB), whether in one radius or another, of no special importance. The paper on

[24]Wanner, J., Die permischen Echinodermen von Timor (Teil 1): Paläontologie von Timor, Lief. 6, Teil 11, p. 206, 1916.

Morrow crinoids[25] pointed out the reasonable certainty that two or more generic types had previously been included under this name, and accordingly *Cibolocrinus* was restricted to apply to crinoids having characters of the genotype species, *C. typus* Weller. A further conclusion based on a study of the radial facets and the character of the sutures between the plates of the cup was that this crinoid belonged to the family Lecanocrinidae among the Flexibilia, rather than to the Poteriocrinitidae among the Inadunata, where it had been placed by previous workers. The somewhat modified emended diagnosis of the genus, as presented by the authors[26] follows.

The calyx is basin-shaped, with evenly rounded or flat base and dicyclic. The infrabasals (IBB) are not visible from the side. The stem impression is round and slightly but sharply depressed. There are three infrabasals (IBB), and the position of the small infrabasal is variable but generally in the anterior or right posterior radius. There are five basals (BB), and the posterior basal (pB) is typically somewhat larger than the others. The five radials (RR) bear articular facets that are not appreciably wider than the thickness of the radial plates and have a well-defined broad furrow at the sides, the confluent furrows on adjoining plates making a crescent-shaped basin in the area of the interradial sutures. Anal x is moderately large, separates the posterior radials (RR), and rests on the posterior basal (pB). The arms are unknown.

It is now possible to make a noteworthy addition, for the recent discovery of a complete crown of a new species of *Cibolocrinus*, from the Marble Falls limestone in central Texas, permits indication of the character of the arms. Most interesting is the complete confirmation of earlier conclusions as to the classificatory position of *Cibolocrinus*. The arms are those of flexible crinoids, and the whole character of the crown is so closely similar to that of some genera of the Lecanocrinidae that no slightest doubt remains as to placement here. Like *Lecanocrinus* and *Mespilocrinus*, in particular, the entire length of the arms is hardly greater than their maximum width; they abut closely and curve inward together at the top.

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[25]Moore, R. C., and Plummer, F. B., Upper Carboniferous crinoids from the Morrow subseries of Arkansas, Oklahoma, and Texas: Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), pp. 225–231, 1938.

[26]Idem, p. 230.

Basing definition of the character of arm structure on the one specimen in which this is now known, it is obvious that in *Cibolocrinus* the arms are relatively very broad and short, with two primibrachs (IBr), three secundibrachs (IIBr) (although it is not known that this is constant in all the rays), and two or more tertibrachs (IIIBr). Branching is regularly isotomous.[26a]

Genotype.—*Cibolocrinus typus* Weller, from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas.

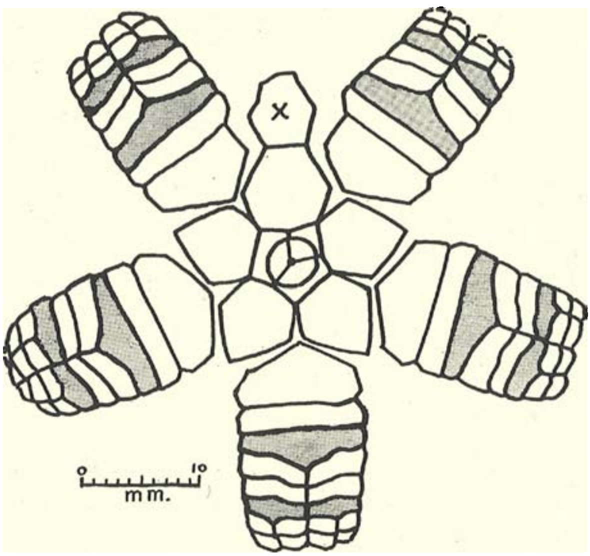

Fig. 7. Diagram showing the shape and arrangement of plates and the structure of the arms in *Cibolocrinus punctatus* Moore and Plummer, n.sp., based on the holotype specimen. The very short arms branch isotomously, the axillary brachial plates being shaded.

Discussion.—An interpretation of the lecanocrinid genus *Mespilocrinus* de Koninck and Le Hon, which most paleontologists would regard as not unreasonably broad, admits of the inclusion of crinoids that have been placed in *Cibolocrinus* as now restricted. *Mespilocrinus* has three infrabasals (IBB) that project slightly beyond the stem impression, one large anal x, and short wide arms that branch isotomously twice in each ray. All these characters appear also in

[26a]Two specimens of *Cibolocrinus* with portions of the arms have been reported by Strimple (Bull. Amer. Pal., vol. 24, no. 87, p. 7, 1939). The structure of the arms, in so far as shown by these specimens, agrees with that shown by *C. punctatus*, n.sp.

Cibolocrinus, and the question should be raised as to whether Weller's genus is to be suppressed as a synonym of *Mespilocrinus.*

Although the general structure in the crown of *Mespilocrinus* and *Cibolocrinus* is unquestionably the same, there are differences that may possibly have generic value. The genotype species of *Mespilocrinus, M. forbesianus* de Koninck and Le Hon, and all other definitely identifiable, typical species of the genus, show a peculiar and characteristic twist of the arms from left to right, which gives to the plates, both of the arms, and the upper part of the cup, an asymmetry of form that is foreign to *Cibolocrinus.* The posterior basal plate of *Mespilocrinus* is exceptionally large, reaching to the summit of the radials or just short of this height; in *Cibolocrinus* the posterior basal (pB) is slightly larger than the other basals (BB) but in no known species rises beyond the mid-height of the radials (RR). The arms of known species of *Mespilocrinus* show rather constantly two primibrachs (IBr) and two secundibrachs (IIBr), although Springer[27] notes that the character of the branching in this genus is somewhat inconstant. The one known example of the arms in *Cibolocrinus* shows two primibrachs (IBr) and three secundibrachs (IIBr). At least three species of *Mespilocrinus* in which the structure of the stem is known, show a striking change in the form of the stem segments downward from the crown, but this is of no value for comparison, since the structure of the stem of *Cibolocrinus* is not known. Finally, the crown in *Mespilocrinus* is both actually and in relative size compared to diameter of the stem much smaller than the average in *Cibolocrinus.* The crown hangs downward from the top of the bent stem in *Mespilocrinus;* it may or may not do this in *Cibolocrinus.*

Springer points out that *Mespilocrinus* is a very rare, diminutive, somewhat plastic genus, that is represented by species known only from lowermost Lower Carboniferous strata in Belgium, England, and the United States. Species of crinoids that are referable to *Cibolocrinus*, as emended, are fairly robust forms that show constant features of the dorsal cup. They are known from lowermost Upper Carboniferous to Lower Permian in the central United States. Basing judgment primarily on differences in the arms, the relative size of the posterior basal, and geologic distribution, it appears inadvisable at present to place *Cibolocrinus* in synonymy

[27]Springer, Frank, The Crinoidea Flexibilia: Smithsonian Inst. Pub. 2501, p. 191, 1920.

with *Mespilocrinus.* Accepting this distinction, there can be no question as to the close kinship of the two genera. This does not mean that *Cibolocrinus* is descended from *Mespilocrinus,* however, for if this were true it would be necessary to assume that the course of evolutionary change led anal x progressively to descend into the dorsal cup rather than to recede upward from it, according to general rule. The twist of the arms and the asymmetry in form of the plates seen in *Mespilocrinus* are specializations that probably are not important enough to eliminate consideration of this genus as possible ancestor of *Cibolocrinus,* but they indicate departure from the line leading to the Upper Carboniferous and Permian forms.

CIBOLOCRINUS TYPUS Weller

Pl. 1, fig. 1

Cibolocrinus typus WELLER, 1909, Jour. Geol., vol. 17, p. 631, pl. 1, figs. 20–22.

Description.—Weller's description slightly modified in form is as follows:

> Dorsal cup low bowl-shaped, nearly hemispherical in form. Surface of all the plates smooth, the sutures flush with the general surface of the cup. The dimensions of the two type specimens are: greatest width of dorsal cup, 25.8 mm. and 22.5 mm., height 11 mm. and 11 mm. Three infrabasals (IBB), forming a pentagonal disc, with three slightly reëntrant sides adjoining the sutures between the plates; diameter of the infrabasal (IBB) circlet in the large type 10 mm. Stem impression circular, moderately depressed, occupying about two-thirds of the diameter of the infrabasal (IBB) disc. Basal plates (BB) large, width equal to length or a little greater, all except the posterior one (pB) regularly pentagonal in general outline, but the anterior pair are generally hexagonal, although the two proximal faces are nearly a straight line and together are in length equal to the proximal faces of the other two; the posterior basal (pB) a little wider than the others, heptagonal in outline, being similar to the two anterior ones except that its distal extremity is truncated for the support of the anal plates. Radials (RR) large, wider than long, pentagonal in outline. Anal x pentagonal, resting between posterior radials, upon the truncate distal extremity of the posterior basal (pB); its angular distal extremity reaches above the level of the radials (RR).

The most important additional feature, called to attention by study of Weller's types, is the character of the radial facets. The outer rim of the facet area is slightly raised. The outer ligament area is very short and most of it is occupied by a ligament pit that reaches nearly to the lateral extremities of the facets. The inner articular ligament area is subhorizontal and nearly plane. The shallow depression with its confluent surface that occupies the area adjacent to the interradial sutures and is bordered on the outer side by the raised edge of the facets, is a characteristic feature.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation); Loc. 188–T–3, on Sierra Alta Creek, about 3 miles north of Shafter, Presidio County, Texas.

Types.—Syntypes, Walker Museum nos. 13370A, 13370B; collected by J. A. Udden.

CIBOLOCRINUS PUNCTATUS Moore and Plummer, n.sp.

Pl. 1, figs. 2–4; text figs. 7, 8

Description.—The crown is subglobular, the line at the summit of the radials (RR) dividing it into nearly equal lower and upper halves. The dorsal cup is truncate bowl-shaped, with height about one-half the width. The base is flat except for stem impression and is formed by the infrabasals (IBB) and proximal edges of the basals (BB). Three infrabasals (IBB) form a slightly stellate pentagon that is mostly covered by the round stem impression. The small infrabasal (IB) is located in the right posterior ray. The five basals (BB) are subequal, except the posterior basal (pB), which is a trifle larger than the others and is broadly truncate distally, instead of pointed. The basals (BB) curve sharply from a horizontal position proximally to an upward-flaring attitude in the median and distal portions. The length of the basals (BB) is about equal to their width. The radials (RR) are pentagonal, with width about twice the length; the two posterior radials (RR) are slightly narrower than the others. The slope of the outer faces of the radials (RR) is evenly confluent with that of the basals (BB), and none of the plates is strongly convex. The articular facets are clearly shown on three of the radials (RR), their character corresponding exactly to the description given under the genus. The anal x is flask-shaped, widest at mid-height, which is in line with the summit of the radials (RR). Its sides narrow slightly downward from this mid-point and abruptly upward from it for a short distance, and then they continue with vertical sides to the rounded top.

The stem impression has vertical sides and a height of about 0.7 mm. The impressed area is smooth except for a central portion, about 2 mm. in diameter, that is covered by a fine labyrinthine pattern of grooves and ridges, like the suture markings on the edges of plates. The central canal is round and 0.29 mm. in diameter.

The segments of the arms are arranged as described under the genus and as shown in figure 7. The primibrachs (IBr) of the right posterior and right anterior rays are in position above the radials (RR); those of the other rays, except the left posterior radial (lpR), are visible, but they and the upper part of the crown have slipped somewhat into the cavity of the cup. The upper articular faces of the brachials (Br) resemble the facets of the radials (RR), with a very wide, short ligament pit at the outer border; the lower articular surfaces are nearly smooth.

The surface of the cup and the arm segments are covered by fine but very distinct granules, many of them elongate so as to resemble short recumbent spines; about fifteen of the granules occur in a square millimeter.

Measurements of the holotype and two paratypes, in millimeters, are as follows:

	Holotype P–11183	Paratype P–11186	Paratype P–11186A
Height of dorsal cup	7.5	8.0	8.8
Greatest width of cup	18.7[a]	20.3	21.6
Ratio of height to width	0.40	0.39	0.41
Diameter of stem impression	4.3	4.7	4.8
Height of crown (estimated)	17	-----	-----

[a]Computed from circumference.

Discussion.—This new species from the Marble Falls limestone is a slightly smaller form than *C. typus* Weller; the flatness of its base is a little more pronounced; the small infrabasal (IB) is in the right posterior instead of the anterior ray, and the surface is distinctly ornamented rather than smooth. A much more closely allied species is *C. tumidus* Moore and Plummer from the Brentwood limestone of Arkansas and Oklahoma. Correspondence of size, shape, position of the small infrabasal (IB) and character of the surface ornamentation is seen, but the plates of *C. tumidus* are notably more convex, the sutures more sharply depressed, the size of the infrabasal (IBB) circlet and stem impression greater, and the character of the granulose ornamentation a little coarser. Comparison of the outlines of examples of *C. punctatus* with the holotype and paratype of *C. tumidus,* as given in figure 8, shows the difference in convexity of the basal and the radial plates. The Texas specimens show some variation from the smooth outline of the cup shown in the holotype toward the form of *C. tumidus,* but among the specimens from the Marble Falls limestone the individual that has most convex plates (P–11186A) and that is unhesitatingly

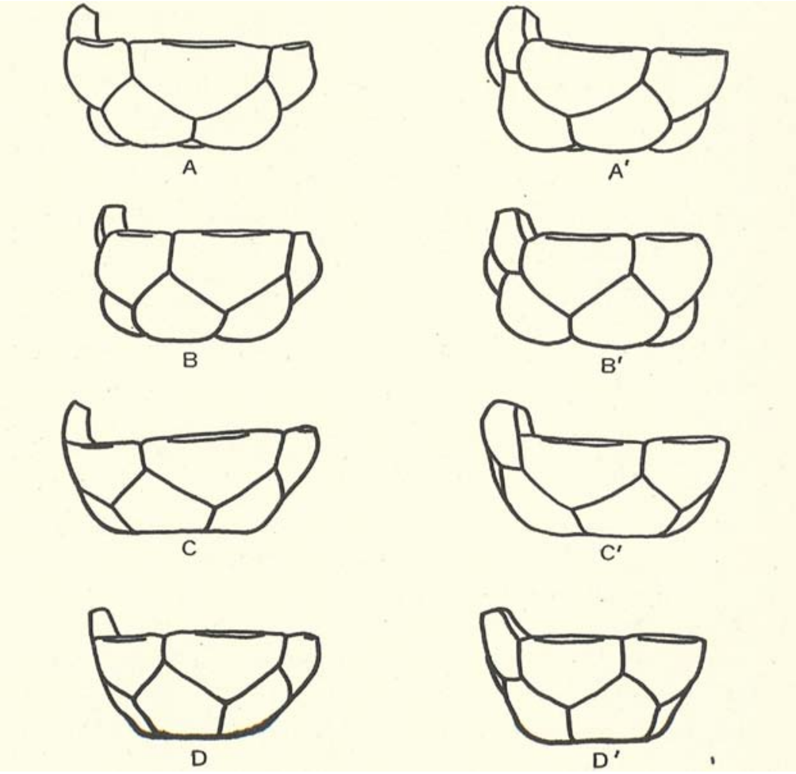

Fig. 8. Outline drawings for comparison of specimens of *Cibolocrinus punctatus* Moore and Plummer, n.sp., and of *C. tumidus* Moore and Plummer, to show the similarity in size and form but the difference in the convexity of the plates of the basal and radial circlets. A–D, specimens viewed normal to the antero-posterior axis; A′–D′, specimens viewed normal to the axis through the left posterior radial and right anterior basal; A,A′, holotype of *C. tumidus;* B,B′, paratype of *C. tumidus;* C,C′, D,D′, two paratypes of *C. punctatus.*

regarded as conspecific with the holotype of *C. punctatus* because of gradations between them shown by other examples is still very noticeably less tumid in appearance than the Oklahoma forms. There can be little question that the two species are closely related, but the differences noted appear to be constant and sufficient to furnish basis for separation. Furthermore, it is believed on the basis of other evidence, that the Texas specimens are somewhat younger than those from the Brentwood limestone in northeastern Oklahoma.

C. regularis Moore and Plummer, also from the Brentwood limestone, is a smaller species with more nearly vertical sides than *C. punctatus.*

Occurrence.—About 10 feet above the base of the Marble Falls limestone, Bend group (Morrow series), Pennsylvanian (Upper Carboniferous); Loc. 205–T–43, about 200 feet north of a cattle tank, in the bank of a creek about 0.1 of a mile west of the Wallace Creek road 11.5 miles by road southwest of Hotel San Saba, San Saba, San Saba County, Texas.

Types.—Holotype, Plummer Collection no. P–11183; paratypes, Plummer Collection nos. P–11186 and P–11186A; all at the Bureau of Economic Geology, The University of Texas, and collected by F. B. Plummer and G. H. Fisher.

CIBOLOCRINUS REGALIS Moore and Plummer, n.sp.

Pl. 1, fig. 5

Description.—One of the largest crinoid cups yet found in Texas belongs to this new species of *Cibolocrinus.* Its width at the top is 53 mm. (slightly over 2 inches), and its height is 20 mm. The outline of the cup is almost perfectly circular as seen in ventral or dorsal view, symmetrical low bowl-shaped, in anterior or posterior view, and distinctly asymmetrical as viewed from the right or left sides. The anterior slope is much steeper than the posterior. The base is almost imperceptibly flattened, but not truncated. The infrabasals (IBB) form a regular pentagon 22 mm. in diameter. The small infrabasal (IB) is in the anterior ray, as in *C. typus* Weller. The round stem impression is located in a steep-sided concavity, 2.5 mm. in depth and 12 mm. across at the rim. The basals (BB) are pentagonal, except the posterior basal (pB), which is hexagonal, distinctly wider than long, and they flare evenly upward and outward. The radials (RR) are twice as wide as long; their surface is nearly plane, sloping upward somewhat more steeply than the basals (BB). The facets are very short and show characters corresponding to those of the genotype species, with a broad flat area at the sutural margins. Anal x is not preserved in the holotype, but its position is indicated by the broad truncated tip of the posterior basal (pB). The surface of the plates is smooth and the sutures are not impressed.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	20.0
Width of dorsal cup	53.0
Ratio of height to width	0.38
Height of basal cavity	2.5
Width of basal cavity	12.0
Width of stem impression	8.2
Length of radial	15.5
Width of radial	31.0
Length of basal	17.0
Width of basal	22.0
Length of suture between basals	8.0
Length of suture between radials	9.0

Discussion.—This new species, more than twice as large as *C. typus* Weller, differs from it also in the much broader, lower form of the cup and in the gentler slope of the posterior part as compared with the anterior. In *C. typus* this asymmetry is reversed, the posterior slope being slightly steeper than the anterior; also the basals (BB) of *C. typus* are longer than wide, whereas in *C. regalis* they are distinctly wider than long. *C. regalis* is not closely similar to any other known species of *Cibolocrinus.*

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Kansas University no. 60374; collected by R. C. Moore.

Family ICHTHYOCRINIDAE Wachsmuth and Springer, 1879

Genus SYNEROCRINUS Jaekel, 1898

Synerocrinus JAEKEL, Zeitschr. deutsch. geol. Gesell., Bd. 49 (1897). p. 47.

NOT *Synerocrinus*, BATHER, 1899, British Assoc., Rpt. for 1898, p. 923; 1900, Treatise on Zoology (Lankester), pt. 3, p. 190.—SPRINGER, 1902, Amer. Geol., vol. 30, p. 95; 1906, Jour. Geol., vol. 14, p. 519; 1913, in

Zittel-Eastman, Textbook of Paleontology, p. 205; 1920, Crinoidea Flexibilia, Smithsonian Inst., Pub. 2501, p. 334.—ZITTEL, 1910, Grundzüge der Paläontologie, p. 166.

This genus is characterized by an elongate, rotund crown extending upward from the radials. The three infrabasals (IBB) are covered by the stem, and the five basals (BB) are laterally in contact, the distal extremities reaching beyond the stem. The posterior basal (pB) is larger than the others and is squarely truncated distally for contact with anal x. The radials (RR) are heptagonal and laterally in contact, except at the posterior interray, where the posterior basal (pB) and anal x intervene. The radianal plate is absent.

The arms are isotomous, each ray branching twice so as to produce 20 arms in the upper part of the crown. There are two primibrachs (IBr), three secundibrachs (IIBr), and ten or more tertibrachs (IIIBr). The interbrachials are few and appear between the rays and between the first two branches of each ray. The rays meet above the interbrachials but do not interlock. The stem is large, round, and composed of very thin segments that increase in diameter proximally.

Genotype.—*Forbesiocrinus incurvus* Trautschold.

Discussion.—The diagnosis of *Synerocrinus*, just given, accords only partly with that presented by Springer[28] in his monograph on the Flexibilia. The reasons for this deviation from previous views of the genus need to be discussed in some detail.

The genus *Synerocrinus* was introduced by Jaekel in 1898 to include flexible crinoids having no radianal, few interbrachials, and upper branches characterized by strong heterotomous division (having unequal branches). The genotype designated by Jaekel was *Forbesiocrinus incurvus* Trautschold. The original description of this species[29] was based on two specimens that have only isotomous divisions (ray or arm having equal branches) of the rays, and no mention is made that the species should include any form with heterotomous arms. The genus *Synerocrinus*, as described

[28]Springer, Frank, The Crinoidea Flexibilia: Smithsonian Inst., Pub. 2501, p. 334, 1920.

[29]Trautschold, H., Einige Crinoideen und andere Tierreste des jungeren Bergkalkes im Gouvernment Moskau: Soc. imp. Nat. Moskau Bull., vol. 40, pt. 2, no. 3, 1867.

and applied by Jaekel[30] and Springer,[31] and now generally understood, includes flexible crinoids having heterotomous arms, rather than isotomous ones. The upper part of the crown of *Synerocrinus*, as defined by Jaekel and by Springer, has 20 main arms and also a considerable number of additional smaller arms, a type of branching that is not at all the same as regular isotomous branching (fig. 9). Hence, the generic diagnosis does not apply to the genotype. Explanation of this strange situation is apparently found

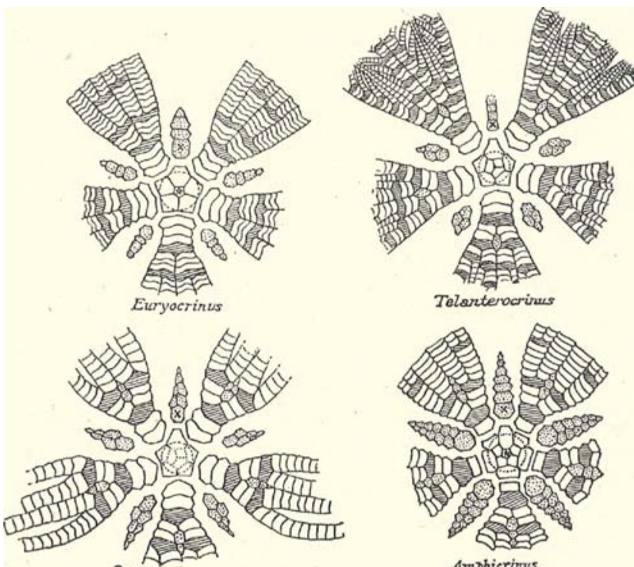

Fig. 9. Diagrams showing the structure of the dorsal cup and arms of *Euryocrinus* Phillips (Devonian to Lower Carboniferous, England and United States), *Synerocrinus* Jaekel (Upper Carboniferous, Russia and Texas), *Talanterocrinus* Moore and Plummer, n.gen. (Upper Carboniferous, Russia), and *Amphicrinus* Springer (Lower and Upper Carboniferous, Scotland and United States). Axillary brachials are shaded; interradials are stippled; a dotted circle shows the border of the stem impression. (Modified from Springer, 1920, except *Synerocrinus*, which is constructed from a study of Trautschold's figures of the original two specimens of the genotype of *Synerocrinus*; the drawing for *Talanterocrinus* is the erroneous interpretation of *Synerocrinus* by Springer and others.)

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[30]Jaekel, Otto. Über einige paläozoische Gattung von Krinoiden: Deutsch. geol. Gesell., Zeitschr., Verh. 1897, Bd. 49, 1898.

[31]Springer, Frank, The Crinoidea Flexibilia: Smithsonian Inst., Pub. 2501, 1920.

in the fact that a later work by Trautschold[32] contains an illustration of a crinoid called *Forbesiocrinus incurvus* showing distinct heterotomous division of the upper branches. No mention of this character, however, was made in the text, and clearly it does not accord with the original types, one of which was refigured by a good reproduction from a photograph.[33]

It is evident, under the rules of zoological nomenclature, that the species *F. incurvus* is based on Trautschold's original types, which have only isotomous division of the rays, even though as many as 18 brachials occur above the second bifurcation. Unless it is established that both isotomous and heterotomous division of the upper branches must be included within the limits of this single species—and this is hardly conceivable—one is forced to the conclusion that Trautschold was in error when he assigned the specimen with heterotomous arms to his *F. incurvus.* Since it is necessary to define the genotype of *Synerocrinus* on the basis of the original types of *Forbesiocrinus incurvus,* the definition of generic characters as given by Jaekel and accepted by later authors is invalid. If the type of crinoid represented by the original types of *F. incurvus* is worthy of differentiation as a distinct generic form, it is known as *Synerocrinus,* and if this is not a valid generic unit, *Synerocrinus* is to be suppressed as a synonym. In any case, a name other than *Synerocrinus* must be sought if one intends, as did Jaekel, to designate the heterotomous type of crinoid as a distinct genus.

The question of whether *Synerocrinus,* understood in terms of Trautschold's original types of *Forbesiocrinus incurvus,* is worthy of generic distinction needs to be considered. The only described genera having characters of the crown like those presented by Trautschold's types are *Euryocrinus* Phillips and *Amphicrinus* Springer. Both these genera show isotomous division of the rays, except that in each certain branches are undivided above the second dichotom. In *Euryocrinus* there are three primibrachs (IBr) and only a single row of interbrachials in the five interrays (fig. 9). In *Amphicrinus* the basals (BB) (except the posterior basal, pB) do not extend beyond the stem impression; interbrachials are generally numerous; the plates, throughout a large part of the crown, are interlocking; and this union produces a fairly solid structure with

[32]Trautschold, H., Die Kalkbruche von Mjatschkowa; eine Monographie des oberen Bergkalks: Soc. imp. Nat. Moscou, Nouv. Mém., vol. 14, pl. 15, figs. 3a, 3b, 1879.

[33]Idem, p. 126, pl. 14, fig. 11.

smooth contour (fig. 9). In *Synerocrinus* a part of each basal plate extends beyond the edge of the column; there are two primibrachs (IBr) as in *Amphicrinus;* interbrachials are more numerous than in *Euryocrinus* and less numerous than in *Amphicrinus;* each ray is isotomously divided two times, whereas in *Euryocrinus* and *Amphicrinus* a third isotomous division occurs typically in a pair of branches of each ray (fig. 9). The distinctions noted seem adequate basis for generic separation, and accordingly *Synerocrinus* is accepted as a valid genus.

The crinoid with heterotomous arms that has generally been identified as *Synerocrinus incurvus* belongs neither to *Synerocrinus* nor to the species *S. incurvus.* As was concluded by Jaekel, it is generically distinct from other Flexibilia, and it is here designated as *Talanterocrinus jaekeli* (fig. 9). Brief diagnosis and notation concerning types are given under separate headings below.

Occurrence.—Upper part of Lower Carboniferous near Moscow, Russia, and Des Moines series, lower-middle Pennsylvanian (Upper Carboniferous), Texas.

SYNEROCRINUS FORMOSUS Moore and Plummer, n.sp.

Pl. 2, figs. 3, 4; text fig. 10

Description.—Description of this new species is based on several fine specimens.

The crown is subglobular, showing in general all characters as described under the genus. The distal parts of the basals (BB) are clearly visible as triangular or subpentagonal areas between the radials (RR) and the edge of the stem. In one small specimen these plates are relatively much more prominent than in the large ones, owing chiefly to the much smaller diameter of the stem. The posterior basal (pB) rises to mid-height of the radials (RR) where it is broadly and squarely truncated for contact with the anal x. The radials (RR) lie entirely outside the area of the stem impression. They are fairly large, nearly twice as wide as long, and their suture at the distal margin is gently curved. In the larger specimens the first primibrach (IBr_1) is of the same shape as the radials (RR) but a little larger; in the presumably immature specimen, it is quadrangular in outline and a little smaller than the radials (RR). The second primibrach (IBr_2) axillary is slightly larger than any of the plates below. Above this, the large specimens shows three secundibrachs (IIBr) in all branches; the tertibrachs (IIIBr) are all subquadrangular segments with gently curved facets, four (incomplete) to eleven being observed in each branch. The segments of adjacent arms do not interlock, and there is a slight spread of the arms at each forking. The small specimen shows only three secundibrachs (IIBr) in some branches, four in others. The tips of the arms curve strongly inward.

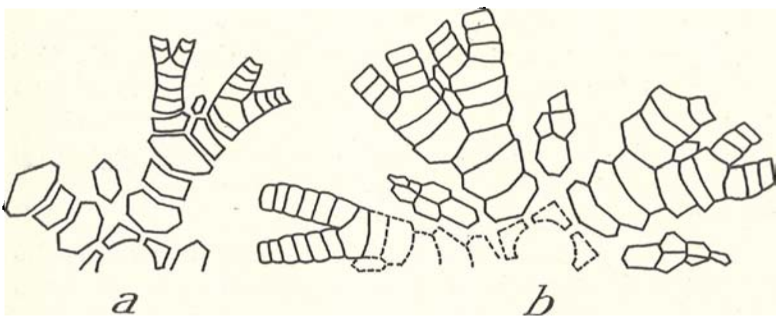

Fig. 10. Diagrams of *Synerocrinus formosus* Moore and Plummer, n.sp., showing arrangement of plates and mode of branching of arms. *a*, Immature form (paratype, H–2); *b*, mature form (holotype, H–1).

Interbrachial plates are relatively few in number, but they appear between each of the main rays and between the first two branches of each ray. One large interbrachial is commonly followed by two in the range next above it, but the series quickly narrows and disappears. Only a single rather large interbrachial is observed between the branches of the small specimen.

The measurements of the crown, in millimeters, are as follows:

	Holotype H–1	Paratype H–2
Height of crown	31	23
Width of crown	36	27

Discussion.—Close comparison of the holotype with figures of the chief type of *S. incurvus*[34] shows such nearly exact correspondence that one might think that they represent a single species. The Texas form is larger, the brachials (Br) are proportionally a little longer, and the points of branching, represented by the axillary

[34]Trautschold, H., Einige Crinoideen und andere Thierreste des jüngeren Bergkalkes im Gouvernement Moskau Soc. imp. Nat. Moskau Bull., vol. 40, pl. 4, fig. 4. Die Kalkbruche von Mjatschkowa; eine Monographie des oberen Bergkalks: Soc. imp. Nat. Moscou, Nouv. Mém., vol. 14, pl. 14, fig. 11, 1879.

plates, are relatively higher on the crown. In *S. incurvus*, the axillary secundibrachs (IIAx) occur at almost exactly the mid-height of the crown, but in *S. formosus*, n.sp., at two-thirds of the height above the base. The Russian species has only three or four small interradial plates between the main rays and one or two between the branches of second order, whereas these areas and the number of plates are a little larger in the Texas species. The anal x in *S. formosus* supports two primibrachs (IBr) in the next overlying series.

No known American crinoid is closely similar to the species here described. The crinoid from Lower Pennsylvanian rocks in southern Oklahoma, identified as *Synerocrinus farishi* Laudon,[35] has almost nothing in common with *S. formosus* and does not belong to the same genus.

Occurrence.—Brannon Bridge limestone member, Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, 3 miles southwest of Brock, Parker County, Texas.

Types.—Holotype, no. H–1, paratype, no. H–2, both in the Harris Collection; collected by Mrs. G. W. Harris, Waco, Texas. Paratypes, nos. M–2, M–5, M–16, M–30, and M–39, in Marrs Collection; collected by Mrs. W. R. Marrs, Austin, Texas.

Genus TALANTEROCRINUS[35a] Moore and Plummer, n.gen.

Synerocrinus Jaekel, BATHER, 1899, British Assoc., Rept. for 1898, p. 923.

Synerocrinus Jaekel, BATHER, 1900, Treatise on Zoology (Lankester), pt. 3, p. 190.

Synerocrinus Jaekel, SPRINGER, 1901, Amer. Geologist, vol. 30, p. 95.

Synerocrinus Jaekel, SPRINGER, 1906, Jour. Geol., vol. 14, p. 519.

Synerocrinus Jaekel, ZITTEL, 1910, Grundzüge der Paläontologie, p. 166.

Synerocrinus Jaekel, SPRINGER, 1913, in Zittel-Eastman, Textbook of Palaeontology, p. 205.

Synerocrinus Jaekel, SPRINGER, 1920, Crinoidea Flexibilia, Smithsonian Inst., Pub. 2501, p. 334.

The crown of this genus is elongate to rotund, expanding upward from the radials. The arrangement of the plates in the cup and arms is generally like that of *Synerocrinus*, except that the branching above the axillary secundibrachs (IIAx) is heterotomous.

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[35]Laudon, L. R., New occurrence of the Upper Carboniferous crinoid genera *Amphicrinus* and *Synerocrinus*: Jour. Pal., vol. 11, p. 706, text fig. 2, 1937.

[35a]From the Greek meaning more enduring.

Genotype.—*Talanterocrinus jaekeli* Moore and Plummer, n.sp.

Discussion.—The reasons for introducing a new genus to contain the heterotomously armed crinoid that Trautschold in 1879 incorrectly referred to his "*Forbesiocrinus incurvus*" and that Jaekel and others have intended to designate as *Synerocrinus incurvus* (Trautschold) have been given in the discussion of *Synerocrinus.* Trautschold's improperly identified hypotype of 1879 and several specimens from the vicinity of Moscow figured by Springer[36] under the name *Synerocrinus incurvus* (Trautschold) are here designated as *Talanterocrinus jaekeli* Moore and Plummer, n.sp. This crinoid is not known in North America. A large flexible crinoid from lower Pennsylvanian beds of southern Oklahoma, described by Laudon[37] under the name *Synerocrinus jarishi,* belongs to *Talanterocrinus;* the type of Laudon's species has been kindly lent for study. Specimens from the upper part of the Lower Carboniferous section of Scotland, reported by James Wright[38] as *Synerocrinus,* sp., on authority of Springer, also belongs to *Talanterocrinus;* as indicated by illustrations. These are figured by Springer[39] as *Synerocrinus incurvus.*

Occurrence.—Upper part of Lower Carboniferous, Russia and Scotland; lower part of Upper Carboniferous, of Pennsylvanian, in Oklahoma.

TALANTEROCRINUS JAEKELI Moore and Plummer, n.sp.

Text fig. 9

Forbesiocrinus incurvus Trautschold, TRAUTSCHOLD, 1879, Soc. imp. Nat. Moscou, Nouv. Mém., vol. 14, pl. 15, figs. 3a, 3b (not p. 126, pl. 14, fig. 11).

Synerocrinus incurvus (Trautschold), SPRINGER, Crinoidea Flexibilia, Smithsonian Inst., Pub. 2501, p. 334, pl. 42, figs. 3–9 (not figs. 1, 2a, 2b; pl. 75, figs. 12, 13).

Description.—The description of *Synerocrinus incurvus* (Trautschold), as given by Springer[40] refers to the species that is here

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[36]Springer, Frank, The Crinoidea Flexibilia Smithsonian Inst., Pub. 2501 pl 42, 1920.

[37]Laudon, L. R., New occurrence of the Upper Carboniferous crinoid genera *Amphicrinus* and *Synerocrinus:* Jour. Pal., vol. 11, p. 706, 1937.

[38]Wright, James, On the occurrence of crinoids in the Lower Carboniferous limestones of Fife: Edinburgh Geol. Soc., Trans., vol. 10. pt. 2, p. 161, 1911. Carboniferous crinoids from Fife, with notes on some localities and provisional lists of species: Geol. Soc. Glasgow. Trans., vol. 16, pt. 3. p. 387, 1918.

[39]Springer, Frank. The Crinoidea Flexibilia: Smithsonian Inst., Pub. 2501, pl. 75 figs. 12, 13, 1920.

[40]Idem, pp. 335, 336.

intended to be designated by a new generic and specific name, because, as pointed out under the discussion of *Synerocrinus,* it appears that the name formerly used can not properly be applied. Apparently all the forms illustrated by Springer (except, of course, his reproductions of the types of *Synerocrinus incurvus,* pl. 42, figs. 1, 2a, 2b) may be assigned to *Talanterocrinus jaekeli,* n.sp.

Occurrence.—Upper part, Lower Carboniferous, near Moscow, Russia, and Scotland.

Types.—The specimen in the Springer Collection at the U.S. National Museum that is illustrated in Springer's figures 4a and 4b, plate 42 (1920), is designated as holotype. This is a Russian specimen from the vicinity of Moscow.

Order INADUNATA Wachsmuth and Springer, 1885

Suborder FISTULATA Wachsmuth and Springer, 1885

Family POTERIOCRINITIDAE Roemer, 1855

SECTION A.—*Poteriocrinitidae with articular facets very distinctly narrower than the width of the radials, and with non-articular outer surface of the radials extended on both sides of the facets.*

SUBSECTION A-1.—*Facets sloping very steeply outward, more or less horseshoe-shaped.*

GROUP b.—*Infrabasals not flaring upward, not visible from the side; cup truncate bowl-shaped; one to three anal plates in the cup.*

Genus MALAIOCRINUS Wanner, 1924

Malaiocrinus WANNER, 1924, Jaarb. Mijnw. Ned. Oost-Indië (1921), p. 183.
Malaiocrinus Wanner, WANNER, 1937, Palaeontographica, Suppl., Bd. 4, Abt. 4, Leif. 2, p. 141.

This genus includes dorsal cups of moderately low truncate globular form. Its five infrabasal plates (IBB) are not visible in the side view of the cup; in all described species these plates are mostly covered by the large round stem impression. The five basals (BB) are subequal in size, as are also the five radials (RR). The chief distinguishing features of the cup are the narrow radial facets that slope rather steeply outward and the presence of three anal plates in the cup. The facets are by no means so constricted as in some crinoids, but there is a readily observed notch along the upper part of the interradial sutures where the nonarticular surface of the plates curves inward at the sides of the facets. The three anal plates comprise a radianal (RA), anal x, and the right tube plate (rt) in normal position.

Genotype.—Zeacrinus? sundaicus Wanner.

Discussion.—The genus is distinguished from *Poteriocrinites* Miller, *Mollocrinus* Wanner, *Springericrinus* Jaekel, and *Strongylocrinus* Wanner, all of which have narrow, rather steeply outward-sloping facets, by the form of the dorsal cup, the infrabasal plates being clearly visible from the side in these genera but not in *Malaiocrinus. Ceratocrinus* Wanner and *Apollocrinus,* n.gen., are comparable to *Malaiocrinus* in the form of the cup and in having

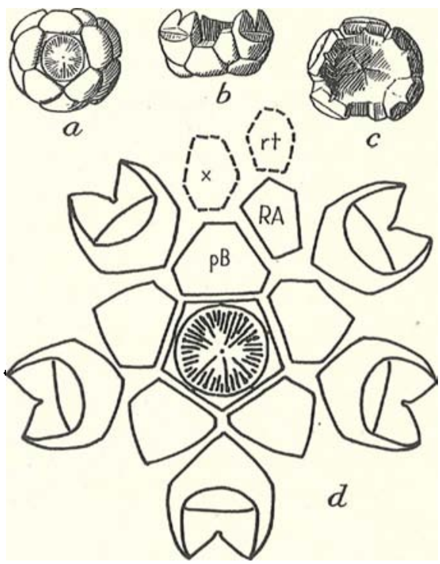

Fig. 11. Sketches of *Malaiocrinus sundaicus* (Wanner), from Permian strata of Timor, showing characters of *Malaiocrinus* as indicated by the genotype species. *a,* Dorsal view of the holotype, x1; *b,* posterior view, the two anal plates that belong above the posterior basal and radial plates missing, x1; *c,* ventral view (after Wanner), x1; *d,* diagram showing arrangement of plates of the dorsal cup (constructed from figures by Wanner), x2.

narrow, steeply outward-facing facets, but differences appear in the structure of the posterior interradius; *Ceratocrinus* has only one anal plate in the dorsal cup; although there are three anal plates in the cup of *Apollocrinus* the arrangement of these is quite different from that of *Malaiocrinus. Eupachycrinus* and numerous other Upper Carboniferous genera that have three anals in the dorsal cup differ in the form of the facets.

Occurrence.—The genus has previously been reported only from Permian rocks in Timor, Dutch East Indies; a species assigned to *Malaiocrinus* is here described from Pennsylvanian rocks in Texas and Oklahoma.

MALAIOCRINUS PARVIUSCULUS Moore and Plummer, n.sp.

Pl. 14, fig. 6

Description.—The dorsal cup is low truncate bowl-shaped with evenly rounded, flaring sides and a small basal concavity. The infrabasal circlet has a slightly stellate pentagonal form, the distal area of the plates is subhorizontal and the proximal parts are included in the hollow stem impression. The basal plates (BB), which are about as wide as long, flare slightly downward in the proximal region and curve evenly outward and upward to about the mid-height of the cup. The basal plane of the cup is tangent to the basals on a line that is about one-fourth the length of the plates distant from the proximal edge. The radials are twice as wide as long; they are only slightly curved longitudinally. The facets are distinctly narrower than the greatest width of the radials, and their plane slopes steeply outward. The outer ligament area, bounded by the strong transverse ridge and a low marginal ridge, is inclined at an angle of about 75° to the horizontal; it contains a moderately deep ligament pit. The inner ligament area is short, somewhat concave, and marked by fairly strong lateral furrows; this part of the facet slopes at an angle of about 45°. The ornamented exterior of the radial plates extends upward around the sides of the facets, occupying a space 0.5 mm. or a little less in width between the facet and the suture of the radial. The posterior interradius is not at all depressed. A moderately long radianal (RA) of quadrangular form rests against the posterior (pB) and right posterior (rpB) basals. A pentagonal anal x lies above the squarely truncated tip of the posterior basal; and a small right tube plate (rt) that barely touches the radianal lies obliquely above anal x and projects slightly above the summit of the right posterior radial (rpR). The surface of the cup appears smooth to the unaided eye and the sutures are not impressed; examination under a microscope shows a well-defined granulose ornamentation, about twelve fine granules occurring to 1 mm.

The arms and anal sac are unknown. The stem is round.

After preparation of the description just given, based on the single observed specimen from Texas, which is designated and illustrated as holotype, seven specimens collected from the Oologah limestone near Tulsa, Oklahoma, have been made available for study. These are identical with the Texas form except for differences in size, and no detail of the description needs modification in order to include the Oklahoma specimens, which are designated as paratypes.

Measurements of the holotype and of six paratypes, in millimeters, follow:

	Holotype	Paratypes a	b	c	d	e	f
Height of dorsal cup	3.1	3.5	3.3	3.0	3.0	2.0	1.9
Greatest width of cup	6.8	10.1	10.5	10.7	10.0	6.1	5.1
Width of body cavity	4.5	7.8	8.1	8.2	8.1	4.5	3.8
Height of basal concavity	0.6	0.9	0.9	0.7	0.9	0.3	0.1
Width of basal concavity, about	3.0	4.5	4.5	5.0	4.5	3.0	2.0
Diameter of stem impression	1.2	1.2	1.4	1.6	1.2	0.9	0.8
Width of radial plate	4.1	5.9	6.0	6.0	6.0	3.8	3.3
Width of facet	2.9	3.0	3.1	3.6	3.6	2.5	2.4
Length of facet	1.2	1.4	1.4	1.3	1.2	0.9	0.8

Additional measurements of the holotype include: width of infrabasal circlet, 2.0 mm.; length of basal plate, 3.0 mm.; width of basal plate, 3.2 mm.; length of radial plate, 2.1 mm.

Discussion.—This little crinoid does not closely resemble any known American Upper Carboniferous or Permian species. It generally corresponds in form of cup, arrangement of the anal plates, and the steep inclination of the facets to *Malaiocrinus sundaicus* Wanner, the genotype species, but differs in the much smaller relative size of the stem and in the shorter facets, as well as in some other features. *M. parviusculus* is not similar to other described species of this genus except in characters that may be regarded as of generic significance, and if the large round stem that is observed in each of the known Permian forms is a distinguishing feature of the genus, this is decidedly absent in *M. parviusculus*.

Occurrence.—Shale below Kickapoo Falls limestone member of Millsap Lake formation, Strawn group, Des Moines series, Pennsylvanian (Upper Carboniferous); Loc. 110–T–4, on bank of small branch about one-quarter of a mile below Kickapoo Falls on Kickapoo Creek, Hood County, Texas (holotype). Upper part of the Oologah limestone (equivalent to Altamont limestone of Kansas), near top of Des Moines series, at Garnett quarry, about 7 miles northeast of Tulsa, Oklahoma (paratypes).

Types.—Holotype, Plummer Collection no. P–10853, Bureau of Economic Geology, The University of Texas; collected by R. C. Moore. Paratypes, Kansas University, Stevens Collection, nos. 45899, 45899a–f (7 specimens); collected by Bob Stevens.

Genus APOLLOCRINUS[40a] Moore and Plummer, n.gen.

Whiteocrinus STRIMPLE, 1939, (not Jaekel), Bull. Amer. Pla., vol. 25, no. 89, p. 4.

The crown is very low. The arms spread subhorizontally outward from the low truncate bowl-shaped dorsal cup, which is typically marked by a shallow basal concavity. The five infrabasals form a regular pentagon, about one-half or more of which is covered by the round stem impression. The five basals are bulbous or angularly convex in form, pentagonal in outline, equal in size, except for the posterior basal (pB) which is hexagonal and a little larger than the others, and their proximal parts form the walls of the basal concavity. The five radials are about twice as wide as long when measured between the tip and margin of the facet. The general plane of the plates below the facets slopes strongly outward as well as upward. The articular facets are distinctly narrower than the greatest width of the radial plates, extensions of the outer face curve inward on each side of the facet, and the plane of the facets slopes slightly inward from a vertical position. Of the three anal plates in the dorsal cup, anal x rests on the squarely truncated distal edge of the posterior basal, and the two tube plates lie above this first anal plate.

The arms are composed of biserially arranged segments and are directed horizontally outward. They branch first on the first primibrach (IBr_1) and again on each of the two primary branches of a ray at a short distance from the cup (at about the 8th to 10th secundibrach). The tegmen and anal sac are unknown.

Genotype.—*Apollocrinus geometricus* Moore and Plummer, n.sp.

Discussion.—This genus, named for the Greek god Apollo, is very unlike any of its associates among Upper Carboniferous crinoids and may be readily distinguished from these by the narrow and

[40a]Now a synonym of *Stellarocrinus* Strimple (*Stellarocrinus*, new name for *Whiteocrinus* Strimple: Bull. Amer. Pal., vol. 25, no. 92A, 4 pp., 1 pl., March 7, 1940).

nearly vertical facets of its radial plates. The facets bear a well-marked transverse ridge, which is regarded as a diagnostic feature of the poteriocrinitids, but it is clear that *Apollocrinus* stands well apart from the common types of poteriocrinitids. The only described genus of closely similar character is *Ceratocrinus* Wanner[41] from the Permian rocks of Timor. This has the same form of low dorsal cup as *Apollocrinus*, with narrow, very steeply inclined radial facets and outspreading arms, but with only one large anal plate in the cup. Wanner's genus is named *Ceratocrinus* because of a prominent hornlike anal sac composed of large thick plates; no trace of the existence of a similar sac has been observed in *Apollocrinus*. Only the lowermost plates of any of the arms have been observed in *Ceratocrinus;* they show an axillary first primibrach, as in *Apollocrinus,* and lowest secundibrachs that occupy the full width of the arms, but it is possible that if additional secundibrachs were present, these would reveal biserial structure. The mode of preservation of the proximal arm sections, which are attached to the dorsal cup by a strongly developed tegmen, as seen in known examples of *Ceratocrinus*, indicates a difference between that genus and *Apollocrinus,* specimens of which show a very weak connection between the cup and arms. In final analysis, however, the only definite distinction between the Upper Carboniferous and the Permian forms under discussion appears to be in the structure of the posterior interradius of the cup; *Apollocrinus* has three anal plates below the summit of the radials, instead of one, and on this basis may be regarded as slightly less advanced in evolutionary trend than *Ceratocrinus*.

Among described species of crinoids, *Aesiocrinus angulatus* Miller and Gurley, from beds of the Missouri series at Kansas City, Missouri, and *Cyathocrinus stillativus* White, from Virgil beds in Woodson County, Kansas, belong to *Apollocrinus*. The holotypes of both these species have been studied and compared with the specimens from Texas. Strimple[41a] has described a species, *Whiteocrinus exsculptus* (Strimple) from Missouri beds at Bartlesville, Oklahoma. This generic name is preoccupied by *Whiteocrinus* Jaekel, 1918.

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[41]Wanner, J., Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor: Paläontographica, Suppl., Bd. 4, Abt. 4, Lief. 2, p. 177, 1937.

[41a]Strimple, H. L., Eight species of Pennsylvanian crinoids: Bull. Amer. Pal., vol. 25, no. 89, p. 5, 1939.

Occurrence.—Des Moines to Virgil series, Pennsylvanian (Upper Carboniferous); central and southwestern United States.

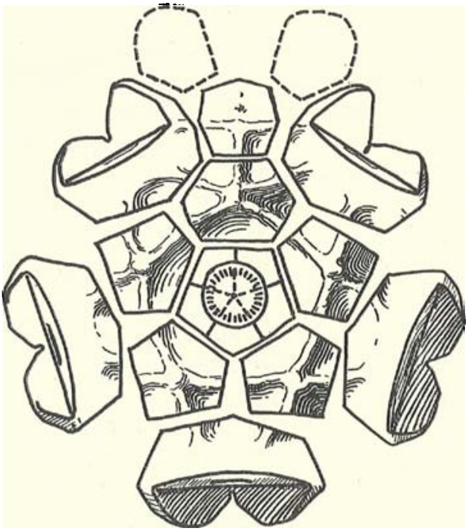

Fig. 12. Diagram showing the arrangement of plates in the dorsal cup of *Apollocrinus*, n.gen., based on the holotype of *A. geometricus* Moore and Plummer, n.sp., x2.5. The two anal plates shown by broken lines are lacking in the holotype of this species but are present in a number of other cups belonging to this genus; they are interpreted as forming part of the dorsal cup because a part of the outer surface of the two posterior radials extends above their lower edges.

APOLLOCRINUS GEOMETRICUS Moore and Plummer, n.sp.

Pl. 19, fig. 2; text fig. 12

Description.—The dorsal cup is subpentagonal in outline, low truncate bowl-shaped, with a comparatively broad shallow basal depression. The most prominent general feature in the appearance of the cup is the pattern of sharp ridges and intervening depressions that masks the position of sutures between the plates. The infrabasals (IBB) form a nearly flat pentagon of regular outline, the central part of which is occupied by the round stem impression; the areas adjoining the sutures between the infrabasals are slightly elevated and the distal extremities of these plates are depressed to form five faint hollows. The basals (BB) are strongly convex and each bears four diverging ridges that lead from a centrally located node or short longitudinal ridge to the two neighboring basal plates and two adjoining radials, uniting with ridges on these plates; the proximal portions of the basals form the sloping sides of the basal concavity of the cup, and the ridges that unite the basal plates define a pentagon, which separates the basal concavity from the sides of the cup. The posterior basal (pB) bears a ridge that joins with one on anal x. The radial plates (RR) are strongly convex, the proximal portions lie in a nearly horizontal position, and the distal parts slope upward steeply. The ridges that rise somewhat below the mid-portion of the articular facets diverge to join ridges of neighboring basal plates, and much fainter ridges connect adjoining radials. One or two elongate nodes may occur at mid-length of the plates between the median and outer pairs of ridges. The facets are nearly vertical in position, the outward slope from the upper edges of the facets measures about 75° downward from a horizontal plane. The outer ligament area is a denticle-bearing, slightly arcuate space that is set off from the face of the radial plate by a narrow groove. The outer part of this area lies in the plane of the distal non-articular surface of the radial, and the inner part is approximately in the plane of the whole facet, an obtuse angle separating these two parts. The ligament pit is short, moderately deep, and occupies the middle third of the facet just outside of the transverse ridge. The inner ligament area is nearly smooth, but shows a shallow central pit, broad lateral furrows that are obscurely separated from the muscle areas, and a distinct intermuscular furrow. There is a broad intermuscular notch, which is asymmetrical in the case of the two posterior radials. At the sides and beyond the limits of the facets the surface of the radials curves upward and inward to the margin of the body cavity. The existence of a cross line located slightly above the extremities of the transverse ridge indicates that the inner part of the curved surface was covered by very thin and probably minute plates belonging to the tegmen or by a non-calcified covering, for granulose marking which occurs on the exterior of the cup terminates at the line mentioned. Anal x is pentagonal in outline, and its proximal edge rests on the squarely truncated tip of the posterior basal (pB). Above it at the left and the right and resting against the edges of the posterior radials are two other anal plates. These are not preserved in the holotype, but their position is shown by the suture faces and they are seen in a number of other specimens belonging to the genus. The granulose ornamentation of the cup extends from anal x and the posterior radials on to the tube plates, and although the proximal edges of the upper two anals are higher than the transverse ridges of the radials they must be regarded as entering the dorsal cup.

Measurements of the holotype specimen, in millimeters, are as follows:

Height of dorsal cup (measured to lower edge of facets)	4.5
Height of dorsal cup (measured to inner edge of facets)	7.3
Width of dorsal cup	17.7
Width of body cavity	13.5
Diameter of stem impression	3.3
Width of infrabasal circlet	6.0
Height of basal concavity	1.3
Length of basal	7.0
Width of basal	7.5
Length of radial	4.5
Width of radial	10.0
Length of radial facet	4.2
Width of radial facet	7.3

Discussion.—The strongly marked pattern of somewhat serrate ridges on the basal and radial circlets and the relatively broad shallow form of the basal concavity are the chief distinguishing features of this species. The granulose ornamentation is faint, requiring good magnification to reveal it. *Apollocrinus geometricus* is readily distinguished from *A. angulatus* (Miller and Gurley) by the absence of ridges on plates of the latter, and this serves also for separation of *A. stillativus* (White), which bears nodes rather than distinct connecting ridges. The basal concavity of the last-named species is much deeper and narrower than in *A. geometricus.*

Occurrence.—Top of Iola limestone, Kansas City group, Missouri series, Pennsylvanian (Upper Carboniferous); Lehigh Portland Cement quarry at south edge of Iola, Kansas.

Types.—Holotype, Kansas University Collection no. 45471; collected by J. M. Jewett. Paratype, Kansas University Collection no. 31121; collected by Vernon May.

APOLLOCRINUS FLOREALIS Moore and Plummer, n.sp.

Pl. 19, fig. 7

Description.—Description of this species is based on an incomplete crown that shows the arm structure in two of the rays but not to the outer extremities of the arms. The specimen adds importantly to a knowledge of the genus, however, since only in one other example has any portion of the arms been found. This is the holotype of *Apollocrinus angulatus* (Miller and Gurley), which shows the proximal seven segments of the right anterior arm.

The dorsal cup is low truncate bowl-shaped, and its basal concavity is well marked. The pattern of ridges described in *A. geometricus*, n.sp., is only very partially and unevenly developed in this species, but there are traces of this. The ridges that girdle the basal concavity are very prominent, and in combination with the long even slope of the proximal part of the basal plates toward the small infrabasal circlet produce a flower-like appearance that characterizes the dorsal view of the cup. In the holotype this flower-like aspect is accentuated by the presence of a short portion of the stem, which suggests stamen and pistils, and by a gentle transverse concavity of the basal plates in this region, which produces a closer resemblance to petals. The stem almost conceals the infrabasal circlet. The three columnals that are attached to the cup are circular in cross-section and sharply bulged at mid-length, showing that the stem is annulated. The two anal plates that occur next above anal x reach downward into the dorsal cup. The surface of the cup appears to be smooth, except for the ridges already mentioned.

The lowest arm plate is an axillary primibrach that occupies the entire width of the radial facet; it is very short but strongly convex, and there is a low node-like projection near the middle of the distal margin. The lowermost secundibrachs occupy the full width of the branches, but immediately following the brachials are biserially arranged wedge-shaped segments that are about half as wide as the branches; some of these brachials bear a single low node, but others are smooth. The second branching in each ray apparently differs from the first in that the axillary plate is a small brachial of triangular outline that occupies only one-third of the arm width, and on each side of it the lowest tertibrachs (IIIBr) rest on secundibrachs (IIBr) that support the axillary secundibrach. The divisions of the rays are isotomous, and at each bifurcation the arms spread apart in Y-shaped manner. Each brachial except the axillaries bears stout pinnules that are composed of short uniserial segments. The pinnules spread out approximately at right angles from the arms.

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup (measured to lowest point of facets)	3.0
Height of dorsal cup (measured to highest point of facets)	7.5
Width of cup	19.0
Diameter of stem	4.0
Height of basal concavity	1.7
Width of infrabasal circlet	4.5
Length of basal	6.5
Width of basal	7.0
Length of radial	3.7
Width of radial	10.0
Width of arms (lower part)	5.0

Discussion.—This new species is readily separated from *Apollocrinus geometricus*, n.sp., by the less regular and strongly marked ridges and by the more shallow depressions at angles between plates of the basal and radial circlets in *A. florealis;* also the infrabasal disc is relatively smaller and more completely covered by the stem in this species. Most closely similar to *A. florealis* is *A. stillativus* (White), from the lower Virgil beds of southeastern Kansas, for both these species have small infrabasal circlets surrounded by petal-like sloping sides of the basal plates, and in both species the nodes or ridges and the depressions on other parts of the cup are not strongly marked, except for prominent nodes on the anal plates of *A. stillativus.* The Virgil species is distinguished by presence of granulose surface ornamentation, absence of linear ridges except on the basals, and by the vertical or even overhanging walls of the basal concavity. *A. angulatus* (Miller and Gurley) has smooth plates, lacks granules, nodes, and ridges, and the basal concavity is broad and very shallow. It is interesting to note that the axillary primibrach of *A. angulatus* occupies only the middle third, approximately, of the radial facet and that the lowest secundibrachs are in contact with the radial facet as well as with one side of the axillary primibrach; this is unlike the structure of the base of the arms in *A. florealis* but corresponds to the arrangement of plates at secondary bifurcations of the arms in the Texas species. Reduction in the size of the axillaries appears to be correlated to some extent with degree of union between the arms and a fairly solid tegmen. Numerous tegminal plates in somewhat disturbed position are preserved with the dorsal cup of *A. angulatus* next to the remnant of the base of one arm.

Occurrence.—Brannon Bridge member of the Millsap Lake formation, Strawn group, Des Moines series, Pennsylvanian (Upper

Carboniferous); Loc. 183–T–14, near road corner about 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Marrs Collection no. M–1; collected by Mrs. W. R. Marrs, Austin, Texas.

[POTERIOCRINITIDAE—SECTION A]

SUBSECTION A–2.—*Facets sloping gently outward.*

GROUP a.—*Infrabasals flaring upward, visible from the side: cup cone-shaped; one to three anals in the cup.*

SUBGROUP α.—*Cup cone-shaped; three anals in cup.*

Genus HAERETOCRINUS[42] **Moore and Plummer, n.gen.**

The dorsal cup is conical, with evenly sloping sides, and its height is approximately one-half of its greatest width. The five infrabasal plates (IBB) are clearly visible from the side and flare upward from the round stem attachment. The five basals (BB) are subequal and large. The five radials (RR) are straight longitudinally but rounded transversely, so that their convexity in this direction is greater than the arc of the circumference subtended; interradial sutures are located in furrows, and the outline of the cup in ventral view is distinctly scalloped. The articular facets slope gently outward, their angle being essentially normal to the longitudinal axis of the radial plates. The length of the transverse ridge is less than the greatest width of the radials, the position of this ridge being set outward from the line connecting the summits of the interradial sutures. The three anal plates in the dorsal cup consist of a large radianal (RA) lying obliquely to the right above the posterior basal, and anal x and the right tube (rt) plates lie above the radianal. The posterior interradius is not depressed.

Arms are composed of uniserially arranged quadrangular segments that are strongly rounded and not laterally in contact. Branching is isotomous on the first primibrach (IBr_1), sixth secundibrach ($IIBr_6$) or thereabouts, and possibly there are additional equal divisions of the arms. Each brachial bears a strong pinnule. The round stem is moderately large, and the columnals have straight, smooth edges; no nodal columnals have been observed. The surface of the dorsal cup and arms is smooth. Sutures are distinct but not impressed. The anal sac is unknown.

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[42]Derived from Greek meaning chosen.

Genotype.—*Haeretocrinus missouriensis* Moore and Plummer, n.sp.

Discussion.—General features of the dorsal cup, as described in *Haeretocrinus*, appear in a dozen or more poteriocrinitid genera. Several of these, such as *Hydriocrinus* Trautschold, *Scytalocrinus* Wachsmuth and Springer, and *Ulrichicrinus* Springer, *Coeliocrinus* White, *Morrowcrinus* Moore and Plummer, and *Woodocrinus* de Koninck have facets fully equal to the greatest width of the radials, and most of these show striking differences from *Haeretocrinus* in structure of the arms. *Poteriocrinites* Miller has much narrower and more rounded facets than *Haeretocrinus* and also has a different type of arm structure. The form of the dorsal cup and the character of the radial facets that are seen in *Moscovicrinus* Jackel and, somewhat less definitely, in *Ophiurocrinus* Jaekel are nearly identical with those of *Haeretocrinus*. Distinction between these genera is found in the character of the arms, only *Haeretocrinus* showing a branching on the first primibrach (IBr_1); there are other differences in the higher parts of the arm. Although characters of the facets are apparently unlike those in *Haeretocrinus* and *Woodocrinus*, the general structure of the arms in these two genera seems closer than any others. The arms of *Woodocrinus* branch isotomously on the first primibrach (IBr_1) and on the fourth to the eighth secundibrachs ($IIBr_{4-8}$); the arms are rounded and relatively heavy. The brachials of *Woodocrinus* are generally very much shorter than are those in *Haeretocrinus*, the cup is lower and more nearly bowl-shaped; the appearance of the posterior interradius is distinctly different; and the stem is strongly annulated, being composed of large rounded segments alternating with much smaller segments with longitudinally straight edges.

Occurrence.—Des Moines and Missouri series, Pennsylvanian (Upper Carboniferous); central United States.

HAERETOCRINUS MISSOURIENSIS Moore and Plummer, n.sp.

Pl. 21, fig. 1; text fig. 13

Description.—Recognition of this species is based on a single very well preserved but fragmentary crown, to which the upper few segments of the stem are attached. The proximal half of the infrabasal plates (IBB) is covered by the stem, the distal half being inflected sharply upward from the plane of the stem impression and being clearly visible in side view of the cup. The basals

(BB) are mostly hexagonal and about as long as wide; the right posterior basal (rpB) is a little larger than the others and heptagonal in outline. The radials (RR) have a width that is about twice the length; they are straight longitudinally but strongly arched transversely. The articular facets are a little narrower than the greatest width of the radial plates, the transverse ridge being set distinctly outward from a line connecting the summits of the interradial sutures, which means that the outer surface of the radials curves inward around the sides of the facet; the plane of the facet is at right angles to the mid-line of the outer surface of the radial. The outer ligament area is slightly depressed and bears denticles and a ligament pit. The inner ligament area contains a well-marked central pit, lateral furrows, and a shallow intermuscular notch. The radianal (RA) is a relatively large

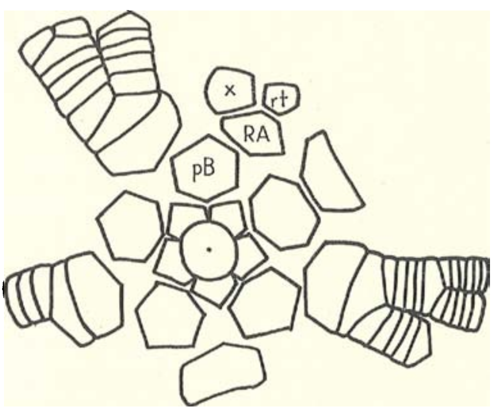

Fig. 13. Diagram showing the arrangement of plates in the dorsal cup and the arms of the holotype of *Haeretocrinus missouriensis* Moore and Plummer, n.sp., x1. The arms are composed of relatively short, uniserially arranged segments. So far as known the branching occurs in each ray on the first primibrach and on about the fifth secundibrach.

hexagonal plate that rests nearly equally on the posterior basal (pB) and right posterior basal (rpB); at the left it is narrowly in contact with the left posterior radial (lpR); above it are the anal x and right tube (rt) plates of the anal series and the right posterior radial (rpR). Anal x is a moderately large pentagonal plate that is rounded above. The right tube plate is about half as large as anal x.

Portions of three arms are preserved in the holotype, each showing an axillary primibrach (IBr_1) that is distinctly smaller than the subjacent radial; the suture between these plates is not gaping. There are five secundibrachs (IIBr) in each branch above the primibrach, the lower four of these segments are quadrangular and much wider than long; the fifth secundibrach has the same general proportions as the others but is an axillary plate that supports two equal branches. There are six quadrangular tertibrachs (IIIBr) remaining in one branch and five in another, but the higher parts of the arms are not known. The arms are strongly rounded and spread apart. Well-developed pinnules are seen.

Measurements of the holotype specimen, in millimeters, are as follows:

Height of dorsal cup	12.5
Greatest width of cup	23.7
Ratio of height to width	0.54
Diameter of stem	7.3
Length of basal	9.3
Width of basal	10.0
Length of radial	6.5
Width of radial	12.7
Length of transverse ridge of facet	8.3

Discussion.—Because of the similarity in form and structure of the dorsal cup of *H. missouriensis* to the cups of some other poteriocrinitids, some uncertainty may be found in identification of specimens that lack the arms; the rounded character of the radials and outwardly set facets may be of aid, but these are less significant than the structure of the arms. Among conical dorsal cups known from American Pennsylvanian rocks, *Hydriocrinus? rosei* Moore and Plummer is distinguished by difference in radial facets, shape of cup, surface ornamentation and presence of a pentagonal stem impression; *Morrowcrinus fosteri* Moore and Plummer has a narrower cup with decorated plates and different radial facets; "*Poteriocrinus*" *macoupinensis* Worthen, from middle Pennsylvanian beds of Illinois, is relatively a little higher than the species described from Kansas City and shows a different arrangement of the anal plates in the cup, but it appears to correspond in the form of the radial plates and may be conspecific with *Haeretocrinus missouriensis*. *Scytalocrinus sansabensis* Moore and Plummer is a diminutive crinoid that differs in the character of the radials, and, of course, has very different arm structure from the type here considered.

Occurrence.—The holotype is recorded in the collection of fossils at the Public Library, Kansas City, Missouri, as from the "Upper Coal Measures, Kansas City, Missouri." The appearance and mode of preservation of the specimen are those characteristic of the many crinoids found in the famous Lane shale collecting horizon at Kansas City, and it is the recollection of Mr. Edward Butts, curator of the collection, that the specimen came from this shale. With only slight question, therefore, the type may be recorded as from the Lane shale, Kansas City group, Missouri series, Pennsylvanian (Upper Carboniferous); Kansas City, Missouri.

Type.—Holotype, Kansas City Public Library Collection (no assigned number), Kansas City, Missouri. Plastoholotype, University of Kansas Collection no. 59415.

HAERETOCRINUS MAGNUS Moore and Plummer, n.sp

Pl. 21, fig. 4

Description.—A somewhat crushed and incomplete dorsal cup is the only example yet known from Pennsylvanian rocks of Texas of a type of crinoid that appears to be not uncommonly represented in collections of dissociated plates. It is referred to *Haeretocrinus* because of the nature of its radial plates and facets, but it is recognized that this assignment is provisional until knowledge of the arm structure is gained.

The dorsal cup is large, the height measuring about 34 mm. and the greatest width (computed from the size of plate at the summit of the cup) about 39 mm.; the sides appear to slope evenly upward from the edge of the stem impression to the tops of the radials (RR). Three of the five infrabasals (IBB) are preserved; they are distinctly longer than wide, the length being about 17 mm. (of which 5 mm. is included in the area of stem impression), and the width 12.3 mm. The basals (BB) are about as long as wide, measuring 20.5 and 19.0 mm., respectively; all are hexagonal except the posterior (pB) and right posterior (rpB) plates. The radials are very incompletely shown, only the left posterior (lpR) plate of this circlet being complete; it is twice as wide (22.0 mm.) as long (11.3 mm.), the vertical profile being straight and the transverse curvature notably greater than the arc of the circumference of the cup subtended by this plate. The transverse ridge intersects the curving margin at a distance of several millimeters from the upper angles of the radial, the outer ligament area being correspondingly reduced in size; the outer border of the area bears an even row of denticles arranged normal to the margin. The inner ligament area is wider than the outer ligament area, and it is of moderate length; its only very distinct markings are the prominent subtriangular central pit, adjacent to the transverse ridge, and the intermuscular furrow; the areas on each side of the furrow and of the shallow intermuscular notch are slightly concave. The general plane of the facet is normal to the mid-line of the outer face of the radial, and this plane accordingly slopes very slightly outward. Two anal plates are seen, a relatively large radianal (RA) obliquely to the right above the posterior basal, and anal x of which the part above the summit line of the radial is broken away. A third anal plate belonging to the dorsal cup was undoubtedly present originally; it belongs above the radianal, and its lower part should extend below the top of the adjacent right posterior radial, which is somewhat higher than the left posterior radial. The arms and anal sac are not known. The surface of the plates is entirely smooth.

Discussion.—This crinoid differs from *H. missouriensis*, n.sp., in the general proportions of the dorsal cup, being relatively narrower and higher, and in the arrangement of the anal plates. The separation of the posterior basal and anal x plates by the intervening radianal in the holotype of *H. missouriensis* may be an individual peculiarity. No other known Upper Carboniferous crinoid is closely similar to *H. magnus* so far as present available material indicates.

Occurrence.—Millsap Lake formation, Strawn group, Des Moines series, Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, about 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Harris Collection no. H–23; collected by Mrs. G. W. Harris, Waco, Texas.

[POTERIOCRINITIDAE—SECTION A]

SUBSECTION A–3.—*Facets subhorizontal or sloping inward.*

GROUP b.—*Infrabasals not flaring upward, not visible from the side; cup truncate bowl-shaped; one anal in the cup.*

Genus APOGRAPHIOCRINUS Moore and Plummer, n.gen.

Graphiocrinus (part) of authors.

The crown is relatively tall and slender and subcylindrical. The arms are generally held closely together. The dorsal cup is small, slightly truncate bowl-shaped and has a small, generally well-defined basal concavity. The plates of the cup are slightly bulbous in typical examples.

The five infrabasals (IBB) are small and form a pentagon at the bottom of the basal concavity. The stem impression, which is round and moderately concave, nearly covers the small infrabasal circlet. The five basals (BB) are subequal except the posterior basal (pB), which is distinctly larger than the others and truncated distally for contact with anal x. Only a very small part of the proximal portion of the basals (BB) is involved in the basal concavity of the cup. The five radials (RR) are pentagonal, their length being about two-thirds of their width, and a transverse convexity gives a scalloped appearance to the summit of the radials (RR) in ventral or dorsal view of the cup. The radial facets are distinctly less than the greatest width of the radials (RR), and an extension of the outer face of the radials (RR) is present along the interradial sutures to the inner border of the facets. The outer ligament area is wide but short and is rather strongly depressed. The transverse ridge is straight and well defined. The inner ligament area slopes strongly inward.

A single anal plate (x) occurs between the posterior radials (RR), resting on the truncated tip of the posterior basal (pB), and about one-half of its height generally rises above the summit of the radials (RR).

The ten arms are composed of uniserial segments of quadrangular or very slightly cuneate form, are approximately uniform in size throughout their length, and branch isotomously on the first primibrach (IBr_1). The axillary primibrach (IBr) of the left and right anterior rays is a little shorter than the others. The outer surface of the arms is gently rounded, but the sides, where the arms fit together, are flat, although some segments are marked by fine grooves and ridges, apparently to effect a firmer union between the arms. A sharp angulation separates the sides from the outer surface of the arms. There is no sign of pinnules on the lower parts of the arms, but traces of pinnules are observed near the top of the crown in some specimens. The anal sac is unknown. The stem is round.

Genotype.—*Apographiocrinus typicalis* Moore and Plummer, n.sp.

Discussion.—This new genus is distinguished primarily from others that it resembles superficially by the character of the articular facets. They are distinctly narrower than the width of the radials (RR), and they slope inward toward the body cavity of the cup. Between adjoining facets, along the interradial sutures, are pronglike narrow extensions of the outer surface of the cup that reach to the inner edge of the facets. These features serve readily to distinguish *Apographiocrinus* from *Graphiocrinus* and *Delocrinus*, in which the facets are as wide as the radials (RR) and, at least in part, slope outward rather than inward. These distinctions are believed to have much importance, even though there are noteworthy points of similarity otherwise.

"Graphiocrinus" carbonarius (Meek and Worthen),[43] *"Graphiocrinus" quinquelobus* Wanner,[44] and *"Delocrinus" verbeeki* var. *pumila* Wanner,[44a] from the Permian of Timor, are referable to *Apographiocrinus*. The types of *"Graphiocrinus" carbonarius*, which were lent for study, comprise two dorsal cups, one almost twice as large as the other and, judged by dissimilarity in form, doubtfully conspecific. The larger specimen shows very clearly the distinctive character of the radials and other features of *Apographiocrinus*. The smaller specimen belongs to this genus, but the character of

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[43]Meek, F. B., and Worthen A. H., Descriptions of new Paleozoic fossils from Illinois and Iowa: Acad. Nat. Sci. Philadelphia, Proc., ser. 1, vol. 13 (listed also as ser. 2, vol. 5), p. 140, 1862. [*Poteriocrinus (Scaphiocrinus?) carbonarius* Meek and Worthen.]

———— Descriptions of new Crinoidea, etc., from the Carboniferous rocks of Illinois and some of the adjoining states: Acad. Nat. Sci. Philadelphia, Proc., ser. 1, vol. 17 (listed also as ser. 2, vol. 9), p. 152, 1865. [*Poteriocrinus (Zeacrinus) carbonarius* Meek and Worthen.]

———— Descriptions of invertebrates from the Carboniferous system: Illinois Geol. Survey, vol. 5, pt. 2, p. 562, pl. 24, fig. 2, 1873. [*Scaphiocrinus carbonarius* (Meek and Worthen).]

Wachsmuth, C., and Springer, F., Revision of the Paleocrinoidea, pt. 1, Acad. Nat. Sci. Philadelphia, Proc. for 1879, p. 123, 1879. [?*Graphiocrinus carbonarius* (Meek and Worthen).]

Keyes, C. R., Paleontology of Missouri: Missouri Geol. Survey, vol. 4, p. 219, 1894. [*Phialocrinus carbonarius* (Meek and Worthen).]

Weller, Stuart, A bibliographic index of North American Carboniferous invertebrates: U. S. Geol. Survey, Bull. 153, p. 300, 1898. [*Graphiocrinus carbonarius* (Meek and Worthen).]

[44]Wanner, J., Die permischen Echinodermen von Timor; 1: Paläontologie von Timor, Lief. 6, Teil 11, p. 171, pl. 104 (9), figs. 11a-c. Stuttgart, 1916. [*Graphiocrinus quinquelobus* Wanner.]

[44a]Wanner, J., idem, p. 194, pl. 107 (12), fig. 10, pl. 108 (13), fig. 2.

the facets is partly concealed by the presence of some of the primibrachs. The larger, better specimen (shown in pl. 24, figs. 2a and 2c of Meek and Worthen's 1873 publication) is here designated as the lectotype. Because neither this nor the other specimen shows the upper part of the crown, *"Graphiocrinus" carbonarius* is not selected as the genotype of *Apographiocrinus.* Wanner's *"Graphiocrinus" quinquelobus* has all the characteristic features of *Apographiocrinus,* in so far as can be determined from the figures and description, although the interfacet "prongs" are regarded as elevated portions of the facets rather than as inward projections of the nonarticular surface of the radials; Wanner mentions the inclination of the median portion of the facets downward toward the inside.

Specimens of *Apographiocrinus* from the upper Ochelata beds at Bartlesville, Oklahoma, recently described and figured by Strimple[45]

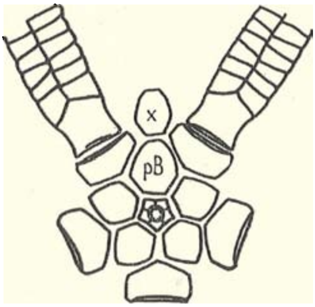

Fig. 14. Diagram showing the arrangement of plates in the dorsal cup and part of two of the rays in *Apographiocrinus typicalis* Moore and Plummer, n.sp., the genotype species. The narrow facets of the radial plates are not clearly seen in the view directed normally to the midportion of the outer surface of these plates but are indicated by the beveled or rounded appearance of the upper corners of the radials. The infrabasal circlet is small and is located in the rather shallow basal concavity.

under the name *Graphiocrinus carbonarius* are believed to belong to *Apographiocrinus typicalis* Moore and Plummer, n.sp.

Occurrence.—Upper Carboniferous and Lower Permian, central United States.

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[45]Strimple, H. D., A group of crinoids from the Pennsylvanian of northeastern Oklahoma: private publ., pp. 4–6 (pages unnumbered), pl. 1, figs. 1–11, pl. 2, fig. 1, Bartlesville, Oklahoma, 1938.

APOGRAPHIOCRINUS TYPICALIS Moore and Plummer, n.sp.

Pl. 3, figs. 4, 5; text figs. 14–16

Graphiocrinus carbonarius (Meek and Worthen), STRIMPLE. A group of crinoids from the Pennsylvanian of northeastern Oklahoma: pp. 4–6 (unnumbered), pl. 1, figs. 1–11, pl. 2, fig. 1. Bartlesville, Oklahoma, 1938.

Description.—This species shows very well all the characteristic features of the genus and is much more common than any other in the collections, at least from Kansas and Oklahoma. Of nearly 500 dorsal cups and crowns belonging to *Apographiocrinus* that have been studied, some 290 are referred to *A. typicalis,* and these show all stages of development from juvenile forms with dorsal cups less than 4 mm. in greatest width to unusually large ones over 10 mm. in width. The proportion of height to width of the cup averages 0.41 in all ontogenetic stages, and the extremes of variation from this norm, amounting to plus or minus 0.09, are about the same for all sizes (see accompanying graph, fig. 15). A specimen that shows both the character of the dorsal cup, the structure of the arms, and the nature of the facets on the radial plates, is selected as the holotype. The total height of this crown is 20.5 mm., but the distal part of the arms is lacking; the height of the dorsal cup is 3.2 mm., and the greatest width, 8.4 mm.

The small but strongly marked concavity of the base of the dorsal cup is one of the diagnostic features of this species. The distal parts of the infrabasals (IBB) slope steeply downward, and the proximal margins of the basal plates (BB) have a similar slope, forming the walls of the concavity, which ranges in height from about 0.5 to 1.2 mm. The proximal parts of the infrabasals carry the round stem impression, 1.0 to 1.5 mm. in diameter, and the greatest width of the basal concavity is generally only two or two and one-half times that of the stem diameter. The basal plane of the cup is tangent to the basals (BB) at a distance of only a third to a fourth of their length from the proximal edges, and the distal extremities of these plates reach approximately to mid-height of the cup. In some specimens the contour of the lower part of the cup is very smoothly rounded, but more typically there is a faintly bulbous appearance of the individual plates that accentuates the sutures between them. The radial plates (RR) slope steeply upward to the margin of the facet without any thickening of the plates or angulated portion near the facet. The outline of the cup in dorsal or ventral view appears almost circular, the scallops at positions of the radials being apparent but not especially striking; the prongs between the facets are prominent. The anal plate is widest at a height slightly above the summit of the radial plates, and the upper portion of the anal curves more or less strongly inward, as in other species of the genus. The surface of the plates is perfectly smooth, excepting in some specimens for traces of granules in the basal concavity.

The primibrach (IBr) segments of the arms show a difference in length between those of the right and left anterior rays, which are short, and the remainder, which are appreciably long. The secundibrachs (IIBr) are quadrangular to slightly cuneiform segments that in mature crowns are about twice as wide as long. The brachials of immature specimens show presence of a narrow longitudinal keel.

Discussion.—Comparison of examples of *A. typicalis* with the types of *A. carbonarius* (Meek and Worthen), from middle Pennsylvanian beds near Springfield, Illinois, readily shows differences that must be judged sufficient to prevent identification of the Mid-Continent forms here described as belonging to Meek and Worthen's species, unless all kinds of cups that are assignable to this genus are thrown together in a single very loosely defined species. Such procedure is absurd. Study of the two type specimens of *A. carbonarius* (Univ. Illinois no. x–258) leads to the conclusion that these represent two distinct species, and there appears to be no certainty that they come from the same horizon. The larger of the Illinois cups, which is here designated as lectotype, has the general form and only very faintly bulbous plates that characterize *A. typicalis*, but the infrabasal circlet is not at all down-flaring, there is no basal concavity, and there is a narrow arcuate area at the summit of the radials, next to the facet, that is set off by an angulation from the main outer surface of these plates. Examples of this type of cup from the Dennis limestone, belonging in the lower part of the Missouri series of Kansas and Missouri, are apparently identifiable as *A. carbonarius* but these are not associated with *A. typicalis* in the upper Missouri beds. According to Dr. H. R. Wanless, of the University of Illinois, the probable horizon of the original specimens of *A. carbonarius* is the Trivoli cythothem at the base of the Missouri series, for this is most widely exposed in the area near Springfield, Illinois; one or both of the types might have come from slightly higher or lower in the section, however. The smaller type of *A. carbonarius* (Meek and Worthen's pl. 24, fig. 2b, 1873) has a well-marked basal concavity, distinctly bulbous plates, and a clearly defined, moderately broad arcuate shoulder at the top of the radial plates; it cannot be regarded as an immature example of the different sort of cup shown in the other type, and it is not like *A. typicalis.*

Strimple[46] has recently figured several fine crowns from upper Ochelata beds (equivalent to parts of the Plattsburg and Stanton formations of Kansas), belonging in the upper part of the Missouri series, at Bartlesville, Oklahoma, that clearly belong to *Apographiocrinus.* These specimens reveal growth stages from very immature examples with height of crown about 4 mm. to a maximum with height of crown about 25 mm. The juvenile specimens show strongly keeled brachial segments. It is not possible from Strimple's illustrations to be certain that all his examples of "*Graphiocrinus carbonarius*" from Bartlesville belong to *Apographiocrinus typicalis,* but this is thought likely; of the numerous specimens available from the same horizon and locality, including four collected by Strimple, all are *A. typicalis.*

Occurrence.—All the many specimens assigned to this species in the northern Mid-Continent region come from upper Missouri series of beds belonging to the Plattsburg and Stanton formations or equivalents; these have been collected at localities in southern Kansas and northern Oklahoma. A single dorsal cup that is identified as belonging to *A. typicalis* has been found in the Palo Pinto formation at Bridgeport, Wise County, Texas; this specimen comes from marine beds just above the coal bed mined in that area. Comparison of this example with specimens from Oklahoma and Kansas indicates correspondence in every respect, except that the Texas form has a slightly smaller height of the anal x plate below the summit of the radials, and this is a matter of no significance.

Types.—Holotype, Kansas University no. 60031, from the Hickory Creek shale member, Plattsburg limestone, at Loc. 6003, SE.¼ NE.¼ sec. 3, T. 30 S., R. 15 E., roadside exposure, about 5 miles southeast of Fredonia, Wilson County, Kansas; collected by R. C. Moore. Paratype, Kansas University no. 60031a, from same horizon

[46]Strimple, H. L., A group of crinoids from the Pennsylvanian of northeastern Oklahoma; pp. 4–6 (unnumbered), pls. 1–2, private publ., Bartlesville, Oklahoma, 1938.

and locality as the holotype. Paratype, Kansas University no. 17451, from Hickory Creek shale member, Plattsburg limestone, Loc. 1745, shale pit in sec. 32, T. 28 S., R. 16 E., about 4 miles north of Altoona, Wilson County, Kansas; collected by N. D. Newell. Paratype, Kansas University no. 17501, Merriam limestone member, Plattsburg limestone, Loc. 1750, center SW.¼ sec. 7, T. 31 S., R. 16 E., Montgomery County, about 4 miles south of Neodesha, Kansas; collected by N. D. Newell. Paratype, Kansas University no. 17531, Hickory Creek shale member, Plattsburg limestone, Loc. 1753, shale pit near center sec. 33, T. 29 S., R. 16 E., at Buffville, Wilson County, Kansas; collected by N. D. Newell. Paratype, Kansas University no. 19581, Hickory Creek shale member, Plattsburg limestone, Loc. 1958, shale pit, sec. 1, T. 27 S., R. 17 E., about 3 miles northwest of Chanute, Neosho County, Kansas; collected by J. M. Jewett. Paratypes, Kansas University nos. 19851, 19851a–c, shale in upper part of Ochelata group, equivalent to Plattsburg and Stanton formations of Kansas, Loc. 1985, The Mound, northwest edge of Bartlesville, Oklahoma; collected by H. L. Strimple. Paratypes, Kansas University nos. 11691, 11691a–b, from same horizon and locality as 1985; collected by R. C. Moore. Paratypes, Kansas University nos. 45511, 45511a–h, from same horizon and locality as 1985; collected by Paul McGuire. Paratypes, Kansas University nos. 46101, 46101a–w, Hickory Creek shale member, Plattsburg limestone, Loc. 4610, roadside pit near NE. cor. NW ¼ sec. 26, T. 30 S., R. 15 E., 2.4 miles west of Neodesha, Wilson County, Kansas; collected by R. C. Moore. Paratypes, Kansas University nos. 59991, 59991a–b, Hickory Creek shale member, Plattsburg limestone, Loc. 5999, roadside exposure on Kansas Highway 47, sec. 18, T. 29 S., R. 16 E., 2.4 miles west of Altoona, Wilson County, Kansas; collected by R. C. Moore. Paratypes, Kansas University nos. 60081, 60081a, Plattsburg limestone, Loc. 6008, brick pit west of U. S. Highway 59 at south edge of Iola, sec. 3, T. 25 S., R. 18 E., Allen County, Kansas; collected by R. C. Moore. Paratype, Kansas University no. 60141, Hickory Creek shale member, Plattsburg limestone, Loc. 6014, roadside exposure on side road just south of Kansas Highway 47, sec. 15, T. 29 S., R. 15 E., about 5 miles east of Fredonia, Wilson County, Kansas; collected by R. C. Moore. Paratype, Kansas University no. 60053, Merriam limestone member, Plattsburg limestone, Loc. 6005, shale pit near south center sec. 13, T. 31 S., R. 15 E., about 0.5 mile north of Sycamore, Montgomery County, Kansas; collected by R. C. Moore. Paratypes, Kansas University no. 60561, 60561a–b, Hickory Creek shale member, Plattsburg limestone, Loc. 6056, near center north line sec. 26, T. 30 S., R. 15 E., 2.5 miles west of Neodesha, Wilson County, Kansas; collected by N. D. Newell. Paratype, Kansas University no. 60631, Hickory Creek shale member, Plattsburg limestone, Loc. 6063, south of center north line sec. 18, T. 29 S., R. 17 E., about 3 miles east of Altoona, Wilson County, Kansas; collected by N. D. Newell. Paratypes, Kansas University nos. 45481, 45481a–d, Stoner limestone member, Stanton limestone, Loc. 4548, quarry of cement plant, sec. 19, T. 29 S., R. 15 E., about 1.5 miles southeast of Fredonia, Wilson County, Kansas; collected by R. C. Moore. Paratypes, Kansas University nos. 45551, 45551a, Stoner limestone member, Stanton limestone, Loc. 4555, Ross quarry, sec. 1, T. 17 S., R. 19 E., about 1 mile southeast of Ottawa, Franklin County, Kansas; collected by R. C. Moore. Paratypes, Kansas University nos. 59731, 59731a, from same horizon and locality as Loc. 4555; collected by Allen Graffham. Paratypes, Kansas University nos. 59831, 59831a–e, from same horizon and locality as Loc. 4555; collected by Arthur Bridwell. Paratype, Kansas University no. 45571, Stanton limestone, Loc. 4557, roadside exposure on Tyro road, just south of U. S. Highway 75, in SW. ¼ SW. ¼ sec. 6, T. 34 S., R. 15 E., about 4 miles east of Wayside, Montgomery County, Kansas; collected by R. C. Moore. Paratype, Kansas University no. 45881, Stoner limestone member, Stanton limestone, Loc. 4588, old cement quarry, sec. 9, T. 32 S., R. 15 E., on east side of Table Mound, about 5 miles northwest of Independence, Montgomery County, Kansas; collected by R. C. Moore. Paratypes, Kansas University nos. 59251, 59251a–b, Captain Creek limestone member, Stanton limestone, Loc. 5925, sec. 31, T, 33 S., R. 15 E., about 3 miles east of Wayside, Montgomery County, Kansas; collected by E. L. Banion. Paratypes, Kansas University nos. 59272, 59272a–z, 59272Aa–x (51 specimens), Stoner limestone member, Stanton limestone, Loc. 5927, railroad cut NW. ¼ sec. 4, T. 34 S., R. 14 E., 1 mile west of Wayside, Montgomery County, Kansas; collected by E. L. Banion. Paratypes, Kansas University nos. 60171, 60171a–z, 60171Aa–z, 60171Ba–s (72 specimens), from same horizon and locality as 5927; collected by R. C. Moore. Paratypes, Kansas University nos. 60181, 60181a–z, 60181Aa (28 specimens), from same horizon and locality as 5927; collected by Paul McGuire. Paratype, Kansas University no. 60361A, from waste dump of old coal mine at west edge of Bridgeport, Wise County, Texas, presumably from marine shale immediately overlying the Bridgeport coal or possibly from the Willow Point limestone, all of these beds being classed by Scott and Armstrong[47] as belonging in the upper part of the Palo Pinto limestone, Canyon group (Missouri series).

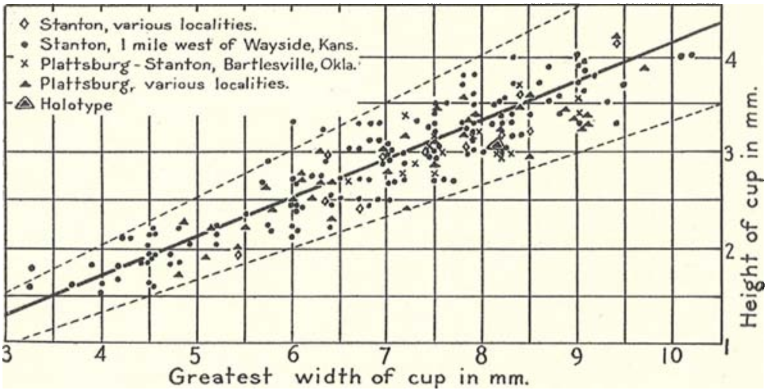

Fig. 15. Graph showing dimensions of 205 dorsal cups of *Apographiocrinus typicalis* Moore and Plummer, n.sp. Each symbol on the diagram represents an individual cup, its vertical position showing the height, and the horizontal position showing the greatest width of the cup. The approximately even distribution from small to large cups and the similarity of proportions of the cups of different size corroborate the conclusion that these individuals, otherwise essentially alike, belong to a single species. The heavy line that crosses the diagram obliquely indicates the mean height-to-width ratio of the cups of this species at all growth stages, and the dotted lines show the approximate extremes of variation.

APOGRAPHIOCRINUS EXCULPTUS Moore and Plummer, n.sp.

Pl. 3, fig. 1; text fig. 16

Description.—This robust representative of the genus is characterized by the moderately deep basal concavity, the distinctly bulbous character of the plates of the dorsal cup, the more than ordinarily well marked scalloped outline of the cup in dorsal or ventral view, and especially by the broadly truncated appearance of the radial plates, with a sharp wavy line dividing the outer face of the plate

[47]Scott, Gayle, and Armstrong, J. M., The geology of Wise County, Texas. The University of Texas Bull. 3224, pp. 26–27, 1932.

from the differently ornamented truncated area near the facets. The radials suggest those of *A. decoratus*, n.sp., but the upper part of the plate, decorated with coarse granules, slopes outward from the facet much more distinctly than in *A. decoratus*, and the lower part of these plates flares outward much more widely in this new species. The line of angulation crossing the upper mid-portion of the radials (RR) tends to have an upward bend in the middle between two narrow, somewhat short, sharp-pointed, downward bends. Except for the granulation above this line and for obscure granules on the proximal portion of the basals (BB), the cup is entirely smooth and unornamented.

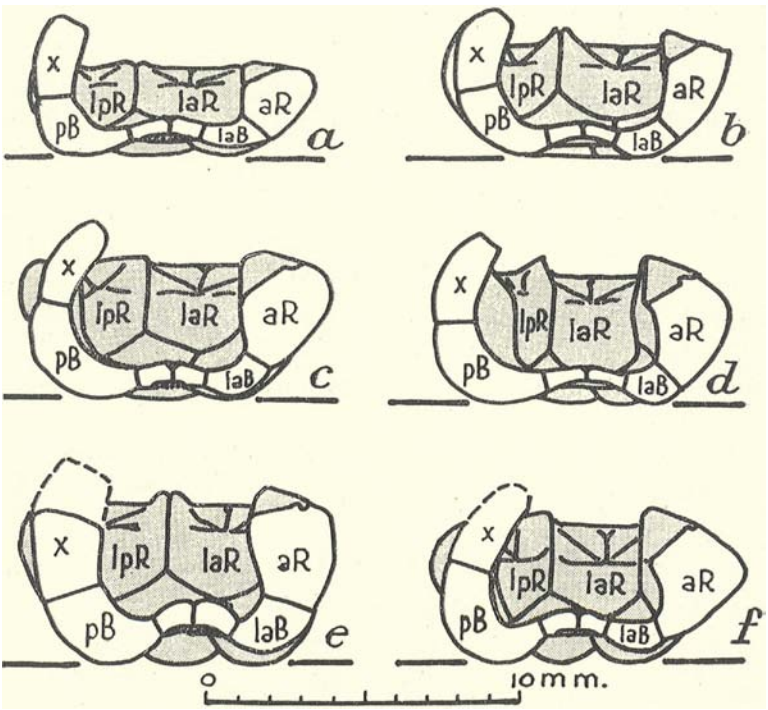

Fig. 16. Median cross-sections of the dorsal cups of the holotypes of six species of *Apographiocrinus* Moore and Plummer, n.gen. The sections are drawn through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, shaded areas representing parts beyond the plane of the section. *a*, *A. calycinus* Moore and Plummer, n.sp.; *b*, *A. typicalis* Moore and Plummer, n.sp.; *c*, *A. facetus* Moore and Plummer, n.sp.; *d*, *A. decoratus* Moore and Plummer, n.sp.; *e*, *A. wolfcampensis* Moore and Plummer, n.sp.; *f*, *A. exculptus* Moore and Plummer, n.sp.

The anal plate of the holotype is broken away, but, like all other structural features of the cup, entire correspondence is seen with peculiarities of this genus. The narrow inward-sloping facets and the interfacet extensions of the outer surface of the cup are unusually well shown.

Lodged in the cup of the holotype specimen is a single axillary primibrach (IBr), nearly twice as long as wide. The mid-portion is constricted, but less strongly than in *A. decoratus.* Because of its relative length, this primibrach evidently belongs to the anterior or one of the two posterior rays.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	4.7
Greatest width of cup	12.0
Height of basal concavity	1.0

Discussion.—Comparison of this species with *A. decoratus* is given in the description of that form. *A. exculptus,* n.sp., is almost identical in size and general appearance with the associated *A. facetus,* n.sp., The latter has a much more shallow basal concavity, somewhat less tumid plates, with margins marked by fine corrugations, and the radials (RR) lack the distinctive peculiarities of *A. exculptus.*

Occurrence.—Mineral Wells formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 25–T–5, about 2½ miles west of Brownwood, Texas.

Type.—Holotype, Plummer Collection no. P–1376, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

APOGRAPHIOCRINUS FACETUS Moore and Plummer, n.sp.

Pl. 3, fig. 3; text fig. 16

Description.—A single, very well preserved dorsal cup furnishes basis for recognition of this species. The specimen comes from the same horizon and locality as that of *A. exculptus,* n.sp., but it shows characters sufficiently distinct to leave little doubt as to its specific separation.

The infrabasals (IBB) are very minute, forming a pentagon 2 mm. in diameter, that is largely covered by the round stem impression, 1.4 mm. in diameter. The maximum height of the basal concavity, including that of the stem impression, is 0.6 mm. As in most other species of the genus, the posterior basal (pB) is distinctly larger than the other basals (BB), and it rises above the mid-height of the cup, whereas the others do not. The radials (RR) flare uniformly outward and upward from the proximal tip, curving inward very abruptly in the distal region. An area that is 1 mm. or a little more in maximum width, lying next to the facet, is ornamented by coarse granules, but there is no sharp line of demarcation or angulation between this area and the smooth or faintly pitted lower surface of these plates. Along all the sutures between plates of the cup there are fine crosswise corrugations, with maximum breadth across the suture about 0.5 mm. A small area near the stem, extending to the proximal portions of the basals (BB) is ornamented by rounded granules.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	4.8
Greatest width of cup	10.5
Height of basal concavity	0.6

Discussion.—The described features, especially of the radials (RR), separate this species both from *A. exculpus*, n.sp., and *A. decoratus*, n.sp. The suture areas between the basals and between the basal and radial plates are more pronounced in *A. facetus* than in the other species, so that the basal plates of *A. facetus* stand out more prominently and appear more bulbous.

Occurrence.—Mineral Wells formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 25–T–5, about 2½ miles west of Brownwood, Brown County, Texas.

Type.—Holotype, Plummer Collection no. P–1376A, Bureau of Economic Geology, The University of Texas, collected by F. B. Plummer.

APOGRAPHIOCRINUS DECORATUS Moore and Plummer, n.sp.

Pl. 3, fig. 2; text fig. 16

Description.—This small crinoid is distinguished by the form and ornamentation of the dorsal cup and by the strongly constricted middle part of the axillary primibrachs, so that the longer ones are shaped like an hour-glass. The base of the cup is concave, the hollowed portions affecting the proximal edges of the basals

(BB) as well as the infrabasal (IBB) circlet. Because the latter has been broken and pushed inward, it is not possible to determine the actual depth of the concavity. The infrabasal (IBB) circlet is very small, not more than 2.8 mm. in diameter. The basals (BB), excepting the posterior basal (pB), are small pentagonal plates, subequal in size, with distal extremities reaching less than one-half the height of the cup; the posterior basal (pB) is about 1.5 times the size of the other basals, hexagonal in outline, and its distal tip rises above mid-height of the cup. The character of the radials (RR) is distinctive. The outer face is divided into two unequal parts with a well-marked line of separation that crosses the central part of the plate subhorizontally and curves upward to the outer margins of the facets. The area below this line slopes smoothly downward and bears an extremely fine granulation that is almost imperceptible even under the microscope; the area above the line is a flattened, subvertical, scar-like tract, carrying granules sufficiently coarse to be visible to the unaided eye. There is a very distinct, moderately sharp angulation at the boundary between these areas. Characters of the articular facets and the inter-facet extension of the outer face are typical of the genus. Anal x is an elongate, subhexagonal, curved plate that projects slightly less than one-half of its length below the summit of the radials (RR); the lower part is narrow and the upper part curves strongly inward.

The primibrachs (IBr) and a few of the higher brachials (Br) are present in each of the rays except the anterior. The two posterior primibrachs (IBr) are nearly twice the length of the other two corresponding plates; all are constricted medially but the effect of this is most noticeable in the longer segments. Where the surface of the brachials (Br) is fresh it is minutely and delicately pitted.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	5.0
Greatest with of cup	10.5
Diameter of stem impression (est.)	1.6

Discussion.—This species is most closely similar to *A. exculptus*, n.sp., which also has angulated radials (RR) divided into two dissimilar areas. The dorsal cup of the latter species is distinctly broader, and the sides flare outward more widely; the plates are more bulbous and are entirely unornamented except the distal parts of the radials (RR) and the area near the stem.

A. decoratus is readily distinguished from a species of *Aesiocrinus* that occurs in the same beds, although this also has but a single anal plate resting on the square tip of posterior basal (pB). In dorsal or ventral view, the outline of the dorsal cup in *Aesiocrinus* is perfectly round, not scalloped, the facets are fully equal to the radials in width, the base is only slightly depressed, and it is marked by a definitely pentagonal stem impression.

Occurrence.—Keechi Creek member, Mineral Wells formation, Strawn group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–67, three-fourths mile north-northeast of Union Hill school, which is about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–4640, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

APOGRAPHIOCRINUS CALYCINUS Moore and Plummer, n.sp.

Pl. 3, fig. 7; text fig. 16

Description.—Dorsal cup small, unusually broad, truncate bowl-shaped, with well-defined basal concavity of moderate depth. The shape and general arrangement of the plates of the cup are as in other species of the genus, but the contour of the surface is a little more even, and the outline of the cup in dorsal or ventral view slightly less scalloped than is general. A relatively narrow, arcuate ornamented area occupies about two-thirds of the width of the radials (RR) and is centrally located at the distal margin of these plates next to the facets. Barely perceptible to the unaided eye are fine ridges and grooves arranged normal to the edge of the facets. The inward slope of the facets is more gentle than that of several other species.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	3.0
Greatest width of cup	9.5
Ratio of height to width	0.32
Height of basal concavity	0.7
Diameter of stem	1.5

Discussion.—The low ratio of height to width of the cup, the markings near the summit of the radials (RR), and the gentle inward slope of the facets distinguish *A. calycinus* from other known species. The vertical profile and markings of the radials (RR) in this species most closely resemble those of *A. facetus*, n.sp., but the ornamented areas of *A. calycinus* are smaller, and the relative height of the cup is distinctly lower than in the other forms mentioned.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10753, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

APOGRAPHIOCRINUS WOLFCAMPENSIS Moore and Plummer, n.sp.

Pl. 3, fig. 6; text fig. 16

Description.—A single, nearly complete dorsal cup, belonging to *Apographiocrinus* has been found in a Lower Permian limestone in west Texas. It is similar in size to most of the Pennsylvanian species described, but it belongs to none of them.

The dorsal cup is truncate bowl-shaped, moderately deep for the genus, and its base bears a small, fairly deep concavity. The outline of the cup in dorsal or ventral view is distinctly but not strongly scalloped. The plates are smooth, moderately tumid, and the sutures between them are located in shallow depressions but not impressed. The infrabasal (IBB) circlet is very small and resembles a five-pointed star rather than a regular-sided pentagon. The distal parts of these plates flare strongly downward forming parts of the wall of the basal concavity. The basals (BB) are more than ordinarily convex, both longitudinally and transversely, and their distal extremities reach to the mid-height of the cup. The posterior basal (pB) is about one-third larger than the others. The radials (RR) show a regular convexity, without special thickening or ornamented area adjoining the facets. The facets are distinctly narrower than the radials (RR) but have an unusually gentle inward slope, or they appear practically horizontal; the narrow interfacet areas slope outward at an angle of about 25 degrees.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	5.4
Greatest width of cup	10.7
Ratio of height to width	0.50
Height of basal concavity	1.2
Diameter of stem impression	1.9

Discussion.—The dorsal cup of *A. wolfcampensis*, n.sp., is relatively a little higher than any other observed. Except for its more bulbous plates, it resembles *A. typicalis*, n.sp., which also has smooth unornamented radials (RR). Absence of markings on the radials (RR), as well as other differences, distinguish this species from *A. facetus*, n.sp., *A. calycinus*, n.sp., and *A. exculptus*, n.sp. A comparison of the shape of the cups of these species is shown in figure 16.

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), near base of Lower Permian; Loc. 188–T–3, type locality of the Cibolo limestone on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, University of Kansas no. 60371; collected by R. C. Moore.

[POTERIOCRINITIDAE]

SECTION B.—*Articular facets equal or nearly equal to the width of the radials, and with the non-articular outer surface of the radials extending only slightly, if at all, inward beyond the transverse ridge of the facet.*

SUBSECTION B–1.—*Facets sloping distinctly outward, either as a whole, or at least in the area of the lateral ridges bounding the facets.*

GROUP a.—*Infrabasals flaring upward, visible from the side.*

SUBGROUP α.—*Cup cone-shaped; three anals in the cup.*

Genus SCYTALOCRINUS Wachsmuth and Springer, 1879

Scytalocrinus WACHSMUTH AND SPRINGER, 1879, Revision of Paleocrinoidea, pt. 1, p. 116.

Scytalocrinus Wachsmuth and Springer, MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 247.

This genus has a slender crown consisting of ten nearly straight arms that spread upward, fanlike, from a conical dorsal cup, in which the width approximately equals, or slightly exceeds, the height. The infrabasals (IBB) flare upward and are visible from the side. There are three anal plates in the dorsal cup. The stem is round. The arms are composed of uniserial, quadrangular or slightly wedge-shaped segments that bear rather long slender pinnules. The arms generally branch on the first primibrach (IBr_1) but in some forms on the second primibrach (IBr_2).

Genotype.—*Scaphiocrinus robustus* Hall.

Occurrence.—Typically developed in Mississippian (Lower Carboniferous) rocks of North America; represented by one described species from the Lower Pennsylvanian (Morrow series, Upper Carboniferous), Texas.

SCYTALOCRINUS SANSABENSIS Moore and Plummer

Pl. 5, fig. 6; Pl. 14, fig. 10; text fig. 17

Scytalocrinus sansabensis Moore and Plummer, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 247, pl. 14, figs. 9a, b, text fig. 9.

Description.—This interesting crinoid has a steeply conical dorsal cup, which is about five-sixths as wide as high; a small circular stem, 0.9 mm. in diameter; five small nearly quadrangular infrabasals (IBB); large basals (BB); and radials (RR) about two-thirds as high as wide, having articular facets nearly at right angles to the plane of the outer face. The facets are divided by a transverse ridge into inner and outer ligament areas. The outer ligament area is about 0.6 mm. in width. The inner ligament area is about 0.8 mm. wide. The crinoid has three anal plates, arranged as illustrated in figure 13.

Measurements[48] of six specimens, in millimeters, are as follows:

	W	H	H/W	HC
Holotype	6.7	5.5	0.82	28
Paratype	5.8	4.8	0.82	24
Hypotype A	6.9	4.6	0.66	25
Hypotype B	6.4	5.0	0.78	27
Hypotype C	5.5	5.0	0.91	----
Hypotype D	----	2.8	----	13

The radianal (RA) is uniformly a fairly large pentagonal plate broadly touching the posterior basal (pB) and more narrowly in contact with the right posterior basal) (rpB); anal x is about half as large as the radianal (RA) and rests on the narrow truncated tip of the posterior basal (pB); the right tube plate (rt) is very

[48]W, width of cup; H, height of cup, H/W, ratio; HC, height of crown.

small and narrow at the base, and it rests on the squarely truncated top of the radianal (RA).

Two of the Yale hypotypes, which have been freed from the matrix, show definitely the lower part of all the arms, proving that the first primibrach (IBr_1) is axillary in all rays and that above these axillaries there are ten simple unbranched arms. Thus, there is no question about the placement of this species in *Scytalocrinus.* Some of the specimens show the pinnules clearly. In all of them the first primibrach (IBr_1) of the two posterior rays and of the anterior ray are elongate, with length approximately twice the width; whereas the other two rays have short first primibrachs (IBr_1).

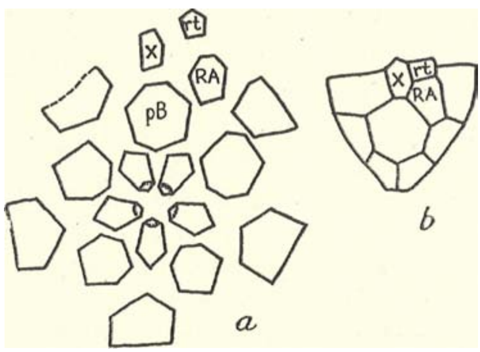

Fig. 17. Diagrams showing the arrangement of plates in the dorsal cup of *Scytalocrinus sansabensis* Moore and Plummer, *a*. Analysis of plates in the dorsal cup, x3; *b*, view of the dorsal cup from posterior side, x3.

Discussion.—Since publication of the original description of this species, Dr. C. O. Dunbar has kindly lent for study five additional well-preserved specimens from the collections at Peabody Museum, Yale University. These specimens correspond closely in all characters to the type. Slight variations in the dimensions of the dorsal cup and the curvature at the top of the cup are observed, but these appear not to be greater than differences between individuals of the same species. One of the specimens, about half as large as the others, has relatively thin plates in the dorsal cup and slender brachials that are proportionally longer than in the large specimen. This small specimen (hypotype D) is evidently a young individual of *S. sansabensis.* Hypotype A differs from other observed examples in the relatively lower height of the dorsal cup and in the distinctly incurved upper edges of the radials; in all other respects, however, it is typical of the species. At least three of the Yale specimens show the character of the posterior side of the cup very much more clearly than in the type specimens.

Occurrence.—Marble Falls limestone, Bend group (Morrow series), Pennsylvanian (Upper Carboniferous); Loc. 205-T-17, on Bend-San Saba road, about 11 miles southeast of San Saba in valley of Rough Creek, San Saba County, Texas.

Types.—Holotype, Walker Museum no. 31721; paratype, no. 31721A; collected by R. C. Moore. Hypotypes, Yale University, Peabody Museum no. 15238A–E; collected by C. Schuchert, D. K. Greger, and A. McCoy.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-1—GROUP a]

SUBGROUP γ.—*Cup truncate cone-shaped; no anal in the cup.*

Genus SPANIOCRINUS Wanner, 1924

Spaniocrinus WANNER, 1924, Jaarb. Mijn. Ned. Oost Indië, Verh. 1921, pt. 3, p. 292.

This genus was established to receive a species of crinoid from the Permian rocks of Timor. It is characterized by the moderately steep-sided conical form of the dorsal cup, which is perfectly pentamerous in symmetry, lacking any anal plate. Five infrabasals (IBB) are clearly visible in side view of the cup. The five basals (BB) are equal in size, moderately large, and hexagonal in outline. The five radials (RR) are about twice as wide as long and are laterally in contact all around the cup. The articular facets are equal to the greatest width of the radials (RR), but because the arms are in position in the single specimen of the only species yet identified as belonging to the genus, the length and slope of the facets are not known. There are five simple uniserial arms composed of massive, large, quadrangular segments.

Genotype.—*Spaniocrinus validus* Wanner (text fig. 18).

Discussion.—This genus differs from other poteriocrinitids in which an anal plate is lacking, both in structure of the arms and in the form of the dorsal cup. The other genera such as *Notiocrinus* Wanner, *Protencrinus* Jaekel, *Encrinus* Schultze, *Parencrinus* Wanner, *Stachyocrinus* Wanner, and *Erisocrinus* Meek and Worthen, which have dorsal cups with structural elements corresponding to *Spaniocrinus*, have cups with flat or concave bases and have infrabasals (IBB) that are not visible in side view of the cup.

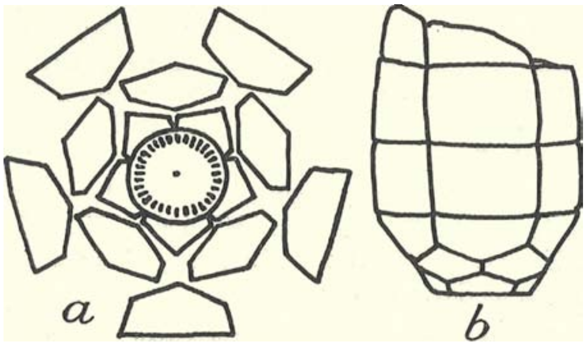

Fig. 18. Diagrams illustrating (*a*) the arrangement of plates and (*b*) the shape of the dorsal cup of *Spaniocrinus validus* Wanner.

SPANIOCRINUS? TRINODUS (Weller)

Pl. 2, fig. 2

Erisocrinus trinodus WELLER, 1909, Jour. Geol., vol. 17, p. 630, pl. 1, figs. 10, 11. (Cibolo limestone, Lower Permian, western Texas.)

Description.—Weller's description, somewhat modified, is as follows:

The dorsal cup is cone-shaped, the sides are nearly straight, diverging from the base at an angle of a little less than 90°. The sutures between the plates are flush with the general surface and are not situated in depressed grooves.

The measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	9.0
Greatest width of cup	14.5

The five infrabasals (IBB) have less than one-half of their proximal extremities covered by the stem impression. The exposed parts of the plate are smooth and form the flaring sides of the shallow cup. The basals (BB) are smooth, wider than long, hexagonal in outline, and their distal extremities are angular. The two distal faces are longer than any of the others, and the two proximal faces meet in an angle so obtuse that the two together make nearly a straight line. The radials (RR) are much wider than long, pentagonal in outline, and their surfaces curve inward toward the distal margin. Each bears three distinct node-like tubercles symmetrically arranged, one near each lateral margin of the plate with the third situated lower down on the median line. No anal plate is present.

Discussion.—The articular facets shown by the type specimen are as wide as the radials (RR). The outer ligament area is short, slit-like, and moderately excavated. The median part of the inner ligament area is somewhat concave; on each side of it are obliquely disposed ligament fossae. There is a faint intermuscular furrow but no well-defined notch at the inner border of the facet. The lateral ridges of the facet slope gently outward.

Assignment of Weller's species from the Cibolo limestone to *Spaniocrinus* is made necessarily with reservation because knowledge of the arm structure in the Texas form is lacking. The nature of the dorsal cup, with relatively very large infrabasals (IBB) that flare strongly upward from the stem, is entirely foreign to *Erisocrinus,* as also is the nodose ornamentation of the radials (RR). The latter feature is probably not more important than a sign of the species.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13368; collected by J. A. Udden.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-1]

GROUP b.—*Infrabasals not flaring upward, not visible from the side.*
SUBGROUP α.—*Cup truncate cone-shaped; three anals in the cup.*

Genus PACHYLOCRINUS Wachsmuth and Springer, 1879

Scaphiocrinus HALL, 1858, Geology of Iowa, vol. 1, pt. 2, p. 550.—WACHSMUTH AND SPRINGER, 1879, Revision of Palaeocrinoidea, pt. 1, p. 112; 1886, pt. 3, p. 235.

Pachylocrinus WACHSMUTH AND SPRINGER, 1879, Revision of Palaeocrinoidea, pt. 1, p. 115; 1886, pt. 3, p. 242.—SPRINGER, 1911, Harvard Mus. Comp. Zoology, Mem., vol. 25, p. 145; 1913, in Zittel-Eastman, Textbook of Palaeontology, p. 222; 1926, U.S. Nat. Museum, Proc., vol. 67, art. 9, p. 70.—JAEKEL, 1918, Palaeont. Zeitschr., Bd. 3, Heft 1, p. 62.

The characters of this genus interpreted somewhat narrowly are as follows: The crown is relatively elongate, with height three or more times the width of the dorsal cup. The arms in the upper part of the crown are numerous. The dorsal cup is truncate bowl-shaped, or modified truncate cone-shaped. The lower part of the sides of the cup has a rounded outline and the upper part tends to flare outward rather straightly at a gentler angle than below. This peculiarity, in conjunction with a flattened or slightly concave base, gives a distinctive appearance to the genotype species. The height of the cup is generally about one-half of the width. The five infrabasals (IBB) are small, subhorizontal or slightly down-flaring and not visible in the side view of the cup. The five basals (BB) are equal in size, except the posterior basal (pB) which is commonly a little larger than the others and very strongly convex longitudinally, so that the surface of these plates curves from horizontal or down-flaring in the proximal area to steeply up-flaring or vertical at the distal extremities. The five radials (RR) are wider than long and their surface generally slopes outward at a distinct angle to the vertical. The facets are as wide as the radials (RR) at their upper and outer edge, or nearly so, but the plates are spread apart, so that a strongly marked notch is generally apparent at the junction of the radials (RR). The outer surface of the radials (RR) bends around the outer extremities of the facets and extends well inward, in some forms almost to the inner border of the facet, or at least beyond the transverse ridge. The slope of the facets in *P. aequalis* (Hall) is not known, but in Pennsylvanian species it is found to be outward and at a very gentle angle. Three anal plates are present below the summit of the radials (RR), occurring in the normal positions, with the radianal (RA) at right of the posterior basal (pB), followed above by anal x and the right tube plate (rt).

The arms are rounded, composed of wedge-shaped, uniserially arranged segments that bear long pinnules. Two or more isotomous divisions of the arms occur in each ray, but the branching does not occur at uniform heights. In the genotype species there are generally two primibrachs (IBr), but in other species there may be only one primibrach (IBr) in a ray.

The stem is round. The surface of the cup and arms is smooth or decorated. The sutures are generally very distinct but not impressed; the small pits may occur at angles between plates of the basal (BB) and the radial (RR) circlets.

The anal sac is elongate, cylindrical or angular in cross-section, and in some species is strongly recurved.

Genotype.—Scaphiocrinus aequalis Hall, Keokuk limestone, lower Mississippian (text fig. 19).

Discussion.—This genus was erected to include poteriocrinitids that had previously been called *Scaphiocrinus,* a name that is taxonomically invalid because its genotype species is regarded as a typical representative of an already established genus, *Graphiocrinus.* Wachsmuth and Springer indicated in their original diagnosis that *Pachylocrinus* was intended to include crinoids with rather low cups having a basal concavity in which the infrabasals (IBB) are concealed, straight articular facets, sutures with primibrachs (IBr) gaping, arms relatively short, composed of angular wedge-shaped segments arranged uniserially, and stem round or

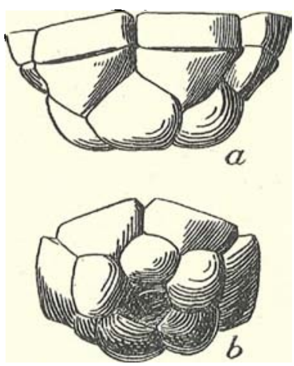

Fig. 19. Dorsal cup of *Pachylocrinus aequalis* (Hall), the genotype species, showing the form of the rounded basals and the outward projection of the radials with strongly marked notches between them (drawn from a topotype specimen from the Keokuk limestone at Crawfordsville, Indiana). *a,* View of the cup from the anterior side, the quadrangular first primibrachs shown above the radials; *b,* view of the anterior side obliquely from below, indicating most clearly the appearance of the radials (primibrachs not shown).

pentagonal. The genotype of *Pachylocrinus* is *Scaphiocrinus aequalis* Hall, as explained by Springer,[49] not *S. subaequalis* Wachsmuth and Springer. In course of time, emphasis came to be laid on the general structure of the arms as a means of recognizing *Pachylocrinus,* and almost any poteriocrinitid with two or three anal plates in the cup and with arms branching dichotomously two or more times was referred to this genus. When the list of Lower

[49]Springer, Frank. Some new American fossil crinoids: Mus. Comp. Zool., Harvard College, Mem., vol. 25, no. 3. p. 145, 1911. Unusual forms of fossil crinoids: U. S. Nat. Mus., Proc., vol. 67, art. 9, p. 70, 1926.

Carboniferous species had grown to 100 or more, Springer[50] suggested removal of those crinoids with a pentagonal stem and assignment of them to *Abrotocrinus* Miller and Gurley, previously suppressed as a synonym of *Pachylocrinus.* More important than the character of the stem, however, is the nature of the dorsal cup and anal sac, along with peculiarities of arms and articular facets. It is obvious that numerous species that have been placed in *Pachylocrinus* do not belong there. It is important, therefore, to scrutinize carefully each species regarded as possibly belonging in this genus and to be certain that it corresponds somewhat closely to the genotype species before making final identification.

Springer[51] notes that the genus *Pachylocrinus* ranges from Kinderhook (lowermost Mississippian) to Upper Carboniferous, although as far as known no published record of any Pennsylvanian species under this name is in the literature. Such species as "*Scaphiocrinus?*" *washburni* Beede or "*Poteriocrinus*" *lasallensis* Worthen cannot be included in this connection, for they are not representative of *Pachylocrinus.* Nevertheless, typical examples of *Pachylocrinus* belonging to undescribed species are contained in collections both from horizons in the Pennsylvanian section and from Lower Permian strata of the Mid-Continent region. Two of these, from upper middle Pennsylvanian beds in Texas, are described in this paper.

Occurrence.—Base of Lower Carboniferous to Lower Permian.

PACHYLOCRINUS UDDENI Moore and Plummer, n.sp.

Pl. 4, fig. 8; text fig. 20

Description.—The holotype of this species is a complete dorsal cup with the lower part of the arms attached. The cup has been somewhat compacted and deformed, but it shows satisfactorily all diagnostic features. Comparison with somewhat similar undescribed species of *Pachylocrinus* in the collection aids in recognition of significant features.

The dorsal cup is truncate bowl-shaped, with height about one-half of the width; the base is very slightly depressed and the sides flare outward. A part of the cup that is not distorted shows that

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[50]Springer, Frank, Unusual forms of fossil crinoids: U. S. Nat. Mus., Proc., vol. 67, art. 9, p. 72, 1926.

[51]Idem, p. 70.

the outward flare of the radials (RR) is at a slightly lower angle than that of the distal parts of the basals (BB). The infrabasal (IBB) circlet is pentagonal in outline and, as a whole, no larger than a single one of the adjoining basals (BB). The large round stem impression occupies almost the entire area of the pentagon, only the tips of the infrabasals (IBB), about 1 mm. in length, extending beyond the impression. The basals (BB) are approximately as wide as long, and because of transverse as well as longitudinal convexity they appear somewhat bulbous. Near the proximal edge, the surface slopes abruptly downward from the border of the infrabasal (IBB) disc, but in a very short space it curves steeply upward. The distal extremities reach a little more than two-thirds the height of the cup. Except the right posterior basal (rpB), which is hexagonal, all the plates of this circlet, including the posterior basal (pB), are pentagonal. The radials (RR) are nearly twice as wide as long; they are approximately equal in size, excepting the right posterior radial (rpR) which is small. The facets are only partly shown where some of the primibrachs (IBr) have been slightly dislodged. The width of the facet is very distinctly less than the greatest width of the radials (RR), and the outer surface of these plates bends inward around the ends of the transverse ridge, extending considerably beyond them. The radials (RR) spread apart at the top, and in undeformed condition of the cup there are broad deep notches at the interradial sutures. Three anal plates occur below the summit of the radials (RR). The radianal (RA) is a large hexagonal plate, with sides of very unequal length, the longest sutures being those adjoining the posterior basal (pB) and the right posterior radial (rpR); it also touches the right posterior basal (rpB), left posterior radial (lpR), and the two anal plates above it. The anal x is about two-thirds as large as the radianal (RA); it rests in the angle between the radianal (RA) and left posterior radial (lpR), and is rather strongly convex, both longitudinally and transversely. Barely reaching below the upper angle of the right posterior radial (rpR) is the right tube plate (rt), which occurs directly above the radianal (RA).

The first primibrach in each ray is axillary; these plates are distinctly smaller than the radials (RR). The sutures between the primibrachs (IBr) and radials (RR) are gaping. The secundibrachs (IIBr) are very short uniserial segments, only five being preserved in the least fragmentary arm. The surface of the cup and arms is entirely smooth and unornamented. The sutures occur in strongly marked furrows between the plates. No trace of the anal sac is visible.

Measurements of the holotype specimen, in millimeters, are given in the following tabulation:

Height of dorsal cup (est.)	8.5
Width of dorsal cup (est.)	24.9
Width of stem impression	5.8
Length of infrabasal	4.6
Width of infrabasal	3.8
Length of basal	9.2
Width of basal	9.8
Length of radial	5.9
Width of radial	10.0
Length of radianal	8.0
Width of radianal	6.7
Length of anal x	5.8
Width of anal x	7.4
Length of suture between basals	4.8

Discussion.—Comparison of *P. uddeni* with topotype specimens of *P. aequalis* (Hall), the genotype species, leaves no doubt as to the generic assignment of this Pennsylvanian species. The cup is very much larger than in *P. aequalis* but is only a little larger than several undescribed Pennsylvanian specimens in the collection. Some of these latter show diagnostic features of the cup, arms, and anal sac, which are not seen, or are less clearly visible, in *P. uddeni.* The two cups are shown in figures 19 and 20.

Occurrence.—Keechi Creek shale member, Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–67, about three-fourths mile north-northeast of Union Hill School, which is about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas.

Types.—Holotype, Plummer Collection no. P–7645, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

PACHYLOCRINUS OGARAI Moore and Plummer, n.sp.

Pl. 4, fig. 7; pl. 19, fig. 3; text figs. 20, 21

Description.—The dorsal cup of this species is of medium size, low truncate bowl-shaped, with a sharply defined basal concavity that is relatively deep for the genus. The sides of the cup flare outward, the average slope of the arm plates being a little more gentle than that of the distal portion of the basals (BB). The infrabasals (IBB) form a small pentagon at the top of the basal concavity. The round stem impression, 2.1 mm. in diameter, covers slightly more than half the width of the infrabasal (IB) pentagon. The basals (BB) are relatively large, subequal plates that reach to a point slightly above mid-height of the cup. The proximal portion forms the lower three-fourths of the sides of the basal concavity, sloping very steeply downward, then curving abruptly

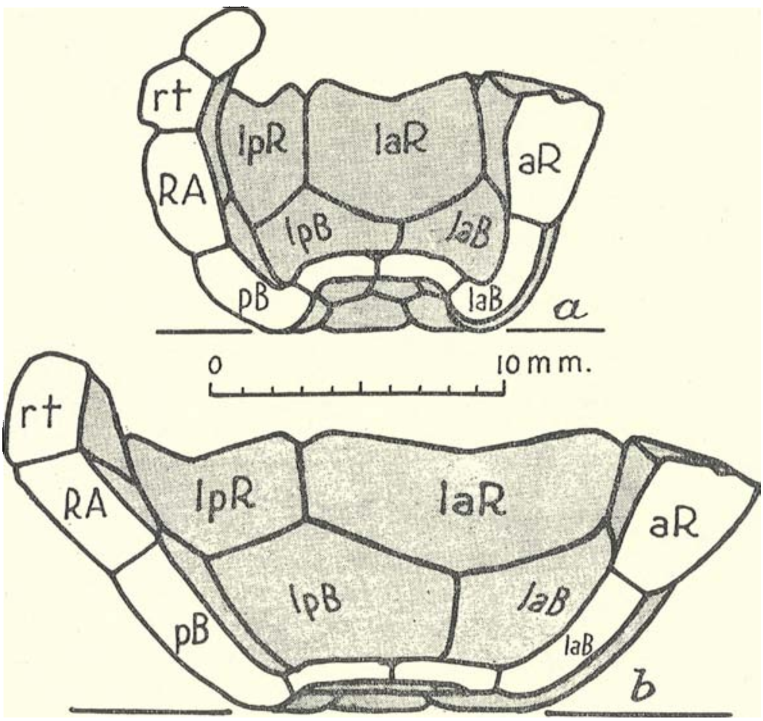

Fig. 20. Diagrams illustrating the shapes of the dorsal cups and arrangement of plates in two species of *Pachylocrinus*. *a*, Cross-section through the anterior radial and posterior interradius showing the left half of the dorsal cup of the holotype of *P. ogarai* Moore and Plummer, n.sp.; *b*, section in the same plane through the holotype of *P. uddeni* Moore and Plummer, n.sp.

outward and upward. The line of tangency to the basal plane of the cup crosses the basals (BB) less than one-fourth of their length from the proximal margin. The length of the radials (RR) is about two-thirds of their width, and the longitudinal profile of their surface is nearly straight. The facets are distinctly less than the greatest width of the radials (RR). An extension of the outer surface of the plate, about 1 mm. wide, reaches along each side of the facets to the edge of the body cavity. These inward extensions of the surface or adjoining facets make a shallow groove, 2 mm. in width, the suture between the radials (RR) occurring in the bottom of the groove. A narrow outer marginal ridge, bordered on the inner side throughout its length by strongly marked denticles, and an unusually large deep ligament pit are chief features of the outer ligament area. The transverse ridge is prominent, being bordered on the inner side by the nearly parallel grooves of the ligament fossae. The slope of the triangular muscle areas and of the lateral ridges is very distinctly outward. The inner margin of the facet is marked by a broad intermuscular notch. The three anal plates that occur below the upper margin of the radials (RR) include a moderately large quadrate radianal (RA), and above this the anal x and right tube plate (rt). Another tube plate that does not form part of the dorsal cup, is present in the holotype specimen. A primibrach (IBr) and one or two secundibrachs (IIBr) are lodged in the body cavity but their characters are not very clearly shown. The surface of the plate is decorated by a fine pattern of low irregular elongate nodes or discontinuous ridges, which are most distinctly shown on the upper part of the cup. Much the most prominent feature about the cup is the wide and comparatively deep furrows that occur along all the sutures. The average width of the furrows is 1.5 mm., and the depth a little less than 1 mm. At each of the angles between the plates of the upper circlets, there is an accentuation of the furrow in the form of a long rounded pit.

Measurements of the holotype specimen, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.0
Width of dorsal cup	17.0
Height of basal concavity	1.8
Width of basal concavity	7.0
Length of basal	9.0
Width of basal	8.0
Length of radial	5.0
Width of radial	8.0
Diameter of stem impression	2.1

Discussion.—Recognition of *P. ogarai* is easily made on the basis of the ornamentation of the plates and of the deep sutures between them. Naturally, account must be taken of the general form and structure of the cup, which furnish indication of a generic relationship. Although the deep furrows along the sutures suggest such a crinoid as *Parulocrinus compactus*, n.sp., which also has a well-marked basal concavity, the shape of the cup is otherwise dissimilar; there are three instead of two anal plates in the cup, and there is a well-marked separation of the facets by extensions of the outer surface of the radial plates. The cup of *Pachylocrinus ogarai* differs from that of species of *Dicromyocrinus* in the outward flare of the radials (RR) and the separation of the facets seen in this new species.

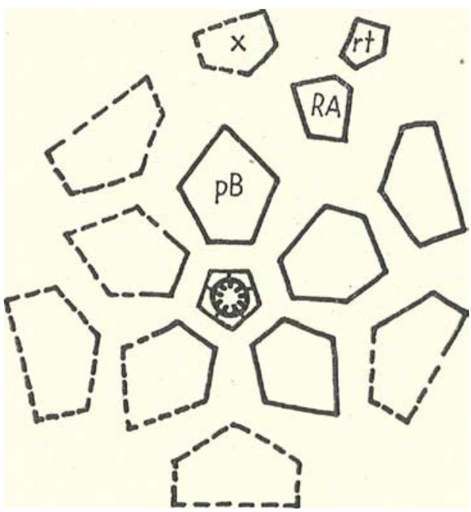

Fig. 21. Diagram showing the analysis of the plates in the dorsal cup of the holotype of *Pachylocrinus ogarai* Moore and Plummer, n.sp.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, on the northwest slope of Kyle Mountain, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10752, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

Genus TEXACRINUS Moore and Plummer, n.gen.

The crown is elongate and somewhat slender. The dorsal cup is truncate cone-shaped. There are probably five infrabasals (IBB), which are not shown in the flattened holotype specimen, and they are apparently covered mostly by the stem. The five basals are subequal and pentagonal, except the right posterior basal (rpB) which is hexagonal and moderately convex longitudinally and transversely. The five radials have a length about two-thirds of their width. The facets are equal to the greatest width of the radials and are not gaping. The three anal plates in the dorsal cup consist of a large radianal (RA) that rests on the sloping edges of the posterior (pB) and right posterior basals (rpB) and touches the left posterior radial (lpR), and of two other plates that barely reach below the summit of the radials. A double series of anal tube plates is visible above these.

The slender uniserial arms branch in each ray on the first primibrach (IBr_1) and thereafter with two or three divisions (branching is confined to the innermost parts of the ray). Long slender pinnules are borne by the arm segments. The stem is round. The anal sac is unknown.

Genotype.—*Texacrinus gracilis* Moore and Plummer, n.sp.

Discussion.—This genus has the general appearance of *Pachylocrinus* but differs in the strictly exotomous character of the branching of the arms and in the absence of an indentation between each of the radials. Crinoids with exotomous branching are uncommon in Carboniferous rocks. *Hydreionocrinus* de Koninck exhibits this type of arm structure, but the segments are biserially arranged; this genus has a mushroom-like anal sac that is girdled at the top by a ring of projecting spines.

Occurrence.—Des Moines series, Pennsylvanian (Upper Carboniferous); Texas.

TEXACRINUS GRACILIS Moore and Plummer, n.sp.

Pl. 15, fig. 4; pl. 21, fig. 5; text fig. 22

Description.—Description of this species is based on a complete but flattened crown, to which a few stem segments are attached. The general characters have been indicated in the definition of the genus. The infrabasals (IBB) are not seen, but it appears from study of the shape and position of the basals and from the position of the attached stem fragment that the base of the cup is probably truncated and perhaps somewhat concave. All five of the basals (BB) are clearly visible; their width and length are about equal. The posterior basal (pB) is pointed distally, instead of truncated, for the radianal plate reaches to the left posterior radial and separates the posterior basal from higher plates of the anal series. The radials (RR) are nearly straight longitudinally; characters of the facet are not determinable except for the observation that their width is fully equal to that of the radial plates and that the transverse ridge is not set outward so as to produce an indentation between adjacent radials like that seen in *Pachylocrinus.* The surface of the dorsal cup is smooth.

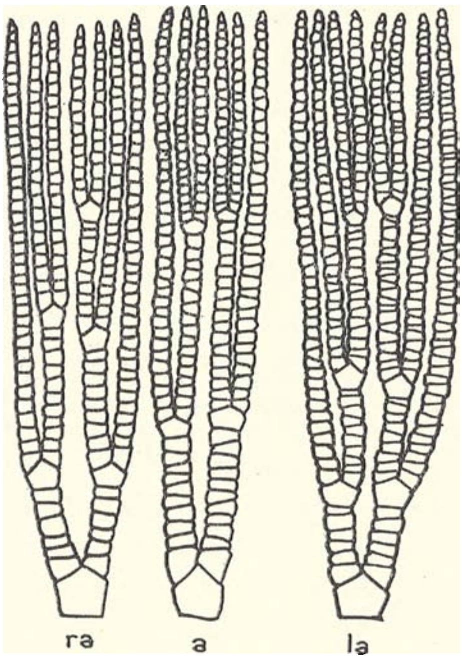

Fig. 22. Diagram showing the arm structure in three rays of the holotype of *Texacrinus gracilis* Moore and Plummer, n.sp., showing repeated bifurcations of the inner branches (ra, right anterior; a, anterior; la, left anterior).

The axillary primibrachs are about equal in size to the radials. The arms are rounded transversely, slender, and somewhat spreading. Six to twelve secundibrachs of slightly cuneiform outline occur below the second axillary plates. The character of the arm structure is shown in the accompanying figure.

Measurements of the holotype specimen, in millimeters, are as follows:

Height of crown	32.0
Height of dorsal cup, about	4.0
Width of dorsal cup, about	8.0
Diameter of stem	2.2
Length of basal	3.0
Width of basal	3.0
Length of radial	2.3
Width of radial	3.5

Discussion.—This species is distinguished by the long slender arms, and especially by the nature of the branching. The crown resembles that of *Schistocrinus parvus,* n.sp., in general size and form, but characters of the dorsal cup, arms and anal sac readily serve to distinguish the latter species. Although the nature of the dorsal cup is not very satisfactorily determined and comparison of this with other known Pennsylvanian crinoid cups is hardly worth while, no other species is known that corresponds in arm structure.

Occurrence.—Brannon Bridge limestone member of the Millsap Lake formation, Strawn group, Des Moines series, Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, near road corner about 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Marrs Collection no. M–17; collected by Mrs. W. R. Marrs, Austin, Texas.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B–1—GROUP b]

SUBGROUP β.—*Cup truncate cone-shaped; one anal plate in cup.*

Genus BRYCHIOCRINUS Moore and Plummer, n.gen.

The crown is approximately ovoid; the arms spread somewhat broadly upward from the dorsal cup, which is one-sixth or less the height of the crown. The sides of the dorsal cup are relatively steep and straight and expand upward, at least this appears to be the arrangement of the plates in the least disturbed part of the dorsal cup, the one available specimen having been flattened by compression. A sharp angulation in the proximal portion of the basals (BB) shows that the lower part of the cup is truncated and almost certainly somewhat depressed, the small infrabasals (IBB) and attachment for the round stem being located in the basal concavity. The greatest width of the cup is at the summit plane of the radials (RR) and is equal to about twice the height of the cup. Portions of the infrabasal (IBB) circlet appear adjoining a fragment of the stem and beneath basals (BB). There are probably five present, but it is not possible definitely to determine their number or shape. The five basals (BB) are approximately equal; all are pentagonal except the posterior basal (pB), which is slightly larger than the others and hexagonal in outline. The short proximal portion is bent nearly at right angles to the long distal part, which is nearly straight in longitudinal profile and gently convex transversely. The five radials (RR) are about equal, pentagonal in outline, in width about twice their length, and are straight in longitudinal profile. Articular facets occupy the entire width of the radials (RR), and the sutures with the primibrachs (IBr) gape slightly. A large anal x intervenes in the line of the radials (RR) on the posterior side of the cup and rests on the squarely truncated, relatively broad, distal extremity of the posterior basal (pB). This anal plate rises very slightly above the summit line of the radials (RR) and supports on oblique facets two tube plates, which are each about two-thirds the size of anal x; following these two plates is another slightly smaller one and then a large number of very small irregularly indented plates belonging apparently to the anal sac.

The arms are round, comparatively slender, and relatively uniform above the first primibrach (IBr_1), which appears to be axillary in each ray and composed of biserial segments that bear coarse pinnules. The branches are isotomous. The first fork above the axillary primibrach (IBr) occurs on the seventh to the tenth secundibrach ($IIBr_{7-10}$). The axillary segments are small triangular pieces which only partly divide the succeeding tertibrachs (IIIBr) of the two branches from one another and from the secundibrachs (IIBr) below the axillary. A third isotomous branching occurs in at least one ray at the eighteenth tertibrach ($IIIBr_{18}$) and, more obscurely, there is a suggestion of a similar forking in the adjoining branch which belongs to the same ray.

The character of the ventral sac is unknown, except that in part it appears to be formed of small plates with pore-bearing interspaces. At the top of the specimen is a relatively large spine that has the form of a terminal sac spine, suggesting that the ventral sac is at least as high as the arms that conceal it.

The stem is composed of relatively thin segments with curved outer edges, so that an indentation appears along the stem at each joint between segments. The stem is perforated by a fine pentolobate canal.

Genotype.—*Brychiocrinus texanus* Moore and Plummer, n.sp.

Discussion.—The form of the dorsal cup and the nature of the arms in *Brychiocrinus* suggests affinities with *Pachylocrinus* and related genera, such as *Abrotocrinus*, *Coeliocrinus*, and *Aulocrinus*. It also suggests *Decadocrinus*, which has a similar cup and coarse pinnules borne on strongly cuneiform arm segments, but in this genus there is only one isotomous division in each ray. All the genera mentioned, however, have three anal plates in the dorsal cup, instead of a single plate, as in *Brychiocrinus*. If one concludes that similarity in structural plan denotes genetic relationship between *Brychiocrinus* and a pachylocrinid genus, the observed reduc-

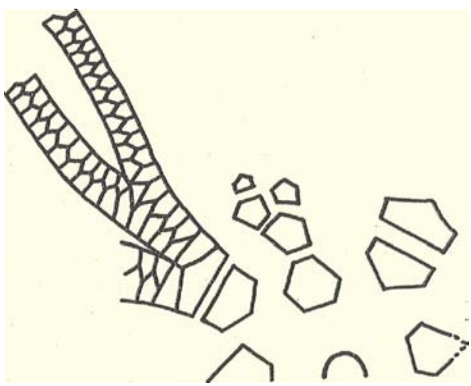

Fig. 23. Diagram showing the arrangement of plates in the dorsal cup and arms of the holotype of *Brychiocrinus texanus* Moore and Plummer, n.sp.

tion in number of anals in the dorsal cup and the change from uniserial to biserial arms accord with expected evolutionary steps.

Except for the biserial arms of *Brychiocrinus* and the occurrence of the first division of the arms on the first primibrach (IBr_1) instead of on the second primibrach (IBr_2), there is marked resemblance of this new genus to *Spheniscocrinus* Wanner, recently described from the Permian of Timor[52]. The form of the dorsal cup in the latter genus, its annulated stem, the presence of only one large anal plate, the isotomous plan of the arms—not to mention the approximate position of the branching and the presence

[52]Wanner, J., Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor: Palaeontographica, Suppl., Bd. 4, Abt. I, Lief. 2, p. 175, 1937.

of coarse pinnules—all suggest *Brychiocrinus.* The cuneiform arm segments of *Spheniscocrinus* indicate, however, that it is less advanced than *Brychiocrinus*, and since it occurs at a much higher stratigraphic horizon, the Timor form can not represent a type ancestral to the Texas genus.

Occurrence.—Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Texas.

BRYCHIOCRINUS TEXANUS Moore and Plummer, n.sp.

Pl. 2, fig. 1; text fig. 23

Description.—The essential characters of this interesting species have been already described in the diagnosis of the genus and need not be repeated. Additional noteworthy features include the occurrence of small spines on upper arm segments and a tabulation of the measurements of the holotype, which is the only known example of the species.

Measurements of the holotype, in millimeters, are as follows:

Height of cup (est.)	5.5
Maximum width of cup (est.)	9.0
Ratio of height to width	0.6
Length of basal	4.0
Width of basal	5.0
Length of radial	3.1
Width of radial	5.3
Length of anal x	2.8
Width of anal x	3.2
Diameter of stem	2.0
Height of crown	35.0

Occurrence.—Brannon Bridge limestone member of Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Harris Collection H–4; collected by Mrs. G. W. Harris, Waco, Texas.

[POTERIOCRINITIDAE—Section B—Subsection B-1—Group b]

Subgroup γ.—*Cup truncate cone-shaped; no anal plate in cup.*

Genus ERISOCRINUS Meek and Worthen, 1865

Erisocrinus Meek and Worthen, 1865, Am. Jour. Sci. (2), vol. 39, p. 174.

This genus includes crinoids having a truncate cone-shaped dorsal cup, the flattened or slightly rounded base with little or no concavity, bearing a circular stem impression. The outline of the cup is regularly pentagonal, as seen in dorsal or ventral view, with angles of the pentagon very clearly defined. The five infrabasals (IBB) are fairly small and largely but not entirely covered by the stem. The five basals (BB) are equal in size, and shaped like diamonds with the lower points truncated. The five radials (RR) are large, smooth, and prominent. Although they may be nearly vertical in the distal portions, they typically flare rather evenly outward. The sides of the cup, as seen in profile, however, do not

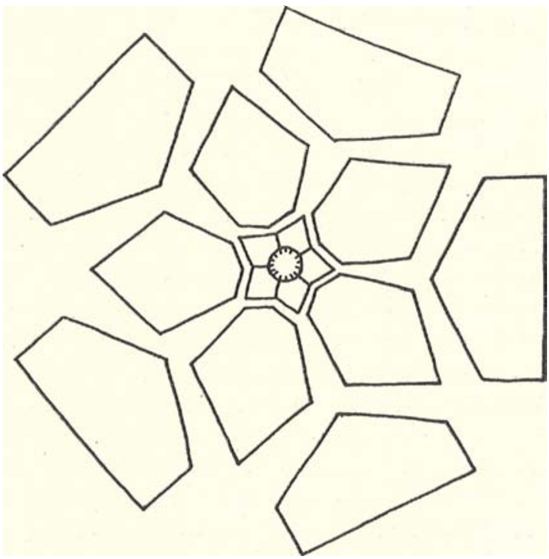

Fig. 24. Diagram showing the symmetrical arrangement of plates in *Erisocrinus*, based on a specimen of *E. typus* Meek and Worthen (K–1389) from Texas, x5.

curve to make a distinctly rounded contour such as appears in side view of *Delocrinus*. The facets are equal to the radials (RR) in width. The outer ligament area is very short. The inner ligament area moderately long with median part concave and lateral ridges sloping gently outward. No anal plates are present on the outside of the cup, but a single small anal plate occurs in a notch between the posterior radial facets at their inner border.

The ten arms are fairly long, biserial, and composed of wedge-shaped interlocking plates. The arms divide isotomously on the first primibrach (IBr_1) which is comparable in size to the radials (RR) and is not spine bearing in any known species.

Genotype.—*Erisocrinus typus* Meek and Worthen, from lower Middle Pennsylvanian beds near Springfield, Illinois.

Discussion.—This genus is characterized by its truncated base and rather evenly flaring sides, which give it a trapezoid shape in vertical cross-section, and by its regular pentagonal outline in ventral or dorsal view. Combined with these characters of form of the cup, is the absence of anal plates below the top of the radials (RR). Among genera having structure similar to *Erisocrinus*, that is, having five infrabasals (IBB), ten arms, and lacking an anal plate in the cup, are *Sinocrinus* Tien, *Encrinus* Schultze, *Protencrinus* Jaekel, *Stachyocrinus* Wanner, and *Paradelocrinus* Moore and Plummer. The form of the cup in *Sinocrinus* is bowl-shaped rather than truncate cone-shaped, and the infrabasals (IBB) flare gently upward, being visible in side view of the cup. *Encrinus*, which occurs in Triassic strata, lacks any trace of an anal plate even on the inner border of the radial facets. *Protencrinus* is distinguished from *Erisocrinus* by the generally lower and relatively broader character of the cup and by reduction in size of the basals (BB), so that they do not touch one another laterally. *Stachyocrinus* is thus far reported only from the Permian of Timor. Neither its basals (BB) nor its infrabasals (IBB) can be seen in side view of the cup, and the arms are uniserial. *Paradelocrinus* differs from *Erisocrinus* in the form of the cup. It is truncate bowl-shaped rather than truncate cone-shaped and is rounded or rounded pentagonal in outline when viewed from above or below. The sides of the cup in *Paradelocrinus* are rather strongly and regularly rounded, as in *Delocrinus*, and bear typically a well-developed basal concavity. Most of the length of the basals (BB) is visible in side view of the cup of *Erisocrinus*, but only the distal extremities of the basals (BB) appear in similar view of *Paradelocrinus*.

The following species from the Pennsylvanian and Permian rocks of North America have been assigned to *Erisocrinus*. Those not now placed in this genus are indicated by an asterisk (*).

Name	Occurrence	H/W	Remarks
E. typus Meek and Worthen, 1865	Middle Pennsylvanian, Springfield, Illinois	0.36	Moderately broad, flat-bottomed cup
E. nebrascensis Meek and Worthen, 1865	Upper Pennsylvanian, Nebraska	....	Same as *E. typus*

Name	Occurrence	H/W	Remarks
**E. tuberculatus* Meek and Worthen, 1865	Pennsylvanian, Illinois	....	*Ethelocrinus tuberculatus* (Meek and Worthen)
E. conoideus Meek and Worthen, 1865	Pennsylvanian, Illinois	0.63	Small, steep-sided conical cup
**E. inflexus* (Geinitz) White, 1880	Upper Pennsylvanian, Nebraska	....	*Paradelocrinus inflexus* (Geinitz)
**E. planus* White, 1880	Upper Pennsylvanian, Kansas	....	*Delocrinus planus* (White)
E. whitei Wachsmuth and Springer, 1886[a]	Upper Pennsylvanian, Kansas	....	Same as *E. planus*
E. cognatus Wachsmuth and Springer, 1886	Upper Pennsylvanian, Kansas	....	Same as *E. planus*
**E. toddanus* Butts, 1898	Middle Pennsylvanian, Kansas City, Missouri	....	*Paradelocrinus toddanus* (Butts)
**E. megalobrachius* Beede, 1900	Upper Pennsylvanian, Kansas	....	*Delocrinus megalobrachius* (Beede)
E. propinquus Weller, 1909	Lower Permian, western Texas	0.53	Relatively high, flat-bottomed cup
**E. trinodus* Weller, 1909	Lower Permian, western Texas	0.57	*Spaniocrinus? trinodus* (Weller)
E. lutana Boos, 1929	Lower Permian, Kansas	....	*Pachylocrinus lutanus* (Boos)
E. elevatus Moore and Plummer, n.sp.	Palo Pinto limestone, Texas	0.51	Broad flat base, high steep sides
E. erectus Moore and Plummer, n.sp.	Mineral Wells formation, Texas	0.46	Small size, erect sides, moderate basal concavity

[a]Not *E. whitei* Meek and Worthen, 1868.

ERISOCRINUS TYPUS Meek and Worthen

Pl. 2, fig. 5; pl. 4, figs. 4, 5; pl. 19, fig. 4; text figs. 24, 25

Erisocrinus typus MEEK AND WORTHEN, 1865, Am. Jour. Sci. (2), vol. 39, p. 174; 1873, Illinois Geol. Survey, vol. 5, p. 561, pl. 24, figs. 6a–h (Pennsylvanian, near Springfield, Illinois).—MEEK, 1872, U. S. Geol. Survey Nebraska, p. 146, pl. 1, figs. 3a, b (Pennsylvanian, near Bellvue, Nebraska).

Erisocrinus nebrascensis MEEK AND WORTHEN, 1865, Am. Jour. Sci. (2), vol. 39, p. 174 (Pennsylvanian, near Bellvue, Nebraska).

Philocrinus pelvis MEEK AND WORTHEN, 1865, Am. Jour. Sci. (2), vol. 39, p. 350.

NOT *Erisocrinus typus* Meek and Worthen, WHITE, 1876, Powell's Rept., Geology of Uinta Mtns., p. 89; 1880, Contrib. Invert. Paleontology, no. 6, p. 126, pl. 33, fig. 5a (Upper Carboniferous, junction of Colorado and Green rivers, Utah).—BEEDE, 1900, Kansas Univ. Geol. Survey, vol. 6, pt. 2, p. 39, pl. 6, figs. 4, 4b (Pennsylvanian, Jefferson County, Kansas).

Description.—Four specimens in the collection of crinoids from Texas are referred to this species. They consist of dorsal cups, without arms or stems, except one somewhat deformed cup (P–7706) which shows three of the primibrachs in place above the radials, and several cuneate secundibrachs (IIBr), which are sufficient to show the biserial structure of the arms.

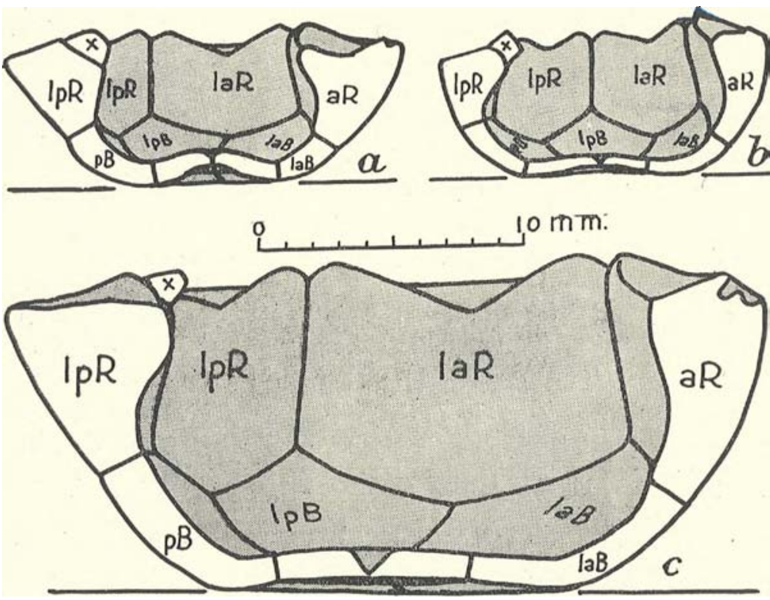

Fig. 25. Median cross-sections of three specimens of dorsal cups of *Eriso-crinus typus* Meek and Worthen, through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *a*, One of the syntypes (Univ. Illinois, x264), from the middle Pennsylvanian beds near Springfield, Illinois; *b*, a hypotype (P–10749), from the middle Pennsylvanian (Graford formation) of Texas; *c*, another hypotype (K–1389), from a somewhat lower horizon (Mineral Wells formation) in Texas.

The dorsal cup is truncate cone-shaped, grading to bowl-shaped, with nearly flat base and gently flaring sides. The greatest width is a little more than twice the height. A horizontal section cut just above the base is nearly circular. but one near the summit is regularly pentagonal. The plates are smooth and moderately thick, their shape and arrangement is shown in the accompanying illustration (fig. 25). The infrabasal (IBB) circlet is pentagonal, small, and about half covered by the stem, the individual infrabasals are diamond-shaped. The basals (BB) are large, pentagonal, slightly wider than long, and with the two longer sides converging to a point at the distal end. The angle at the distal tip of the basals (BB) measures 75 to 80 degrees. The radials (RR) are pentagonal in outline, with width approximately twice the length. The outer ligament area of the facets is characterized by its moderate depth and extreme shortness. The median part of the inner ligament area is distinctly concave, and the lateral parts are elevated and slope outward. One of the specimens (P–10749) shows very remarkable preservation of the facets, and it is desirable to give special notice to the characters shown. The outer ligament area lacks only a little of the width of the transverse ridge but is very short, being only 0.6 mm. across at the middle; the excavated character of the area accentuates the sharpness of the outer marginal ridge and the transverse ridge that border it. A fine, sharp-crested median ridge divides the area into two nearly equal parts, that on the inner side carries a deep ligament pit, 1.8 mm. in width, and minute denticles parallel to those of the transverse ridge occur on the median ridge and floor of the outer ligament area. The transverse ridge is narrow, crested, straight, and prominent. It carries on its inner slope a row of fine denticles with axes normal to the ridge. The denticles become very short and obsolescent in a space about 2 mm. long at mid-length of the ridge. The inner ligament area is shaped like a moth or butterfly with outspread wings, and this comparison is made to seem more real by the occurrence of a depression that extends from the mid-length of the transverse ridge to the strongly marked intermuscular notch. The depression corresponds to the body of a winged insect, as suggested. Two broad shallow ligament fossae, trending parallel to the transverse ridge, are located on each side of the median furrow. Two sloping triangular muscle areas that are also faintly furrowed adjoin them on the inner side of the facets. Along the interradial sutures, between the facets, there are deep flat-bottomed grooves that widen inward. On first inspection the walls of these grooves appear to be vertical-sided, but they are actually overhanging. The inner lobes of the facets are thin, flange-like projections. Although the length of the facets, measured from center of outer marginal ridge to a line connecting the lateral lobes on the inner border, is 3.5 mm., the thickness of the radial plate below is reduced to only 1.2 mm.

A small anal plate, triangular in outline, as viewed from above, occurs at the inner border of the facets between the posterior radials. This plate, observed in profile, appears to be directed upward and inward. The plate is truncated in a plane normal to this axis and in well-preserved examples, such as the specimen with nearly perfect facets, just described, may show a ring of fine denticles, which serve for sutural union with the tube plates.

Measurements of two specimens, one average in size, the other about twice as large as the type but showing the same form and proportions, are given in millimeters in the following tabulation:

	P–10749	K–1389
Height of dorsal cup	5.9	12.4
Greatest width of cup	13.8	30.0
Ratio of height to width	0.42	0.40
Width of body cavity	6.3	15.5
Diameter of stem impression	1.4	4.4
Maximum length of infrabasal	2.9	4.0
Maximum width of infrabasal	2.4	4.0
Maximum length of basal	4.8	11.9
Maximum width of basal	5.4	12.9
Maximum length of radial	4.8	9.5
Maximum width of radial	8.7	18.3
Length of suture between basals	2.4	9.0
Length of suture between radials	3.3	7.3

Discussion.—The known species of *Erisocrinus* from the Pennsylvanian strata of Texas have a general similarity, but each may be distinguished by the shape of the dorsal cup and especially by the form and attitude of the basal plates. *E. elevatus*, n.sp., has a relatively higher dorsal cup with steeper sides than is seen in *E. typus*, and its wide, short basal plates curve sharply to form an angular boundary between the flat base and the steep sides. *E. erectus*, n.sp., is a small species with very steep, slightly rounded sides, that is characterized by concavity of the base. *Paradelocrinus obovatus*, n.sp., resembles *Erisocrinus* in the pentagonal outline of the cup in dorsal or ventral view, but the cup is lower than that of *E. typus*, and its base is concave.

Occurrence.—The specimens identified as belonging to *E. typus* are distributed from the upper part of the Mineral Wells formation, Strawn group (Des Moines series), to the Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous). The observed occurrences may be listed as follows: Mineral Wells formation, Loc. 181–T–67, three-fourths mile north-northeast of Union Hill School, Palo Pinto County (P–7706), collected by

F. B. Plummer; Loc. 181–T–86. 0.1 mile south of road fork, on Salesville-Graford road, 2 miles west of Salesville, Palo Pinto County (K–1389), collected by Ralph King. Palo Pinto limestone; Loc. 181–T–48, quarry about 3½ miles north of Strawn, Palo Pinto County (P–4938), collected by F. B. Plummer. Graford formation; Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County (P–10749), collected by W. T. O'Gara.

Types.—Hypotypes, Plummer Collection no. P–4938 and King Collection no. K–1389, at Bureau of Economic Geology, The University of Texas.

ERISOCRINUS ELEVATUS Moore and Plummer, n.sp.

Pl. 4, fig. 1; text fig. 26

Description.—This interesting species has a bowl-shaped dorsal cup with upward-flaring sides, flat base, and pentagonal periphery. Its height is equal to about one-half its width. The stem cross-section is circular. The surface of the cup is smooth. The most characteristic features of this species are the flat base and the sharp bend between the base and nearly perpendicular sides. The infrabasals (IBB) are wide and short; the circlet of these plates is more nearly pentagonal than star-shaped, and less than half of it is covered by the stem impression. The basals (BB) are wider than long. The distal angle of these plates is about 100°. The radials (RR) are relatively long and nearly straight in longitudinal profile, and their proximal tips are well above the basal plane of the cup. A very small anal plate is identifiable at the inner margin of the facets between two radials (RR) of the paratype, but it is not well shown in the holotype.

Measurements of the holotype (P–10906) in millimeters, are given in the following tabulation:

Height of dorsal cup	9.3
Greatest width of cup	18.2
Ratio of height to width	0.5
Width of body cavity	10.5
Diameter of stem impression	3.7
Maximum length of infrabasal	4.0
Maximum width of infrabasal	3.4
Maximum length of basal	13.2
Maximum width of basal	8.5
Maximum length of radial	6.3
Maximum width of radial	10.9
Length of suture between basals	3.4
Length of suture between radials	4.5

Discussion.—This species is distinguished by the shape of its cup. It is proportionally higher and has a sharper angle between its base and sides than other known members of this genus. *E. propinquus* Weller, from the Lower Permian of western Texas, resembles *E. elevatus* most closely, for it is about the same in size, in the ratio of height to width, and in the steepness of the sides of the cup. The base of the Permian species is a little less broad, and the curvature from the base to sides a little more gradual than in the new species; also, the basals (BB) are longer and the radials (RR) shorter in *E. propinquus* than in the form here described.

Occurrence.—Palo Pinto limestone, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181-T-41, quarry 3 miles southeast of Oran, Palo Pinto County, Texas.

Types.—The holotype, Plummer Collection no. P-10906, and paratype, no. P-10903, are in the collection of the Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

ERISOCRINUS ERECTUS Moore and Plummer, n.sp.

Pl. 4, fig. 3; text fig. 26

Description.—This small crinoid has a steep-sided dorsal cup with relatively broad, moderately concave base. The infrabasals (IBB) form a star-shaped disk. The stem impression covers less than one-third of the length of each infrabasal (IB). The distal part of these plates flares downward and forms most of the sides of the basal concavity. The basals (BB) have a length approximately equal to their width. The proximal margins are horizontal or barely involved in the basal concavity. The median and distal parts curve evenly upward. The radials (RR) are twice as wide as long and curve very gently longitudinally and have a nearly vertical attitude. The facets are relatively short. The outer ligament area is slit-like. The inner ligament area is marked by a single obliquely placed ligament fossa on each side of the intermuscular furrow, and a small pit occurs on each side of this furrow near its inner extremity. A small triangular notch at the inner margin of the facets between two of the radials (RR) indicates the position of the anal plate, but this plate is not preserved in the type.

Measurements of the holotype, in millimeters, are as follows:

Height of cup	4.2
Greatest width of cup	9.0
Ratio of height to width	0.46
Width of body cavity	5.5
Height of basal cavity	0.8
Width of basal cavity	4.0
Greatest length of infrabasal	1.6
Greatest width of infrabasal	1.2
Greatest length of basal	3.7
Greatest width of basal	4.2
Greatest length of radial	3.0
Greatest width of radial	5.5
Length of suture between basals	1.2
Length of suture between radials	2.4

Discussion.—The dorsal cup of *E. erectus* has a broader base and steeper sides than in *E. typus* Meek and Worthen. The form ratio of the cup and the steepness of its sides are comparable to those in *E. elevatus*, n.sp., but that species lacks the basal concavity and is characterized by the sharp curvature between the plane of the base and of the sides. It is possible that the small cup on which description of the species is based may be immature; if that is true, the shape and proportions of a young example are probably not different from those of a mature specimen.

Occurrence.—Palo Pinto formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 248–T–4, 1.5 miles south of Bridgeport, west of Martins Lake, Wise County, Texas.

Type.—Holotype, no. K–4732, in collections of Bureau of Economic Geology, The University of Texas; collected by Ralph H. King.

ERISOCRINUS PROPINQUUS Weller

Pl. 4, fig. 2; text fig. 26

Erisocrinus propinquus WELLER, 1909, Jour. Geol., vol. 17, p. 629, pl. 1, figs. 14, 15. (Cibolo limestone, Lower Permian, western Texas.)

Description.—Weller's description of this species, slightly modified in form of statement, follows:

The dorsal cup is basin-shaped (truncate cone-shaped), perfectly symmetrical. The sutures between plates are flush with the general surface. The measurements of the holotype are:

Height of dorsal cup	9.5 mm.
Greatest width of cup	18.0 mm.

The infrabasals (IBB) form a slightly concave pentagonal disk, 6.5 mm. in diameter. The central part occupied by the circular stem impression is 4 mm. in diameter. The basals (BB) are all similar in form and size, hexagonal in outline, and with the two proximal faces meeting in a very obtuse angle and together nearly equal in length to one of the lateral faces, so that

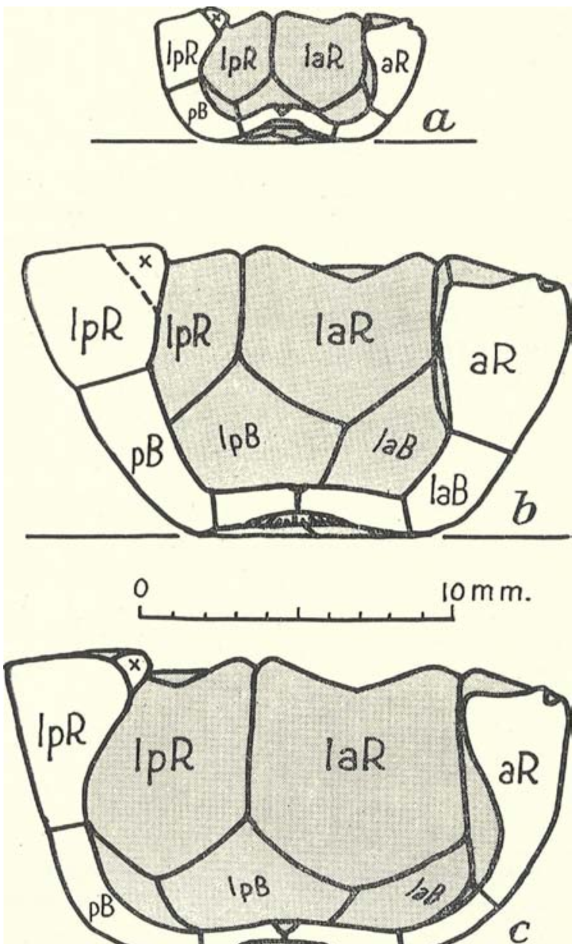

Fig. 26. Median cross-sections of the dorsal cups of three species of *Erisocrinus*. *a*, Holotype of *E. erectus* Moore and Plummer, n.sp.; *b*, holotype of *E. propinquus* Weller; *c*, holotype of *E. elevatus* Moore and Plummer, n.sp. The sections are drawn through the anterior radial (aR) and the posterior interradius, showing the left halves of the cups. The shaded areas represent parts beyond the plane of the sections.

the general outline of the plates is pentagonal; the proximal parts of the basals (BB) are nearly horizontal but curve upward rapidly, so that the major portion of the plates slopes upward and outward. The radials (RR) are much wider than long, pentagonal in outline, and the distal faces bear well-defined articular ridges. No anal plates are present.

Discussion.—This species is readily separated from *E. typus* Meek and Worthen by its relative greater height, steeper sides and presence of a shallow concavity at the base. *E. propinquus* is more closely similar to *E. elevatus*, n.sp., but it has a narrower base that is slightly concave instead of flat, its sides are a little less steep, and the upper points of the basals (BB) rise distinctly higher above the basal plane than in *E. elevatus.*

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, Sierra Alta Creek on Cibolo ranch 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13367; collected by J. A. Udden.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-1—GROUP b]

SUBGROUP δ. *Cup truncate bowl-shaped; three anal plates in cup.*

This subgroup of poteriocrinitids, characterized by the distinct outward slope of the facets that are nearly as wide as the radials, or equal to them in width, and marked also by the low truncate form of the dorsal cup with infrabasals not visible from the side, is represented by several genera and species in the Upper Carboniferous and Permian strata in Texas. The genera that are recognized include: *Aatocrinus, Athlocrinus, Lasanocrinus, Laudonocrinus, ?Marathonocrinus, Neozeacrinus, Perimestocrinus, Pirasocrinus, Plaxocrinus, Schistocrinus,* and *Sciadiocrinus.* The species to be described can be arranged conveniently according to the relative development of the basal concavity, those belonging to genera in which such concavity is undeveloped or barely perceptible being considered first. The interesting crinoid called *Marathonocrinus* probably belongs in this group, but lack of complete knowledge of the dorsal cup makes its position somewhat uncertain.

Genus NEOZEACRINUS Wanner, 1937

Neozeacrinus WANNER, 1937, Palaeontographica, Suppl., Bd. 4, Abt. 4, Lief. 2, p. 144. (Regarded as a subgenus of *Zeacrinus* Hall.)

This genus, defined mainly on the characters of the arms, was described from a single, unusually large crinoid from the Permian of Timor. The dorsal cup is low, somewhat truncate bowl-shaped, with flat base except for the sharply depressed large stem impression. The five infrabasals (IBB) are mostly covered by the stem,

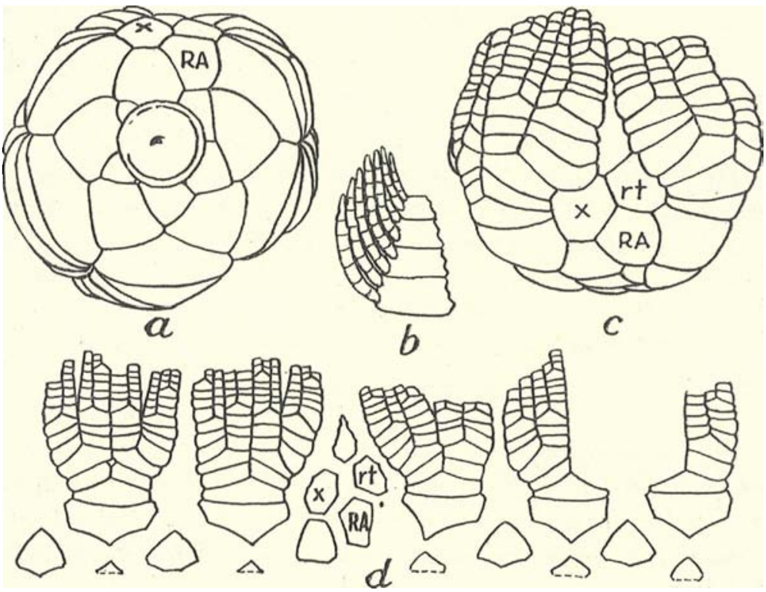

Fig. 27. Drawings to show the structural characters of *Neozeacrinus peramplus* Wanner, the genotype species, from the Permian of Timor, based on the holotype (after Wanner). *a*, Dorsal view, x0.8; *b*, portion of an arm showing hyperpinnulation, enlarged; *c*, posterior view of crown, x0.8; *d*, analysis of plates of the dorsal cup and arms, reduced.

only the tips extending beyond the impression, and are not visible in side view of the cup. The five basals (BB) are subequal, the proximal parts are horizontal, the distal parts flare gently upward and are clearly visible in side view. The lateral contacts between the basals (BB) are very short, in some forms being reduced nearly to the points of the angles. The five radials (RR) are large and have a width about twice their length. The three anal plates are in the dorsal cup in normal arrangement. A large radianal (RA) is in contact with the right posterior basal (rpB). A large anal x rests on the truncated tip of the posterior basal (pB), and the right tube plate, which is nearly equal in size to anal x, lies above the radianal (RA).

The arms are formed of very broad, short, uniserially arranged segments with isotomous branching on the first primibrach (IBr_1), the second secundibrach ($IIBr_2$), and the third tertibrach ($IIIBr_3$). Above the axillary tertibrachs (IIIBr) subdivision of the arms appears restricted to the outer two branches of each pair, thus giving rise to two endotomous divisions in the upper parts of each ray. Another feature is the presence of four pinnules on each brachial (Br).

Genotype.—*Neozeacrinus peramplus* Wanner (text fig. 27).

Occurrence.—This genus has been reported only from the Permian rocks of Timor. Three Mid-Continent species are now referred to it: *Hydreionocrinus uddeni* Weller, from the Lower Permian of Texas, *H. kansasensis* Weller, from the upper Pennsylvanian of Kansas, and a new species, *Neozeacrinus praecursor* Moore and Plummer, n.sp., from the lower Pennsylvanian beds in Texas.

NEOZEACRINUS UDDENI (Weller)

Pl. 6, fig. 8; text fig. 28

Hydreionocrinus uddeni WELLER, 1909, Jour. Geol., vol. 17, p. 624, pl. 1, figs. 1–5.

Description.—Weller's description of this species, slightly modified in form of statement, is as follows:

The dorsal cup is saucer-shaped, 42 mm. in greatest width and 12 mm. in height. The base is deeply excavated for the attachment of the stem. The surfaces of the plates are convex, and all sutures except those between the infrabasals (IBB) are situated in groove-like depressions. The infrabasals (IBB) form a pentagonal disk, 15 mm. in diameter, that is mostly covered by a deep circular depression, with sides slightly converging toward the bottom. The width of the depression at the rim is 12.5 mm. The width of the stem facet at its base is 9.6 mm. The depth of the depression is 3 mm. The distal extremities of the infrabasals (IBB) beyond the rim of the stem impression are short and convex or node-like. The basals (BB) are large and wider than long. The right anterior basal (raB), left anterior basal (laB), and the left posterior basal (lpB) are uniform in size and shape and pentagonal, with the proximal and two distal margins of nearly equal length. The lateral margins are not more than one-third the length of the other margins. The outlines of the posterior basal (pB) and the right posterior basal (rpB) are modified by introduction of the large radianal (RA), and these plates are mainly pentagonal but not symmetrically so, like the other three. The radials (RR) are large with a width of about twice the length, pentagonal in outline, and marked by strong articular ridges on their distal faces. The radianal (RA) is large with a width about two-thirds the length and an area about equal to that of the adjacent posterior basal (pB). The general outline is quadrangular, but really pentagonal, the distal face supporting the right tube plate (rt) being very short. The proximal angle of the plate in contact with the distal angle of the right posterior infrabasal (rpIB). The anal x is imperfectly preserved in the type specimen, but apparently it is smaller than the radianal (RA). The right tube plate (rt) is incorporated in the cup, at least in its proximal region.

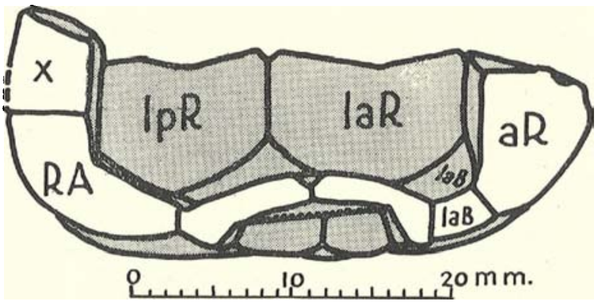

Fig. 28. Median section of the dorsal cup of the holotype of *Neozeacrinus uddeni* (Weller), showing its broad, low form, the large infrabasal circlet, and the deeply impressed stem area.

The arms and ventral sac of the species are not known, but accompanying the dorsal cup are a number of large spatulate spinose plates which characteristically form the border of the distal surface of the mushroom-shaped sac in *Hydreionocrinus*. These plates probably represent the same species as the cup and their form and size is such as to indicate that about 15 of them formed the border of a disk 60 to 70 mm. in diameter, exclusive of the spinose projections of the plate.

Discussion.—The holotype of Weller's species is the only known example of this form. Through the kindness of Prof. Carey Croneis of the University of Chicago, the opportunity to study the original specimen has been offered. Little need be added to the published description by Weller. The plates of the dorsal cup are smooth, even the best-preserved plates lacking any trace of ornamentation. The radial facets have a distinct outward inclination, but for hydreionocrinid or zeacrinid genera the angle is unusually low.

A small but distinct notch at the summit of interradial sutures is observed, but the width of the facets is barely less than the greatest width of the radials (RR). The very short outer ligament area is bounded by a fine outer marginal ridge and by the narrow straight transverse ridge. The ligament pit is narrow and not very deep. The inner ligament area shows obscurely defined, obliquely disposed ligament fossae, and a well-marked intermuscular furrow, but the lateral lobes of the facet appear to be short and the intermuscular notch is not prominent.

Weller's assignment of this species to *Hydreionocrinus* is based chiefly on the low bowl-shaped form of the dorsal cup and on the occurrence in the collection from the Cibolo limestone of large spines that are undoubtedly the peripheral spines of an anal sac, such as appears in *Hydreionocrinus.* The dorsal cup differs from that of the genotype of *Hydreionocrinus* in that the infrabasals (IBB) are not visible in side view of the cup, and the form is also very much larger. The occurrence of the anal sac spines is not of special significance, since these are known to occur in several genera of the general type of *Hydreionocrinus.*

This species is referred to Wanner's genus, *Neozeacrinus*, because the dorsal cup is practically identical with that of *N. peramplus* Wanner, the genotype species. Closely corresponding are such peculiarities as the sharp stem impression, the triangular node-like distal parts of the infrabasals (IBB), contact of the radianal (RA) with the infrabasal (IBB) circlet, convexity of the plates and impression of the sutures, as well as general size and shape of the cup.

An upper Pennsylvanian (Virgil) crinoid, described by Weller[53] as *Hydreionocrinus kansasensis,* which Weller notes is especially like *Neozeacrinus uddeni,* is also referable to *Neozeacrinus* and serves to strengthen the conclusion as to generic placement of *N. uddeni.* The arms of the Kansas species are sufficiently preserved to show that the structure is the same as in *N. peramplus.* although the character of the pinnules is not known. *N. kansasensis* has an anal sac that expands laterally at the top, like a mushroom, and it carries a bordering row of spine-bearing plates. In the type specimen of *N. peramplus* a strong anal sac of tubular form rises slightly above the highest part of the remaining arms, but the top

[53]Weller, Stuart. Description of a new species of *Hydreionocrinus* from the Coal Measures of Kansas: New York Acad. Sci. Trans., vol. 16, p. 372, 1898.

is broken away. Accordingly, it is not known whether the sac possessed a terminal expansion bordered by spines. If *N. kansasensis* is rightly placed in *Neozeacrinus,* as indicated by the nature of the arms and dorsal cup, the conclusion is that the sac in this genus is mushroom-like and is bordered by a ring of spine-bearing plates. Therefore, the spine-bearing plates associated with the cup of *N. uddeni* do not oppose placement of this species in *Neozeacrinus.*

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, near Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13363; collected by J. A. Udden.

NEOZEACRINUS PRAECURSOR Moore and Plummer, n.sp.

Pl. 5, figs. 5, 8; pl. 6, fig. 7; pl. 20, fig. 5; pl. 21, fig. 7; text fig. 29

Description.—The crown is elongate and ovoid, with a height nearly twice the greatest width. The dorsal cup is moderately low and truncate bowl-shaped, and the base formed mostly by the infrabasal (IBB) circlet is flat, except for the concavity of the stem impression. The sides of the cup flare upward rather evenly and gently. The surface is smooth. As is characteristic of the genus, all the sutures are distinctly impressed. The portions of the infrabasals (IBB) that appear outside of the stem impression are essentially triangular in outline, although a very short lateral contact between some of these areas makes them actually pentagonal. Their convexity emphasizes a peculiarity of appearance that is duplicated in *N. peramplus* Wanner, *N. uddeni* (Weller), and *N. kansasensis* (Weller). The basals (BB) are subequal in size, and the posterior basal (pB) is differentiated chiefly by its truncated tip at the contact with anal x. The proximal margins of the basals (BB) are horizontal, but throughout most of their length they flare outward and upward gently, being visible in side view of the cup. The holotype specimen shows the plates of this circlet laterally in contact all around, and this is also clearly shown by paratypes H–9, H–22, and H–25, but in paratype H–13 the posterior basal (pB) and the right posterior basal (rpB) barely meet at two of their angles, a feature that also appears to be a tendency in the genus. Characters of the infrabasal circlet are not clearly shown in the other paratypes. The width of the radials (RR) is about twice their length. The two posterior radials (RR) are inappreciably smaller than the others. The posterior interradius is relatively broad and not concave, being evenly confluent with the rounded contour of the cup. Three anal plates, all large, reach below the summit of the radials (RR). The radianal (RA) is a pentagonal plate, longer than wide. In paratype H–13 it is broadly in contact with the posterior basal (pB) and the right posterior basal (rpB), the angle between them touching the right posterior infrabasal (rpIB), but in the holotype specimen and in paratypes H–9, H–22,

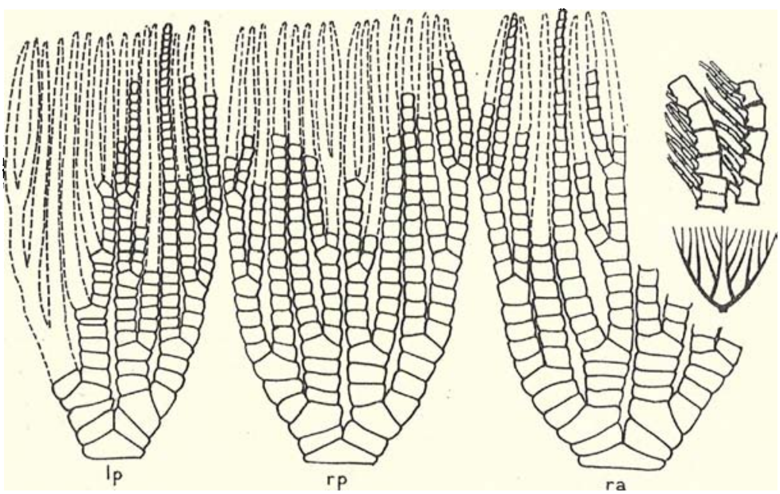

Fig. 29. Diagrams showing the arm structure in the holotype of *Neozeacrinus praecursor* Moore and Plummer, n.sp., branches of the left posterior (lp), right posterior (rp). and right anterior (ra) rays being indicated. At the upper right is a sketch of portions of two branches and pinnules attached to one side of each; the dotted line on the brachial segment marks a faint groove that may denote syzygal suture. At the middle right is a diagrammatic representation of the bi-endotomous type of branching that appears in each ray of this species.

as well as in others that are less well shown, the radianal (RA) is separated from the infrabasal circlet by a space of 2 to 4 mm. Anal x is a large hexagonal plate directly above the posterior basal (pB), and the right tube plate (rt) is located to the right of it above the radianal (RA). Another anal plate that is in contact laterally with the arms, occurs above these.

The arms are composed of quadrangular, uniserially arranged segments that are proportionately a little longer than in the genotype species. Each ray is divided isotomously on the first primibrach (IBr_1), the second secundibrach ($IIBr_2$), the second to the sixth tertibrachs ($IIIBr_{2-6}$), and thereafter at still higher points in the two outer branches of each half ray. The character of the branching, as shown diagrammatically in figure 29, may be designated as bi-endotomous, which means that each ray contains two arm groups that respectively give off unbranched series of segments on their inner sides, whereas the outer branches repeatedly bifurcate. The arms are rounded transversely, but slender branches in the higher part of the crown are somewhat compressed laterally and bear a distinct longitudinal keel on the mid-line. This keel form of the brachials extends on immature specimens downward to about the middle of the crown, and the proximal edge of each brachial plate is set inward so that the distal edges produce shelf-like rims. These features do not appear on lower parts of the arms or on a very large specimen, such as the holotype. Slender pinnules are clearly visible at some points on all the arm plates of the type, and each of the specimens reveals hyperpinnulation, that is, brachial segments with two pinnules on a side. In some specimens brachials with two pinnules on a side alternate with brachials bearing one pinnule, but in others each of several succeeding brachials bears two pinnules on a side. The stem is round. The anal sac is unknown.

Measurements of the holotype and of two paratypes (partly approximate, due to distortion) are given in millimeters, as follows:

	Holotype	Paratype H-13	Paratype M-21
Height of dorsal cup	10.0	7.5	6.0
Greatest width of cup	38.0	33.0	21.0
Height of crown	95.0	63.0	55.0
Width of crown	70.0	47.0	35.0
Diameter of stem	6.0	7.0	------

Discussion.—Definition of this new species is based on the study of five nearly complete crowns and two less complete specimens. In addition there are two crowns that are much smaller than average size, which do not show diagnostic features clearly enough to be included with the types but are assigned to this species with small doubt.

Neozeacrinus praecursor, n.sp., is the oldest known representative of the genus and is interesting because of some of the primitive features that it shows. Aside from characters of the dorsal cup and the general structure of the arms, all of which indicate that this species belongs to *Neozeacrinus,* a special interest attaches to the occurrence of hyperpinnulation—a larger than normal number of pinnules to each brachial—along parts of the arms of this species. This character of *Neozeacrinus* was deemed especially important by Wanner[54] in his differentiation of the genus. In *N. peramplus* Wanner from the Permian of Timor, each brachial bears four pinnules, two on a side. Some of the brachials of *N. praecursor* also bear four pinnules, whereas others have only two. A few of the former group, those with four pinnules, show a very faint horizontal groove around the middle of the plate that seems to be the vestige of a former division between two separate brachials. Brachials bearing four pinnules are only a trifle larger than adjacent ones with two pinnules.

The features of pinnulation just discussed, the relative length of the brachials, and the length and slender form of the arms indicate a distinctly earlier evolutionary stage than that of *N. peramplus* from the Permian beds. Possibly an earlier and more primitive representative of this stock will be found, and, if so, it will probably show characters indicating origin not in *Zeacrinites* (sensu stricto) which has a highly specialized dorsal cup, but in an ancestor more like *Cercidocrinus* Kirk or a pachylocrinid type.

N. praecursor is most closely similar to *N. kansasensis* (Weller), with which it agrees almost exactly in size and shape of cup and appearance of the crown. Differences appear in the form and interrelations of some of the plates of the cup, for in *N. kansasensis* the radials (RR) are nearly in contact with the infrabasals (IBB), and the radianal (RA) broadly touches one of these plates. The arrangement of plates in the cup of *N. uddeni* (Weller) is almost exactly that of this species, but the latter is a smaller form with less convex plates and less strongly impressed sutures.

Occurrence.—Brannon Bridge limestone member, Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, road corner about 3 miles southwest of Brock, Parker County, Texas.

Types.—Holotype, Harris Collection no. H–25; paratypes, nos. H–9, H–13, H–22, and H–25; collected by Mrs. G. W. Harris, Waco,

[54]Wanner, J., Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor: Palaeontographica, Suppl., Bd. 4 Abt. 1 Lief. 2, p. 144, 1937.

Texas. Paratypes, Marrs Collection nos. M–18, M–21, and M–24; collected by Mrs. W. R. Marrs, Austin, Texas. Two additional specimens, M–3 and M–8, collected by Mrs. Marrs, are referred to this species.

Genus ATHLOCRINUS Moore and Plummer, n.gen.

Study of the large assemblage of low truncate bowl-shaped dorsal cups with three anal plates, the number of this group now at hand amounting to more than 600 specimens, calls attention to a type of cup that cannot be referred satisfactorily to any genus yet described. Accordingly, these are set apart under the new generic name *Athlocrinus*.[55]

The dorsal cup is extremely shallow bowl-shaped, discoid, with base almost perfectly flat, except for indentation of the round stem impression. The sides of the cup flare gently upward to a subvertical position at the summit plane. The posterior interradius is typically rather broad, giving the cup a subhexagonal outline in ventral or dorsal view. The sutures are not at all impressed, and the contour of the surface of the cup is entirely smooth. The five infrabasals (IBB) form a regular pentagon that is covered largely by the somewhat deeply indented stem impression. The distal parts of the infrabasals (IBB) are horizontal, and not visible in side view of the cup. The five basals (BB) are subequal. The proximal parts are horizontal. The distal parts upflare and are visible in the side view of the cup. The five radials (RR) have proximal tips extending to the basal plane. The facets are slightly less than the maximum width of the radials (RR). A very shallow notch is visible at the interradial sutures at the summit plane. The slope of the facets is gently outward. There are three anal plates in the dorsal cup. The radianal (RA) touches the right posterior basal (rpB) or is not in contact with it. The anal x is typically resting on the distal tip of the posterior basal (pB). At least one species, as yet undescribed, has only two anal plates in the dorsal cup, a small radianal (RA) separating anal x from the posterior basal (pB).

Genotype.—Athlocrinus placidus Moore and Plummer, n.sp.

Discussion.—The very low discoid form of the dorsal cup, the flatness of its base, and the smooth contour of its surface are the

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[55]From the Greek, meaning gift.

chief distinguishing features of *Athlocrinus.* It resembles somewhat *Laudonocrinus,* but the cup is very much lower and flatter. Some species classed as belonging to *Sciadiocrinus* have a nearly flat basal area that is formed by the infrabasals (IBB), the basals (BB), and the proximal parts of the radials (RR), but this is bordered by down-flaring slopes of the median strongly bulbous radials (RR),

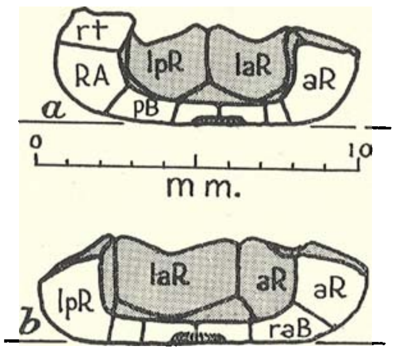

Fig. 30. Median cross-sections of the dorsal cup of the holotype of *Athlocrinus placidus* Moore and Plummer, n.sp., showing the very low truncate bowl-shaped form of the cup and the absence of a basal concavity. *a,* Median section through the anterior radial (aR) and posterior interradius, showing the left half of the cup, the shaded areas representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

so that the base of the cup as a whole is broadly concave, and only the radials (RR) are visible in side view of the cup. This is very unlike *Athlocrinus.*

Occurrence.—Des Moines and Missouri series, Pennsylvanian (Upper Carboniferous); Texas, Oklahoma, and Kansas.

ATHLOCRINUS PLACIDUS Moore and Plummer, n.sp.

Pl. 6, fig. 1; text fig. 30

Description.—The dorsal cup has characters as described in the definition of the genus. The surface of the cup appears smooth, but microscopic examination shows that there is actually an extremely fine ornamentation of closely spaced granules. The outer ligament area of the facet shows a fairly strong median ridge. The inner ligament area has clearly defined ligament fossae which extends obliquely from the outer angles of the facets to a central point between a triangular depression next to the transverse ridge and the base of the intermuscular notch. The muscle areas are triangular and slope gently inward.

The measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	2.8
Greatest width of cup	11.0
Ratio of height to width	0.25
Height of basal concavity (stem impression)	0.6
Diameter of stem impression	1.7

Discussion.—A slightly greater elongation antero-posteriorly, the slightly smoother contour of the cup, and the presence of extremely fine ornamentation distinguish this species from *A. nitidus*, n.sp.

Occurrence.—Base of the Plattsburg limestone, Lansing group, Missouri series, Pennsylvanian (Upper Carboniferous); Loc. 5999, on State Highway 47, 2.4 miles west of Altoona, Kansas.

Type.—Holotype, Kansas University no. 59991; collected by R. C. Moore.

ATHLOCRINUS NITIDUS Moore and Plummer, n.sp.

Pl. 6, fig. 3

Description.—The dorsal cup is rounded hexagonal in outline, very low truncated and bowl-shaped. The base of the cup is flat except for a very faint depression that involves the infrabasals (IBB) and proximal portions of the basals (BB). The stem impression is a gently rounded concavity that is distinctly shallower, as represented by the type, than in *A. placidus*, n.sp. The articular facets are slightly but distinctly narrower than the greatest width of the radials (RR). Shallow notches occur at the summit plane between the radials (RR). The posterior interradius is relatively broad, nearly as wide as one of the posterior radials (RR) and very gently concave transversely. Three anal plates are present in the dorsal cup. The radianal (RA) is in contact with the right posterior basal (rpB), and anal x rests on the squarely truncated tip of the posterior basal (pB). The right tube plate (rt) lies above the radianal (RA) and has nearly half of its height below the summit of the radials (RR).

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	2.8
Greatest width of cup	10.2
Ratio of height to width	0.27
Height of basal concavity (stem impression)	0.4
Diameter of stem impression	2.0

Discussion.—A comparison of this species with *A. placidus*, n.sp., is given under description of that form. *A. nitidus*, n.sp., is distinguished from *A. clypeiformis*, n.sp., by its slightly smaller size, a difference in the attitude of the basals (BB), and by the smoother contour between the basals (BB) and the radials (RR).

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 153–T–23, 2.5 miles north, 2.5 miles east of Rochelle, McCulloch County, Texas.

Type.—Holotype, King Collection no. K–504, Bureau of Economic Geology, The University of Texas; collected by Ralph King.

ATHLOCRINUS CLYPEIFORMIS Moore and Plummer, n.sp.

Pl. 6, fig. 2; text fig. 31

Description.—The dorsal cup has the general form and proportions of the other species described. The infrabasal (IBB) circlet forms a pentagon that is relatively a little larger than in *A. placidus*, n.sp., but it is covered almost entirely by the large, very shallow stem impression. The rim of the stem impression is slightly raised and the distal extremities of the infrabasals (IBB) are gently upflaring. The proximal parts of the basals (BB) are flat. The distal parts gently upflare and are clearly visible in side view of the cup. The radials (RR) are moderately convex, both longitudinally and transversely. A well-marked depression occurs along each of the interradial sutures. The facets are slightly but distinctly less than the maximum width of the radials (RR). A faint notch is present at the summit plane between the radials (RR). The facets, which are very well preserved in the type, show slight but possibly significant differences as compared with the other described species. The ligament pit in the outer ligament area is unusually wide and a little more than one-third as long as the transverse ridge. A barely perceptible median ridge bounds the pit externally but disappears laterally before joining the transverse ridge. The outer extremities of the ligament fossae in the inner ligament area are expanded and extend outward slightly beyond the line of the transverse ridge. The intermuscular notch is shallow but very well defined. The plates of the posterior interradius are gently concave outward. There are three anal plates, including a relatively small radianal (RA) that is not in contact with the right posterior basal (rpB), a rather large anal x that rests on the posterior basal (pB), and a large right tube plate (rt) that is in line above the radianal (RA).

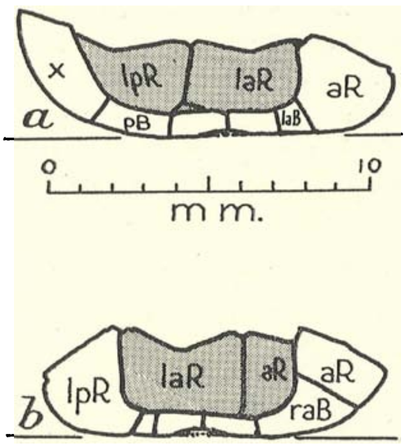

Fig. 31. Median cross-sections of the dorsal cup of the holotype of *Athlocrinus clypeiformis* Moore and Plummer, n.sp., showing the broad low form of the cup and the flat base without concavity, except for a slightly hollowed stem impression. *a,* Median section through the anterior radial (aR) and posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	3.1
Greatest width of cup	11.8
Ratio of height to width	0.26
Height of basal concavity (stem impression)	0.2
Diameter of stem impression	2.7

Discussion.—This species is distinguished chiefly by the slightly bulbous appearance of the radials (RR) and by the large stem impression, with slightly raised rim. In general appearance it is a little closer to *A. nitidus,* n.sp., than to *A. placidus,* n.sp.

Occurrence.—Merriman limestone member, Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–31, just west of highway, 2¾ miles in direct line northwest of Graford, Palo Pinto County, Texas.

Type.—Holotype, Kansas University no. 1095; collected by R. C. Moore.

Genus **LAUDONOCRINUS**[75a] Moore and Plummer, n.gen.

Definition of this new genus is based chiefly on characters of the dorsal cup. Our specimen shows the presence of spine-bearing primibrachs (IBr) and a few secundibrachs (IIBr) are preserved, but the structure of the higher parts of the crown is not known.

The dorsal cup is moderately low, bowl-shaped, and characterized essentially by the smooth contour of the surface. The base is flat or, at most, marked by a small, almost imperceptible concavity. The summit of the interradial sutures generally lacks a well-defined notch but has this feature well developed in some species. There are five infrabasals (IBB) which form a small regular pentagon, subhorizontal in position and mostly covered by the round stem impression. The five basals (BB) are subequal. The posterior basal (pB) is very slightly longer, and the right posterior basal (rpB) is wider than the others; except for a small proximal portion in some forms, most of the basals (BB) flare upward and in all forms are clearly visible from the side. The five radials (RR) are pentagonal and have a width generally about twice their length. The facets slope outward at a moderate angle. The transverse ridge and ligament areas are clearly defined. The first inspection of the genotype species and also of various others that are regarded as typically representing this group gives the impression that the width of the radial facets is equal to the greatest width of the radials (RR). An interradial notch at the summit plane is hardly perceptible. Such specimens, however, all show a definite adsutural slope at the margins of each facet and the areas, thus defined, correspond exactly to the gap between facets in forms where the width of the suture is very distinctly less than that of the radials (RR). Some example of dorsal cups show all other generic features of *Laudonocrinus* and show also the interradial notch at the

[75a]Named in recognition of work done by L. R. Laudon of the University of Tulsa, Tulsa, Oklahoma.

summit plane very strongly marked. The width of the facets is definitely less than that of the radials (RR). The posterior interradius is moderately broad and shows increasingly strong concavity upward from the base. The upward slope of this interradius is typically more gentle than that of the anterior radius. The arrangement of the three anal plates within the cup is the normal

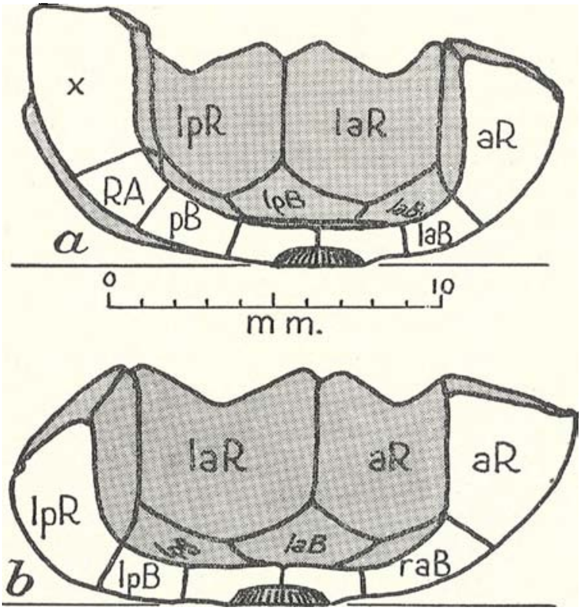

Fig. 32. Median cross-sections of the dorsal cup of the holotype of *Laudonocrinus subsinuatus* (Miller and Gurley), the genotype species, showing the smooth contour of the cup and the absence of a basal concavity, excepting that of the stem impression. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and opposite interradius, bisecting the right anterior basal and showing the right sutural face of the anterior radial (aR).

unspecialized plan with a relatively elongate radianal (RA) in contact with the right posterior basal (rpB), followed above by anal x, which rests on the truncated tip of the posterior basal (pB), and the right tube plate (rt), which occurs above the radianal (RA) and at the right of anal x. None of the sutures is impressed.

The paratype of the genotype species has axillary primibrachs (IBr) which are produced laterally in a strong spine. The succeeding two arms of each ray are composed of broad, relatively low segments of quadrangular pattern and uniserial arrangement. The arms are not preserved above the third axillary secundibrach, however. Presumably a similar type of arm characterizes other species assigned to the genus. The walls of the lower part of the anal sac are composed of four or five vertical rows of small stellate plates with pores at the sutural margins. The diameter of this sac is slightly less than the width of one of the radials. The upper part of the sac is unknown.

Genotype.—*Hydreionocrinus subsinuatus* Miller and Gurley (Pl. 6, fig. 6; text fig. 32), from an undetermined stratigraphic position in Missouri series at Kansas City, Missouri.

Discussion.—Most specimens of *Laudonocrinus* can be distinguished without difficulty by means of characters of the dorsal cup as described. The absence of a well-marked central concavity distinguishes this genus from *Perimestocrinus, Sciadiocrinus, Pirasocrinus, Zeacrinites, Aatocrinus,* and several others. *Plaxocrinus* and *Athlocrinus* resemble some species of *Laudonocrinus* more closely. In these forms the configuration of the cup, including especially the profiles of the basals (BB) and the radials (RR) and the degree of impression of the sutures, is generally a reliable guide to separation. *Athlocrinus* has a much lower and flatter cup.

Occurrence.—The species of *Laudonocrinus* are at present known only from Middle Pennsylvanian (upper Des Moines and Missouri series) from the Mid-Continent region.

LAUDONOCRINUS CUCULLUS Moore and Plummer, n.sp.

Pl. 6, fig. 4

Description.—The dorsal cup is a smoothly rounded shallow bowl, very similar in form and proportions to the genotype species, *L. subsinuatus* (Miller and Gurley). It has a shallow and narrow basal concavity that involves only the infrabasal circlet. It is entirely possible that this concavity is due altogether to distortion, for the infrabasals (IBB) have been slightly crushed and pushed inward. The stem impression is gently concave. Two of the axillary primibrachs (IBr), which are preserved in position above the radials of the holotype, bear a laterally directed spine located very high on the segment, just below the articulation for the secundibrachs (IIBr). The lower faces of these plates are smooth except for a granulation and are not distended. The basals (BB) are nearly horizontal throughout most of their length but flare upward distally and are clearly visible in the side view of the cup. The radials (RR) curve smoothly upward from their union with the basals (BB) and are not strongly convex. The facets slope outward at an angle of about 30 degrees and are practically as wide as the radials (RR). No notches occur at the summit of the interradial sutures. The posterior interradius is narrow, strongly bent inward and has a well-marked concavity shown in the dorsal view of the cup. The anal plates are normal. The radianal (RA) touches the right posterior basal (rpB) and anal x rests on the posterior basal (pB), and the right tube plate (rt) lies above the radianal (RA).

The contour of the surface is smooth. The sutures are distinct but not at all impressed. The surface is ornamented by closely spaced fine granules that are well preserved in the holotype.

Measurements of the holotype, in millimeters, are as follows:

Height of cup	3.7
Maximum width of cup	15.0
Ratio of height to width	0.25
Height from basal plane to inner margin of articular facets	5.3
Diameter of stem impression	2.8

Discussion.—This species is most closely similar to *L. subsinuatus* (Miller and Gurley), among described forms, but it is a much smaller form. The dorsal cup of *L. cucullus* is slightly deeper, more rounded, and distinctly more bowl-shaped than that of *Plaxocrinus aplatus*, n.sp., with which it is associated, and the basal concavity in the latter slightly but definitely includes the proximal parts of the basals (BB) as well as the infrabasal (IBB) circlet. *Laudonocrinus catillus*, n.sp., from the Millsap Lake formation, has a very faint basal concavity, and its cup is narrower and deeper than that of *L. cucullus;* also the facets of *L. catillus* are very noticeably less than the width of the radials (RR).

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, Kansas University no. 60442; collected by R. C. Moore.

LAUDONOCRINUS CATILLUS Moore and Plummer, n.sp.

Pl. 6, fig. 5; text fig. 33

Description.—This new species shows the shallow bowl-like form and smooth contour with unimpressed sutures that chiefly characterize this genus. The base is a little flattened, almost imperceptibly concave. The stem impression, which occupies almost all of the infrabasal (IBB) circlet, is rather strongly concave. Inspection of the outline of the cup in ventral or dorsal view calls attention to the gentle concavity at the posterior interradius and to the very marked shallow notches that mark each of the interradii. The articular facets are rather markedly less than the maximum width of the radials (RR). In this character, *L. catillus* departs somewhat from the norm for the genus. Because of the excellent preservation of the dorsal cup, it is possible to trace the inward extension of the outer face of the cup between the articular facets to a point well beyond the transverse ridges, but the surface does not include all the broad-bottomed groove that reaches to the margin of the body cavity. This inner portion of the inter-articular groove is neither a part of the adjoining facets nor, strictly speaking, does it appear to be classifiable as part of the external surface of the cup. Probably it was covered by very small interradial plates such as have been observed in a number of poteriocrinitid genera.

The structure of the posterior interradius is that normal for the genus, with the radianal (RA) adjoining a small portion of the right posterior basal (rpB), and the anal x resting on the extremity of the posterior basal (pB). The surface of the plates is entirely smooth. The foregoing description is based on the holotype specimen from Palo Pinto County, Texas, but it applies without change to specimens collected from the vicinity of Tulsa, Oklahoma, and the latter are designated as paratypes.

Measurements of the holotype and of three paratype specimens, in millimeters, are given below:

	Holotype P–10610	45893	Paratypes 45893a	45893b
Height of dorsal cup	3.7	3.0	3.3	2,7
Greatest width of cup	14.0	14.4	13.8	10.1
Ratio of height to width	0.26	0.21	0.24	0.27
Height of stem impression	0.8	1.4	1.1	0.5
Diameter of stem impression	2.7	2.3	2.3	1.8
Width of anterior radial	9.0	7.9	7.9	5.1
Width of anterior radial facet	6.0	6.3	6.2	4.2

Discussion.—This species is distinguished chiefly by the shape and proportions of the cup, the almost imperceptible basal depression, and especially by the relative narrowness of the radial

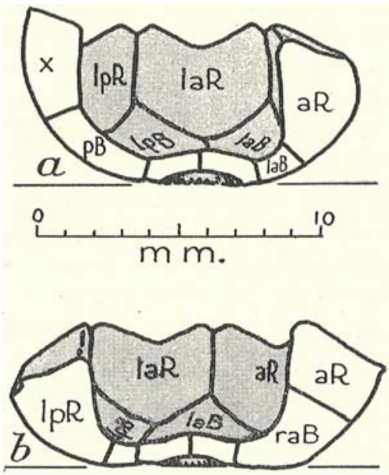

Fig. 33. Median cross-sections of the dorsal cup of the holotype of *Laudonocrinus catillus* Moore and Plummer, n.sp., showing the slightly truncate bowl-shaped form of the cup with the concave stem impression. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

facets that is accompanied by angulation at the interradial sutures. No other known species of the genus has such narrow facets. A well-marked indentation occurs at the summit of the interradial sutures in *L. arrectus*, n.sp., but the form of the cup is distinctly unlike that of *L. catillus.*

Occurrence.—The holotype specimen was collected from the Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–93, Potato Knob, on tap road to Gold ranch, east of old Santo-Patillo road, Palo Pinto County, Texas. The paratypes are from the upper part of the Oologah limestone, about 300 feet below top of the Des Moines series; Loc. 4589, at Garnett quarry, about 7 miles northeast of Tulsa, Oklahoma.

Types.—Holotype, Plummer Collection no. P–10640, The University of Texas; collected by G. D. Harris. Paratypes, Stevens Collection, University of Kansas, nos. 45893, 45893a-g (8 specimens); collected by Bob Stevens.

LAUDONOCRINUS ARRECTUS Moore and Plummer, n.sp.

Pl. 5, fig. 7

Description.—Designation of this new species is made with some hesitation because of the fragmentary character of the specimens on which it is based. It seems reasonably certain, however, that they are referable to no described species. One is evidently a mature specimen with height of cup 4 mm. and greatest width (at summit plane) about 15 mm. (estimated); except for the infrabasal (IBB) circlet, all of which is preserved, the specimen shows only the right half of the dorsal cup, but includes enough of the posterior area to show the arrangement of the anal plate series. The other specimen is a much smaller, apparently juvenile individual that shows about three-fifths of the anterior part of the cup.

The dorsal cup is low bowl-shaped and has the typical form for the genus except for somewhat straighter, more regularly flaring sides The infrabasal circlet is very slightly concave. The basals (BB) flare upward throughout their length and are not involved in the shallow basal depression. The slope of the radials (RR) is smoothly confluent with that of the lower plates. The radial facets slope moderately outward and are distinctly narrower than the maximum width of the radials (RR). Notches that are only slightly less prominent than in *L. catillus* occur at the summit of the interradial sutures. The structure of the posterior interradius is normal, with the radianal (RA) in contact with the right posterior basal (rpB) and probably with anal x on the posterior basal (pB).

A single axillary primibrach (IBr) is attached to the large specimen. It is subquadrate in outline, and from the lower articular face the surface curves up to a low rounded spine that is centrally located near the upper margin. One or two stellate anal tube plates, like those observed in *L. subsinuatus* (Miller and Gurley), are lodged in the interior of the cup.

The surface is covered by a fine evenly spaced granulose ornamentation.

Discussion.—Although this species suggests *L. catillus*, n.sp., in the character of the facets, the form of the cup is entirely different, as is also the surface ornamentation. *L. arrectus* most closely resembles *L. cucullus*, n.sp., in size and surface ornamentation, but it differs from that species in the straighter sides of the cup and wider articular facets. Comparison of the primibrachs (IBr), which are preserved in both species, shows readily determinable differences. The spine-bearing plates of *L. cucullus* are distinctly larger, and the outward-facing surface less concave.

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2; east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Types.—The holotype and paratype (small specimen), Kansas University no. 60444; collected by R. C. Moore.

Genus LASANOCRINUS[56] Moore and Plummer, n.gen.

The dorsal cup is very low, almost discoidal. The outline is distinctly pentagonal in dorsal or ventral view, but, unlike most crinoids, with the angles of the pentagon in the mid-portion of the radial plates instead of at the position of the interradial sutures. The greatest width of the cup is below the mid-height or at the basal plane. The outline of the cup in side view is subrectangular to trapezoidal, depending on the orientation. The sutures are distinct but not impressed, and the surfaces of adjoining plates are smoothly confluent. The five infrabasals (IBB) form a regular pentagon of a diameter about twice that of the stem impression. The distal portion of the infrabasals (IBB) is subhorizontal to distinctly down-flaring. The base of the cup is broadly and shallowly concave or marked by a central moderately deep concavity that involves the infrabasal (IBB) circlet and the proximal half of the basals (BB).

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[56]From the Greek, meaning trivet or small tool.

The five basals (BB) are subequal, and the length is generally greater than the width, giving a distinctly stellate outline to the basal circlet. In longitudinal profile the proximal part of the basal plates is down-flaring, the mid-portion subhorizontal, and the distal part gently up-flaring. The posterior basal (pB) is slightly longer than the others and truncated distally for contact with anal x. The five radials (RR) are of distinctive form due to the strongly bulbous or spinose projection of the mid-portion of the plates in a lateral, or downward and lateral direction. The distal portion of the plates slopes strongly inward as well as upward. The radial facets are subhorizontal or slope outward at a barely perceptible angle. The width of the facets is distinctly, or only slightly, less than the maximum width of the radials (RR). The transverse ridge and ligament areas are well defined on the facets. There are three anal plates. The radianal (RA) is elongate, and the narrow lower end is typically in contact with the right posterior basal (rpB). Anal x rests on the truncated distal extremity of the posterior basal (pB) and is situated obliquely above the radianal (RA). The right tube plate (rt) is relatively large and in normal contact with anal x and the radianal (RA). The posterior interradius is naturally somewhat wider than the others but is not depressed and is rather slightly convex.

The arms, ventral sac, and stem are unknown. The stem impession, however, shows that the stem is round.

Genotype.—*Hydreionocrinus daileyi* Strimple. Morrow beds (probably Wapanucka limestone), 6 miles southeast of Fittstown, Oklahoma.

Discussion.—*Lasanocrinus* may be distinguished from other genera of low, discoidal form by the distinctive shape of the cup and the nearly horizontal attitude of the radial facets. At first glance this form might easily be confused with *Utharocrinus* which has spines projecting from the lower part of the cup and subhorizontal radial facets. The spines of *Utharocrinus*, however, are borne by the basal plates. The centrally produced radial plates of *Lasanocrinus* might be regarded a feature having no more than specific value, were it not for association with facets which are distinctly unlike those of any genus with which it might otherwise reasonably be compared. At present there is no good basis for suggestion concerning the Lower Carboniferous stock that gave rise to *Lasanocrinus.*

Occurrence.—Morrow series, Lower Pennsylvanian (Upper Carboniferous); Oklahoma and Texas.

LASANOCRINUS DAILEYI (Strimple)

Pl. 7, figs. 5, 6; text fig. 34

Hydreionocrinus daileyi STRIMPLE, 1940, Bull. Amer. Pal., vol. 25, no. 91, p. 93, pl. 1, figs. 4–6, 1940.

Description.—The general features of this species are those described for the genus. The characters that are regarded as having specific value are the basal concavity, which is deeper and narrower than in the one other observed species; the relatively long, narrow, and longitudinally curved basals (BB); and the lateral, rather than downward, projection of the spinous processes on the radials (RR). The basal plane of the cup touches the mid-length of the basals (BB) and the distal tips of the radials (RR). The spines are slightly but distinctly above this plane. The anterior radial (aR) of specimen K.U. 451925 shows a pair of nodes, or double termination of the produced central portion of the plate, but this is evidently only a slight individual variation. The radial projections are most pronounced on one of the other specimens (Pl. 7, fig. 6). Sutures are very distinct but not at all impressed. The surface of K.U. 451925, which is a little better preserved than that of the two other specimens, shows a faint, very fine granulose ornamentation.

The measurements of three specimens, in millimeters, are as follows:

	K.U. 451925	K.U. 451925A	K.U. 59911
Height of cup	3.1	3.4	3.2
Width of cup, maximum	10.5	12.5	11.4
Ratio of height to width	0.30	0.27	0.28
Height of basal concavity	1.2	1.6	1.1
Diameter of stem impression	1	1.4	----

Occurrence.—Brentwood limestone, Morrow series, Pennsylvanian (Upper Carboniferous); Loc. 4519, Keough quarry, sec. 36, T. 16 N., R. 19 E., about 1½ miles north of Fort Gibson, Oklahoma; C. L. Foster collector; also Loc. 5991, on north-south road, north of center of sec. 22, T. 16 N., R. 20 E., south of Hulbert, Oklahoma;

collected by R. C. Moore. Original types came from the Morrow series near Fittstown, Oklahoma.

Types.—Hypotypes, Kansas University nos. 451925, 451925A, and 59911.

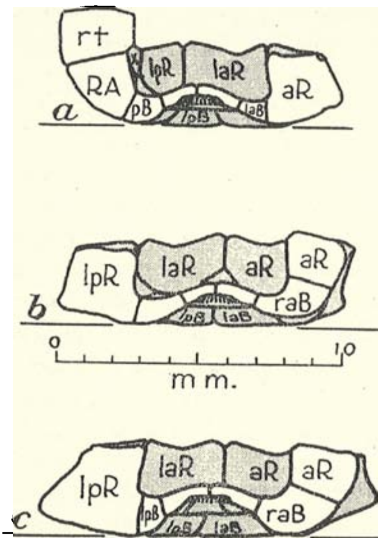

Fig. 34. Median cross-sections of the dorsal cup of *Lasanocrinus daileyi* (Strimple), the genotype species, hypotype K.U. 451925, showing the form of the basal concavity and the produced character of the radials. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

LASANOCRINUS CORNUTUS Moore and Plummer, n.sp.

Pl. 7, fig. 4; text fig. 35

Description.—The dorsal cup is very low, relatively broad, and the base is gently and rather evenly concave. The infrabasal (IBB) circlet is regularly pentagonal, not depressed to form a distinct central concavity as in *L. daileyi* (Strimple), but lies in nearly the same plane as the basals (BB), which are mostly flat and subhorizontal. The posterior basal (pB) slopes very gently upward and is clearly visible in posterior view of the cup, whereas only the distal extremities of other basals (BB) can be seen in side view.

The length of basals (BB) is approximately equal to their width, and accordingly they are relatively shorter than in *L. daileyi.* The radials (RR) are strongly protuberant at about mid-length, giving rise to spinelike bulges that are directed downward and laterally. If the cup is placed on a plane surface, it rests on the point of these spinous outgrowths of the radials (RR), and the general plane of the basal (BB) and infrabasal (IBB) circlets is 2 or 3 mm. above the plane on which the spines rest. The outer face of the radials (RR) from the tips of the spines to the margins of the articular facets slope not only upward but strongly inward, and in the holotype this surface is somewhat concave. The slopes from the spine tips to the lateral extremities at the summit of the radials (RR) is nearly straight, but the interradial sutures are depressed so as to form broad grooves that slope downward and inward. The radial facets are slightly but distinctly less than the greatest width of the radials (RR). They show distinct straight transverse ridges, a narrow clearly defined outer ligament area containing the centrally located slit-like ligament pit, and a relatively broad inner ligament area that is divided by a fairly deep broad intermuscular notch. The surface of the facets is nearly horizontal, although the margins of the interradial sutures are slightly raised to produce a gentle outward slope. The arrangement of the anal plates is normal for the genus, but the posterior projection of this area is slightly greater than in the genotype species; in ventral view it is slightly concave in cross-profile. The holotype preserves two tube plates above the anal plate (x) and the right tube plate (rt). The surface, which is very well preserved in part of the paratype, is perfectly smooth and unornamented.

The measurements of two specimens, in millimeters, are as follows:

	Holotype	Paratype
Height of cup	4.5	3.5
Greatest width of cup	15.2	12.0
Ratio of height to width	0.30	0.29
Height of basal concavity	1.5	1.4
Diameter of stem impression	1.1	1.0

Discussion.—Description of this species is based on one complete specimen of the dorsal cup (holotype), and another slightly smaller specimen that is nearly complete (paratype). Another specimen showing the distinctive character of the radial plates but lacking the basals (BB) and infrabasal (IBB) circlet is identified as belonging to this species. This fragmentary specimen comes from the Brentwood limestone (Morrow series) from the vicinity of Fort Gibson in northeastern Oklahoma.

L. cornutus is readily distinguished from *L. daileyi* (Strimple), by the more strongly downward direction of the bulging outgrowths

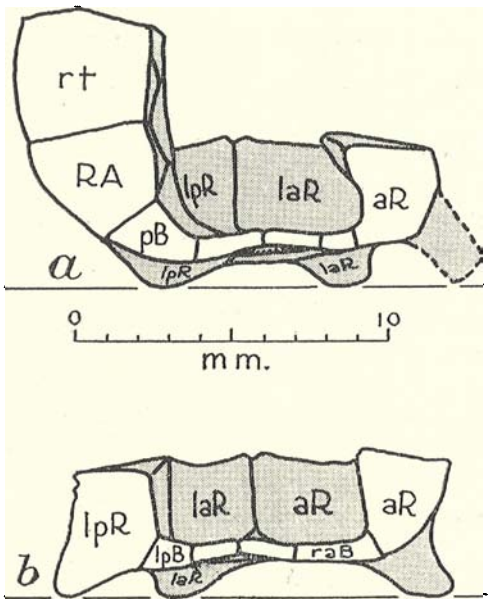

Fig. 35. Median cross-section of the dorsal cup of the holotype of *Lasanocrinus cornutus* Moore and Plummer, n.sp., showing the very strong downward-projecting spines of the radials, the base of the cup not markedly concave, except in relation to the spines. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

of the radials (RR) and the nearly flat, very gentle concavity of the base. Indeed, the concave appearance of the base of *L. cornutus* is due more to the downward projection of the radial spines than to a definite depression of the proximal basal (BB) and the infrabasal (IBB) circlets. Moreover, *L. cornutus* is smooth, whereas the genotype species shows a faint granulose ornamentation.

Occurrence.—Near the middle of the Marble Falls limestone (Morrow series), Pennsylvanian (Upper Carboniferous); Loc. 205–T–17, on Rough Creek, about 11 miles southeast of San Saba, San Saba County, Texas.

Types.—Holotype, Peabody Museum no. 15246, Yale University; paratype, no. 15246A; collected by C. Schuchert, D. K. Greger, and A. McCoy.

Genus PLAXOCRINUS Moore and Plummer, 1938

Plaxocrinus Moore and Plummer, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 277.

The dorsal cup is very low, truncate bowl-shaped, widest at the summit plane, and its base is marked by a broad and very shallow concavity. The five infrabasals (IBB) form a regular pentagonal disc that is subhorizontal and covered largely by the stem impression. The five basals (BB) are subequal, and the proximal parts are slightly downflaring and form part of the basal concavity. The distal parts are upflaring and are visible in side view of the cup. The five radials (RR) are moderately to strongly convex. The facets are typically a little less than the maximum width of the radials (RR) and are inclined gently outward. The three anal plates form strong upward projections at the posterior side of the cup. The interradius at the anal side is generally not strongly depressed.

The character of the arm structure in the genotype species of *Plaxocrinus* is not known, but fragmentary crowns from Texas strata that are identified as belonging to two new species of this genus show isotomously branching arms composed of uniserially arranged, wide, short, quadrangular brachials. The first primibrach is axillary in all rays, so far as indicated, and this plate is commonly produced to form a blunt or sharp spine. At least one bifurcation occurs in each ray above the first one. The most nearly complete crown that is assigned to this genus, a lower Virgil specimen from northern Oklahoma, has either 4 or 6 secundibrachs (IIBr) in each arm above the axillary primibrachs (IBr), and there are about 8 tertibrachs (IIIBr) in each of the four uppermost arms of each ray. One specimen from Texas seems to show a bifurcation of the arms on the first or second secundibrach (IIBr) in some rays, although there are 5 secundibrachs below the axillary secundibrach in at least one of the arms. A circle of spines that are directed horizontally projects from the top of the anal sac above the tips of the arms, as in *Sciadocrinus, Xystocrinus, Pirasocrinus,*

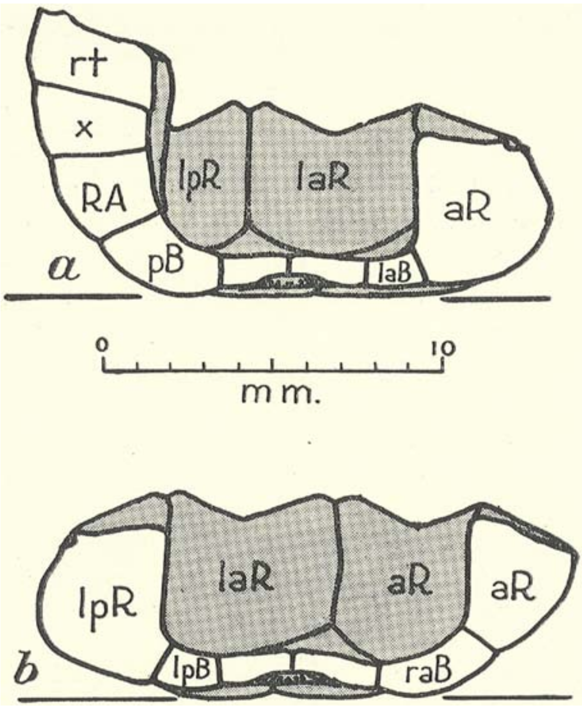

Fig. 36. Median cross-sections of the dorsal cup of the holotype of *Plaxocrinus crassidiscus* (Miller and Gurley), the genotype species, showing the thick radial plates and the shallow form of the basal concavity, with the basal plates distinctly visible in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

Schistocrinus, Hydreionocrinus, and probably in other genera of this group.

The stem is round; relatively long, large nodal segments with longitudinally rounded profile alternate with groups of a small number of thin small internodals.

Genotype.—*Hydreionocrinus crassidiscus* Miller and Gurley (Pl. 8, fig. 1; text fig. 36).

Discussion.—This genus was established to include crinoids that formerly were included in *Hydreionocrinus* de Koninck. As represented by the genotype species (*H. woodianus* de Koninck), *Hydreionocrinus* is distinguished by a type of arm structure that has not been observed in comparable crinoids from North America, and it has a dorsal cup differing from that of *Plaxocrinus* in that the infrabasals (IBB) are visible from the side. Among associated low bowl-shaped cups with three anal plates, *Plaxocrinus* includes somewhat generalized forms, marked more by an absence of special distinguishing features than by well-developed peculiarities. All species show the presence of a wide and shallow basal concavity, never narrow and deep, and in no form does this concavity affect the distal parts of the basals (BB). The arrangement of plates in the posterior interradius is variable—the principal anal plate (x) rests on the posterior basal (pB) or is separated from it by the radianal (RA) with the radianal in contact or not in contact with the right posterior basal (rpB). Some species show a constant arrangement of the anal plate, whereas others appear to be variable.

Plaxocrinus is distinguished from *Perimestocrinus* by the form of the basal concavity, which in the latter genus is narrowly restricted, comparatively deep, and generally has nearly vertical sides. It is separated from *Adinocrinus, Sciadiocrinus,* and *Pirasocrinus* by the greater breadth and depth of the basal concavity in these three genera, which show the basals (BB) flaring downward throughout their length; only the radials (RR) are visible in side view.

Occurrence.—Morrow to Virgil series, Pennsylvanian (Upper Carboniferous); North America.

PLAXOCRINUS OBESUS Moore and Plummer, n.sp.

Pl. 8, figs. 2, 3

Description.—The dorsal cup is low, truncate bowl-shaped, subquadrate in cross-section, and its base has a broad shallow concavity. This species is distinguished chiefly by the strong convexity of the radials (RR) which project downward even beyond the basals (BB), so that the basal plane of the cup is tangent to the lower part of the radials (RR) and slightly beneath the lowest point reached in the curvature of the basals (BB). The distal parts of the basals (BB) are visible in side view of the cup, however. The radial facets are slightly but inappreciably narrower than the greatest width of the radials (RR). The outer ligament area is subvertical, like the outer face of the radials (RR); it is bounded by a fine outer ridge and carries a relatively strong median ridge. The inner ligament area slopes gently outward, its central part is strongly concave, and its ligament fossae, muscle area, and intermuscular furrow are well defined. The plates of the anal series have a normal arrangement, the elongate, narrow radianal (RA) touching the right posterior basal (rpB), and a somewhat elongate principal anal plate (x) rests on the distally truncated tip of the posterior basal (pB). Each of the plates of the anal series is gently convex longitudinally and transversely. Well-preserved specimens show that the surface is perfectly smooth.

Two of the paratype specimens from the Millsap Lake formation show portions of the arms, and one has the proximal 25 mm. of the stem. The first primibrachs (IBr_1) are axillary, pointed, spine-bearing plates that are approximately as large as the subjacent radials. The exact structure of higher portions of the arms is not satisfactorily determinable. In one specimen the lowest secundibrachs appear to be spine-bearing axillary plates, like the primibrachs but naturally much smaller, and these secundibrachs are followed by a series of wide, short tertibrachs (IIIBr) numbering about eight, succeeded by an axillary and two even-sized rows of quartibrachs (IVBr); the arm structure is rather obscure in this specimen, however. The other specimen appears to have about six short quadrangular secundibrachs below the isotomous division of the series. The round columnals are of two sizes, large nodals and thin small internodals; the short crenellae, about twenty-eight on each face, are raised above the bulging mid-portion of the nodals but are even with the edge of the internodals; a quinquelobate lumen, 0.3 mm. in diameter, occupies the center of the segments, which measure 2.8 to 3.0 mm. in diameter in the specimen observed.

Measurements of the holotype specimen, in millimeters, are as follows:

Height of dorsal cup	5.0
Width of dorsal cup	17.0
Ratio of height to width	0.29
Height of basal concavity	1.0
Diameter of stem impression	3.4

Discussion.—This species is not a typical representative of *Plaxocrinus* in that the radials (RR) are abnormally bulbous, their proximal tips being slightly downflaring and thus forming part of the basal concavity. These are characters of *Sciadiocrinus,* but the upflaring distal parts of the basals (BB) and the very shallow form of the basal concavity are distinguishing features of the dorsal cup in *Plaxocrinus. P. obesus* differs from *P. crassidiscus* (Miller and Gurley) in having much more convex radials (RR) and in having the normal, rather than a specialized, arrangement of the plates of the anal series. This new species is similarly distinguished from *P. discus* (Meek and Worthen). *P. strigosus* Moore and Plummer is much smaller than the form here described; it similarly has very convex radials (RR) but their outward extension is greater and downward extension less.

Occurrence.—Shale below Kickapoo Falls limestone member, Millsap Lake formation, Strawn group (Des Moines series); Loc. 110–T–4, below Kickapoo Falls in northern Hood County, near the Hood-Parker County line, southwest of Dennis, Texas (holotype). Brannon Bridge limestone member, Millsap Lake formation; Loc. 183–T–14, about 3 miles southwest of Brock, Parker County, Texas (H–30, M–35). Palo Pinto limestone, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–41, quarry, 3 miles northwest of Salesville, Palo Pinto County, Texas (P–664).

Types.—Holotype, Plummer Collection no. P–8187, collected by Gayle Scott; paratype, Harris Collection no. H–30, collected by Mrs. G. W. Harris; paratype, Marrs Collection no. M–35, collected by Mrs. W. R. Marrs; all from the Millsap Lake formation. Paratype, Plummer Collection no. P–664, collected by F. B. Plummer, from the Palo Pinto limestone.

PLAXOCRINUS PERUNDATUS Moore and Plummer, n.sp.

Pl. 8, fig. 5; pl. 15, fig. 5; text fig. 37

Description.—The dorsal cup is very low, truncate bowl-shaped, with a broad well-defined but a shallow basal concavity. The outline in dorsal or ventral view is hexagonal. The three posterior sides are subequal and shorter than the anterior sides. The infrabasals (IBB) form a small pentagon that is covered almost entirely by the shallow round stem impression. The distal extremities are subhorizontal. The basals (BB) are moderately large and approximately equal. The posterior basal (pB) and right posterior basal (rpB) are hexagonal, the others pentagonal. The proximal edges of the basals (BB) are smoothly confluent with the plane of the infrabasal (IBB) circlet and flare gently downward. They are horizontal at mid-length or slightly beyond, and distally they curve upward. The tips of the basals (BB) are clearly visible in side view of the cup. The surfaces of the radials (RR) are horizontal in the proximal region, curve very strongly upward at mid-length, and in the distal area form an arcuate flattened vertical space adjoining the facets. The facets are less than the greatest width of the plates and a very distinct shallow notch occurs at the summit of the interradial (RR) sutures. The outer ligament area, bounded by a very faint curving ridge, has a nearly vertical plane like the adjoining face of the radial beneath it. The ligament pit, centrally located next to the transverse ridge, is unusually long, wide, and deep, the width being only a little less than that of the entire outer ligament area. The transverse ridge is narrowed and slightly depressed where it adjoins the ligament pit, and this central part of the ridge is bordered ventrally by a shallow depressed triangular area with apex near the middle of the inner ligament area. The inner ligament fossae are sharply defined oblique grooves that extend from the base of the intermuscular notch to the lateral extremities of the transverse ridge. The adsutural slopes are marked by a low but distinct ridge that is parallel to the suture and to the main ridge bounding the muscle areas. Thus there are four parallel ridges in the area where facets adjoin. The arrangement of plates in the anal series is normal, with the radianal (RA) broadly in contact with the posterior basal (pB) and resting on the right posterior basal (rpB). The suture between the principal anal (x) and the posterior basal (pB) cuts obliquely across the end of the posterior basal (pB) rather than squarely. One of the paratypes, a slightly deformed specimen, shows the lower part of the arms. The first primibrachs (IBr_1) are projecting, somewhat bulbous axillaries with pentagonal outline; they are as large as the radials or a little larger. Each secundibrach (IIBr) series consists of two plates, a quadrangular segment below, and a subpentagonal blunt-spined axillary above; the quadrangular brachial is about three times as wide as long. Only a few of the tertibrach

(IIIBr) series are preserved in some of the branches, and the lowermost of these plates is somewhat longer and more rounded than the others. The branches divide uniformly in isotomous manner. The general appearance of the lower arms resembles that of *Pirasocrinus scotti*, n.sp., but the structure is different, and the dorsal cups of *P. scotti* and *Plaxocrinus perundatus* are very readily distinguished. It is undoubtedly true, however, that *Pirasocrinus, Plaxocrinus,* and *Sciadocrinus* are related genera that are characterized by isotomously branching arms composed of uniserial quadrangular brachials; probably *Schistocrinus* and *Perimestocrinus* may be included with the others mentioned.

Measurements of the holotype and two paratypes, in millimeters, are as follows:

	Holotype P–11190	Paratype M–33	Paratype H–34
Height of dorsal cup	6.2	5.8	5.0
Greatest width of cup	25.2	26.0	29.0
Ratio of height to width	0.24	0.22	0.17
Height of basal concavity	2.4	1.6	2.9
Diameter of stem impression	4.2	4.6	4.1

Discussion.—This new species is readily distinguished from *Plaxocrinus crassidiscus* (Miller and Gurley) and *P. discus* (Meek and Worthen) by the greater thickness and convexity of the radials (RR), the lesser transverse convexity of the basals (BB), and the broader and slightly greater depth of the smooth-bottomed basal concavity. Also, the very distinct notches at the summit of the interradial sutures are not seen in the other species mentioned. From *P. obesus*, n.sp., this new species is distinguished by the notches between the radials (RR), just mentioned, the somewhat deeper basal concavity, and, apparently also, by the smoother surface and more nearly upright position of the plates of the anal series.

Occurrence.—Millsap Lake formation below Kickapoo Falls limestone, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 110–T–4, on Kickapoo Creek about one-fourth mile below Kickapoo Falls southwest of Dennis, Hood County, Texas (holotype). Brannon Bridge limestone member, Millsap Lake formation; Loc. 183–T–14, about 3 miles southwest of Brock, Parker County, Texas (M–33, H–34).

Types.—Holotype, Plummer Collection no. P–11190, Bureau of Economic Geology, The University of Texas. Paratype, Marrs Collection no. M–33, collected by Mrs. W. R. Marrs, Austin, Texas.

Paratype, Harris Collection no. H–34, collected by Mrs. G. W. Harris, Waco, Texas.

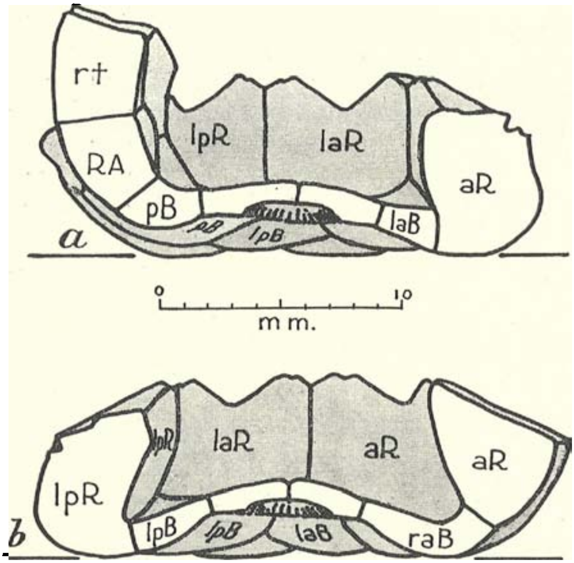

Fig. 37. Median cross-sections of the dorsal cup of the holotype of *Plaxocrinus perundatus* Moore and Plummer, n.sp., showing the thick radial plates and the broad basal concavity, the distal parts of the basal plates being visible in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

PLAXOCRINUS OMPHALOIDES Moore and Plummer, n.sp.

Pl. 8, fig. 4; pl. 9, fig. 4

Description.—The dorsal cup is shallow bowl-shaped, with flaring sides and comparatively narrow, shallow but well-defined basal concavity; except for the truncated posterior side, the outline is distinctly pentagonal. The infrabasal (IBB) circlet is very small, covered almost entirely by the stem impression, which is set well below the horizontal plane of the distal extremities of the infrabasals (IBB). The basals (BB) are downflaring proximally and upflaring distally, the tips are visible in side view of the cup; their form and arrangement is like that of other species of the genus, but the sutures at their edges are somewhat less distinct, and the contour from the basals (BB) to the radials (RR) is more smoothly confluent than is normal. The radials (RR) are not strongly convex and slope rather smoothly upward and outward to the margin of the facets. The width of the articular facets is a very little less than the width of the radials (RR) so that a narrow truncation, but no distinct notch, occurs at the summit of the interradial sutures. The slope of the facet is gently outward; the plane of the outer ligament area, however, slopes strongly downward and makes a sharp angle with that of the inner ligament area. Markings of the facet are essentially the same as in other species of the genus. The width of the posterior interradius is distinctly less than that of the left posterior radial (lpR) or the right posterior radial (rpR); the space between the posterior radials is distinctly though not strongly concave. This concavity continues faintly into the basal concavity but disappears upward, where the principal anal (x) and right tube plate (rt) form a smooth vertical face. The arrangement of the anal plates is normal, with the radianal (RA) in contact with the right posterior basal (rpB) and principal anal (x) resting on the distal tip of the posterior basal (pB).

Measurements of two specimens, in millimeters, are as follows:

	Holotype	Paratype
Height of dorsal cup	5	5.4
Greatest width of cup	17	16.2
Ratio of height to width	0.29	0.31
Height of basal concavity	1.6	1.4
Diameter of stem impression	3.1	3.5

Discussion.—The chief distinguishing features of *P. omphaloides* are the comparatively narrow and shallow basal concavity, the outwardly flaring sides of the cup, the nearly smooth contour of the surface across the suture lines, and the absence of distinct notches between radials at the summit plane. Some of these features, especially the general contour of the cup, make for similarity to species of *Laudonocrinus*, but the very distinct basal concavity is foreign to that genus. *Plaxocrinus omphaloides* has a shallower cup, with more gently rounded and flaring sides than is seen in *P. obesus*, n.sp., and *P. perundatus*, n.sp. From the latter species and from *P. lobatus*, n.sp., this form is distinguished also by the absence of interradial notches.

Occurrence.—Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc.

153–T–23, 2½ miles east and 2½ miles north of Rochelle, McCulloch County, Texas (holotype): Loc. 181–T–19, west end of dam at Lake Pinto, Palo Pinto County, Texas (paratype).

Type.—Holotype, King Collection no. K–11189, Bureau of Economic Geology: collected by Ralph King. Paratype, King Collection no. K–451; collected by Ralph King.

PLAXOCRINUS LOBATUS Moore and Plummer, n.sp.

Pl. 9, fig. 1; text fig. 38

Description.—The form of the dorsal cup is closely similar to that of *P. omphaloides* except for the nearly circular outline in ventral or dorsal view. The posterior interradius is as wide as either of the adjoining radials (RR) and slightly convex, and it does not interrupt the rounded contour of the rim of the cup. The infrabasal (IBB) circlet is small and covered almost entirely by the stem impression, which is strongly concave. The proximal portions of the basals (BB) are rather strongly downflaring and make a distinct angle with the plane of the infrabasals (IBB); the distal parts upflare and are visible in side view of the cup. These plates are gently convex transversely, the bordering sutures are distinct, and the general surface is less smoothly confluent than in *P. omphaloides,* n.sp. The radials (RR) are not strongly convex, their surfaces slope gently upward and outward. The radial facets are very distinctly less than the greatest width of the radials (RR), and there are strong but shallow notches between these plates at the summit plane. The facets slope gently outward and in general show the same features as other described species of the genus. The three anal plates are in normal position, with the radianal (RA) somewhat broadly touching the right posterior basal (rpB) and the principal anal (x) resting on the distally truncated tip of the posterior basal (pB). Each of the anal plates is relatively broad, and the width of the posterior interradius is greater than in most observed species of *Plaxocrinus.*

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	4.0
Greatest width of cup	16.5
Ratio of height to width	0.24
Height of basal concavity	1.9
Diameter of stem impression	2.7

Discussion.—The form of the cup seen in *P. lobatus* corresponds most closely to that of *P. omphaloides*, n.sp., but the latter species is readily differentiated by the absence of distinct interradial notches, by the smoother contour of the surface of the cup, and by the narrower concave posterior interradius. The nearly circular outline of the cup, seen in dorsal view, corresponds to that of *P. crassidiscus* (Miller and Gurley), but the shape of the cup in vertical profile

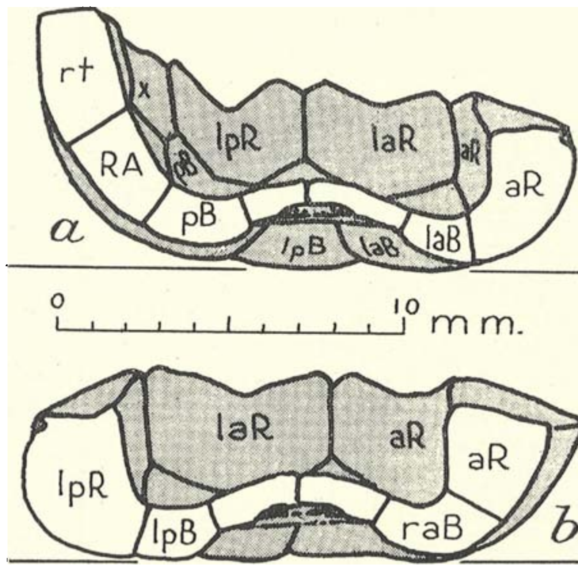

Fig. 38. Median cross-sections of the dorsal cup of the holotype of *Plaxocrinus lobatus* Moore and Plummer, n.sp., showing the moderate concavity of the basal, which is combined with visibility of the outer parts of the basals in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

and the greater convexity of the basals (BB) and radials (RR) in the former species furnish clear basis for differentiation.

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 153–T–23, 2½ miles east and 2½ miles north of Rochelle, McCulloch County, Texas.

Type.—Holotype, King Collection no. K–11188, Bureau of Economic Geology, The University of Texas; collected by Ralph King.

PLAXOCRINUS APLATUS Moore and Plummer, n.sp.

Pl. 9, figs. 2, 3

Description.—The outline of the dorsal cup in ventral or dorsal view is very distinctly pentagonal except for the scalloped indentation of the posterior interradius. The greatest width in two specimens at hand appears to be in a direction transverse to the postero-anterior axis. The height of the cup is distinctly less than the average for the genus, and the resulting appearance of flatness is regarded as having value in identifying the species. The base of the cup is slightly but distinctly concave; the proximal parts of the basals (BB), as well as the infrabasals (IBB), are included in the depression. The moderately deep excavation of the stem impression, which reaches almost to the edge of the infrabasal (IBB) circlet, adds to the appearance of concavity of the base. Although the distal portions of the basals (BB) flare upward so that they are clearly visible in side view of the cup, the average plane of these plates departs only slightly from horizontal. The paratype is abnormal in showing a division of the right posterior basal (rpB) into two plates. The radials (RR) slope gently and regularly upward. The articular facets attain almost, but not quite, the greatest width of the radials (RR). A very small but distinct notch appears at the summit of the interradial sutures, and a narrow, straight-sided groove extends between the facets to the edge of the body cavity. The facets, which have a more nearly plain surface than is seen in most species, slope outward at a moderate angle. The posterior interradius is relatively narrow and distinctly concave transversely. The arrangement of the anal plates is normal, the radianal (RA) touching the right posterior basal (rpB), and the principal anal (x) rests on the posterior basal (pB), but all the anal plates are elongate and narrow. The surface is smooth and unornamented, as shown by the paratype; the slightly roughened surface of the holotype appears due to conditions of preservation.

Measurements of two specimens, in millimeters, are as follows:

	Holotype	Paratype
Height of dorsal cup	3.7	4.1
Greatest width of cup	15.5	19.1
Ratio of height to width	0.24	0.21
Height of basal concavity	1.9	1.5
Diameter of stem impression	3.0	3.1

Discussion.—This species departs from the normal features observed in *Plaxocrinus* in the even contour of the surface, which is a character of *Laudonocrinus*. It is assigned to *Plaxocrinus* because of the distinctness of the shallow basal concavity, combined with visibility of the basals (BB) in side view of the cup. The plates are much less convex than in *P. obesus*, n.sp., and *P. crassidiscus* (Miller and Gurley).

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Types.—Holotype, Kansas University no. 60441; collected by R. C. Moore. Paratype, Plummer Collection no. P–1020, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

PLAXOCRINUS PARILIS Moore and Plummer, n.sp.

Pl. 9, figs. 5, 6; text fig. 39

Description.—The dorsal cup is very low, truncate bowl-shaped. The height, measured from the basal plane to the transverse ridges of the radials (RR) is only one-fourth of the greatest width; the base shows the moderate concavity and curvature of the basals (BB) that are characteristic of *Plaxocrinus*. The infrabasal (IBB) disk is regularly pentagonal, 4 mm. in width in the holotype specimen. The proximal half of each plate is covered by the round concave stem impression, and the distal part slopes slightly but perceptibly downward. A distinct angulation, measuring about 120 degrees, separates the infrabasal (IBB) and basal (BB) circlets. The proximal margins of the basals (BB) slope downward steeply but only for a very short distance, then curve to a horizontal position at mid-length and flare gently upward in the distal portion. These plates are gently convex transversely as well as longitudinally. The width of the radials (RR) is a little less than twice the length. In median longitudinal profile the surface slopes strongly outward in the proximal portion and then rather steeply upward in the distal portion. The facets are almost, but not quite, equal to the greatest width of the radials (RR). A very slight notch is observed at the summit of the interradial sutures. The very short outer ligament area, containing a deep ligament pit, faces almost directly outward.

The inner ligament area has a gentle outward slope and is marked by a long, well-defined oblique ligament fossa and a median narrow intermuscular furrow. The lateral ridges and adsutural slopes are strongly marked. The posterior interradius is very gently concave in the upper portion but not so in the lower part. There are three anal plates in the holotype arranged in normal manner, with the radianal (RA) in contact with the right posterior basal (rpB) and followed above by the principal anal (x) and right tube plate (rt), the former resting on the truncated end of the posterior basal (pB). The surface is entirely smooth and although the sutures are in shallow furrows they are not impressed.

The arrangement of plates in the posterior interradius of the paratype specimen calls for special notice, because its character is unusual in hydreionocrinid cups. The posterior basal (pB) is distinctly larger and longer than the other basals (BB). It is broadly truncated at the tip for contact with a large anal plate which is the only one in the dorsal cup. This plate is about twice as long as wide, and irregularly pentagonal in outline. Sutural faces at the top indicate positions of two other anal plates, of which the one at the right reaches barely below the elevated left extremity of the right posterior radial (rpB). Presumably this large anal plate is the principal anal (x), and, if so, the radianal (RA) plate has been entirely resorbed. That this crinoid cup belongs in the genus *Plaxocrinus* is clearly indicated by all its characters except the unusual character of the posterior interradius.

Measurements of the holotype and paratype specimens, in millimeters, are given in the following tabulations:

	Holotype	Paratype
Height of dorsal cup	3.3	4.2
Greatest width of cup	13.8	16.4
Ratio of height to width	0.24	0.26
Height of basal concavity	1.6	2.3
Width of body cavity	7.4	8.4
Width of stem impression	2.8	3.0

Discussion.—Recognition of this species is based on a study of a dorsal cup from the Graford formation. Comparison has been made with two dozen or more closely similar cups from beds of about the same horizon in Kansas and Missouri. Only one of these cups appears referable to the species here described, and it differs notably in the arrangement of plates of the posterior interradius.

The Texas specimen is designated as holotype and the Kansas specimen as a paratype. The characters of the dorsal cup observed in *P. parilis* are more like those of the genotype species, *P. crassidiscus* (Miller and Gurley) than any other species. The general outline and proportions of the dorsal cup are the same in these two species. Distinguishing features are the lesser depression of the infrabasal (IBB) disk in *P. crassidiscus*, the smaller convexity of its basals (BB) including especially the lack of abrupt slope at the proximal edges of these plates, and the somewhat more swollen or bulbous appearance of the radials (RR) in this species. Another difference appears in the character of the surface near the stem impression. Although Miller and Gurley state that the surface of *P. crassidiscus* is granular, this character is observable only on the distal parts of the infrabasals (IBB) and the proximal edges of the basals (BB); the remainder of the cup is perfectly smooth. This smoothness is

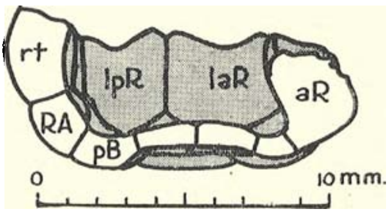

Fig. 39. Median cross-section of the dorsal cup of the holotype of *Plaxocrinus parilis* Moore and Plummer, n.sp., through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section.

not due to weathering or abrasion, for examination under the microscope at magnification of about x75 shows a characteristic microscopic pattern that is apparently to be found on any unabraded poteriocrinitid plate but is not observable on weathered surfaces. No granular ornamentation of the infrabasals (IBB) and proximal part of the surface of the basals (BB) is observed in *P. parilis*.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); from Loc. 119–T–29, north of the road one-half mile west of Joplin, Jack County, Texas (holotype). Argentine limestone member of the Wyandotte limestone, Kansas City group, Missouri series; Loc. 6032 at Lake-of-the-Forest, Wyandotte County, Kansas (paratype).

Types.—Holotype, King Collection no. K–13128, Bureau of Economic Geology, The University of Texas; collected by Ralph King. Paratype, University of Kansas no. 60321; collected by R. C. Moore.

Genus PERIMESTOCRINUS Moore and Plummer, 1938

Perimestocrinus MOORE AND PLUMMER, 1938, Denison Univ., Bull., Jour. Sci. Labs., vol. 32 (1937), p. 281.

The dorsal cup is low bowl-shaped, with narrow, moderately deep, steep-sided basal concavity. The five infrabasals (IBB) are subhorizontal or slightly downflaring, forming a regular pentagon that is largely covered by the round stem impression. The infrabasals (IBB) form the floor of the basal concavity and are not visible in side view of the cup. The five basals (BB) are subequal, laterally in contact and flaring strongly upward except for the proximal portions which form the steep sides of the basal concavity. A large part of each basal plate is visible in side view of the cup. The five radials (RR) are pentagonal, with the outer surface sloping strongly upward. The facets slope outward at a moderate angle and are less than the greatest width of the radials (RR). Notches are present at the summit of the interradial sutures. There are three anal plates in the dorsal cup; the radianal (RA) is in contact with the right posterior basal (rpB) or separated from it; the principal anal (x) rests on the posterior basal (pB) or is separated from it by the radianal (RA). The right tube plate (rt) rests on the radianal (RA).

The arms are composed of uniserial quadrangular segments which branch isotomously on the primibrachs (IBr_1). The upper part of the arms is unknown. The axillary primibrach (IBr) is not spine-bearing in species where this plate is known.

The stem is round. The anal sac is unknown. The surface is smooth or ornamented by granules. The sutures are moderately to strongly impressed.

Genotype.—*Hydreionocrinus nodulifer* Miller and Gurley (text fig. 40).

Discussion.—The genus *Perimestocrinus* is distinguished primarily by the shape of its dorsal cup. The basal concavity is narrower and deeper than in *Plaxocrinus.* The concavity is similar to that of *Aatocrinus* which is distinguished from *Perimestocrinus* by the more depressed form of the dorsal cup and the downflaring slope of the proximal parts of the radials (RR). The basal concavity of *Sciadiocrinus* and *Pirasocrinus* is much broader in general than in *Perimestocrinus.*

Occurrence.—Upper Carboniferous (Morrow to Virgil series); Mid-Continent region, North America.

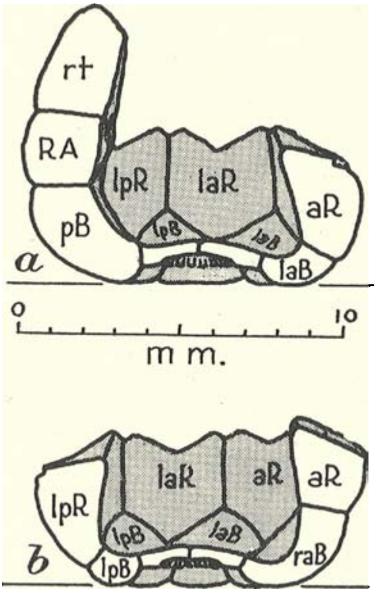

Fig. 40. Median cross-sections of the dorsal cup of the holotype of *Perimestocrinus nodulifer* (Miller and Gurley), the genotype species, showing the steeply abrupt edges of the basal concavity and the moderately deep truncate bowl-shaped form of the dorsal cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

PERIMESTOCRINUS FORMOSUS Moore and Plummer, n.sp.

Pl. 7, fig. 7; Pl. 10, fig. 1; text fig. 41

Description.—Definition of this species is based on a single specimen consisting of an almost perfectly preserved dorsal cup. It is a beautifully decorated form and this feature serves most readily to distinguish it, even though characters of the shape and arrangement of parts serve also for identification.

The regular pentagon formed by the infrabasals (IBB) is sharply impressed but less deeply than is typical in the genus; the plates flare very slightly downward, are unornamented, and their proximal half is covered by the round stem impression that is depressed about 1 mm. below the general surface of the pentagon. The junction between the basals (BB) and infrabasals (IBB) forms nearly a right angle, but the subvertical proximal portion of the basals (BB) that forms most of the walls of the central depression is short. The mid-portion of the basals (BB) is subhorizontal and the distal portion flares upward, all being clearly visible in side view of the cup. The bordering sutures are very distinct but only slightly impressed. The entire surface of the plates is covered by an irregularly disposed pattern of moderately elevated, very distinct granules. The radials (RR) flare upward and are ornamented like the basals (BB), but in addition a well-defined arcuate ridge occurs at about the mid-length of each plate, the ends of the ridge being at the upper lateral angle of each radial; the median part of the ridge is most elevated and rather distinctly nodose. The face of each radial between the ridge and the articular facet is subvertical, and it is evident that this structure forms a backstop against which the primibrachs (IBr) may rest when the arms are extended. The radial facets are distinctly less than the greatest width of the radials (RR). A notch appears at the summit of the interradial sutures, and a strong groove, formed by the adsutural slopes, lies between the facets. The transverse ridge is straight, narrow, and clearly defined. The outer ligament area with the ligament pit is narrow and sharply marked. The inner ligament area is divided into two subtriangular parts by a deep intermuscular notch and shows relatively fine, obliquely disposed ligament fossae, sloping muscle areas, and, adjoining the transverse ridge centrally, a subtriangular pit that marks the position of the central canal.

The posterior interradius is normal, showing a radianal (RA) broadly in contact with the posterior basal (pB) and resting on the right posterior basal (rpB). The principal anal (x) rests on the truncated tip of the posterior basal (pB) and partly supports the right tube plate (rt).

Measurements of the holotype, in millimeters, are as follows:

Height of cup	3.8
Maximum width	14.5
Ratio of height to width	0.26
Height of basal concavity	1.8
Diameter of stem impression	2.3

Discussion.—Characters of the ornamentation, especially including the arcuate nodose ridges of the radials (RR), distinguish *P. formosus* readily from any known species of the genus. The general shape of the cup in this species resembles that of *P. impressus*, n.sp., but the latter has much more bulbous plates with strongly

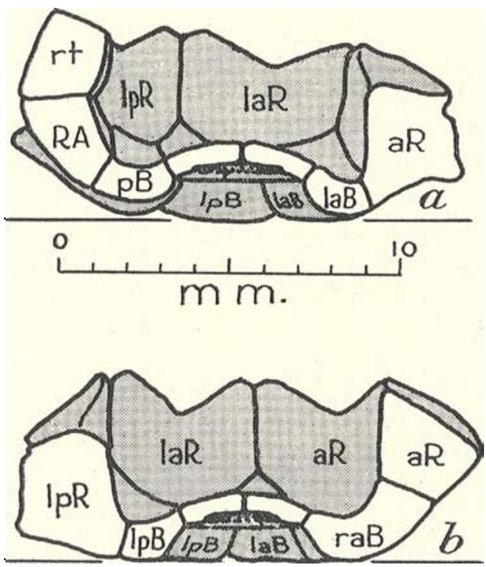

Fig. 41. Median cross-sections of the dorsal cup of the holotype of *Permestocrinus formosus* Moore and Plummer, n.sp., showing the depth and the steep sides of the basal concavity and giving details of the arcuate ridge on the radials. *a,* Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

impressed sutures and the central concavity is distinctly deeper. The dorsal cup of *P. formosus* is somewhat broader and relatively shallower than that of *P. nodulifer* (Miller and Gurley), the genotype, and *P. granulifer* (Miller and Gurley) both of which are ornamented by fine granules but show no ridges on the radials (RR).

Occurrence.—Martins Lake limestone, Palo Pinto formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); west of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, no. P–5285, Bureau of Economic Geology, The University of Texas; collected by E. Böse.

PERIMESTOCRINUS IMPRESSUS Moore and Plummer, n.sp.

Pl. 10, figs. 3, 4; text fig. 42

Description.—The dorsal cup is low bowl-shaped, with a central narrow moderately deep concavity, the floor of which is formed by the infrabasal (IBB) circlet and the walls by the vertical proximal edges of the basals (BB). The holotype actually shows a slight downward convergence of the walls of the depression toward the stem, so as to form a small bowl-like hollow with overhanging lip. All the plates in the dorsal cup excepting those of the infrabasal (IBB) circlet are strongly convex longitudinally and transversely, the sutures between them being sharply impressed. The arrangement of plates in the posterior interradius is normal. The radianal (RA) is in contact with the right posterior basal (rpB) and the principal anal (x) touches the narrow extremity of the posterior basal (pB).

The surface is covered by granulose ornamentation, which is much finer than in *P. formosus*, n.sp. The radial facets resemble those of *P. formosus*, except that the angle of outward slope is somewhat more gentle.

Measurements of two specimens, in millimeters, are as follows:

	Holotype	Paratype
Height of cup	4.7	5.0
Maximum width	15.7	18.2
Ratio of height to width	0.30	0.28
Height of basal concavity	2.5	2.8
Diameter of stem impression	3.1	2.7

Occurrence.—Keechi Creek shale member, Mineral Wells formation, Strawn group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–67, three-fourths of a mile north-northeast of Union Hill school, which is about 5 miles north-northwest of Mineral Wells, Palo Pinto County (holotype). East Mountain shale member, Mineral Wells formation (Des Moines series), Pennsylvanian; Loc. 181–T–2, at east end of Barber Mountain southwest of Mineral Wells, Palo Pinto County, Texas (paratype).

Types.—Holotype, Plummer Collection no. P–4628; paratype, no. P–6924; both deposited at the Bureau of Economic Geology, The University of Texas.

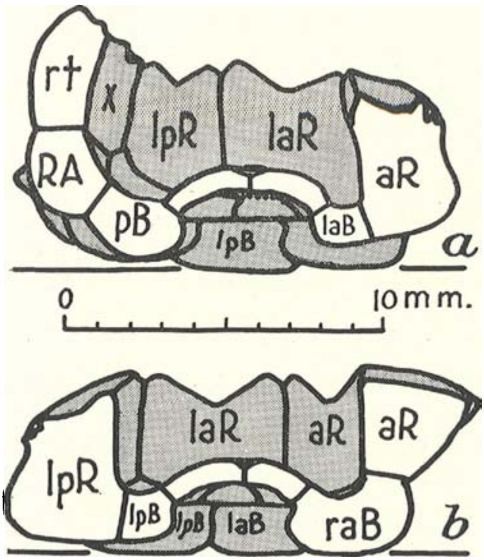

Fig. 42. Median cross-sections of the dorsal cup of the holotype of *Perimestocrinus impressus* Moore and Plummer, n.sp., showing the deep, slightly overhanging sides of the basal concavity and the bulbous form of some of the plates. *a,* Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded areas representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and the opposite interradius bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

PERIMESTOCRINUS CALYCULUS Moore and Plummer, n.sp.

Pl. 10, fig. 2; text fig. 43

Description.—The dorsal cup is rather shallow bowl-shaped with a deep, nearly vertically sided central concavity, the floor of which is formed by the infrabasal (IBB) circlet and the side walls by the proximal extremities of the basals (BB). The distal parts of the basals (BB) flare upward so that they are visible in side view of the cup. The lower tips of the radials (RR) reach to the basal plane but do not curve inward to form part of the central basal concavity. The radial facets are slightly but distinctly less than the greatest width of the radials (RR); the plane of the facets slopes outward at a moderate angle. The posterior interradius of *P. calyculus* is especially interesting in that the principal anal plate (x) and right tube plate (rt) retain their normal positions, although somewhat narrowed, above the truncated tip of the posterior basal (pB), but the radianal (RA) has vanished. There is a suggestion of the existence of a vestige of the radianal (RA) at the

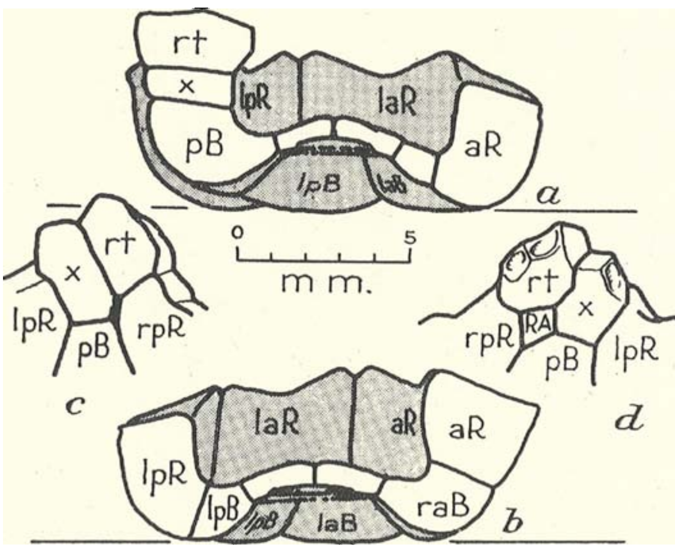

Fig. 43. Median cross-sections of the dorsal cup and sketches of the posterior interradius of the holotype of *Perimestocrinus calyculus* Moore and Plummer, n.sp., showing the moderately deep basal concavity and the steep sides of the cup. *a,* Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR). *c,* Plates of the posterior interradius, from the outside of the cup, showing the small depression between the posterior basal (pB) and the right tube plate (rt) but no other indication of the presence of the radianal (RA). *d,* Same, from the inside of the cup, showing the very distinct, though small, radianal (RA).

right of the principal anal (x), but this is not certain. It can not be assumed that either of the plates lying next above the posterior basal (pB) corresponds to the radianal (RA), for these correspond exactly to the principal anal (x) and to the right tube plate (rt) in many other examples of *Perimestocrinus* and related genera.

Furthermore, specimens in which various degrees of reduction in the size of the radianal (RA) down to a mere vestige may be seen, in which the other anal plates remain normal. This bears on the problem of the evolution of the radianal (RA) and the principal anal (x), already discussed by Bather,[57] Springer,[58] Clark,[59] and Wanner.[60] It is clear that in the forms here noted the radianal (RA) suffers gradual reduction and resorption, disappearing from the dorsal cup before other plates of the anal series. This observation, however, does not mean necessarily that the same evolutionary tendency exists in all genera of crinoids. The radianal (RA) is not detected on the outside of the cup of *P. calyculus* but is identified on the inside of the cup (fig. 43).

The surface is smooth and unornamented.

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	3.7
Greatest width of cup	12.8
Ratio of height to width	0.29
Height of basal concavity	1.9
Diameter of stem impression	2.0

Discussion.—This species is defined on the basis of a single, beautifully preserved dorsal cup that shows clearly all the typical features of *Perimestocrinus* but which differs obviously from any of the species yet described. The general form of *P. calyculus* resembles that of *P. impressus,* n.sp., but the difference in the convexity of the plates and degree of impression of the sutures, not to mention dissimilarity in the nature of the posterior interradius, makes it easy to distinguish from these species.

Occurrence.—Mineral Wells shale, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, east end of Barber Mountain southwest of Mineral Wells, Palo Pinto County, Texas.

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[57] Bather, F. A. The homologies of the anal plate in Antedon: Ann. Mag. Nat. Hist., ser. 9, vol. 1, p. 296, 1918.

[58] Springer, Frank. The Crinoidea Flexibilia: Smithsonian Inst., Pub. 2501, pp. 56–59, 79–87, 1920.

[59] Clark, A. H. The homologies of the so-called anal and other plates in the pentacrinoid larvae of the free crinoids: Washington Acad. Sci., Jour., vol. 2, p. 309, 1912.

[60] Wanner, J., Die permischen Echinodermen von Timor: Palaeontologie von Timor, Lief. 6, Teil 11, p. 153, 1916. Die permischen Krinoiden von Timor: Jaarb. Mijnw. Ned.-Indie, Verh. 1921, Gedeelte 3, pp. 197, 250, 1924.

Type.—Holotype, Plummer Collection no. P–1759; Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

PERIMESTOCRINUS EXCAVATUS (Weller)

Pl. 10, fig. 7; text fig. 44

Delocrinus excavatus WELLER, 1909, Jour. Geol., vol. 17, p. 628, pl. 1, figs. 16, 17. (Cibolo limestone, Lower Permian, western Texas.)

Description.—Weller's description, slightly modified in form of statement, follows:

The dorsal cup is basin-shaped (low truncate bowl-shaped), deeply and broadly excavated at the base. The plates are a little convex, and the sutures are impressed in shallow grooves. Measurements of the holotype are:

Height of cup	7.0 mm.
Width	20.0 mm.

The infrabasals (IBB) are entirely included in the basal concavity, which in the holotype has a diameter of 8 mm. at its margin, a depth of 3 mm. or more, and nearly vertical sides. The basals (BB) are rather large; their proximal borders incurve to form the sides of the basal concavity. The distal extremities are angular except that of the posterior basal (pB) which is truncated to support the principal anal (x). The radials (RR) are large, much wider than long, pentagonal in outline, and their distal faces are furnished with articulating ridges. The two anal plates together occupy the position of the single anal plate, which is commonly present in this genus. The two plates of nearly equal size, rest upon the truncated distal extremity of the posterior basal (pB) and are separated by a vertical suture nearly midway in position between the posterior lateral margins of the two posterior radials (RR). The distal extremities extend beyond the level of the radials (RR).

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	6.6
Greatest width of dorsal cup	20.5
Ratio of height to width	0.32
Height of basal cavity	4.6
Width of basal cavity	12.0
Width of stem impression	5.0
Length of basal	10.6
Width of basal	8.5
Length of radial	7.5
Width of radial	12.3
Length of suture between basals	6.8
Length of suture between radials	3.3
Height of proximal margin of posterior basal above basal plane	3.9
Height of distal margin of posterior basal above basal plane	4.0
Ratio of height of proximal margin to height of distal margin of posterior basal above basal plane	0.98

Discussion.—The height and unusual breadth of the basal concavity at its top, its nearly vertical sides, and the very sharp angulation at the base of this concavity, clearly differentiate this species from other Upper Carboniferous and Permian crinoid cups.

When the holotype specimen representing this species was first examined, it was thought that the very faint vertical line which

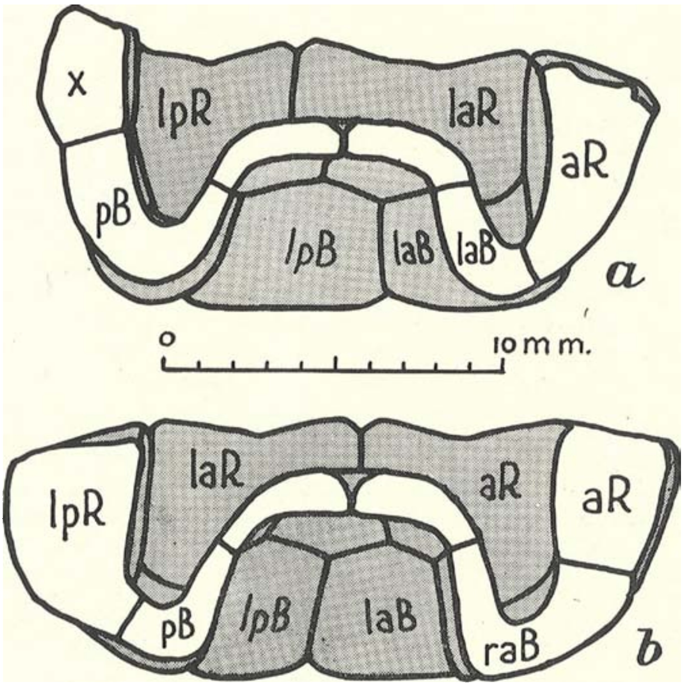

Fig. 44. Median cross-sections of the dorsal cup of the holotype of *Perimestocrinus excavatus* (Weller), showing the very deep broad basal concavity with nearly vertical sides. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

Weller had concluded to be the suture between two anal plates resting on the posterior basal (pB) was really a fracture, and accordingly that there is only one anal plate above the posterior basal (pB), as is normal in *Delocrinus*. Later and more careful study, accompanied by cleaning and by removal of the matrix from inside the anal area, has established very definitely the correctness of Weller's description. The two anal plates are identified both by difference in orientation of the crystalline calcite and by observation of the finely serrate line of the suture that separates these plates. The anal plate at the right is a little smaller than the one at the left, its contact with the posterior basal (pB) is much narrower, and the suture between it and the posterior basal (pB) is inclined differently from that beneath the other anal plate.

With establishment of the structure of the posterior interradius from study both of the outside and inside of the cup, it is apparent that unless this is regarded as a single accidental abnormality, the species can not belong to *Delocrinus.* A recent collecting trip to the Cibolo locality resulted in finding three other specimens of this species. Each is a nearly complete dorsal cup, identical in form and general appearance of the plates to the holotype, but two of the recently discovered specimens are only about half as large. The additional specimens throw light on generic relations of the species, for two of them show definitely the presence of a long narrow radianal (RA) at the right of the posterior basal (pB). In one specimen the radianal (RA) is very narrowly in contact with the right posterior basal (rpB), but in the other the lower tip is separated from the right posterior basal (rpB) by a space of about 1 mm. The third specimen is like the holotype, lacking a radianal (RA). Apparently there are two anal plates above the truncated posterior basal (pB), but this is not determinable certainly, because it happens that the specimen is broken along a line barely above the posterior basal (pB). This leads to the conclusion that the species is somewhat variable as regards arrangement of the anal plates, that the radianal (RA) may be present, in contact with the right posterior basal (rpB) or not in contact with this plate, or the radianal (RA) may be absent. The plates above the posterior basal (pB) are respectively the principal anal (x) and the right tube plate (rt). The species belongs among hydreionocrinids rather than with *Delocrinus.* The radial facets slope gently outward, and the transverse ridge of the facet joins the outer marginal ridge before reaching the interradial sutures. The form and structural features of the cup accord with characters belonging to the genus *Perimestocrinus,* which is distinguished mainly by the relatively deep, nearly vertical-sided basal concavity, combined with clear visibility of the distal parts of the basals (BB) in side view of the cup.

Perimestocrinus excavatus differs from other species placed in this genus in the greater breadth and depth of the basal concavity. Furthermore, no other species of the genus are known in which plates of the anal interradius may have the appearance seen in the holotype of this species.

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Types.—Holotype, Walker Museum no. 13366; collected by J. A. Udden. Hypotypes, University of Kansas nos. 60371–60373; collected by R. C. Moore.

Genus AATOCRINUS Moore and Plummer, n.gen.

Comparative study of more than 600 specimens of very low bowl-shaped to discoid crinoid cups having three anal plates and characterized by facets less than the width of the radials (RR), has called attention to groups that have a community of characters differing more or less clearly from those of other groups. One of these types of dorsal cup is well represented by Beede's *Zeacrinus? robustus*, and it is here selected as type of a new genus, *Aatocrinus.*[61]

The dorsal cup is very low. The inner margin of the radial facets is generally about as high above the summit of the radials (RR) as the latter is above the basal plane of the cup. The central part of the base is strongly depressed, but the distal portions of the basals (BB) and radials (RR) flare upward and are not involved in the basal concavity. The five infrabasals (IBB) are subhorizontal or slightly downflaring and form a small pentagon covered largely by the round stem impression at the bottom of the basal concavity. The five basals (BB) are subvertical near their proximal margin and curve downward and outward to a subhorizontal position beyond the mid-length, and then curve upward, strongly convex in longitudinal profile and moderately convex transversely. The distal parts of these plates are clearly visible in the side view of the cup.

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[61]From the Greek, meaning strong.

The left posterior basal (lpB), the left anterior basal (laB), and the right anterior basal (raB) are subequal. The posterior basal (pB) is about equal in width but distinctly longer than the others. The right posterior basal (rpB) is distinctly wider than any of the rest and also the largest. The radials (RR) are relatively large,

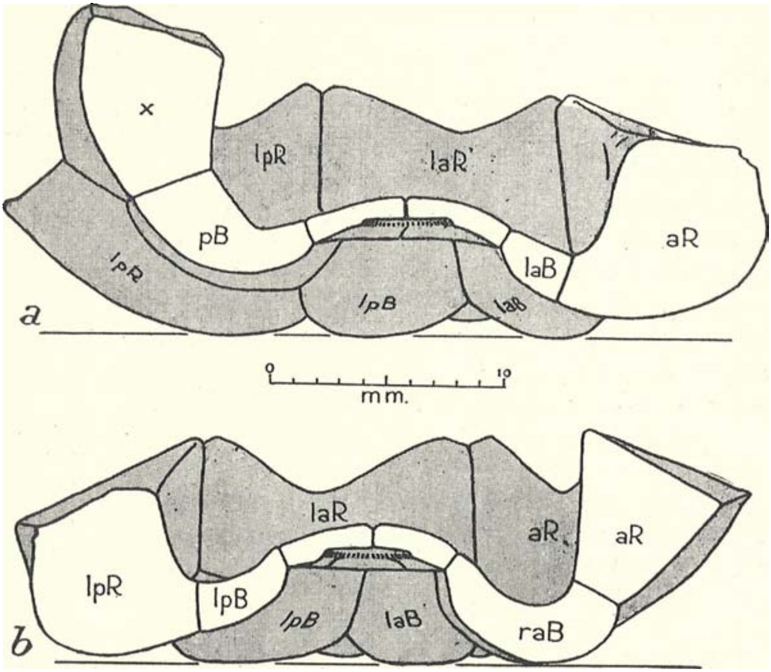

Fig. 45. Median cross-sections of the dorsal cup of the holotype of *Aatocrinus robustus* (Beede), the genotype species, showing the deep, steep-sided basal concavity and the broad low form of the dorsal cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

having a width about twice their length. Their proximal portion is subhorizontal or slightly downflaring in longitudinal profile and curves slightly upward to the margin of the ligament area in the distal portion. The radial facets are very slightly less than the maximum width of the plates, but because of lateral projection of radials (RR) beyond the point of union with neighbors there are well-defined notches between the plates, and the outer surface of the cup is confluent with a space along the inner articular suture that is not covered by the facets. The facets are relatively broad and slope outward at an angle of about 30 to 40 degrees.

The posterior interradius is comparatively narrow and rather deeply indented. It contains three anal plates consisting of the radianal (RA), which is in contact with the right posterior basal (rpB); the principal anal (x) rests on the truncated tip of the posterior basal (pB), and about half its length extends above the facet of the left posterior radial (lpR); the right tube plate (rt) rests on the principal anal (x), and the radianal (RA) reaches only slightly below the right posterior radial (rpR).

Discussion.—This genus most closely resembles *Perimestocrinus* in the strong, comparatively narrow central concavity. It differs from *Perimestocrinus* in its much broader and lower form of the dorsal cup and especially in the attitude of the radials (RR), which in *Perimestocrinus* are invariably strongly upflaring, never forming part of the basal concavity. This genus differs from *Plaxocrinus* in the much greater and narrower central depression.

Genotype.—*Zeacrinus? robustus* Beede (Pl. 7, fig. 1; text fig. 45).

Occurrence.—Middle Pennsylvanian (Des Moines and Missouri series); Mid-Continent region, North America.

AATOCRINUS CAVUMBILICATUS Moore and Plummer, n.sp.

Pl. 7, figs. 2, 3; text fig. 46

Description.—Two incomplete specimens from the Mineral Wells shale correspond in features of the dorsal cup very closely to the genotype of *Aatocrinus* and are here designated as types of a new species, *A. cavumbilicatus.* There is a deep central concavity containing the infrabasal (IBB) circlet and the proximal portions of the basals (BB), but the distal portions of the latter are readily visible in side view of the cup. The proximal parts of the radials (RR) are slightly but distinctly downflaring, thus being involved in the central concavity. The height of the radials (RR) is the same as the height of the cup. The facets are distinctly narrower than the greatest width of the radials (RR), giving rise to fairly wide obtuse notches at the junction of the plates. Characters of the facets are unusually well shown in the holotype. The transverse ridge is very narrow and sharp and not strongly elevated. The outer ligament area is marked off by a distinct fine ridge and contains a central, fairly deep pit; a smooth, slightly depressed subtriangular area is centrally located on the inner side of the transverse ridge and is adjoined laterally by rows of fine teeth transverse to the ridge. The ligament fossae are traceable obliquely from near the lateral extremities of the transverse ridge to the central

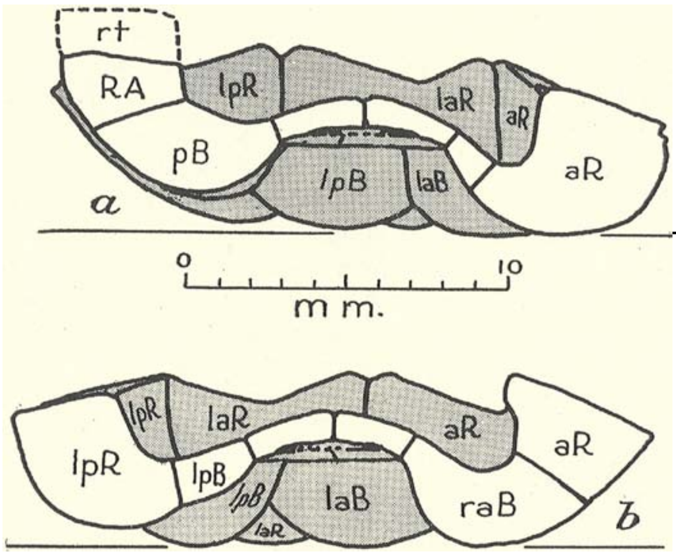

Fig. 46. Median cross-sections of the dorsal cup of the holotype of *Aatocrinus cavumbilicatus* Moore and Plummer, n.sp., showing the deep concavity of the base with the outer extremities of the basals visible in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

part of the facets, where they meet the tip of the intermuscular notch, the sloping areas to right and left marking the muscle areas.

The radianal (RA) is a relatively small quadrangular plate resting on the upper right shoulder of the posterior basal (pB) and does not reach the right posterior basal (rpB). The principal anal (x) is a plate of slightly larger size that rests on the truncated tip of the posterior basal (pB) and rises somewhat above the summit of the radials (RR); the right tube plate (rt) occurs above the radianal (RA) and adjoins the principal anal (x) obliquely.

Measurements of the holotype, in millimeters, are as follows:

Height of cup	3.7
Maximum width of cup (est.)	21.5
Ratio of height to width	0.17
Height of basal concavity	3.3
Diameter of stem impression	3.7

Discussion.—This is a much smaller species than *A. robustus* (Beede). Because of the small size of the radianal (RA), the posterior basal (pB) is relatively much wider. The notches between radials (RR) are somewhat broader and more oblique in *A. cavumbilicatus*, and the longitudinal profile of these plates is distinctly different in the two species. This crinoid is not closely similar to any other Texas crinoid that has been discovered.

Occurrence.—East Mountain shale member, Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Types.—Holotype, Kansas University no. 60443; paratype, no. 60443a; collected by R. C. Moore.

Genus SCHISTOCRINUS Moore and Plummer, n.gen.

Description.—The dorsal cup is low, truncate bowl-shaped, and the base is nearly flat except for sharply depressed, vertically walled, round stem impression. The sides of cup are gently and rather evenly flaring. The posterior side has a strongly elevated thick plate of the lower anal series. The surface is smooth. The sutures are distinct but not impressed. The five infrabasals (IBB) are not visible from the side, except the distal extremity of the right posterior infrabasal (rpIB) in posterior view. Each infrabasal is truncated distally for contact with the radials (RR), the infrabasal (IBB) disc resembling a cog-wheel. The five basals (BB) are small, subquadrangular, and shaped like an arrow-head, not laterally in contact. The five radials are large, hexagonal, slightly wider than long, proximally in contact with the infrabasals (IBB). The articular facets slope outward, and are slightly narrower than maximum width of the plates. Three anal plates are in the dorsal cup. The radianal (RA) rests on a small right posterior infrabasal (rpIB) and supports a large principal anal (x) and a right tube plate (rt) which are mostly above the summit line of the radials (RR). A large tube plate rests on the upper margins of the principal anal plate (x) and the right tube plate (rt).

The arm structure of the genotype species is not known, but several examples of the Texas species, *S. confertus*, n.sp., and the holotype of *S. parvus*, n.sp., show both the character of the arms and the character of the anal sac. The first primibrach is a broad axillary plate in all rays; the succeeding plates are wide, short quadrangular segments or pentagonal axillary segments, and the division of the branches in the lower part of the rays is regularly isotomous. Beyond the third bifurcation, however, the branching is slightly heterotomous. the arms next above the axillary plates are even-sized, but the inside branches of each half-ray are undivided, whereas the outer branches of each half-ray continue to be divided. This type of branching may be designated as bi-endotomous. Comparison with *Neozeacrinus* Wanner shows that the structural plan of the rays corresponds closely in these two genera, though the arms of *Schistocrinus* are more delicate. Slender pinnules are numerous, and two specimens of *S. confertus* appear to show exisence of hyperpinnulation, two pinnules being attached to one side of a brachial segment.

The anal sac is relatively large, mushroom-shaped, its summit reaching higher than the tips of the arms; the top of the sac is covered by polygonal plates, and at its margin is a girdle of long narrow spines that project outward subhorizontally.

Genotype.—Schistocrinus torquatus Moore and Plummer, n.sp.

Discussion.—This new genus is very readily distinguished from other known crinoids of generally similar form by the relatively large size and shape of the infrabasals (IBB) and by the relatively very small size of the basals (BB), which are separated from one another by the proximal portions of the radials (RR). The shape of the cup appears to be a distinctive feature, also. The strong, nearly vertically sided stem impression that occurs in the genotype is observed also in some undescribed species that are referred to the genus.

Schistocrinus resembles *Adinocrinus* Kirk, *Prolobocrinus* Wanner, and *Benthocrinus* Wanner in the much-reduced size of the basals (BB), but it differs from all these genera in the shape of the dorsal cup. The base of the cup is flat in *Schistocrinus*, and the basals (BB) are visible from the side; in the other forms mentioned the base is broadly and, mostly, rather deeply concave, and the basals (BB) are not visible from the side. Distinctions in the structure of the arms and probably of the anal sac are also to be noted.

James Wright[62] has illustrated and discussed Scottish specimens referred by him to *Hydreionocrinus*, some of which exhibit nearly the same plate arrangement and cup form of *Schistocrinus*. Wright notes that two or more species seem to be recognizable in the specimens studied by him, but as is true of some other groups among the Scottish crinoids, there is much variation among individuals from the same horizon and locality. A difference between most of the forms illustrated by Wright and this new genus appears to be clear visibility of the infrabasals in side view in the majority of Scottish cups. A further difference of importance appears in the pentagonal shape of the stem and stem impression. Examples of this type of "*Hydreionocrinus*" from Roscobie, sent by Mr. Wright, show a very distinct surface ornamentation and a tumidity of the plates that is lacking in specimens of *Schistocrinus*.

It is evident that *Schistocrinus* is close to *Neozeacrinus* Wanner, for the arm structure is practically identical, possibly including occurrence of hyperpinnulation in both. On the other hand, differences in the dorsal cups of these genera seem to be sufficiently well marked to warrant separation. The basal plates (BB) of *Schistocrinus* are typically much more reduced than in *Neozeacrinus*, and the radials (RR) are in contact with the infrabasals (IBB) instead of separated more or less strongly, as in *Neozeacrinus;* the radianal plate (RA) of *Schistocrinus* is generally in contact with the right posterior infrabasal (rpIB) but somewhat separated from the infrabasal circlet in *Neozeacrinus*, although in *N. uddeni* (Weller) the radianal and the right posterior infrabasal almost meet. Finally, it may be noted that the sutures of the cup are impressed in *Neozeacrinus* but not in *Schistocrinus*.

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[62]Wright, James, Some variations in *Ulocrinus* and *Hydreionocrinus*: Geol. Mag., vol. 64, pp. 365, 371, 1927.

Occurrence.—Upper Carboniferous; Mid-Continent region of the United States.

SCHISTOCRINUS TORQUATUS Moore and Plummer, n.sp.

Pl. 2, fig. 6; text fig. 47

Description.—The dorsal cup has the features described in the diagnosis of the genus. Except for the vertically-sided, round stem impression, 1.3 mm. in depth and 5 mm. in diameter, and the slightly inclined position of the right posterior basal (rpIB), the

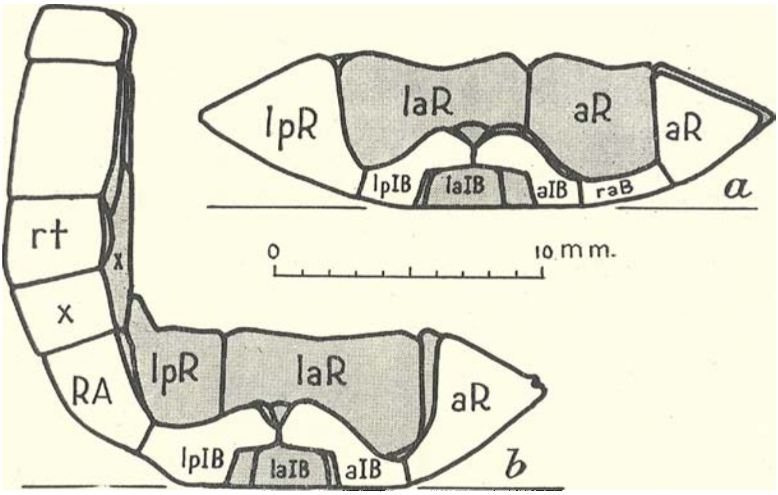

Fig. 47. Median cross-sections of the dorsal cup of the holotype of *Schistocrinus torquatus* Moore and Plummer, n.sp., the genotype species, showing the large infrabasal circlet and the broad, gently flaring sides of the cup. *a*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR). *b*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. (For lpIB in fig. 47b read rpIB.)

infrabasal (IBB) disc is a flattish cog-wheel about 11 mm. in greatest diameter. Four of the infrabasals (IBB) are pentagonal and nearly equal, and their distal extremities are broadly truncated for contact with adjacent radials (RR). The right posterior infrabasal (rpIB) is hexagonal and slightly larger than other plates of this disc. An extra facet is introduced for its junction with the radianal (RA). The basals (BB) are arrow-shaped. The sutures adjoining the radials (RR) are slightly curved and a little longer than the others; the average length and width being about 3.5 mm. The radials (RR) are hexagonal, but because the width of the facets is a little less than the greatest width of these plates, the upper corners appear truncated, giving an octagonal outline. The average width is 11 mm. and the length is 6.5 mm. The outer face is gently convex transversely, nearly plane and regularly flaring longitudinally. The articular facets are relatively broad, about 6 mm. from outer to inner margin and distinctly less than the greatest width of the plate. Adjacent facets are divided by a trough-like furrow 1.0 to 1.5 mm. in width. The external ligament area is very short, slightly less than 1 mm. long in its central part and narrowing toward the sides. A slit-like ligament pit, about 2 mm. in width, occurs centrally at the inner margin. The transverse ridge is distinct but not prominent, straight, about 7 mm. long, and disposed so as to intersect the curving sharp outer lip of the plate at a distance of 2 or 3 mm. from the interradial sutures. The inner part of each facet is nearly plane and shows very faint interarticular ligament and muscular fossae, and a long, narrow intermuscular notch or furrow. The facets slope outward at an angle of about 30 degrees.

The anal series comprises four plates of which only the radianal (RA) forms a really essential part of the cup. The radianal (RA) is pentagonal but appears unevenly quadrangular. It rests on the posterior basal (pB) and on the right posterior infrabasal (rpIB), touches the left posterior radial (lpR), and is broadly in contact above with the right posterior radial (rpR) and with the principal anal (x). The principal anal (x) is very large, nearly twice the size of the radianal (RA), and its length is nearly twice its width. Only about one-fifth of its lower portion is below the upper angles of the posterior radials (RR). Only the lower tip of the right tube plate (rt) extends below the upper angle of the right posterior radial (rpR). It is almost as large as the principal anal (x) and is much longer than wide. A large tube plate rests on the principal anal (x) and on the right tube plate (rt). The holotype shows fragments of additional tube plates above those already described.

Discussion.—This crinoid does not resemble closely any described species, but is to be compared with other new forms from Kansas, Oklahoma, and Texas. One of these, *S. planulatus*, n.sp., is much flatter than the genotype species.

Occurrence.—Dennis limestone, about 2 feet above base of Winterset limestone member, Bronson group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 4603, outcrop in sec. 29, T. 49 N., R. 31 E., near U. S. Highway 40, east of Kansas City, Missouri.

Type.—Holotype, Kansas University no. 46031; collected by J. M. Jewett.

SCHISTOCRINUS CONFERTUS Moore and Plummer, n.sp.

Pl. 2, fig. 8; pl. 5, fig. 1; text fig. 48

Description.—The crown of this species is somewhat like an hour-glass in form, owing to the manner in which the upper part of the arms converge beneath the expansion of the summit of the anal sac. The dorsal cup is very low, discoid in form, and nearly flat across the base; some specimens appear to have a broad, shallow basal concavity, but this is found to be due to deformation. The arrangement of the infrabasals (IBB), basals (BB), and radials (RR) is normal for the genus, the infrabasals being in contact with the radials and separating the basals in practically all cases. The posterior interradius is strongly elevated, and the plates in this part of the cup are rather unusually large and thick. The radianal (RA) is in contact with the right posterior basal (rpB), and some specimens show clearly a contact between the radianal (RA) and the right posterior infrabasal (rpIB). The principal anal (x), which is unusually large, rests on the distal extremity of the posterior basal (pB); the right tube plate (rt) and another plate of the anal series that rests about equally on the x and rt plates are both large. These plates on the posterior side of the cup form a pyramid that appears not to have been merely a portion of the anal sac, for there are no marks of contact with other tube plates, the two sides of the pyramid being also rather smoothly confluent. The thickness of the plates under discussion is approximately equal to their width. They are joined firmly together.

The lower parts of the arms are almost perfectly preserved in several of the types, and at least two specimens (especially paratype M-10) show enough of the upper parts of the arms, as well as the lower, to permit accurate determination of their structure. Each ray branches isotomously on the first primibrach (IBr_1), on the second secundibrach ($IIBr_2$), and again on the third to fifth tertibrach ($IIIBr_{3-5}$); above this point there is further bifurcation only in the two outermost and the two innermost branches of the ray, or, stated otherwise, the outside branches of each of the two half-rays may be subdivided as many as three times above the axillary tertibrachs, but the other arms do not bifurcate. This produces a bi-endotomous type of arm structure. The brachials (Br) are uniserially arranged and quadrangular in form; those in the lower branches have a width that is more than twice their

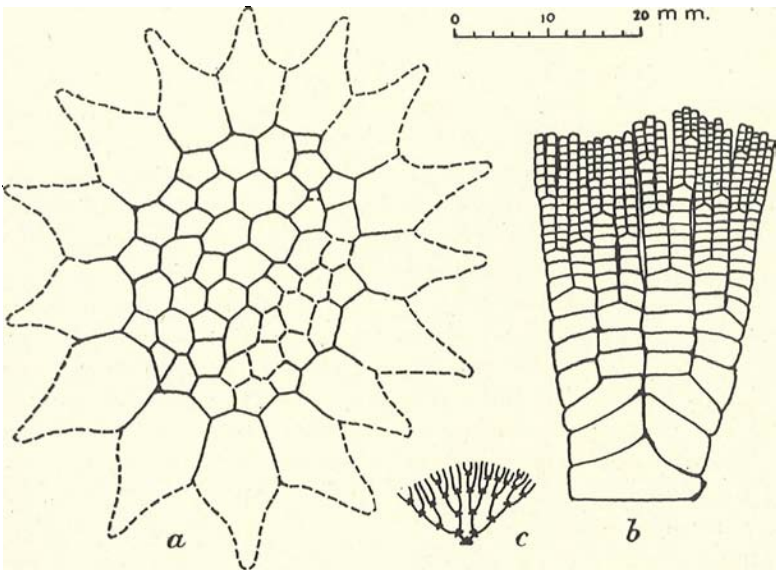

Fig. 48. Drawings of *Schistocrinus confertus* Moore and Plummer, n.sp. *a*, Top of the anal sac, as shown in paratype H–6; the outer edges of the spine-bearing plates are restored. *b*, Arm structure of a ray (composite diagram made from the study of different parts of three rays, since no one ray is completely shown). *c*, Sketch to indicate plan of branching in a ray.

length, but in the slender upper branches the width of the brachials is about equal to the length. The arms are distinctly rounded on the dorsal side. Slender pinnules are observed in several of the types, and locally there appear to be two pinnules attached to each of two or three successive brachial segments, thus indicating hyperpinnulation.

The mushroom-like anal sac is preserved in the largest of the types (H–6), but the laterally projecting spines that fringe the summit are broken off. Some of these spine-bearing plates are shown by the holotype and are especially well preserved in paratype M-26. The width of the summit portion of the sac, including the border of spines, is at least 60 mm., as indicated by paratype H-6. The central part of the top of the sac in this specimen is covered by some 45 irregular polygonal plates that fit closely together. Other examples in which the top part of the crown is preserved are so flattened that characters of the sac are not determinable from them.

Measurements of the holotype and two paratypes, in millimeters, are as follows:

	Holotype	Paratypes	
		M-10	M-13
Height of dorsal cup	3	3?	3
Greatest width of cup	26	25	27.8
Ratio of height to width	0.12	0.12	0.11
Diameter of stem	3?	?	5.4

The height of the crown in paratype H-6 is about 56 mm., and its greatest width, at a point one-third above the base, is about 45mm. The diameter of the expanded summit of the anal sac in this specimen is 40 mm., and the estimated original diameter, with spines, is about 60 mm. The height of the crown in paratype M-10 is about 54 mm., and the width of the flattened specimen at one-third of the height is 39 mm.

Discussion.—Four nearly complete crowns, collected by Mrs. G. W. Harris, of Waco, and ten cups and crowns collected by Mrs. W. R. Marrs, of Austin, form the basis for recognition of this species. These specimens show constant features among themselves and supplement one another in several ways. The plan of the arms in *S. confertus* appears to be the same as that in *Neozeacrinus* Wanner, but the arms are more delicate in the forms classed as *Schistocrinus.* The low broad crown and wide discoid form of the dorsal cup, and the large strong plates of the posterior interradius, also, furnish characters that readily distinguish this species. The cup is much broader and more evenly rounded than in *S. planulatus,* n.sp.

Occurrence.—Brannon Bridge limestone member, Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183-P-14, about 3 miles southwest of Brock, Parker County, Texas.

Types.—Holotype, Harris Collection no. H–3; paratypes nos. H–5, H–6, and H–10; collected by Mrs. G. W. Harris, Waco, Texas. Paratypes, Marrs Collection nos. M–10, M–11, M–12, M–13, M–14, M–20, M–26, M–29, M–38, and M–43; collected by Mrs. W. R. Marrs, Austin, Texas.

SCHISTOCRINUS PLANULATUS Moore and Plummer, n.sp.

Pl. 7, fig. 8

Description.—An incomplete crown, which is here described, is the first observed example of *Schistocrinus* giving information concerning the arm structure. The dorsal cup is complete, although a few of the plates in the posterior region are slightly dissociated. The cup is a low, flat-bottomed disc with sides that slope gently to the sharp angle at the summit of the radials (RR).

The distinctive features of each circlet of plates, as described for this genus, are well shown. The sutures between the infrabasals (IBB) and radials (RR) are slightly less than 2 mm. in length. Each of the small basals (BB) has a length of about 2.4 mm. and width of 2 mm.; they are shaped like a broad spearhead, subtriangular in outline. The radials (RR) are broad, gently curving plates, 8 mm. wide and 6 mm. long. The articular facets have not been observed.

The lower arm plates of all but one of the rays are visible, showing an axillary first primibrach (IBr_1), followed by one or two quadrangular secundibrachs (IIBr), and then an axillary plate in each of the two isotomous divisions of the ray. Beyond this point the branches become very slender and are formed of quadrangular uniserial segments with a length about equal to their width. At least one or two additional isotomous divisions occur in this part of the crown, but the exact structure is not satisfactorily determinable from the type specimen. No pinnules are observed.

The arrangement of anal plates is as in *S. torquatus*, n.sp., with the principal anal (x) nearly twice as large as the radianal (RA).

The measurements of the dorsal cup of the holotype, in millimeters, are as follows:

Height of cup	3.0
Width of cup	16.5
Ratio of height to width	0.18
Diameter of stem	4.0

(Since one or two segments of the stem remain in the stem impression it is not possible to determine its depth.)

Discussion.—This species is characterized chiefly by its broad, flat base and by its distinctly smaller relative height as compared with *S. torquatus*, n.sp. The cup is narrower and the sides more sharply rounded than in *S. confertus*, n.sp.

Occurrence.—Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, road corner 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Harris Collection no. H–8; collected by Mrs. G. W. Harris, Waco, Texas.

SCHISTOCRINUS PARVUS Moore and Plummer, n.sp.

Pl. 19, fig. 1; text fig. 49

Description.—A very perfect, though slightly distorted crown furnishes the basis for recognition of this species. The height of the crown, about 21 mm. in the holotype, is a little greater than the width, about 17 mm., and is a little below the summit of the anal sac. The dorsal cup is low bowl-shaped, without basal concavity, and about one-third as high as wide. The infrabasal circlet is small, the plates are horizontal in position, and because of direct contact with the truncated tips of radial plates there are corresponding truncations of some of the infrabasals. The basal plates are reduced in size, as is typical of the genus, subtriangular in outline, and inclined outward more than upward; the posterior basal (pB) is larger than the others and truncated distally for contact with anal x. The radials slope evenly with little longitudinal curvature; their width is about twice the length. Three anal plates, apparently normal in position, occur in the dorsal cup, but the radianal is not well shown. The surface is smooth.

Almost all the arms are preserved to their distal extremities. They are composed of uniserial segments and show clearly the mode of branching. Isotomous division takes place on the first primibrachs, and two additional forks occur in each of the primary and secondary branches. The bifurcation of the inner branches in each ray tends to be a little higher than that of the outer branches. The segments of the lower part of the arms show faint irregularities of the surface that tend to be arranged in longitudinal lines; these become distinct below the mid-height of the arms, and in the upper half of the crown the brachial segments are seen to be marked by a prominent median line running longitudinally, and less distinct lines parallel to the main one. Moderately stout pinnules are seen, and at two points there is indication of hyperpinnulation, for two pinnules appear to be borne on one side of individual brachials. The evidence, however, is not definite enough to establish satisfactorily the occurrence of hyperpinnulation in *Schistocrinus* as well as in *Neozeacrinus*.

A hydreionocrinid type of anal sac is represented by the occurrence of a ring of spade-shaped sac spines that project laterally above the arm tips, and inside this ring are several small polygonal plates that form part of the summit of the anal sac. There are about twelve of the spines, some larger than others; the tips of a few

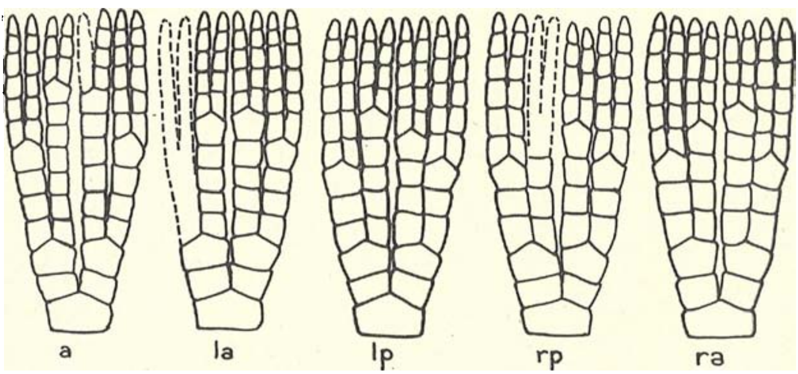

Fig. 49. Diagrams showing the arm structure in *Schistocrinus parvus* Moore and Plummer, n.sp., showing the isotomous division of the rays (a, anterior; la, left anterior; lp, left posterior; rp, right posterior; ra, right anterior).

are broken, but others appear to show a very blunt, short spine and a relatively long flat base.

Measurements of the holotype specimen, in millimeters, are as follows:

Height of crown	21.0
Width of crown	17.0
Height of dorsal cup (approximate because of distortion)	3.0
Width of dorsal cup (approximate)	8.0
Diameter of stem	2.0
Diameter of summit of anal sac, about	16.0
Length of basal	1.8
Width of basal	2.2
Length of radial	2.5
Width of radial	4.5

Discussion.—This species is distinguished from other known examples of *Schistocrinus* by its small size and by the longitudinal ridges on the brachial segments. The arms are relatively longer and more slender than in *S. confertus*, n.sp.

Occurrence.—Brannon Bridge limestone member of the Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); at Loc. 183–T–14, at the road intersection about 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Marrs Collection no. M–6; collected by Mrs. W. R. Marrs, Austin, Texas.

Genus SCIADIOCRINUS Moore and Plummer, 1938

Sciadiocrinus MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 275.

This genus includes crinoids with very low, discoidal dorsal cups that have a wide, gentle or strong basal concavity, which affects not only the infrabasal (IBB) circlet but all the basals (BB) and the proximal tips of the radials (RR).

The five infrabasals form a regular pentagon, generally almost covered by the round stem. The five basals (BB) are downflaring and are not visible in a side view of the dorsal cup, except the distal part of the posterior basal (pB).

The five radials are very convex in longitudinal profile and are in contact with the basal plane of the cup. The facets are slightly less than the width of the radials (RR), and a small notch appears at the summit of the interradial sutures. The slope of the facets is outward at a distinct angle. The three anal plates in the dorsal cup are normal in some species, with radianal (RA) on the right posterior basal (rpB) and the principal anal (x) on the posterior basal (pB). In others, the radianal (RA) is not in contact with the right posterior basal (rpB), and the principal anal (x) is separated from the posterior basal (pB). The anal sac is prominent, mushroom-shaped, and its expanded top is surrounded by a fringe of outspreading spines. The anal vent is at about mid-height on the anterior side of the sac.

The arms are composed of uniserial, quadrangular segments, branching isotomously on the first primibrach (IBr_1), the second secundibrach ($IIBr_2$), and the third to sixth tertibrachs ($IIIBr_{3-6}$), and somewhat irregularly at higher points. They are rather short and do not extend above the anal sac.

Genotype.—*Hydreionocrinus acanthophorus* Meek and Worthen (text fig. 50).

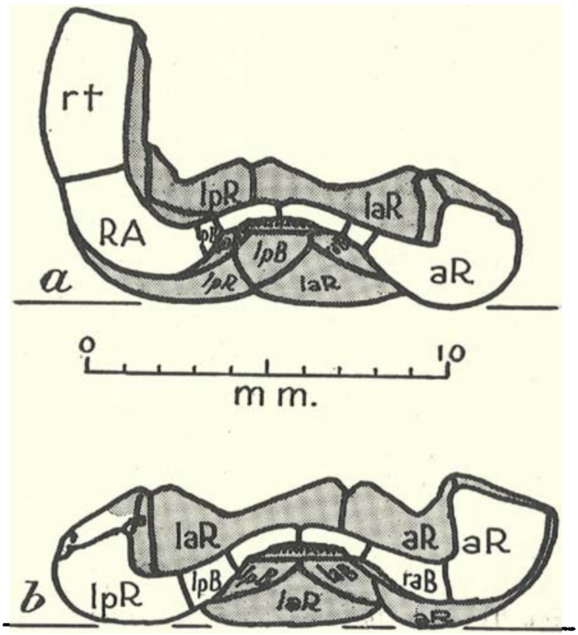

Fig. 50. Median cross-sections of the dorsal cup of the holotype of *Sciadiocrinus acanthophorus* (Meek and Worthen), the genotype species, showing the broad and moderately deep form of the basal concavity and the down-flaring basals (BB) and proximal part of the radials, which are not visible in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

Discussion.—The genus *Sciadiocrinus* is distinguished by the character of its dorsal cup and arms. The cup is like that of *Pirasocrinus*, n.gen., but the arms are quite different. The form of the cup, but not the character of infrabasals (IBB) and the basals (BB), correspond to *Adinocrinus* Kirk. *Sciadiocrinus* differs from *Aatocrinus* in that no part of the basals (BB) is visible from the side.

Occurrence.—Pennsylvanian (Upper Carboniferous); North America.

SCIADIOCRINUS DISCULUS Moore and Plummer, n.sp.

Pl. 10, fig. 5; text fig. 51

Description.—The dorsal cup is low discoid, subpentagonal in outline, and the dorsal side is characterized by a broad, shallow, central concavity, surrounded by the discontinuous ring of bulbous radials (RR). The posterior interradius is relatively narrow, sloping obliquely upward, and it has a definite but not strong concavity indenting the outline in the line of the radials (RR).

The infrabasal (IBB) circlet is covered almost entirely by the circular stem, the impression of which in the cup is surrounded by a low rim from which distal extremities of the infrabasals (IBB) flare slightly upward. The basals (BB) slope gently but distinctly downward as they extend outward from the infrabasals (IBB), and, excepting a tiny portion at the tip of one or two, they are not visible in the side view of the cup. The proximal portions of the radials (RR) are downflaring and form part of the basal concavity, but in the distal region the slope is very steeply upward. The radial facets are slightly less than the maximum width of the radials (RR), and they slope outward at a moderate angle. The outer ligament area is narrow and sharply defined by an outer fine ridge and by the thin, straight, transverse ridge. The ligament pit is deep and occupies about two-thirds of the width of the outer ligament area. The inner ligament area is broad and shows a well-defined, obliquely placed pair of ligament fossae, a central triangular depression next to the transverse ridge, and a strong V-shaped inter-muscular furrow which, however, is marked only on the surface of the facets.

The arrangement of plates in the anal series is normal with the radianal (RA) in contact narrowly with the right posterior basal (rpB), and the principal anal (x) rests on the truncated distal tip of the posterior basal (pB). Above the principal anal (x) and right tube plate (rt) there are two tube plates, the upper edges of which show clearly that additional plates of the ventral sac were formerly attached to them.

Measurements of the holotype, in millimeters, are as follows:

Height of cup	3.7
Maximum width of cup	17.8
Ratio of height to width	0.21
Height of basal concavity	1.3
Diameter of stem impression	3.1

Discussion.—Although the concavity of the base of the dorsal cup in this species is less pronounced than is normal in *Sciadiocrinus,* little question is felt in the generic assignment. The distinguishing features of the species are the relatively gentle concavity, the strongly bulbous form of the radials (RR) and the comparatively narrow, moderately depressed posterior interradius. *Schistocrinus confertus,* n.sp., has a relatively shallow basal concavity but is a

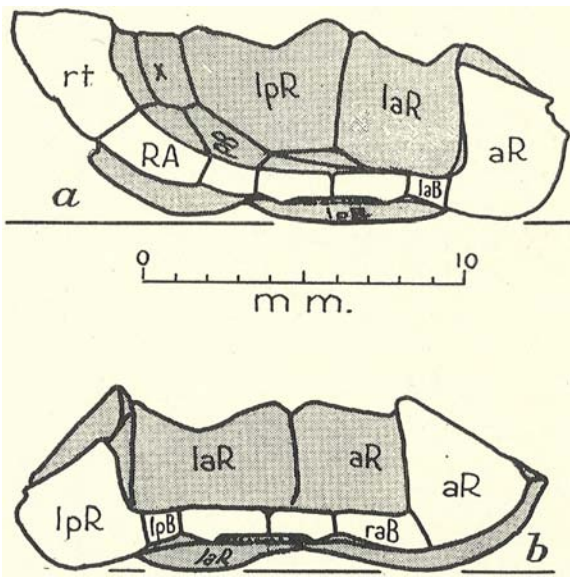

Fig. 51. Median cross-sections of the dorsal cup of the holotype of *Sciadiocrinus disculus* Moore and Plummer, n.sp., showing the unusually shallow basal concavity and the horizontal and downward-flaring basal plates, which are not visible in the side view of the cup. *a,* Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b,* Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

much larger form, and its radials (RR) are relatively straight in longitudinal profile. *Sciadiocrinus acanthophorus* (Meek and Worthen) has a distinctly deeper basal concavity, and plates of the anal series are relatively much larger.

Occurrence.—Merriman limestone, Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–31, about 2¾ miles in direct line northwest of Graford, Palo Pinto County, Texas. A dorsal cup that is practically identical with the holotype except for the slightly deeper basal concavity comes from beds classed as belonging to the Mineral Wells formation, Strawn group (Des Moines series); Loc. 153-T-23, 2½ miles east and 2½ miles north of Rochelle, McCulloch County, Texas.

Type.—Holotype, Walker Museum no. 31495; collected by F. B. Plummer. Paratype, King Collection no. K-507, Bureau of Economic Geology, The University of Texas; collected by Ralph King.

SCIADIOCRINUS HARRISAE Moore and Plummer, n.sp.

Pl. 16, figs. 7, 8; text fig. 52

Description.—Recognition of this species is based on 16 excellent specimens of the dorsal cup, all of which are characterized by low height, presence of a broad but strongly marked basal concavity, and swollen appearance of the radials (RR).

Almost all the infrabasal (IBB) circlet is occupied by the stem impression, which is gently concave with raised rim; each infrabasal (IB) bears about 11 fine radial grooves and as many ridges at the edge of the stem impression. The distal extremity of the infrabasals (IBB) is slightly upflaring. The basals (BB) are nearly equal, except the posterior basal (pB), which is much longer and narrower than the others. The plates are pentagonal in outline, but appear to be nearly triangular, with length approximately equal to their width. They are gently curved in longitudinal profile and flare downward throughout their length, are not visible in side view of the cup and nearly straight transversely. The statements just made do not apply to the posterior basal (pB), however, which curves upward distally and can be seen in the posterior view of the dorsal cup. The radials (RR) are pentagonal and strongly bulbous, the proximal portion forms part of the basal concavity, but the outer face stands nearly vertical. The basal plane of the cup is tangent to the midlength of the radials (RR), whereas the infrabasals (IBB) and the basals (BB) are well above the basal plane. Some of the radial facets are equal to the maximum width of the radials (RR), but others are slightly less than this greatest width, so that an offset occurs at the junction of the facets. The slope of the facets is at a gentle angle outward; the transverse ridge is straight and sharp but not elevated and constitutes rather an angulation between the inner and outer ligament areas. The outer ligament area is divided into inner and outer fossae by a medial ridge and is distinctly marked off from the face of the radial plates by a fine ridge. The inner ligament area is obscurely differentiated into paired oblique pits and areas of muscle attachment. Some of the facets show a distinct intermuscular furrow, but there is little or no notch at the inner border of the facets. The posterior interradius is narrow and slightly to rather strongly depressed. The radianal (RA),

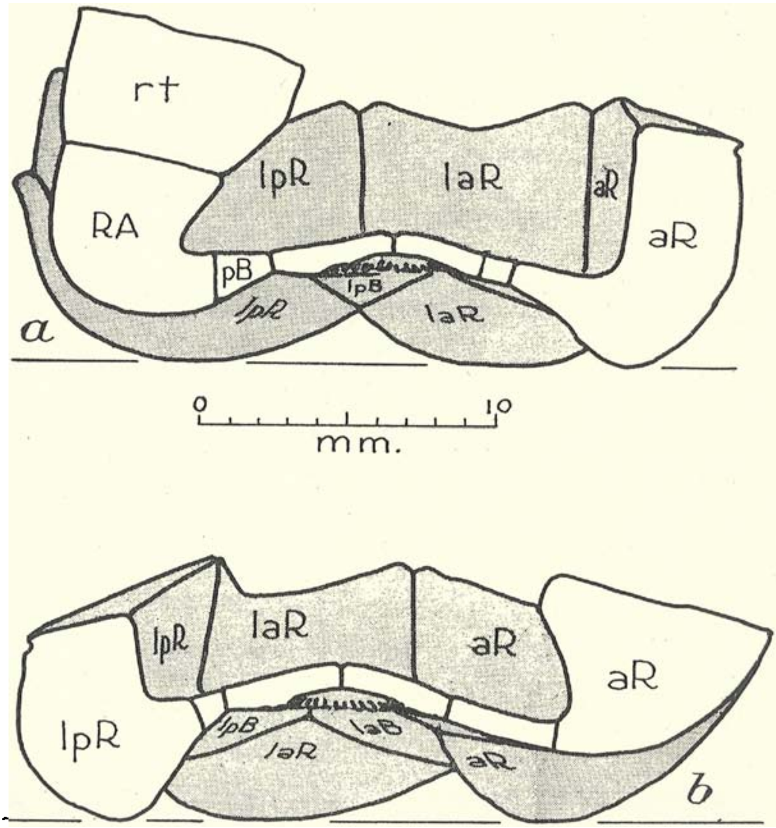

Fig. 52. Median cross-sections of the dorsal cup of the holotype of *Sciadiocrinus harrisae* Moore and Plummer, n.sp., showing the form and depth of the basal concavity and the downward-flaring attitude of the basal plates, which are not visible in the side view of the cup. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

as characteristic of the genus, is very long and narrow, extending in most specimens to the lower left margin of the right posterior basal (rpB) and nearly touching the circlet of the infrabasals (IBB); distally it adjoins the principal anal (x) which rests on the narrowly truncated end of the posterior basal (pB). The proximal tip of a third plate, the right tube plate (rt), barely extends below the summit of the right posterior radial (rpB). The outer faces of the principal anal (x) and the right tube plate (rt) are approximately vertical. Three specimens from among the lot from northeastern Oklahoma show abnormal arrangement of the anal plates in that the radianal (RA) does not touch the right posterior basal (rpB); in two of these specimens, furthermore, the radianal (RA) has migrated upward so that it touches the left posterior radial (lpB), separating the posterior basal (pB) and anal x plates.

The surface of the cup appears smooth, but examination of most specimens under a microscope shows that there is a fine granulose ornamentation, which is best preserved in the basal depression near the stem and in the depressed areas along sutures between the radials (RR).

Measurements of two specimens, in millimeters, are as follows:

	Holotype M-45	Paratypes 6026c	45897	45897a	45897b
Height of cup	7.4	6.2	4.4	4.6	4.5
Greatest width of cup	29.5	27.5	24.2	18.9	24.0
Ratio of height to width	0.25	0.23	0.18	0.24	0.19
Height of basal concavity	4.5	2.7	4.8	2.6	4.0
Diameter of stem impression	5.0	5.8	3.9	2.7	3.8

Discussion.—This species shows typically the characters of the dorsal cup of *Sciadiocrinus* as observed in the genotype, *S. acanthophorus* (Meek and Worthen). An unfortunate and rather obvious error appears in the figure of the base of the cup of *S. acanthophorus* as published by Moore and Plummer[63] in that the radianal (RA) is omitted. Just as in most specimens of *S. harrisae* this plate lies along all of the right border of the posterior basal (pB), extending to the right posterior basal (rpB). The basal concavity is generally somewhat shallower in *S. harrisae* than in the genotype species, and the cup of the new species is distinctly larger and deeper. Slight but distinct differences in the shape of the plates also make discrimination easy.

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[63]Moore, R. C., and Plummer, F. B., Upper Carboniferous crinoids from the Morrow subseries of Arkansas, Oklahoma, and Texas: Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 275, fig. 23d, 1938.

A spine-bearing primibrach plate is lodged on the summit of the holotype specimen of *S. harrisae* but this is believed to be adventitious, belonging to some entirely different form. The presence of this type of spine in a species of *Sciadiocrinus* has not been observed, but more significant in the present species, is that the spine in question is very much narrower than the radial facets of the specimen against which it is lodged.

Occurrence.—Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous). Holotype from Loc. 110–T–3, about 4½ miles east-northeast of Lipan, Hood County, Texas. Paratype, 6026C, from Loc. 110–T–4, north side of Kickapoo Creek, one-quarter mile below Kickapoo Falls, southwest of Dennis, Hood County, Texas. Paratypes, M–31 and M–32, from Loc. 183–T–14, about 3 miles southwest of Brock, Parker County, Texas. Paratypes, 45897 and 45897a–k, from the Oolagah limestone at Garnett quarry, 7 miles northeast of Tulsa, Oklahoma.

Types.—Holotype, Marrs Collection no. M–45; collected by Mrs. W. R. Marrs. Paratype, Scott Collection no. 6026C, Texas Christian University; collected by Gayle Scott. Paratype, Marrs Collection nos. M–31, M–32, collected by Mrs. W. R. Marrs, Austin, Texas. Paratypes, Stevens Collection no. 45897, Kansas University, nos. 45897a–k in Bob Stevens private collection; collected by Bob Stevens.

Genus PIRASOCRINUS Moore and Plummer, n.gen.

The crown is tall, relatively slender, and widest at the height of the axillary secundibrachs (IIAx). The total height is about three times the greatest width; the isotomous branching takes place at uniform heights in each ray. This and the strongly bulbous nodose character of the axillary brachials, produces a pagoda-like, turretted appearance. Horizontally placed sac spines spread outward above the arm tips at the summit of the crown.

The dorsal cup is very low truncate, bowl-shaped, or discoid, with strongly concave base. Except at the posterior side, only the radials (RR) are visible in the side view of the cup. The height of the cup is only about one-fifteenth that of the crown, and because the axillary primibrachs (IBr) are considerably more bulky than any plates of the cup and project considerably beyond the outer edges of the radials (RR), the dorsal cup appears a relatively insignificant part of the crown. The five infrabasals (IBB) are entirely, or almost entirely, covered by the stem, at the base of the deep central concavity, so that it is difficult to determine whether all are present. The five basals are subequal and strongly downflaring throughout their entire length, and all are pentagonal except the posterior basal (pB) which is hexagonal and truncated distally for contact with the principal anal (x). None of the basals (BB) are visible in side view of the cup except, in some specimens, the distal tip of the posterior basal (pB). The five radials (RR) are moderately convex transversely and extremely convex longitudinally, the proximal parts sloping very steeply into the basal concavity and the distal parts forming the subvertical sides of the cup. The circlet of radials (RR) is interrupted on the posterior side by the intervention of three anal plates in normal position. An elongate radianal (RA) lies parallel to the posterior basal (pB) and narrowly touches the right posterior basal (rpB), a large principal anal (x), and the right tube plate (rt). The former touches the distal tip of the posterior basal (pB). Another large anal plate, well above the summit of the radials (RR), occurs above the principal anal (x) and right tube plate (rt) and is in contact laterally with the secundibrachs (IIBr).

The arms are long, rounded exteriorly, branching isotomously at regular intervals, and composed of uniserial, quadrangular segments that are much wider than long. The axillary brachials (Br) are also bulbous and much thicker than the succeeding segments. Each ray branches typically four times, so that at the top of the crown there is a maximum of 80 slender branches. The first three divisions of each ray are very uniform, but the fourth is less regular; some branches are apparently undivided above the third dichotom. Slender pinnules are borne by at least the upper arm branches. All observed specimens show the arms lying parallel and closely adjoining.

The anal sac is formed of relatively strong plates and rises to the summit of the crown. It is roofed by a few broad plates that project laterally in the form of spines.

The stem is round.

Genotype.—Pirasocrinus scotti Moore and Plummer, n.sp.

Discussion.—The distinctive features of the arm structure, as described in *Pirasocrinus,* correspond closely enough to those of *Adinocrinus* Kirk to raise strong presumption of relationship. The genotype of *Adinocrinus, A. nodosus* (Wachsmuth and Springer), occurs in lower Mississippian strata. It resembles *Pirasocrinus* in having a basal concavity in the dorsal cup, relatively very large radials (RR) and arms of essentially similar structure; but it differs in the much shallower depth of the basal concavity, in having greatly reduced basals (BB) that are not laterally in contact, and in the distinctly less differentiated character of the axillary brachials (Br). The upper Mississippian (Chester) species, *Adinocrinus compactilis* (Worthen), which on the basis of structure of the cup and branching of the arms appears rightly regarded hy Kirk as a typical representative of *Adinocrinus*, is closer to *Pirasocrinus* than is *Adinocrinus nodosus*. This is shown by very close correspondence in the appearance of the arms and the normal unspecialized arrangement of the anal plates, with the principal anal (x) in contact with the posterior basal (pB) and the radianal (RA) adjoining the right posterior basal (rpB). The anal plates of *A. nodosus* are pushed upward so that the principal anal (x) is rather widely separated from the posterior basal (pB). The arms of *A. nodosus* may be regarded as more advanced than are those of *Pirasocrinus* in having distinctly cuneate brachials, but in another direction the lesser differentiation of axillaries shows less specialization. Reduction in size of the basals (BB) and the upward shift of the principal anal (x) are evolutionary modifications not shown in *Pirasocrinus*. Taking account of the geologic occurrence of the forms discussed, and weighing the significance of the similarities and dissimilarities that have been noted, it can not be concluded that *Pirasocrinus* is directly descended from *Adinocrinus*. Rather, it appears strongly probable that these genera are derived from a common ancestor occurring in lowermost Mississippian or older rocks.

The dorsal cup of *Pirasocrinus* resembles that of *Sciadiocrinus* in that only the radials (RR) are visible in side view of the cup except from the posterior side. The basal concavity of the cup in *Sciadiocrinus*, however, is generally much less pronounced, and the basals (BB) are less strongly downflaring. Although both genera have isotomously branching arms composed of uniserial segments, the plan of the branching in the two genera is quite different above the primibrachs (IBr). In *Sciadiocrinus*, the branching occurs uniformly on the second secundibrach ($IIBr_2$) instead of on the sixth secundibrach ($IIBr_6$) or on the seventh secundibrach

($IIBr_7$) as in *Pirasocrinus,* and the position of the next branching is also different.

Occurrence.—Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Texas.

PIRASOCRINUS SCOTTI Moore and Plummer, n.sp.

Pl. 5, figs. 2–4; text fig. 53

Description.—Recognition of this species is based on five specimens, each of which shows the dorsal cup and attached arms. All have been deformed somewhat by pressure, but the smallest one has a nearly perfect, undistorted dorsal cup. A large crown that, in addition to characters of cup and arms, shows the nearly intact summit of the anal sac, is selected as the holotype. The other specimens are paratypes.

All the features described in the definition of the genus *Pirasocrinus* apply to this species, which at present is the only one known. The proportions of the dorsal cup, the shape of the brachials, the smooth surface, and the four broad-based, laterally directed spines that, without intervening small plates, unite to form the roof of the anal sac, may be regarded as specific characters. The large plates of the posterior interradius are possibly distinctive. The radianal (RA) is an unusually long and narrow plate that is strongly curved longitudinally; besides its contact with the right posterior basal (rpB), at least two of the specimens indicate that the narrow lower extremity of the radianal (RA) may touch the circlet of the infrabasals (IBB). The length of the radianal (RA), measured along its curvature, is 10 to 11 mm. in the larger specimens, and its greatest width is about 3 mm. The principal anal (x) is a large convex plate in which the width, about 7 mm., more nearly equals the length, about 9 mm.

The brachials, except axillaries and the segments next above them, are unusually short and wide, and the sutures between them are parallel. The primibrach axillaries are very bulbous, but smoothly rounded and not spinose. The axillary plates which belong higher on the crown, however, are both bulbous and spine-bearing. In most specimens the spines have been broken off or been weathered away, and the diameter of the spine is shown by the round scar. These markings, and remnants of spines several millimeters in length, show that the spines are relatively slender, and they rise, nipple-like, from the rounded surface of the axillary that closely resembles a tumid breast.

Measurements of several specimens, in millimeters, are given below:

	Holotype	Paratype P–8190	Paratype P–8199	Paratype K.U. 60262
Height of crown	75	83	70[a]	----
Height of dorsal cup	5.5	7.2[a]	5.4	4
Width of dorsal cup	27[a]	29[a]	26[a]	17.5
Height of basal cavity	7.7[a]	8.2[a]	7.5[a]	5.1
Width of basal cavity	18[a]	20[a]	17.5[a]	12
Diameter of stem	4.5	---	-	4

[a] Approximate because of distortion; computed from measurements and from comparison with paratype Kansas University 60262.

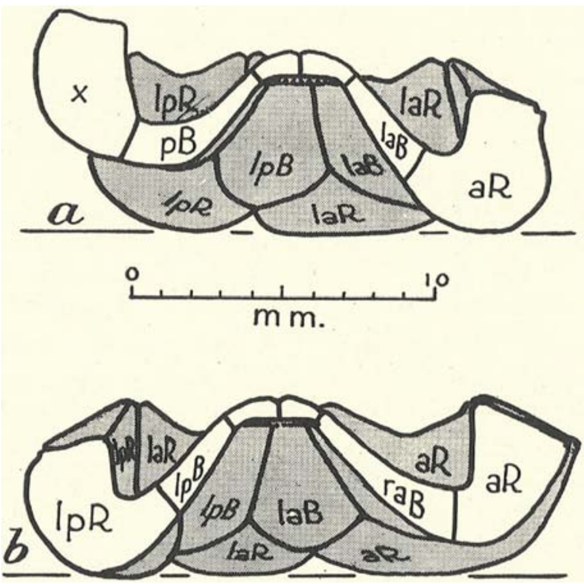

Fig. 53. Median cross-sections of the dorsal cup of the holotype of *Pirasocrinus scotti* Moore and Plummer, n.sp., the genotype species, showing the broad, very deep basal concavity, the basal plates and the proximal part of the radial plates being invisible in the side view of the cup. The height of the posterior basal (pB) and of other basals (BB) above the basal plate is also shown. *a*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *b*, Section through the center of the left posterior radial (lpR) and the opposite interradius bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR).

Discussion.—The dorsal cup of *P. scotti* somewhat resembles that of *Adinocrinus pentagonus* (Miller and Gurley) from the Missouri series of the Pennsylvanian at Kansas City, ,Missouri, but the basal concavity of the cup is much deeper in the Texas species, and there are readily observed differences in the characters of the basals (BB) and of the anal plates. As already noted, the arm structure of *Pirasocrinus scotti* is very similar to that of *Adinocrinus compactilis* (Worthen) from the Chester of Illinois, but there are differences of generic importance in features of the dorsal cup. The basals (BB) of *A. compactilis* are not laterally in contact, the radials (RR) are much less convex, and the basal concavity less deep than in *Pirasocrinus scotti.*

Occurrence.—Shale below the Kickapoo Falls limestone member of the Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 110–T–4, about one-fourth mile downstream (east) from Kickapoo Falls, southwest of Dennis, Hood County, Texas.

Types.—Holotype, Kansas University no. 60261; paratype, no. 60262; collected by R. C. Moore. Paratypes, Plummer Collection nos. P–8190 and P–8199, Bureau of Economic Geology, The University of Texas; collected by Gayle Scott.

Genus MARATHONOCRINUS Moore and Plummer, n.gen.

The crown is pyriform, and the closely appressed arms flare outward to a maximum width at about two-thirds the height of the crown, above which point they curve inward. The dorsal cup is apparently very low and probably has a central basal concavity. The only definitely identifiable parts of the cup are three radials (RR), which are about twice as wide as long and strongly convex longitudinally; fragments of the lower circlets of plates also appear. Recognition of the genus is based chiefly on peculiarities of the arm structure.

The type shows two nearly complete rays and fragments of others. The branching is exotomous; that is, the branches above the second isotomous division of the rays remain unbranched, whereas the inner ones continue to bifurcate. The arm segments are uniserially arranged and, excepting the axillaries, are quadrangular in outline, with length approximately equal to the width.

Near the base of the arms the brachials (Br) are more or less strongly curved transversely, but in the middle and upper parts of the crown these plates are nearly flat. In the two essentially complete rays the primibrachs (IBr) are axillary. The first secundibrachs ($IIBr_1$) are wide and relatively short segments, and the second secundibrachs ($IIBr_2$) are axillaries, with length about equal to width. The outer branches of these two axillaries in each ray remain unbranched to the top of the crown, but the two inner branches bifurcate again on the second tertibrachs ($IIIBr_2$). The outer branches of these two axillaries, in turn, remain unbranched, but the inner ones may branch at least once again. Sections of numerous pinnules are observable at the top of the crown.

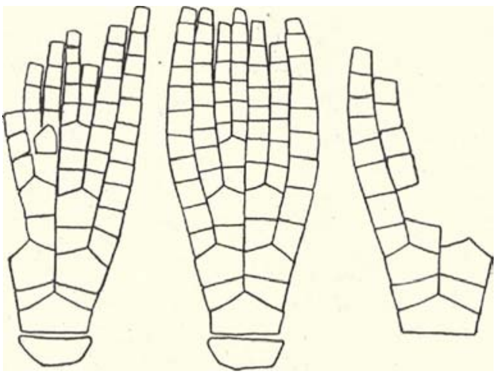

Fig. 54. Diagrams showing the arm structure in three rays of *Marathonocrinus bakeri* Moore and Plummer, n.sp., the genotype species, as shown in the holotype, x1. These arms apparently belong to the anterior side of the crown, but incompleteness of the dorsal cup makes this conclusion uncertain.

The stem and anal sac are unknown. Judging by the form of the crown, it is possible that a bulbous anal sac, much as in *Coeliocrinus*, is present, but this can be only an inference.

Genotype.—*Marathonocrinus bakeri* Moore and Plummer, n.sp.

Discussion.—The arrangement of the branches in *Marathonocrinus* is very clearly different from that in all zeacrinitid genera in which the arms are known, for in these the branching, though heterotomous, is endotomous rather than exotomous, undivided branches being given off on the inside rather than on the outside of the ray. Genera of this endotomous type are *Cercidocrinus* Kirk, *Linocrinus* Kirk, *Xystocrinus* Moore and Plummer, *Eratocrinus* Kirk, *Alcimocrinus* Kirk, and *Zeacrinites* Troost. A few genera with very low, bowl-shaped cups have regular isotomous branching; included here are *Laudonocrinus,* n.gen., *Perimestocrinus* Moore and Plummer, *Piraso-crinus,* n.gen., and *Sciadiocrinus* Moore and Plummer. Heterotomous branching of exotomous type, closely comparable to that described in *Marathonocrinus,* occurs in *Hydreionocrinus* de Koninck, basing definition of this genus on characters exhibited by the genotype species, *H. woodianus* de Koninck. The arms of *Hydreionocrinus,* however, are biserial and there is a mushroom-like anal sac, the top of which is edged by outwardly projecting spines. None of these features, except the mode of branching, occur in *Marathonocrinus.*

The straight sides and closely appressed position of the branches in *Marathonocrinus* are suggestive of the arms in several zeacrinitid genera, but otherwise there is little similarity. The relatively coarse elongate form of the brachials in *Marathonocrinus* clearly indicates a rather primitive form, one that is surely less advanced than *Hydreionocrinus.* These two genera may well have been derived from a common ancestral stock.

Occurrence.—The age of the beds in which this fossil was formed is unknown, but is probably lower Pennsylvanian. The holotype was collected from a limestone block, which is one of many, presumably erratic, blocks in the Haymond formation, of Lower Pennsylvanian age, in the vicinity of Marathon, Brewster County, Texas.

MARATHONOCRINUS BAKERI Moore and Plummer, n.sp.

Pl. 21, fig. 2; text fig. 54

Description.—The holotype, the only known specimen, has the characters described under the genus. It is a fragmentary, slightly crushed and abraded specimen, part of which, however, is fairly well preserved.

This specimen, on which this description has been based, was kindly placed at the disposal of the writers through the courtesy of Prof. Carey Croneis, of the University of Chicago, to whom it was sent by the collector, Prof. C. L. Baker, in whose honor the genotype species is named.

The measurements, in millimeters, are as follows:

Height of crown	43
Maximum width of crown	36

Occurrence.—Erratic? block in Haymond formation,, lower Pennsylvanian (Upper Carboniferous); exact locality not recorded. In vicinity of Marathon, Brewster County, Texas.

Type.—Holotype, Walker Museum no. 44295; collected by C. L. Baker.

Genus ZEACRINITES Troost, 1858

Zeacrinites TROOST, 1850, Am. Assoc. Adv. Sci., Proc., vol. 2, p. 61 (*nomen nudum*).

Zeacrinites TROOST, 1858, in Hall, Iowa Geol. Survey, vol. 1, pt. 2, p. 543.

Zeacrinus Troost (part), WACHSMUTH AND SPRINGER, 1879, Revision of Palaeocrinoidea, pt. 1, p. 125; 1886, idem, pt. 3, p. 243.

Zeacrinus (Troost) Hall (part), SPRINGER, 1926, U. S. Nat. Mus. Proc., vol. 67, art. 9, p. 77.

Zeacrinus Troost, KIRK, 1938, Washington Acad. Sci., Jour., vol. 28. p. 160.

Zeacrinus Troost (part), SUTTON AND HAGAN, 1939, Jour. Pal., vol. 13. p. 84.

NOT *Zeacrinus* (Troost), HALL, 1858, Iowa Geol. Survey, vol. 1, pt. 2, p. 544.

NOT *Zeacrinus* Troost, MEEK AND WORTHEN, 1860, Illinois Geol. Suivey, vol. 2, p. 186.

NOT *Zeacrinus* Hall, MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 267.

This genus belongs to a group of crinoids that have very low, truncate, bowl-shaped dorsal cups, with a strongly concave base and three anal plates below the top of the radials. They have closely set, uniserial arms, whose inside members branch repeatedly. The branches, for the most part, are short, wide, and quadrangular. The anal sac is well developed pyramidal or club-shaped and does not rise above the summit of the arms. It does not have a mushroom-like distal expansion, like that of *Hydreionocrinus* and *Sciadocrinus*.

The genus is characterized by the shape of its arms, all the branches of which originate from the inner side of the main branches of each ray. The radial plates (RR) have close lateral junctions and well-defined but moderate outward inclination of the articular facets, which have even summit levels. The decidedly strong, upward extension of thick plates belonging to the anal series is also a typical feature.

According to Sutton and Hagan,[64] who recently restudied species classed as belonging to "*Zeacrinus*," two of the especially significant characters of the genus are occurrence of one or more quadrangular primibrachs below the first axillary plate in the anterior ray, but in no others, and the structure of the posterior interradius which forms a solid upward projection generally composed of several plates.

Genotype.—*Cyathocrinus magnoliaeformis* Owen and Norwood from limestone of Chester age, upper Mississippian, in Tennessee.

Discussion.—Nomenclatural confusion in the designation of this genus has arisen, partly from the failure of paleontologists to follow closely certain applicable taxonomic rules and partly from a latitude or vagueness in concepts of the generic definition. The name *Zeacrinites* was formulated by Troost and included, without any definition, in a catalogue of Tennessee crinoids that was orally made public at a meeting of the American Association for the Advancement of Science in 1849, only a little more than a month before Troost's death. Publication of the mere name for a proposed genus of crinoids, which followed in 1850, has no validity under zoological rules, and accordingly, *Zeacrinites* can not be regarded as established nor credited to Troost as author by reason of this publication. A long manuscript, describing this and numerous other crinoids, had been completed by Troost just before his death, however, and this was turned over to the Smithsonian Institution in 1850 for publication. Troost's crinoids and manuscript were referred to James Hall for review; publication was delayed. As a matter of fact, it was not until 1909, more than a dozen years after Hall's death, that the Troost manuscript came belatedly to be published, with necessary annotations and additions by another author, Wood.[65]

Hall's report on the paleontology of Iowa, which appeared in 1858, contains descriptions of two new species of crinoids that he regarded as congeneric with Troost's manuscript genus *Zeacrinites*,

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[64] Sutton, A. H., and Hagan, W. W., Inadunate crinoids of the Mississippian—*Zeacrinus*: Jour. Pal., vol. 13, p. 85, 1939.

[65] Wood, Elvira, A critical study of Troost's unpublished manuscript on the crinoids of Tennessee: U. S. Nat. Mus. Bull. 64, pp. 1–150, pls. 1–15, 1909.

and he therefore published under Troost's name that author's diagnosis of the genus and description of the species, *Zeacrinites magnoliaeformis* (Owen and Norwood), on which it was founded; a drawing from Troost's specimen, apparently prepared by Hall, was also given. Thus, in 1858, all requirements of zoological procedure in establishment of a new genus were met, and it is clear both that this new genus was given the name selected by Troost, *Zeacrinites*, and that authorship of the genus belongs definitely to Troost. Immediately following this publication—indeed, partly on the same pages—Hall introduces the name *Zeacrinus*, very evidently assuming that this is identical in meaning with *Zeacrinites*. Such a change accorded with custom that was apparently begun by Agassiz[66] in 1836 when, without comment or excuse, he altered the *-crinites* ending of several crinoid genera to *-crinus*. In spite of the general adoption of these changes, they lack validity. There seems to be no doubt that Hall must be regarded as originator of the name *Zeacrinus*, and this name must be dropped as a synonym of *Zeacrinites*, if the species described by him (or the one chosen as type of *Zeacrinus*) is congeneric with *Zeacrinites magnoliaeformis*. Even if Hall's two species are really distinct in generic features from Troost's genotype, the fact that Hall gave no generic diagnosis of *Zeacrinus*, coupled with reasonable certainty that he regarded *Z. magnoliaeformis* as the first-described example of his *Zeacrinus*, and his clear intent to substitute the name *Zeacrinus* for Troost's original term, require acceptance under the Rules (Art. 30f) of the same genotype (*Z. magnoliaeformis*) for both *Zeacrinites* and *Zeacrinus*. Accordingly, *Zeacrinus* must be treated as a synonym of *Zeacrinites*. Kirk[67] has recently pointed out characters that have led him to remove both of the species described by Hall in 1858 (*Zeacrinus elegans* and *Z. ramosus*) to a new genus which he designates *Eratocrinus*, *Zeacrinus elegans* being the genotype.

ZEACRINITES? SELLARDSI Moore and Plummer, n.sp.

Pl. 10, fig. 6; pl. 17, fig. 2; text fig. 55

Description.—The dorsal cup of this interesting and distinctive little crinoid is recognized by its general resemblance to the cups

[66] Agassiz, L., Soc. Neuchâtel, Mém., vol. 1, p. 195, 1836.

[67] Kirk, E., Five new genera of Carboniferous Crinoidea Inadunata: Washington Acad. Sci., Jour., vol. 28, no. 4, p. 165, 1938.

of *Delocrinus*, by the elongate petal-like appearance of the basals (BB), and by its granulose ornamentation. Similarity to species of *Delocrinus* is found in the deep basal concavity and smooth contour of the surface of the cup. The curvature from the central concavity to the base and sides is very regular; and only one anal plate is present below the summit line of the radials (RR), and this plate rests against the posterior basal (pB). The oblique disposition of the suture between the anal plate and the posterior basal (pB), the presence of two other anal plates that reach below the inner edges of the posterior radial facets although not extending below their outer borders, and a general outward inclination of the facets that is distinctly greater than that in *Delocrinus* serve to show that this species belongs to some other genus. It is referred tentatively to *Zeacrinites* because the configuration of the cup is like that of *Z. magnoliaeformis* (Owen and Norwood), the genotype species, and other representatives of this genus, and because of the petaloid form of the basals (BB) which is a typical zeacrinitid feature.

The height of the dorsal cup, measured from the basal plane to the transverse ridges of the radials (RR), is only one-fourth the greatest width, and the height of the basal concavity is nearly four-fifths that of the cup.

The infrabasal (IBB) circlet forms a small concave pentagon at the summit of the basal concavity. It is covered largely by the round stem impression, but the distal parts of the plates extend a short distance beyond it and flare gently downward.

The basals (BB) are about three times as long as wide, elongate petal-shaped, except the posterior basal (pB) which is slightly longer than the others, of nearly equal width throughout, and truncated distally. The proximal parts of these plates slope downward, but near the distal extremities they curve slightly upward so that they are partly visible in side view of the cup.

The radials (RR) are a little wider than long, the sutures bordering the basals (BB) are curved. A small area near the proximal tip of each plate is included in the basal concavity, the adjacent area is tangent to the basal plane, and the distal part curves upward evenly to an arcuate line just below the facet, where the surface bends abruptly to a vertical or slightly inward slope. The outer ligament area of the facet is very short and almost undepressed. It is bordered by an almost imperceptible outer marginal ridge and by a strong, sharp-crested transverse ridge. The inner ligament area is marked by short, shallow fossae near the outer angles. A well-defined small hollow adjoins the ligament pit, and a deep intermuscular notch is present. The triangular muscle areas are moderately elevated, ending laterally in the sharp crest of the lateral ridges, beyond which are steep adsutural slopes.

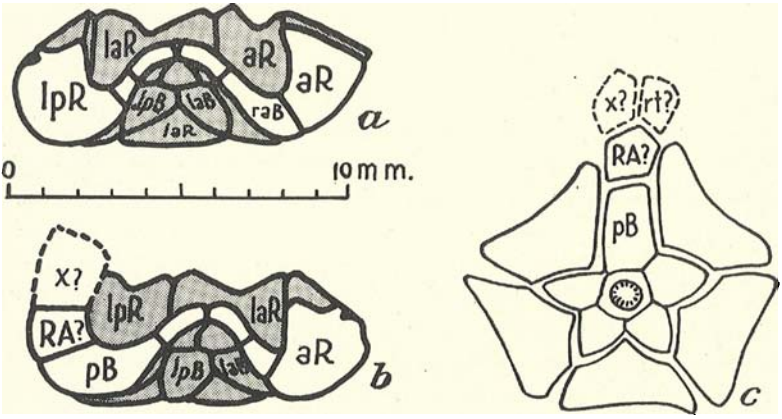

Fig. 55. Median cross-sections (*a* and *b*) of the dorsal cup of the holotype of *Zeacrinites? sellardsi* Moore and Plummer, n.sp., showing the broad, deep basal concavity in which the proximal parts of the radial plates are involved, and (*c*) an analysis of the plates in the cup of this species as indicated by two paratypes. *a*, Section through the center of the left posterior radial (lpR) and opposite interradius, bisecting the right anterior basal (raB) and showing the right sutural face of the anterior radial (aR), the shaded area representing parts beyond the plane of the section. *b*, Median section through the anterior radial (aR) and the posterior interradius, showing the left half of the cup. *c*, Diagram showing the arrangement of plates in the dorsal cup of paratype H–28; the large posterior basal plate is followed by an anal plate, questionably regarded as the radianal, that is laterally in contact with the two posterior radials and projects above their upper edges; the two succeeding plates are drawn from paratype H–29.

The single anal plate that occurs below the top of the radials (RR) rests against the end of the posterior basal (pB), which is truncated at an angle slightly oblique to its axis, not at right angles, as in *Delocrinus*. Probably this plate represents the radianal (RA), for there are notches just above it. at the left and right, that indicate the positions of two other anal plates, presumably the principal anal (x) and the right tube plate (rt). These latter plates have receded upward from the dorsal cup until only a small part of their length reaches below the inner borders of the facets.

Essentially the same features of the posterior interradius are shown by two other specimens of *Zeacrinites? sellardsi* in the Harris Collection (H–28, H–29), probably from the Graford formation of Palo Pinto County. In one of these cups the anal plate that rests against the posterior basal projects well above the summit of the radials, and only one-fourth of the total length of 4 mm. is in the cup. The other specimen, which is somewhat smaller, also shows the first anal plate projecting somewhat above the line of the radials; it is followed above by two elongate anal plates that probably represent anal x and the right tube plates.

The surface is marked by numerous small rounded granules. Otherwise, it is smooth, without any impression of the sutures.

Measurements of the holotype, in millimeters, are given below:

Height of dorsal cup	2.6
Greatest width of cup	11.0
Ratio of height to width	0.24
Height of basal concavity	2.0
Ratio of height of concavity to height of cup	0.77
Length of basal, except posterior basal	5.7
Width of basal	1.9
Length of radial	4.8
Width of radial	6.3
Width of stem impression	1.5

Discussion.—No known Pennsylvanian crinoid is closely similar to this one. *Perimestocrinus impressus*, n.sp., and *Aatocrinus cavumbilicatus*, n.sp., have deep concavities at the base, but they are obviously only very distantly related to *Zeacrinites? sellardsi*, differing especially in the well-marked convexity of the individual plates as well as in their outline. *Alcimocrinus girtyi* (Springer), which was formerly classed as a species of *Zeacrinites* has a broad, very low cup with shallow concavity and is not at all similar to this new species.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, on west slope of Kyle Mountain, Palo Pinto County, Texas.

Type.—Holotype, Plummer collection no. P–10876, Bureau of Economic Geology, The University of Texas; collected by R. C. Moore. Paratypes, Harris Collection nos. H–28 and H–29; collected by Mrs. G. W. Harris.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-1—GROUP b]

SUBGROUP e.—*Cup truncate bowl-shaped; one anal plate in cup.*

The form of the dorsal cup seen in this subgroup has much in common with that of the last subgroup considered. The height of the cup is small as compared to the width, and all genera are characterized by the presence of a distinct basal concavity, which in some forms is very deep. The fact that only one anal plate occurs in the dorsal cup is a less significant character than the form of the articular facets, which are generally equal fully to the width of the radials and which show a less distinctly marked outward slope than the low truncate bowl-shaped cups with three anals.

The number of described genera in this subgroup is not large, and at present only three can be listed among crinoids known from the Upper Carboniferous and Permian rocks of Texas. One of these, however, is *Delocrinus,* which is the most common of all post-Mississippian Paleozoic crinoids. Not only are specimens of *Delocrinus* abundant and widely distributed, both geographically and stratigraphically, but a large number of species can be recognized. There is no one genus of Upper Carboniferous and Permian crinoids that better serves to characterize this part of the section. Another genus of this subgroup is *Graphiocrinus,* to which one species from Texas is referred. It is rare in Upper Carboniferous rocks of the Mid-Continent region. Although found in the Permian of Timor, no example of the genus is known from Permian beds in the United States. This calls attention to need for distinction between *Graphiocrinus* and the small crinoids of comparable form that are now included in the new genus *Apographiocrinus.* The latter, which are fairly common, are believed to differ fundamentally from true *Graphiocrinus* as regards character of the articular facets. A third genus, very closely related to *Delocrinus* but showing certain constant peculiarities that are judged to be significant, is *Endelocrinus,* n.gen. Several species from Texas belong here.

Genus DELOCRINUS Miller and Gurley, 1890

Delocrinus MILLER AND GURLEY, 1890. Cincinnati Soc. Nat. Hist. Jour., vol. 13, p. 9 (Pennsylvanian, central United States).—WANNER, 1916, Paläontologie von Timor, Lief. VI, no. 11, p. 186 (Permian, Timor).

Ceriocrinus WHITE, 1880, U. S. Geol. Geog. Survey Terr., 12th Ann. Rept., p. 127 (Upper Carboniferous, United States).—WANNER, 1924, Jaarb. Mijnw. Ned. Oost-Indië (1921), p. 237 (Permian, Timor).

NOT *Ceriocrinus* KÖNIG, 1825, Icones Fossilium sectiles, p. 10, fig. 127 (London).—AGASSIZ, 1836, Soc. Neuchâtel, Mém., vol. 1, p. 195.—E. DESOR, 1845, Soc. Neuchâtel Bull., vol. 1, p. 215.

This genus comprises the most common group of Pennsylvanian crinoids. The cup is low truncate bowl-shaped, generally with height less than half the width. The base is deeply impressed in the form of a funnel-shaped concavity that involves the proximal part of the basals (BB).

The five infrabasals (IBB) are small, and about one-half or less of their length is covered by the round stem impression; their distal portions flare strongly downward almost parallel to the sides of the stem. The five basals (BB) are nearly equal, with a length about equal to their width, and strongly curved in longitudinal profile. The proximal part slopes strongly downward and forms the outer portion of the funnel-like basal concavity. The median part is tangent to the basal plane of the cup, and the distal part curves upward to form part of the sides of the cup and is commonly nearly vertical near the tip. The posterior basal (pB) is generally slightly different in size and shape from the other plates of this circlet and is generally truncated at the distal end for contact with anal x. The five radials (RR) are subequal and have a width about twice their length. The facets are fully as wide as the radials and moderately long. The lateral ridges are generally prominent and slope gently but distinctly outward. The general plane of the facets is nearly horizontal. A single anal plate, generally elongate hexagonal in outline, occurs between two of the radials (RR), resting on the truncated tip of the posterior basal (pB), or, less commonly, slightly separated from it. Anal x protrudes above the radials in most species.

The arms are biserial, long, and branch only once, evenly, on the first primibrach. Sharp angulations separate the outside of the arms, which is gently rounded, and the sides, which are distinctly flattened, so that the arms fit snugly together in a vertical position.

The anal sac is unknown. It is certainly shorter than the arms and not prominent, probably covered by a leathery integument that is possibly studded by minute calcareous plates.

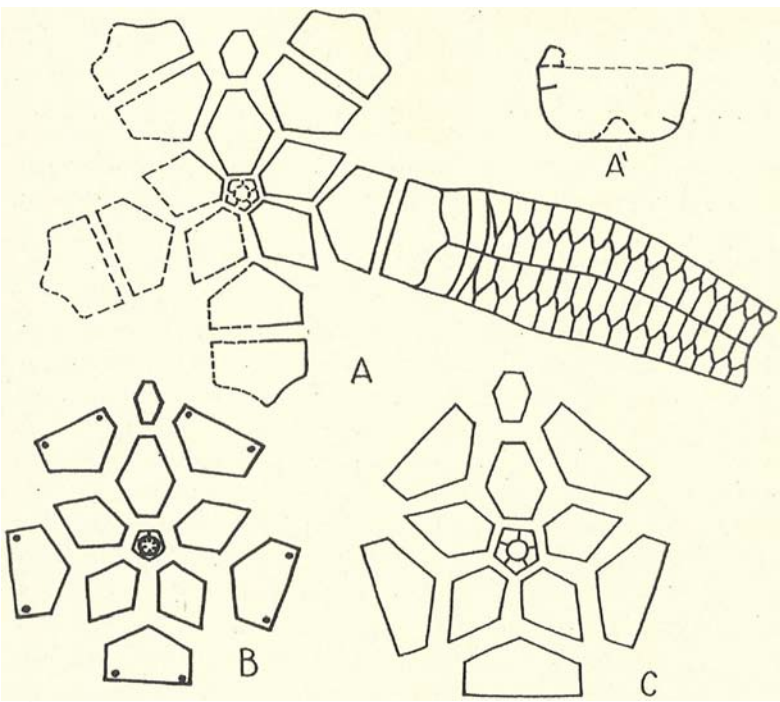

Fig. 56. Diagrams showing the arrangement of plates in three species of *Delocrinus*. A, Plates of the dorsal cup, primibrachs in each ray, and the arms of one ray complete almost to the extremities in *D. pictus* Moore and Plummer, n.sp. A′, Profile of the same species from the posterior interradius (at left) through the anterior radial at right). B, Plates of the dorsal cup in *D. bispinosus* Moore and Plummer, n.sp., showing the two prominent nodes on each radial plate. C, Plates of the dorsal cup in *D. subhemisphericus* Moore and Plummer, n.sp.

Genotype.—Poteriocrinus hemisphericus Shumard.

Discussion.—Some uncertainty is attached to precise definition of *Delocrinus,* since the species selected by Miller and Gurley as genotype was not figured by its author, Shumard, and because the types of the species have been lost, probably destroyed by fire.

Shumard's specimens came from two somewhat widely separated localities in Missouri, one near Columbia and the other near Lexington. Both these localities indicate lower Pennsylvanian beds, the horizon of the type from the vicinity of Columbia being probably somewhat lower (possibly Cherokee) than that from the locality near Lexington (possibly Marmaton).

Miller and Gurley[68] identified specimens that they had obtained from Kansas City as belonging to *Delocrinus hemisphericus*, giving a description and illustrating one of their specimens with an attached long-spined primibrach, and later[69] figuring a complete crown. The figured specimens and another dorsal cup belong to the Gurley collection in Walker Museum, University of Chicago. Examination of the specimens, which have been lent for study, shows beyond doubt that they came from the Lane shale, which has yielded many other crinoidal remains. This is indicated both by the character of the preservation and by comparison with other specimens of the same species from this horizon and locality. It seems almost certain that Miller and Gurley were mistaken in referring their Kansas City crinoids to Shumard's species, for the original description of *Poteriocrinus hemisphericus* mentions a finely granulose surface and refers to two strongly crenulated ridges of the articular facets. Miller and Gurley's specimens, like numerous others in the collection from the Lane shale at Kansas City, are entirely smooth. The transverse ridge of the facet bears denticles, but the outer marginal ridge lacks these. The recorded proportions of Shumard's types correspond closely to the cups under discussion from Kansas City, but this is not sufficient to prove specific identity. Furthermore, most species of Pennsylvanian crinoids have a rather narrow vertical range, and unless contrary evidences are clear, it appears doubtful that these forms from widely separated horizons are the same. Probably most, if not all, the crinoids that have been identified as *D. hemisphericus* do not actually represent this species. Although choice of the genotype

[68]Miller, S. A., and Gurley, W. F. E., Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri and Iowa: Cincinnati Soc. Nat. Hist., Jour., vol. 13, pp. 12, 13, pl. 2, figs. 8–10, 1890.

[69]Miller, S. A., and Gurley, W. F. E., Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri and Iowa: Dept. Geol. Nat. Hist. Survey Indiana, 16th Ann. Rept., pl. 10, fig. 5, 1890.

species for *Delocrinus* is unfortunate, the essential characters of the genus and its validity are not in doubt.

Delocrinus is most closely comparable to *Graphiocrinus* de Koninck and Le Hon, *Aesiocrinus* Miller and Gurley, *Apographiocrinus*, n.gen., and *Paradelocrinus* Moore and Plummer.[69a] All these genera have truncate bowl-shaped dorsal cups, and all but the last have one anal plate in the cup. *Paradelocrinus* is most similar to *Delocrinus* in the form of the cup, although some species lack a strong basal concavity; a difference in the anal plate distinguishes these two genera. *Aesiocrinus* and *Apographiocrinus* have facets that slope inward, unlike those of *Delocrinus*. The arms of *Delocrinus* and *Paradelocrinus* are biserial, and in the other genera mentioned they are uniserial. Also, the axillary primibrach plates in *Delocrinus* and *Paradelocrinus* may be spinose, whereas this is not true of any of the others. *Aesiocrinus* is distinguished by its long anal sac, lack of concavity at the base of the dorsal cup, and pentagonal cross-section of the stem. *Graphiocrinus* has a relatively deeper cup than *Delocrinus* with a shallower basal concavity.

The species of crinoid from Kansas City described and figured by Miller and Gurley as *Delocrinus hemisphericus* Shumard is not the genotype of *Delocrinus*, and, as has been indicated, is apparently entirely distinct from Shumard's species. This Kansas City crinoid is here renamed *Delocrinus subhemisphericus* Moore and Plummer, n.sp.

In the accompanying table the listed species from the Pennsylvanian and Permian rocks of North America have been referred to this genus. Those that are now removed from *Delocrinus* are indicated by an asterisk (*). All measurements are in millimeters.

[69a] A paper by H. L. Strimple (A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, pp. 3-21, pls. 1-3, 1939), which became available for reference after the present report was in proof, contains descriptions of three new genera with truncate bowl shaped form of dorsal cup having one anal plate below the summit of the radials. These genera are called *Moundocrinus* (p. 9), *Pentadelocrinus* (p. 11), and *Luertsocrinus* (p. 13). On the basis of an examination of the types by Mr. Moore, the present authors have no doubt in classing *Moundocrinus* and *Pentadelocrinus* as synonyms of *Aesiocrinus*. *Luertsocrinus* may possibly be valid, for the appearance of the dorsal cup corresponds closely to that of *Erisocrinus*, the obvious difference being the presence of an anal plate below the line of the radials on the exterior of the cup in *Luertsocrinus*. On the other hand no good evidence appears for excluding the single known species of this genus from *Graphiocrinus*.

Species of Delocrinus *from the Pennsylvanian and Permian strata of North America*
(Measurements in millimeters)

Species	Occurrence	Height	Width	H/W	Depth of basal depression	Length of brachial spine	Depth of anal x below top of radials	Notes
**D. allegheniensis* Burke	Conemaugh near Pittsburgh, Pennsylvania	3.9	12.8	0.30	1.6	7.0	1.7	*Endelocrinus allegheniensis*
D. craigii (Worthen)	Middle Pennsylvanian, Vandalia, Illinois	8.1	18.5	0.45	?	9?	2.3	
**D. dubius* Mather	Morrow, Fayetteville, Arkansas	8.0	19.6	0.41	4.2	?	0.0	*Paradelocrinus dubius*
**D. excavatus* Weller	Lower Permian near Shafter, Texas	8.0	19.0	0.42	2.9	?	2.8	*Perimestocrinus excavatus*
**D. fayettensis* (Worthen)		4.2	11.0	0.38	0.8	3.5	2.7	*Endelocrinus fayettensis*
D. megalobrachius (Beede)	Upper Pennsylvanian, Topeka, Kansas	9.3	30.3	0.31	4.0	7.8	4.0	Granulose ornamentation
D. hemisphericus (Shumard)	Lower Pennsylvanian near Columbia, Missouri	7.6	22.8	0.33	?	?	?	Type lost; species not now recognizable
D. inflexus (Geinitz)	Upper Pennsylvanian, Nebraska City, Nebraska	9.2	18.4	0.50	?	?	?	High trapezoidal cross-section
D. major Weller	Lower Permian, near Shafter, Texas	13.7	37.5*	0.36	6.8	?	7.4	Large size trapezoid
D. matheri Moore and Plummer	Morrow, Brentwood, Arkansas	3.6	11.1	0.32	1.3	?	1.8	Very low height

D. missouriensis Miller and Gurley	Middle Pennsylvanian, Kansas City, Missouri	5.5	17.0	0.32	2.0	?	2.1	Pentagon cross-section
**D. monticulatus* Beede	Upper Pennsylvanian, Topeka, Kansas	——	——	——	——	——	——	*Ethelocrinus monticulatus*
D. nodulifer Butts	Middle Pennsylvanian, Kansas City, Missouri	10.0	20.5*	0.49	2.5	8.0	3.0	Large rounded nodes
**D. pendens* Moore and Plummer	Morrow, Brentwood, Arkansas	——	——	——	——	33.5	——	Spines only, *Acantharthropterum pendens*
**D. pentanodus* Mather	Morrow, Ft. Gibson, Oklahoma	——	——	——	——	——	——	*Utharocrinus pentanodus*
**D. planus* White	Pennsylvanian, 30 mi. W. of Humbolt, Kansas	4.1	11.4	0.36	——	——	——	*Paradelocrinus planus*
**D. texanus* Weller	Cibolo ls., Permian, Shafter, Texas	7.3	29.6	0.25	2.2	?	3.3	*Endelocrinus texanus*
D. nodosarius Strimple	Middle Pennsylvanian, Bartlesville, Oklahoma	9.0	21.0	0.23	?	?	4.0	Elongate, nodose ornamentation
**D. tumidus* Strimple	Middle Pennsylvanian, Bartlesville, Oklahoma	——	——	——	——	——	——	*Endelocrinus tumidus*
D. conicus Boos	Lower Permian, southern Kansas	15.5	3.0	0.52	?	0.0	7.0	High straight-sided cup
D. somersi (Whitfield)	Pottsville, Lower Pennsylvanian, Hocking County, Ohio	4.0	16.5	0.24	?	?	?	Granulose and nodose ornamentation
D. rugosus (Shumard)	Lower Pennsylvanian, Putnam County, Missouri	8.0	23.0	0.35	?	?	?	Irregular nodes. Not figured; type lost

*Average width.

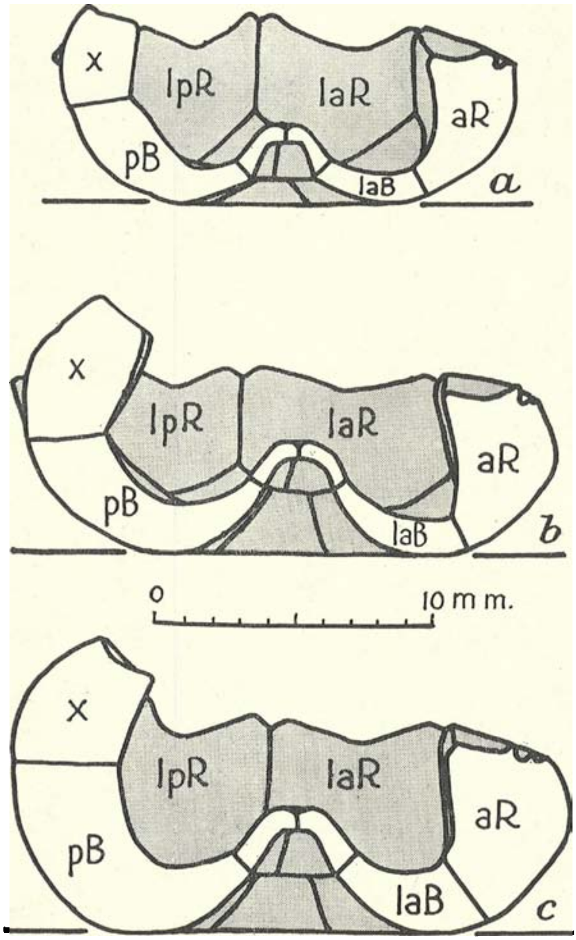

Fig. 57. Median cross-sections of the dorsal cups of two species of *Delocrinus* through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *a*, Holotype of *D. missouriensis* Miller and Gurley, showing the low height of the proximal margin of the basals (BB) above the basal plane and the angulation between this circlet and that of the infrabasals (IBB). *b*, *c*, Paratypes of *D. subhemisphericus* Moore and Plummer, n.sp. (Walker Museum no. 6234, University of Kansas no. 45444), showing the relatively deep basal concavity, which is more than half formed by the proximal parts of the basals (BB).

Excluding "*D. monticulatus*" and "*D. pentanodus*," which really belong to genera not closely related to *Delocrinus*, study of the species that have been assigned to this genus calls attention to three distinct groups, which are made the basis of revised generic grouping. These may be indicated as follows.

I. *Delocrinus*, dorsal cup medium to large-sized, with even contour, sutures generally not impressed, arms biserial to the base or nearly so, and x generally resting on the posterior basal (pB) but in some forms slightly separated from it, the basal concavity funnel-like and moderately deep. *D. missouriensis* Miller and Gurley and *D. subhemisphericus*, n.sp., are typical examples (fig. 57).

II. *Endelocrinus*, n.gen., dorsal cup generally small, characterized by the bulbous form of the plates and moderate impression of sutures; commonly, sharp little pits or dimples occur at angles between plates; basal concavity somewhat weaker than in *Delocrinus* and narrower; anal x rests on the tip of the posterior basal (pB), or, rarely, somewhat separated from it. The arms with the lower third composed of uniserial, though somewhat cuneate segments, the upper part biserial. Typical examples are *Endelocrinus fayettensis* (Worthen) and *E. allegheniensis* (Burke) (figs. 62, 63).

III. *Paradelocrinus*, dorsal cup as in *Delocrinus*, except that some species placed here have a much shallower basal concavity, and anal x does not extend below the summit of the radials; the arms are biserial throughout, like *Delocrinus*. Examples are *Paradelocrinus dubius* (Mather) and *P. brachiatus*, n.sp. (fig. 64).

The relationship between these three groups is evidently a close one. The essential plan of the dorsal cup and the arms and the character of the facets are the same, or so nearly the same that one might well feel doubt as to the propriety of designating them as genera, or perhaps even as subgenera. If judgment were based on described species alone, such doubt would be more than justified. The very large collection of delocrinids, which includes many new species, gives support to definition of the groups that have been indicated. It seems well to designate them by names that indicate their delocrinid affiliation and to avoid the objectionable trinomial nomenclature involved in subgeneric classification. Characters that have value for differentiation of species include the shape and proportions of the dorsal cup, including relative depth of the basal concavity, ornamentation of the surface, shape and length of the primibrach spines, and in some forms features of the arms. Although *Paradelocrinus* is defined chiefly on the basis of the absence of anal x from the exterior of the dorsal cup, the extent to which this plate descends below the summit of the radials and whether or not it is in contact with the posterior basal, generally has no value in differentiation of species. This conclusion accords with observations by Wanner[70] on several crinoids from Timor. In several cases where a considerable number of specimens are definitely identifiable as representing a given species, some variation in the shape and position of anal x is almost certain to appear.

DELOCRINUS SUBHEMISPHERICUS Moore and Plummer, n.sp.

Pl. 11, fig. 4; pl. 20, fig. 3; text figs. 56, 57

Delocrinus hemisphericus (Shumard), MILLER AND GURLEY, 1890, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 12, pl. 2, figs. 8–10 (Pennsylvanian, Kansas City, Missouri); 1890, Indiana Geol. Survey, 16th Ann. Rept., p. 335, pl. 2, figs. 8–10, also p. 370, pl. 10, fig. 5 (Pennsylvanian, Kansas City, Missouri).

Ceriocrinus hemisphericus (Shumard), KEYES, 1894, Missouri Geol. Survey, vol. 4, p. 220, pl. 28, figs. 2, 5 (Pennsylvanian, Kansas City, Missouri).

Description.—This species is not represented in collections from the Pennsylvanian rocks of Texas, although it is likely to be found in strata belonging to the lower part of the Canyon group. Description of it is introduced by Miller and Gurley's use of it in erecting their genus *Delocrinus.* It is reasonably certain that their identification of the Kansas City crinoids, illustrated by them as *D. hemisphericus* (Shumard), was an error that until now has been unnoted, and because of this, general conception of the genotype species of *Delocrinus* has been incorrect. Nevertheless, no question arises as to the very typical character of this Kansas City crinoid as an example of *Delocrinus.*

The dorsal cup is low, broadly truncate bowl-shaped, height about one-third of the width, the base marked by a funnel-shaped concavity with height equal to about one-half that of the dorsal cup.

The infrabasals (IBB) form the upper one-third of the height of the basal concavity, and on the inside of the cup this circlet appears as a small steep-sided dome, perforated at the top by a star-shaped opening that corresponds to the central canal in the stem segments. The proximal part of each infrabasal (IB), which is covered by the stem impression, is nearly horizontal. The distal

[70]Wanner, J., Die permischen Echinodermen von Timor: Paläontologie von Timor, Lief. 6, Teil 11, 1916. Die permischen Krinoiden von Timor: Jaarb. Mijn. Ned-Indie, Verh. 1921, Gedeelte 3, 1924.

part flares outward and slopes strongly downward. The outline of the infrabasal (IBB) circlet is a slightly stellate pentagon.

The basal (BB) circlet is distinctly star-shaped, rather than pentagonal in outline. In dorsal view of the cup, the extremities of these plates appear to reach outward almost to the periphery of the cup. The proximal third of each plate flares downward, the middle third is subhorizontal, and the distal third slopes gently upward. The curvature of the basals (BB) in longitudinal profile is nearly uniform throughout, and there is no angulation at the boundary between the infrabasals (IBB) and the basals (BB).

The width of the radials (RR) is approximately twice the length. Their surface is smoothly confluent with adjoining parts of the cup. The longitudinal profile of these plates is strongly curved, but they are not distinctly bulbous. A crescentic area adjoining the facets slopes slightly inward and is flattened or gently concave. The facets are of moderate length, and as a whole slope very gently outward. The outer ligament area is very short but moderately deep and well defined; closely spaced denticles are readily apparent along the sharp-crested transverse ridge; well-defined ligament fossae lie parallel to the ridge on its inner side near each end; the muscle areas are broad subtriangular, slightly sloping areas that are separated by a wide notch and narrow intermuscular furrow; the adsutural slopes of the lateral ridges are steep and sharply differentiated from a somewhat broad flat area along the interradial suture.

The anal plate is characteristically long and narrow, about one-third of its proximal portion reaching below the line of the radials (RR) and having a subvertical surface; the remainder slopes upward and strongly inward. Typically this plate rests on the truncated end of the posterior basal (pB), but in at least two specimens that are entirely normal otherwise, the tip of the posterior basal (pB) and the lower end of the principal anal (x) are both sharply pointed, and they are not in contact. The space between these two plates in one specimen is 3 mm.

The lowest arm plate bears a long, strong, laterally directed spine. These plates are relatively short, and the thickness of the spine at its base is equal to the length of these plates. Two biserial arms are borne by each of the spine-bearing axillary primibrachs just described.

Measurements of Delocrinus subhemisphericus, *in millimeters*

Specimen	H	W	HBC	WBC	WS	HpB	HpB¹	H/W	HBC/H	HpB/HpB¹	dB	pR	dB/pR
Holotype, W. M. 6234	5.8	19.4	3.8*	9.6	2.5	2.5	4.3	0.30	0.65	0.58	9.4	7.0	0.74
Paratype, W. M. 6234	6.4	19.4	3.4	11.4	2.2	1.5	2.7	0.33	0.53	0.56	9.6	6.4	0.75
45441	5.2	18.0	3.0	10.0	1.7	1.8	2.9	0.29	0.58	0.62	8.0	6.0	0.75
45442	5.8	18.0	4.0	11.0	1.8	2.5	4.1	0.32	0.69	0.61	9.4	6.2	0.66
45443	6.0	17.8	?	10.2	2.4	2.0	3.6	0.34	......	0.56	8.2	5.9	0.72
45444	6.0	20.3	4.0	10.0	2.4	2.4	4.0	0.30	0.67	0.60	9.6	7.0	0.73
45444a	6.2	20.8	3.1	11.8	2.6	2.1	3.6	0.30	0.50	0.58	9.8	6.9	0.71
45445	6.3	20.6	3.7	11.2	2.0	2.0	4.1	0.31	0.58	0.49	9.5	6.8	0.71
45446	6.6	19.1	3.2	9.9	2.0	2.6	3.9	0.36	0.49	0.67	9.4	7.0	0.74
45447	6.8	20.0	?	10.4	?	1.9	4.1	0.34	......	0.47	9.0	6.4	0.71
45448	7.0	21.2	3.8	11.6	2.2	2.5	4.4	0.33	0.54	0.57	10.3	7.7	0.75
45449	7.4	19.6	?	11.7	?	2.5	4.8	0.38	......	0.52	9.4	7.1	0.75
45591	7.6	22.7	3.5	13.0	2.8	2.5	4.2	0.33	0.57	0.60	11.2	7.8	0.70

H. height of dorsal cup
W, width of cup
HBC, height basal concavity
WBC, width basal concavity
WS, width of stem
HpB, height of proximal margin of pB above basal plane
HpB¹, height of distal extremity of pB above basal plane
dB, horizontal distance from center stem canal to distal tip of raB
pR, horizontal distance from center of stem canal to proximal tip of aR
*Approximate, concavity partly filled by stem

Discussion.—This species is readily separated from somewhat similar dorsal cups occurring at lower and higher horizons, for none of these show exactly the proportions or the form of the plates in *D. subhemisphericus*. *D. missouriensis* Miller and Gurley (fig. 57), which also occurs in the upper Missouri series, is distinguished by the shallower basal concavity showing angulation between the infrabasals (IBB) and the basals (BB), and also by the more pentagonal outline of the basal circlet.

Occurrence.—This species is fairly common in the Lane shale, upper part of the Kansas City group, Missouri series, Pennsylvanian (Upper Carboniferous), at Kansas City, Missouri.

Types.—The specimen figured by Miller and Gurley,[71] which is in the Gurley Collection, Walker Museum no. 6234, University of Chicago, is designated as the holotype of this species. The other specimens figured by Miller and Gurley, and also the University of Kansas nos. 45441 to 45449, and 45591, are indicated as paratypes. A majority of the University of Kansas specimens were collected by J. B. Kleihege of Kansas City.

DELOCRINUS BULLATUS Moore and Plummer, n.sp.

Pl. 11, fig. 2

Description.—This crinoid is easily recognized by prominent nodes or bulges located near the center of each radial and on the distal part of each basal. These give the plates a bulbous appearance.

The cup is about twice as wide as high. The basal depression is narrow but prominent, and the surface is smooth, with sutures not impressed. The infrabasals (IBB) are completely concealed by the stem when it is attached to the cup, but about 0.5 mm. of the distal end of these plates is visible beyond the stem impression in the holotype, which lacks the stem. The basals (BB) are twice as long as wide; they bulge near the middle, and are bent inward at the proximal end to form the basal depression. With the exception of the posterior basal (pB) these plates are pentagonal. The radials (RR) are twice as wide as high, and relatively thick, the

[71]Miller, S. A., and Gurley, W. F. E., Description of some new genera and species of Echinodermata from the Coal Measures and Subcarboniferous rocks of Indiana, Missouri, and Iowa: Cincinnati Soc. Nat. Hist., Jour., vol. 13, pl. 2, figs. 8, 9, 1890.

greatest thickness being at the bulge near the center. The surface slopes in all directions from this central spot. The greatest width of the cup is, therefore, not at the summits of the radials (RR), but about at mid-height of the radials (RR). The facets are marked by a prominent curving outer marginal ridge, a short deep outer ligament area, a strong denticulate, straight transverse ridge, which reaches entirely to the margins of the radials (RR), and rather deeply excavated ligament fossae in the inner facet area. The oblique ridge reaches nearly to the median line of the plate.

The first primibrach is triangular-shaped and convex, with the greatest convexity near the center of the plate. The surface of all the plates is smooth.

The measurements of the cup and plates, in millimeters, of the holotype are shown in the following tabulation:

Height of dorsal cup	4.2
Greatest width of cup	11.3
Ratio of height to width	0.37
Width of body cavity	6.6
Width of basal depression	6.9
Diameter of stem impression	1.5
Length of basal	4.4
Width of basal	6.5
Length of radial	4.0
Width of radial	7.2
Length of anal x	2.5
Width of anal x	2.1
Distance of base of anal x below top of radial	1.6
Length of suture between basals	3.3
Length of suture between radials	2.0

Discussion.—This crinoid resembles species of *Endelocrinus*, such as *E. parvus*, n.sp., but is distinguished easily by the nodes or swellings near the central part of the radials (RR) and basals (BB) that are restricted to this part, and there are no sharp, dimple-like hollows at the angles between plates.

Occurrence.—Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–89, about 3 miles southeast of Santo, on Highway 89, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10879, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer and R. C. Moore.

DELOCRINUS BISPINOSUS Moore and Plummer, n.sp.

Pl. 11, fig. 1; text fig. 56

Description.—This delocrinid is distinguished by its small basal depression and characteristic ornamentation in the form of a small but prominent single node at the upper corners of each radial plate. These nodes are placed close to the sutural margins.

The infrabasals (IBB) are entirely concealed by the small stem and by the slight disturbance of the basals (BB). The basals (BB) are diamond-shaped and strongly flexed longitudinally. The radials (RR) are about twice as wide as long and smooth-surfaced except for the two small nodes mentioned above. The facets are marked by a strong denticulate transverse ridge which extends to the margins of the radials (RR). The ligament pit is 1.8 mm. wide or about one-fifth of the width of the outer ligament furrow. The short ligament fossae between the transverse ridge and the inconspicuous oblique ridges are denticulate. The muscle area is smooth and poorly exposed. The arms are unknown.

The surface of the crinoid, except for the marginal spines mentioned above, is smooth.

Measurements of the plates and cup of the somewhat deformed holotype, in millimeters, are given in the following tabulation:

Width of cup (mean of 16.4 and 13.4)	14.9
Width of body cavity (mean of 7.2 and 9.8)	8.5
Width of basal depression (mean of 6.4 and 8.7)	7.5
Depth of basal depression	2.0+
Diameter of stem impression	2.3
Length of basal	8.4
Width of basal	6.6
Length of radial	5.7
Width of radial	8.8
Length of anal x	4.1
Width of anal x	2.9
Distance of base of anal x below summit of radials	2.3
Length of suture between basals	4.0
Length of suture between radials	3.3
Thickness of radials	3.4

Discussion.—The dorsal cup of this species has the general proportions and approximate size of an average specimen of *D. verus*, n.sp., but is readily distinguished from this as well as from other known species by the two rather prominent nodes that occur on each radial.

Occurrence.—Upper part of the Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–43, about one-fourth mile northwest of Union Hill school, which is about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10885, Bureau of Economic Geology, The University of Texas; collected by R. C. Moore.

DELOCRINUS BENTHOBATUS Moore and Plummer, n.sp.

Pl. 11, fig. 8

Description.—This robust delocrinid has a wide truncate bowl-shaped cup with smooth surface, about 2.5 times as wide as high, with a depressed base. The infrabasals (IBB) are entirely concealed in the holotype, which is compressed at right angles to the antero-posterior axis. The basals (BB) are long, narrow, and all except the posterior basal (pB) are spearpoint shaped. The posterior basal (pB) plate and the single anal plate are hexagonal, with narrow bases and tops. The radials (RR) are nearly twice as wide as long, and are characterized by an abrupt inward curvature near the facet that makes a shelf-like shoulder.

The primibrachs are unusually short and wide, bluntly pointed, without a spine, and more nearly quadrate than triangular-shaped. The primibrachs of the right and left anterior rays are distinctly shorter than the other three. The arms are biserial, stout, and fairly long, and their greatest width is at the broken distal end. Approximately the upper quarter of the arms is broken off. The attached portion measures about 28 mm., and the diameter of each arm at the broken distal ends is 6.5 mm. At the base of the branch the diameter is 4.7 mm. The wider and flatter upper portion of the arms is apparently not due to crushing of the specimen, for this character also appears on arms that have the outer surface at an angle to the direction of compaction. This is, therefore, a peculiarity of the species.

Average and approximate measurements of the cup and principal plates of the somewhat deformed holotype (P–6915), in millimeters, are as follows:

Height of dorsal cup	7.5
Greatest width of cup	18.1
Ratio of height to width	0.41
Depth of basal cavity	3.0
Width of basal depression	9.4
Diameter of stem impression	1.7
Length of basal	10.5
Width of basal	7.8
Length of radial	6.5
Width of radial	11.4
Length of anal x	4.8
Width of anal x	3.0
Distance of base of anal x below top of cup	2.5
Length of suture between basals	7.2

Discussion.—This rather unusual delocrinid is distinguished chiefly by the shelf-like projection near the top of the radials, smooth surface, short non-spinose primibrachs, and thick robust arms. The dorsal cup most closely resembles that of *D. verus*, n.sp., but is more robust, differently shaped, and shows dissimilar appearance of the plates.

Occurrence.—The holotype was collected from the East Mountain shale of the Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, at the east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–6915, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer. Incomplete dorsal cups that are referred to this species with some doubt are no. P–1758, also from Loc. 181–T–2, and no. K–504a, from the Mineral Wells formation at Loc. 153–T–23, which is 2.5 miles east and 2.5 miles north of Rochelle, McCulloch County, Texas.

DELOCRINUS GRANULOSUS Moore and Plummer, n.sp.

Pl. 11, figs. 5, 6; pl. 12, figs. 5, 6

Description.—This ornamented delocrinid is known from several dorsal cups, and one specimen belonging to a variety of the species shows the lower part of the arms. Characteristic features of the species, including its varieties, are the low wide form of the cup, which is about three times as wide as high; its wide, deep basal depression; and its fine granulose ornamentation combined with a coarsely noded surface.

The infrabasals (IBB) are very small and are wholly concealed in the basal cavity. The proximal portions are covered by the round stem impression, and the distal portions are inflected sharply to form walls of the cavity. The basals (BB) are large, convex, and diamond-shaped, except for a short truncation at their proximal end and a truncation on the distal end on the posterior basal (pB). The downward slope of the proximal part of these plates is much steeper than the upward curvature of the distal area. The granulose ornamentation that has been mentioned, which is very well developed on the median and distal part of these plates as well as on the radials (RR), is lacking on the proximal parts of the basals (BB) and on the infrabasals (IBB). The radials (RR) are pentagonal, about twice as wide as long, very gently and evenly convex longitudinally, and slope distinctly inward near the facets. The articular facets are bordered externally by a low but very distinct outer marginal ridge. The outer ligament area is extremely short, very little excavated and marked by a median denticulate ridge. The transverse ridge is sharp-crested and prominent but only weakly marked by denticles. The inner ligament area carries two deep ligament fossae lying subparallel to the transverse ridge near its extremities. The intermuscular notch is broad and relatively shallow. The adsutural slopes are steep, moderately high, and are not separated from the suture by a flattened area.

Anal x is a hexagonal plate that rests on the truncated tip of the posterior basal (pB). In average specimens one-half or slightly more of its length extends below the summit of the radials (RR), but in the holotype more than two-thirds of its length is above the radials; the surface of this part slopes strongly upward and inward.

One of the paratypes (P–6911) of the type form of the species, shows three of the primibrach plates above the radials. That belonging to the left anterior (and presumably also the right anterior) ray is distinctly shorter than the primibrach of the anterior and two posterior rays. The base of these plates appears slightly trapezoidal quadrangular in outline. The vertical profile of the mid-portion shows a short outward and slightly upward slope near the base to a strong node, and above this a steeply upward slope to a second node that is centrally located near the upper margin of the plate. The higher parts of the arms are undoubtedly similar to those seen in the variety *D. granulosus* var. *moniliformis* (P–6922), which are strongly rounded, biserial, and in addition to granulose ornamentation, marked by a node near the pointed tip of each cuneate segment. The features just described appear clearly also in paratypes from Oklahoma.

The surface of all the plates of the cup and arms, excepting the infrabasals and parts of the basals, is marked by very fine, even granulation. In addition, parts of the surface are marked by low rounded tubercles, about 1 mm. across at the base and 0.5 mm. or less in height. Four to six of these protuberances, their slopes marked by granules like those on the general surface of the plate, are arranged in a shallow festoon across the distal part of the radials. These nodes, especially those at the upper angles of each plate, are relatively prominent. Very low nodes, or barely perceptible swellings, are arranged in rows bordering the sutures between the radials and basals, occurring near the margins of both of these plates. This gives a rather strongly impressed appearance to the sutures.

The dimensions of the holotype, in millimeters, are shown in the following tabulation:

Height of dorsal cup	7.3
Greatest width of cup	20.8
Ratio of height to width	0.35
Width of body cavity	10.2
Depth of basal cavity	3.0
Width of basal depression	8.6
Diameter of stem impression	3.1
Length of basals	7.5
Width of basals	8.0
Length of radials	6.0
Width of radials	12.4
Length of anal x	5.4
Width of anal x	3.0
Distance of base of anal x below top of the radials	2.4
Length of suture between basals	4.7
Length of suture between radials	3.0

Discussion.—This species is very readily distinguished from *D. pictus*, n.sp., *D. graphicus*, n.sp., and *D. papulosus*, n.sp., by its fine granulose ornamentation combined with low rounded tubercles or swellings. The examples of this species from the Wewoka formation near Okmulgee, Oklahoma, correspond in every feature, including size, to typical specimens from the Mineral Wells shale in Texas. The description and figures of *Cyathocrinus somersi* Whitfield, from Pottsville beds at Carbon Hill, Hocking County, Ohio, indicate that this crinoid is very probably a species of *Delocrinus,* closely related to *D. granulosus.* The ornamentation of the cup of *D. somersi* consists of closely spaced granules and of coarse rounded nodes, as in *D. granulosus,* but the nodes appear to be distinctly more numerous and crowded in the Ohio species. The dorsal cup of *D. somersi* is relatively wider and lower than that of *D. granulosus,* according to measurements given by Whitfield. The type specimens of *D. somersi* have not been located.

Occurrence.—Most of the specimens representing this species, both the typical form and the two varieties described, were collected from the East Mountain shale of the Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, at the east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. Three paratypes come from the Wewoka formation, just below the dam on the river at Okmulgee, Oklahoma; this horizon is relatively high in the Des Moines series.

Types.—Holotype, Plummer Collection no. P–6913, and paratypes, nos. P–6911, P–10897, K–184, and K–178, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer and Ralph King. Paratypes, Kansas University nos. 60531, 60531a, 60531b (from Wewoka formation in Oklahoma); collected by Ben Taylor, University of Tulsa.

DELOCRINUS GRANULOSUS var. MONILIFORMIS Moore and Plummer, n.var.

Pl. 12, fig. 3; pl. 13, fig. 1

Description.—Four specimens of dorsal cups, two of them with attached portions of the arms, are very readily recognized as belonging to the species *D. granulosus,* n.sp., but they differ sufficiently from the typical form to make separation of them as a variety desirable.

The general proportions and appearance of the dorsal cups are very similar to those of the type form, but the radials (RR) are noticeably less convex, so that very little, if any, inward slope toward the borders of the facets can be detected. The entire surface, except that of the basal concavity, is covered by fine granules, but occurrence of the relatively coarse and rounded tubercles is confined to a single necklace-like festoon around the cup just above mid-height of the radials (RR). In one specimen (P–10898), a single node that is less distinct than those of the row just mentioned, occurs centrally on the lower part of each radial, but there are no nodes or tubercles on the basals (BB), and the sutures between the plates do not appear strongly impressed.

The holotype of this variety shows the lower part of some of the arms to a height of about 13 mm. The primibrachs (IBr) of the two posterior rays and of the anterior ray are slightly but distinctly longer than those of the right and left anterior rays. These plates are not marked by a centrally located tubercle near the lower border of the brachial. In addition to the granulose ornamentation, there is a tubercle at the upper angle of the primibrach (IBr) and near the middle of the arm on each secundibrach (IIBr).

Discussion.—This variety is distinguished primarily on the basis of differences in its ornamentation.

Occurrence.—Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, at east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Types.—Holotype, Plummer Collection no. P–6922; paratypes, nos. P–1758, P–2540, P–10898; all at the Bureau of Economic Geology, The University of Texas.

DELOCRINUS GRANULOSUS var. ZONATUS Moore and Plummer, n.var.

Pl. 11, fig. 3; pl. 12, fig. 2

Description.—One small dorsal cup in the collections shows the granulose ornamentation and the relatively coarse tubercles that are distinctive of *D. granulosus*, n.sp. It is differentiated, however, by peculiarities in the distribution of the tubercles. A horizontally arranged pair of these, more prominent than the others, is located near the center of each radial, and at a distance about twice that between the nodes of the pair is another node at each of the upper angles of the radials. Just beyond the mid-length of the basals (BB) measured from the proximal edges, a horizontal row of three tubercles occurs. The basal circlet is thus marked by a nearly perfect ring of tubercles. The sutures between plates are not impressed.

Occurrence.—Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–2, at east end of Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10894, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS PICTUS Moore and Plummer, n.sp.

Pl. 12, fig. 1; pl. 13, fig. 5; text fig. 56

Description.—Description of this new species is based on a very well-preserved but incomplete crown in which the left side, including four arms and part of the dorsal cup, are lacking. Fortunately, the posterior side is intact, and although the specimen is slightly flattened anteroposteriorly, all essential features are very clearly shown.

The cup is rather low, truncate bowl-shaped, with a moderately depressed base and is made up of the usual number of delocrinid plates, as shown in figure 56. The infrabasals (IBB) are not visible, owing to dislocation of the basals (BB), but, as is typical for the genus, it is evident that they form the bottom portion of a strongly defined funnel-shaped basal concavity.

The basal circlet is represented on the type specimen only by the posterior basal (pB), the right posterior basal (rpB), and right anterior basal (raB), but these are complete, and the proximal portions form part of the sides of the basal concavity. The distal extremities rise on the outer part of cup to slightly above mid-height.

The radials (RR) are about two-thirds as long as wide. The right anterior radial (raR) and parts of the right posterior radial (rpR) and the anterior radial (aR) are missing. The longitudinal and transverse convexity is moderate; a slight bulge appears in the central part of the plate. The upper central one-fourth is slightly flattened or concave, and this part lacks the ornamentation that is prominently shown elsewhere. The principal anal (x) is hexagonal and about twice as long as wide; its lower half is below the summit of the radials (RR), and its base rests on the squarely truncated tip of the posterior basal (pB). The distal part curves gently inward. The primibrachs (IBr) are about as large or slightly larger than the radials (RR), somewhat produced at the middle on the upper margin but not developed as a distinct spine. The primibrachs (IBr) of the posterior rays and that of the anterior ray are distinctly larger (about one-third greater in height) than that of the right anterior ray. The first two or three secundibrachs (IIBr) are quadrangular, uniserially arranged segments, but the remainder of the arms is formed of biserial segments. The greatest width of the arms is about 6 mm. at mid-height, about which they taper evenly. The outer margins of each arm are sharply angulated, and the sides are flat so that adjacent arms fit snugly together. No trace of pinnules is seen.

The surface of the plates of the dorsal cup and of the lower half of the arms is covered by numerous pimple-like granules that are very readily visible to the naked eye. They are circular in outline, 0.2 to 0.3 of a mm. in diameter, and resemble the base of irregularly spaced minute spines set 0.5 to 1 mm. apart, or about 64 in 25 square mm. A narrow zone at the margins of the plates and broader areas adjacent to the articulation between the radials (RR) and primibrachs (IBr) are devoid of granules. The sutures of the cup plates are marked by fine ridges and grooves disposed at right angles to the plate margins; seven of these ridges occur in 1 mm. The segments of the upper arms are smooth, and in the zone where the granulose ornamentation disappears, it is interesting to note that the granules extend farthest upward along the outer margins of the arms.

Measurements of the cup and plates of the holotype (P–1760), in millimeters, are given in the following tabulation:

Height of dorsal cup	6.5
Width of cup (deformed)	15.0
Ratio of height to width	0.43
Depth of basal cavity	1.6
Width of basal depression (deformed)	6.0
Maximum length of basals	9.5
Maximum width of basals	7.8
Maximum length of radials	7.0
Maximum width of radials	10.7
Maximum length of anal x	6.0
Maximum width of anal x	3.7
Maximum length of posterior basal	5.6
Maximum width of posterior basal	10.5
Distance of base of anal x below top of radials	2.7
Length of suture between basals	4.0
Length of suture between radials	3.5
Thickness of radials	3.3

Discussion.—Among described species[71a] of *Delocrinus*, only *D. harshbargeri* (Beede), *D. rugosus* Wanner, and *D. verbeeki* Wanner carry granulose or rugose ornamentation that may be compared with that shown by *D. pictus.*[71b] The first two mentioned species differ materially in shape and size. All occur at much higher horizons than the Texas species, and the shape of the cup and character of ornamentation differ so markedly from *D. pictus* that there is really no reason to compare them closely. Most similar to *D. pictus* is the crinoid described here as *D. graphicus*, n.sp. Because of evident general similarity and occurrence in the same formation, the two were at first thought to be variants of a single species; the decision that the two forms represent distinct species needs corroboration from additional specimens. However, if the differences noted are constant, the two can be separated at a glance. *D. graphicus* has a larger, slightly lower dorsal cup that is ornamented by finer, much more closely spaced pustulose granules. The radials of *D. pictus* are proportionally a little longer (ratio length to width, 0.57 to 0.58) than in *D. graphicus* (0.53 to 0.54), and the former shows a crescentic unornamented concave area next to the facets that is not evident in the latter. Slight differences in the appearance and proportions of the primibrachs are also noted.

Delocrinus rugosus (Shumard), from lower Pennsylvanian strata of Missouri, corresponds to *D. pictus* and other decorated delocrinids in having an ornamented surface. The plates of *D. rugosus* are "thickly studded with short rugae, strong and irregularly disposed, but sometimes with granulae." Since no figures have been published and the types have been lost, Shumard's species is not now recognizable, but it may become so on the basis of topotype specimens.

Occurrence.—This crinoid occurs in the Wolf Mountain shale of the Graford formation, Canyon group (Des Moines series), Penn-

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[71a] *D. rugosus* Wanner, 1916, is a homonym of *D. rugosus* (Shumard), 1858, and the name for the Permian species from Timor accordingly requires alteration. Shumard's species, originally assigned to *Poteriocrinus*, seems undoubtedly to belong to *Delocrinus*, and although the type was not figured and has been lost, it is possible that the species will be established from the topotype specimens. The homonymy was not called to attention until this report was in proof, and opportunity to suggest to Prof. Wanner that he select a new name for this species has not been available.

[71b] Another ornamented delocrinid has been described recently by H. L. Strimple (A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, p. 8, pl. 1, figs. 13, 14, 17, 1939) under the name *Delocrinus nodosarius*, which occurs in the upper Missouri beds of northeastern Oklahoma. *D. nodosarius* is distinguished from the decorated Texas delocrinids here described by the elongate ridgelike form of the nodes on the plates.

sylvanian (Upper Carboniferous); Loc. 181–T–27, at east end of McKenzie (Long) Mountain, Palo Pinto County, Texas.

Types.—Holotype, Plummer Collection no. P–1760, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS GRAPHICUS Moore and Plummer, n.sp.

Pl. 12, figs. 4, 11

Description.—The dorsal cup is truncate bowl-shaped, of medium height, and with a strongly defined funnel-like basal concavity. The holotype is a beautifully preserved, undistorted dorsal cup to which are attached three of the primibrachs (IBr) and a few of the secundibrachs (IIBr). A short length of the stem, consisting of five or six segments, remains attached to the base. Only the tips of the infrabasals (IBB) are visible, deeply within the basal concavity. The edges of this circlet form a slightly stellate pentagon. The basals (BB) slope evenly outward and downward in the proximal region, bend sharply at about mid-length, and flare upward in the distal portion. The posterior basal (pB) is broadly truncated for contact with anal x. The radials (RR) are almost exactly twice as wide as long, the ratio of length to width being 0.53 to 0.54; the two posterior radials (pR) are very slightly narrower than the others. The facets differ somewhat from characters generally observed in species of this genus in that the median ridge of the outer ligament area bears strong denticles throughout its length, and denticles of similar size are prominent on the inner side of the transverse ridge. A very deep and wide intermuscular notch indents the inner margin of the inner ligament area and separates broad nearly smooth muscular areas. Short ligament fossae parallel to the transverse ridge at its ends are moderately depressed and marked by denticles. The adsutural slopes of the lateral ridges are abrupt but low. The general plane of the facets slopes outward at a very low angle.

Anal x is widest at the summit line of the radials; it narrows somewhat downward and rather abruptly upward. The upper part of this plate slopes inward rather strongly.

The outer surfaces of the primibrachs (IBr) flare outward with uniform slope to a point at the middle of the distal margin, but they are not extended to form a spine. The length of the two posterior primibrachs (IBr) is at least one and one-half times that of this plate in the right anterior ray. As in other delocrinids, it is almost certain that the primibrachs (IBr) of the left anterior ray and anterior ray, which are missing, are short and long, respectively.

The surface of all the plates, except a zone about 1 mm. or slightly less in width at the edge of each, is covered by closely crowded, irregularly arranged, sharp-pointed pustules or granules that, in spite of their minute size, are clearly visible to the naked eye. The ornamentation is similar to that of *D. pictus*, n.sp., but is very noticeably finer. Not only are the pustules much smaller in this species, but they are more closely crowded.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.3
Greatest width of cup	23.0
Ratio of height to width	0.32
Height of basal cavity (about)	4.0
Width of basal cavity	6.5
Width of stem	3.0
Length of basal	10.5
Width of basal	9.0
Length of radial	7.2
Width of radial	13.4
Length of anal x	7.0
Width of anal x	4.5
Base of anal x below summit of radials	2.6
Length of suture between basals	7.4
Length of suture between radials	4.5

Discussion.—Comparison of this species with *D. pictus*, to which obviously it is most closely similar, has already been given. The fine pustules of *D. graphicus* are coarser, more widely spaced and more strongly elevated than the granules of *D. granulosus*, n.sp., which in addition is marked by broad but low rounded tubercles.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10748, Bureau of Economic Geology, The University of Texas; collected by W. C. O'Gara.

DELOCRINUS PAPULOSUS Moore and Plummer, n.sp.

Pl. 12, fig. 7; pl. 13, fig. 4

Description.—Description of this species is based on two complete dorsal cups, one of which has been a little compressed vertically. They belong to the group of *D. pictus*, n.sp., as indicated by the pustulose ornamentation, but are not very closely similar to that species. The dorsal cup is broad and low truncate bowl-shaped, with strong basal concavity that has somewhat more than half the height of the cup. The infrabasals (IBB) form a very strongly concave pentagonal disc with slightly stellate margins, about 4.1 mm. across. The distal parts of these plates flare strongly downward but are not vertical. The basals (BB) slope downward and outward in the proximal half, which is smooth and entirely devoid of ornamentation, and flare gently upward in the distal portion. The curvature of the mid-section of these plates, in the area of the basal plane of the cup, is not sharp. The width of each basal equals about four-fifths of the length. Measurements of the radials (RR) along the surface, including the curvature, show a length-to-width ratio in both types of 0.56, but vertical compaction of the paratype makes these plates appear relatively shorter. A crescentic area that is widest at the mid-width of the plates lacks ornamentation. The articular facets show very strongly defined markings, the outer ligament area, containing a deep pit at the center on its inner side, is marked by denticles disposed normally to the narrow, sharp-crested outer marginal ridge. The transverse ridge, also marked by denticles, sags abruptly in the area next to its ligament pit. The outer angles of the inner ligament area carry deep ligament fossae that trend nearly parallel to the transverse ridge. The muscle areas are smooth, rounded elevations, separated by a weak furrow and barely perceptible intermuscular notch. The adsutural slopes are low but very abrupt, bordering a moderately broad flat area along the interradial sutures.

The anal plate x, though apparently quadrangular in outline, is really hexagonal, slightly longer than wide, has one-half its length above the summit of the radials (RR), and slopes slightly inward. This plate has fairly broad contact with the posterior basal (pB) in both the types.

Except for the basal concavity, a narrow belt on each side of the sutures, and the distal margins of the radials (RR), the surface of the cups is ornamented by irregularly scattered, in part distinctly clustered, sharply raised small pustules. These are very much like the markings of the cup in *D. pictus*, n.sp., and *D. graphicus*, n.sp., except that they are coarser, fewer, and much less regularly spaced. A tendency toward grouping of the pustules in rows that border the edges of the basals (BB) may be noted, but this does not appear along the corresponding margin of the radials. The paratype differs slightly from the holotype in the rather definite grouping of the pustules in six node-like areas arranged in a shallow festoon just below the facets.

Measurements of the type specimens, in millimeters, are indicated in the following tabulation:

	Holotype	Paratype
Height of dorsal cup	6.5	5.2[a]
Greatest width of cup	22.0	21.0
Ratio of height to width	0.29	0.25[a]
Width of body cavity	13.0	12.2
Height of basal cavity	4.0	3.5
Width of basal cavity	11.3	11.0
Diameter of stem impression	2.0	2.0
Length of basal	9.8	10.0
Width of basal	8.3	8.0
Length of radial	7.5	7.8
Width of radial	13.4	13.8
Length of suture between the basals	5.7	5.0
Length of suture between the radials	3.6	3.0
Length of anal x	5.0	5.4
Width of anal x	4.0	3.5

[a]Measurement approximate, due to distortion of the cup.

Discussion.—This species is distinguished from *D. pictus*, n.sp., and *D. graphicus*, n.sp., by the readily observed difference in ornamentation. The deep ligament fossae of the facets seen in this species are absent in *D. graphicus*. *D. paucinodus*, n.sp., has a very much smaller dorsal cup marked by fewer and less sharply elevated small nodes.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Types.—Holotype, Plummer Collection no. P–10736, and paratype, no. P–10735, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

DELOCRINUS PAUCINODUS Moore and Plummer, n.sp.

Pl. 13, fig. 2

Description.—This little delocrinid is characterized by its low cup, small size, and nodose sculpture. The cup is truncate bowl-shaped, about three times as wide as high, and has a deep and moderately narrow basal depression. The infrabasals (IBB) are plainly visible around the periphery of the stem impression and bend abruptly downward. The basals (BB) are nearly twice as wide as long, curving downward, outward, and then upward with a nearly uniform convexity. The distal margins of the basals (BB) form the petal-like points of the star-shaped basal circlet. The radials (RR) are comparatively thin and twice as wide as high. The facets are marked by a prominent transverse ridge and short depressed ligament fossae that are separated from the muscle areas by ridges. Anal x rests on the truncated end of the posterior basal (pB) and has about one-half of its length extending above the summit of the radials (RR).

The most significant characteristic of this crinoid is its sculpture. The suture lines separating the plates of the cup are marked by a faint ridge that is plainly visible with the low power of a microscope. The radials (RR) and basals (BB) are ornamented by low, rounded, pimple-like nodes. The nodes vary in size from 0.1 to 0.5 mm. They are irregularly and, in general, widely spaced over the plates, with the greatest concentration and largest nodes near the central portion of each plate. The number of nodes per radial plate varies from 13 to 30, the largest number occurring on the anterior radials and the fewest and smallest nodes on the posterior radials and anal plates. The number of nodes on the basals (BB) ranges from 0 to 5 and they are all placed near the mid-length and distal parts.

The significant measurements of the holotype, in millimeters, are shown in the following tabulation:

Height of dorsal cup	4.3
Width of cup	12.6
Ratio of height to width	0.34
Width of body cavity	6.4
Depth of basal cavity	2.3
Width of basal cavity	6.9
Diameter of stem impression	1.4
Length of basal	7.2
Width of basal	4.9
Length of radial	4.1
Width of radial	8.0
Length of anal x	2.9
Width of anal x	2.2
Distance of base of anal x below top of cup	1.5
Length of suture between basals	3.4
Length of suture between radials	2.6

Discussion.—This little crinoid is easily distinguished from *D. pictus,* n.sp., by its proportionately lower cup and by the absence of the fine, evenly persistent granulations, which cover the plates and arms of that species. It is distinguished from *D. granulosus,* n.sp., by the absence of the fine granulations between the nodes, by the fewer number of nodes on the basal plates, and by the tiny marginal ridge which marks its suture lines. *D. papulosus,* n.sp., also differs from this species in the nature of its ornamentation and appearance of the sutures, as well as in size.

Occurrence.—This crinoid was collected from yellow shale of the Palo Pinto formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 248–T–4, on the west side of Martins Lake, Wise County, Texas.

Type.—Holotype, Plummer Collection no. P–6445, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS WOLFORUM Moore and Plummer, n.sp.

Pl. 12, fig. 9

Description.—Description of this species is based on a well-preserved, nearly complete, undistorted crown. The dorsal cup is broad, truncate bowl-shaped, and lower than in most species of the genus, for the height is less than one-third of the greatest width. The basal depression of the cup is broad and relatively deep. Other characteristic features are the spine-bearing primibrachs and the character of the surface ornamentation, consisting of fine granules and rows of elongate nodes.

The infrabasals (IBB) form a pentagonal disk having a greatest width of 5.8 mm. Most of this disk is covered by the large round stem. The visible distal portion of these plates flares downward only very slightly. The basals (BB) have the outline of a spear-head, except the posterior basal (pB), which is truncated distally for contact with anal x and has a width equal to about three-fourths of its length. The basal circlet has the form of a five-pointed star, or rather, because of the outward curvature of the distal margins of these plates, there is strong resemblance to a five-petaled flower. From their union at sharp angles with the infrabasals (IBB), the proximal parts of the basals (BB) flare downward steeply, but at mid-length they are horizontal and in the distal parts gently upflaring. The outer tips reach less than half the height of the cup. The radials (RR) are about two-thirds as long as wide. From the proximal tips which reach the basal plane, the surface slopes regularly upward to a subvertical position near the facets. The characters of the facet surface are not known because all of them are covered by the arms. Anal x is long and narrow, the lower one-third reaching below the summit of the radials (RR) and the upper two-thirds above this line sloping strongly inward.

The primibrachs (IBr) are relatively short, quadrate in outline, but near the upper margin produced in a strong laterally directed spine. The spines of the holotype specimen have been broken near the arm bases, so that it is not possible to determine their original complete length. The right and left anterior primibrachs are very slightly shorter than the others. Excepting the relatively elongate first secundibrach (IIBr), which is quadrangular in outline, all the remaining arm segments are wedge-shaped and interlocked to form the typical biserial type of arms. The exterior of the arms is rounded near the base, but throughout the middle and distal portions it is distinctly flattened. A sharp angle at the two sides of each arm separate the outer surface from the flattened sides. Near the top of the crown numerous slender, elongate pinnules are visible.

On parts of the dorsal cup and arms, where the surface is best preserved, an ornamentation of very closely spaced minute granules is clearly visible, and it is probable that this type of ornament was originally spread over the entire crown except possibly the basal concavity and middle and upper parts of the arm. In addition to this, the radials (RR) are marked by rather prominent elongate nodes arranged in a row close to the lower edges and parallel to them. The nodes are about 1 mm. wide at their base, and at places they coalesce to form a continuous ridge parallel to the radial basal sutures.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of crown	50.0
Height of dorsal cup	6.2
Greatest width of cup	22.1
Ratio of height to width	0.28
Height of basal concavity	3.0
Width of basal concavity	14.6
Diameter of stem impression	3.8
Length of basal	9.5
Width of basal	7.0
Length of radial	8.3
Width of radial	12.8
Length of anal x	6.2
Width of anal x	2.8
Distance of base of anal x below summit of the radials	2.1
Length of suture between the basals	5.5
Length of suture between the radials	3.7

Discussion.—This delocrinid is distinguished from other described species of the genus by the broad, low form of its cup, its steep outer sides, the wide basal depression, the strongly petaloid form of the basal circlet, and by its ornamentation, including especially the sculpture of the radial plates.

Occurrence.—Graham formation, Cisco group (Virgil series), Pennsylvanian (Upper Carboniferous); Loc. 25–T–47, near an oil derrick, one-half mile south of New Byrds Store, Brown County, Texas.

Type.—Holotype, no. P–11087, collection of Mr. Hugo Wolfe, Stephenville, Texas. Plastotype, Plummer Collection no. P–11087A, Bureau of Economic Geology, The University of Texas.

DELOCRINUS SUBCORONATUS Moore and Plummer, n.sp.

Pl. 17, fig. 1

Description.—The dorsal cup is moderately high, truncate bowl-shaped, with steep sides and deep funnel-like basal concavity. The infrabasals (IBB) form the upper one-third of the basal concavity; the proximal parts are covered by the stem impression, and the distal parts slope downward very steeply. On the inside of the cup the infrabasal cone has a height of 2.5 mm. and rises almost to the level of the radial facets. The basals (BB) are diamond shaped, except for the truncated proximal margins, and have a width of about two-thirds of their length. These plates are very strongly curved in longitudinal profile and slope downward very steeply in the proximal half and upward in the distal half, where the tip reaches slightly more than mid-height of the cup. The radials (RR) slope upward steeply and fairly uniformly. There is a slight angulation near the border of the facets, above which the slope is slightly inward. The facets are marked by a very short outer ligament area, and the inner ligament area with broad shallow intermuscular notch. The adsutural slopes are steep and not separated from the suture by a flat area. About one-third of the length of anal x is below the summit line of the radials (RR); the upper part slopes inward steeply.

The surface is very slightly roughened, but this seems to be due chiefly to a closely adhering, thin film of calcareous deposits on the cup, probably of algal origin. At the upper angles of the radials (RR) there are very distinct nodes of moderate size, and other faint nodes occur along the angulation near the top of the radials (RR), previously mentioned. Two or three distinct nodes occur at the summit line of the radials (RR), crossing anal x.

The arms are unknown.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.5
Greatest width of cup	21.1
Ratio of height to width	0.43
Width of body cavity	10.8
Height of basal concavity	4.4
Width of basal concavity	10.0
Diameter of stem impression	2.5
Length of basal	14.0
Width of basal	9.0
Length of radial	6.7
Width of radial	12.4
Length of anal x	5.2
Width of anal x	3.7
Length of suture between basals	11.3
Length of suture between radials	3.6

Discussion.—This species has a relatively higher dorsal cup with steeper sides and deeper basal concavity than appears in *D. verus*, n.sp., and it is marked further by the nodes near the top of the radials. The nodes of *D. subcoronatus* are smaller than those in *D. granulosus*, n.sp., and the fine granular ornamentation is lacking in this species.

Occurrence.—Keechi Creek member, Mineral Wells formation, Strawn group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–43, about one-quarter mile northwest of Union Hill School, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–1950, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS VERUS Moore and Plummer, n.sp.

Pl. 13, fig. 3

Description.—The dorsal cup is truncate, bowl-shaped, of medium height, with strong funnel-shaped basal concavity that is half or slightly more than half of the height of the cup. The surface is smooth, with even contour and undepressed sutures.

The infrabasals (IBB) are hardly visible if the stem is attached to the dorsal cup. These plates form the top and the nearly vertical sides of the upper half of the basal concavity. Because of the nearly vertical position of the distal parts of the infrabasals, the outer margin of this disc is a slightly stellate pentagon not much larger than the stem diameter in width.

The proximal half of the basals (BB) slopes downward at first steeply and then more gently. A rather narrow belt near the mid-section of these plates is tangent to the basal plane, and the distal parts flare steeply upward and reach about the mid-height of the cup. This circlet is especially characterized by the strong curvature in the mid-section of the plates.

The radials (RR) have a length a little more than one-half their width. In longitudinal profile the lower two-thirds of their length slope steeply upward and outward, and the upper one-third curves slightly inward to the margin of the facets. The facets are proportionately a little longer than in *D. subhemisphericus*, n.sp., but otherwise show entirely similar features. The lateral ridges and adjoining muscle areas slope gently but very distinctly outward. Anal x is typically a hexagonal plate nearly as wide as long; nearly one-half its length extends below the summit line of the radials (RR), and it rests on the truncated tip of the posterior basal (pB). In paratype 60192, this plate is extremely narrow, and although visible externally, really does not enter the dorsal cup, being separated by a space of 3.5 mm. from the pointed tip of the posterior basal (pB).

The arms of this species have not been observed

Measurements of Delocrinus verus, *in millimeters*

	P-2575	(Holotype) P-666	60191	45411	45412
H	5.8	6.3	6.0	7.0	7.0
W	15.8	17.5	16.5	20.6	21.7
HBC	2.4	3.5	2.7	4.1	4.4
WBC	8.4	9.0	9.2	10.8	11.4
WS	2.4	1.8	2.0	2.2	2.3
HpB	2.0	1.7	2.1	2.9	3.0
HpB¹	3.0	3.6	3.5	5.1	3.1
H/W	0.37	0.36	0.36	0.34	0.32
HBC/H	0.42	0.55	0.45	0.59	0.63
HpB/HpB¹	0.66	0.49	0.60	0.57	0.97
dB	7.8	7.7	7.6	8.8	9.0
pR	5.8	6.3	5.8	7.2	7.0
dB/pR	0.74	0.82	0.76	0.82	0.78

H, height of dorsal cup
W, width of cup
HBC, height of basal concavity
WBC, width of basal concavity
WS, width of stem
HpB, height of proximal margin of pB above basal plane
HpB¹, height of distal extremity of pB above basal plane
dB, horizontal distance from center of stem canal to distal tip of raB
pR, horizontal distance from center of stem to proximal tip of of aR

Discussion.—The slightly greater relative height of the dorsal cup and distinctly stronger curvature of the mid-portion of the basals (BB), as well as the average smaller size, separate *D. verus* from *D. subhemisphericus*. Most closely similar to *D. verus* is *D. vulgatus*, n.sp., from the upper Pennsylvanian beds of Harpersville and Virgil age. This is shown by the almost identical proportions of height to width of the cup, steepness of slope of the sides, and similar appearance of the basal and radial circlets in the dorsal and side views. *D. vulgatus* is a distinctly larger species, with basal concavity proportionally a little less broad, with curvature in the median part of the basals less sharp, and the proximal part of the basals reaching less deeply into the concavity.

Occurrence.—Palo Pinto limestone, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–41, abandoned quarry about 3 miles northwest of Salesville and 3 miles southeast of Oran, Palo Pinto County, Texas. Winterset limestone member, Dennis limestone, Bronson group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 4541, near northeast corner sec. 19, T. 26 N., R. 14 E., along highway east of Bartlesville, Oklahoma; same horizon, Loc. 6019, Cedar Hill, 1 mile north of Coffeyville, Montgomery County, Kansas.

Types.—Holotype, Plummer Collection no. P–666, and paratype P–2575, from Palo Pinto limestone, in collections of the Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer. Paratypes 45411 and 45412, from Winterset limestone east of Bartlesville, in collections at the University of Kansas; collected by R. C. Moore and N. D. Newell. Paratypes 60191 and 60192 from the Winterset limestone at Coffeyville, collected by Paul McGuire; types in collection of Paul McGuire.

DELOCRINUS? PEREXCAVATUS Moore and Plummer, n.sp.

Pl. 4, fig. 6; text fig. 58

Description.—A fragmentary crinoid crown from upper Pennsylvanian rocks of western Texas, which is here described, shows characters that separate it readily from any known species, but because the posterior side of the dorsal cup is lacking, generic assignment can not be ascertained definitely.

The dorsal cup is truncate bowl-shaped, very steep-sided and relatively high. A very deep funnel-shaped concavity is present at the base, and the general appearance of the cup is that typical of *Delocrinus.* The infrabasal circlet has the form of a deeply concave, slightly stellate pentagon. It is located at the summit of the basal concavity and forms about one-third of its height. The basals (BB) are very strongly and evenly curved longitudinally, and form a nearly perfect half-circle with tips equidistant above the basal plane of the cup. Their length is slightly greater than their width.

The radials (RR) comprise the nearly vertical upper part of the sides of the cup. They are about twice as wide as long and are only very slightly convex longitudinally. The facets are not visible. The lower part of the arms of three rays are preserved, showing in each a blunt axillary primibrach (IBr) of practically identical height as compared, one with another, followed by uniserially arranged secundibrachs (IIBr) that become increasingly wedge-shaped upward until a biserial arrangement of the arm segments appears, beginning with the seventh or eighth segment.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	8.3
Greatest width of cup	22.0
Ratio of height to width	0.38
Height of basal concavity	5.9
Ratio of height of concavity to height of cup	0.71
Width of basal concavity	12.5
Width of stem impression	3.5
Length of basals	11.8
Width of basals	9.8
Length of radials	7.3
Width of radials	14.0
Length of suture between basals	6.9
Length of suture between radials	5.3
Height of proximal margin of basal	4.0
Height of distal margin of basal	4.0
Ratio of height of proximal to distal margins of basal	1.0

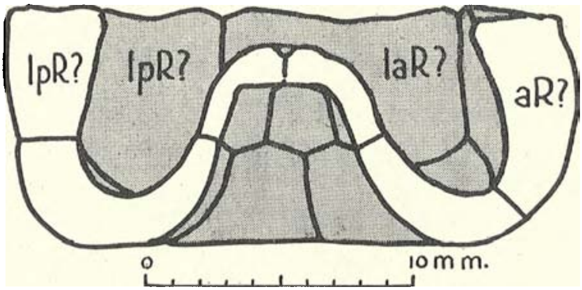

Fig. 58. Median cross-section of the dorsal cup of the holotype of *Delocrinus? perexcavatus* Moore and Plummer, n.sp., showing the unusually deep concavity and the height of the proximal margin of the basal plates equal to that of the distal margin. The section is drawn through one of the radials and the opposite interradial sutures.

Discussion.—This species has a relatively deeper basal concavity than is observed in any other American species of *Delocrinus,* although it is not proportionally as extreme as in *D. excavatissimus* Wanner, from the Permian of Timor, for in that species the infrabasal cone rises above the level of the facets of the radials. The arm structure is like that observed in *Endelocrinus,* rather than in typical examples of *Delocrinus,* but the dorsal cup has none of the characters of *Endelocrinus.* The fact that two adjoining primibrachs (IBr) have exactly the same height, which exceeds that of the third one, suggests that in species with the primibrach (IBr) of unequal size, these two equal plates belong to the posterior rays, for in no other position around the cup are adjacent primibrachs (IBr) the same in height. If the two rays indicated in this manner are actually the posterior ones, no anal plate occurs below the line of the radials (RR). Little weight, however, can be attached to this reasoning because the shortest primibrach (IBr) is only 0.7 mm. less in height than the two others.

Occurrence.—Gaptank formation (*Uddenites* zone), Pennsylvanian (Upper Carboniferous); Loc. 22-T-3, at Wolf Camp, near Marathon, Brewster County, Texas.

Type.—Holotype, in collection of the Humble Oil Company, Midland, Texas; specimen loaned by John Skinner.

DELOCRINUS VULGATUS Moore and Plummer, n.sp.

Pl. 18, figs. 1, 2

Description.—This delocrinid is of medium size and has a perfectly smooth dorsal cup that is somewhat higher than the average for the genus. The sides flare broadly, and the basal concavity is sharply defined, relatively narrow, and equal to less than half the height of the cup. The sutures are distinct but not at all impressed.

The infrabasals (IBB) form a rather small, somewhat stellate pentagon that is strongly concave and mostly covered by the stem impression. The basals (BB) have a fairly regular longitudinal curvature. The line of tangency to the basal plane crosses these plates nearer to the proximal than to the distal margins. The height of the proximal margin above the basal plane is about one-third of that of the distal tip, and this is a diagnostic feature as compared with some other apparently similar species. The posterior basal (pB) is broadly truncated for contact with the principal anal (x).

The radials (RR) are a little less than twice as wide as long. In longitudinal profile they flare strongly outward as well as upward, to a point near the distal margin where their surface is nearly vertical. The appearance of these plates is moderately but not strongly convex. The facets are characterized by the extreme shortness of the outer ligament area, with coalescence of the outer marginal ridge and transverse ridge before reaching the lateral margins of the facets. The inner ligament area is broad, with nearly smooth gently sloping muscle areas divided by a wide, fairly deep intermuscular notch, and with moderately impressed, short, oblique ligament fossae. The adsutural slopes are steep and lead directly to the interfacet sutures.

The principal anal (x) is a longitudinally curved plate with a length equal to about twice its width and nearly quadrangular in outline. The upper half is above the summit of the radials (RR) and slopes inward.

Measurements of the holotype and two paratypes, in millimeters, are given in the following tabulation:

	Holotype P–10325	Paratypes K–1581	P–1502
Height of dorsal cup	7.9	9.1	9.5
Greatest width of cup	21.9	24.0	26.8
Ratio of height to width	0.36	0.37	0.35
Width of body cavity	11.5	12.9	16.0
Height of basal concavity	3.9	3.6	?
Width of basal concavity	9.6	12.0	...
Diameter of stem impression	2.2	2.3	3.6
Ratio of height of basal concavity to height of cup	0.49	0.35	0.37
Length of basals	11.0	12.0	13.6
Width of basals	9.0	10.6	11.3
Length of radials	6.7	7.6	8.7
Width of radials	12.0	13.0	16.6
Length of anal x	6.6	7.2	8.2
Width of anal x	4.4	4.0	4.5
Length of suture between basals	6.3	7.0	9.0
Length of suture between radials	4.2	5.5	5.2

Discussion.—The general proportions of the cup and its outline in side view are almost identical in *D. vulgatus*, n.sp., and *D. verus*, n.sp., but the height of the basal concavity is relatively greater in the latter species, and its ratio of the height of proximal to distal margins of the basals (BB) is approximately twice that of *D. vulgatus*. A study of the significant measurements of the described species of delocrinids with smooth surface indicates that *D. vulgatus* resembles closely *D. missouriensis* Miller and Gurley, although the latter has a much smaller dorsal cup. Distinction between these two species appears in the stronger longitudinal curvature of the basals (BB) in *D. vulgatus* and a lack of a distinct angulation between the basals (BB) and infrabasals (IBB), such as occurs in *D. missouriensis*. *D. vulgatus* occurs at a much higher horizon than either *D. verus* or *D. missouriensis*. Comparison of *D. vulgatus* with the plastotype of *D. inflexus* (Geinitz) and authentic undistorted examples of this higher upper Pennsylvanian species shows that the dorsal cup is distinctly wider and the sides more flaring in this form than in *D. vulgatus*.

Occurrence.—The holotype (P–10325) is from the Saddle Creek limestone near the top of the Harpersville formation (30 feet below the conglomerate), Cisco group (Virgil series), Pennsylvanian (Upper Carboniferous); Loc. 251–T–45, northwest one-quarter sec. 616, T. E. and L. Survey, Young County, Texas. The paratype, P–1502, is from the Harpersville formation, Loc. 214–T–15, about 2 miles north of Breckenridge, Stephens County, Texas. Paratype, Kansas University 4584, is from the Harpersville formation; Loc. 251–T–37, about 4 miles east-northeast of Newcastle, Young County, Texas. The paratypes, Kansas University 45781, 45781a–b, were collected from the Brownville limestone, Wabaunsee group (Virgil series), Pennsylvanian; Loc. 4578, about 7 miles southwest of Strohm, near center NW. 1/4 sec. 10, T. 24 N., R. 6 E., Osage County, Oklahoma.

Types.—Holotype, Plummer Collection no. P–10325, and paratype, P–1502, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer. Paratype no. 4584, Kansas University; collected by Wallace Lee. Paratypes nos. 45781, 45781a–b, Kansas University, Paul McGuire Collection; collected by Paul McGuire.

DELOCRINUS PUEBLOENSIS Moore and Plummer, n.sp.

Pl. 15, fig. 7

Description.—The dorsal cup is truncate bowl-shaped, of moderate height, with a medium-sized basal depression and gently curving sides. The infrabasals (IBB) are visible around the periphery of the stem and bend sharply downward and form a crown-like circlet. The basals (BB) are large, two-thirds as wide as long, have blunt points and nearly straight distal margins. The radials (RR) are proportionally narrow and thick. The facets are marked by a strong, finely denticulate transverse ridge which extends to the lateral margins of the plate. The inner ligament area is marked by a short lateral and a longer marginal ridge, which meet the outer margin of the plate in a V-like form. The intermuscular furrow is distinct, but the notch at the inner margin of the facet is shallow and weak. The short, narrow anal plate is wedge-shaped in the holotype and extends only 1.5 mm. below the summits of the adjacent radials (RR). It is pointed at the lower end and does not touch the posterior basal (pB). The surface of the cup is smooth.

The stem and arms are not preserved, and their characters are unknown.

The measurements of the somewhat deformed holotype, in millimeters, are shown in the following tabulation:

Height of dorsal cup	10.4
Greatest width of cup (24.5–22.2)	23.3
Width of body cavity (12–11)	11.5
Depth of basal cavity	6.7
Width of basal depression (11.9–13.8)	12.8
Diameter of stem impression	3.7
Length of basal	15.8
Width of basal	10.0
Length of radial	8.5
Width of radial	14.4
Length of anal x	5.0
Width of anal x	3.3
Length of suture between basals	11.2
Length of suture between radials	4.8

Discussion.—This early Permian delocrinid is distinguished from the Pennsylvanian members of this genus by the proportions of the dorsal cup, combined with the rounded curvature of the sides. The height of the proximal margin of the basals (BB) above the basal plane of the cup in comparison to that of the distal tips of these plates (ratio 0.27) is comparable to that in *D. missouriensis* Miller and Gurley (ratio 0.29) and *D. vulgatus,* n.sp. (ratio 0.32), but the relative height of the cup is distinctly greater in *D. puebloensis* than in either of these species, and the sides are steeper. The longitudinal curvature of the basals (BB) is more uniform in *D. puebloensis* than in *D. abruptus,* n.sp., and the sides of its cup are more rounded than in the latter.

Occurrence.—Putnam formation, Lower Permian: Loc. 30–T–14, about 3 miles north of Putnam, Callahan County, Texas.

Type.—Holotype, Plummer Collection no. P–1585, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS ABRUPTUS Moore and Plummer, n.sp.

Pl. 18, figs. 3, 4; text fig. 59

Description.—This is a relatively large species of delocrinid characterized by the extremely steep sides of the dorsal cup, sharp curvature of the basals (BB) near their mid-length, and the strongly defined but not extremely deep basal concavity. The height of the cup is about two-fifths of the width. The infrabasals (IBB) are almost entirely covered by the stem, but a small part of the distal area is visible sloping steeply downward. The width of the infrabasal (BB) disc is 6 mm. The width of the basals (BB) is slightly less than the length. The line of greatest width is located distinctly nearer the distal than the proximal margin. The proximal part of these plates slopes steeply and rather evenly downward, the mid-length is rather narrowly tangent to the basal plane, and the distal part slopes steeply upward. The very strong curvature of the mid-portion of these plates is a characteristic feature. The radials (RR) are not quite twice as wide as long. The longitudinal profile is nearly straight and almost vertical. There is almost no perceptible bulge of the surface below the margin of the facets. Only the outer ligament area of the facets is visible. It is very short, bounded by a sharp outer marginal ridge, and it is marked by a faint median ridge inside of which is a deep, short ligament pit 4 mm. wide.

The anal x rests on the truncated tip of the posterior basal (pB), the suture along this margin being practically as wide as any part of the plate; about half of the length of the principal anal (x) projects above the summit of the radials (RR) and slopes strongly inward.

The lower parts of the arms in four of the rays are attached to the dorsal cup. The height of the primibrachs (IBr) of the two posterior rays and of the anterior ray is nearly equal to the length of the radials (RR), but that of the right anterior ray is shorter. The outline of these plates is subquadrate. In longitudinal profile there is almost no perceptible outward slope of the mid-line and the upper point is not even moderately produced as in some species. A short quadrangular secundibrach (IIBr) follows the axillary primibrach (IBr) and the remaining brachials are wedge-shaped and biserial in arrangement.

The surface is entirely smooth and unornamented. The sides of the cup of the holotype are marked by a row of shallow, round pits 4 or 5 mm. in diameter, evidently made by a boring animal. There are ten of these depressions and they almost girdle the cup. This type of marking on crinoid plates and stems is not uncommon, but no specimen shows the depression penetrating the inside of a crinoid cup. The borings are very much like those made by carnivorous gastropods on shells of other marine animals, and association of gastropods and crinoids in which the gastropod is attached to the crinoid near the anal vent has been observed in many examples of Devonian, Lower Carboniferous, and Upper Carboniferous specimens, but these gastropods appear to have fed on the refuse from the crinoids rather than on the soft parts of the animal itself.

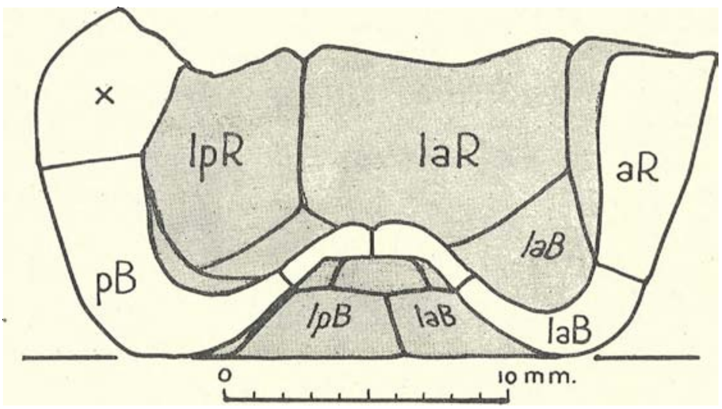

Fig. 59. Median cross-section of the dorsal cup of the holotype of *Delocrinus abruptus* Moore and Plummer, n.sp., through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. The steep slope of the sides and the very sharp curvature of the basal plane are indicated.

The writers know of no examples of Carboniferous or Permian brachiopods or of mollusk shells that show signs of having been bored in this manner.

Measurements of the holotype specimen, in millimeters, are given in the following tabulation:

Height of dorsal cup	10.5
Greatest width of cup	25.1
Ratio of height to width	0.40
Height of basal concavity	3.5
Width of basal depression	12.5
Diameter of stem impression	4.0
Length of basal	13.5
Width of basal	10.8
Length of radial	8.2
Width of radial	14.5
Length of suture between basals	8.2
Length of suture between radials	4.8

Discussion.—The proportions and shape of the dorsal cup, and to some extent the large size, distinguish *D. abruptus* from other described species. *D. inflexus* (Geinitz) has a relatively lower dorsal cup with more curved and flaring sides. The distinctly more angular outlines of the cup in side view distinguish *D. abruptus* from *D. puebloensis*, n.sp., and from *D. vulgatus*, n.sp. *D. conicus* Boos, which comes from higher beds in the lower Permian of Kansas and northern Oklahoma, is distinguished from *D. abruptus* by larger average size, greater relative height, more flaring sides, and especially by much greater height of basal concavity.

Occurrence.—Florena shale member of the Beattie formation (holotype), Council Grove group (Big Blue series), Lower Permian; Loc. 4587, near Grand Summit, Cowley County, Kansas. Moran formation (paratype), Lower Permian; Loc. 30–T–13, about 1 mile northwest of Pueblo, Callahan County, Texas.

Type.—Holotype, University of Kansas no. 45871; collected by J. W. Mickle. Paratype, Plummer Collection no. P–1581, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

DELOCRINUS MAJOR Weller

Pl. 15, fig. 10; text fig. 60

Delocrinus major WELLER, 1909, Jour. Geol., vol. 17. p. 627, pl. 1, figs. 6, 7 (Lower Permian, western Texas).

Description.—Weller's description of this species, slightly modified in form of statement, is as follows:

The dorsal cup is large, basin-shaped (relatively high truncate bowl-shaped), with a deep basal concavity, the surface of the plates is flat, the sutures are flush with the surface and not depressed in furrows. The measurements of the holotype are:

Height of dorsal cup	14 mm.
Greatest width of cup (est.)	40 mm.

The infrabasals (IBB) are small, nearly covered by the stem, and situated in the bottom of the basal concavity. The basals (BB) are large and a little longer than wide. Their proximal part includes nearly half the total length of the cup and is inflected to form the sides of the basal concavity. The distal part forms the lower part of the flaring sides of the cup. Four of the basals are angular at their distal extremities; the posterior basal (pB) is truncated to support the principal anal plate (x). The radials (RR) are large, nearly twice as wide as high, pentagonal in outline, and form more than half the flaring sides of the cup. The principal anal plate (x) is longer than wide, hexagonal in outline, resting between the posterior radials (RR) upon the truncated distal tip of the posterior basal (pB) and extending nearly one-half of its length above the level of the radials. Its surface is convex in median longitudinal profile and concave transversely along the line joining the two lateral angles.

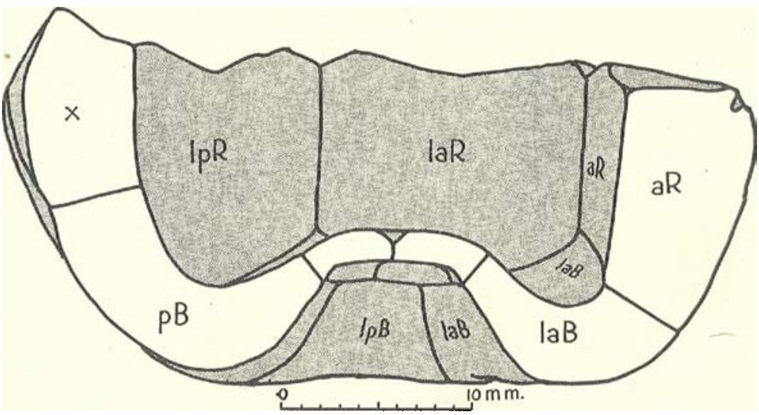

Fig. 60. Median cross-section of the dorsal cup of the holotype of *Delocrinus major* Weller, with restoration of the anterior part of cup. The section is drawn medially through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section.

The following additional measurements, taken from the holotype, which consists of the left posterior half of the dorsal cup, are given below:

Height of basal concavity	6.4
Height of proximal margin of basal plate above basal plane	5.3
Height of distal tip of basal plate above basal plane	7.6
Length of basal	20.0
Width of basal	16.1
Length of radial	12.3
Width of radial	22.0
Length of anal x	11.2
Width of anal x	8.3
Length of suture between basals	13.2
Length of suture between radials	7.0
Width of body cavity	23.5
Width of basal concavity	19.5

Discussion.—The proportions of the dorsal cup in *D. major* show a height-to-width ratio that is closely comparable to that in *D. verus*, n.sp., *D. missourienses* Miller and Gurley, and *D. vulgatus*, n.sp., *D. major* is distinguished from all these species by its large size and by the extreme flatness of the widely flaring sides. Also the ratio of the height above the basal plane of the proximal and distal margins of the posterior basal (pB) differs markedly from those of *D. vulgatus* and *D. missouriensis*. *D. conicus* Boos may prove to be a synonym of *D. major*. The types of Boos' specimens have not yet been available for study, and discrepancies between her description and published figures give rise to some uncertainties. Several dorsal cups in the University of Kansas collection show characters that suggest identification as *D. major*, and they appear to represent *D. conicus* also.

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13664; J. A. Udden, collector.

DELOCRINUS QUADRATUS Moore and Plummer, n.sp.

Pl. 14, fig. 8; pl. 15, fig. 8; text fig. 61

Description.—This species of delocrinid is distinguished by the nearly vertical sides and subquadrate form in side view and by the broad shallow form of the basal concavity and the relatively large size of the infrabasal (IBB) circlet. The cup is truncate bowl-shaped and relatively high, having a ratio of height to width of 0.44. The height of the basal concavity is one-fourth that of the cup.

The infrabasals (IBB) form a pentagonal disc at the top of the basal concavity. Somewhat less than half of the length of each plate is covered by the stem impression and the distal part of each infrabasal (IB) flares gently downward. The length and width of the basals (BB) are nearly equal. A short section of these plates along the proximal margin flares downward somewhat steeply, beyond which there is very sharp curvature where the plate is tangent to the basal plane. The median and distal parts of the basals (BB) curve very steeply upward, forming the sides of the cup. The distal tip rises somewhat above the mid-height of the cup.

The posterior basal (pB) is narrowly truncated for contact with principal anal (x). The radials (RR) are nearly twice as wide as long, and their outer face is nearly straight and subvertical in position. The facets have a short outer ligament area, and normal features appear on the inner ligament area, although the characters of the facets are not very clearly visible.

The principal anal (x) is hexagonal in outline, somewhat longer than wide, and its upper two-fifths are above the line of the radials (RR) and slope inward. The surface is smooth. The basals (BB) show a slight transverse as well as longitudinal convexity, so that the sutures between these plates are located in shallow furrows.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.1
Greatest width of cup	16.0
Ratio of height to width	0.44
Height of basal concavity	1.8
Ratio of height of basal concavity to height of the cup	0.25
Width of basal concavity	9.0
Width of stem impression	3.0
Length of basal	8.2
Width of basal	8.0
Length of radial	5.3
Width of radial	9.3
Length of suture between basals	4.6
Length of suture between radials	2.8
Length of anal x	3.6
Width of anal x	3.2
Height of proximal margin of the posterior basal above basal plane	1.0
Height of distal margin of the posterior basal above basal plane	6.0
Ratio of height of proximal to distal margin	0.16

Discussion.—This species is rather easily recognized by unusual characters in the form of the dorsal cup. The sides of the cup are even steeper than in *D. abruptus*, n.sp., and the height of the basal concavity is proportionally less than in that species. The ratio of the height of the proximal margin of the posterior basal (pB) above the basal plane to that of the distal margin of this plate is lower in *D. quadratus* than in any described species. The very sharp curvature of the basals (BB) in longitudinal profile at a point near the proximal margin is also an important distinguishing character.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta

Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Kansas University no. 60376, paratype no. 60377; collected by R. C. Moore.

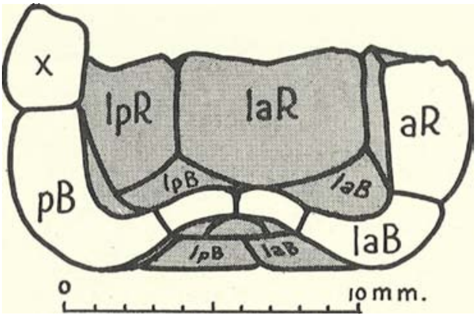

Fig. 61. Median cross-section of the dorsal cup of the holotype of *Delocrinus quadratus* Moore and Plummer, n.sp., showing the shallow basal concavity and the nearly vertical sides of the cup. The section is drawn medially through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section.

Genus ENDELOCRINUS Moore and Plummer, n.gen.

Under this name it is proposed to designate delocrinids with dorsal cups characterized by a strong transverse as well as longitudinal convexity of the basals (BB) and radials (RR), which makes these plates appear distinctly bulbous; or by sharp inflections of the borders of the basals (BB) and radials (RR) at angles where they meet; or by both of these features. The arms are uniserial, composed of somewhat cuneate segments, in about the lower one-third of their length, becoming biserial above. Otherwise, the characters appear to correspond exactly to those observed in *Delocrinus*.

Genotype.—*Eupachycrinus fayettensis* Worthen, Pennsylvanian; Hickory Creek, Fayette County, Illinois.

Discussion.—That the crinoids falling under the brief description given above are readily separable from typical *Delocrinus* is shown by experience. In handling several hundred specimens of delocrinids, mostly dorsal cups, but including also fairly numerous crowns, no difficulty has been found in recognizing forms that it is intended to place under *Endelocrinus*. Just as in *Delocrinus*, there are variations in the proportions of the cup, relative width and height of the basal concavity, and other features, which permit definition of different species. The average size of cups belonging to *Endelocrinus* is distinctly smaller than in *Delocrinus*. Judged from this standpoint and the somewhat more primitive character of the arms, the generic group *Endelocrinus* is regarded as an offshoot of the delocrinid stock that was differentiated at a somewhat earlier stage than is represented by any known species of *Delocrinus*, and it evidently preserved most of its distinguishing characters during Pennsylvanian time, living side by side with normal *Delocrinus*. Like late Upper Carboniferous and Permian species of *Delocrinus* that show average increase in size, *Endelocrinus texanus* (Weller), from the Lower Permian of western Texas, may be cited as an example of increase of size in this parallel stock.

ENDELOCRINUS FAYETTENSIS (Worthen)

Pl. 2, fig. 7; pl. 16, figs. 2, 3; text fig. 62

Eupachycrinus fayettensis WORTHEN, 1873, Illinois Geol. Survey, vol. 5, p. 565, pl. 24, fig. 10. (Pennsylvanian, Fayette County, Illinois.)

Description.—The dorsal cup is relatively broad, low truncate bowl-shaped. The height is less than one-third the width, and the basal concavity is shallow and relatively broad. The infrabasals (IBB) are almost entirely concealed by the stem, but the distal extremities are visible and flare downward at a moderate angle. The outline of the infrabasal disc is regularly pentagonal and the greatest width in the hypotype is 2.8 mm. The basals (BB) are strongly convex in longitudinal profile, moderately convex transversely, and a little less than one-half the proximal portion of the plates is involved in the basal concavity. Near the distal tip the surface is subvertical. The radials (RR) are moderately bulbous, with sharpest curvature in the longitudinal profile slightly above the mid-length. An arcuate area adjoins the facet, is flattened or very gently concave, and slopes inward toward the outer marginal ridge. The facets have not been observed.

Anal x is a small hexagonal plate resting on the truncated tip of the posterior basal (pB) and apparently more than half of its length lies below the summit of the radials (RR). Its surface forms a concave area between the bulging radials (RR) at the left and right. The surface is entirely smooth and the sutures appear moderately impressed by reason of the bulbous form of the basals (BB) and radials (RR). The holotype specimen shows very distinct dimples at the angles between the plates, but these are very faint on the hypotype.

The primibrachs are quadrate in outline and produced at the upper margin in a short very blunt spine. These plates in the right and left anterior rays are only two-thirds as long as in the other rays. The first secundibrach (IIBr) is subquadrate and has a length about two-thirds of its width. The following six to nine brachials (Br) are quadrate to cuneate segments that occupy the full width of the arms, and this definitely uniserial portion is followed by sharp-pointed, biserially arranged, wedge-shaped segments that have a width equal, or almost equal, to the width of the arms. The arms are rounded on the outer surface and flat on the sides. The two types are not laterally in contact but are spread laterally outward in fan-like manner.

The following measurements of the types, in millimeters, are shown in tabular form:

	Holotype	Hypotype
Height of dorsal cup	3.2	3.9
Width of dorsal cup	11.2	12.5
Ratio of height to width	0.29	0.31
Height of basal concavity (est.)	1.0	1.5
Width of basal concavity	6.2	6.7
Length of basal	5.0	5.0
Width of basal	4.3	4.5
Length of radial	4.1	4.3
Width of radial	6.8	6.7
Width of stem	1.8	2.0
Length of anal x	2.1	----
Width of anal x	1.8	2.0
Length of suture between basals	3.0	2.5
Length of suture between radials	2.0	2.2
Height of proximal margin of the posterior basal above basal plane	1.0	1.1
Height of distal margin of posterior basal above basal plane	2.5	3.8
Ratio of height of proximal to distal margin of the posterior basal	0.40	0.39

Discussion.—This species of Worthen has been selected as genotype of *Endelocrinus* because it shows satisfactorily characters both of the dorsal cup and of the arms. The brief description and new illustrations of the holotype are needful because of the inadequate and erroneous figures given by Worthen.

A curious situation has been developed in study of the type material, kindly loaned by the Illinois State Museum at Springfield. The specimen that must be regarded as holotype, because it is the only one figured or mentioned by Worthen, shows a dorsal cup with four exposed primibrachs lying obliquely on a small limestone slab; as received for study and as shown in Worthen's figure, the slab showed a short segment of a biserial arm disappearing in the matrix a short distance away from the cup. With matrix removed to show all of this and four other arms, this specimen is shown in Plate 2, figure 7, and Plate 16, figure 3. On the same slab with

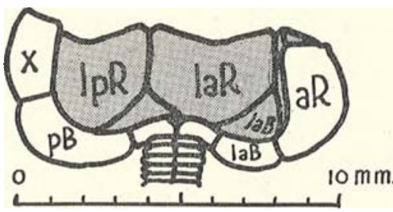

Fig. 62. Median cross-section of the dorsal cup of the holotype of *Endelocrinus fayettensis* (Worthen), the genotype species, showing the moderately bulbous form of the plates and the shallow basal concavity. The section is drawn medially through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section.

the holotype but almost entirely concealed by matrix, another complete dorsal cup with the arms belonging to two of the rays (Pl. 16, fig. 2) was uncovered. The two specimens clearly represent the same species, but in spite of its occurrence on the same slab with the type specimen, the cup and arms recently uncovered can be classed only as a hypotype, for it was not seen or studied by Worthen.

Occurrence.—Pennsylvanian; Hickory Creek, Fayette County, Illinois. Dr. H. R. Wanless of the University of Illinois writes that in Fayette County, which is just west of the deepest part of the Illinois coal basin, there are outcrops of the Lasalle, upper Bogota, and Newton cyclothems, all belonging to the Missouri series. Therefore, this fossil occurs in beds corresponding to those in the vicinity of Kansas City, Missouri, and in the Canyon group of Texas.

Types.—Holotype, Illinois State Museum (Springfield) no. 1905 (specimen marked *A* on slab); hypotype, same slab (specimen marked *B*).

ENDELOCRINUS RECTUS Moore and Plummer, n.sp.

Pl. 14, figs. 3–5; text fig. 63

Description.—Description of this species is based on four dorsal cups that are a little smaller than *E. parvus*, n.sp., in average size. The proportions of the cup are almost the same as in that species, the ratio of height to width being 0.38. The height of the basal

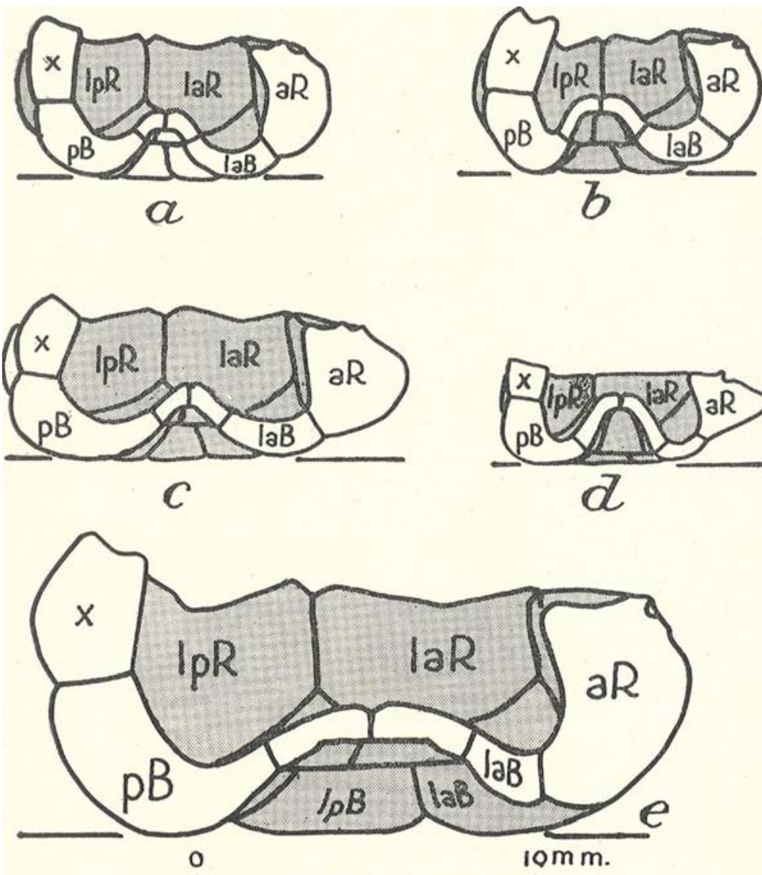

Fig. 63. Median cross-sections of the dorsal cups of five species of *Endelocrinus* Moore and Plummer, n.gen., all representing holotype specimens. *a, E. parvus* Moore and Plummer, n.sp.; *b, E. mitis* Moore and Plummer, n.sp.; *c, E. allegheniensis* (Burke) from the Conemaugh formation in western Pennsylvania; *d, E. rectus* Moore and Plummer, n.sp.; *e, E. texanus* (Weller).

concavity is also nearly the same, although it is relatively a little greater and narrower and the basals and radials are more bulbous.

The basals (BB) and radials (RR) are strongly bulbous, and the summit of the cup made by the distal part of the outer face of the radials (RR) and the facets produces a nearly smooth straight surface. On each plate this surface is divided into an outer and inner part by the depression of the outer ligament area, bordered on the inner side by the transverse ridge.

A distinguishing feature of the species is the relatively large height of the infrabasal (IBB) circlet, which forms most of the basal concavity and, as corollary, the very slight part of the concavity that is made by the proximal margin of the basals (BB). The ratio of height of the proximal margin of the posterior basal (pB) above the basal plane to that of the distal margin of this plate is only 0.13 as compared to 0.50 in *E. parvus*.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	3.0
Greatest width of cup	8.0
Ratio of height to width	0.38
Width of body cavity	4.0
Height of basal concavity	1.6
Width of basal concavity	4.0
Diameter of stem impression	0.9
Height of proximal margin of posterior basal above basal plane	0.3
Height of distal margin of the posterior basal above basal plane	2.2
Ratio of height of proximal to distal margin of posterior basal	0.13
Length of basal	3.7
Width of basal	3.7
Length of radial	3.3
Width of radial	5.0
Length of anal x	1.1
Width of anal x	1.0
Length of suture between the basals	2.2
Length of suture between the radials	1.0

Discussion.—The described characters of the basal concavity and the strongly bulbous radials, with distal surfaces nearly in the plane of the articular facets, distinguish *E. rectus* from *E. parvus*, n.sp., and from *E. mitis*, n.sp., which it resembles otherwise. *E. bifidus*, n.sp., is marked by the ridgelike protuberances of the basal and radial circlets, which are not seen in *E. rectus*.

Occurrence.—Brannon Bridge limestone member of Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian, (Upper Carboniferous); Loc. 183–T–14, exposure along road 3 miles southwest of Brock, Parker County, Texas.

Types.—Holotype, Plummer Collection no. P–10870; paratypes, P–10869, P–10871, P–10872, at Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer and R. C. Moore.

ENDELOCRINUS MITIS Moore and Plummer, n.sp.

Pl. 12, fig. 8; text fig. 63

Description.—This diminutive crinoid has a low truncate bowl-shaped dorsal cup with almost exactly the proportions of height to width that are observed in *E. parvus*, n.sp., which is 0.45. The basal concavity is narrow and only a little less than half the height of the dorsal cup. The infrabasals (IBB) form a small concave pentagonal disc that has about half the height of the basal concavity. The basals (BB) are moderately bulbous. The proximal part forms the outer slope of the basal concavity, and the distal parts curve to a subvertical position at mid-height of the cup. The radials (RR) have a width nearly twice their length. Their maximum bulge is located near the distal margin, above which is a short but steep inward slope to the margin of the facet. The outer ligament area of the facet is moderately excavated and slopes downward from the strong transverse ridge. The inner ligament area is marked by short oblique ligament fossae and by a shallow intermuscular notch. The principal anal (x) is nearly as wide as long; its upper one-third is above the line of the radials (RR) and slopes inward.

A single primibrach at the top of the cup has a height nearly equal to its width, is subquadrate in outline, and has a bluntly pointed protuberance at its upper margins. The surface of the cup is smooth. The sutures are located in shallow furrows, and there are small but distinct dimple-like depressions at the angles between the plates of the radials (RR) and basals (BB).

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	3.8
Greatest width of cup	8.4
Ratio of height to width	0.45
Height of basal concavity	1.7
Ratio of height of concavity to height of cup	0.45
Width of basal concavity	4.4
Width of stem impression	1.5
Length of basal	4.5
Width of basal	3.2
Length of radial	3.3
Width of radial	5.7
Length of suture between the basals	3.0
Length of suture between radials	1.6
Length of anal x	3.0
Width of anal x	2.0
Height of proximal margin of the posterior basal above basal plane	0.8
Height of distal margin of the posterior basal above basal plane	2.8
Ratio of height of proximal margin to height of distal margin of the posterior basal above basal plane	0.29

Discussion.—The closest resemblance to this small species of *Endelocrinus* is seen in *E. parvus*, n.sp., which has a steep-sided dorsal cup with height nearly half of its width. The basal concavity of *E. mitis* is proportionally a little deeper in *E. parvus*, and much more of it is formed by the infrabasals (IBB) than in that species. The plates of *E. mitis* are distinctly less convex, and the ratio of the height of the proximal to the distal margins of the posterior basal (pB) above the basal plane differ in the two species. *E. mitis* has a very different shape and proportions than those of *E. rectus*, n.sp.

Occurrence.—Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–89, about 3 miles southeast of Santo, on Highway 89, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10880, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

ENDELOCRINUS PARVUS Moore and Plummer, n.sp.

Pl. 14, figs. 1, 2; text fig. 63

Description.—This diminutive delocrinid has a dorsal cup about 9 mm. in greatest diameter and a little less than 4 mm. in height. The cup is truncate bowl-shaped, with a narrow basal concavity of moderate height and steep sides. The plates of the basal and radial circlets are very convex, both transversely and longitudinally. The sutures, therefore, appear strongly depressed. The infrabasal (IBB) circlet has the form of a small pentagon at the top of the basal concavity, with only a very small distal part of each plate visible beyond the round stem impression. This circlet forms only about one-fourth of the height of the concavity. The proximal part of the basals (BB) forms most of the basal concavity. A fairly broad area in the mid-portion is approximately tangent to the basal plane; and the distal part curves strongly upward to a vertical position or even very slightly inward. The extremities of these plates are slightly above the mid-height of the cup. The radials (RR) bulge strongly, with the proximal part curving outward and the distal part sloping inward. The outer ligament area of the facet is moderately excavated and in general slopes rather strongly outward; the denticulate transverse ridge is sharp-crested and straight. The general plane of the inner ligament area is subhorizontal, the mid-portion of the inner border being slightly depressed and the lateral margins raised and sloping slightly outward. The ligament fossae near the outer angles are short and rather deep. The intermuscular furrow is narrow and well defined, and the adsutural slopes steep, leading directly to the interfacet suture. The intermuscular notch on the inner margin of the facet is lacking, so that the border of the body cavity appears perfectly round. The principal anal (x) is hexagonal. Its width is only slightly less than its length, and a little more than one-half of its length lies below the summit line of the radials (RR). The surface is smooth. The outstanding features of the cup are the strongly bulbous plates, the depressions along the sutures, and dimple-like pits at the angles between the plates.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	3.6
Greatest width of cup	9.0
Ratio of height to width	0.40
Width of body cavity	4.7
Height of basal concavity	1.5
Ratio of height of basal concavity to height of cup	0.42
Width of basal concavity	4.5
Diameter of stem impression	1.2
Height of proximal margin of posterior basal above the basal plane	1.1
Height of distal tip of the posterior basal above basal plane	2.2

Ratio of proximal to distal height of posterior basal above basal plane	0.50
Length of basal	4.8
Width of basal	3.4
Length of radial	3.4
Width of radial	5.2
Length of anal x	1.6
Width of anal x	1.3
Length of suture between basals	3.0
Length of suture between radials	1.9

Discussion.—This species has the general appearance of *Endelocrinus allegheniensis* (Burke) (fig. 63), resembling it much more closely than *E. fayettensis* (Worthen). This is because of the very strong convexity of the plates, which considerably exceeds that of the genotype species. *E. allegheniensis* has an average size approximately twice as great as that of *E. parvus*, n.sp., a proportionally lower and broader dorsal cup, and a shallower basal concavity.

Study of the description and figures given by Strimple[71c] for his recently published *Delocrinus tumidus*, supplemented by comparison with several specimens from the same horizon and locality in collections of the University of Kansas, indicates that both *Endelocrinus parvus*, n.sp., and *E. grafordensis*, n.sp., of the present paper are included in *"Delocrinus" tumidus*. Unfortunately Strimple does not indicate whether one of his types is designated as holotype and others as paratypes, or whether all are syntypes. The present authors recognize both *Endelocrinus parvus* and *E. grafordensis* at The Mound near Bartlesville, where the specimens of *Endelocrinus tumidus* (Strimple) were collected, and they are reasonably certain that *E. parvus* is specifically distinct from *E. grafordensis*. Apparently one or the other of the two new species here described is to be placed in synonymy as equivalent to Strimple's species, but which one can be determined only by reference to the types of *Endelocrinus tumidus*.

Occurrence.—Mineral Wells formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous). The holotype is from Loc. 25–T–5, about 2½ miles west of Brownwood, Brown County, and the paratype is from Loc. 119–T–29, one-half mile west of Joplin, Jack County, Texas. Three specimens, slightly smaller than the types, and another that is larger, collected from the Winterset limestone member of the Dennis limestone at Coffeyville,

[71c] Strimple, H. L., A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, p. 8, pl. 2, figs. 1–8, 1939.

Kansas, and from the Stanton limestone at the locality 1 mile west of Wayside, Kansas, respectively, are referred to this species with some question; these horizons occur in the middle and upper parts of the Missouri series. Specimens belonging to this species have been collected also from the Plattsburg limestone 2 miles west of Ramona, Oklahoma, and from the Plattsburg-Stanton horizon at The Mound, Bartlesville, Oklahoma.

Types.—Holotype, Plummer Collection no. P–1376–B, and paratype, King Collection no. K–13129, Bureau of Economic Geology, The University of Texas. Holotype collected by Monroe G. Cheney; paratype by Ralph King. Paratypes, University of Kansas nos. 45513, collected by Paul McGuire at The Mound, Bartlesville, and 59261, collected by E. L. Banion west of Ramona, Oklahoma.

ENDELOCRINUS GRAFORDENSIS Moore and Plummer, n.sp.

Pl. 14, fig. 11

Description.—This crinoid is represented by one of the few complete crowns in the collection of delocrinids from Texas. The dorsal cup is low, truncate bowl-shaped, with moderately strong basal concavity. The height of the concavity is not determinable because of partial flattening of the cup. The curvature of the surface from a point deep within the concavity to the summit of the radials (RR) appears to have been very uniform, making a nearly perfect half-circle. The infrabasals (IBB) form a small circlet deep within the basal concavity. They are not visible in the holotype specimen. The basals (BB) are large, longer than wide, and, excepting posterior basal (pB), are arrow-shaped. As nearly as can be determined, the height of the proximal margin of the basals (BB) above the basal plane is about the same as that of the distal extremity. The radials (RR) are nearly twice as wide as long. In longitudinal profile their surface flares outward to a point a short distance below the facets and then curves sharply inward to the margin of the facets. The principal anal (x) is a subhexagonal plate resting on the truncated tip of the posterior basal (pB); about one-third of its length extends above the summit line of the radials (RR). The surface of the cup is smooth. At each of the angles between the basals (BB) and the radials (RR) there is a sharp, dimple-like pit. The radials (RR) are moderately bulbous and the interradial sutures are in furrows, but there is only a very slight swelling in the distal part of the basals (BB), and the sutures bordering these plates, though very sharply defined, are not in furrows.

The primibrachs are quadrate in outline, those of the right and left anterior rays distinctly shorter than the others. The midline of these plates flares upward to a fairly sharp-pointed node just below the center of the upper margin, but this is not at all like a spine. The first six or seven of the secundibrachs (IIBr) of the arms above the axillary primibrachs are uniserial and the higher parts are biserial. The surface of the arms is smooth.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	4.3
Greatest width of cup	12.2
Height of basal concavity (est.)	2.0
Width of basal concavity (est.)	6.0
Length of basal	6.7
Width of basal	4.9
Length of radial	4.1
Width of radial	7.6
Length of anal x	3.0
Width of anal x	1.5
Length of suture between basals	2.2
Length of suture between radials	2.2
Height of crown	38.0

Discussion.—This species is much more closely related to *E. fayettensis* (Worthen) than to any other known form. The cup and arms have almost exactly the same size in these two species, and comparison of the types indicates that about the only noteworthy differences are the slightly less bulbous form of the plates in the Texas form, relatively a little higher dorsal cup, a little deeper basal concavity, and the nearly equal height of the proximal and distal margins of the basals above the basal plane. *E. grafordensis* is very much larger than *E. parvus*, n.sp., and *E. rectus*, n.sp., both of which are distinguished by the extremely convex basals and radials. As noted under the discussion of *E. parvus*, it appears that *E. grafordensis* may have to be suppressed as a synonym of *E. tumidus* (Strimple).

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–61, on the west slope of Crawford (Wolf) Mountain near the road to Belding ranch, Palo Pinto County, Texas. A specimen that is practically identical to the holotype, but less complete, has been obtained from the Stanton limestone, upper part of the Missouri series (Loc. 5927, University of Kansas), one mile west of Wayside, Montgomery County, Kansas. Other specimens have been obtained from the Stanton limestone (Loc. 5984, University of Kansas), one mile southwest of Fredonia, Wilson County, Kansas, and at the Stanton horizon on The Mound, Bartlesville, Oklahoma (Loc. 1169, University of Kansas).

Types.—Holotype, Plummer Collection no. P–8189, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara. Paratypes, Banion Collection nos. 59273 and 11692, University of Kansas; collected by E. L. Banion. Paratype, University of Kansas no. 59841; collected by R. C. Moore.

ENDELOCRINUS BIFIDUS Moore and Plummer, n.sp.

Pl. 12, fig. 10

Description.—This very beautiful and distinctive crinoid cup is very minute, measuring only 6.4 mm. in greatest width (one-fourth inch) and 2.5 mm. in height. In side view the base appears broadly truncated and the sides steep, but the plates are so strongly convex that slight differences in orientation of the cup produce differences in outline. The basal concavity has a height of about two-fifths of that of the cup, the concavity is moderately narrow and steep sided. About two-thirds of the infrabasal (IBB) circlet has been broken away in the holotype specimen, but enough remains to show that it is a shallow pentagon covered largely by the round stem segment. The distal extremities of the plates flare gently downward; the diameter of the disc is 1.4 mm. The basals (BB) are somewhat angulated, with greatest bulge slightly beyond mid-length on the distal side. A fairly broad median area is approximately tangent to the basal plane of the cup, and from this area the proximal edges slope moderately into the basal concavity, and the distal extremities bend abruptly upward to a point slightly above the mid-height of the cup. Low ridges diverge from the points of maximum bulge on the basals to unite with neighboring bulges on the radials and on adjacent basals. This feature accentuates the hollows at the angles between the plates of the radial and basal circlets. The distal tip of the posterior basal (pB) is broadly truncated for contact with anal x, and the suture between these two plates is situated in a deep hollow. The radials (RR) carry a pair of bulges arranged horizontally at about mid-length of the plates. This gives to them a distinctly bifid appearance. The bulges are joined by the low broad ridges, previously mentioned, to the protuberances of the basals. The distal portion of each radial is flattened or gently concave and slopes strongly inward to the margin of the facet. The outer ligament area of the facet is short, moderately excavated, outwardly inclined, bordered externally by a distinct marginal ridge and contains, besides the deep ligament pit, a faint median ridge. The inner ligament area is subhorizontal. The transverse ridge is continuous with a relatively elevated and medially thickened part of the facet that adjoins the curving ligament fossae. A small pit occurs at the middle of the ridge where it is widened and thickened. The subtriangular muscle areas are nearly flat and are divided by a narrow intermuscular notch. The lateral ridges of the facet are low and the adsutural slopes not prominent. As a whole, the facets have a very distinctive appearance, together forming a decorative blunt-pointed star-like design.

Anal x is a little longer than wide curving inward both above and below from the line of its greatest width at the summit of the radials (RR).

The surface is smooth. The sutures are very well marked but are only very slightly impressed. The sutures between the basals (BB) are bordered by a faint swelling of the plates on each side which gives them a double-seamed appearance. The most distinctive feature of the surface is the pattern of bulges, low connecting ridges, and moderately deep somewhat angular hollows, which have been described.

The measurements of the holotype, in millimeters, are given below:

Height of dorsal cup	6.4
Width of dorsal cup	2.5
Ratio of height to width	0.39
Width of body cavity	3.4
Height of basal concavity	1.0
Width of basal concavity	2.0
Height of proximal margin of posterior basal above basal plane	0.6
Height of distal margin of posterior basal above basal plane	2.1
Ratio of proximal to distal height of posterior basal above basal plane	0.28
Length of basal	2.5
Width of basal	2.9
Length of radial	2.4
Width of radial	3.7
Length of suture between basals	1.7
Length of suture between radials	1.2

Discussion.—No previously described species among those referable to *Endelocrinus* has closer resemblance to this new species than is comprised in characters that have been given generic value. *E. rectus*, n.sp., from the Millsap Lake formation has nearly the same size as *E. bifidus* and is also marked by very prominent bulges, but the pattern of low connecting ridges, the somewhat angular nature of intervening hollows, and the distinctive bifid appearance of the radials (RR) are lacking in the older form.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–10750, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

ENDELOCRINUS TEXANUS (Weller)

Pl. 14, fig. 12; text fig. 63

Delocrinus texanus WELLER, 1909, Jour. Geol., vol. 17, p. 627, pl. 1, figs. 12, 13. (Lower Permian, western Texas.)

Description.—Weller's description, slightly modified in form of statement, is as follows:

The dorsal cup is basin-shaped (low truncate bowl-shaped) and broadly excavated at the base. The surface of the plates is convex and the sutures slightly impressed, especially the lateral sutures of the basals (BB) and at the distal extremities of these plates. The dimensions of the holotype are: height of dorsal cup, 7 mm., greatest width of cup, 20 mm.

The infrabasals (IBB) are in the bottom of the basal concavity. The diameter of the infrabasal disc is about 5.5 mm. It is partly covered by the round stem impression which has a diameter of one-half that of the infrabasal disc. The basals (BB) are large, longer than wide, and the proximal portion forms the sloping sides of the basal concavity. The distal portion slopes outward and upward, the distal extremities are angular in all except the posterior basal (pB), which is truncated for contact with the anal (x). The radials (RR) are large, about twice as wide as long, pentagonal in outline, and their distal faces are furnished with strong, articular ridges. The anal plate is small, and rests between the posterior radials upon the truncated distal extremity of the posterior basal (pB). It is pentagonal in outline, and the distal extremity is angular and extends somewhat beyond the level of the radials.

Additional measurements taken from the holotype specimen may be given as follows. Although the dorsal cup is undistorted, it is a little asymmetrical. The height of the cup, measured at the midlength of the right posterior or right anterior rays, is 7.0 mm., but on the anterior or left anterior rays only 5.5 mm. Using an average figure for height, the ratio of height to width is 0.30.

Measurements of the holotype, in millimeters, are as follows:

Height of dorsal cup	7.0
Width of dorsal cup	20.0
Diameter of infrabasal disc	5.5
Height of basal concavity	2.2
Width of basal concavity	10.2
Ratio of height of basal concavity to height of cup	0.35
Height of proximal margin of posterior basal above basal plane	1.4
Height of distal extremity of posterior basal above basal plane	3.8
Ratio of proximal to distal margins of posterior basal above basal plane	0.37
Length of basal	9.6
Width of basal	7.9
Length of radial	7.0
Length of anal x	3.9
Width of anal x	2.2
Length of suture between basals	4.4
Length of suture between radials	3.0
Diameter of stem	3.2

Discussion.—The characters of the dorsal cup in this species, including the somewhat bulbous form of the basals and radials, the furrows along the sutures, and the dimple-like depressions at angles between the plates, correspond to those recognized in *Endelocrinus.* This is the largest species known, being nearly twice as wide and high as the middle Pennsylvanian forms, *E. allegheniensis* (Burke), *E. fayettensis* (Worthen), and *E. grafordensis*, n.sp. The sides of the cup in *E. texanus* are more gently sloping than in any of the named species, and characters of the plates in vertical profile serve readily to differentiate this form.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek on Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13365; collected by J. A. Udden.

Genus GRAPHIOCRINUS de Koninck and Le Hon, 1854

Graphiocrinus DE KONINCK AND LE HON, Acad. Royale Belgique, Mém., vol. 28, no. 3, p. 115, 1854.

Scaphiocrinus HALL (part), Iowa Geol. Survey, vol. 1, pt. 2, p. 549, 1858.

Graphiocrinus de Koninck and Le Hon, WACHSMUTH AND SPRINGER, Revision of Palaeocrinoidea, pt. 1, p. 121, 1879.

Graphiocrinus de Koninck and Le Hon, SPRINGER, Harvard Museum Comp. Zoology, Mem., vol. 25, no. 3, p. 144, 1911.

Graphiocrinus de Koninck and Le Hon, ZITTEL-EASTMAN, Textbook of Paleontology, p. 225, 1913.

Graphiocrinus de Koninck and Le Hon, WANNER, Paläontologie von Timor, Lief. 6, Teil 11, p. 166, 1916.

Graphiocrinus de Koninck and Le Hon, WANNER, Mijnwezen ned. Oost-Indië, Jaarb., Verhandel. 1921, Gedeelte 3, p. 232, 1924.

Graphyocrinus Kenn. (= *Graphiocrinus* de Koninck and Le Hon), TIEN, Geol. Survey China, Paleont. Sinica, ser. B, vol. 5, fasc. 1, p. 40, 1926.

Graphiocrinus de Koninck and Le Hon, WANNER, Palaeontographica, Suppl. Bd. 4, Abt. 4, Teil 2, p. 172, 1937.

Description.—The genus *Graphiocrinus* is characterized by the tall, slender form of the crown and the small, truncate bowl-shaped dorsal cup containing one anal plate below the summit of the radials (RR). There is typically a small basal concavity, but in some species regarded as belonging to the genus the base of the cup is flat or even faintly convex. The presence of infrabasal plates (IBB) was overlooked by de Koninck and Le Hon, who described the dorsal cup as composed of only two circlets of plates, but a small infrabasal circlet is known to occur in the genotype species, even though it is concealed largely by the stem. Alternating with the five infrabasals (IBB) are five nearly equal-sized lozenge-shaped basal plates (BB), one of which, the posterior basal (pB), is generally truncated distally for contact with the anal plate; the distal extremities of the basals reach upward to about the mid-height of the cup. The five radials (RR) are pentagonal in outline, generally a little wider than long, and laterally in contact with one another, except on the posterior side where anal x plate intervenes. The features of the radial facets are not described in the original publication, and this important character of the genus does not appear to have been reported elsewhere in reference to the genotype species. Judging from de Koninck and Le Hon's figure and from study of available specimens in the Springer collection at the U. S. National Museum, the facets are fully equal in width to the radial plates. The single anal plate that occurs in the dorsal cup is not in contact with the posterior basal (pB), as shown by the holotype of the original species, *G. encrinoides* de Koninck and Le Hon, but other specimens from the same horizon and approximate locality, as noted by Springer,[72] show anal x resting against the truncated tip of the posterior basal (pB).

There is one axillary primibrach in each ray, next above the radial, and the arms are unbranched above the primibrachs. Thus, there are ten simple arms in the crown, each long and slender, and nearly the same in diameter throughout its length. The arms are rounded externally. They are formed by quadrangular segments that bear short, slender pinnules.

The character of the anal sac in the genotype species has not been described, but in other species, such as *G. longicirrifer* Wachsmuth and Springer, from American rocks of nearly the same age as those containing *G. encrinoides*, there is a long very slender tube that may reach beyond the tips of the arms.

The stem is composed of alternating thick and thin round segments.

Genotype.—*Graphiocrinus encrinoides* de Koninck and Le Hon, from shale in the upper part of the Lower Carboniferous (Viséan), at Tournai, Belgium, and reported also from Hook Point, near Bristol, England.

[72]Springer, Frank. Some new American fossil crinoids. Harvard Mus. Comp. Zoology, Mem., vol. 25, no. 3 p. 145, pl. 5, figs. 4, 5, 1911.

Discussion.—The definitive characters of this genus are not yet unequivocally established, chiefly because of lack of information as to the character of the radial facets and of the anal sac in *G. encrinoides.* It is possible, although very unlikely, that the facets of *Graphiocrinus* are narrower than the greatest width of the radials and that the general plane of the facets slopes downward and inward, in which case there would be no basis for recognition of *Apographiocrinus.* There is no external indication of the "prongs" between the facets in *Graphiocrinus.*

Springer[73] is thought to have erred in classing Miller and Gurley's genus *Aesiocrinus* as a synonym of *Graphiocrinus,* for *Aesiocrinus* has a sharply pentagonal stem, the cup is typically flat-bottomed rather than concave, the long anal sac is composed of thick, distinctive sorts of plates, the known species are much more robust than most species of *Graphiocrinus,* and the plane of the radial facets slopes downward and inward. The last-named character is not known to distinguish *Aesiocrinus* from *Graphiocrinus encrinoides,* but it serves readily to separate *Aesiocrinus* from cups that are regarded as belonging to *Graphiocrinus,* the facets of the latter being comparable in appearance to those of *Delocrinus* or *Erisocrinus.* The arms of all species that are regarded as belonging to *Graphiocrinus* branch on the first brachial above the radials, whereas the genotype and other species of *Aesiocrinus* have two primibrachs in each ray. Trautschold's[74] genus, *Phialocrinus* (1879), which has been regarded by several authors as a synonym of *Graphiocrinus,* is a homonym of *Phialocrinus* Eichwald (1856) and accordingly invalid, but it is thought to correspond to *Aesiocrinus* rather than *Graphiocrinus,* this opinion being based on study of an authentic example of the genotype species, *Phialocrinus patens* Trautschold.

Most of the crinoids that are designated *Endelocrinus* Moore and Plummer correspond to *Graphiocrinus* in their small size, moderate basal concavity, presence of one anal plate in the dorsal cup, and in having ten arms with the branching upon the first primibrach in all rays. The cup of *Endelocrinus* is relatively lower and broader, and the arms are composed of interlocking wedge-shaped

[73]Idem; also in Zittel-Eastman, Textbook of Paleontology, p. 225, 1913.

[74]Trautschold, H., Die Kalkbruche von Mjatschkowa: Soc. imper. Naturalistes Moscou, Mém., vol. 14, fasc. 1, p. 24, 1879.

segments (biserial) in the middle and upper parts and of trapezoidal segments (uniserial) in the lower part, whereas in *Graphiocrinus* the arms are uniserial throughout their length and are composed typically of quadrangular segments.

The genus *Paragraphiocrinus* Wanner[75] differs from *Graphiocrinus* in having only five, instead of ten, simple arms.

A recently proposed genus, *Euerisocrinus* Strimple,[75a] is based on a single dorsal cup that has the flattened base and evenly flaring sides typical of *Erisocrinus* but that differs obviously from *Erisocrinus* in having an anal plate between the posterior radials on the exterior side of the cup. No definite indication appears to show that this cup does not belong to *Graphiocrinus* or *Paragraphiocrinus*, however, unless the flatness of the base is a reliable criterion. The present authors have specimens from the same locality and horizon that yielded Strimple's type, and these correspond to his, except that the anal x plate rests on the posterior basal instead of being separated from it. These specimens have been identified as belonging to *Graphiocrinus*.

Occurrence.—Lower Carboniferous, Europe and North America; Upper Carboniferous, central United States; Permian, Timor.

GRAPHIOCRINUS KINGI Moore and Plummer, n.sp.

Pl. 3, fig. 8

Description.—This species is described mainly from an unusually well preserved, beautifully ornamented crown, but important supplemental information is obtained from study of two other specimens. The dorsal cup is truncate bowl-shaped, about twice as wide as high, and moderately concave at the base; the sides curve evenly outward and upward to a nearly vertical position at the margin of the facets. The surface of the plates in the basal and radial circlets bulge almost imperceptibly above the general contour of the cup, but sufficiently to accent the suture lines between the plates. The arrangement of the plates is that which is normal for the genus. The radials (RR) have only a gentle longitudinal convexity, without marked thickening in the region near the facets.

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[75] Wanner, J., Neue Beiträge zur Kenntnis der permischen Echinodermen von Timor, VIII–XIII. Palaeontographica, Suppl. Bd. 4, Abt. 4, Teil 2, p. 173, 1937.

[75a] Strimple, H. L., A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Paleont., vol. 24, no. 87, p. 13, 1939.

A very slight upward extension of the outer face of the radials is observed at the upper corners of these plates in the holotype, suggesting the "prongs" between the facets as observed in *Apographiocrinus*, but this feature is not found at the summit of all interradial sutures on this specimen and is entirely lacking on the two examples that are designated as paratypes. One of the latter specimens is a dorsal cup that shows all the facets clearly, indicating close correspondence with *Delocrinus* rather than *Apographiocrinus*—in fact, this cup would be identified unhesitatingly as belonging to *Delocrinus* if it were not shown by the closely similar associated specimens that retain the arms to be different from *Delocrinus*. The surface of the dorsal cup and arms is covered by a minute pattern of closely spaced granules or discontinuous, slightly irregular fine ridges, arranged with trend normal to the sutures between the plates. This decoration is beautifully preserved on the holotype specimen, but it persists only locally and faintly on the paratypes.

Measurements of the holotype and paratypes, in millimeters, are as follows:

	Holotype K–1388	Paratypes H–26	H–27
Height of crown	34.0	-	35.0[a]
Height of dorsal cup	6.4	5.8	5.3
Greatest width of dorsal cup	12.0[b]	13.0[b]	12.0[b]
Diameter of stem	2.6	2.1	

[a]Estimated, upper one-half of arms missing.
[b]Mean of long and short measurements; cup deformed.

The depth of the basal concavity is not accurately measurable because of deformation of the cups.

Discussion.—This species is readily distinguished from all other known crinoids from Texas by the characters of its dorsal cup, which resembles that of *Delocrinus*, combined with long uniserial arms, which correspond in structure to those of *Apographiocrinus*. The features just mentioned are the most important in classification, but the distinctive ornamentation of this species is also an aid in identification. In collections from upper Missouri beds of southern Kansas, there are a number of dorsal cups that resemble *G. kingi* in the character of decoration of the plates and in arrangement of the plates in the cup, but the base of the cups is flat rather than hollow, as in the Texas species here described. The forms from

Kansas are about the same in size as *G. kingi* or a little smaller and are regarded as belonging to *Graphiocrinus*.[75b]

This species is named for Ralph H. King, of Lawrence, Kansas.

Occurrence.—Keechi Creek shale member of the Mineral Wells formation, Strawn group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–86, 2 miles west of Salesville, Palo Pinto County, Texas (holotype). Loc. 181-T-67, about three-quarters of a mile northeast of Union Hill school, about 6 miles north-northwest of Mineral Wells, Palo Pinto County, Texas (paratypes).

Types.—Holotype, Bureau of Economic Geology no. K–1388, The University of Texas; collected by Ralph H. King. Paratypes, Harris Collection nos. H–26, H–27; collected by Mrs. G. W. Harris, Waco, Texas.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B–1—GROUP b]

SUBGROUP ς.—*Cup truncate bowl-shaped; no anal plate in cup.*

The crinoids belonging to this subdivision of poteriocrinitids are characterized by articular facets that are as wide as the radials and that slope outward, at least in the area of the lateral ridges. The infrabasal plates are not visible in side view of the dorsal cup, because in each genus of the subgroup they lie deep within the basal concavity. Absence of an anal plate below the summit of the radials gives nearly perfect pentameral symmetry to the cup. As a whole, the subgroup represents a rather highly specialized assemblage of crinoids, only a few of which occur in rocks older than Permian. The genus *Paradelocrinus* is represented in Upper Carboniferous formations of Texas and the northern Mid-Continent region.

Genus PARADELOCRINUS Moore and Plummer, 1938

Paradelocrinus MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 294. (Pennsylvanian, North America.)

This genus was erected to include poteriocrinitids having a low truncate dorsal cup like that of *Delocrinus*, but lacking an anal plate as an element below the upper edge of the cup. In typical

[75b]See the previous note concerning *Euerisocrinus* Strimple under the discussion of the genus *Graphiocrinus*. Some 20 specimens from Kansas in the collections of the present authors show characters described for *Euerisocrinus*, but until the arm structure is found to show a plan different from that of *Graphiocrinus*, it is here proposed to class these cups as representatives of *Graphiocrinus*.

species the base of the cup is marked by a strong concavity of funnel-like form, but in a few forms where this is lacking, the subcircular outline of the cup in dorsal or ventral view and the nearly regular strong curvature of the sides in profile view distinguish representatives of this genus from *Erisocrinus*.

The five infrabasals (IBB) form a pentagonal disc that is largely covered by the round stem impression and is generally strongly concave. The five basals have their proximal parts generally flaring downward and forming part of the basal concavity. The distal parts curve upward and are visible in side view of the cup. The five radials (RR) are equal and have a width commonly about twice their length. The proximal parts curve outward and upward, the distal parts are subvertical or sloping very slightly inward to the margin of the facets. The markings and general outward slope of the facets are essentially as in *Delocrinus*. A small anal plate is located in a notch between the facets of the posterior radials (RR) at their inner margin. It is not visible in specimens that have the arms attached.

The arms are moderately long, biserial, branching isotomously on the first primibrach (IBr_1), which, as in *Delocrinus*, may or may not be produced in a laterally directed spine. The anal sac is unknown.

Genotype.—*Paradelocrinus aequabilis* Moore and Plummer.

Occurrence.—Morrow to Virgil series, Pennsylvanian (Upper Carboniferous); central United States.

PARADELOCRINUS BRACHIATUS Moore and Plummer, n.sp.

Pl. 15, fig. 6; pl. 16, fig. 1; pl. 17, fig. 3; text fig. 64

Description.—This simply constructed crinoid has a low, truncate bowl-shaped cup with a diameter nearly three times its height. The base is moderately concave and the sides are evenly convex. The outline of the cup in ventral or dorsal view is almost circular, but the regular pentagonal symmetry may be seen also. The surface is smooth and the suture lines between the plates are only slightly depressed. The infrabasal (IBB) circlet is small, pentagonal, and rather strongly concave, due partly to the deep stem impression. The individual infrabasal plates are arrow-shaped, about 2 mm. long, nearly 2 mm. wide, plainly visible around the periphery of the narrow stem, and flexed inward at the proximal tips to form the stem impression. The basal circlet has the form of a symmetrical five-pointed star. Each basal is a small, six-sided plate, that is longer than wide and strongly pointed at the distal end, the angle between the sides being 50° to 60°. It is shaped like a spearhead with short sides adjoining the infrabasals (IBB) and long sides joining them to the radials (RR). The longitudinal profile of the basals slopes mostly downward and outward at a gentle angle.

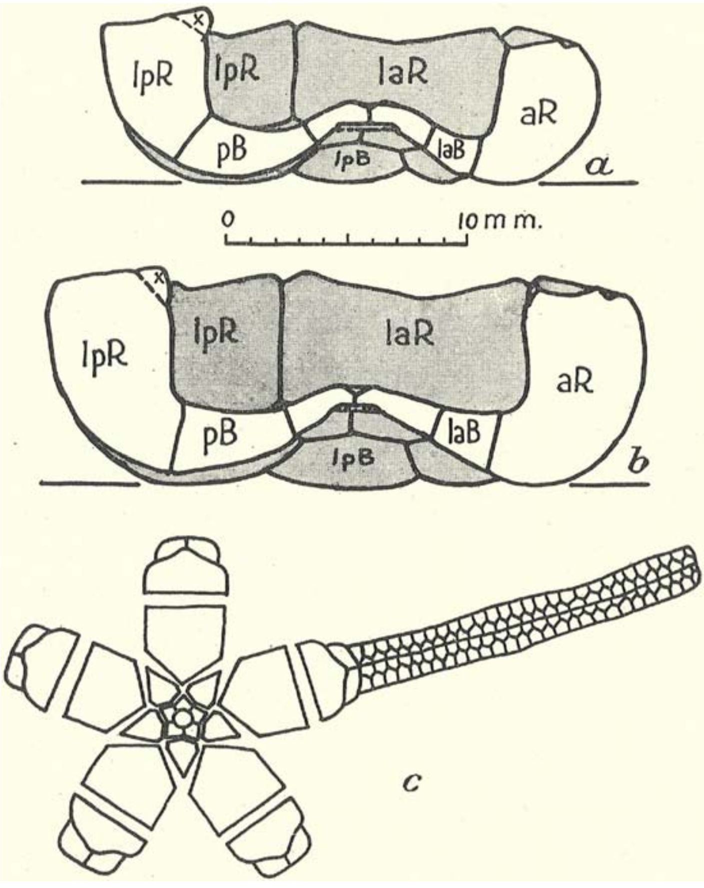

Fig. 64. Median cross-sections of the dorsal cup of *Paradelocrinus brachiatus* Moore and Plummer, n.sp., through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *a*, Paratype (University of Kansas no. 60263); *b*, holotype. *c*, Diagram showing the arrangement of the plates in the dorsal cup, the basal part of the arms, and, in one ray, the pair of long biserial arms, as indicated by the holotype.

The radials (RR) are large and longer than normal for the genus, since the length is seven-eighths of the width. They are slightly incurved at their proximal points to form part of the base, and they bow inward near the margin of the facet. The outer ligament area of the facet is very short, slit-like, and moderately excavated; it contains a deep ligament pit. The transverse ridge is sharp-crested and prominent. The inner ligament area contains a pair of shallow fossae parallel to the transverse ridge, located near the lateral margins of the facet. An intermuscular notch is lacking, or it is so shallow as hardly to be noticed. At the posterior interradial position a small, inwardly directed, triangular-shaped anal plate is distinguishable.

The ten arms are simple, biserial, without secondary branches, long, and only slightly tapering. The height of the arms in the holotype specimen is 72 mm.; that of the entire crown, 81 mm. The arms are not decorated by any sculpture or spines.

Four specimens belonging to this species are contained in the available collections: the holotype (P–8196), which is a complete crown, with slightly distorted dorsal cup and the lower circlets pushed inward; a paratype (60263) with dorsal cup undeformed except for displacement of the lower circlets—the lower part of the arms are in position above the radials; and two other paratypes, one of which is a complete cup without the arms.

The measurements of three cups and the plates of the cups are given in the following tabulation. All three specimens have been somewhat deformed, so that average measurements are presented.

	Holotype P–8196	Paratype P–10856	Paratype 60263
Height of dorsal cup	8.5	6.7	7.0
Greatest width of cup	24.3	11.1	20.5
Ratio of height to width	0.35	0.35	0.34
Width of body cavity	--	9.7	---
Depth of basal cavity	3.3[a]	2.4[a]	2.5[a]
Width of basal depression	15.0	11.0	11.5
Diameter of stem impression	3.6	3.4	3.6
Greatest length of infrabasal	?	3.7	3.8
Greatest width of infrabasal	?	2.9	3.0
Greatest length of basal	6.0	4.8	6.0
Greatest width of basal	5.6	3.9	5.2
Greatest length of radial	14.6	10.2	10.3
Greatest width of radial	16.5	11.9	12.3
Length of suture between basals		1.2	2.0
Length of suture between radials	11.9	6.5	6.5

[a] Based on restoration

Discussion.—This crinoid corrsponds in size and general form of the cup to *P. subplanus*, n.sp., but *P. brachiatus* is proportionally a little broader, has a larger basal concavity, but, most importantly, it has distinctly more convex plates and more depressed sutures, and generally no part of the basals is visible from the side. *P. brachiatus* is distinguished from *P. protensus*, n.sp., by the much more nearly vertical sides of the cup and broader, shallower basal concavity in the former, and the marked difference in appearance of the basals.

Occurrence.—Millsap Lake formation just below the Kickapoo Falls limestone, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 110–T–4, about one-third mile below the falls on Kickapoo Creek in a small valley on the north side of the creek, southwest of Dennis, Hood County, Texas.

Types.—Holotype, Plummer Collection no. P–8196, and paratypes, nos. P–10856 and P–10854, Bureau of Economic Geology, The University of Texas; collected by Gayle Scott. Paratype, University of Kansas no. 60263; collected by R. C. Moore.

PARADELOCRINUS SUBPLANUS Moore and Plummer, n.sp.

Pl. 16, figs. 4, 5; text fig. 65

Description.—The description of this species is based upon 26 dorsal cups without stems or arms. The form of the cup is low, about three times as wide as high. The base has a shallow concavity but is nearly flat. The lower part of the sides flare outward gently, but near the summit they are vertical or curve slightly inward to the edge of the facet. The outline of the cup is almost perfectly circular in dorsal or ventral view, but the pentameral form is discernible. The infrabasal (IBB) circlet of plates is distinctly star-shaped, closely conforming to the shape of the basal circlet, but alternating in position with it, of course. The individual infrabasal plates are longer than wide and protrude about halfway beyond the circular stem impression. They flare gently downward, forming most of the basal concavity. The basals (BB) are a little wider than long and nearly flat. The circlet of these plates has the form of a five-pointed star. The angles at the points of this star measure about 70°. The radials (RR) are twice as wide as long and of nearly equal size. The facets are not very well preserved on any of the types, as regards fine details of structure, but it is clear that they conform to characters of the genus. The holotype shows a distinct bulge of the radial surface below the outer marginal ridge of the facet, and this is also present, but less prominent, in the paratype. The outer ligament area is narrow and slit-like; the mid-portion of the inner ligament area is concave, and near the lateral borders are outward-sloping ridges. The anal plate is not observed, but a distinct notch at the inner border of the facets between two of the radials (RR) in the holotype marks the position of this plate; the notch is marked by fine sutural ridges.

The measurements of the holotype and of three paratypes, in millimeters, are given in the following tabulation:

	Holotype H-11	Paratype P-9109	Paratype P-10641	Paratype M-41
Height of dorsal cup	7.2	6.1	6.5	5.4
Greatest width of dorsal cup	19.2	21.8	16.8	16.6
Ratio of height to width	0.38	0.28	0.39	0.33
Width of body cavity		----	9.5	9.1
Depth of basal cavity	1.2	1.6	?	1.3
Width of basal depression	8.0	8.0	9.3	9.2
Diameter of stem impression	3.0	3.8	3.1	2.9
Greatest length of infrabasal	3.5	4.0	3.6	3.4
Greatest width of infrabasal	2.3	2.7	2.5	2.2
Greatest length of basal	5.4	5.1	4.1	4.2
Greatest width of basal	6.0	6.7	4.1	4.3
Greatest length of radial	10.0	7.3	6.8	8.3
Greatest width of radial	11.6	12.6	12.7	10.7
Length of suture between basals	2.0	2.2	2.2	1.5
Length of suture between radials	6.0	4.5	5.4	4.5

Discussion.—The absence of a well-marked basal concavity in this species represents a departure from the character of the dorsal cup seen in other species of the genus, and in this respect the dorsal cup of *P. subplanus* corresponds to the typical form in *Erisocrinus*. The general contour of the cup, its very low height, nearly circular rather than strongly pentagonal outline in dorsal or ventral view, and the comparatively strong regular curvature of the radials (RR) in longitudinal profile, are characteristic of *Paradelocrinus*. These features are seemingly more significant than the shallowness of the concavity of the base.

P. subplanus is distinguished from the cup of *P. brachiatus*, n.sp., which resembles it most closely, by the smaller basal concavity and by the extension of the basals (BB) to the outer sides of the cup. *P. protensus*, n.sp., is a much larger crinoid with narrow deep basal concavity, more gently flaring sides, and with distinctly though slightly impressed sutures. *P. obovatus*, n.sp., is distinguished from this species by its more angular, pentagonal outline, greater relative height, and well-marked basal concavity.

Occurrence.—The holotype, H-11, was collected from shale just below the Kickapoo Falls limestone member of the Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 110-T-3, about 4½ miles east-northeast

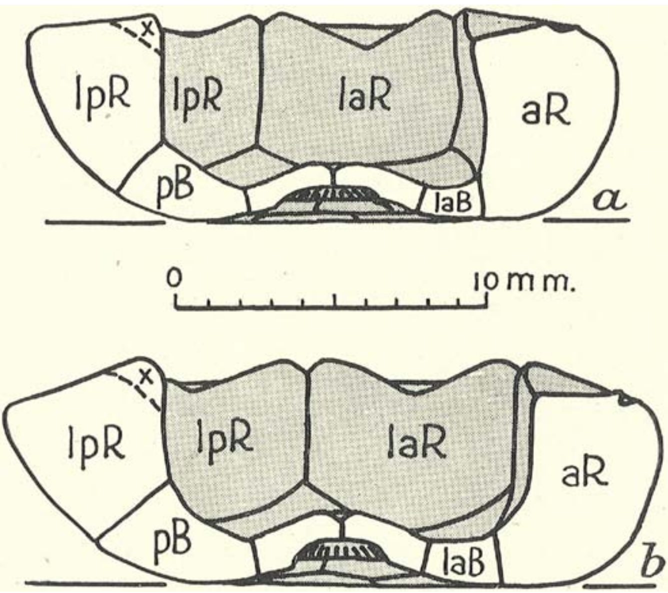

Fig. 65. Median cross-sections of the dorsal cup of *Paradelocrinus subplanus* Moore and Plummer, n.sp., through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *a*, Holotype; *b*, paratype (P-10641).

of Lipan, Hood County, Texas. Paratype, M-41, is from the Brannon Bridge limestone member of Millsap Lake formation, about 3 miles southwest of Brock, Parker County, Texas. The paratype, no. P-9109, is from the upper Mineral Wells shale or lower Canyon beds (?Missouri series), Pennsylvanian; Loc. 134-T-17, on Llano River, about 1 mile west of Camp Walton, Kimble County, Texas. The paratype, no. P-10641, is from the Graford formation, Canyon group (Missouri series), Pennsylvanian; Loc. 153-T-92, one-fourth mile east of Mercury, McCulloch County, Texas. Paratypes, nos. 458910, 458910a–g, 45941, and 45941a–l (21 specimens), were collected from the Oologah limestone, upper part of Des Moines series (about 300 feet below top), Pennsylvanian, at the Garnett quarry, about 7 miles northeast of Tulsa, Oklahoma.

Types.—Holotype, Harris Collection no. H–11; collected by Mrs. G. W. Harris, Waco, Texas. Paratype, Marrs Collection no. M–41; collected by Mrs. W. R. Marrs, Austin, Texas. Paratype, Plummer Collection no. P–9109; collected by F. B. Plummer. Paratype, Plummer Collection no. P–10641; collected by Robert Cuyler. Paratypes in the Plummer Collection deposited in the Bureau of Economic Geology, The University of Texas. Paratypes, Stevens Collection no. 458910, 458910a–g; collected by Bob Stevens. Paratypes, Laudon Collection no. 45941, 45941a–l; collected by L. R. Laudon. Paratypes of the Stevens and Laudon collections deposited in the University of Kansas.

PARADELOCRINUS PROTENSUS Moore and Plummer, n.sp.

Pl. 16, fig. 6; text fig. 66

Description.—This species is described from a single well-preserved dorsal cup. The outline of the cup in dorsal or ventral view is rounded pentagonal; in side view it appears low truncate bowl-shaped, with sides curving gently and then steeply from base to summit. The surface is smooth, and the sutures are slightly but distinctly impressed. The base of the cup is marked by a strong, nearly vertical-sided concavity, with height equal to about half the height of the cup. The infrabasal (IBB) circlet is a stellate pentagon, horizontal in the area of the stem impression, the remainder is strongly down-flaring. The basal (BB) circlet is in the form of a star, with moderately extended points that have an angle of about 70° at the tip. The length and width of the basals (BB) are nearly equal. The proximal part of the basals flares downward, forming part of the basal concavity. The mid-portion is horizontal and the outer part flares upward and is visible in side view of the cup. The radials (RR) are nearly twice as wide as long and their proximal tips reach to the basal plane of the cup or nearly so. The distal part swells outward, so that the surface near the margin of the facets is vertical or slightly sloping inward.

The facets, which are well shown in the type, slope gently outward. The outer ligament area is very short and rather strongly excavated; the lateral portions of the inner ligament area bear strong ligament fossae subparallel to the strong transverse ridge. The muscle areas are subtriangular, rather strongly sloping, and are separated by a

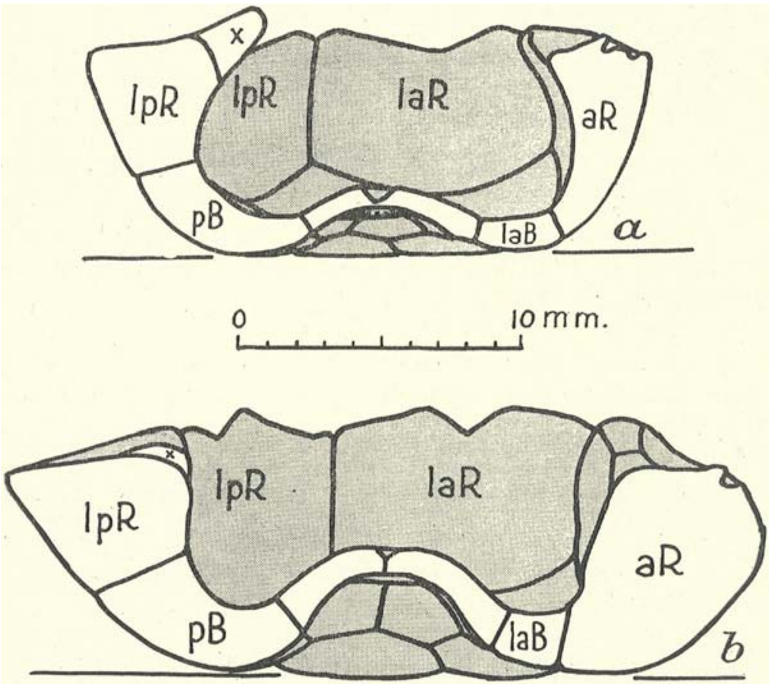

Fig. 66. Median cross-sections of the dorsal cups of two species of *Paradelocrinus*, through the anterior radial (aR) and the posterior interradius, showing the left half of the cups, the shaded area representing parts beyond the plane of the section. *a*, Holotype of *P. obovatus* Moore and Plummer, n.sp.; *b*, holotype of *P. protensus* Moore and Plummer, n.sp.

deep and narrow intermuscular notch. The anal plate has not been observed, but its position is marked by a wide notch between the posterior radials (RR) at the inner margin of the facets.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	8.0
Greatest width of dorsal cup	28.0
Ratio of height to width	0.28
Width of body cavity	13.0
Height of basal cavity	3.7
Width of basal concavity	13.0
Diameter of stem impression	3.0
Greatest length of infrabasal	5.0
Greatest width of infrabasal	3.5
Length of basal	8.2
Width of basal	8.0
Length of radial	10.0
Width of radial	16.0
Length of suture between basals	2.7
Length of suture between radials	6.0

Discussion.—This species is readily distinguished from *P. brachiatus*, n.sp., and *P. subplanus*, n.sp., by the strong basal concavity and by the configuration of the cup. It differs from *P. obovatus*, n.sp., chiefly in the greater depression of its base and impression of the sutures.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–40, about 5 miles in direct line west-northwest of Lone Camp, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–1553, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer.

PARADELOCRINUS OBOVATUS Moore and Plummer, n.sp.

Pl. 15, fig. 9; pl. 20, fig. 4; text fig. 66

Description.—The dorsal cup is relatively low truncate bowl-shaped rather than truncate cone-shaped, like the typical form of cup in *Erisocrinus*. The sides of the cup are nearly vertical just below the summit and curve regularly below to the plane of the broad base, but the central part of the basal area is rather strongly concave. The surface is smooth and the sutures are not impressed. The infrabasals (IBB) form a small, somewhat stellate pentagon that is mostly covered by the round stem impression. The distal parts of the infrabasals flare downward and form part of the sides of the basal concavity. The basals (BB) are evenly convex in longitudinal profile; their length is a little greater than their width; the distal extremities reach a little less than one-half the height of the cup; and the angle at the upper tip of the basals (BB) is 84°. The radials (RR) have a length a little more than one-half the width; their proximal tips reach almost to the basal plane of the cup. The facets, which are very well preserved in the type, show features corresponding closely to those described in other species of *Paradelocrinus* and in *Erisocrinus typus* Meek and Worthen, except that the ligament fossae of the inner area are more sharply defined and the ridges between them more elevated and angular. The intermuscular notch is very broad. Anal x is an elongate plate, heart-shaped in cross-section, and located at the inner border of the posterior radial facets. Its long axis is directed upward and inward, and the upper face is truncated nearly normal to this axis.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.6
Greatest width of dorsal cup	20.3
Ratio of height to width	0.37
Width of body cavity	11.7
Height of basal cavity	1.7
Width of basal cavity	10.0
Diameter of stem impression	2.8
Greatest length of infrabasal	3.3
Greatest width of infrabasal	3.2
Greatest length of basal	7.9
Greatest width of basal	7.5
Greatest length of radial	7.0
Greatest width of radial	12.6
Length of suture between basals	3.4
Length of suture between radials	4.5

Discussion.—The low height, bowl-shaped form, and basal concavity, as described for this species, are characters of *Paradelocrinus.* There is here a closer approach to *Erisocrinus,* however, than in typical species of the genus. The distal parts of the radials are not thickened to make the surface bow inward, as seen in longitudinal profile of many typical examples of *Delocrinus* and *Paradelocrinus.* This species is separated from almost any species of true *Erisocrinus* by the contour of the cup in side view. Also the basal concavity is greater than that in species of *Erisocrinus. Paradelocrinus obovatus,* n.sp., has greater relative height and straighter sides than *P. subplanus,* n.sp., and *P. brachiatus,* n.sp. This species differs from *P. protensus,* n.sp., in its greater smoothness of contour, shallower basal concavity, and greater steepness of the sides of the cup.

Occurrence.—Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Types.—Holotype, Plummer Collection no. P–10737, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

[POTERIOCRINITIDAE—SECTION B]

SUBSECTION B–2—*Facets horizontal, including area of lateral ridges, generally broad and nearly plane.*

GROUP a.—*Infrabasals flaring upward, visible from side.*
SUBGROUP β.—*Cup cone-shaped; one anal plate in cup.*

Section B of the poteriocrinitids, as here subdivided, is characterized by the wide breadth of the articular facets, which nearly or entirely match the greatest width of the radial plates. All the genera of Subsection B–2, which is distinguished on the basis of horizontality of the facets, show a width of facets that is fully equal to that of the radials. Among these, there is one genus with cone-shaped cup and infrabasals visible from the side, that is differentiated by having a single anal plate in the cup. This crinoid, called *Stuartwellercrinus*, is known only from the Permian of western Texas. It is a specialized form in that the number of infrabasal plates has been reduced to three.

Genus STUARTWELLERCRINUS Moore and Plummer, 1938

Stuartwellercrinus MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 305.

This genus includes crinoid cups that originally were referred to *Cibolocrinus*, mainly because of their bowl-like form and possession of three infrabasals (IBB). Actually, they differ markedly from the genotype of *Cibolocrinus* in character of the articular facets and in the upflaring attitude of the infrabasals. This type of cup, designated by the generic name *Stuartwellercrinus*, is believed to belong among the poteriocrinitids, whereas it has been demonstrated that *Cibolocrinus* is a flexible crinoid. The following diagnosis of *Stuartwellercrinus* is taken, with slight modification, from a recent publication by Moore and Plummer.[76]

[76]Moore R. C., and Plummer F. B., Upper Carboniferous crinoids from the Morrow subseries of Arkansas, Oklahoma, and Texas: Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), pp. 305, 306, 1938

The calyx is low, turbinate to conical and dicyclic. The infrabasals (IBB) are clearly visible from the side. The position of the small infrabasal (IB) is variable in different species but lies generally in the anterior, the left posterior, or the right posterior radius. The stem impression is typically crateriform. There are five basals (BB) of which the posterior basal (pB) is typically larger than the others; except in a few forms it shows marked upward migration of anal x. It is truncated distally where it is in contact with anal x. The five radials (RR) bear broad articular facets that project inward so as to constrict the aperture to the body cavity. The muscle area is centrally depressed, and the borders near the interradial sutures are more or less distinctly elevated. Anal x is typically present and separates the posterior radials (RR) and rests on the posterior basal (pB). In some forms the anal x is pressed entirely out of the dorsal cup. The arms are unknown.

Genotype.—*Cibolocrinus turbinatus* Weller, from the Cibolo limestone, Lower Permian, Presidio County, Texas.

Occurrence.—Lower Permian, western Texas.

STUARTWELLERCRINUS *TURBINATUS* (Weller)

Cibolocrinus turbinatus WELLER, 1909, Jour. Geol., vol. 17, p. 632; pl. 1, figs. 23-26. (Lower Permian, western Texas.)

Description.—Weller's description, slightly modified in form, is as follows:

The dorsal cup is turbinate and the sides diverge with a convex curvature from the margin of the stem impression to the distal margins of the radials (RR). The surface of the plates is smooth and the sutures are not impressed in grooves. The dimensions of a complete dorsal cup are: height, 17 mm., greatest width, 25 mm. Of the three infrabasals (IBB) one small plate is in the anterior ray and two large ones lie posteriorly. A little more than one-third of the length of each plate at the proximal end is covered by the stem impression, which is in the form of a cone-like depression. The exposed distal parts of the plates form the flaring sides of a shallow cup. The basals (BB) are large. The right and left postero-lateral ones are nearly symmetrically pentagonal in outline, the two anterior ones are hexagonal, but the two proximal faces meet in a very wide angle so as to form nearly a straight line, the two faces together being equivalent to the single proximal face of the postero-lateral plate. The posterior plates are similar to the two antero-lateral ones, but the distal angle is truncated to support the anal plates.

The radials (RR) are nearly twice as wide as high and pentagonal in outline; their surface curves a little inward near the distal margin and their distal faces bear strong articular ridges. Anal x is small. It rests between the posterior radials (RR) upon the truncated distal extremities of the posterior basal (pB). It is widest between the posterior distal angles of the radials (RR) on each side, and is probably pentagonal in outline so that the distal portion, which extends beyond the level of the radials (RR), is imperfect in the type specimen.

Measurements of the two syntypes, in millimeters, are given in the following tabulation:

Height of dorsal cup	16.3	14.1
Greatest width of dorsal cup	25.3	22.3
Ratio of height to width	0.65	0.65
Height of basal concavity	1.2	0.7
Width of infrabasal disc	12.2	11.3
Length of basal	10.7	8.5
Width of basal	11.7	10.2
Length of radial	8.1	7.0
Width of radial	14.1	12.9
Length of suture between basals	5.8	4.2
Length of suture between radials	5.8	4.8
Width of body cavity	13.8	12.0
Height of infrabasal disc	4.8	4.2

Discussion.—This species is characterized primarily by the shape of the cup, the sides increasing in steepness from the base to the top. The sides of the cup in *S. texanus* (Weller) are nearly straight, and in *S. symmetricus* (Weller) also straight, and the plates are slightly bulbous.

A comparative study of Weller's types of *S. turbinatus* and *S. symmetricus,* together with another very good specimen of the latter species (Kansas University no. 60375), leads to the rather definite conclusion that one of the three syntypes (Walker Museum no. 13372, specimen C) of *S. symmetricus* actually belongs with *S. turbinatus.* This is shown by the very smooth contour of this cup, rounding toward the top, lack of even a very slightly bulbous form of the basals and radials, proportionally low infrabasal circlet, and broad stem impression, all of which are characters of *S. turbinatus.* Placement of this specimen in *S. turbinatus* indicates that anal x may be present or lacking in the species, for specimen no. 13372C lacks an anal in the cup. Although Weller states that the surface of the plates is smooth, one of the syntypes (13371–B) shows locally a fine, granulose ornamentation, which is definite, even though mostly obscured or effaced by weathering.

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Types.—Syntypes, Walker Museum no. 13371; collected by J. A. Udden.

STUARTWELLERCRINUS TEXANUS (Weller)

Pl. 15, fig. 1

Cibolocrinus texanus WELLER, 1909, Jour. Geol., vol. 17, p. 633, pl. 1, figs. 18, 19.

Description.—Weller's description, slightly modified in form, is as follows:

The dorsal cup is turbinate with sides diverging, with gently concave curvature from the margin of the stem impression to slightly convex with the distal border of the cup. The surface of the plates is smooth and sutures are not impressed in grooves. The dimensions of the holotype are: height of cup 14 mm., greatest width, 21 mm. The three large infrabasals (IBB) show one-half of their length occupied by the large stem impression, which is in the form of a conical depression at the base of the cup. The distal parts of the plate diverge upward and form the sides of the shallow cup. The basals (BB) and radials (RR) are large and similar in form and size to those of *C. turbinatus.* The anal plate is small and similar to that in *C. turbinatus.*

Measurements of this species, based on the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	14.0
Width of dorsal cup	21.0
Ratio of height to width	0.67
Height of basal concavity	1.7
Width of infrabasal disc	12.7
Length of basal	7.3
Width of basal	9.6
Length of radial	5.9
Width of radial	7.4
Length of suture between basals	3.9
Length of suture between radials	4.0
Width of body cavity	13.6
Height of infrabasal circlet	4.3
Width of stem impression	6.6

Discussion.—As noted by Weller, this species most closely resembles *S. turbinatus* (Weller). It is distinguished from that form by its much larger stem impression and the slightly concave sides of the dorsal cup.

Occurrence.—Cibolo limestone (equivalent to part of Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13373; collected by J. A. Udden.

STUARTWELLERCRINUS SYMMETRICUS (Weller)

Pl. 15, figs. 2, 3

Cibolocrinus symmetricus WELLER, 1909, Jour. Geol., vol. 17, p. 633, pl. 1, figs. 27–30. (Permian, western Texas.)

Description.—Weller's description, slightly modified in form of statement, is as follows:

The dorsal cup is turbinate, and the sides diverge from the margin of the stem impression to the distal margins of the radials (RR). The surface of the plates is smooth, and they have the regular curvature of the surface of the cup, or in some cases they may be a little convex. The sutures are not impressed in furrows. The dimensions of the most complete examples are: height of dorsal cup, 13 mm.; greatest width, 18 mm.

The infrabasals (IBB) are like those in *C. turbinatus*. The basals (BB) are also like those in that species, except that the posterior basal (pB) is angular at its distal extremity like the others, not being truncated for contact with an anal plate. The radials (RR) are also similar to those in *C. turbinatus*, except that the two posterior ones are in contact laterally. The anal plate, situated above the radials (RR), is in a notch between the two posterior radials.

Measurements of two syntypes (Walker Museum no. 13372, specimens A and B) and of a hypotype (Kansas University no. 60375), in millimeters, are given in the following tabulation:

	Syntype 13372A	Syntype 13372B	Hypotype 60375
Height of dorsal cup	12.9	13.0	16.5
Width of dorsal cup	19.3	21.4	22.2
Ratio of height to width	0.67	0.61	0.75
Width of stem impression	3.2	......	3.3
Height of stem impression	0.4	...	0.9
Height of infrabasal circlet	3.5	....	3.5
Width of infrabasal circlet	9.3	9.3	10.4
Length of basal	8.8	8.4	9.2
Width of basal	8.6	9.5	10.0
Length of radial	6.1	6.0	7.5
Width of radial	11.5	12.2	12.7
Length of suture between basals	3.9	4.0	5.3
Length of suture between radials	4.7	4.1	5.0

Discussion.—It has already been indicated that one of the syntypes of *S. symmetricus* should be transferred to *S. turbinatus* (Weller). The other two syntypes of *S. symmetricus*, and the hypotype assigned to this species, are distinguished from *S. turbinatus* by the proportionally high infrabasal circlet and by the form of the dorsal cup, which is more nearly conical than bowl-shaped, the slight but distinct bulbous form of the plates belonging to the basal and radial circlets. In dorsal view of the cup a slight furrow appears between the radials. The ratio of the height of the infrabasal circlet to the height of the cup in *S. symmetricus* is 21 to 27, as compared to 15 or 16 in *S. turbinatus*. Basing recognition of the species on the characters just noted, rather than on the presence or the absence of an anal plate below the summit of the radials, differentiation can be made without much difficulty.

Attention may now be called to the fact that the hypotype, which has all the described characters of *S. symmetricus* just noted, differs in having an anal plate between the posterior radials resting on a narrow tip of the posterior basal. It is evident, therefore, that no special weight in this case is attached to the presence or absence of the anal plates on the exterior of the dorsal cup as a character having value for specific differentiation. On the other hand, among crinoid cups in which the structure of the posterior interradius is essentially constant, characters of the anal plates may have value not merely for specific but for generic diagnosis.

It is odd that Weller should have failed to notice that one of his syntypes of *S. symmetricus* (13372–A) is not smooth, as indicated in his description of the species, but over most of the cup carries a very well preserved, fine granulose ornamentation. Syntype no. 13372–B also shows this decoration in the least weathered parts of the cup.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, about 3 miles north of Shafter, Presidio County, Texas.

Types.—Syntypes, Walker Museum no. 13372, specimens A and B; collected by J. A. Udden. Hypotype, Kansas University no. 60375; collected by R. C. Moore.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B–2—GROUP a]

SUBGROUP γ.—*Cup bowl shaped; two or three anal plates in cup.*

Crinoids of this subgroup have infrabasals that are clearly visible in the side view of the cup and articular facets that are horizontal and equal in width to the radial plates. The genus *Ulocrinus*, which belongs here, and the crinoid called *Cromyocrinus magnus* Mather, from Morrow beds of northwestern Arkansas, are the only described forms known to occur in Pennsylvanian (Upper Carboniferous) rocks of North America; *Ulocrinus* is identified as occurring also in Lower Permian rocks of Texas. The Mississippian crinoid, *Agassizocrinus,* which has a dorsal cup lacking a stem attachment in most cases, has been reported from Pennsylvanian beds on the basis of finding the distinctive fused infrabasal circlets that have been supposed to belong only to this genus. It is now possible to demonstrate that some of the Pennsylvanian agassizocrinid cup bases really belong to a form that must be regarded as generically distinct from *Agassizocrinus,* and it is likely that most, if not all, these Pennsylvanian crinoid remains are properly placed in the new genus, *Paragassizocrinus.* Infrabasal circlets that probably belong to *Ulocrinus* occur in Texas, but no complete dorsal cups have yet been found except that of a Permian species.

Genus AGASSIZOCRINUS Owen and Shumard, 1852

Agassizocrinites (Troost), 1850, Am. Assoc. Adv. Sci., Proc., vol. 2, p. 60 *(nomen nudum).*

Agassizocrinus Owen and Shumard, 1852, Acad. Nat. Sci, Philadelphia Jour., ser. 2, vol. 2, p. 93; 1852, in Owen, Rept. of geol. survey of Wisconsin, Iowa, and Minnesota, p. 597, Philadelphia.

Agassizocrinus Troost, Wachsmuth and Springer, 1886, Revision of Palaeocrinoidea, pt. 3, p. 262.

Agassizocrinus Shumard ex Troost MS. Bather, 1900, Lankester's Zoology, pt. 3, p. 181.

Agassizocrinus Shumard ex Troost MS, Zittel–Eastman, 1913, Textbook of Palaeontology, p. 224.

Agassizocrinus Owen and Shumard, Springer, 1926, U. S. Nat. Mus., Proc., vol. 67, art. 9, p. 53.

Agassizocrinus Owen and Shumard, Moore and Plummer, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 250.

Astylocrinus Roemer, 1855, Lethaea geognostica, vol. 1, pl. 2, p. 229.

Troost first coined a generic name for a crinoid using the surname of the great naturalist, Agassiz, as part of the term. Troost's *Agassizocrinites* was published in a check list of species of Tennessee without any description or definition, however, and it therefore has no validity. The many years of delay in publishing Troost's manuscript describing the genus, coupled with circulation among several paleontologists of knowledge concerning the peculiar character of the crinoid that was to be called *Agassizocrinites,* resulted in publication that must be reckoned to establish a slightly different name, different authorship, and a different genotype than were originally intended.

Owen and Shumard, in 1852, used the name *Agassizocrinus* for a new species of stemless crinoid called *A. conicus*. It is generally like the form that Troost termed *Agassizocrinites dactyliformis* in his manuscript, but the two species are readily separated. The fact that Owen and Shumard are the first to publish scientifically adequate indication of the new genus, requires that they, rather than Troost, be listed as authors, and this is additionally established by the difference in the name that they used, for *Agassizocrinus* is not a term ever used by Troost.

This genus includes crinoids that have an elongate, smooth-surfaced, bluntly pointed cup and more or less fused plates. Most of the species were floating forms and at maturity had no stem or visible means of support. Most fossil specimens lack the radials and basals, consisting only of infrabasals, which are fused to form a single conical or semi-elliptical cup, scalloped radially at the top in five equal divisions. A few forms possessed a small stem, and some immature forms show infrabasals (IBB) that are not completely fused. The Mississippian specimens of the genus have three anal plates in the dorsal cup, like *Cromyocrinus*. The Pennsylvanian forms from Texas all are smooth infrabasal (IBB) cones having no stem and no basal or radial plates attached.

There are ten uniserial arms, the division in each ray occurring on the first primibrach (IBr_1).

Genotype.—*Agassizocrinus conicus* Owen and Shumard; from the Chester group, upper Mississippian (Lower Carboniferous), Chester, Illinois.

Discussion.—Fossils from the Pennsylvanian rocks of Texas that resemble *Agassizocrinus* consist of fused infrabasal (IBB) circlets with rounded base and absence of stem impression, and dissociated plates of the basal (BB) and radial (RR) circlets that can be identified as agassizocrinid in structure and form, because of their unusual thickness, because they can be fitted to the infrabasal (IBB) circlets in many species, and because no crinoid material, except associations of these infrabasals (IBB), basals (BB), and radials (RR), of distinctive appearance is found at a number of localities. It has been possible to determine from study of collections of dissociated elements of Texas agassizocrinid cups that some of them, at least, represent an *Agassizocrinus*-like genus but certainly do not belong to true *Agassizocrinus*. After reaching this conclusion, a nearly complete specimen of dorsal cup of this type, with attached parts of the arms, has been found, and this gives definite confirmation as to distinctions between the Pennsylvanian fossils under consideration and *Agassizocrinus*.

A new genus, *Paragassizocrinus*, is therefore introduced to include the Pennsylvanian forms, which are characterized by the presence of only one anal plate in the cup and by the occurrence of two primibrachs (IBr) instead of one, in each ray. So far as known, species that are positively assignable to *Agassizocrinus* are Mississippian in age. Therefore, discussion of the Pennsylvanian forms that have been classed previously as belonging to *Agassizocrinus* is given in treatment of the new genus.

Genus ULOCRINUS Miller and Gurley, 1890

Ulocrinus MILLER AND GURLEY, 1890, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 6.

Ulocrinus Miller and Gurley, BATHER, 1917, Geol. Soc. Glasgow, Trans., vol. 16. p. 207.

Ulocrinus Miller and Gurley, WANNER, 1927, Mijn. Ned. Oost-Indië, Verh. (1921), p. 192.

Ulocrinus Miller and Gurley, WRIGHT, 1927, Geol. Mag., vol. 64, p. 353.

This genus is characterized by its relatively large dorsal cup of subglobular or high bowl-shaped form with convex base, with the gently upward-flaring five infrabasals (IBB) visible in a side view of the cup. The five basals (BB) are each as large as, or larger than, the infrabasal disc. These plates form most of the curving sides of the cup. The radials (RR) are pentagonal, much wider than long, with articular facets equal to the full width of these plates and projecting somewhat over the interior of the cup so as to form a broad, horizontal, nearly plane articulating surface for the primibrachs (IBr). There are two anal plates in the cup, one a large quadrangular radianal (RA), which rests against the posterior basal (pB) and the right posterior basal (rpB) below, and obliquely above this is a smaller anal x that generally projects somewhat above the summit of the radials (RR). The stem is round, and the lumen at its center is petaloid or strongly pentalobate. The structure of the arms and anal sac is not known.

Genotype.—*Ulocrinus buttsi* Miller and Gurley, from middle Pennsylvanian beds (precise horizon unrecorded), at Kansas City, Missouri.

Discussion.—The diagnostic features of the genus *Ulocrinus* are the upward-flaring position of the infrabasal plates, so that they are plainly visible from a side view of the cup, the presence of two anal plates below the summit of the radials, and the wide, comparatively long, nearly horizontal articular facets of the radials. The average large size of specimens belonging to *Ulocrinus* is a characteristic feature but not necessarily a matter of any generic significance.

Ulocrinus differs from *Cromyocrinus* in having only two, instead of three, anal plates in the dorsal cup. There are two anal plates in the dorsal cup of *Parulocrinus* and *Ethelocrinus*, which have large cups somewhat resembling those of *Ulocrinus*, but the infrabasal disc is horizontal, or at least not definitely down-flaring, in the first, and the base is distinctly concave in the latter.

Species of *Ulocrinus* from North America that are now recognized include: *U. americanus* (Weller), from lower Permian limestone of west Texas; *U. buttsi* Miller and Gurley, the genotype species, from beds of the Missouri series, middle Pennsylvanian, at Kansas City, Missouri; *U. kansasensis* Miller and Gurley, also from middle Pennsylvanian beds at Kansas City, Missouri; *U. occidentalis* Miller and Gurley, described from dissociated basal plates and an infrabasal circlet from Pennsylvanian rocks near Gilpin, Missouri; and *U. sangamonensis* (Meek and Worthen), from lower Missouri beds in Sangamon County, Illinois.[76a] Other species of *Ulocrinus* are: *U. globularis* (de Koninck), from the upper part of the Lower Carboniferous of Scotland; and *U.? goliathus* (Waagen), from the middle *Productus* limestone, of Permian age, in India. Crinoids called *U. nuciformis* (McCoy), from the Lower Carboniferous of Scotland, and *U. indicus* Wanner and *?U. conoideus* Wanner, from the Permian of Timor, appear not to belong in *Ulocrinus*. *U. blairi* Miller and Gurley is here transferred to the new genus, *Parulocrinus*, as genotype species.

[76a]A crinoid from upper Missouri beds at Bartlesville, Oklahoma, recently described by H. L. Strimple (A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, p. 13, pl. 1, figs. 11, 12, 15, 16, 1939) under the name of *Ethelocrinus convexus* belongs to *Ulocrinus*.

Occurrence.—This genus is known to range in North America from Lower Pennsylvanian (Des Moines series) to Lower Permian beds. It is reported to occur also in upper Lower Carboniferous rocks of Scotland and possibly in Permian beds of India.

ULOCRINUS AMERICANUS (Weller)

Pl. 19, fig. 6; text fig. 67

Phialocrinus americanus WELLER, 1909, Jour. Geol., vol. 17, p. 625, pl. 1, figs. 8, 9. (Lower Permian, western Texas.)

Description.—Weller's description of this species, slightly modified in form of statement, follows:

The dorsal cup is large and subglobose. The diameter of the type specimen is approximately 47 mm., and its height approximately 30 mm. The surface of the plates is smooth. All the sutures except those between the infrabasals (IBB) are situated in shallow, narrow grooves. The infrabasals (IBB) form a shallow, saucer-shaped basin which is visible in side view; its diameter is about 22 mm. in the type specimen. The stem impression, slightly depressed below the surface of the plates, has a diameter about one-third that of the infrabasal (IBB) disc. The basals (BB) are large; all except the posterior basal (pB) are hexagonal, but the two proximal facets are nearly in a straight line, and together they are about equal in length to each one of the other sides, so that the general outline of the plates is nearly regularly pentagonal. The length and width of each of these plates in the type specimen are about 24 mm.; the posterior basal (pB) is not complete in the type specimen but is probably similar to the others except in being somewhat wider and in having the distal angle truncated for the reception of an anal plate. The radials (RR) are large, pentagonal, and wider than long. The anal plate is not present in the type specimen. It is probably quadrangular or pentagonal in outline and rests upon the truncated distal end of the posterior basal (pB) between the two posterior radials (RR).

Discussion.—The description of this species is based on a somewhat fragmentary dorsal cup in which only the infrabasal circlet is perfectly shown. Weller referred the species to *Phialocrinus* (an invalid name that is a synonym of *Aesiocrinus* Miller and Gurley), because he concluded that there was probably only a single anal plate in the dorsal cup. Careful recent study of the holotype specimen, including not only measurements of all the plates but restoration of missing parts in plasticine, leads to the conclusion that Weller was mistaken in thinking that there was room for only a single anal plate on the posterior side of the cup. The comparative measurements of the cup and the restoration both indicate that a radianal belongs obliquely above the posterior basal. Another anal plate certainly belongs obliquely at the left above the radianal, and it would be entirely possible for two plates to

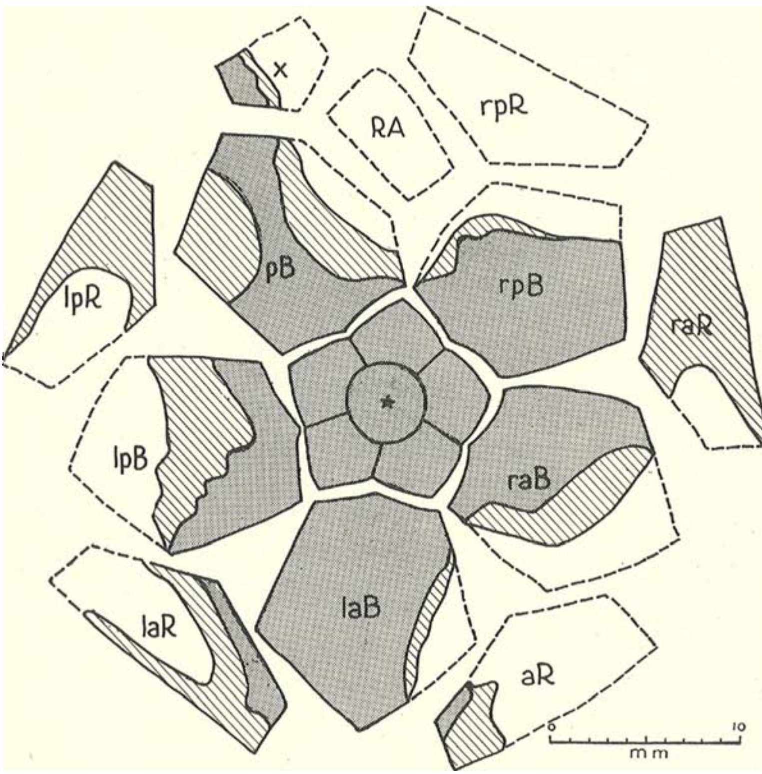

Fig. 67. Diagram showing the shape and arrangement of plates in the dorsal cup of *Ulocrinus americanus* (Weller), based on the holotype. Areas in which the surface of the dorsal cup is preserved are shown in gray; calcite belonging to part of the plates beneath the surface is shown by the ruled pattern; dotted lines indicate restoration.

occur in this position. If the anal plates consist of the radianal and one other, the genus is *Ulocrinus*, but if there are three anal plates all together, the genus is *Cromyocrinus*. Because undoubted examples of *Cromyocrinus* younger than lowermost Pennsylvanian have not been seen, whereas representatives of *Ulocrinus* are common in middle and upper Pennsylvanian strata, it seems reasonable to conclude that this Permian crinoid belongs to *Ulocrinus*. A drawing showing the observed and inferred relations of plates in the dorsal cup of this species is given in figure 67.

Ulocrinus americanus is distinguished from *U. buttsi* Miller and Gurley, the genotype, by its much wider, lower form. It is a larger species and the infrabasals flare more gently than in *U. occidentalis* Miller and Gurley.

Occurrence.—Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian; Loc. 188–T–3, on Sierra Alta Creek, Cibolo ranch, Presidio County, Texas.

Type.—Holotype, Walker Museum no. 13369; collected by J. A. Udden.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-2—GROUP a]

SUBGROUP δ.—*Cup bowl-shaped; one anal plate in cup.*

Crinoids with subhorizontal facets as wide as the radials, with infrabasals visible from the side, and with one anal plate in the rather high bowl-shaped cup are assigned to this subgroup. Here belongs the new genus, *Paragassizocrinus*, so termed because of its close relationship to *Agassizocrinus*. Essential features of *Paragassizocrinus* were learned first from study of collections of infrabasal cup bases and dissociated basal and radial plates obtained from Pennsylvanian outcrops in Texas. Subsequently, a complete dorsal cup with attached lower arm plates was obtained from southern Kansas, and this confirms earlier conclusions as to occurrence of only one anal plate in the cup and as to difference from *Agassizocrinus* in arm structure.

Genus PARAGASSIZOCRINUS Moore and Plummer, n.gen.

Agassizocrinus Owen and Shumard, STRIMPLE, 1938, A group of crinoids from the Pennsylvanian of northeastern Oklahoma; private publication, p. 10 (unnumbered), Bartlesville, Oklahoma.

This genus is made to include elongate, conical crinoids having no stem at maturity and having only one anal plate in the dorsal cup. The infrabasals (IBB) form a thick, somewhat elongate, fused calcareous mass that is rounded or bluntly pointed at the base and scalloped at the top for contact with the basals (BB). Rarely, and chiefly in immature specimens, sutures between the plates of this circlet are visible. Ligament markings may appear at the top of the infrabasal (IBB) cone.

The basals (BB) are pentagonal, excepting the posterior basal (pB), which is hexagonal. These plates are relatively thick and by this character can generally be recognized as belonging to *Paragassizocrinus* rather than to another genus. They are slightly curved at the proximal end and pointed at the distal end, as shown in figure 68.

The radials (RR) are also quite thick, about twice as wide as long, pointed at the base, and gently curved at the top. The general plane of the facets is subhorizontal, their width is equal to that of the radials (RR), and their length does not exceed the thickness of the plates. The outer ligament area is short, moderately excavated, and inclined slightly outward; the inner area is nearly plane and slopes inward throughout the mid-portion.

A single anal plate rests between the posterior radials (RR) on the broadly truncated extremity of the posterior basal (pB).

The arms are composed of uniserially arranged segments, branching isotomously once on the second primibrach (IBr_2). The first primibrach (IBr_1) is quadrate; the second is pentagonal, pointed at the top, and is strongly grooved and ridged for articulation with the arm branches.

Genotype.—*Agassizocrinus tarri* Strimple.

Discussion.—The new genus closely resembles *Agassizocrinus* Owen and Shumard in shape and appearance but differs generically in the lesser number of anal plates in the cup and in the structure of its arms, for in *Agassizocrinus* there are three anals below the summit of the radials (RR) and only one primibrach (IBr) is found in each ray. The half-egg-shaped or subconical, fused infrabasal (IBB) circlets of *Paragassizocrinus* are indistinguishable from those of *Agassizocrinus.*

The conclusion that agassizocrinid remains consisting of dissociated infrabasal cones (actually hemi-ellipsoids), and other plates of the crown, found at certain localities in Texas, Oklahoma, and Kansas, belong to a genus that is really distinct from *Agassizocrinus,* was first reached from reconstruction of the cup and lower part of the arms. It was possible to be reasonably certain that the scattered fragments represent a single type of crinoid because, interestingly enough, only smooth, thick plates of *Agassizocrinus* type were found at some of these places, and because it was not difficult to fit these plates together. The evenly curved proximal margin of the basal plates, which in itself is a distinctive feature among crinoid plates, exactly matched the scalloped edge of the agassizocrinid infrabasal cones, and radial plates corresponded in thickness and shape to notches between the basals when assembled. Although no example of an anal plate was identified, it was apparent from reconstruction of the cup that there was room only for a single such plate below the summit of the radials and that this plate rested squarely on the truncated tip of the posterior basal. On the basis of this study it seemed appropriate to establish a new genus, for which the name *Paragassizocrinus* was selected because of its obvious relationship to *Agassizocrinus*. The genotype species was, of course, named and described in manuscript.

At this point Dr. Carl O. Dunbar made available a nearly complete dorsal cup with attached primibrachs, which Dr. G. E. Condra had collected from the Stanton limestone in southern Kansas, and it was apparent that this specimen belonged to *Paragassizocrinus*. It was preferable as holotype for the genotype species. However, H. L. Strimple[77] described and figured a crinoid from Ochelata beds (upper Missouri series) near Bartlesville that must be concluded to be conspecific with our new agassizocrinid, both as judged from illustrations and description and from the occurrence of Strimple's types in beds exactly, or almost exactly, the same as the Stanton in Kansas. Strimple's species was named *Agassizocrinus tarri*. Even though the specimen from the Stanton limestone is more perfect than the type material of *A. tarri*, Strimple's types unavoidably stand taxonomically first.

It is very probable that *Agassizocrinus carbonarius* Worthen from the upper part of the Middle Pennsylvanian beds of Illinois belongs also to this genus, and when more complete specimens are obtained from Illinois, they may prove to be conspecific with *Paragassizocrinus tarri*. *Agassizocrinus magnus* Moore and Plummer and *A. caliculus* Moore and Plummer are known only from their fused basal circlets and hence it is not possible to determine surely whether they belong to *Agassizocrinus* or *Paragassizocrinus* until more complete material is obtained from the Morrow beds. On the other hand,

[77]Strimple, H. L., A group of crinoids from the Pennsylvanian of northeastern Oklahoma: private pub., pp. 10–11 (unnumbered), pl. 2, figs. 7, 10, 13, Bartlesville, Oklahoma., Nov., 1938.

since all the species that are known definitely to belong in *Agassizocrinus* are upper Mississippian in age, and since the only Pennsylvanian agassizocrinids that can be identified positively belong to *Paragassizocrinus,* it is a reasonable assumption that isolated infrabasal (IBB) cones of this type from the Pennsylvanian rocks probably belong to this new genus rather than to *Agassizocrinus.*

Five species from Pennsylvanian rocks of North America have been identified as belonging to *Agassizocrinus,* as follows: [77a]

A. conicus Owen and Shumard, of Morgan	Morrow, Oklahoma
A. carbonarius Worthen (type)	Upper Missouri or Lawer Virgil, Illinois
A. carbonarius Worthen, of Beede	Upper Missouri, Missouri
A. magnus Moore and Plummer	Morrow, Arkansas
A. caliculus Moore and Plummer	Morrow, Arkansas
A. tarri Strimple	Missouri, Oklahoma

Since the differentiation of all these species, except the last, was based only on the study of the fused infrabasal portion of the cup, exact specific distinctions are difficult. The authors were obliged to rely largely on the shape of the infrabasal (IBB) circlet and on the appearance of the upper ends of the fused infrabasal (IBB) plates. The following table shows a comparison of measurements of the diameter and height of the Upper Carboniferous forms (IBB cones) referred to this genus and of the genotype of *Agassizocrinus* from the Lower Carboniferous:

Species	Diameter *mm.*	Height *mm.*	H/D
A. tarri Strimple (syntypes)	12.0[a]	8.7[a]	0.72
A. conicus Owen and Shumard (holotype of genotype)	14.6	12.3	0.84
A. conicus Owen and Shumard, of Morgan	10.6	12.4	1.07
A. carbonarius Worthen (holotype)	10.8	7.0	0.65
A. carbonarius Worthen, of Beede	9.8	6.5	0.66
A. magnus Moore and Plummer (holotype)	23.4	21.8	0.93
A. caliculus Moore and Plummer (holotype)	7.0	5.0	0.72

[a]Measurements approximate, based on author's illustrations.

If these proportions can be relied upon as specific characters, *A. conicus,* of Morgan, from the Wapanucka limestone (Morrow) is probably conspecific with *A. magnus* Moore and Plummer from the Morrow, and it differs from the typical *A. conicus* Owen and

[77a]In addition to the forms tabulated, the fused infrabasal (IBB) circlets, designated respectively as *Henanobasis coffeyvillensis* Moore (The use of fragmentary crinoidal remains in stratigraphic paleontology: Denison Univ. Bull., Jour. Sci. Labs., vol. 33 (1938), p. 206, pl. 2, figs. 3a–c, pl. 3, fig. 11, 1939) and *Agassizocrinus mcguirei* Strimple (A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Amer. Pal., vol. 24, no. 87, p. 18 pl. 2, figs. 9, 10, 1939) probably belong to *Paragassizocrinus.*

Shumard from the upper Mississippian (Chester). The shapes of different individuals collected from a single locality in some cases vary so much, however, that it is doubtful whether these measurements have diagnostic value in differentiation of species. For example, the shape of agassizocrinid infrabasal (IBB) cones collected from a single locality, the clay pit at Bridgeport, Wise County, vary considerably in measurements, as indicated in the following tabulation for twelve specimens:

Specimen	Diameter *mm.*	Height *mm*	H/D
P-4292B	11.7	6.6	0.56
P-6167B	13.7	8.1	0.59
P-4292C	13.0	8.3	0.64
P-2619	12.5	8.1	0.65
P-1164	11.5	8.0	0.70
P-4292	12.8	9.1	0.71
P-6167	10.0	7.5	0.75
P-6167A	13.2	10.1	0.77
P-31511	13.0	10.0	0.77
P-1054	10.8	9.0	0.83
P-4292A	12.0	10.8	0.90
P-4752	15.3	14.4	0.94

The markings at the top of the infrabasal (IBB) cone appear to have value for recognition of species, however, indicating that the specimen just recorded may actually represent more than a single species.

Consideration of the generic affinities of *Paragassizocrinus* is incomplete without notice of resemblances to *Petschoracrinus* Yakovlev, from Permian rocks of the Petschora district, northeastern Russia.[78] The shape of the dorsal cup, the arrangement and proportions of plates in the different circlets, the presence of a single anal plate centrally located on the truncated top of the posterior basal (pB), and the occurrence of two moderately large primibrachs (IBr) in each ray are points of close similarity in these genera. All the specimens of *Petschoracrinus,* however, are reported to have the infrabasals (IBB) unfused, and a stem is definitely present in at least some examples. A curious tendency of the infrabasals to fuse with basals is described by Yakovlev (1930), the number of infrabasals in different specimens ranging from 5 to 0,

[78]Yakovlev, N. N., Deux nouveaux genres de crinoides (Poteriocrinidae) du Paléozoic supérieur du pays de la Petschora: Mus. Géol. près l'Acad. Sci. U. R. S. S., Travaux, vol 3 1926.

———— Le genre *Petschoracrinus* et le passage des crinoides monocycliques: Acad. Sci. U. R. S. S., Comptes Rendus, no. 2, pp 27–29, 1930.

———— Exegolrek Vseross. Palaeontol., vol. 11, Zak, 1613, pp. 129–131, 1938.

with all gradations. The infrabasals are extremely thickened, as in *Agassizocrinus* and *Paragassizocrinus*, so as to form an essentially solid base for the cup, but one figure given shows a very narrow, deep pit at the base of the circlet, which is filled by the proximal dozen or more segments of the small round stem. Some illustrations suggest absence of a stem. Three specimens of *Petschoracrinus* with attached arms are figured by Yakovlev (1938), but the total number of arms and the mode of their union are not discernible. The arms are rounded, composed of uniserially arranged segments, less than half as wide as the primibrachs. and Yakovlev thinks that there is only one arm in each ray; the second primibrach is squarely truncated distally, instead of pointed, as in *Paragassizocrinus*. Although no mention of *Agassizocrinus* is made in the Russian papers, there can be little doubt that *Petschoracrinus* is a peculiarly variable and aberrant agassizocrinid.

Occurrence.—Missouri series, Pennsylvanian (Upper Carboniferous), of Kansas, Oklahoma, and Texas; probably also Morrow, Des Moines, and Virgil series, Pennsylvanian, in Illinois and throughout the Mid-Continent region.

PARAGASSIZOCRINUS TARRI (Strimple)

Pl. 1, fig. 6; pl. 16, fig. 9; text fig. 68

Agassizocrinus tarri STRIMPLE, 1938, A group of crinoids from the Pennsylvanian of northeastern Oklahoma: private publication, p. 10 (unnumbered) pl. 2, figs. 7, 10, 13, Bartlesville, Oklahoma.

Description.—Original definition of this species was apparently based on two incomplete dorsal cups and on an unstated number of infrabasal (IBB) cones. One of the incomplete cups consists of the lower two circlets, and the other shows the upper two circlets and some attached brachials. The specimens represent individuals of nearly identical size, and there is no doubt about their belonging to the same species. The infrabasal (IBB) cone belonging to one of the types is bluntly rounded at the base, and the flaring sides near the top of the cone define an angle of about 65° in profile view; measurements are not given, and, because of discrepancies in size of the two views of this specimen, it is not possible to determine them satisfactorily from the figures (height, 6.5–8.8 mm.; greatest width, approximately 11.7–12.1 mm.). A ventral view of a dissociated infrabasal cone (Strimple's pl. 2, fig. 7a) indicates a width of 12.0 mm., and a width of the hollow space in the central part of the cone of 7.2 mm., the ratio of the latter to the former being 0.60. The height of the entire dorsal cup is computed from the two specimens to be 20.45 mm., and the greatest width of the cup (presumably based on the specimen showing the upper two circlets of plates) is given as 18.0 mm., measured from right to left, and 12.0 mm. in an antero-posterior direction. The measurements of width indicate that the specimen on which they were based is probably deformed, and the mean figure of 15.0 mm. is regarded as more likely to represent the true greatest width of this cup. Illustrations of the basal (BB) plates indicate that these are slightly longer than wide, measurements of a posterior basal (pB) taken from a figure of one of the types being 8.8 mm. for the length and 7.5 mm. for the width, ratio of width to length being 0.85. The radials (RR) are about twice as wide as long, the range in width being 8.0 to 8.75 mm., and there is not the definite sort of variation in width that was noted by Springer[79] in species of *Agassizocrinus*. One of the types of *P. tarri* shows the quadrangular first primibrach (IBr_1) and pentagonal axillary second primibrach (IBr_2) in the right posterior, right anterior, and anterior rays, and a dorsal cup from the Stanton limestone of Kansas shows the primibrachs of the left anterior and left posterior rays, which are of the same sort. The single anal plate of this species of crinoid is symmetrical in outline, its lower two-thirds being below the summit of the radials (RR), the squarely cut base in contact with the posterior basal (pB); the upper edge of the anal plate bears three facets for contact with tube plates, and thus the plate has six edges all together. Strimple's plate 2, figure 10, shows this plate slightly displaced toward the interior of the cup.

Attention may now be given to the hypotype specimens (Nebraska Geol. Survey nos. 836, 836a, 836b) consisting of a nearly complete dorsal cup and two infrabasal cones, from the Stanton limestone near Wayside, Kansas. The height of the dorsal cup is 16.5 mm., which is appreciably less than the computed height (20.45 mm.) of the types from Bartlesville (although measurements taken from

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[79]Springer, Frank, Unusual forms of fossil crinoids: U. S. Nat. Mus., Proc., vol. 67, art. 9, pp. 58–59, 1926.

the figures give about 17 to 19 mm.). The width at the top of the cup is 15 mm., without regard to direction of measurement; this corresponds exactly to the mean of long and short measurements of one of the Bartlesville types. The ratio of height to width of the Kansas specimen is 0.91. The sides of the upper two-thirds of the cup are approximately vertical, and the base is very bluntly pointed, the angle between slopes near the top of the infrabasal (IBB) cone, in profile view, being about 67°. The infrabasal circlet is a solidly fused cone, having a height (measured from outer edge of one of the sutures) of 6.0 mm. and a width at the top of 11.2 mm., which indicates a ratio of height to width amounting to 0.54. The curved sutural faces at the top of the circlet, which slope gently outward, have a thickness of 3.0 mm., and the width of the hollow space in the central part of the cone is 6.6 mm., the ratio of the former to the latter being 0.60. The basals (BB) are a little wider than long, practically straight in longitudinal profile, and regularly curved transversely. Excepting the posterior basal, which is hexagonal, each edge of the pentagonal basals has almost exactly the same length as the others. The radials (RR) are slightly less than twice as wide as long, the greatest widths ranging from 7.7 to 8.3 mm., and like the type described by Strimple, without reduction in size of the anterior ray. The facets are divided by a fairly prominent transverse ridge into a short outer ligament area that is moderately excavated and slopes slightly outward, and a wider but also short inner ligament area that bears faint fossae near the outer angles. The anal plate is lacking in the Wayside hypotype, but the space for it below the summit of the radials is about 3.5 mm. wide and the same in length. The first primibrachs (IBr_1) are quadrangular segments that are about twice as wide as long; the second primibrach (IBr_2) is an axillary plate, much longer in the middle than at the sides, so that the angle between the upper articular edges is approximately 90°. A few secundibrachs (IIBr) that are preserved are quadrangular segments about half as wide as the primibrachs. The surface of the dorsal cup is entirely smooth; the sutures are very clearly marked but are not impressed.

Measurements of the hypotypes from near Wayside, in millimeters, are as follows:

Hypotype (Nebraska Geol. Survey no. 836)—	
Height of dorsal cup	16.5
Width of dorsal cup	15.0
Ratio of height to width	0.91
Length of basal	7.6
Width of basal	9.0
Length of radial	5.4
Width of radial	9.0
Length of suture between basals	4.0
Length of suture between radials	3.5
Hypotype (Nebraska Geol. Survey no. 836a)—	
Height of infrabasal circlet	8.0
Width of infrabasal circlet	12.8
Hypotype (Nebraska Geol. Survey no. 836b)—	
Height of infrabasal circlet	9.5
Width of infrabasal circlet	13.3

About 50 specimens of infrabasal cones (IBB) and numerous basals (BB) and radials (RR) that are found in the Graford formation at localities in north-central Texas are referred to *P. tarri.* The average width of the cones is 12.5 mm. and the height about 9 mm. The thickness of suture edges at the top of the cones is mostly about 4.5 mm., and the hollow in the central part of the cones averages 7 mm. in diameter and 2.7 mm. in depth; the ratio of the diameter of the cavity to that of the cone ranges from 0.50 to 0.55, averaging about 0.52. The upper edges of the cones bear five sharp radiating ridges, between which are broad shallow outwardly sloping saddles that, in well-preserved specimens, show a very distinct but delicately sculptured pattern near the inner margin; the design of the pattern, which reflects the character of ligamentous union between the plates, is not exactly the same in different specimens, but the significance of the variation, if any, is not known. Using the dissociated basal and radial plates that are found with the infrabasal cones, it is possible to reconstruct the dorsal cup, and loose primibrachs indicate the character of the arms, at least to the extent of showing the presence of one or more quadrangular segments below the axillary primibrach. Comparison with the articulated specimens from Bartlesville and near Wayside permit conclusion that only one quadrangular primibrach occurs in each ray. The basal plates (BB) are a little longer than wide, a typical example measuring 9.4 mm. in length and 8.5 mm. in width; specimens of the posterior basal (pB) are hexagonal, with truncation at the top for contact with the anal plate, as already described in other specimens. The average width of the radials (RR) is 1.65 times that of the length, a large example measuring 9.5 mm.

in width and 5.8 mm. in length. No plates identifiable as anal x have been found, but reconstruction of the cup shows clearly that the fragments under discussion belong to *Paragassizocrinus*, and, although they differ very slightly from *P. tarri*, so far as now appears, there is hardly any ground for assigning them to a new species.

Discussion.—The infrabasal circlets, including those of fairly complete dorsal cups, that are regarded as belonging to *P. tarri*,

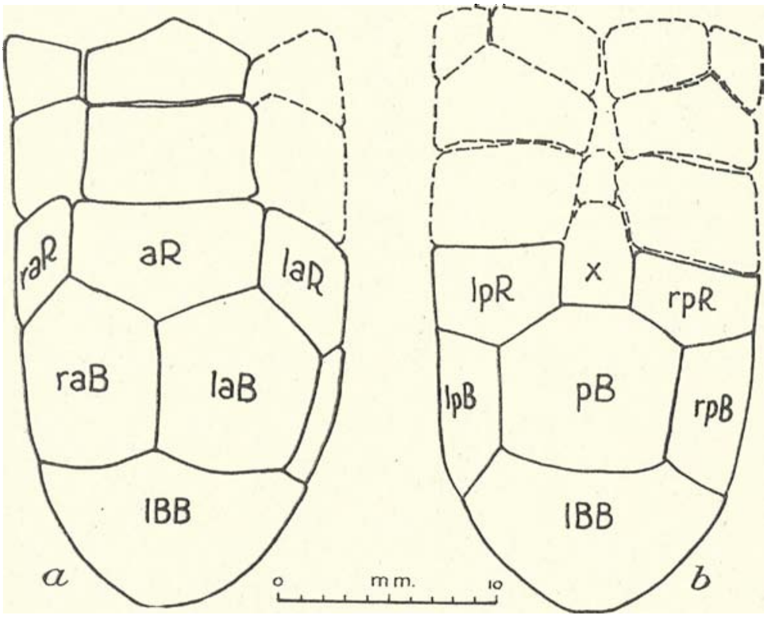

Fig. 68. Drawings of the anterior and posterior sides of a hypotype (Nebraska Geol. Survey no. 836) of *Paragassizocrinus tarri* (Strimple), the genotype species, showing two primibrachs in each ray and one anal plate in the dorsal cup.

correspond closely in appearance to that of "*Agassizocrinus*" *carbonarius* Worthen, which occurs in Illinois strata of Missouri age about the same as the deposits yielding remains of *Paragassizocrinus tarri*. The height of the cone in types of Worthen's species is 6.0 mm. and the width 10.5 mm., giving a ratio of height to width of 0.57, which corresponds to that of examples of *P. tarri*. The suture edges are notably thicker and sharper in infrabasal cones of *P. tarri* than in the Illinois form, which has a proportionally larger central cavity. It is not possible to differentiate between

Agassizocrinus and *Paragassizocrinus* on the basis of characters of the infrabasal cones, and because only these cones of the Worthen species are known, it is quite as likely that they represent the latter as the former.[80] Likewise, the infrabasal cones from Morrow beds of northwestern Arkansas described as *Agassizocrinus caliculus* Moore and Plummer and *A. magnus* Moore and Plummer,[81] may belong to *Paragassizocrinus* or conceivably to still another agassizocrinid genus, such as *Petschoracrinus.* The dimensions of basal and radial plates classed as belonging to *Paragassizocrinus tarri* from Texas correspond a little more closely to the types of the species than those of the dorsal cup from near Wayside, Kansas.

Occurrence.—The type specimens of *P. tarri* come from beds of the Ochelata group close to the horizon of the Stanton limestone, Missouri series, Pennsylvanian (Upper Carboniferous), from NE. ¼ sec. 1, T. 25 N., R. 12 E., about 4 miles south of Bartlesville, Oklahoma; collected by H. L. Strimple, and deposited in the U. S. National Museum. Hypotypes, Nebraska Geol. Survey nos. 836 (dorsal cup), 836a–b (infrabasal cones), from the Eudora shale member of the Stanton limestone, Missouri series, 2.5 miles east of Wayside, Montgomery County, Kansas; collected by G. E. Condra. Hypotypes, infrabasal cones and numerous plates, were collected from clay above the Willow Point limestone, Graford formation, Canyon group, Missouri series, Pennsylvanian (Upper Carboniferous); Loc. 248–T–6, in the brickyard clay pit at Bridgeport, Wise County, Texas. Also from the Graford formation on the northwest side of Kyle Mountain, Palo Pinto County, Texas, and from the Graford formation at the east end of Long Mountain, north of Brazos River and west of the Palo Pinto-Graford road, Palo Pinto County, Texas.

Types.—Syntypes in U. S. National Museum; collected by H. L. Strimple. Hypotypes, Nebraska Geol. Survey no. 836 (dorsal cup), 836–a, b (infrabasal cones); collected by G. E. Condra. Hypotypes, Plummer Collection nos. P–1054, P–1164, P–2619, P–11088,

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[80] It may be preferable to designate the fragmentary remains of this sort as *Hemanobusis carbonarius* (Worthen) (Moore, R. C., The use of fragmentary crinoidal remains in stratigraphic paleontology: Denison Univ. Bull., Jour. Sci. Labs., vol. 33 (1938), p. 206, 1939).

[81] Moore, R. C., and Plummer, F. B., Upper Carboniferous crinoids from the Morrow subseries of Arkansas, Oklahoma, and Texas: Denison Univ. Bull., Jour. Sci. Labs., vol. 37 (1937), pp. 250–254, 1938.

P–31516, P–6167A (numerous cones and plates), P–4752, P–10890, P–4292C (cones and plates), Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer, R. C. Moore, and W. T. O'Gara. Hypotypes, Kansas University nos. 60361, 60361a–t (Bridgeport); collected by R. C. Moore.

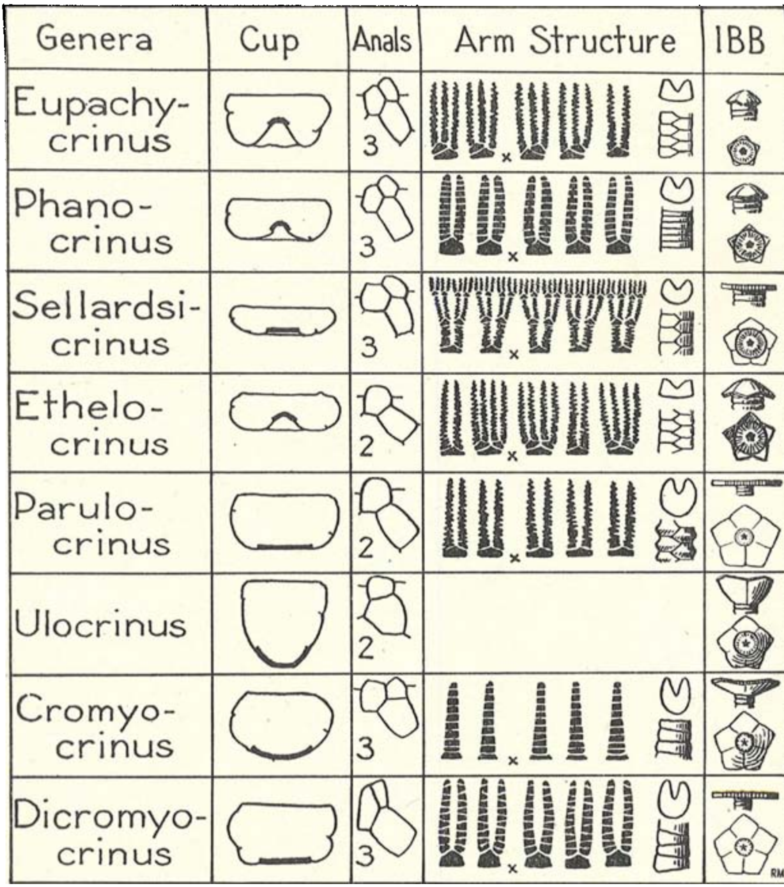

Fig. 69. Diagram showing comparison of eight genera of poteriocrinitids having subglobular dorsal cups with two or three anal plates in the cup: *Cromyocrinus* Trautschold, *Dicromyocrinus* Jaekel, *Ethelocrinus* Kirk, *Eupachycrinus* Meek and Worthen, *Parulocrinus*, n.gen., *Phanocrinus* Kirk, *Sellardsicrinus*, n.gen., and *Ulocrinus* Miller and Gurley.

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-2—GROUP a]

SUBGROUP ε.—*Cup globe-shaped; three anal plates in cup.*

Genus CROMYOCRINUS Trautschold, 1867

Cromyocrinus TRAUTSCHOLD, 1867, Soc. imper. Nat. Moscou, Bull., vol. 40, pt. 2, p. 19; 1879, Kalkbrüche von Mjatschkowa, Moscow, p. 117.—KEYES, 1894, Missouri Geol. Survey, vol. 4, p. 216.—SPRINGER, 1913, in Zittel-Eastman, Textbook of Palaeontology, p. 224.—MATHER, 1915, Denison Univ. Bull., Jour. Sci. Labs., vol. 18, p. 102.—JAEKEL, 1918, Palaeont.

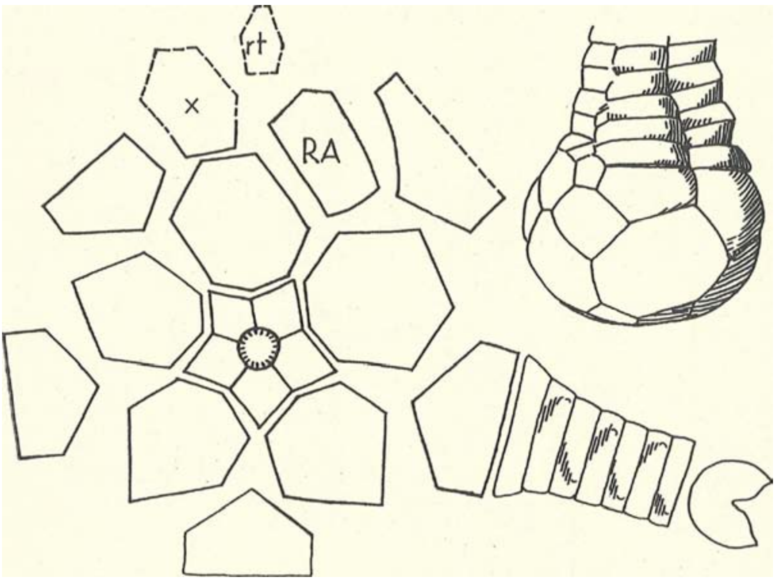

Fig. 70. Drawings showing the arrangement of plates in the dorsal cup and lower part of the arms of *Cromyocrinus simplex* Trautschold, the genotype species, based on a typical specimen (Walker Museum no. 7992, from near Moscow, Russia). The infrabasals are visible from the side as shown in the sketch at the upper right. There are five simple unbranched arms composed of uniserially arranged quadrangular segments, which are strongly rounded externally (see section of arm, lower right).

Zeitschr., Bd. 3, Heft 1. p. 66.—MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 254.

Eupachycrinus Meek and Worthen, WACHSMUTH AND SPRINGER (part), 1879, Revision of Palaeocrinoidea, pt. 1, p. 133.

This genus includes crinoids with cups of subglobular form, a circular stem impression, strong suture lines between the plates, a distinctly convex base containing large infrabasals (IBB) which are clearly visible from the side, fairly large but thin basals (BB) and radials (RR), and three anal plates below the summit of the radials (RR). These crinoids have only five short uniserial arms which, if present, distinguish it at once from *Dicromyocrinus* which has a dorsal cup of generally flat or concave base with the infrabasals (IBB) mostly not visible at all from the side, and which has ten arms made up of cuneiform, uniserially arranged plates. The surface of the plates of the cup and arms in *Cromyocrinus* is smooth, or nearly so. A comparison of *Cromyocrinus* with other genera is shown in figures 69, 71.

Genotype.—*Cromyocrinus simplex* Trautschold (fig. 70), from Moscovian (lower Upper Carboniferous) beds near Moscow, Russia.

Occurrence.—Mississippian to Lower Pennsylvanian.

Discussion.—The following species described from Mississippian and Pennsylvanian strata of North America have been assigned to this genus. Those not now included in *Cromyocrinus* are indicated by an asterisk (*).

Species	Age	Present generic position
Cromyocrinus globosus (Worthen)	Upper Mississippian (Chester), Illinois	----------------------
**Cromyocrinus hemisphericus* (Worthen)	Upper Mississippian (Chester), Illinois	Dicromyocrinus
**Cromyocrinus papillatus* (Worthen)	Upper Mississippian (Chester), Illinois	Dicromyocrinus
Cromyocrinus grandis (Mather)	Lower Pennsylvanian (Morrow), Arkansas	----------------------
**Cromyocrinus sangamonensis* (Meek and Worthen)	Middle Pennsylvanian, Illinois	Ulocrinus
**Cromyocrinus buttsi* (Miller and Gurley), of Keyes	Middle Pennsylvanian, Missouri	Ulocrinus
**Cromyocrinus gracilis* Wetherby	Upper Mississippian (Chester), Illinois	Eupachycrinus
**Cromyocrinus kansasensis* (Miller & Gurley), of Keyes	Middle Pennsylvanian, Missouri	Ulocrinus

[POTERIOCRINITIDAE—SECTION B—SUBSECTION B-2]

GROUP b.—*Infrabasals not flaring upward, not visible from side.*

SUBGROUP *a.*—*Cup truncate bowl-shaped; two or three anal plates in cup.*

The wide, horizontal facets that characterize the Section and Subsection of poteriocrinitids to which this group belongs, are better shown in no other subdivision. The facets have also in many species, nearly plane surfaces that extend inward to constrict very perceptibly the opening to the body cavity in the cup. They join laterally to make a roadway around the cup, interrupted only at the posterior interradius where a plate of the anal series rises above the summit of the radials. The inward curvature of the upper part of the radials produces a globular shape, but generally the height of the cup is so much less than the greatest width that the form of the globe is strongly flattened. The base is flat or distinctly concave, but the basal plates generally are not very appreciably involved in the concavity.

The genus *Eupachycrinus*, restricted to include cups having three anal plates, is apparently represented in lowermost Pennsylvanian rocks, but the most common Pennsylvanian genus of this subgroup is *Parulocrinus*, which has two anals in the cup.

Genus EUPACHYCRINUS Meek and Worthen, 1865

Eupachycrinus MEEK AND WORTHEN. 1865, Acad. Nat. Sci. Philadelphia, Proc., vol. 17, p. 159.

Eupachycrinus Meek and Worthen, TIEN, 1926, Geol. Survey China, Paleont. Sinica, ser. B, vol. 5, fasc. 1, p. 28.

Eupachycrinus Meek and Worthen, KIRK, 1937, Jour. Pal., vol. 11, p. 599.

This genus was introduced to include crinoids with a low subglobular dorsal cup, marked by a strong basal concavity. The arms are long and stout, uniserial or biserial, and ranging in number from 10 to 20. Because of the variety of somewhat distantly related forms that came in time to be referred to this loosely defined genus, it has become apparent that the name *Eupachycrinus* should be restricted to crinoids corresponding somewhat narrowly in character and in structure to the genotype species, *Graphiocrinus quatuordecimbrachialis* Lyon, as Kirk[92] has done.

The dorsal cup is truncate globe-shaped, with greatest width somewhat below the summit of the radials (RR); the base is strongly concave. The five small infrabasals (IBB) are located at the base of the concavity. The five basals (BB) are large, their proximal parts flare downward and form the sides of the basal concavity, the distal parts flare upward and generally reach above the midheight of the dorsal cup. The five radials (RR) are broad and low,

[92]Kirk, E., *Eupachycrinus* and related Carboniferous genera: Jour. Pal., vol. 11, p. 598, 1937.

with articulating facets horizontal and equal to the full width of the radials (RR). There are three anal plates in the dorsal cup, consisting of a large radianal (RA) in contact with the right posterior basal (rpB). Anal x rests on the truncated tip of the posterior basal (pB), and the right tube plate (rt) is located above anal x and the radianal. The arms are relatively short, stout, and biserial, with the first primibrach axillary in all rays. One of the first secundibrachs ($IIBr_1$), or possibly both, is axillary in most of the rays except the anterior. The genotype species has fourteen arms.

Genotype.—*Graphiocrinus quatuordecimbrachialis* Lyon.

Discussion.—In form and structure of the dorsal cup *Eupachycrinus* is closely similar to *Phanocrinus* Kirk, with which it is associated in upper Mississippian rocks (figs. 69, 71). Both genera are distinguished by the presence of three anal plates in the cup, a strongly marked basal concavity, and a very small infrabasal circlet, but there are important differences in the character of the arms, for these are biserial in *Eupachycrinus* and typically fourteen in number, whereas there are ten uniserial arms in *Phanocrinus*. The form and structure of the cup also correspond closely in *Eupachycrinus* and *Ethelocrinus* Kirk, the latter genus being distinguished by the presence of only two anals below the summit of the radials; the biserial arms of *Ethelocrinus* branch essentially as in *Eupachycrinus* but are twelve to eighteen in number. *Sellardsicrinus*, n.gen., differs from *Eupachycrinus* in the lower form of its dorsal cup, relatively larger infrabasal circlet that is horizontal rather than downflaring, virtual absence of a basal concavity, and especially in the very different plan of branching of the biserial arms. *Dicromyocrinus* Jaekel has a dorsal cup containing three anal plates and resembles *Eupachycrinus* in the form of the cup except for its nearly flat base and relatively large infrabasal circlet, which are very unlike those of *Eupachycrinus*; also, there are ten uniserial arms in *Dicromyocrinus*. Comparison with *Parulocrinus*, n.gen., shows that this differs from *Eupachycrinus* in its relatively large, subhorizontal infrabasal circlet, which is mostly even with the base of the cup, in having only two anal plates in the cup, and, so far as known, in possessing ten biserial arms.

The American species of crinoids that have been assigned to *Eupachycrinus* and those that are now included under this genus are listed in the following tabulation:

American species that have been assigned to Eupachycrinus

Species	Occurrence	Present generic assignment
E. asperatus Worthen	Chester (Ill.)	Eupachycrinus
E. bassetti Worthen	Pennsylvanian (Ill.)	Ethelocrinus
E. boydii Meek and Worthen	Chester (Ill.)	Eupachycrinus
E. craigii Worthen	Pennsylvanian (Ill.)	Delocrinus
E. crassus (Meek and Worthen)	Pennsylvanian (Ill.)	Ethelocrinus
E. fayettensis Worthen	Pennsylvanian (Ill.)	Endelocrinus
E. formosus (Worthen)	Chester (Ill.)	Phanocrinus
E. germanus Miller	Chester (Ky.)	E. spartarius
E. gracilis (Wetherby)	Chester (Ky.)	Phanocrinus
E. harii Miller	Pennsylvanian (Mo.)	Ethelocrinus
E. magister Miller and Gurley	Pennsylvanian (Mo.)	Ethelocrinus
E. maniformis (Yandell and Shumard)	Chester (Ill., Ky.)	Eupachycrinus
E. monroensis Worthen	Chester (Ill.)	Eupachycrinus?
E. mooresi (Whitfield)	Pennsylvanian (Ohio)	Plaxocrinus
E. orbicularis (Hall)	Keokuk (Iowa)	Dicromyocrinus
E. parvus Miller and Gurley	Pennsylvanian (Mo.)	Perimestocrinus
E. platybasis White	Pennsylvanian (Utah)	Sciadiocrinus
E. quatuordecimbrachialis (Lyon)	Chester (Ky., Ill.)	Eupachycrinus
E. sanctiludovici Worthen	St. Louis	Plaxocrinus??
E. spartarius Miller	Chester (Ky.)	Eupachycrinus
E. sphaeralis Miller and Gurley	Pennsylvanian (Mo.)	Ethelocrinus
E. subtumidus (Worthen)	Chester (Ill.)	Eupachycrinus
E. tuberculatus (Meek & Worthen)	Pennsylvanian (Ill.)	Ethelocrinus?
E. tumulosus Miller	Chester (Ky.)	Eupachycrinus?
E. verrucosus (White & St. John)	Pennsylvanian (Iowa)	Parulocrinus

Generic assignments of several of these species are doubtful, because type specimens have not been available. Kirk[83] has reported study of the genotype species of *Eupachycrinus, E. quatuordecimbrachialis,* and *E. spartarius,* and on the basis of typical specimens of *E. formosus,* he established the new genus *Phanocrinus,* to which he also assigned *E. gracilis.* The present authors have had opportunity to examine the types of *E. boydii, E. crassus, E. fayettensis, E. harii, E. magister, E. parvus, E. platybasis, E. sphaeralis,* and *E. verrucosus.* In addition, typical examples of *E. mooresi* from the type locality have been lent for study.

Genotype.—*Graphiocrinus quatuordecimbrachialis* Lyon.

Occurrence.—The genus *Eupachycrinus,* as restricted, is thus far known only from upper Mississippian strata of the United States, although Kirk notes its probable extension into the Pennsylvanian.

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[83]Loc. cit.

The new species described in this paper under the name *Ethelocrinus texasensis,* from the basal Marble Falls limestone of early Pennsylvanian age, is apparently on the dividing line between *Eupachycrinus* and *Ethelocrinus,* for some specimens definitely have three anal plates in the cup, in some the third anal barely reaches below the upper border of the radials, and in some there are only two anal plates in the cup. This species has been somewhat arbitrarily referred to *Ethelocrinus,* rather than to *Eupachycrinus,* because of its obvious close resemblance to *Ethelocrinus oklahomensis* Moore and Plummer from rocks of approximately equivalent age in Oklahoma.

Genus SELLARDSICRINUS Moore and Plummer, n.gen.

The crown is ovoid, with a height about three times the greatest width of the dorsal cup. The dorsal cup is very low truncate bowl-shaped, with a slight basal concavity. The five infrabasals are subhorizontal and form a regular pentagon that is only slightly larger than the round stem impression. The five basal plates are subequal and pentagonal in outline except the posterior basal (pB) and the right posterior basal (rpB), which are hexagonal, the proximal edges forming the border of the shallow basal concavity of the cup. The five radial plates are about twice as wide as long, thick, and rather bulbous. The articular facets are subhorizontal, as wide as the radial plates but moderately short, and lack a distinct flangelike inward projection. The anal series consists of three plates in the dorsal cup and the arrangement of these is normal, with the radianal (RA) in contact with the right posterior basal (rpB), the anal x above the posterior basal (pB), and the right tube plate (rt) above the radianal.

The arms are relatively slender, round externally, and composed of biserially arranged segments that bear long pinnules. The arms branch isotomously in each ray on the first primibrach (IBr_1) and another isotomous division occurs on each branch about eight or ten segments above the axillary primibrach. A third equal division of the branches may occur. The character of the anal sac has not been observed.

Genotype.—*Sellardsicrinus marrsae* Moore and Plummer, n.sp.

Discussion.—The dorsal cup of *Sellardsicrinus* is the same in structure and generally similar in form to those of *Eupachycrinus* Meek and Worthen, *Dicromyocrinus* Jaekel, and *Phanocrinus* Kirk. Distinction is found chiefly in the character of the arms. The latter two genera, which are nearly identical, except in the shape of the bottom of the cup, have uniserial arms that branch only once. *Eupachycrinus* has biserial arms that, as in this new genus, *Sellardsicrinus*, branch isotomously on the first primibrach, but above this plate there is further division only in certain arms and such division invariably occurs on the first secundibrach, whereas, in *Sellardsicrinus* each primary branch divides at some distance above the axillary primibrach and there may be still further branching. The arms of *Eupachycrinus* are relatively stouter and less strongly rounded, and they are fewer than in *Sellardsicrinus*. The difference in the mode of branching of the arms is the most striking and significant character. If the evolutionary trend in crinoid arm structure is in the direction of numerous bifurcations of rays to few, and migration of the points of branching is downward, as seems to be the trend among inadunates, the new genus here described is less specialized than *Eupachycrinus* and *Ethelocrinus*. Also the horizontal attitude of the infrabasal circlet of *Sellardsicrinus* and the absence of a deep basal concavity in the dorsal cup are characters that indicate less advancement than in *Eupachycrinus*. These considerations indicate that *Sellardsicrinus* cannot be a descendant of *Eupachycrinus*. It appears, rather, to belong to an entirely different line.

This genus is named in honor of Dr. E. H. Sellards, Director of the Bureau of Economic Geology, The University of Texas, who has made numerous important contributions to paleontology, stratigraphy, economic geology, and general geology.

Occurrence.—Des Moines series, Pennsylvanian (Upper Carboniferous); Texas.

SELLARDSICRINUS MARRSAE Moore and Plummer, n.sp.

Pl. 3, fig. 9; pl. 20, figs. 1, 2; pl. 21, fig. 3

Description.—Description of this species is based on seven specimens, one of which is included with question. The holotype and two paratypes consist of crowns; another paratype shows the entire dorsal cup with a few attached stem segments and plates of the lower part of some of the arms; two paratypes are well-preserved, undistorted dorsal cups. The seventh specimen, which is not included among the types, shows almost completely the arms of an individual that is a little larger than the holotype, but the dorsal cup is lacking. This specimen is very interesting in that three isotomous divisions appear to be present in all the rays, making eight branches in the upper part of each ray, or forty all together. The holotype also shows a third bifurcation in all rays except two that are broken away or concealed by matrix.

The dorsal cup is somewhat more than three times wider than high, and in dorsal or ventral view is nearly circular in outline, without any depression of the posterior interradius. The plates are smooth. All of them, except those of the infrabasal disc, are convex both longitudinally and transversely, appearing somewhat bulbous, and an edge view of the basal and radial plates (obtainable on paratype M–7) shows an unusual thickness. The infrabasal circlet forms a horizontal pentagon that comprises the flat top of the shallow basal concavity, situated about 1 mm. above the basal plane of the cup; only the distal extremities of the plates appear beyond the edge of the round stem impression. The basals (BB) are about as wide as long; they also lie nearly horizontal, the distal tips being only a trifle higher than the proximal margins. The radials (RR) slope strongly outward as well as upward, but there is a sharp inward curvature near the edge of the articular facet. The outer ligament area of the facets is relatively long; the surface slopes evenly downward from the denticulate outer edge to the most depressed part that lies next to the transverse ridge, a narrow, short ligament pit occurring centrally next to the ridge. The transverse ridge is straight, rather strongly elevated, and bears denticles on both sides near its extremities. The inner ligament area is nearly plane, but shows slightly marked oblique furrows and a central pit.

The axillary primibrachs of the arms are short, strongly convex and somewhat pointed but not produced in a spine. The rounded arms above these plates are narrowed upward, so that adjacent arms are not in contact, and this is true of all the lesser branches. Long delicate pinnules are visible at many points in the spaces between the arms. The first subdivision of the branches above the axillary primibrach occurs at a height slightly greater than the width of this plate, eight or ten biserially arranged segments occurring between the axillary secundibrach and primibrach plates. Another bifurcation appears on at least eleven branches of the holotype and is probably present on all, but the structure of part of the crown is obscured on the holotype. The specimen showing arm structure very clearly but lacking the dorsal cup (M–22) is believed with very little doubt to belong to the species, and it shows definitely three branchings in each of the rays at fairly regular heights above the arm bases. There is no bifurcation of any branch above the third dichotom, and as many as 40 brachial segments can be counted in a single unbranched arm above the third axillary plate.

Measurements of the dorsal cup, in millimeters, are given for two undistorted paratypes (H–24,, M–34). The paratype M–23 is a slightly flattened crown, 55 mm. in height and about 40 mm. in greatest width. The holotype (P–12,372) is a beautifully preserved but flattened crown, 64 mm. in height and about 53 mm. in greatest width.

		Paratypes	
	H–24	M–34	M–7
Height of dorsal cup	7.0	7.2	
Width of dorsal cup	24.0	26.0	.
Width of body cavity	15.0	15.5	
Height of basal concavity	1.0	1.5	-- -
Width of infrabasal disc	6.8	8.0	
Width of stem	5.0	5.0	6.0
Length of basal	8.5	9.5	9.5
Width of basal	8.0	9.0	9.2
Length of radial	8.5	9.5	9.6
Width of radial	14.5	15.0	17.5

Occurrence.—Brannon Bridge limestone member, Millsap Lake formation. Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, 3 miles southwest of Brock, Parker County, Texas.

Types.—Holotype, Plummer Collection no. 12,372, Bureau of Economic Geology, The University of Texas; collected by Ralph King. Paratypes, M–7, M–23, and M–34, in the collection of Mrs. W. R. Marrs, Austin, Texas; paratypes, H–7 and H–24, in the Harris Collection, collected by Mrs. G. W. Harris, Waco, Texas. Specimen M–22, showing arms only, is also in the Marrs Collection.

Genus PARULOCRINUS Moore and Plummer, n.gen.

Among Pennsylvanian crinoids there are dorsal cups of subglobular form that generally resemble *Cromyocrinus, Dicromyocrinus,* and *Ulocrinus,* but which differ significantly from these genera.

The presence of only two instead of three anal plates in the cup separates the forms here termed *Parulocrinus*, n.gen., from the first two genera named, and the generally broad and flat base of the cup, with infrabasals (IBB) not visible or only barely perceptible in side view of the cup, indicates a character quite unlike the base of the cup in *Ulocrinus*.

The dorsal cup of crinoids assigned to *Parulocrinus* is subglobular, of low or moderate height, with steep sides, and flat or nearly flat base. The five infrabasals (IBB) are horizontal in position and tangent to the basal plane of the cup, or, less commonly, forming the top of a basal concavity. These plates form a regular pentagon of fairly large size, which, however, is not ordinarily larger in area than any one of the basals (BB). The basals (BB) are relatively large, about as wide as long, curving from a nearly horizontal position in the proximal area to very steeply inclined or subvertical at the distal extremities. The radials (RR) are wider than long and of nearly equal size, and they bear facets that are comparable in every way to those of *Ulocrinus*. The two anal plates of the dorsal cup include a fairly large quadrangular radianal (RA), and obliquely above this is a somewhat smaller anal x. The surface of the plates is generally smooth. The sutures are very distinct but are not noticeably impressed in the genotype species.

Genotype.—*Ulocrinus blairi* Miller and Gurley (Pl. 19, fig. 5), from the middle Pennsylvanian beds, Cass County, Missouri.

Discussion.—The genus *Parulocrinus* has two anal plates in the dorsal cup, as in *Ulocrinus* and *Ethelocrinus*, and is distinguished by this and other characters from *Cromyocrinus, Phanocrinus, Dicromyocrinus, Sellardsicrinus,* and *Eupachycrinus,* which have three anal plates below the summit of the radials (figs. 69, 71). *Ulocrinus* is readily separated from *Parulocrinus* by the distinctly upflaring attitude of its infrabasal plates. *Ethelocrinus* is unlike *Parulocrinus* in having relatively small infrabasals that flare downward, and, excepting a few forms that are assigned to *Parulocrinus*, in having a well-marked basal concavity. The arms of *Ethelocrinus* are rather sharply angular in cross-section; they are composed of biserially arranged segments that are smooth externally, and the number of arms ranges from 12 to 18, the typical number being 16.

Two examples of crowns that are referred to *Parulocrinus* have arms that are nearly circular in cross-section; they are composed of biserially arranged segments that are rather strongly keeled, and there are two arms in each ray, making 10 in all. Whether or not the character of arm structure that is observed in the two specimens just mentioned is a diagnostic feature of *Parulocrinus* can not now be affirmed because the arms of the genotype species are unknown. It is thought, however, that the arms of *Ethelocrinus* are unlike those of this new genus. Study of about 125 dorsal cups, including the holotypes of the genotype species of *Ethelocrinus, Ulocrinus,* and *Parulocrinus,* indicates that the subhorizontal attitude of the infrabasal circlet and its proportionally large size are significant features for differentiation of *Parulocrinus.* Generally, but not invariably, the subhorizontal infrabasals are tangent to the basal plane of the cup, and in this case there is no basal concavity. The stem diameter is smaller in ratio to the width of the infrabasal circlet than in *Ethelocrinus,* and all observed specimens that are referred to *Parulocrinus* have a strongly petaloid or pentastellate lumen in the stem, whereas the shape of this opening in species of *Ethelocrinus* appears to be rounded-pentagonal. The shape of the lumen cannot be given very great weight without further study, however. Surface characters of the plates, such as smoothness or the occurrence of granules, tubercles, or strong ridges, are not of any value as criteria for generic assignments.

Crinoid cups that possess upflaring infrabasal circlets are closer to the primitive condition of poteriocrinitids than those having subhorizontal infrabasals, and the latter are less specialized than those having downflaring infrabasals. The shape of the base of the cup is controlled generally by the attitude of the infrabasal circlet, but a concave form of the cup base is associated with horizontal infrabasals in some forms, signifying that the proximal part of the basal plates flares downward. All features of cup form are deemed to have some value, small or great, in definition of generic characters, and the attitude of the infrabasal circlet is thought to be more important than the presence or the absence of a basal concavity. It is readily understood that the genus *Ethelocrinus* may have been derived from *Eupachycrinus,* for the dorsal cup in both of these forms is marked by a small infrabasal circlet at the summit of a deep basal concavity, and distinction rests mainly on a slight difference in the number of arms and on whether there are two or three anals in the cup. *Parulocrinus* appears not to be a descendant of *Eupachycrinus* nor a close relative of *Ethelocrinus,* and this is indicated chiefly by the large subhorizontal infrabasal circlet of *Parulocrinus,* which is less advanced than the corresponding part of the cup in the other genera mentioned. It is very possible, on the other hand, that *Parulocrinus* is derived from *Dicromyocrinus* or from a form closely allied to it, for there is close similarity in the shape of the dorsal cups, including the attitude of the infrabasal circlet, and the arm structure and anals of the dorsal cup are only slightly more advanced in *Parulocrinus* than in *Dicromyocrinus.*

Among described species that appear to belong in *Parulocrinus,* in addition to the genotype species, *Ulocrinus blairi* Miller and Gurley, are the following: *Ethelocrinus plattsburgensis* Strimple, from upper Ochelata beds, Missouri series, near Bartlesville, Oklahoma, and *Hydreionocrinus? verrucosus* White and St. John, from Upper Pennsylvanian rocks of western Iowa. The following new species are here described: *Parulocrinus beedei, P. marquisi,* and *P. compactus.*

Measurements of the basal part of the cup of several specimens of *P. compactus,* showing comparison with other species that are assigned to this genus and with typical representatives of other poteriocrinitid genera having globular cups, are given in the accompanying tabulation.

Occurrence.—Morrow to Virgil series, Pennsylvanian (Upper Carboniferous); North America.

Comparison of the basal parts of the dorsal cups of subglobular poteriocrinitid genera, as shown by representative examples.

WS—Width of stem impression
WIBB—Width of infrabasal circlet
W—Width of dorsal cup
*—Genotype species

SB—Shape of base of cup: 1, Base convex, IBB distinctly visible from side; 2, Base flat or very gently concave, IBB mostly not visible from side; 3, Base distinctly concave, IBB not visible from side.

(All measurements in millimeters)

Species	WS	WIBB	W	WS/WIBB	WIBB/W	SB
Eupachycrinus boydii Meek and Worthen[b]	3.0[a]	3.7	20.5	0.81	0.18	3
*E. quatuordecimbrachialis (Lyon)[c]	3.0[a]	3.5[a]	24.0	0.85	0.15	3
E. spartarius Miller[d]	3.0[a]	3.6	16.0	0.83	0.22	3
*Phanocrinus formosus (Worthen)[d]	2.7	4.0	16.0	0.68	0.25	3
*Sellardsicrinus marrsae, n.sp.[e]	4.2	7.5	24.0	0.56	0.31	2
Ethelocrinus magister (Miller and Gurley)[f]	6.0	10.4	45.5	0.58	0.23	3
E. sphaeralis (Miller and Gurley)[f]	4.5	10.0	37.5	0.45	0.27	3
*Parulocrinus blairi (Miller and Gurley)[f]	5.5	20.0	41.0	0.28	0.49	2
P. compactus, n.sp.[f]	2.6	8.0	26.0	0.33	0.31	2
P. compactus, n.sp.[g]	2.0	6.1	15.2	0.33	0.40	2
P. compactus, n.sp.[h]	3.5	10.5	29.0	0.33	0.36	2
P. compactus, n.sp.[i]	3.0	9.5	26.5	0.32	0.36	2
P. compactus, n.sp.[j]	2.8	8.6	22.5	0.32	0.38	2
P. compactus, n.sp.[k]	3.1	9.9	24.8	0.31	0.40	2
P. compactus, n.sp.[l]	3.1	8.8	21.7	0.35	0.41	2
P. compactus, n.sp.[m]	3.7	11.2	26.8	0.33	0.42	2
P. verrucosus (White and St. John)[f]	4.6	13.4	34.0	0.34	0.39	2
P. oklahomensis (Moore and Plummer)[f]	3.4	9.3	30.5	0.36	0.30	3?
P. beedei, n.sp.[f]	2.4	6.4	15.3	0.38	0.42	2
P. marquisi, n.sp.[n]	6.8	17.5[a]	38.0[a]	0.39	0.46	2
Parulocrinus, n.sp. (Coffeyville)	3.6	14.0	30.5	0.27	0.46	2
Parulocrinus n.sp. (Magdalena)	3.7	9.0	27.0	0.41	0.33	2
Parulocrinus, n.sp. (Stranger)	4.9	13.5	37.5	0.35	0.36	2

*Ulocrinus buttsi Miller and Gurley[f]	9.0[a]	28.0[a]	37.5	0.32	0.75	1
*Cromyocrinus simplex Trautschold[o]	4.4	15.4	26.7	0.29	0.57	1
C. simplex Trautschold[o]	4.0	13.1	22.8	0.30	0.57	1
C. simplex Trautschold[o]	3.0	9.4	17.0	0.32	0.55	1
*Dicromyocrinus ornatus (Trautschold)[o]	2.7	9.7	22.0	0.28	0.44	2
D. ornatus (Trautschold)[o]	3.0	11.5	23.8	0.26	0.48	2
D. ornatus (Trautschold)[o]	2.7	11.0	22.4	0.26	0.49	2

[a]Measurement approximate only.
[b]Based on plastoholotype and Kirk's description.
[c]Based on plastoholotype.
[d]Based on Kirk's figures and description of hypotype.
[e]Based on paratype, no. H–24.
[f]Based on holotype.
[g]Based on paratype, no. 60281. Brad formation, Texas.
[h]Based on paratype, no. 4761. Iola limestone, Iola, Kansas.
[i]Based on paratype no. 45901, Dennis limestone, Coffeyville, Kansas.
[j]Based on paratype, no. 60193, Dennis limestone, Coffeyville, Kansas.
[k]Based on paratype, no. 31122, Iola limestone, Iola, Kansas.
[l]Based on paratype, no. 45401, Dennis limestone, Coffeyville, Kansas.
[m]Based on paratype no. 45401a Dennis limestone, Coffeyville, Kansas.
[n]Based on holotype; dimensions of infrabasal circlet computed from size of proximal edges of basals.
[o]Based on typical specimens from near Moscow, Russia.

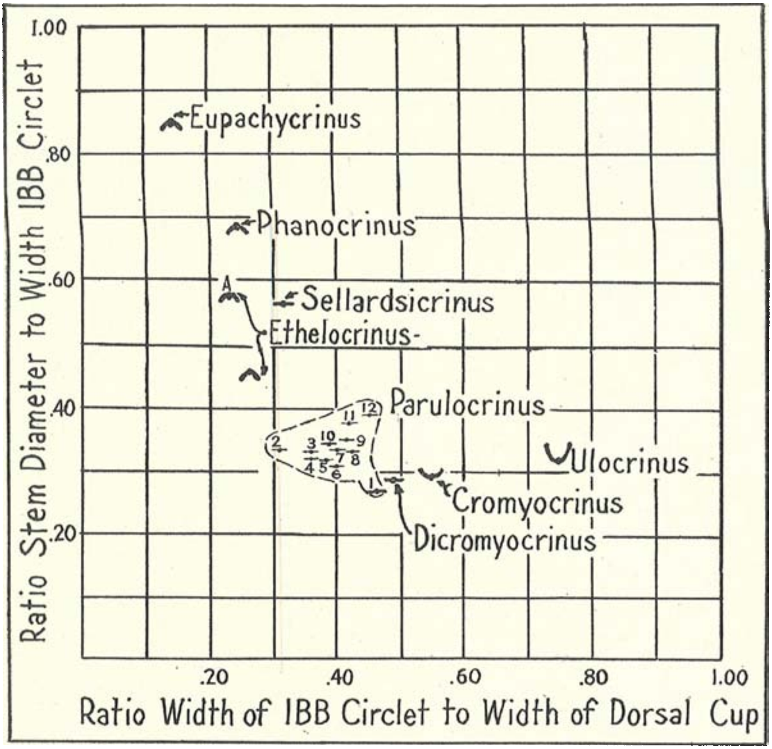

Fig. 71. Diagram showing comparison of *Parulocrinus* with genera having somewhat similar form and structure. The position of different crinoids on the vertical and horizontal scales marks relationships of the stem diameter, width of the infrabasal circlet, and width of the dorsal cup. Downward-flaring infrabasals are indicated by lines curving downward from plotted points, subhorizontal infrabasals by horizontal lines through the plotted points, and upward-flaring infrabasals by lines curving upward from the plotted points.

Eupachycrinus based on plastoholotype of the genotype species, *E. quatuordecimbrachialis* (Lyon), and on Kirk's description.

Phanocrinus, based on Kirk's description and figures of his hypotype of the genotype species, *P. formosus* (Worthen), and on the plastohypotype.

Sellardsicrinus, n.gen., based on types of the genotype species, *S. marrsae*, n.sp.

Ethelocrinus. A represents the genotype species, *E. magister* (Miller and Gurley), based on the holotype specimen; B represents *E. sphaeralis* (Miller and Gurley), based on the holotype specimen.

Parulocrinus. 1 represents the genotype species, *P. blairi* (Miller and Gurley), based on the holotype specimen; 2, holotype of *P. compactus*, n.sp.; 3, paratype, no. 4761, of *P. compactus*, from the Iola limestone of Kansas; 4, paratype, no. 45901, of *P. compactus*, from the Dennis limestone of Kansas; 5, paratype, no. 60193, of *P. compactus*, from the Dennis limestone of Kansas; 6, paratype, no. 31122, of *P. compactus*, from the Iola limestone of Kansas; 7, paratype, no. 60281, of *P. compactus*, from the Brad formation, Texas; 8, paratype, no. 45401a, of *P. compactus*, from the Dennis limestone of Kansas; 9, paratype, no. 45401, of *P. compactus*, from the Dennis limestone of Kansas; 10, holotype of *P. verrucosus* (White and St. John); 11, holotype of *P. beedei*, n.sp.; 12, holotype of *P. marquisi*, n.sp.

Ulocrinus, based on the holotype of the genotype species, *U. buttsi* Miller and Gurley, but stem diameter doubtful.

Cromyocrinus, average of five typical specimens of the genotype species, *C. simplex* Trautschold, from near Moscow, Russia.

Dicromyocrinus, average of three typical specimens of the genotype species, *D. ornatus* (Trautschold), from near Moscow, Russia.

PARULOCRINUS BEEDEI Moore and Plummer, n.sp.

Pl. 14, fig. 9; text fig. 72

Description.—This crinoid has a low, bowl-shaped cup with a broad, flat base. The height of the cup is a little less than one-half of the width. The infrabasal (IBB) disc at the center of the flat basal area is pentagonal in outline and a little smaller than one of the basals. It is horizontal in position, tangent to the basal plane of the cup, and no part of its surface can be seen in side view of the cup. A relatively large, round stem impression occupies about half the length of the infrabasal plate. The basals (BB) curve strongly in longitudinal direction, but only a small part near the

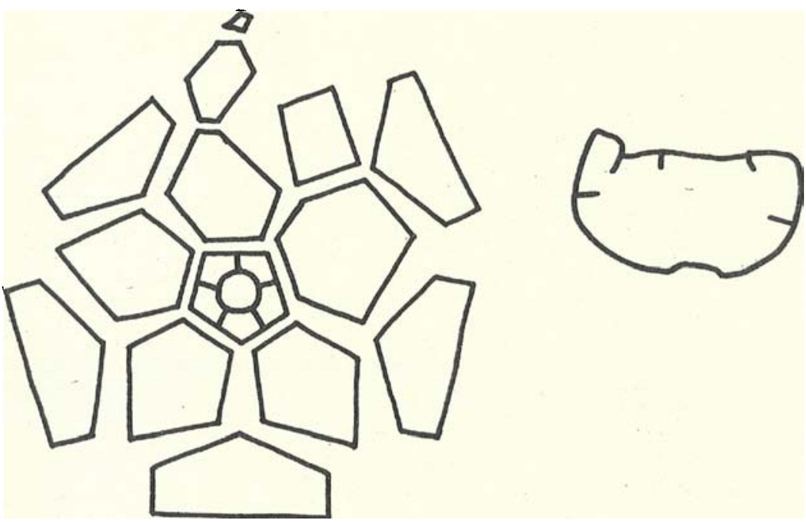

Fig. 72. Diagram showing the arrangement of plates in the dorsal cup of the holotype of *Parulocrinus beedei* Moore and Plummer, n.sp., and (at right) the outline of the form of the cup in antero-posterior section, the posterior side being at the left, x2.

distal extremity slopes upward steeply. The radials (RR) are pentagonal and much wider than long. Although in places the distal portion of these plates seems to curve slightly inward, this is due to weathering of the plates; where the radials (RR) are best preserved, the surface rises vertically to the margin of the facets. Characters of the facets are apparently the same as in the genotype species and in *Ulocrinus*, but they are poorly preserved in the holotype specimen of this species. There are two anal plates in the cup, a large irregularly hexagonal radianal (RA) that has a very broad contact with the posterior basal (pB), and a somewhat smaller pentagonal anal x that has only a narrow contact with the posterior basal (pB). The surface of the cup is smooth. The sutures are not impressed.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	7.0
Diameter of dorsal cup	14.5
Width of body cavity	9.0
Diameter of stem impression	3.0
Length of infrabasal	3.1
Width of infrabasal	3.0
Length of basal	8.5
Width of basal	7.5
Length of radial	3.7
Width of radial	8.2
Length of radianal	6.5
Width of radianal	5.1
Length of anal x	5.0
Width of anal x	3.5
Distance of base of anal below top of calyx	2.0
Length of suture between basals	4.5
Length of suture between radials	2.3

Discussion.—Distinguishing features of this species are the very broad low form of the dorsal cup and its comparatively small size. The shape of the anal plate and the very asymmetrical outline of the posterior basal (pB), as shown in the species, correspond exactly to those of *P. blairi* (Miller and Gurley), but the dorsal cup of that species is very much larger and relatively higher.

Occurrence.—Palo Pinto limestone, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–1, about 3.5 miles west of Strawn, Palo Pinto County, Texas.

Type.—Holotype, Plummer Collection no. P–8938, Bureau of Economic Geology, The University of Texas; collected by J. W. Beede.

PARULOCRINUS COMPACTUS Moore and Plummer, n.sp.

Pl. 18, figs. 5, 6; text fig. 73

Description.—This species is represented in the collection of Texas crinoids by two almost perfectly preserved dorsal cups and by numerous individual plates. In addition, nearly 30 specimens from Kansas include several almost perfect examples. The cups are truncate globe-shaped, with a flat base or very shallow basal concavity, and the height measures almost exactly one-half the greatest width. The infrabasal (IBB) circlet forms a pentagon that lies in the basal plane of the cup or only a very few millimeters above it. The greatest width of the infrabasal (IBB) circlet is about one-third that of the cup, and its area is one-half to two-thirds that of one of the basal plates. The distal parts of the infrabasals (IBB) slope very gently downward in the holotype specimen and in one of the paratypes from Kansas (no. 4761), but they are horizontal in the remaining paratypes. The basals (BB) are pentagonal, excepting the posterior basal (pB) and the right posterior basal (rpB) which are somewhat unevenly hexagonal. They are strongly convex longitudinally, with very uniform curvature throughout. The radials (RR) are about twice as wide as long and they have nearly vertical sides, but near the top the surface slopes distinctly inward toward the facets. The outer ligament area of the facets is relatively long, sharply excavated, is bounded externally by a thin but well-defined outer marginal ridge and on the inside by a prominent straight transverse ridge. The inner ligament area has an almost plane surface that is only faintly marked by ligament fossae and by a narrow intermuscular furrow that joins a barely perceptible notch at the inner margin of the facets. The quadrangular radianal (RA) is only a little larger than anal x; approximately the upper half of the latter extends above the summit of the cup. The surface of the plates is covered by closely spaced but not crowded minute granules that are too fine to be seen readily by the unaided eye but are clearly visible with the low power of a microscope. The granules are more numerous and somewhat more readily seen near the suture lines than over the middle parts of the plates. Their arrangement in the latter areas is irregular, but on the average about five occur in 1 mm. or 20 to 25 in a square millimeter. All the sutures are located in prominent, but shallow, furrows with broad V-shaped cross-sections that have an average width of 2 mm. at the top, except that the furrows of the infrabasal (IBB) circlet are much smaller.

Measurements of the Texas type specimens, in millimeters, are given in the following tabulations:

	Holotype	Paratype
Height of dorsal cup	13.0	7.4
Width of dorsal cup	26.0	15.2
Ratio of height to width	0.50	0.51
Width of body cavity	14.0	6.7
Height of basal cavity	1.8	0.9
Width of basal cavity	14.9	8.4
Diameter of stem impression	2.6	2.0
Length of infrabasal	2.3	1.8
Width of infrabasal	3.7	2.8
Length of basal	14.9	7.1
Width of basal	13.5	7.6
Length of radial	7.2	3.6
Width of radial	14.6	8.3
Length of radianal	8.3	5.6
Width of radianal	6.0	3.8
Length of anal x	7.6	2.9
Width of anal x	5.0	3.2
Length of suture between basals	8.0	4.8
Length of suture between radials	4.1	2.1

Discussion.—The dorsal cup of *P. compactus* closely resembles that of *P. pustulosus*, n.sp., in size and shape, distinction of these two species being found chiefly in the ornamentation of the plates and in the more strongly impressed sutures of *P. pustulosus.* The cup of *P. beedei*, n.sp., is proportionally much lower than in *P. compactus*, the surface of the plates appears entirely smooth (although this may be due to weathering), and the sutures are only very faintly impressed. *Ethelocrinus monticulatus* (Beede) resembles the new species here described in the form of the dorsal cup, except for the basal concavity that is a characteristic feature of *Ethelocrinus;* the decoration of the plates of *E. monticulatus* consists of granules or small nodes that are distinctly coarser than those of *P. compactus.*

Occurrence.—The holotype and one paratype (Kansas University no. 60281) were collected from the Brad formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–81, about 1.3 miles east of Pickwick, Palo Pinto County, Texas. Other paratypes (Kansas University nos. 45401, 45401a–f, 45901, 45901a–i, 60193, 60193a–b) are from the Winterset limestone member of the Dennis limestone, Missouri series, on Cedar

Bluff, at the north edge of Coffeyville, Montgomery County, Kansas. Another paratype (Kansas University no. 46161) was collected also from the Winterset limestone near the middle of sec. 3, T. 34 S., R. 16 E., about 6 miles north of Coffeyville, Kansas. Paratypes,

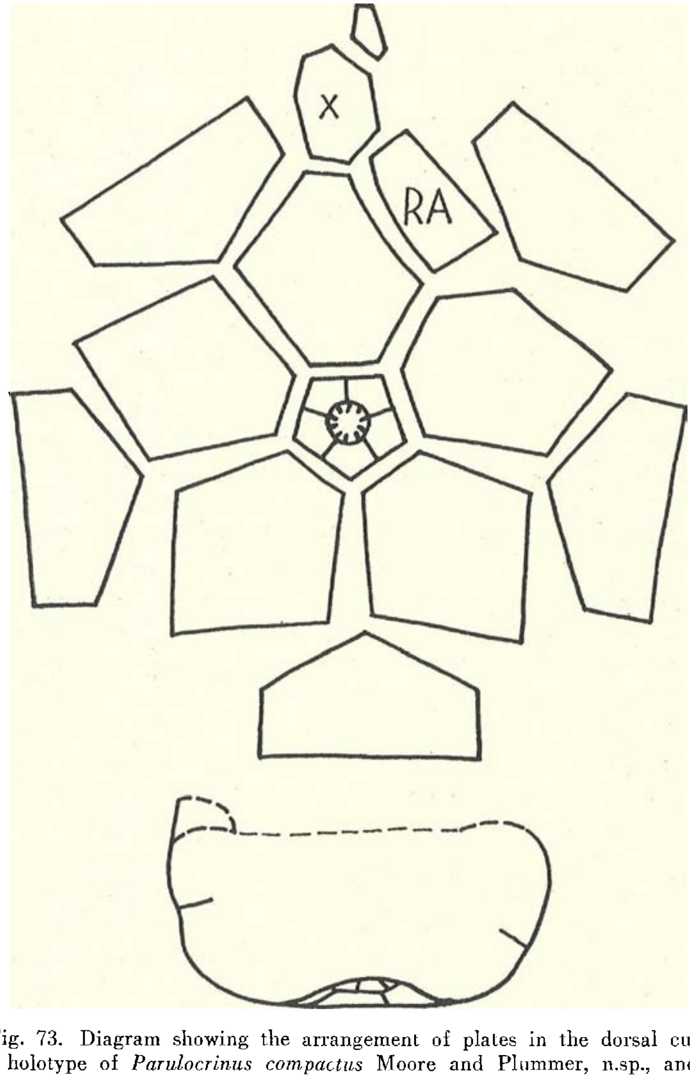

Fig. 73. Diagram showing the arrangement of plates in the dorsal cup of the holotype of *Parulocrinus compactus* Moore and Plummer, n.sp., and an antero-posterior profile of the cup, x2.

Kansas University nos. 31122, and 4761, are from the Iola limestone, Missouri series, at the quarry located at the south edge of Iola, Kansas. *Parulocrinus plattsburgensis* Strimple resembles the species here described in size and shape, but the sutures of *P. plattsburgensis* are said to be unimpressed, and the surface is described as entirely smooth.

Types.—Holotype, Plummer Collection no. P–7885, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer. Paratypes, University of Kansas nos. 60281, 4761, 31122, 45401, 45401a–f (10 specimens); collected by R. C. Moore, Paratypes, University of Kansas nos. 45901, 45901a–i (10 specimens); collected by E. L. Banion. Paratype, University of Kansas no. 46161; collected by J. M. Jewett. Paratypes, McGuire Collection nos. 60193, 60193a, 60193b; collected by Paul McGuire.

PARULOCRINUS PUSTULOSUS Moore and Plummer, n.sp.

Pl. 18, fig. 7; text fig. 74

Description.—This ornate crinoid is truncate globe-shaped with a gently concave base, nearly perpendicular sides, deeply impressed sutural furrows, and plates that are ornamented along their borders by a single row of elongate nodes spaced about five in 5 mm. and elongated in a direction transverse to the side of the plate. The surface of the plates is covered also by microscopic granules like those of *P. compactus*, n.sp. The surface of the radial plates has, in addition, a few irregularly placed and irregularly shaped low nodes inside the noded border. The infrabasal circlet has been lost, but the outline shown by the proximal ends of the basals (BB) reveals a pentagonal disc that is 6.5 mm. in diameter and has slightly incurving sides. The basals (BB) are uniformly convex. Three are nearly regular pentagons, one is nearly a regular hexagon, and one, the posterior basal (pB), is an elongate irregular hexagon. The radianal (RA) is quadrate. The anal x is an irregular pentagon. One small anal plate is in position obliquely above the anal x at its right, but above the radials (RR). The radials (RR) are of the usual shape and about twice as wide as long. The arms and the stem of this specimen are lost. Two or three detached arm plates and one primibrach (IBr) were preserved in a rock matrix in the interior of the cup. The primibrach (IBr) is twice as wide as high, bluntly pointed at the distal end, and ornamented on the outer surface by the same granular markings that are on the plates of the cup. The detached arm plates indicate that the arms were biserial.

Measurements of the cup and some of the individual plates of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	10.5
Width of dorsal cup	24.2
Ratio of height to width	0.43
Width of body cavity	13.5
Width of basal depression	12.1
Length of infrabasal	13.5
Width of infrabasal	13.0
Length of radial	7.5
Width of radial	13.3
Length of radianal	9.5
Width of radianal	6.0
Length of anal x	7.4
Width of anal x	6.4

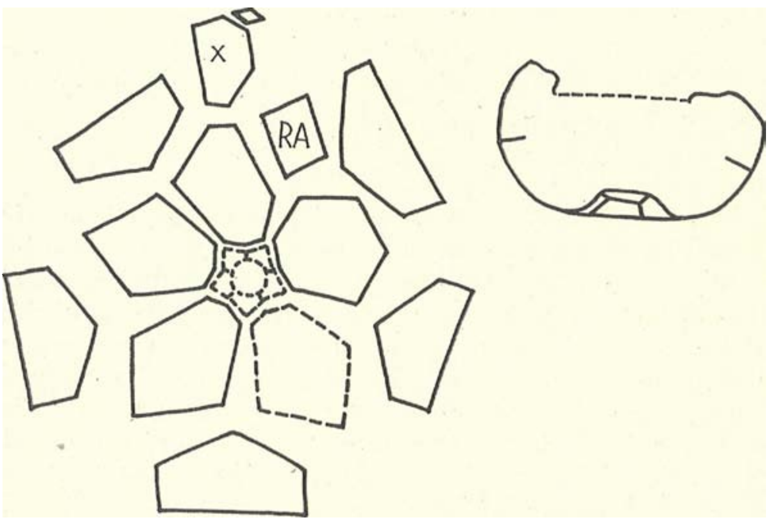

Fig. 74. Diagram showing the arrangement of plates in the dorsal cup of the holotype of *Parulocrinus pustulosus* Moore and Plummer, n.sp., and an antero-posterior profile.

Discussion.—This species differs only in minor respects from *P. compactus.* It has slightly longer basal plates proportionately. Its posterior basal (pB) has a straight lateral suture line instead of a curved edge, as in *P. compactus.* Its radianal (RA) is more quadrate than the corresponding plate of *P. compactus,* and most noteworthy is the pronounced bordering of nodes present on all the plates (probably excepting the infrabasals) in the cup of *P. pustulosus.* Between 25 and 30 nodes form a frame for the pustulose surface of each plate, which has 16 to 20 granules to each square millimeter.

Specimens of *Parulocrinus* from lower Missouri beds of southern Kansas correspond closely to *P. pustulosus* in all respects except the distinctly noded borders of the plates; the general surface of the plates bears both tubercles and fine granules, but the Kansas specimens are not assigned to *P. pustulosus.*

Occurrence.—The holotype was collected from the upper part of the Mineral Wells formation, Strawn group, Pennsylvanian (Upper Carboniferous); Loc. 25–T–30, near Brownwood city cemetery, Brownwood, Brown County, Texas. Recent stratigraphic work and evidence from the character of the fossils indicates that this horizon belongs in the lower part of the Missouri series.

Type.—Holotype, King Collection no. K–424, Bureau of Economic Geology, The University of Texas; collected by Ralph King.

PARULOCRINUS MARQUISI Moore and Plummer, n.sp.

Pl. 17, fig. 4; text fig. 75

Description.—This beautiful, complete specimen is unfortunately flattened by compression that has partially disarranged the plates of the dorsal cup. The specimen is remarkable for the length and large size of the arms, and it is unique among crinoids of this general type in that there are only ten arms. The dorsal cup is undoubtedly bowl- or globe-shaped, but the specimen is so mashed that one can not be certain as to the form of its base, whether gently convex, or flat, or moderately concave. The curvature of the basal plates and comparison with undistorted cups from Kansas that have almost identical peculiarities in appearance of the plates indicate strong probability that the base of the dorsal cup is flat or only moderately concave, as in *Parulocrinus.* The infrabasals (IBB), however, are not visible in the Texas specimen. The basals (BB) are pentagonal, with nearly straight edges and moderate longitudinal curvature. The radials (RR) are two-thirds as long as wide. The outer part of the facet, which is visible on two or three of the plates, shows a wide, short, rather deeply excavated outer ligament area; it is bounded externally by a narrow marginal ridge and on the inner side by a strong transverse ridge. A quadrangular radianal (RA) and possibly a portion of anal x are visible on one side of the specimen, and comparison with the Kansas specimens mentioned strengthens the conclusion that there are two anal plates, exactly like those of *Parulocrinus* and *Ethelocrinus*. The primibrachs (IBr) are low but massive, protruding laterally to form a short blunt point in the middle of the upper margin. These plates are about 18 mm. wide and 6.5 mm. long. The first secundibrach (IIBr) in each arm is quadrangular in outline and at least twice as long as any of the wedge-shaped segments that follow it. The

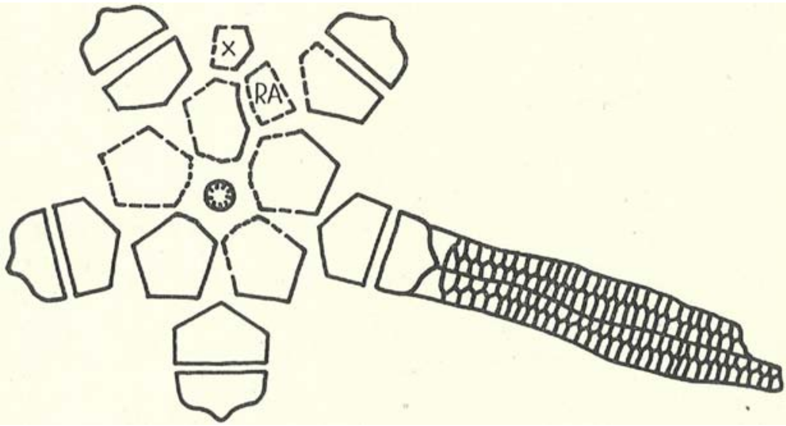

Fig. 75. Diagram showing the arrangement of plates in the dorsal cup, the primibrach plates, and the arms in one ray of the holotype of *Parulocrinus marquisi* Moore and Plummer, n.sp.

arms are of nearly uniform diameter throughout their length and are biserial down to the lowest secundibrach (IIBr). The horizontally crested form of each arm segment makes the branches appear to be made up of narrowly constricted wedges.

The surface of the basals (BB) is ornamented with a row of elongate elevations around the border of each plate, and a second row of nodes or short ridges inside the outer row. The radials (RR) have a broad shallow transverse furrow, about 4 mm. in width, just below the summit of the plate, and below the furrow is a very strong rounded horizontally disposed ridge that, joining with the ridges of neighboring plates, makes a prominent girdle near the rim of the cup; the lower part of these plates carries a few very irregularly shaped low ridge-like markings. The borders of the radials (RR) and basals (BB) are bent inward to make strong V-shaped furrows along the suture line. The bottoms of these furrows are sharply marked by regularly spaced ridges and furrows that extend a distance of 1 mm. from the suture on each side, five ridges and as many furrows occurring in each 5 mm. along the suture. The stem is formed of thin, round plates about 4 mm. in diameter, with a strong depression between each two segments.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of dorsal cup	20.5[a]
Width of dorsal cup	38.0[a]
Length of basal	18.5
Width of basal	19.7
Length of radial	14.0
Width of radial	21.4
Length of suture between basals	13.5
Length of suture between radials	7.5
Length of arms, including primibrach	100.0

[a]Approximate.

Discussion.—This species is distinctively marked by peculiarities of the plates in the dorsal cup and by the ten arms of even width, which are formed by horizontally ridged biserial segments. At least two undescribed species that are closely comparable in characters of the cup occur in the Pennsylvanian rocks of Kansas, and another species that shows nearly identical characters of the arms is found in lower Pennsylvanian rocks of New Mexico, but *P. marquisi* is not very similar to any crinoid that is already described. The surface features of the plates furnish ready basis for separation of this species from *P. compactus*, n.sp., and *P. pustulosus*, n.sp.

Occurrence.—The single specimen of this form came from the banks of Llano River above Mason, Mason County, Texas (Loc. 159–T–22). The stratigraphic horizon from which it came is not known, but judging by the occurrence of closely related forms in Kansas, it is very probable that *P. marquisi* is a form of the Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous).

Types.—Holotype, Plummer Collection no. P–8188, Bureau of Economic Geology, The University of Texas; collected by Col. R. L. Marquis of North Texas State Teachers College.

Genus ETHELOCRINUS Kirk, 1937

Ethelocrinus KIRK, 1937, Jour. Pal., vol. 11, p. 605.
Ethelocrinus Kirk, MOORE AND PLUMMER, 1938, Denison Univ. Bull., Jour. Sci. Lab., vol. 32 (1937)), p. 255.

This genus includes crinoids having a moderately low, truncated, subglobular dorsal cup with a well-defined basal concavity, two anal plates below the summit of the radials (RR), wide and relatively long horizontal facets, and about 14 to 18 biserial arms. The five infrabasals (IBB) are relatively small and flare downward from the stem impression; they occur at the top of the basal concavity and are therefore not visible in side view of the cup. The central part of the pentagonal infrabasal (IBB) disc is covered by a round stem impression. The five basals (BB) are relatively large, about equal in size; their proximal parts are involved in the basal concavity and their distal parts generally reach above mid-height of the cup. The five radials (RR) are wider than long and their distal parts curve distinctly inward to the margin of the facets. The outer and inner ligament areas of the facets are divided by a strong, straight transverse ridge that extends to the angles of the facet, and the inner edge of the facet extends inward far enough to constrict noticeably the width of the body cavity. The two anal plates comprise a quadrangular radianal (RA) located obliquely beneath the right posterior radial (rpR) and anal x, which occurs between the posterior radials (RR) with its upper edge projecting somewhat above the summit of the radials (RR).

The lowest brachial of each ray is an axillary plate, and an additional branching may occur following one or both of the next succeeding brachials. This gives rise to the slightly variable number of arms as previously mentioned.

Genotype.—*Eupachyrinus magister* Miller and Gurley (fig. 76), from the upper Missouri series, Pennsylvanian, at Kansas City, Missouri.

Discussion.—Species of *Ethelocrinus* are generally characterized by the moderately large size of the dorsal cup—at least this is true when compared with such genera as *Apographiocrinus, Endelocrinus,* and *Delocrinus.* Genera of a form somewhat similar to that of *Ethelocrinus* that have two anal plates in the dorsal cup include *Ulocrinus* and *Parulocrinus.* The first of these is distinguished by the well-marked convexity of the base formed by the upflaring infrabasals (IBB) which are readily visible in side views. The second has a flat or nearly flat base with horizontal infrabasals (IBB) that are not visible from the side, and the cup typically (but not invariably) lacks a distinct basal concavity. *Dicromyocrinus* and *Eupachycrinus,* in which the infrabasals (IBB) are not visible in side view of the cup, have three anal plates below the summit of the radials (RR). Most species of *Ethelocrinus* are beautifully adorned with elongate granules or nodes or other decorative markings.

Species that are referred to the genus *Ethelocrinus* include the following:

Species of Ethelocrinus

Species	Occurrence
Ethelocrinus bassetti (Worthen)	Pennsylvanian (probably Missouri series), Illinois
?Ethelocrinus expansus Strimple	Upper Ochelata group, Pennsylvanian, northeastern Oklahoma
Ethelocrinus harii (Miller)	Missouri series, Pennsylvanian, Kansas City, Missouri
Ethelocrinus magister (Miller and Gurley)	Missouri series, Pennsylvanian, Kansas City, Missouri
Ethelocrinus monticulatus (Beede)	Virgil series, Pennsylvanian, near Topeka, Kansas
Ethelocrinus oklahomensis Moore and Plummer	Brentwood limestone, Morrow series, Pennsylvanian, northwestern Oklahoma
Ethelocrinus sphaeralis (Miller and Gurley)	Missouri series, Pennsylvanian, Kansas City, Missouri
Ethelocrinus tuberculatus (Meek and Worthen)	Missouri series, Pennsylvanian, Illinois

The following species, described from the Brentwood limestone, Morrow series, of northwestern Arkansas and northeastern Oklahoma, are not positively identifiable as belonging to *Ethelocrinus* because the type specimens consist of dissociated plates of the dorsal cup. These may be assigned questionably, therefore, to *Ethelocrinus: E. costalis* Moore and Plummer, *E. hispidus* Moore and Plummer, *E. papulosus* Moore and Plummer, and *E. subsinuatus* Moore and Plummer.

The species described as *Ethelocrinus plattsburgensis* Strimple, from upper Ochelata beds, Missouri series, near Bartlesville, Oklahoma, is here assigned to *Parulocrinus*, n.gen.

Occurrence.—Pennsylvanian (Upper Carboniferous) of the United States, Morrow to Virgil series.

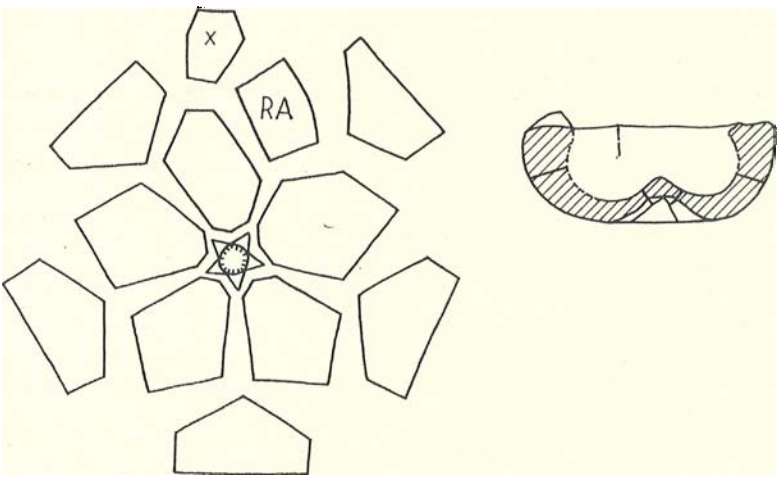

Fig. 76. Diagram showing the arrangement of plates in the dorsal cup of the holotype of *Ethelocrinus magister* (Miller and Gurley), the genotype species. At the right is a median cross-section of the dorsal cup showing the relatively low height and the shallow basal concavity.

ETHELOCRINUS TEXASENSIS Moore and Plummer, n.sp.

Pl. 20, fig. 6

Description.—Four large dorsal cups, found in the Marble Falls limestone of San Saba County, Texas, show a form and structure that indicate assignment to *Ethelocrinus* or *Eupachycrinus*. The cups are low truncate globe-shaped, with a strong basal concavity; the greatest width is nearly three times the height. The infrabasals (IBB) flare gently downward and make a pentagon with concave surface. The width of the infrabasal circlet is 10 to 12.5 mm. The round stem impression at the center of the disc is relatively small, measuring 3.0 to 3.5 mm. The basals (BB) are strongly curved longitudinally; the proximal one-third forms part of the basal concavity, the middle one-third is subhorizontal and tangent to the basal plane of the cup, the distal one-third curves upward to a nearly vertical position. The width of these plates is approximately equal to their length. The posterior basal (pB) is distinctly smaller than the other basals (BB) and because of the very long suture face adjoining the radianals (RA), it is distinctly asymmetrical, and its distal extremity is truncated for contact with anal x.

The width of the radials (RR) is a little less than twice the length; the proximal parts are nearly vertical and the distal parts curve strongly inward. The two posterior radials (RR) are slightly but distinctly narrower than the others. The radial facets are as wide as the summit of the radials (RR), and they are relatively long, thus constricting the body cavity. The outer ridge and the transverse ridge of each facet are about equally developed, and because the intervening outer ligament area with the ligament pit is very short, the ridges closely adjoin throughout their extent between points of coalescence at the lateral margins of the facets. In a view of the summit of the cup three ridges form a prominent double-lined pentagon that is interrupted at the posterior interradius. The interarticular ligament area is gently concave, nearly plane, without distinct ridges or grooves, but the intermuscular notch is well marked. Except in one specimen (P–11182A), there are three anal plates in the dorsal cup. A large quadrangular radianal (RA) is almost equal in size to the posterior basal (pB); its sutures along the contacts with the posterior basal (pB) and the right posterior basal (rpB) are nearly equal in length and about one-third longer than the other two sutures. The suture between the radianal (RA) and the right posterior basal (rpB) is equal in length to the straight edge of the radianal (RA) that makes contact with anal x and the right tube plate (rt). Anal x is a pentagonal plate, narrowest at the face where it rests on the posterior basal (pB). Its distal extremity rises very slightly above the summit of the radials (RR) and directly above it is a small left tube plate (lt) that does not enter the dorsal cup. The right tube plate (rt) is an elongate plate placed obliquely above anal x and narrowly in contact with the radianal (RA) and the right posterior radial (rpR). About half its height is above the line of the radials (RR). Details of this description of the anal plate are based on the holotype. Paratype P–11182A differs from the other specimens in having only two anal plates in the dorsal cup, the small right tube plate (rt) not being present; the exact structure is difficult to ascertain in the case of this specimen but occurrence of only two anals is considered definitely established.

The surface of the dorsal cup is thickly covered by coarse rounded tubercles, 1 mm. or more in height and slightly less than 1 mm. in diameter; the lower slopes of the tubercles are marked by radially dispersed, fine grooves and ridges. The surface of the plates between tubercles is marked by minute granules. Some of the sutures between the plates are bordered on each side by a row of closely spaced tubercles much smaller than the large ones but distinctly coarser than the granules; this feature is not clearly seen in all parts of the cup.

Measurements of the holotype and two paratypes, in millimeters, are given in the following tabulation:

	Holotype P–11182	Paratype P–11181	Paratype P–11182A
Height of dorsal cup	18.0	16.5	17.0
Greatest width of cup	37.5	43.0	39.7
Ratio of height to width	0.48	0.38	0.43
Greatest width at summit plane of cup	32.0	33.0	32.0
Width of body cavity	19.3	18.0	19.5
Height of basal concavity	6.4	7.0	5.5
Approximate diameter of basal concavity	22.0	26.0	24.5
Diameter of stem impression	3.3	?	3.6
Greatest width of infrabasal circlet	11.6	13.3	13.1

Discussion.—The size and proportions of the dorsal cup and the strongly tubercled ornamentation of the plates in *Ethelocrinus texasensis* are rather strikingly like those characters in *E. tuberculatus* (Meek and Worthen) from Lower Pennsylvanian beds in Illinois. The Texas species is distinguished by the slightly higher form of the cup and more bulbous appearance of the basal plates, as well as by the tendency toward occurrence of three anals in the cup of *E. texasensis*. The species called *Ethelocrinus oklahomensis* Moore and Plummer, from the Brentwood limestone of northeastern Oklahoma, is so nearly like *E. texasensis* that, taking account of approximate identity of stratigraphic position, no doubt exists as to close relationship. The Brentwood species is about one-half as large as *E. texasensis*, is a little more smooth in outline, and, so far as known, constantly has two anals in the cup instead of having three, as do some specimens of the Texas form. There is variation in the size and crowding of the tubercles on the surface of *E. texasensis* of such nature that no distinction from *E. oklahomensis* can be made on this basis. The inferred close relationship of the Texas and Oklahoma crinoids here discussed has influenced the generic assignment of *E. texasensis* to *Ethelocrinus.* The tendency toward occurrence of three anals, instead of two, in the cup of *E. texasensis* suggests the slightly older, more primitive condition of this species than that represented by *E. oklahomensis;* similar slight differences are observed between *Cibolocrinus punctatus,* n.sp., characterized by nearly smooth outline of the cup, and *C. tumidus* Moore and Plummer, which is marked by distinctly bulbous plates, the former associated with *Ethelocrinus texasensis* and the latter with *E. oklahomensis.*

Attention may be directed to the relatively large size and nearly horizontal attitude of the infrabasal circlet in examples of *E. oklahomensis* and *E. texasensis,* although paratype no. P–11182A of the latter species shows distinct downward curvature of the infrabasal plates. The stem impression, also, is relatively small in relation to the width of the infrabasal circlet, this ratio being 0.28 in the holotype of *E. texasensis,* 0.27 in a paratype of the same species, and 0.36 in the holotype of *E. oklahomensis.* The ratio of the width of the infrabasal circlet to that of the dorsal cup is 0.32 and 0.33 in two types of *E. texasensis,* and 0.30 in the holotype of *E. oklahomensis.* These characters of the infrabasal circlet fall within the typical range that belongs to *Parulocrinus,* and the general characters are foreign to *Ethelocrinus* and *Eupachycrinus.* The very strongly downward inflection of the proximal part of the basal plates, which is mainly responsible for the deep basal concavity of the cup in the two species under discussion, is typical of *Ethelocrinus* and *Eupachycrinus* but foreign to *Parulocrinus.* Consideration of probable phylogenetic significance of these observations leads to the conclusion that *Ethelocrinus texasensis* and *E. oklahomensis* are more plausibly interpreted as derivatives of a *Parulocrinus* type of cup than from the other two genera mentioned. Altogether, the generic placement of these species is unsatisfactory, but it seems unwise at present to differentiate them under a new generic name.

Occurrence.—Marble Falls limestone, Bend group (Morrow series), Pennsylvanian (Upper Carboniferous). The holotype and paratypes, P–11182A and P–11181, are from Loc. 205–T–43, 200 feet north of a cattle tank on the left side of the Wallace Creek road, about 11.5 miles by road southwest of San Saba, Texas (horizon about 10 feet above the base of the Marble Falls). A badly weathered specimen, identified as belonging to the same species, has been found from 4 to 6 feet above the base of the Marble Falls limestone on the Cherokee-Chappel road 0.1 of a mile northeast of the road fork near benchmark 1317, San Saba County, Texas.

Types.—Holotype, Plummer Collection no. 11182; paratypes, Plummer Collection nos. 11181, 11182A, and 11181A, Bureau of Economic Geology, The University of Texas; collected by F. B. Plummer and G. H. Fisher.

ETHELOCRINUS MILLSAPENSIS Moore and Plummer, n.sp.

Pl. 21, fig. 6

Description.—A single specimen consisting of a complete but compressed crown furnishes basis for recognition of this species. The crown is slender, the height being about three times the width. The dorsal cup is about twice as wide as high, truncate bowl-shaped, and apparently slightly concave at the base. These observations are indefinite because of the flattened condition of the cup. The basals (BB) are large, wider than long, and most strongly curved longitudinally near the proximal edge. The radials (RR) are about twice as wide as long; they are relatively straight longitudinally but curve inward near the margin of the facet. A large quadrangular radianal is present, and there is apparently one other anal plate (x) that is located just above it in a narrow space between the two posterior radials, but the inferred anal x has been dislodged.

There are twelve slender biserial arms, each about 2 mm. in width throughout their length; the exterior surface of the arms is gently rounded, and there is an angulation between this surface and the flat sides where the arms closely adjoin. Branching occurs on the lowest primibrach (IBr_1) in all the rays, and one of the two lowest secundibrachs (IIBr) is also axillary in each of the two posterior rays, which accordingly contain three arms, instead of two. The surface of the plates is marked by a fine pattern of low irregular ridges and depressions, and there are faint raised areas on some of the basals that radiate from the center of the plate toward the angles. The brachials are smooth.

Measurements of the holotype, in millimeters, are given in the following tabulation:

Height of crown	32.0
Greatest width of crown, about	10.0
Height of dorsal cup, about	5.5
Greatest width of cup, about	9.5
Length of basal	3.7
Width of basal	4.5
Length of radial	3.0
Width of radial	6.0

Discussion.—This new species is much smaller than average for the genus, and the possibility that it is a juvenile individual must be recognized. The presence of twelve arms may be a character of specific value. *E. magister* (Miller and Gurley), the genotype, commonly has sixteen arms but the number appears to be slightly variable. *Parulocrinus marquisi*, n.sp., which somewhat resembles this species, has only ten arms.

Occurrence.—Millsap Lake formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 183–T–14, 3 miles southwest of Brock, Parker County, Texas.

Type.—Holotype, Harris Collection no. H–31; collected by Mrs. G. W. Harris, Waco, Texas.

[POTERIOCRINITIDAE—SECTION B]

SUBSECTION B–3.—*Facets sloping inward.*

GROUP b.—*Infrabasals not flaring upward, not visible from side.*

SUBGROUP *a.*—*Cup truncate bowl-shaped; one anal plate in cup.*

The inward slope of the articular facets, which distinguishes this section of poteriocrinitids, is an interesting and apparently distinctive feature that sets the crinoids belonging to it apart from the great majority. The attitude of the facets is almost opposite to that in *Poteriocrinites* and other genera with steep outward-sloping facets that are much narrower than the radials. If narrowness and steep outward slope are signs of little advancement, as seems clear, the wide inward-sloping facets are to be regarded as highly specialized. The occurrence of all the genera in this section, except one, only in Permian strata, so far as known, is corroborative evidence.

The older representative of this subgroup is the genus *Aesiocrinus*, described from upper part of the Middle Pennsylvanian strata at Kansas City, Missouri, where it is unusually common, and also occurs typically in Texas. Its characters show clearly that it belongs to the branch of the poteriocrinitids here indicated.

Genus AESIOCRINUS Miller and Gurley, 1890

Aesiocrinus MILLER AND GURLEY, 1890, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 14.

Phialocrinus TRAUTSCHOLD (not Eichwald), 1879, Soc. imper. Nat. Moscow, Nouv. Mém., vol. 14, fasc. 1, p. 24.

Moundocrinus STRIMPLE, 1939, Bull. Am. Pal., vol. 24, no. 87, p. 9.

Pentadelocrinus STRIMPLE, 1939, Bull. Am. Pal., vol. 24, no. 87, p. 11.

This genus was proposed to include crinoids with a bowl-shaped dorsal cup having one anal plate, with a pentagonal stem, generally possessing ten long slender arms composed of uniserial segments that bear long, delicate pinnules, and characterized especially by a long stout anal sac of distinctive appearance, formed by four or five columns of ornamented rugose plates. The genus was founded on the species *A. magnificus* Miller and Gurley (fig. 77), from the Lane shale (Missouri series) in the Middle Pennsylvanian at Kansas City, Missouri. Many fine specimens of this species and others assigned to the genus have come from this locality, and most paleontologic museums have displays of some of them. The arms generally spread out in radiating fashion from the dorsal cup, and the long anal sac shows at one side of the cup.

In spite of its apparently distinctive features and the good specimens that are available in many places, this genus has been much misunderstood. Springer[84] concluded that *Aesiocrinus* was not generically distinct from *Graphiocrinus* de Koninck and Le Hon, apparently basing his opinion on the occurrence of one anal plate in the dorsal cup and ten uniserial arms, which are features corresponding to *Graphiocrinus*. Following Springer, other workers have classed *Aesiocrinus* as a synonym of *Graphiocrinus*. It appears now

[84]Springer, Frank, Some new American fossil crinoids: Mus. Comp. Zool., Harvard Coll., Mem., vol. 26, no. 3, p. 145, 1911.

that these two genera are actually only very distantly related. Entirely foreign to *Graphiocrinus* is the strong, peculiarly specialized anal tube in *Aesiocrinus*, and likewise the sharply angular pentagonal stem. Although the arms of *Graphiocrinus* are uniserial, their form and the habit of the crown are quite unlike *Aesiocrinus*. In the former genus the arms are flat sided and held closely together in an erect position. They are not cylindrical, but are spread widely apart in a subhorizontal position, as in the latter genus. Not all species have ten simple unbranched arms, for *A. basilicus* Miller and Gurley, has more than ten arms, and *A. barydactylus* (Keyes) has only five arms.

One of the most critical diagnostic features of *Aesiocrinus* is the character of the articular facets. They are fully equal to the radials in width, and they are inclined gently or strongly inward toward the body cavity. *Apographiocrinus* has similar facets except for their narrow width, leaving interfacet extensions of the outer surface of the radials that reach to the margin of the body cavity. *Graphiocrinus* has facets as wide as the radials, but it has not been possible to learn the form of the slope of the facets in the genotype species, *G. encrinoides* de Koninck and Le Hon. Judging by other species that are thought properly to belong to this genus, it is probable that the slope of the facets in *Graphiocrinus* is gently outward. One other feature, of no intrinsic importance but apparently of some significance, is the matter of size. Species of *Graphiocrinus* and of *Apographiocrinus* are almost without exception much smaller forms than species of *Aesiocrinus*.

Taking account of all the points that have been mentioned, *Aesiocrinus* is here accepted as a valid genus that is entirely distinct from others that superficially resemble it in some features. Its ancestral stock among poteriocrinitids is not known, but the line of its development is thought to be quite different from that of *Graphiocrinus*, *Apographiocrinus*, *Delocrinus*, or other genera with bowl-shaped cups having one anal plate.

Trautschold's genus *Phialocrinus*, 1879, to which species of *Aesiocrinus* have been referred by some authors, is an invalid name that must be suppressed because it is a homonym of *Phialocrinus* Eichwald, 1856.

Examination of the illustrations and the types of two crinoid cups from the Stanton limestone horizon near Bartlesville, Oklahoma, called *Moundocrinus osagensis* Strimple and *Pentadelocrinus typus Strimple*[84a] leaves no room for doubt that both belong to *Aesiocrinus.* The first-mentioned form is said to have a round stem impression, although the figure shows a distinctly subpentagonal impression. All other characters are typically those of *Aesiocrinus.*

Occurrence.—Near top of Lower Carboniferous in Scotland, apparently distributed throughout Upper Carboniferous in the central United States, and reported from Permian rocks in Timor.

Species of Aesiocrinus.—The following tabulation indicates the names, geologic occurrence, and chief distinguishing characteristics of crinoids described as belonging to *Aesiocrinus,* or to its synonym, *Phialocrinus:*

Name	Occurrence	Characteristics or other generic assignment
A. angulatus Miller and Gurley	Missouri series, Pennsylvanian, Kansas City, Missouri	*Apollocrinus angulatus;* angular plates, steeply outward facing facets
P. barydactylus Keyes	Missouri series, Pennsylvanian, Kansas City, Missouri	Five heavy unbranched arms
A. basilicus Miller and Gurley	Missouri series, Pennsylvanian, Kansas City, Missouri	More than ten arms
A. harii Miller and Gurley	Missouri series, Pennsylvanian, Kansas City, Missouri	Very slender, unornamented anal sac, ten slender arms
A. lykinsi Butts	Missouri series, Pennsylvanian, Kansas City, Missouri	Five moderately slender arms, high bowl-shaped cup
A. magnificus Miller and Gurley	Missouri series, Pennsylvanian, Kansas City, Missouri	Ten long, slender arms, strong anal sac, with rugose plates
P. americanus Weller	Cibolo limestone, Lower Permian, western Texas	*Ulocrinus americanus;* Very large bowl-shaped cup

AESIOCRINUS BARYDACTYLUS (Keyes)

Pl. 14, fig. 7; text fig. 77

Phialocrinus barydactylus Keyes, 1894, Missouri Geol. Survey, vol. 4, p. 220, pl. 28, fig. 1. (Pennsylvanian, Kansas City, Missouri.)

This rather simply constructed little crinoid has a low bowl-shaped cup with a diameter about three times its height, and a

[84a]Strimple, H. L., A group of Pennsylvanian crinoids from the vicinity of Bartlesville, Oklahoma: Bull. Am. Pal., vol. 24, no. 87, pp. 9—11, pl. 1, figs. 5-10, 1939.

smooth surface. The sides of the cup are steep, and there is a distinct but shallow basal concavity. The slender stem has a pentagonal cross-section with sharp angles. The infrabasals (IBB) are diamond-shaped, and the infrabasal circlet forms a nearly perfect five-pointed star occupying the floor of the basal concavity. The

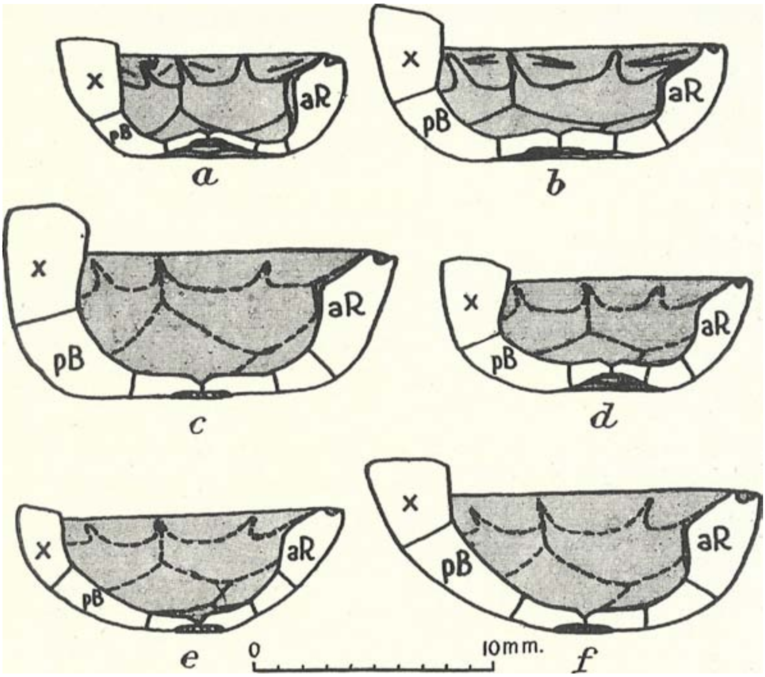

Fig. 77. Median cross-sections of the dorsal cups of four species of *Aesiocrinus*, through the anterior radial (aR) and the posterior interradius, showing the left half of the cup, the shaded area representing parts beyond the plane of the section. *a, b,* Hypotypes of *A. barydactylus* (Keyes) from Texas (Kansas University no. 551 and P–10731). *c,* Holotype of *A. basilicus* Miller and Gurley. *d,* Holotype of *A. barydactylus* (Keyes), with slight restoration, which is a little distorted by pressure. *e,* Holotype of *A. harii* Miller and Gurley. *f,* Holotype of *A. magnificus* Miller and Gurley, the genotype species. The types of these four species are from the Lane shale, Missouri series, Kansas City, Missouri.

basals (BB) are pentagonal, except the posterior basal (pB), which is hexagonal; they are rather strongly convex and also form a star-shaped circlet. The radials (RR) are about four-sevenths as long as wide. The facets are not visible in the holotype specimen, which has been lent for study, but if the dorsal cups from Texas assigned in this paper to this species properly belong there, it can be said that the facets slope strongly inward, as is characteristic of the genus.

The single anal plate is nearly as wide as long, subquadrangular, and it protrudes only about one-quarter of its height above the summit of the radial circlet. It has an erect, nearly vertical position.

The arms belonging to this species are long, round, and unusually thick, and there appear to be only five of them. The holotype specimen shows three of the arms attached to the anterior of the cup, but removal of matrix from the other side failed to show any trace of the arms belonging to the other two rays. The arms are not preserved on any of the Texas specimens. A few scattered arm plates show them to be similar to the type from Kansas City, nearly circular in cross-section.

The surface of the plates, with the exception of the infrabasals and surface of the arms, is smooth. The surface of the infrabasal plates is decorated with minute, dot-like pilations.

The measurements of the cup and plates of the specimen (K–551) from the Mineral Wells formation, in millimeters, are given in the following tabulation:

Height of dorsal cup	4.2
Greatest width of cup	12.5
Ratio of height to width	0.35
Width of body cavity	7.1
Depth of basal cavity	0.8
Width of basal depression	6.5
Diameter of stem impression	1.4
Greatest length of infrabasal	1.8
Greatest width of infrabasal	1.5
Greatest length of basal	5.3
Greatest width of basal	4.9
Greatest length of radial	4.3
Greatest width of radial	7.0
Greatest length of anal x	3.8
Greatest width of anal x	4.0
Distance of base of anal x below top of cup	2.6
Length of suture between basals	2.0
Length of suture between radials	2.0

Discussion.—Identification of species of *Aesiocrinus* on the basis of the characters of the dorsal cup alone is difficult and apparently somewhat uncertain. The type specimens of all described species of this genus, excepting that of *A. lykinsi* Butts, which is lost, are available for comparison and study. Differences in the structure of the arms and of the anal sac are readily apparent. All the species described from specimens collected at Kansas City, Missouri, come from the Lane shale, and as may be expected of crinoids collected from a soft shale, the dorsal cups are likely to be distorted somewhat by pressure. This is true of a majority of some scores of cups of *Aesiocrinus* in material from the Lane shale at Kansas City. The types of *A. basilicus* Miller and Gurley and *A. magnificus* Miller and Gurley retain very closely their original form, those of *A. barydactylus* and *A. harii* Miller and Gurley are slightly deformed. The accompanying drawings show the characters of the cups of these species as indicated by the types, and in addition drawings of two specimens from Texas are given for comparison (fig. 77).

The form ratio of the dorsal cup in described species of *Aesiocrinus* is nearly identical, 0.34 to 0.37. The cup of *A. magnificus* can be recognized by the gentle flare of the posterior side as compared to the anterior. *A. barydactylus* is a steep-sided cup with a definite, though shallow, basal concavity. *A. basilicus* has also a steep-sided cup but lacks a basal concavity.

The geologic horizons from which the examples of *Aesiocrinus* collected in Texas have come are a little lower than the Lane shale, and identification of the Texas forms must be regarded as tentative until more complete specimens are found.

Occurrence.—Upper part of the Mineral Wells formation, Strawn group (Des Moines series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–43, one-quarter of a mile north of Union Hill School, which is about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas. Lower part of the Graford formation, Canyon group (Missouri series), Pennsylvanian (Upper Carboniferous); Loc. 181–T–97, northwest side of Kyle Mountain, Palo Pinto County, Texas.

Types.—Hypotype, Kansas University no. 551, from the Mineral Wells formation; collected by R. C. Moore; hypotype, Plummer Collection no. P–10731, from the Graford formation, Bureau of Economic Geology, The University of Texas; collected by W. T. O'Gara.

Family HYPOCRINIDAE Wanner, 1929

Genus COENOCYSTIS Girty, 1908

This genus comprises very small acornlike armless crinoids with the calyx composed of three circlets of plates and with a round anal vent located on the side at the juncture of three of the plates. The lowermost circlet consists of a single fused calcareous piece, the sides of which flare upward from the round stem impression. Wanner[85] has shown that this plate corresponds to the infrabasal (IBB) circlet of other hypocrinids. There are five plates in the next higher circlet and these are classed as basals (BB). The contiguous upper corners of the posterior basal (pB) and right posterior basal (rpB) are notched by the anal opening. Radial plates (RR) are lacking. The third circlet of plates covers the top of the calyx. It contains five plates, classed as orals, and these occur in alternating position in contact with the basals.

Genotype.—*Coenocystis richardsoni* Girty, from the Delaware Mountain formation, west Texas.

Discussion.—Wanner's study of the several genera that are now grouped together in the family Hypocrinidae indicates evolutionary modifications in the direction of loss of arms and simplification of the structure of the calyx, *Coenocystis* marking an extreme development in its fused infrabasal disc and in its lack, not only of arms, but of the radial plates that normally support the arms. The hypocrinids were evidently reef-dwellers for the most part.

Occurrence.—Lower Carboniferous to Permian.

COENOCYSTIS RICHARDSONI Girty

Text fig. 78

Coenocystis richardsoni Girty, 1908, U. S. Geol. Survey, Prof. Paper 58, p. 108, pl. 27, figs. 19–22. (Delaware Mountain formation, Permian.)

Description.—The following digest of Girty's description is introduced here simply to include in this paper information about all known Texas crinoids from Upper Carboniferous and Permian rocks. It is based on the somewhat lengthy discussion given in

[85] Wanner, J., Ueber armlose Krinoiden aus den jüngeren Palaeozoikum: Geol.-Mijnb. Genootsch. Ned. Kolonien, Verhand., Geol. ser., Deel 5, pp. 21–35, 1920. Die permischen Krinoiden von Timor: Mijnw. ned. Oost-Indie Jaarb., Verhand. 1921, Gedeelte 3, p. 161, 1924.

Girty's "Guadalupian Fauna." No study of the original specimens has been made, and no representatives of this species are in the collections available for study.

The lowermost part of the calyx consists of a somewhat elongated conical mass, which is evidently formed by fusion of plate elements. The expanded mid-portion of the calyx is composed of five subequal pentagonal plates, which are firmly joined laterally and appear almost fused to the conical base. The contiguous upper angles of two of the plates are indented by a round opening that evidently marks the anal vent. Similar but much smaller passageways occur at the upper angles of the other plates in this circlet, the four small openings being clearly visible in top view of specimens that lack the tegmen. The third circlet of plates forms a low vault

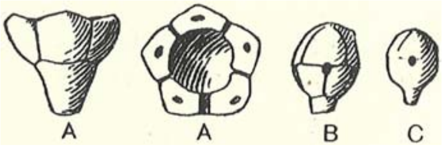

Fig. 78. *Coenocystis richardsoni* Girty, from the Delaware Mountain formation, southern Delaware Mountains, Culberson County, Texas. *A*, Side view of a large dorsal cup; *A'*, top view of the same specimen, showing the tubular passageways between the plates at the summit of the sutures, the largest passageway being the anal vent; *B*, a somewhat smaller specimen, showing the entire calyx; *C*, a small specimen with obscure sutures between the plates. (All figures x3, after Girty.)

that encloses the top of the cup; the five plates alternate in position with those of the next lower series that form the sides of the calyx.

Discussion.—No other American crinoid from Upper Carboniferous or Permian rocks has been found that closely resembles *C. richardsoni*, although Peck has recognized the genus in lower Mississippian rocks. The Permian species of *Coenocystis* described by Wanner are distinguished mainly by differences in the shape of the calyx.

Occurrence.—The types of this species are reported to have been collected in the Delaware Mountain formation in the southern part of the Delaware Mountains; the precise horizon, not determinable from Girty's data, seems to belong in the *Parafusulina* zone (Leonard-Word).

Types.—U. S. Geological Survey collections.

DESCRIPTIONS OF TEXAS CRINOID LOCALITIES

The following list includes 96 localities in Texas where crinoid cups and plates have been collected. Localities marked by two asterisks (**) indicate places where crinoid crowns have been found. Those marked by a single asterisk (*) indicate places where cups and plates occur. At unmarked localities only plates have been found up to the present date. The designation in parentheses immediately following the locality number refers to coördinates on the county geologic maps issued by the Bureau of Economic Geology.

Brewster County

***22–T–3.** Shale slope in saddle on north side of prominent hill just north of abandoned well of Wolf Camp ranch house, Wolf Camp, Glass Mountains. This is the type locality for *Delocrinus? perexcavatus,* n.sp. Upper part of Gaptank formation (*Uddenites* zone), Pennsylvanian.

****22–T–147.** Erratic block of limestone in Haymond formation near Marathon. This is the type locality for *Marathonocrinus bakeri,* n.sp. Lower Pennsylvanian.

Brown County

25–T–4 (D–25). Shale exposure near foot of escarpment capped by Adams Branch limestone, 1½ miles in direct line southeast of Brookesmith and one-half mile in direct line northwest of the Winchell-Brownwood highway, along a secondary road across Clear Creek. Brownwood shale member, Mineral Wells formation, Pennsylvanian.

***25–T–5 (G–17).** *Triticites* ledge across old Brownwood-Bangs road at point 2.3 miles by road west of freight depot in west edge of Brownwood. The holotypes of *Apographiocrinus exculptus,* n.sp., *A. facetus,* n.sp., and *Endelocrinus parvus,* n.sp., have been collected from this bed. Brownwood shale member, Mineral Wells formation, Pennsylvanian.

***25–T–30 (H–17).** *Triticites* ledge just south of Brownwood city water tank and in a topographic saddle, about one-quarter mile west of cemetery, southwest of the city of Brownwood. The best exposure is on the northeast side of the knoll. This is the type locality for *Parulocrinus pustulosus,* n.sp. Brownwood shale member, Mineral Wells formation, Pennsylvanian.

25–T–43 (D–23). Shale about 100 feet below Adams Branch limestone near foot of slope along a small branch about 100 yards northwest of Winchell-Brownwood highway at a point 4.3 miles by road northeast of T-road to Brookesmith on this highway. Brownwood shale member, Mineral Wells formation, Pennsylvanian.

****25–T–47 (G–8).** Near derrick about one-half mile south of Byrds near road to Weedon School. This is the type locality for *Delocrinus wolforum,* n.sp. Graham formation, Pennsylvanian.

Callahan County

30–T–1. Shale exposure along roadside 6 miles north of Putnam. Putnam formation, Permian.

30–T–8 (S–1). Shale and marl exposure on north side of Moran-Cisco highway about 5 miles south-southeast of Moran and 1.6 miles by road north-west of the railroad station in Pueblo, on the way to Moran. Along the road ditch and in the slopes in the pasture just north of the road on the west side of a broad valley are good exposures of fossiliferous beds in the section above the Camp Colorado limestone. A very fossiliferous yellow marl about 6 feet thick lies about 10 feet below a breccia conglomerate at the top of the exposure. Moran formation, Permian.

***30–T–13 (S–1).** About 300 feet west of M. K. & T. RR. tracks and 1 mile northwest of Pueblo. A paratype of *Delocrinus abruptus*, n.sp., has been collected from this exposure. Moran formation, Permian.

***30–T–4 (Q–5).** Shale exposure 3 miles north of Putnam on the Moran road near a cattle tank. This is the type locality for *Delocrinus puebloensis*, n.sp. Putnam formation, Permian.

Coleman County

42–T–30 (Q–16). Limestone and variegated shale along old Brownwood-Coleman road 1.7 miles east of Santa Anna. Pueblo formation, Pennsylvanian?

42–T–32 (O–29). Shale exposures in numerous gullies on south and south-east slopes of Parks Mountain about 1½ miles north-northwest of Mitchell's Crossing on Colorado River. Graham formation, Pennsylvanian.

42–T–41 (L–27). Shale at base of bluff, west of highway, 2.4 miles by road southwest of Rockwood. Harpersville formation, Pennsylvanian?

42–T–42 (M–27). Shale below lower bench and above coal on east side of bluff west of highway, 1.15 miles by road southwest of Rockwood. Harpersville formation, Pennsylvanian?

Comanche County

47–T–1. Shale exposure on north side of bluff, 2½ miles due south of Sipe Springs. Mineral Wells formation, Pennsylvanian.

Eastland County

67–T–7 (H–5). Shale exposures in west-facing slopes and in gullies about one-eighth of a mile due north of the Eastland-Cisco highway 4½ miles in direct line due west of Eastland. The locality is best reached by driving 4.7 miles by road west from Connellee Hotel in Eastland to an abandoned road that leads northward. By following this old road northward as far as it goes and then continuing across the pasture northward the extensive exposures are readily found. The lowest strata are rich in fossils including crinoid fragments and bryozoa. This is the type locality for a large number of bryozoan species described by R. C. Moore.[86] Graham formation, Pennsylvanian.

67–T–26 (A–2). Marl and shale at base of prominent outlier about 150 feet west of the old Cisco-Moran highway, 1.2 miles by road southeast of the railroad station in Pueblo and almost on the Eastland-Callahan county line. About 10 feet above Camp Colorado limestone, base of Moran formation, Permian.

***67–T–28 (F–2).** Gully 0.3 of a mile north of road corner where Cisco-Breckenridge road ("Canyon" road) turns from northeast to north, 4.6 miles by road north of the T. & P. RR. crossing, which is about a mile east of Cisco. Shale below Blach Ranch limestone, Thrifty formation, Pennsylvanian?

67–T–29 (F–3). Limestone outcrop along escarpment on Cisco-Breckenridge road ("Canyon" road out of Cisco) at point 3.1 miles by road from T. & P. RR. crossing which is about 1 mile east of Cisco. Thrifty formation, Pennsylvanian?

67–T–30 (E–6). Roadside excavation in shale at northeast corner of Randolph Junior College campus in northwest part of the town of Cisco. Shales about 75 feet below Saddle Creek limestone, Harpersville formation, Pennsylvanian?

Hood County

***110–T–3.** Shale exposure on north side of small creek, on south side of an east-west road, back of abandoned stone barn, at point 0.45 of a mile south and 0.2 of a mile east of Kickapoo Falls. This is the type locality for *Sciadiocrinus harrisae*, n.sp., and *Paradelocrinus subplanus*, n.sp. This location is also about 4½ miles east-northeast of Lipan. Shales below Kickapoo Falls limestone, Millsap Lake formation, Pennsylvanian.

***110–T–4.** Shale below Kickapoo Falls limestone about one-quarter of a mile east of the falls, 8.5 miles by road southwest of the bridge at Dennis. This is the type locality for *Malaiocrinus parviusculus*, n.sp., *Plaxocrinus obesus*, n.sp., *P. perundatus*, n.sp., *Pirasocrinus scotti*, n.sp., and *Paradelocrinus brachiatus*, n.sp. Paratypes of *Sciadiocrinus harrisae*, n.sp., *Pirasocrinus scotti*, n.sp., and *Paradelocrinus brachiatus*, n.sp., have been collected from this exposure. Shales below the Kickapoo Falls limestone. Millsap Lake formation, Pennsylvanian.

Jack County

119–T–4 (Q–14). Limestone exposure at T-road. 1 mile west-northwest of Vineyard. Middle Graford formation, Pennsylvanian.

119–T–8 (L–14). Shale exposure in railroad cut under viaduct over Rock Island Railroad, 3.7 miles by road southeast of courthouse in Jacksboro, on the Mineral Wells highway. Shale below upper Jacksboro *Triticites*-bearing limestone, basal Graham formation, Pennsylvanian.

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[86]Moore, R. C., A bryozoan fauna from the upper Graham formation, Pennsylvanian, of north-central Texas: Jour. Pal., vol. 3, pp. 1-27, 121--156, pls. 1-3. 15-18 text figs, 1-5, 1929.

119–T–16 (C–14). Shale exposure on Jacksboro-Graham highway 2.2 miles east of Bryson. Crinoid plates are associated with a brachiopod fauna rich in *Chonetina verneuiliana* (Norwood and Pratten). Graham formation, Pennsylvanian.

119–T–19 (O–8). Shale exposure 3¼ miles southwest of Cundiff on Jacksboro-Chico highway. Caddo Creek formation, Pennsylvanian.

119–T–29 (Q–17). North of road one-half mile west of Joplin. This is the type locality for *Plaxocrinus parilis*, n.sp., and a paratype of *Endelocrinus parvus*, n.sp., has come from this exposure. Graford formation, Pennsylvanian.

119–T–30 (M–9). Shale exposure south of low hill southeast of cattle tank north of Jacksboro-Chico highway, 6½ miles northeast of Jacksboro. Probably upper Caddo Creek formation, possibly lower Graham, Pennsylvanian.

Kimble County

*__134–T–17.__ Shale bank on south side of Llano River at road leading down to river from Camp Walton. Exposure is now largely covered by alluvium, and the exact stratigraphic relationships and age are unknown. A paratype of *Paradelocrinus subplanus*, n.sp., has been collected from this exposure. Mineral Wells or lower Graford, Pennsylvanian.

McCulloch County

153–T–8. Shale outcrop on west side of Saddle Creek, 1½ miles south of its junction with Colorado River. *Fusulina*-bearing limestone of Waldrip member, Pueblo formation, Pennsylvanian?

153–T–9. Shale on west bank of Saddle Creek, 1 mile south of its junction with Colorado River. About 20 feet below middle Waldrip limestone, Pueblo formation, Pennsylvanian?

153–T–10. Shale slope on south side of road 1.75 miles east of Fife. Graham formation, Pennsylvanian.

153–T–22. Red and variegated shale on east side of a north-south creek valley, 3½ miles due east of Rochelle. The outcrop is reached by driving 3.6 miles by road from the railroad crossing in Rochelle on the San Saba road to a gate that lies just east of a north-south fence, and then by following southward along the fence 0.7 of a mile. The valley lies just west of the fence, and several exposures of pink shales rich in the chonetids, *Mesolobus rochellensis* R. H. King and *Chonetina robusta* R. H. King, are readily found. Crinoid fragments are abundant in these shale exposures. Millsap Lake formation, Pennsylvanian.

*__153–T–23.__ Shale exposure 2½ miles east and 2½ miles north of Rochelle, on a small outlier just west of the north-south road to Mercury that turns north from the Rochelle-San Saba highway at a point 2.6 miles by road east-northeast of Rochelle. This is the type locality for *Athlocrinus nitidus*, n.sp., *Plaxocrinus omphaloides*, n.sp., and *P. lobatus*, n.sp. An incomplete cup of *Delocrinus benthobatus*, n.sp., has been found here. Mineral Wells formation, Pennsylvanian.

153–T–26. Shale exposure east of concrete culvert 2.7 miles east and 2.7 miles north of Placid. Brownwood shale, Mineral Wells formation, Pennsylvanian.

153–T–71. Exposure on west side of road about three-quarters of a mile west of Rochelle and 1½ miles north of Williams Ranch house, which is near the railroad crossing south of Rochelle. Exact age unknown, probably Graford or Brad formation, Pennsylvanian.

153–T–82. Excavation pit for road material on west side of Brady-Mason road, about 5 miles southeast of Brady. Marble Falls formation, Pennsylvanian.

153–T–86. Shale and limestone exposure near spillway at Shropshire Lake, 2¾ miles east of Brady. Marble Falls formation, Pennsylvanian.

***153–T–92.** Top of escarpment about quarter of a mile east of Mercury. A paratype of *Paradelocrinus subplanus,* n.sp., has been found in this bed. Adams Branch limestone, Graford formation, Pennsylvanian.

Mason County

***159–T–22.** Shale along Llano River south of Mason. Collection made by Col. R. L. Marquis of North Texas State Teachers College. Exact locality not known. This is the type locality for *Parulocrinus marquisi,* n.sp. Age of formation possibly Mineral Wells or lower Graford, Pennsylvanian.

Palo Pinto County

***181–T–1 (A–21).** Slope below limestone escarpment 3½ miles due west of Strawn on north side of old road to Strawn oil field near 5000-barrel oil tank and south of small lake. This is the type locality for *Parulocrinus beedei,* n.sp. Palo Pinto limestone, Pennsylvanian.

***181–T–2 (P–11).** Thin crinoidal limestone layer at base of slope in pasture at east end of Barber Mountain, 6 miles in direct line southwest of Mineral Wells and 1½ miles due west of Oaks Crossing on Brazos River. This is the type locality for *Laudonocrinus cucullus,* n.sp., *L. arrectus,* n.sp., *Plaxocrinus aplatus,* n.sp., *Perimestocrinus calyculus,* n.sp., *Aatocrinus cavumbilicatus,* n.sp., *Delocrinus benthobatus,* n.sp., *D. granulosus,* n.sp., *D. granulosus* var. *moniliformis,* n.var., and *D. granulosus* var. *zonatus,* n.var. Paratypes of *Plaxocrinus aplatus,* n.sp., *Perimestocrinus impressus,* n.sp., *Aatocrinus cavumbilicatus,* n.sp., *Delocrinus granulosus,* n.sp., and *D. granulosus* var. *moniliformis,* n.var., have been collected from this bed. East Mountain shale, Mineral Wells formation, Pennsylvanian.

***181–T–3 (B–21).** Weathered shale and limestone on south side of old road to Strawn oil field, 2 miles west of Strawn. Keechi Creek shale, Mineral Wells formation, Pennsylvanian.

181–T–4 (S–9). Shale exposure on west side of clay pit of Reliance Brick Company in east edge of the town of Mineral Wells. The crinoid fragments are found in the Village Bend limestone, a thin layer exposed in the East Mountain shale escarpment capped by Lake Pinto sandstone in the vicinity of Mineral Wells. Mineral Wells formation, Pennsylvanian.

181–T–5 (T–14). Bare spot in pasture about 400 feet west of road, 0.15 of a mile south of Goen Cemetery on Louis Goen farm, 2 miles in direct line east-northeast of Inspiration Point and 7 miles in direct line east-southeast of Mineral Wells. Millsap Lake formation, Pennsylvanian.

***181–T–9 (S–9).** Shale slope below Lake Pinto sandstone at north end of East Mountain about 0.6 of a mile east of Crazy Hotel in Mineral Wells. East Mountain shale member, Mineral Wells formation, Pennsylvanian.

181–T–10 (R–8). Extensive shale exposures below Turkey Creek sandstone on Mineral Wells-Union Hill School road, 2.85 miles by road north-northwest of Crazy Hotel in Mineral Wells. Salesville shale member, Mineral Wells formation, Pennsylvanian.

***181–T–19 (R–9).** Yellow, fossiliferous marl at west end of dam at Lake Pinto, 1 mile west of Mineral Wells. A paratype of *Plaxocrinus omphaloides,* n.sp., was found in this layer. Mineral Wells formation, Pennsylvanian.

***181–T–25 (G–5).** Limestone 2 miles southeast of Pickwick; lowest limestone bench of McAdams Peak. Ranger limestone, Brad formation, Pennsylvanian.

***181–T–27 (I–8).** East end of McKenzie (Long) Mountain near foot of steep escarpment about one-quarter of a mile northwest of Brazos River and 3 miles southwest of Palo Pinto-Graford bridge over Brazos River. The locality is reached by following the Dalton ranch road south from Dalton, and it lies just west of the ranch road at Dalton Bend of Brazos River. *Delocrinus pictus,* n.sp., was found in the upper fossiliferous shale of this section. Graford formation, Pennsylvanian.

***181–T–31 (L–2).** Merriman limestone just west of highway, 2¾ miles in direct line northwest of Graford. This is the type locality for *Athlocrinus clypeiformis,* n.sp., and *Sciadiocrinus disculus,* n.sp. Graford formation, Pennsylvanian.

181–T–39 (E–16). Shale exposure about center of line between sections 71 and 72, Block 3, T. & P. RR. survey, about 7 miles northeast of Strawn. Graford formation, Pennsylvanian.

***181–T–40 (I–14).** Near road corner 4 miles by road south-southwest of Lover's Retreat and 5 miles in direct line west-northwest of Lone Camp. This is the type locality for *Paradelocrinus protensus,* n.sp. Graford formation, Pennsylvanian.

***181–T–41 (S–3).** Abandoned quarry of the Mineral Wells Crushed Stone Company, 3 miles northwest of Salesville and 3 miles southeast of Oran. This is the type locality for *Erisocrinus elevatus,* n.sp., and for *D. verus,* n.sp. A paratype of *Plaxocrinus obesus,* n.sp., comes from this exposure. Palo Pinto limestone, Pennsylvanian.

***181–T–43 (Q–5).** Shale exposure in small rain gully in pasture about one-quarter of a mile north-northwest of Union Hill School, which is about 6 miles northwest of Mineral Wells. This is the type locality for *Delocrinus bispinosus*, n.sp., and for *D. subcoronatus*, n.sp., and a hypotype of *Aesiocrinus barydactylus* (Keyes) has been found here. Keechi Creek shale, Mineral Wells formation, Pennsylvanian.

181–T–45 (M–12). Steep bluff on north side of Brazos River at western extremity of Village Bend, near west side of section 37, Block 1, T. & P. RR. survey, 2½ miles in direct line southeast of Palo Pinto. Mineral Wells formation, Pennsylvanian.

181–T–46 (G–5). Shale exposure in pasture on north side of Graford-Pickwick road on south side of prominent outlier (Dalton Mountain) capped by Ranger limestone, 3 miles in direct line east of Pickwick. Brad formation about 160 feet below Ranger limestone, Pennsylvanian.

***181–T–48 (D–18).** Small roadside excavation in limestone close to gate to Couch's ranch on Strawn-Mineral Wells highway, 3.5 miles by road north of bridge over Palo Pinto Creek in north edge of Strawn. A hypotype of *Erisocrinus typus* Meek and Worthen has been collected from this exposure. Palo Pinto limestone, Pennsylvanian.

***181–T–58 (P–8).** Shale on secondary road in northeast corner section 60, T. & P. RR. survey (E. of B.), 4½ miles in direct line northwest of Mineral Wells. Salesville shale, Mineral Wells formation, Pennsylvanian.

181–T–59 (P–9). Prominent shale slope on south side of Mineral Wells-Palo Pinto highway at sharp curve, 0.5 of a mile by road southeast of Brazos River bridge and about 4 miles west of Mineral Wells. East Mountain shale, Mineral Wells formation, Pennsylvanian.

181–T–60 (K–5). Shale exposure one-half mile east of old Dalton townsite on Dalton Ranch, 5 miles southwest of Graford. Wolf Mountain shale, Graford formation, Pennsylvanian. (Collection by F. R. Schenck, Prairie Oil and Gas Company.)

****181–T–61 (H–11).** Shale slope below Merriman limestone at extreme northwest point of Crawford (Wolf) Mountain near road to Belding ranch, 6 miles in direct line west-northwest of Palo Pinto. This is the type locality for *Endelocrinus grafordensis*, n.sp. Wolf Mountain shale, Graford formation, Pennsylvanian.

181–T–63 (R–4). Exposure of shale along roadside on north side of Salesville-Graford road, 3.5 miles by road northwest of Salesville. Keechi Creek shale, Mineral Wells formation, Pennsylvanian.

181–T–64 (R–4). Exposure of shale along roadside on north side of Salesville-Graford road, 2.5 miles by road from the railroad crossing at Salesville. Keechi Creek shale just below the calcareous strata indicated as Sa_1 on the county geologic map (Bureau of Economic Geology), which lies farther up the slope, Mineral Wells formation, Pennsylvanian.

***181–T–67 (Q–5).** Shale exposure in slope below Palo Pinto limestone about one-half mile north-northeast of Union Hill School, which is about 6 miles in direct line north-northwest of Mineral Wells. This is the type locality for *Apographiocrinus decoratus*, n.sp., *Pachylocrinus uddeni*, n.sp., and

Perimestocrinus impressus, n.sp. A hypotype of *Erisocrinus typus* Meek and Worthen and paratypes of *Graphiocrinus kingi*, n.sp., have been collected from this locality. Keechi Creek shale, Mineral Wells formation, Pennsylvanian.

***181–T–81 (F–5).** Gullies in shale just south of Graford-Pickwick road at point 1.3 miles by road east of Pickwick and 0.1 of a mile east of the entrance to the State Game Preserve. The holotype and a paratype of *Parulocrinus compactus*, n.sp., have come from this shale. Placid shale, Brad formation, Pennsylvanian.

181–T–83 (R–9). Shale exposure in field near secondary road just north of the head of Lake Pinto and northwest of a small bridge over the creek that feeds the lake, northwest corner of the town of Mineral Wells. The locality is reached by following the road along the east side of the lake to a point 0.6 of a mile north of the Mineral Wells Water Company Plant. East Mountain shale, Mineral Wells formation, Pennsylvanian.

***181–T–86 (R–4).** Shale exposure about 0.1 of a mile south of the road fork that lies 2.7 miles by road west-northwest of Salesville on the Salesville-Graford road. This is about 2 miles in direct line almost due west of Salesville. This is the type locality for *Graphiocrinus kingi*, n.sp., and a hypotype of *Erisocrinus typus* Meek and Worthen has been collected from this exposure. Mineral Wells formation, Pennsylvanian.

***181–T–89 (O–20).** Shale on north side of new highway, 3.3 miles by road southeast of Santo and about half a mile east of the junction of the State highway and the Santo-Patillo road. This is the type locality for *Delocrinus bullatus*, n.sp., and *Endelocrinus mitis*, n.sp. Millsap Lake formation, Pennsylvanian.

***181–T–93 (O–20).** Shale exposure just south of the tap road to Gold ranch, one-quarter of a mile east of its junction with the Santo-Patillo road, about 3 miles south-southeast of Santo. This is the type locality for *Laudonocrinus catillus*, n.sp. Millsap Lake formation, Pennsylvanian.

181–T–95 (I–8). Shale exposure in north edge of J. Poitivent survey opposite Garland Bend of Brazos River, at side of secondary road, 4 miles in direct line southwest of old Dalton townsite. Graford formation, Pennsylvanian.

***181–T–97 (J–9).** Shale on northwest slope of Kyle Mountain about three-quarters of a mile northwest of the Boy Scout Camp (on Worth ranch), and about 4 miles north-northwest of Palo Pinto. This is the type locality for *Apographiocrinus calycinus*, n.sp., *Pachylocrinus ogarai*, n.sp., *Zeacrinites? sellardsi*, n.sp., *Delocrinus graphicus*, n.sp., *Delocrinus papulosus*, n.sp., *Endelocrinus bifidus*, n.sp., and *Paradelocrinus obovatus*, n.sp. Hypotypes of *Erisocrinus typus* Meek and Worthen and *Aesiocrinus barydactylus* (Keyes) have been found in these shales. Wolf Mountain shale, Graford formation, Pennsylvanian.

Parker County

***183–T–14 (C–16).** Shale exposure at road corner close to the site of old Consolation School, 3 miles in direct line southwest of Brock. This is the type locality for *Synerocrinus formosus*, n.sp., *Neozeacrinus praecursor*, n.sp., *Schistocrinus planulatus*, n.sp., *S. confertus*, n.sp., *S. parvus*, n.sp., *Endelocrinus rectus*, n.sp., *Apollocrinus florealis*, n.sp., *Haeretocrinus magnus*, n.sp., *Texacrinus gracilis*, n.sp., *Ethelocrinus millsapensis*, n.sp., *Sellardsicrinus marrsae*, n.sp., and *Brychiocrinus texanus*, n.sp. Paratypes of *Synerocrinus formosus*, n.sp., *Neozeacrinus praecursor*, n.sp., *Schistocrinus confertus*, n.sp., *Endelocrinus rectus*, n.sp., *Sciadiocrinus harrisae*, n.sp., *Sellardsicrinus marrsae*, n.sp., *Plaxocrinus obesus*, n.sp., and *P. perundatus*, n.sp., have come from this shale. Just below Brannon Bridge limestone, Millsap Lake formation. Pennsylvanian.

Pecos County

185–T–3. Limestone ledge containing fusulinids on south side of road at Gaptank, Glass Mountains. Gaptank formation, Pennsylvanian.

Presidio County

188–T–3. East bluff of Sierra Alta Creek, 3 miles north of Shafter and one-half mile below Cibolo ranch. This is the type locality for *Cibolocrinus typus* Weller, *C. regalis*, n.sp., *Apographiocrinus wolfcampensis*, n.sp., *Spaniocrinus? trinodus* (Weller), *Erisocrinus propinquus* Weller, *Neozeacrinus uddeni* (Weller), *Perimestocrinus excavatus* (Weller), *Delocrinus major* Weller, *D. quadratus*, n.sp., *Endelocrinus texanus* (Weller), *Stuartwellercrinus turbinatus* (Weller), *S. texanus* (Weller), *S. symmetricus* (Weller), and *Ulocrinus americanus* (Weller). This is the locality from which Stuart Weller[87] described the Permian crinoid fauna. Lower brecciated bed of the Cibolo limestone (equivalent to part of the Wolfcamp formation), Lower Permian.

San Saba County

205–T–1. Exposure of shale and limestone on bluff at Flat Rock Bend of Colorado River, about 2 miles west of Bend. Smithwick? formation, Pennsylvanian.

***205–T–17.** Limestone escarpment on north side of Rough Creek, about 5 miles northwest of Bend and a few hundred yards east of the road crossing on Rough Creek, approximately 11 miles southeast of San Saba. This is the type locality for *Scytalocrinus sansabensis* Moore and Plummer and *Lasanocrinus cornutus*, n.sp. The crinoids are in a yellowish-gray limestone ledge near the base of the escarpment. Marble Falls limestone, Pennsylvanian.

205–T–23. Shale and limestone in steep bank near top of hill, on San Saba-Llano road, 2.7 miles by road south of San Saba courthouse in the town of San Saba. Near base of Marble Falls limestone, Pennsylvanian.

205–T–43. Steep creek bank about 500 feet west of San Saba-Wallace Creek road at point 11.5 miles by road southwest of Hotel San Saba, in San Saba. This is the type locality for *Cibolocrinus punctatus*, n.sp., and *Ethelocrinus texasensis*, n.sp. Marble Falls limestone, Pennsylvanian.

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[87] Weller, Stuart, Description of a Permian crinoid fauna from Texas: Jour. Geol., vol. 17, pp. 623–635, pl. 1, 1909.

Shackelford County

*208–T–6. Outlier on north side of Ibex road, 8.3 miles by road north of Moran. Pueblo formation, Pennsylvanian?

Stephens County

214–T–2 (M–5). Shale exposure at south end of a prominent escarpment capped by Ivan limestone, 2.3 miles by road southwest of Ivan on the Breckenridge highway. The crinoids occur in a fusulinid-bearing zone 44 feet below the top of the Ivan limestone, Thrifty formation, Pennsylvanian?

***214–T–15 (G–8).** Shale exposure on east side of prominent escarpment nearly a mile west of the old Breckenridge-Crystal Falls road measured from a point 2 miles north of the courthouse in Breckenridge, in northwest corner section 1, Lunatic Asylum Lands. A paratype of *Delocrinus vulgatus*, n.sp., has been collected from this exposure. This outcrop is somewhat above a coal bed and below the Belknap limestone. Harpersville formation, Pennsylvanian.

***214–T–16 (G–5).** Shale exposure on small outlier 6 miles due north of Breckenridge and 1 mile west of the Breckenridge-Crystal Falls highway, in section 1219, T. E. & L. survey. Shale below Belknap limestone, Harpersville formation, Pennsylvanian?

Wise County

***248–T–4 (G–12).** Calcareous shale on west side of creek flowing eastward into Martins Lake, 1.6 miles by road south of city hall in Bridgeport. This is the type locality for *Erisocrinus erectus*, n.sp., *Perimestocrinus formosus*, n.sp., and *Delocrinus paucinodus*, n.sp. Shale in Palo Pinto formation, Pennsylvanian.

248–T–6 (G–10). Clay pit in north edge of Bridgeport. Hypotypes of *Paragassizocrinus tarri* (Strimple) have been collected from this exposure. Shale in base of Graford formation, above the Willow Point limestone, Pennsylvanian.

***248–T–19 (B–5).** Abandoned quarry on south side of Chico-Jacksboro highway, about 5½ miles northwest of Chico and 2.6 miles by road east of the Jack-Wise county line. Brad formation, Pennsylvanian.

248–T–28 (G–11). Shale above coal bed in Bridgeport. Upper part of Palo Pinto formation, Pennsylvanian.

Young County

251–T–3 (M–13). Shale near top of bluff on west side of Salt Creek, one-eighth of a mile north of bridge on Graham-Murray highway, about 1 mile west of Graham. Graham formation, Pennsylvanian.

****251–T–6 (K–19).** Shale on west side of hill, one-half mile south-southwest of South Bend and just north of the site of the Goode No. 1, drilled by Roxana Petroleum Company in 1918. Crinoid plates and a complete calyx have been collected from a thin limestone slab near the top of the hill. Graham formation, Pennsylvanian.

251–T–7 (M–13). Shale slope on north side of Mars Hill, 1 mile southwest of Graham, south of the Graham-South Bend road, on the slope facing east and northeast. This slope is now largely covered by talus, and collecting is not so good as formerly. Graham formation, Pennsylvanian.

251–T–22 (C–19). Shale exposure on south side of road and south of the southeast corner of E. L. Goudy survey, Abs. 1315, 5 miles south and 1 mile east of Murray. Saddle Creek member, Harpersville formation, Pennsylvanian?

***251–T–37 (K–9).** Shale exposure 4 miles east and one-half mile north of Newcastle. This locality has furnished one of the paratypes of *Delocrinus vulgatus*, n.sp. Harpersville formation, Pennsylvanian?

***251–T–45 (K–8).** Northeast corner section 616, T. E. & L. survey, 4½ miles northeast of Newcastle. This is the type locality for *Delocrinus vulgatus*, n.sp. Saddle Creek member, Harpersville formation, Pennsylvanian?

251–T–46 (L–7). Southeast corner of northwest quarter of section 608, T. E. & L. survey, 6 miles northeast of Newcastle. Harpersville formation, Pennsylvanian?

251–T–47 (K–8). Southeast quarter of section 616, T. E. & L. survey, 4 miles northeast of Newcastle. Harpersville formation, Pennsylvanian?

LIST OF LOCALITIES IN STRATIGRAPHIC SUCCESSION

The crinoid localities described on the previous pages are here presented by number in stratigraphic succession. A question mark preceding a locality number signifies that doubt exists as to the formational age of the strata represented by this outcrop.

Permian—
  Wolfcamp formation (including Cibolo limestone)—
    Presidio County: 188–T–3
  Putnam formation—
    Callahan County: 30–T–1, 30–T–14
  Moran formation—
    Callahan County: 30–T–8, 30–T–13
    Eastland County: 67–T–26
Pennsylvanian?—
  Cisco group—
    Pueblo formation—
      Coleman County: 42–T–30
      McCulloch County: 153–T–8, 153–T–9
      Shackelford County: 208–T–6
    Harpersville formation—
      Coleman County: 42–T–41, 42–T–42
      Eastland County: 67–T–30
      Stephens County: 214–T–15, 214–T–16
      Young County: 251–T–22, 251–T–37, 251–T–45, 251–T–46, 251–T–47
Pennsylvanian—
  Cisco group—
    Thrifty formation—
      Eastland County: 67–T–28, 67–T–29
      Stephens County: 214–T–2
    Graham formation—
      Brown County: 25–T–47
      Coleman County: 42–T–32
      Eastland County: 67–T–7
      Jack County: 119–T–8, 119–T–16, ?119–T–30
      McCulloch County: 153–T–10
      Young County: 251–T–3, 251–T–6, 251–T–7
  Canyon Group—
    Caddo Creek formation—
      Jack County: 119–T–19, ?119–T–30
    Brad formation—
      McCulloch County: ?153–T–71
      Palo Pinto County: 181–T–46, 181–T–81, 181–T–98
      Wise County: 248–T–19

Graford formation—
Jack County: 119–T–4, 119–T–29
McCulloch County: ?153–T–71, 153–T–92
Palo Pinto County: 181–T–27, 181–T–31, 181–T–39, 181–T–40, 181–T–60, 181–T–61, 181–T–95, 181–T–97
Wise County: 248–T–6
Palo Pinto formation—
Palo Pinto County: 181–T–1, 181–T–41, 181–T–48
Wise County: 248–T–4, 248–T–28
Canyon Group (undetermined formation)—
Kimble County: 134–T–17
Mason County: 159–T–22
Strawn Group—
Mineral Wells formation—
Brown County: 25–T–4, 25–T–5, 25–T–30, 25–T–43
Comanche County: 47–T–1
Kimble County: ?134–T–17
McCulloch County: 153–T–23, 153–T–26
Palo Pinto County: 181–T–2, 181–T–3, 181–T–4, 181–T–9, 181–T–10, 181–T–12, 181–T–19, 181–T–43, 181–T–45, 181–T–58, 181–T–59, 181–T–63, 181–T–64, 181–T–67, 181–T–83, 181–T–86
Millsap Lake formation—
Hood County: 110–T–3, 110–T–4
McCulloch County: 153–T–22
Palo Pinto County: 181–T–5, 181–T–89, 181–T–93
Parker County: 183–T–14
Bend Group—
Smithwick formation—
San Saba County: 205–T–1
Marble Falls formation—
McCulloch County: 153–T–82, 153–T–86
San Saba County: 205–T–17, 205–T–23, 205–T–43
Pennsylvanian undifferentiated—
Gaptank formation—
Brewster County: 22–T–3
Pecos County: 185–T–3
Haymond formation—
Brewster County: 22–T–147

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PLATE 1

(All figures x1.5)

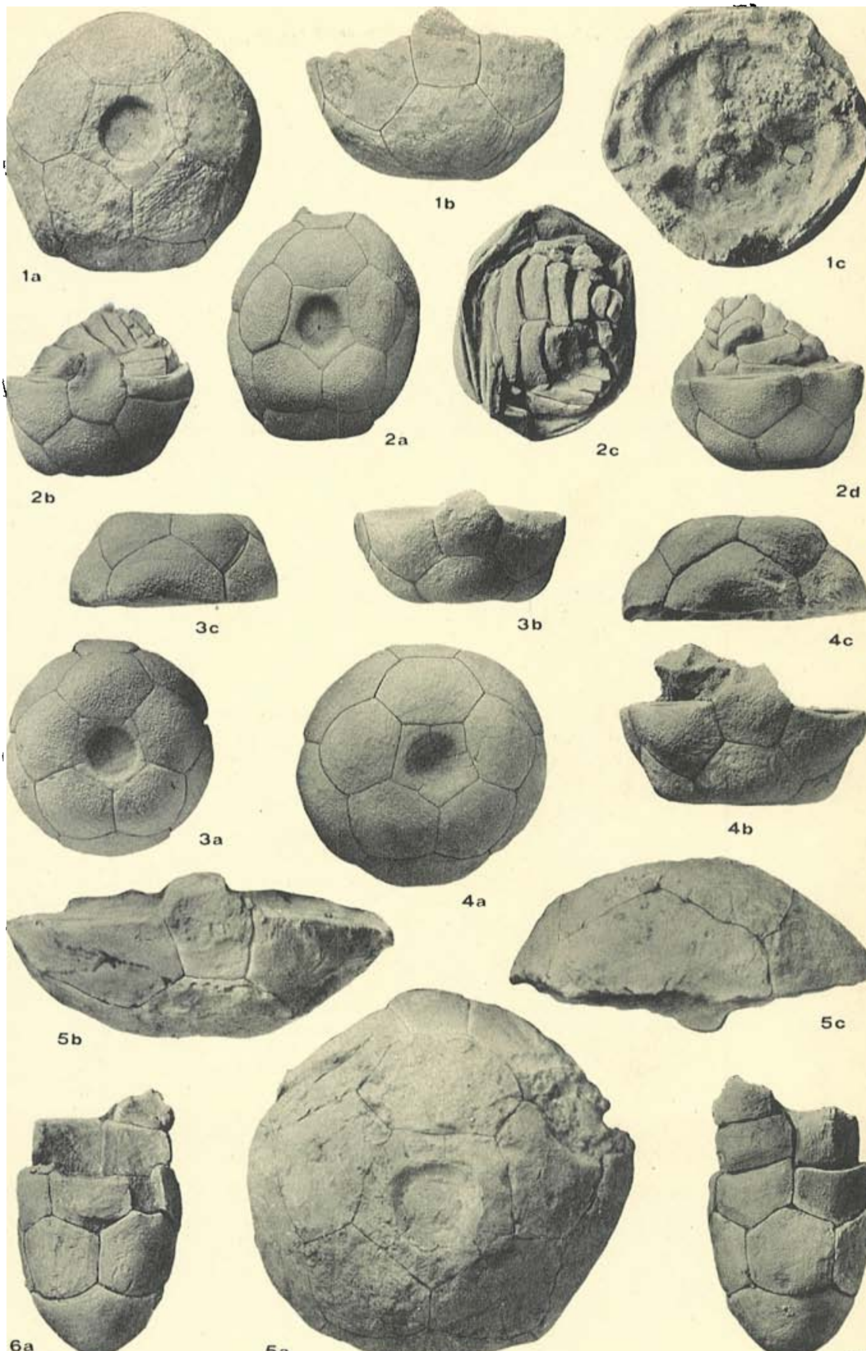
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PLATE 2

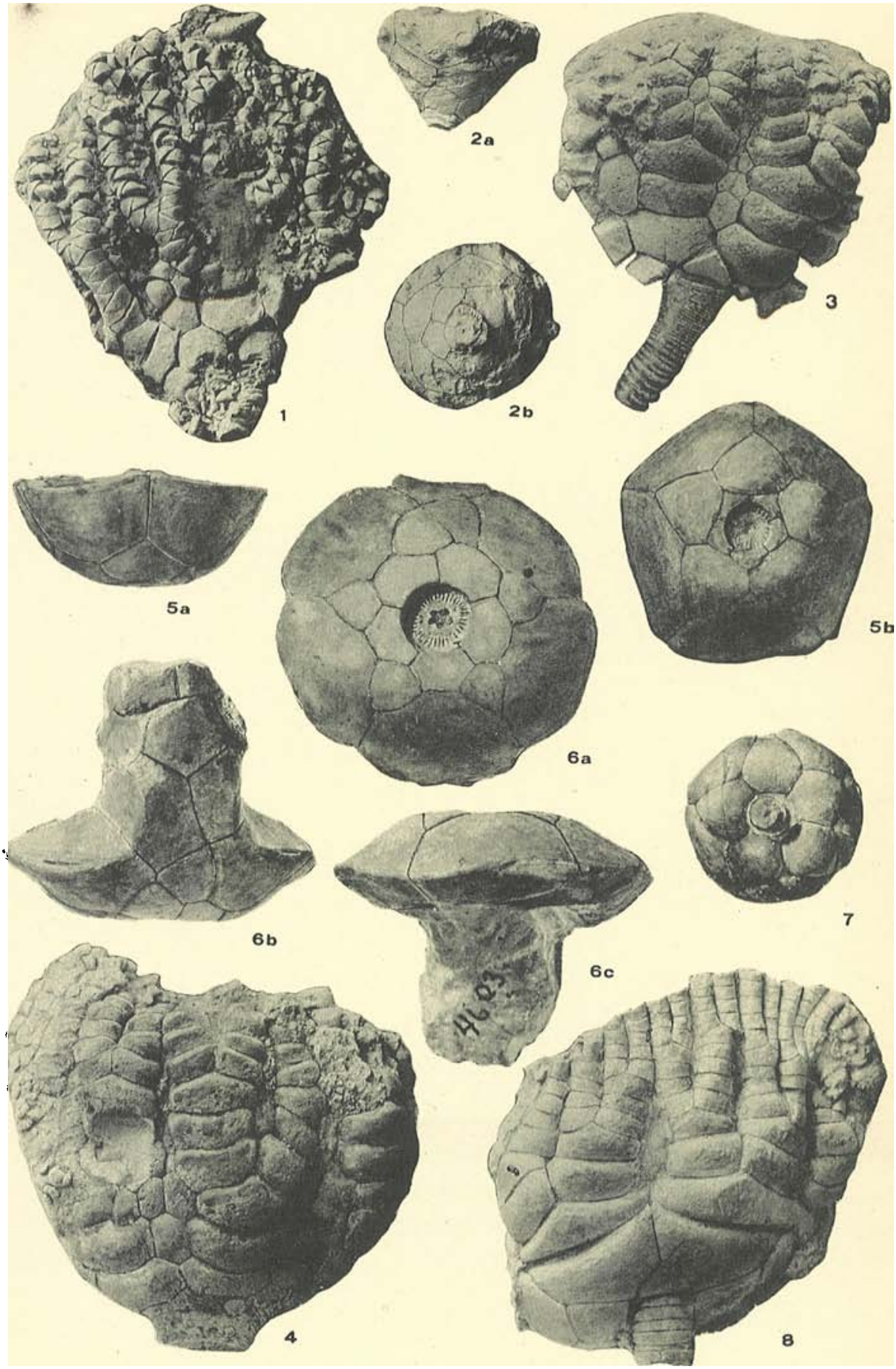
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PLATE 3

(All figures x2 except as otherwise indicated)

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Apographiocrinus exculptus Moore and Plummer, n.sp. 123

1. Holotype (P–1376), from the Graford formation, 2.5 miles west of Brownwood, Brown County, Texas. *a*, Dorsal view; *b*, posterior view, showing sharp angulation of the radial plates and decorated upper parts; *c*, ventral view, showing separation of the articular facets by inward projections of the outer surface of the radials, and the ornamented area below the facets.

Apographiocrinus decoratus Moore and Plummer, n.sp. 126

2. Holotype (P–4640), from the upper Mineral Wells formation, near Union Hill School, about 5 miles northwest of Mineral Wells, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, anterior side, enlarged to show markings on upper part of radial plates, x4.

Apographiocrinus facetus Moore and Plummer, n.sp. 125

3. Holotype (P–1376A), from the Graford formation, 2.5 miles west of Brownwood, Brown County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view.

Apographiocrinus typicalis Moore and Plummer, n.sp. 118

4. Holotype (K.U. 60031), from the Hickory Creek shale member of the Plattsburg limestone, Wilson County, Kansas. *a*, Side view of crown from the anterior side; *b*, dorsal view.
5. Paratype (K.U. 60031A), from the same horizon and locality. Ventral view.

Apographiocrinus wolfcampensis Moore and Plummer, n.sp. 129

6. Holotype (K.U. 60371), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas. *a* Dorsal view; *b*, posterior view.

Apographiocrinus calycinus Moore and Plummer, n.sp. 128

7. Holotype (P–10753), from the Graford formation, on northwest side of Kyle Mountain, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view.

Graphiocrinus kingi Moore and Plummer, n.sp. 315

8. Holotype (K–1388), from the Keechi Creek shale, Mineral Wells formation, 2 miles west of Salesville, Palo Pinto County, Texas. *a*, Dorsal view, cup slightly crushed; *b*, posterior view of crown, showing unusually large size and strong, even uniserial arms; *c*, anterior side of crown; *d*, basal plate of holotype, x4, showing sculpture of surface.

Sellardsicrinus marrsae Moore and Plummer, n.sp. 358

9. Paratype (M–22), from the Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. A weathered specimen showing arm structure.

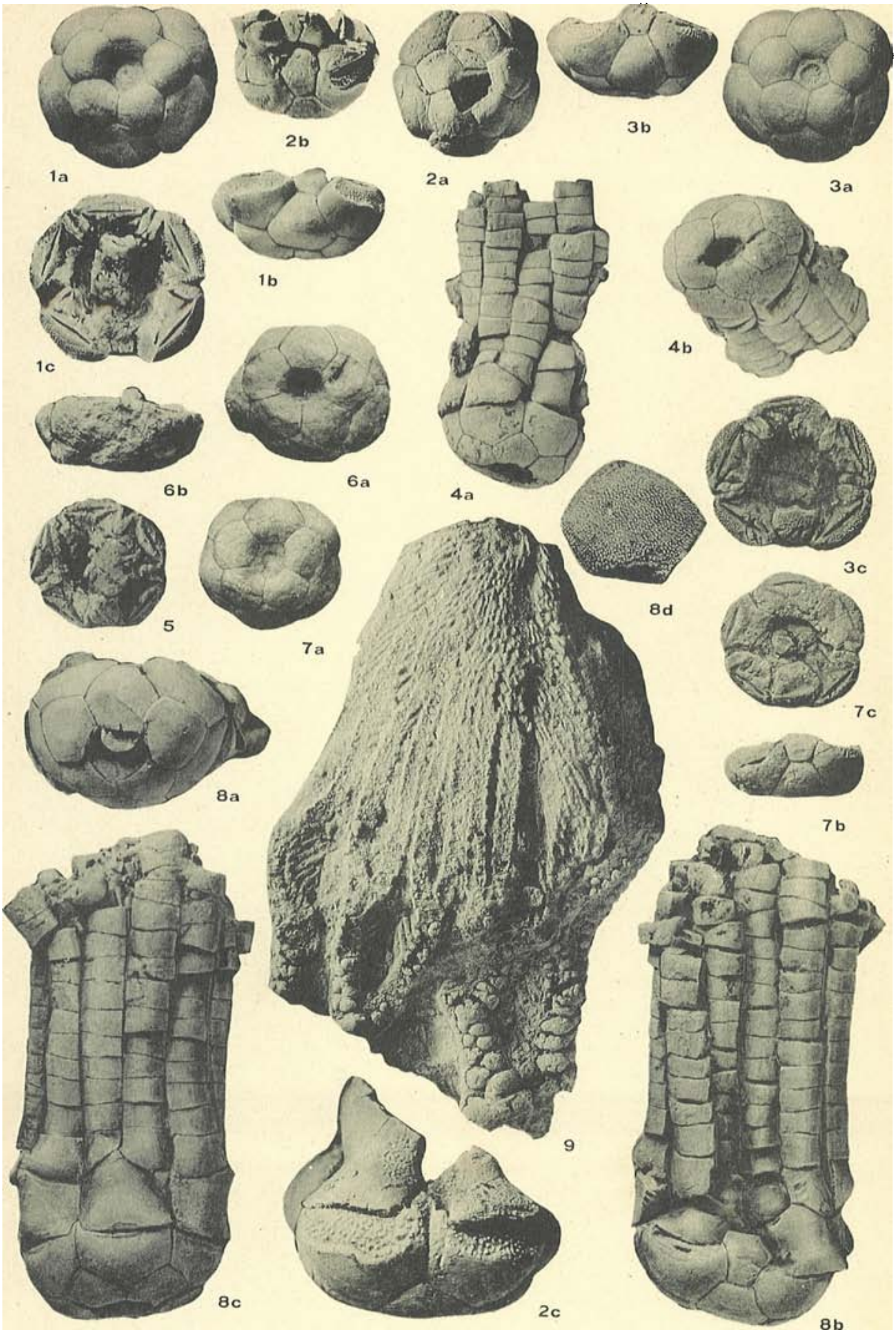
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PLATE 4

(All specimens x2, except as otherwise indicated)

PAGE

Erisocrinus elevatus Moore and Plummer, n.sp. 156

1. Holotype (P–10906), from the Palo Pinto limestone, 3 miles southeast of Oran, Palo Pinto County, Texas. *a*, Dorsal view; *b*, side view, showing the very steep and nearly straight sides of the cup.

Erisocrinus propinquus Weller 158

2. Holotype (Walker Museum 13367), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas. *a*, Dorsal view; *b*, side view.

Erisocrinus erectus Moore and Plummer, n.sp. 157

3. Holotype (K–4732), from the Mineral Wells shale, at south end of Martins Lake, 1.5 miles south of Bridgeport, Wise County, Texas. *a*, Dorsal view, showing the small but sharply depressed basal concavity; *b*, side view, showing the steep sides.

Erisocrinus typus Meek and Worthen 152

4. Hypotype (K–1389), from the Keechi Creek shale, Mineral Wells formation 2 miles west of Salesville, Palo Pinto County, Texas. *a*, Side view, x1; *b*, ventral view, showing some of the brachial segments lodged in the cup, x1; *c*, dorsal view.
5. Hypotype (P–4938), from the same horizon, about 3½ miles north of Strawn, Palo Pinto County, Texas. Dorsal view, x1.

Delocrinus? perexcavatus Moore and Plummer, n.sp. 284

6. Holotype (Humble Oil and Ref. Co. coll.), from the Gaptank formation, Pennsylvanian, at Wolfcamp, Brewster County, Texas. *a*, Side view of cup and lower part of arms; *b*, dorsal view, showing the very deep basal concavity.

Pachylocrinus ogarai Moore and Plummer, n.sp. 140

7. Holotype (P–10752), from the Graford formation, on the northwest side of Kyle Mountain, Palo Pinto County, Texas. *a*, Dorsal view, showing the moderate deep basal concavity; *b*, posterior view, showing the impressed sutures; *c*, proximal columnals.

Pachylocrinus uddeni Moore and Plummer, n.sp. 138

8. Holotype (P–7645), from the upper Mineral Wells shale, near Union Hill School, about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas. *a*, Dorsal view, showing shallow basal concavity and slightly impressed character of the sutures; *b*, posterior view.

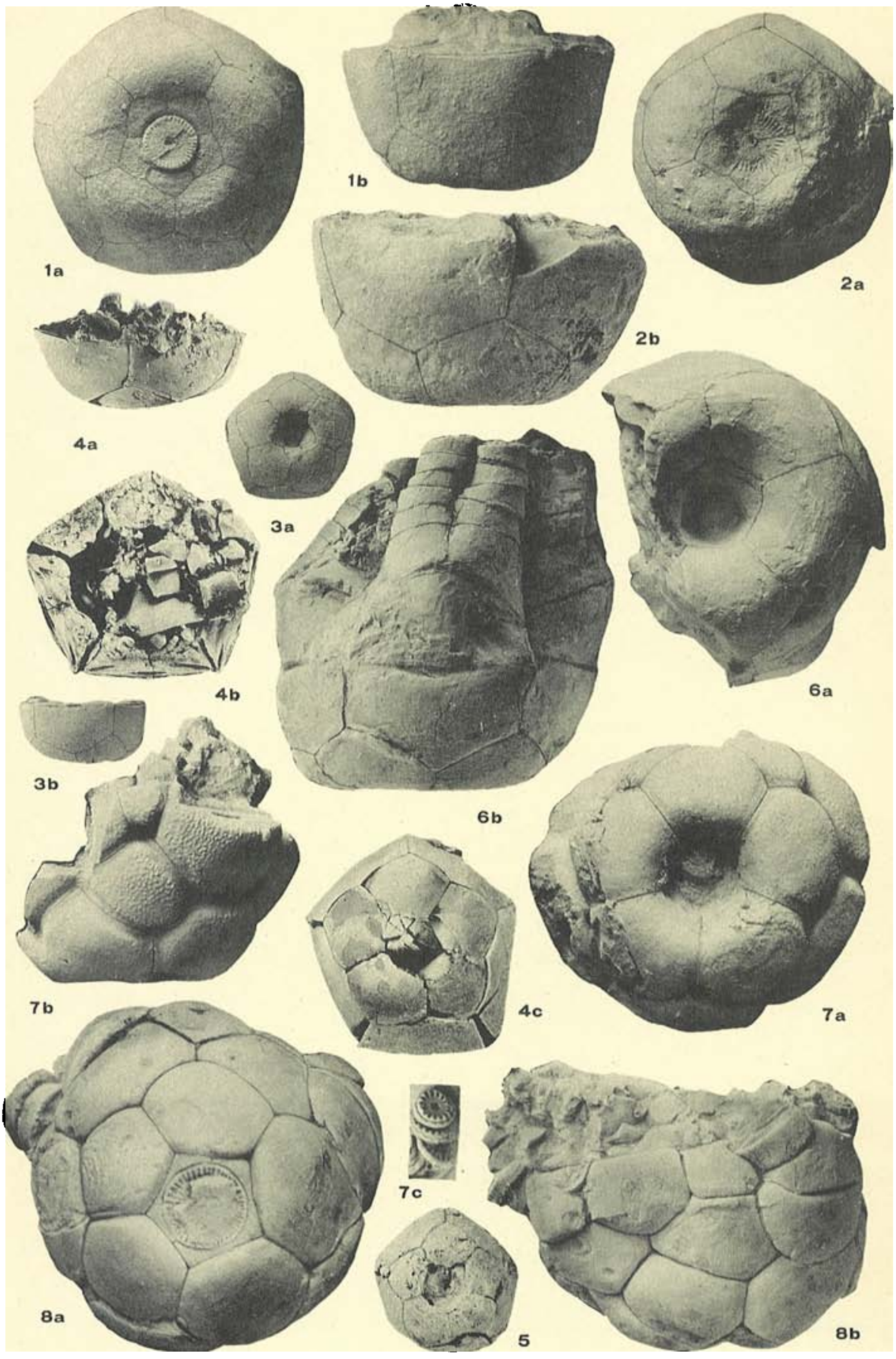
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PLATE 5

PAGE

Schistocrinus confertus Moore and Plummer, n.sp. 222

1. Paratype (H–5), from the Brannon Bridge limestone member of the Millsap Lake formation. 3 miles southwest of Brock, Parker County, Texas. *a*, Dorsal and posterior view of a deformed specimen, showing part of the basals, radials, and arms, x1; *b*, side view, showing anal plates and arm structure, x1.

Pirasocrinus scotti Moore and Plummer, n.sp. 238

2. Holotype (K.U. 60261), shale below Kickapoo Falls limestone member of the Millsap Lake formation, below Kickapoo Falls, southwest of Dennis, Hood County, Texas. *a*, Dorsal view, x1; *b*, posterior view of complete crown, with anal sac plates protruding above arms, x1.
3. Paratype (P–8190), from the same horizon and locality. Anterior view of a nearly complete crown, x1.
4. Paratype (K.U. 60262), from the same horizon and locality. Dorsal view, showing nearly undistorted cup with deep basal concavity, x1.

Neozeacrinus praecursor Moore and Plummer, n.sp. 165

5. Paratype (H–22), from the Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. Dorsal view of a nearly undistorted cup with attached proximal stem segments, x1.
8. Paratype (H–13), same horizon and locality. Side view of crown, showing anal series and structure of uniserial arms, with hyperpinnulation indicated near extremities of two arms, x1.

Scytalocrinus sansabensis Moore and Plummer 131

6. Hypotype (Peabody Museum 15238A), from the middle part of the Marble Falls limestone, on Rough Creek, 11 miles southeast of San Saba, San Saba County, Texas. *a*. Anterior view of crown, showing typical conical cup and uniserial arms, which branch isotomously on the first brachial, x2; *b*, same, x1.

Laudonocrinus arrectus Moore and Plummer, n.sp. 180

7. Holotype (K.U. 60444), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. Side view of cup, x2.

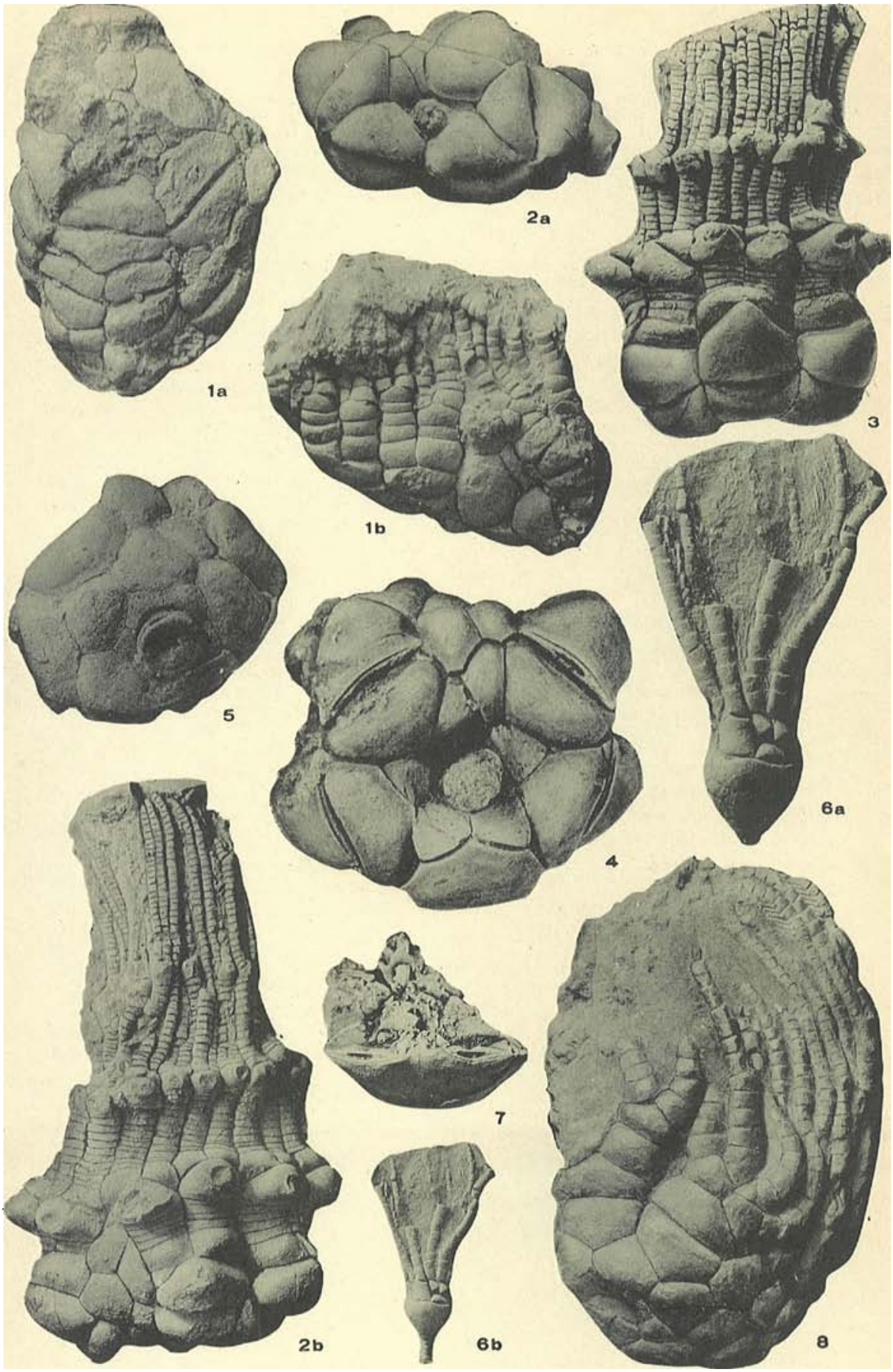
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PLATE 6

(All figures x2, except as otherwise indicated)

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Athlocrinus placidus Moore and Plummer, n.sp. 170

1. Holotype (K.U. 59991), from the Plattsburg limestone, near Altoona, Kansas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Athlocrinus clypeiformis Moore and Plummer, n.sp. 172

2. Holotype (K.U. 1095), from the Merriman limestone, northwest of Graford, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Athlocrinus nitidus Moore and Plummer, n.sp. 171

3. Holotype (K-504), from the Mineral Wells shale, near Rochelle, McCulloch County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Laudonocrinus cucullus Moore and Plummer, n.sp. 176

4. Holotype (K.U. 60442), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, anterior view.

Laudonocrinus catillus Moore and Plummer, n.sp. 178

5. Holotype (P-10640), from the Millsap Lake formation, Potato Knob, tap road to Gold ranch, east of old Santo-Patillo road, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view.

Laudonocrinus subsinuatus (Miller and Gurley) 176

6. Syntype (Walker Museum 6185A), from Missouri series, Pennsylvanian, at Kansas City, Missouri. *a*, Dorsal view; *b*, posterior view.

Neozeacrinus praecursor Moore and Plummer, n.sp. 167

7. Paratype (H-9), from Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. *a*. Posterior view of crown; *b*, anterior view.

Neozeacrinus uddeni (Weller) 162

8. Holotype (Walker Museum 13363), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas. *a*, Dorsal view of cup, x1.5; *b*, posterior view, x1.5.

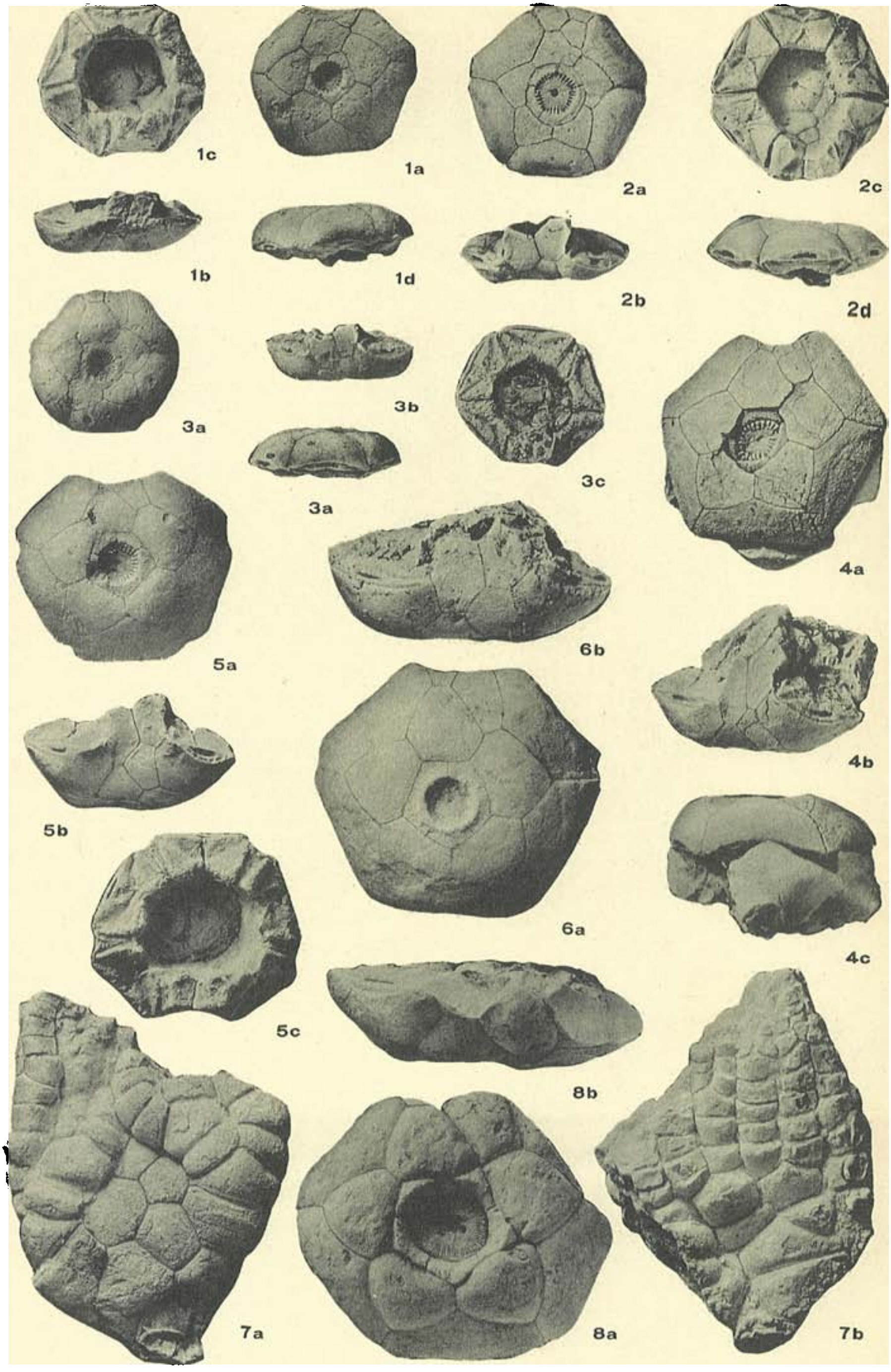
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PLATE 7

(All figures x2, except as otherwise indicated)

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Aatocrinus robustus (Beede) 215

1. Holotype (K.U. 1765), from Missouri series, Pennsylvanian, at Kansas City, Missouri, *a*, Dorsal view, showing notches between radial plates and strongly concave posterior interradius, x1; *b*, posterior view, the cup slightly tilted to show basal concavity, x1; *c*, ventral view, showing aspect of articular facets, x1.

Aatocrinus cavumbilicatus Moore and Plummer, n.sp. 215

2. Holotype (K.U. 60443), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. *a*. Dorsal view; *b*, posterior view; *c*, ventral view.
3. Paratype (K.U. 60443A), same horizon and locality. Posterior view.

Lasanocrinus cornutus Moore and Plummer, n.sp. 184

4. Holotype (Peabody Museum 15246), from middle part of Marble Falls limestone on Rough Creek, about 11 miles southeast of San Saba, San Saba County, Texas. *a*, Dorsal view; *b*, posterior view, showing strong elevation of anal plates.

Lasanocrinus daileyi (Strimple) 183

5. Hypotype, (K.U. 451925), from Brentwood? limestone, Morrow series, near Fort Gibson, Oklahoma. *a*, Dorsal view; *b*, posterior view; *c*, ventral view.
6. Hypotype, (K.U. 451925A), from same horizon and locality. *a*, Dorsal view; *b*, ventral view; *c*, posterior view.

Perimestocrinus formosus Moore and Plummer, n.sp. 203

7. Holotype (P-5285), from shale in Palo Pinto formation, near Martins Lake, Wise County, Texas. Dorsal view enlarged to show sculpture of the basal and radial plates, x4.5.

Schistocrinus planulatus Moore and Plummer, n.sp. 225

8. Holotype (H-8), Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. A somewhat crushed dorsal cup, showing prominent radial plates, and part of the slender uniserial arms, x1.

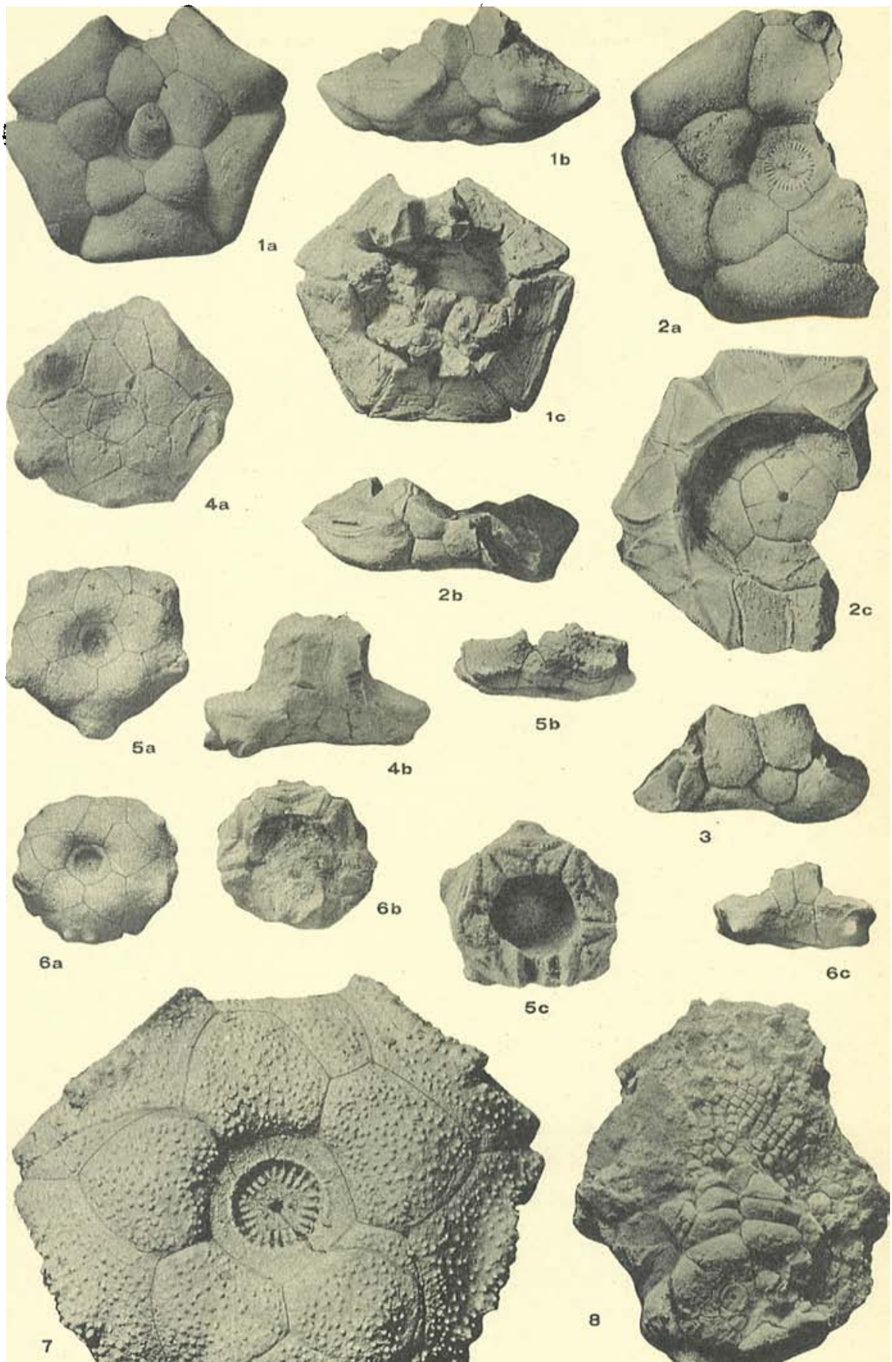
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PLATE 8

(All figures x2)

PAGE

Plaxocrinus crassidiscus (Miller and Gurley) 189

1. Holotype (Walker Mus. 6238), from Missouri series, Pennsylvanian, at Kansas City, Missouri. *a*, Dorsal view; *b*, posterior view.

Plaxocrinus obesus Moore and Plummer, n.sp. 189

2. Holotype (P-8187), from shale below Kickapoo Falls limestone member of the Millsap Lake formation, below Kickapoo Falls, Hood County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.
3. Paratype (P-664), from the Palo Pinto limestone, 3 miles northwest of Salesville, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, anterior view.

Plaxocrinus omphaloides Moore and Plummer, n.sp. 194

4. Holotype (P-11189), from Mineral Wells shale, northeast of Rochelle, McCulloch County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Plaxocrinus perundatus Moore and Plummer, n.sp. 191

5. Holotype (P-11190), from shale below Kickapoo Falls limestone member of the Millsap Lake formation, below Kickapoo Falls, Hood County, Texas. *a*, Dorsal view, showing incrusting arenaceous Foraminifera; *b*, posterior view; *c*, ventral view; *d*, anterior view.

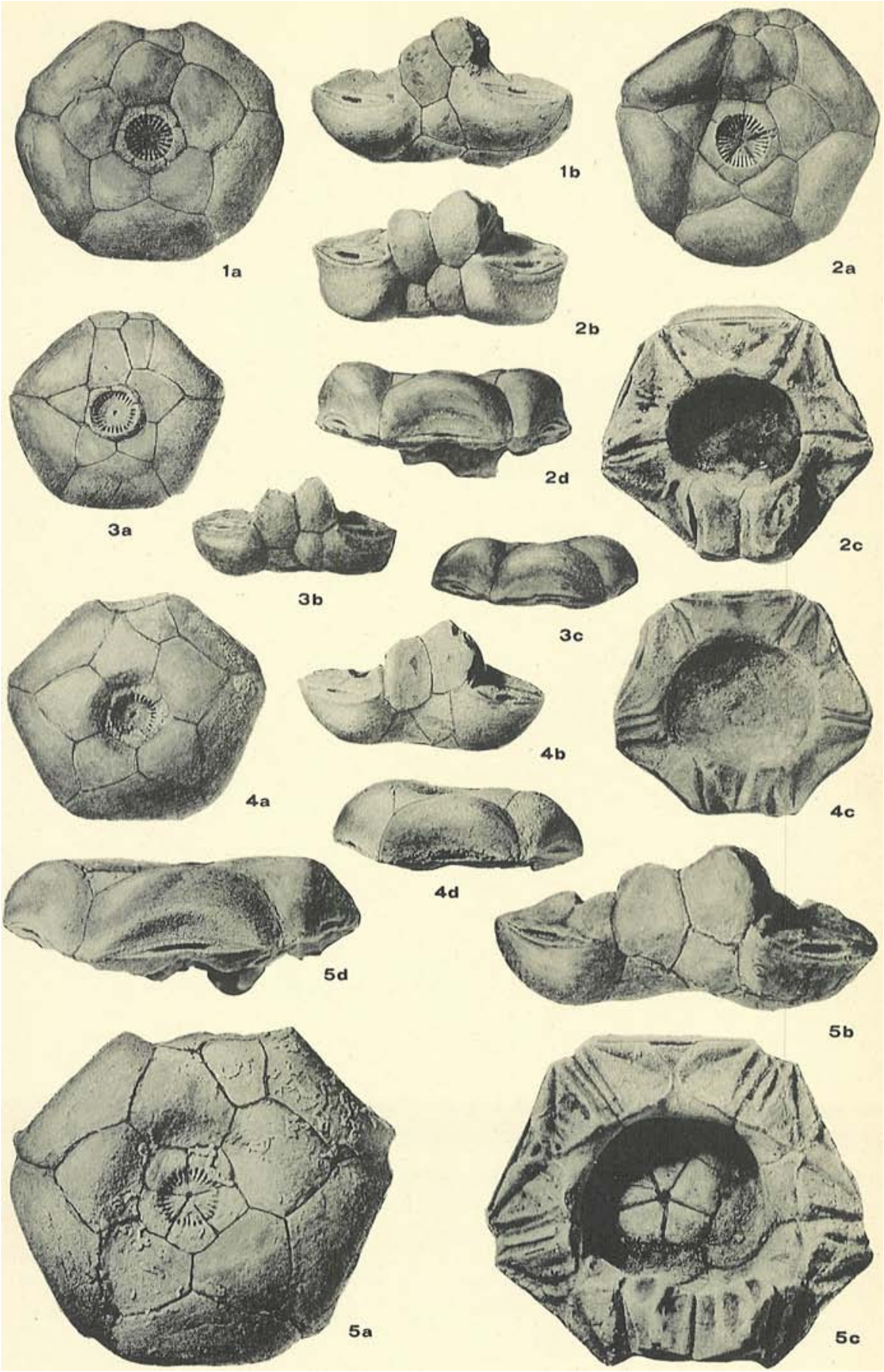
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PLATE 9

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Plaxocrinus lobatus Moore and Plummer, n.sp. 196

1. Holotype (P–11188), from the Mineral Wells shale, northeast of Rochelle, McCulloch County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Plaxocrinus aplatus Moore and Plummer, n.sp. 198

2. Paratype (P–1020), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. *a*. Dorsal view, showing strongly concave posterior interradius; *b*, ventral view; *c*, posterior view; *d*, anterior view.
3. Holotype (K.U. 60441), from same horizon and locality. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Plaxocrinus omphaloides Moore and Plummer, n.sp. 194

4. Paratype (K–451), from Village Bend limestone, Mineral Wells formation, from west end of dam at Lake Pinto, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.

Plaxocrinus parilis Moore and Plummer, n.sp. 199

5. Holotype (P–13128), from the Graford formation, west of Joplin, Jack County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.
6. Paratype (K.U. 60321), from Argentine limestone, Lake-of-the-Forest, Wyandotte County, Kansas. Dorsal view.

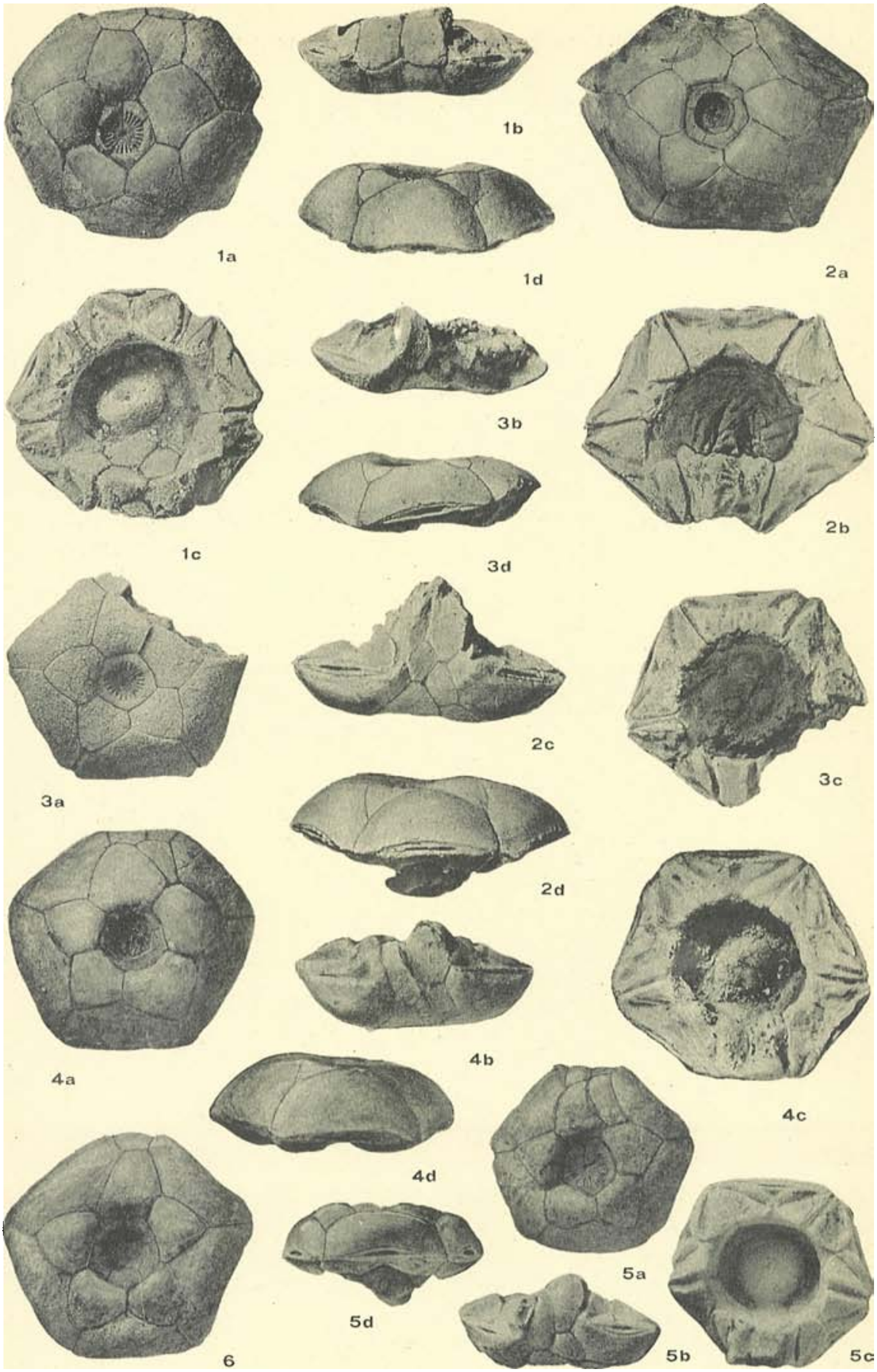
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PLATE 10

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Perimestocrinus formosus Moore and Plummer, n.sp. 203

1. Holotype (P–5285), from shale between the Balsora limestone and Bridgeport coal, Palo Pinto formation, west of Martins Lake, Wise County, Texas. *a*, Dorsal view, showing granulose ornamentation and slightly impressed nature of the sutures; *b*, posterior view, showing the arcuate, nodose ridge on the radials; *c*, ventral view; *d*, anterior view.

Perimestocrinus calyculus Moore and Plummer, n.sp. 207

2. Holotype (P–1759), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. *a*, Dorsal view, a proximal stem segment attached at base of the moderately deep basal concavity; *b*, posterior view, showing large, nearly equal-sized anal x and right tubes plates without external evidence of the presence of a radianal; *c*, ventral view; *d*, anterior view.

Perimestocrinus impressus Moore and Plummer, n.sp. 206

3. Holotype (P–4628), from the Keechi Creek shale member, Mineral Wells formation, near Union Hill School, about 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas. *a*, Dorsal view, showing the bulbous appearance of the plates above the proximal circlet and the very steep-sided basal concavity; *b*, posterior view; *c*, ventral view, showing furrows on muscle areas of the articular facets; *d*, anterior view.
4. Paratype (P–6924), from East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. Dorsal view, a typical specimen, showing plates that are a little less bulbous than in the holotype.

Sciadiocrinus disculus Moore and Plummer, n.sp. 230

5. Holotype (Walker Museum 31495), Brad formation, 2¾ miles northwest of Graford, Palo Pinto County, Texas. *a*, Dorsal view; *b*, posterior view, showing strong concavity of the anal interradius; *c*, ventral view.

Zeacrinites? sellardsi Moore and Plummer, n.sp. 245

6. Holotype (P–10876), from the Graford formation, on west slope of Kyle Mountain, Palo Pinto County, Texas. *a*, Dorsal view, showing elongate, petaloid outline of the basal plates, and narrow, deep basal concavity; *b*, posterior view, the two notches above the single anal plate indicating positions of the anal x and right tube plates; *c*, ventral view.

Perimestocrinus excavatus (Weller) 210

7. Holotype (Walker Museum 13366), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas. *a*, Dorsal view, showing the large, nearly vertical-walled basal concavity; *b*, posterior view, showing the nearly equal anal plates resting on the distal tip of the posterior basal plate.

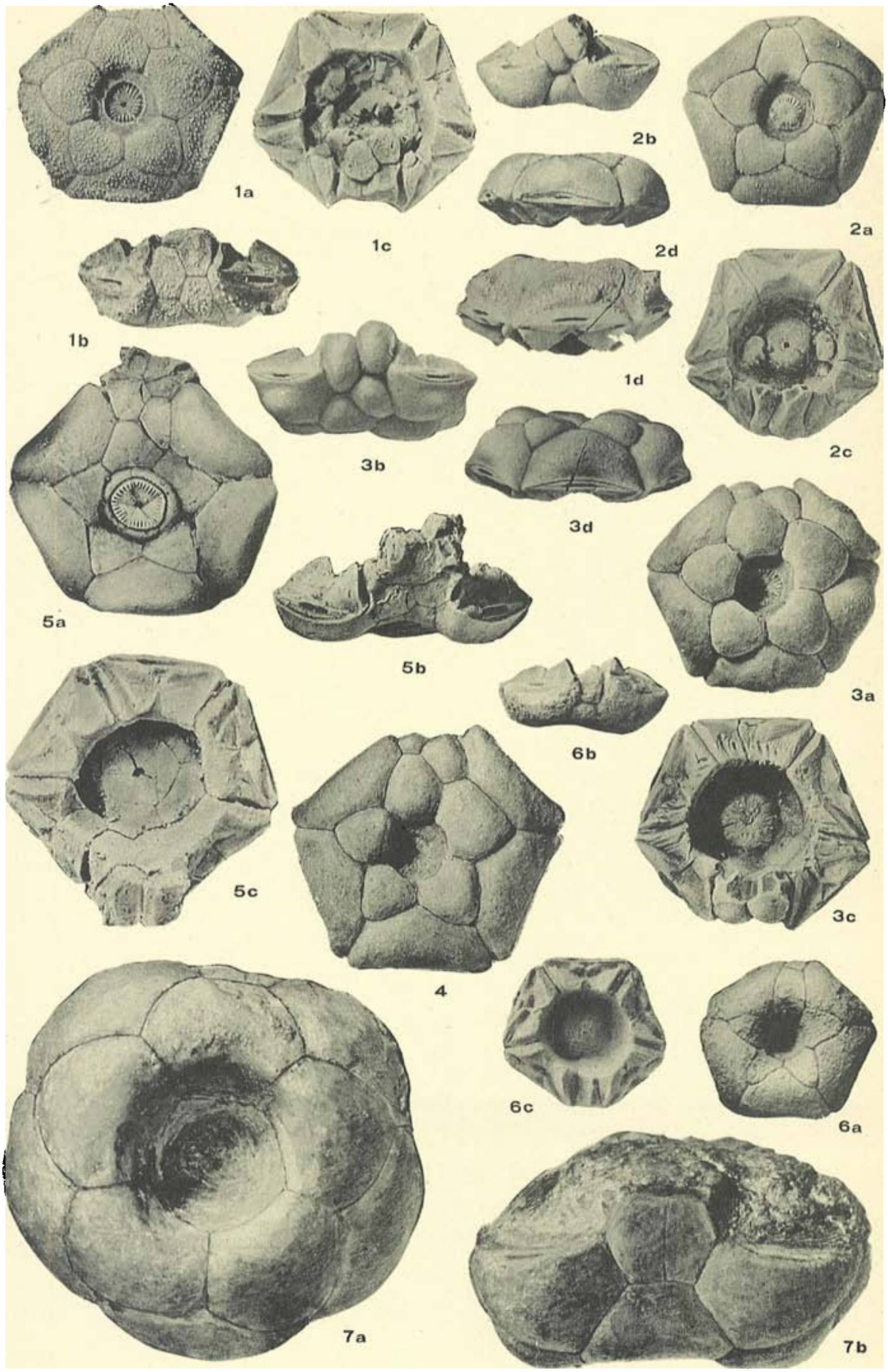
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PLATE 11

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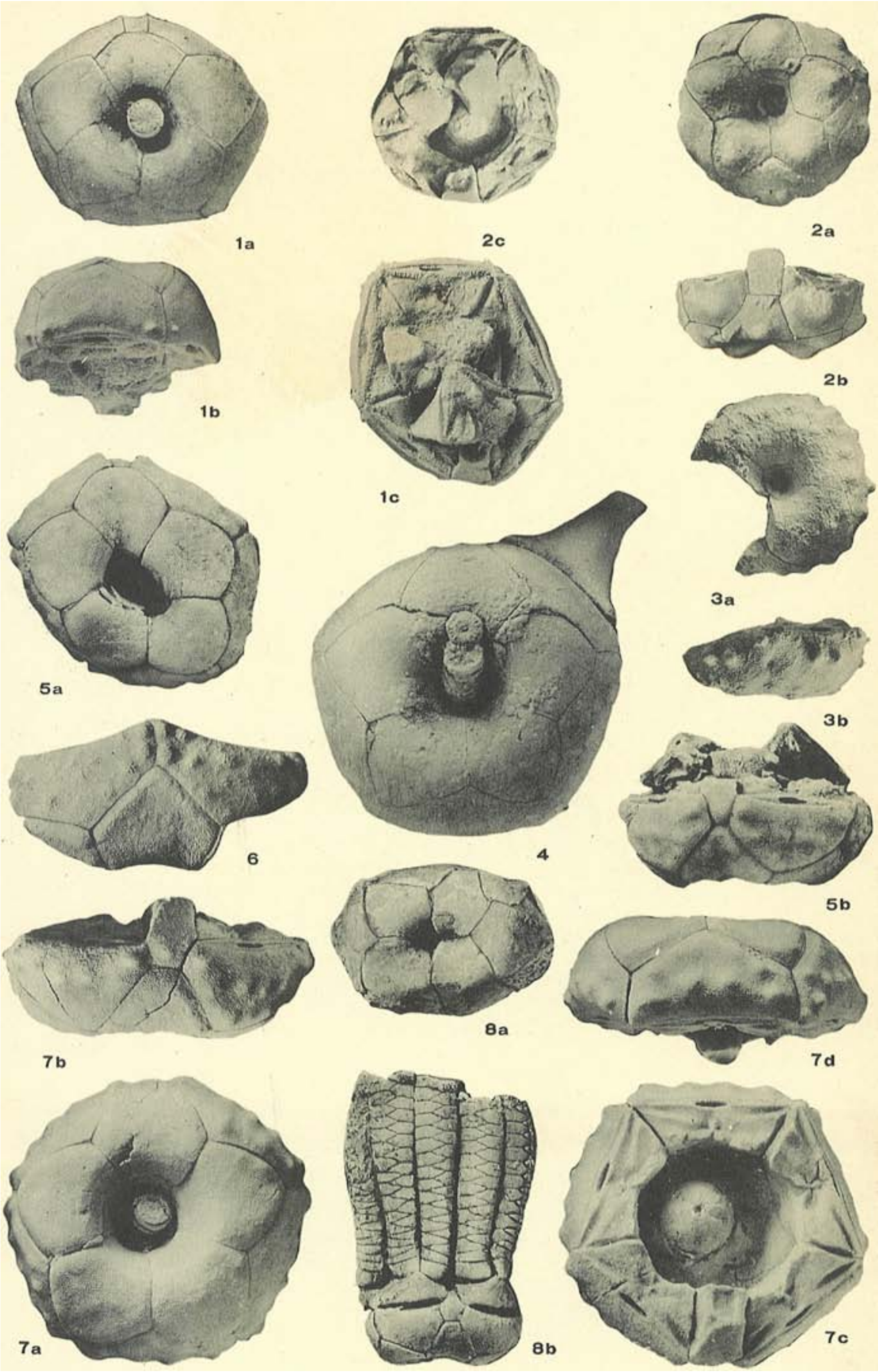
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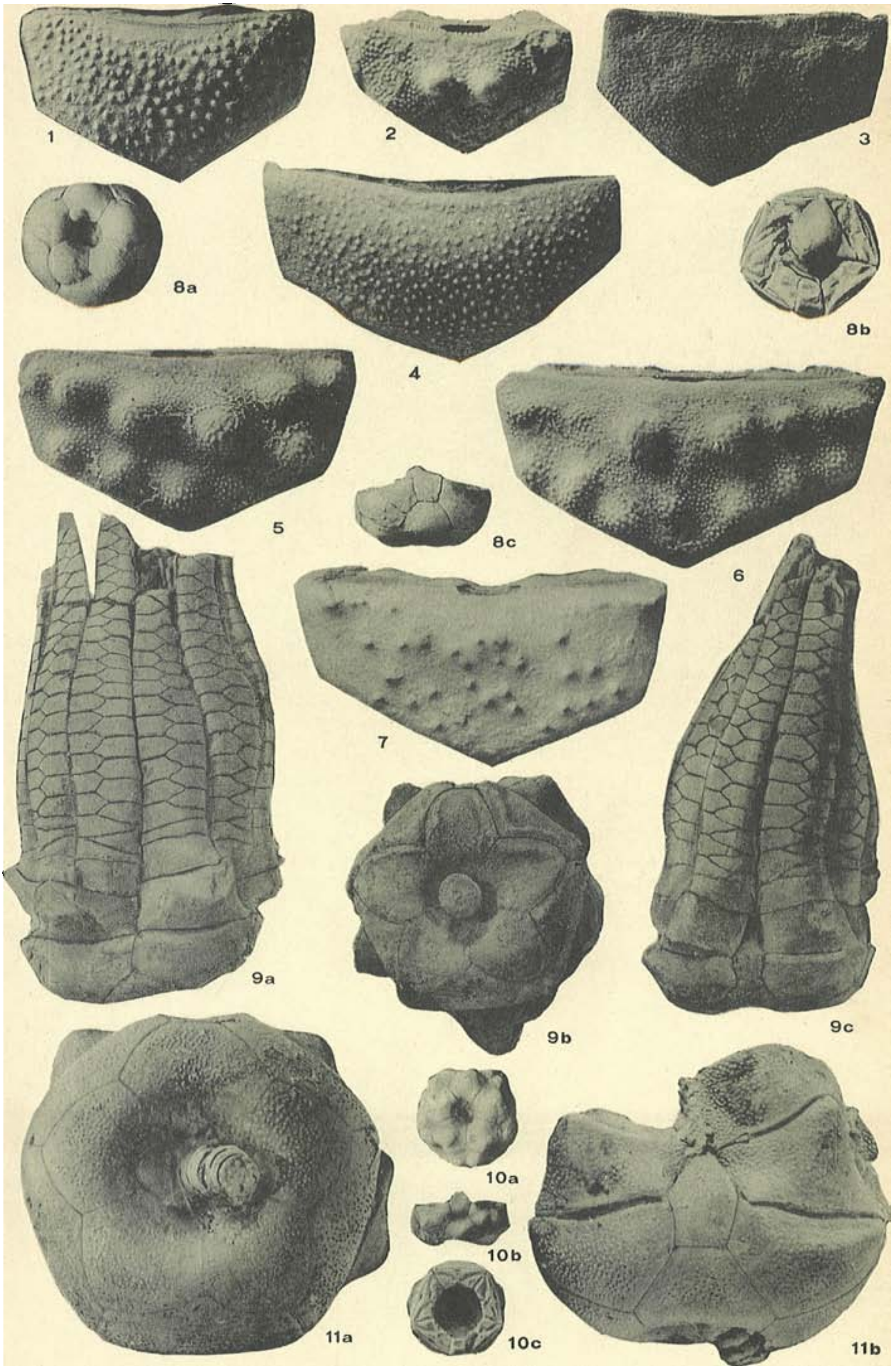
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PLATE 13

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Delocrinus granulosus var. *moniliformis* Moore and Plummer, n.var. 268

1. Holotype (P–6922), from the East Mountain shale, Mineral Wells formation, Barber Mountain, southwest of Mineral Wells, Palo Pinto County, Texas. Posterior view, showing dorsal cup and lower part of the arms.

Delocrinus paucinodus Moore and Plummer, n.sp. 276

2. Holotype (P–6445), from a shale in the Palo Pinto formation, west of Martins Lake, Wise County, Texas. *a*, Dorsal view, showing low narrow ridge along sutures and surface decoration; *b*, posterior view.

Delocrinus versus Moore and Plummer, n.sp. 282

3. Holotype (P–666), from the Palo Pinto limestone, 3 miles northwest of Salesville, Palo Pinto County, Texas. *a*, Dorsal view; *b*, ventral view; *c*, posterior view. The two round shallow pits on the posterior side of the cup are probably the work of a boring gastropod.

Delocrinus papulosus Moore and Plummer, n.sp 274

4. Holotype (P–10736), from the Graford formation, northwest side of Kyle Mountain, Palo Pinto County, Texas. *a*, Dorsal view of cup, showing ornamentation; *b*, ventral view; *c*, posterior view.

Delocrinus pictus Moore and Plummer, n.sp. 270

5. Holotype (P–1760), from the Wolf Mountain shale member of the Graford formation, 3.5 miles west of the Graford-Palo Pinto bridge over Brazos River, Palo Pinto County, Texas. *a*, Posterior side of incomplete crown, showing the characteristic finely noded surface and relatively broad, gentle curving arms; *b*, anterior view; *c*, dorsal view of cup, which is slightly crushed.

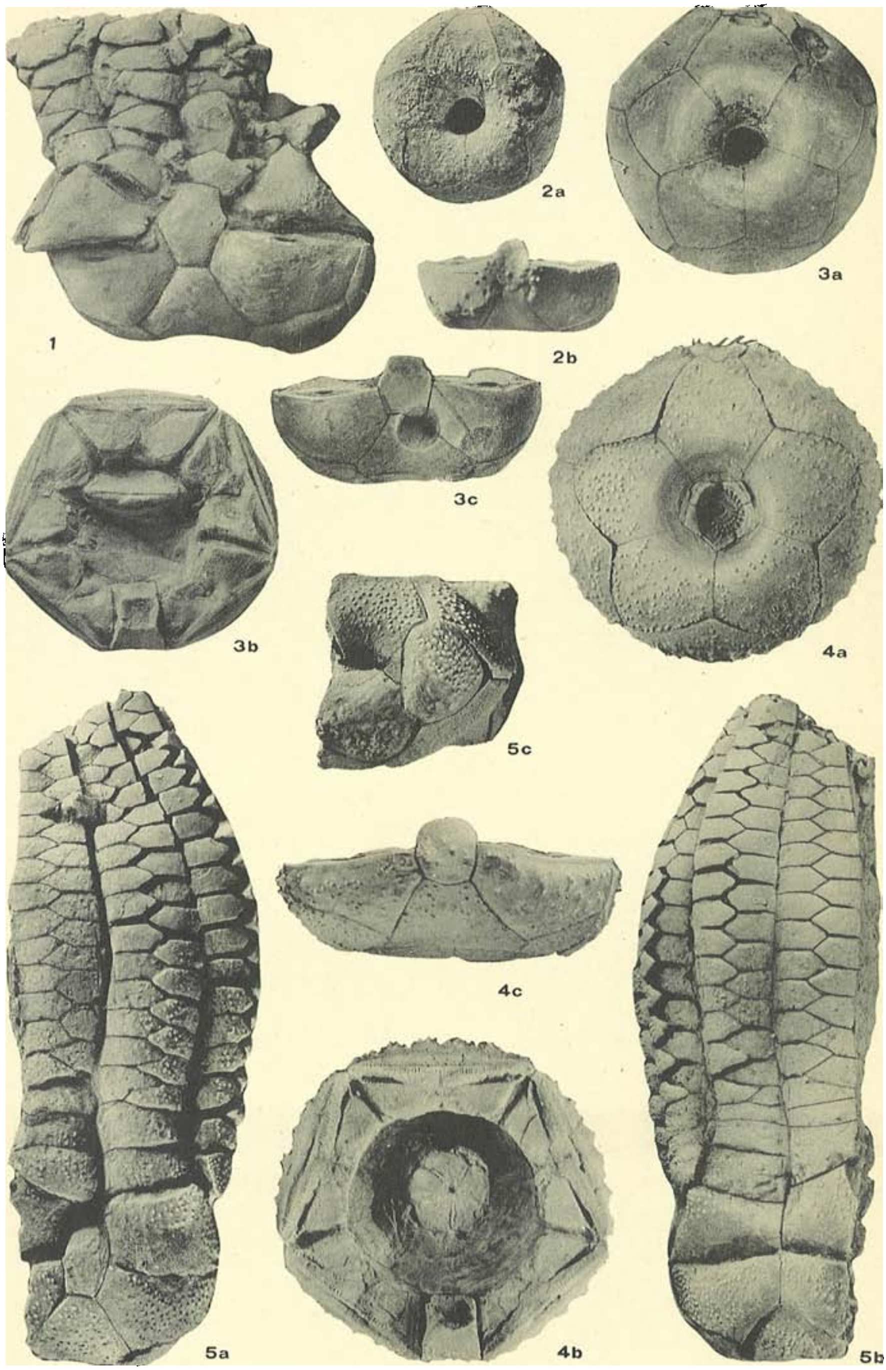
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PLATE 14

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Endelocrinus parvus Moore and Plummer, n.sp. 303

1. Holotype (P–1376B), from the Graford formation, 2.5 miles west of Brownwood, Brown County, Texas. *a*. Dorsal view: *b*. posterior view; *c*. ventral view
2. Paratype (K–13129), from the Graford formation, one-half mile west of Joplin, Jack County, Texas. *a*, Posterior view; *b*, ventral view.

Endelocrinus rectus Moore and Plummer, n.sp. 300

3. Holotype (P–10870), from the Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. *a*. Dorsal view; *b*, posterior view.
4. Paratype (P–10872), from the same horizon and locality. *a*, Dorsal view; *b*, posterior view.
5. Paratype (P–10871), from the same horizon and locality. Ventral view.

Malaiocrinus parviusculus Moore and Plummer, n.sp. 100

6. Holotype (P–10853), from shale below the Kickapoo Falls limestone member of the Millsap Lake formation, below Kickapoo Falls, southwest of Dennis, Hood County, Texas. *a*. Dorsal view; *b*, posterior view, showing the three anal plates in the cup and the narrow outwardly inclined radial facets; *c*, ventral view, showing "notches" between the facets on the radial plates."

Aesiocrinus barydactylus (Keyes) 387

7. Hypotype (K.U. 551), from the Keechi Creek shale, Mineral Wells formation, near Union Hill School, 5½ miles north-northwest of Mineral Wells, Palo Pinto County, Texas, *a*. Dorsal view, showing gentle posterior slope and steep anterior slope of cup, and indicating pentagonal stem impression; *b*, posterior view, showing large anal plate; *c*, ventral view, the slope of the radial facets being inward.

Delocrinus quadratus Moore and Plummer, n.sp. 294

8. Holotype (K.U. 60376), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County, Texas. *a*. Dorsal view; *b*, view from left posterior side.

Parulocrinus beedei Moore and Plummer, n.sp. 367

9. Holotype (P–8938), from the Palo Pinto limestone, 3.5 miles west of Strawn, Palo Pinto County, Texas. *a*, Posterior view, showing nearly flat base of cup and the two anal plates in the cup; *b*, dorsal view.

Scytalocrinus sansabensis Moore and Plummer 131

10. Hypotype (Peabody Museum 15238), from the Marble Falls limestone, about 11 miles southeast of San Saba, San Saba County, Texas. Anterior view of crown and stem, showing uniserial arms that branch once in each ray.

Endelocrinus grafordensis Moore and Plummer, n.sp. 306

11. Holotype (P–8189), from the Graford formation, west slope of Crawford Mountain, Palo Pinto County, Texas. *a*. Dorsal view, specimen flattened antero-posteriorly; *b*, posterior side of crown, showing typical arm structure; *c*, anterior view of crown.

Endelocrinus texanus (Weller) 310

12. Holotype (Walker Museum 13365), from the Cibolo limestone (Wolfcamp), Lower Permian, Presidio County. Texas. *a*. Posterior view; *b*, dorsal view.

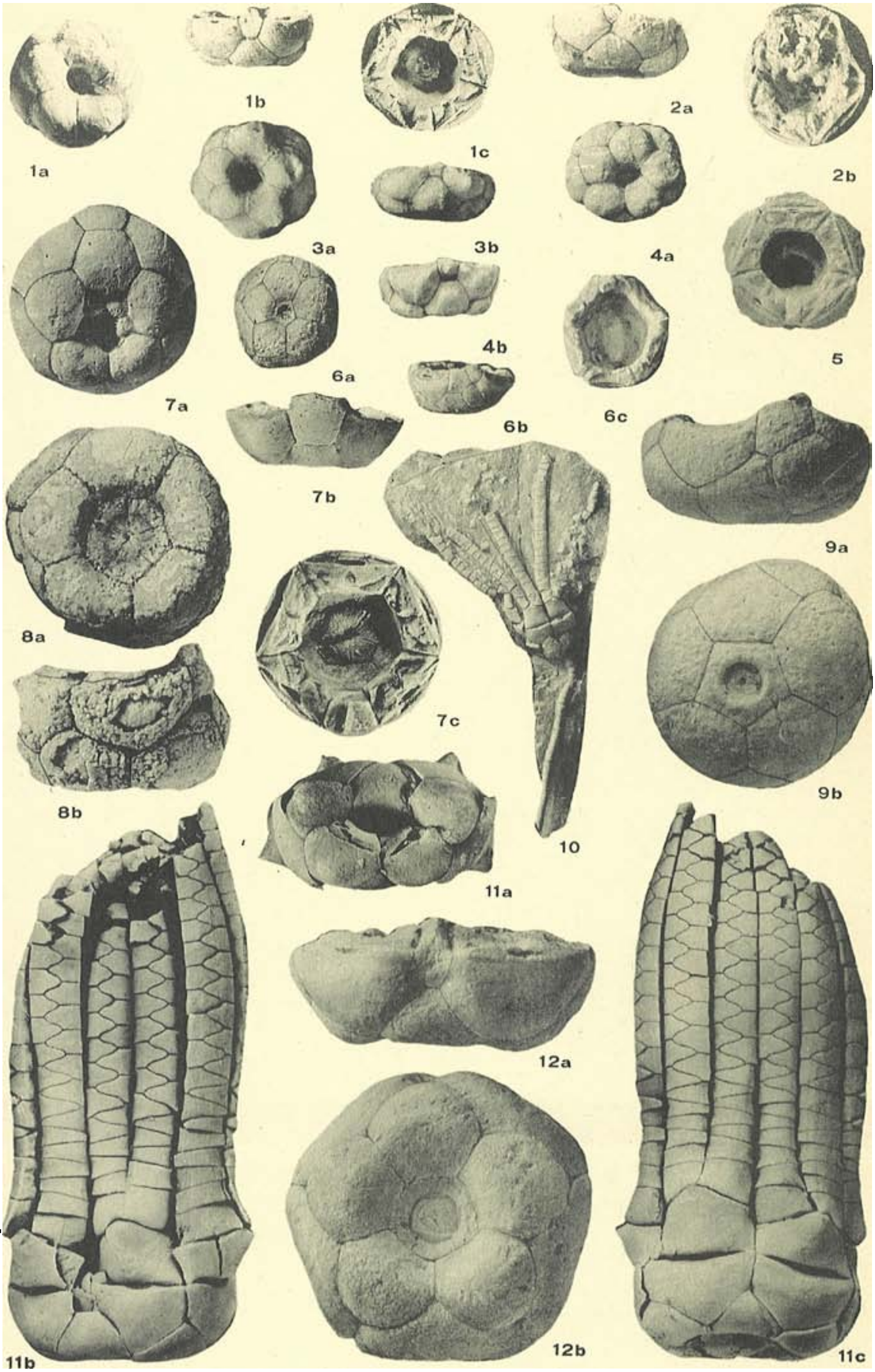
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PLATE 15

(All figures x1.5 except as otherwise indicated)

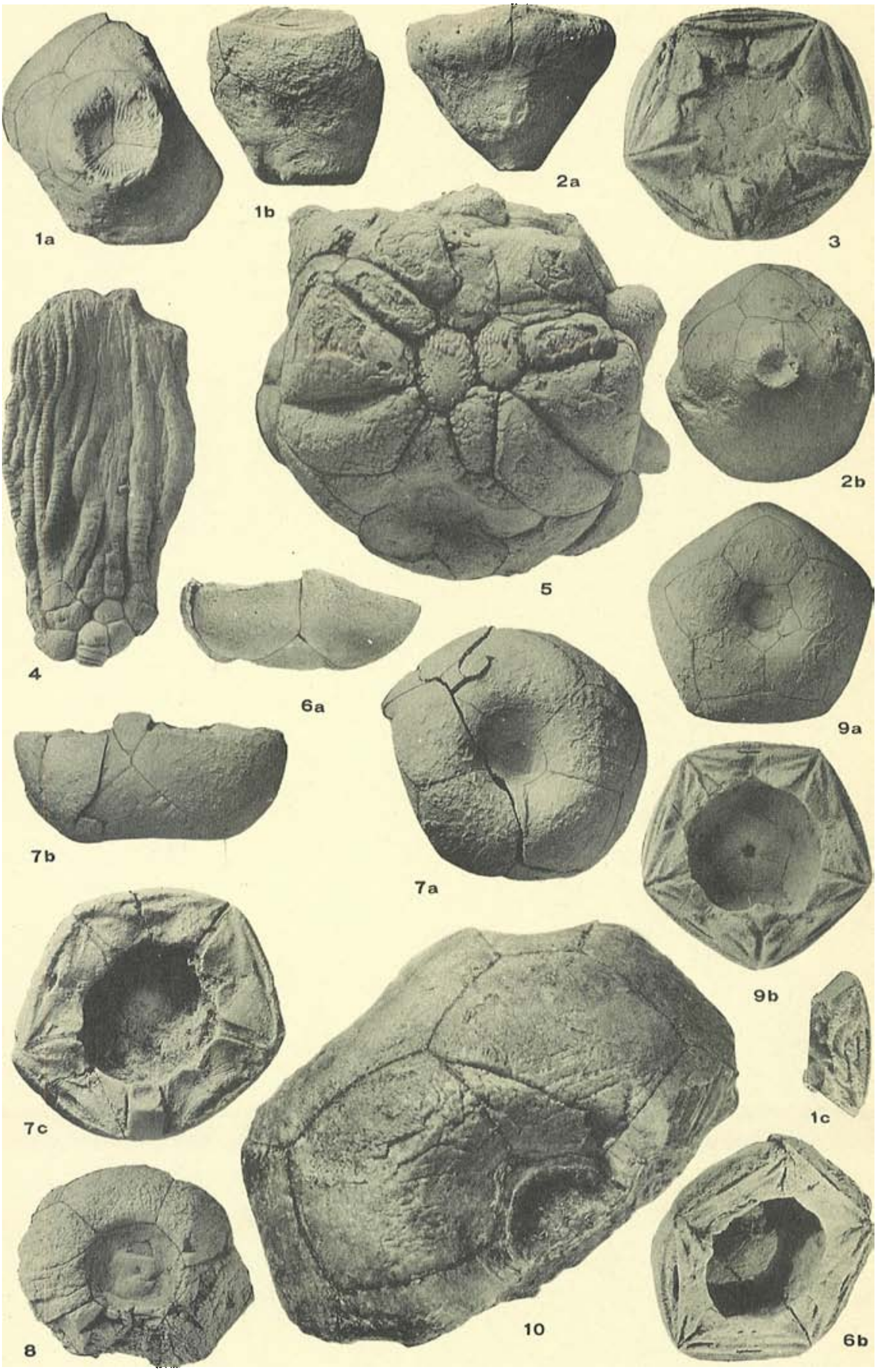
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PLATE 16

(All figures x2 except as otherwise indicated)

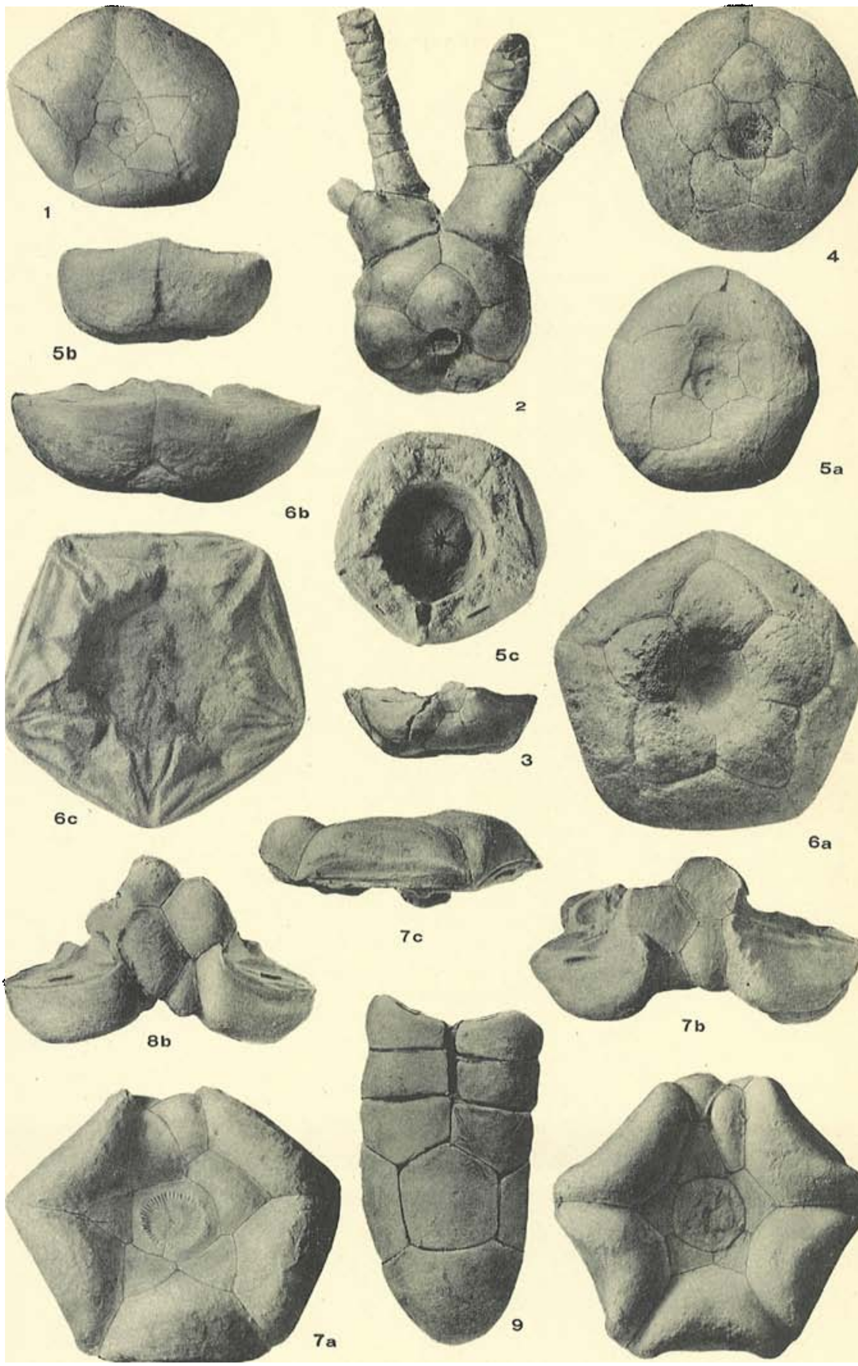
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PLATE 17

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Delocrinus subcoronatus Moore and Plummer, n.sp. 280

1. Holotype (P–1950), from the Mineral Wells shale, about one-quarter of a mile north-northwest of Union Hill School, Palo Pinto County, Texas. *a*, Dorsal view, showing deep, narrow basal concavity and roughened surface, x1.5; *b*, posterior view, x1.5; *c*, ventral view of a part of the cup, showing an articular facet, x3.

Zeacrinites? sellardsi Moore and Plummer, n.sp. 245

2. Holotype (P–10876), from the Graford formation, on northwest side of Kyle Mouutain, Palo Pinto County, Texas. Dorsal view, showing basal concavity and petaloid outline of basal plates, x3.

Paradelocrinus brachiatus Moore and Plummer, n.sp. 318

3. Holotype (P–8196), from shale below the Kickapoo Falls limestone member of the Millsap Lake formation, below Kickapoo Falls, southwest of Dennis, Hood County, Texas. *a*, Dorsal view, showing distorted outline due to crushing and lower circlets of cup pushed inward, x1; *b*, side view of crown, showing long biserial arms, x1; *c*, another side view, showing dorsal cup and primibrach plates, x1.

Parulocrinus marquisi Moore and Plummer, n.sp. 374

4. Holotype (P–8188), from undetermined horizon, probably Canyon group, Pennsylvanian, on Llano River above Mason, Mason County, Texas. *a*, Posterior side of complete crown, showing the carinate brachial plates of the biserial arms, x1; *b*, anterior view, showing clearly the corrugated margins of the plates of the cup and the faint decoration of the basal and radial plates, x1.

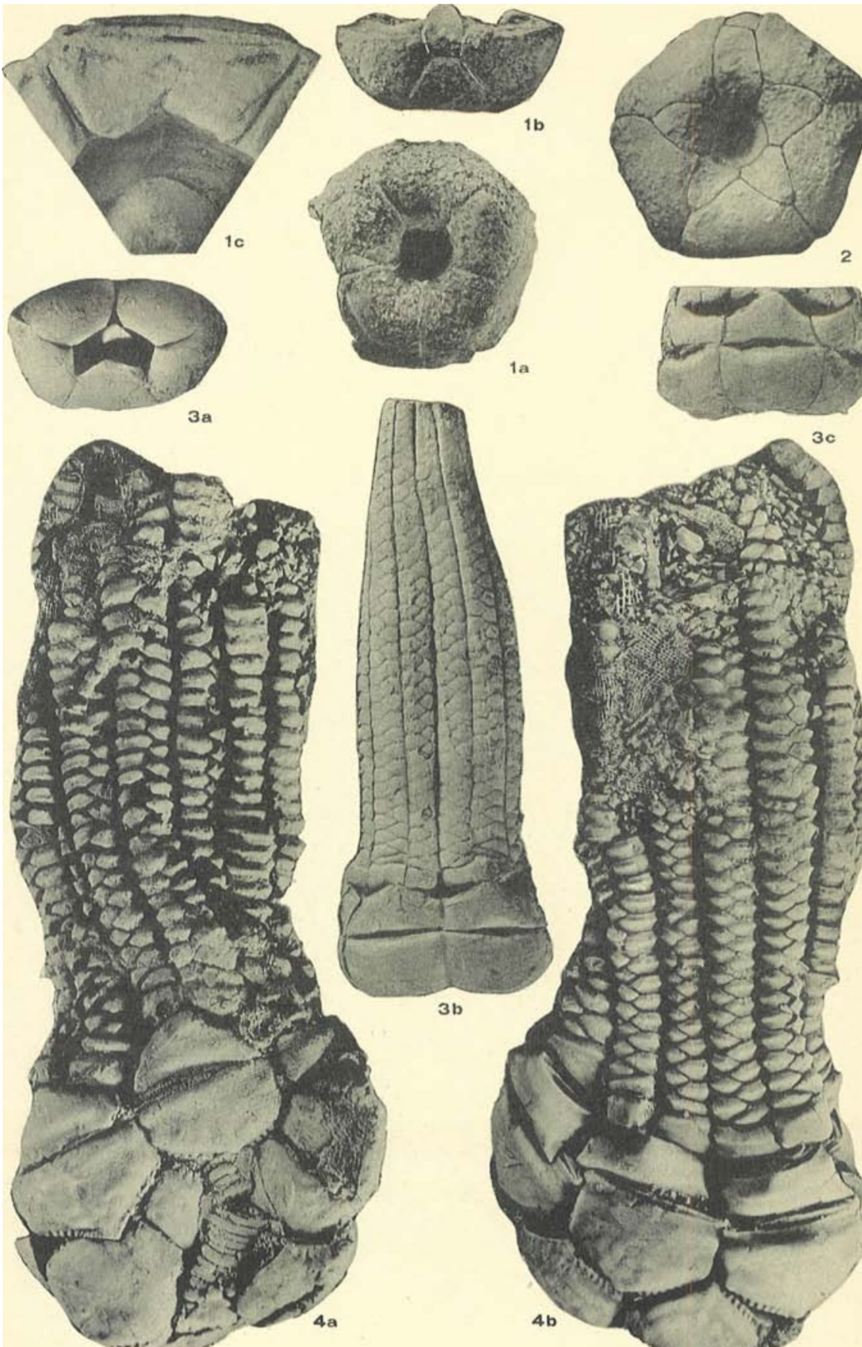
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PLATE 18

(All figures x1.5)

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Delocrinus vulgatus Moore and Plummer, n.sp. 286

1. Holotype (P–10325), from the Saddle Creek limestone member of the Harpersville formation, upper Pennsylvanian, Young County, Texas. *a*, Dorsal view; *b*, posterior view; *c*, ventral view.
2. Paratype (K.U. 4584), from the Harpersville formation, 4 miles east and 0.5 mile north of Newcastle, Young County, Texas. Dorsal view of a typical specimen.

Delocrinus abruptus Moore and Plummer, n.sp. 289

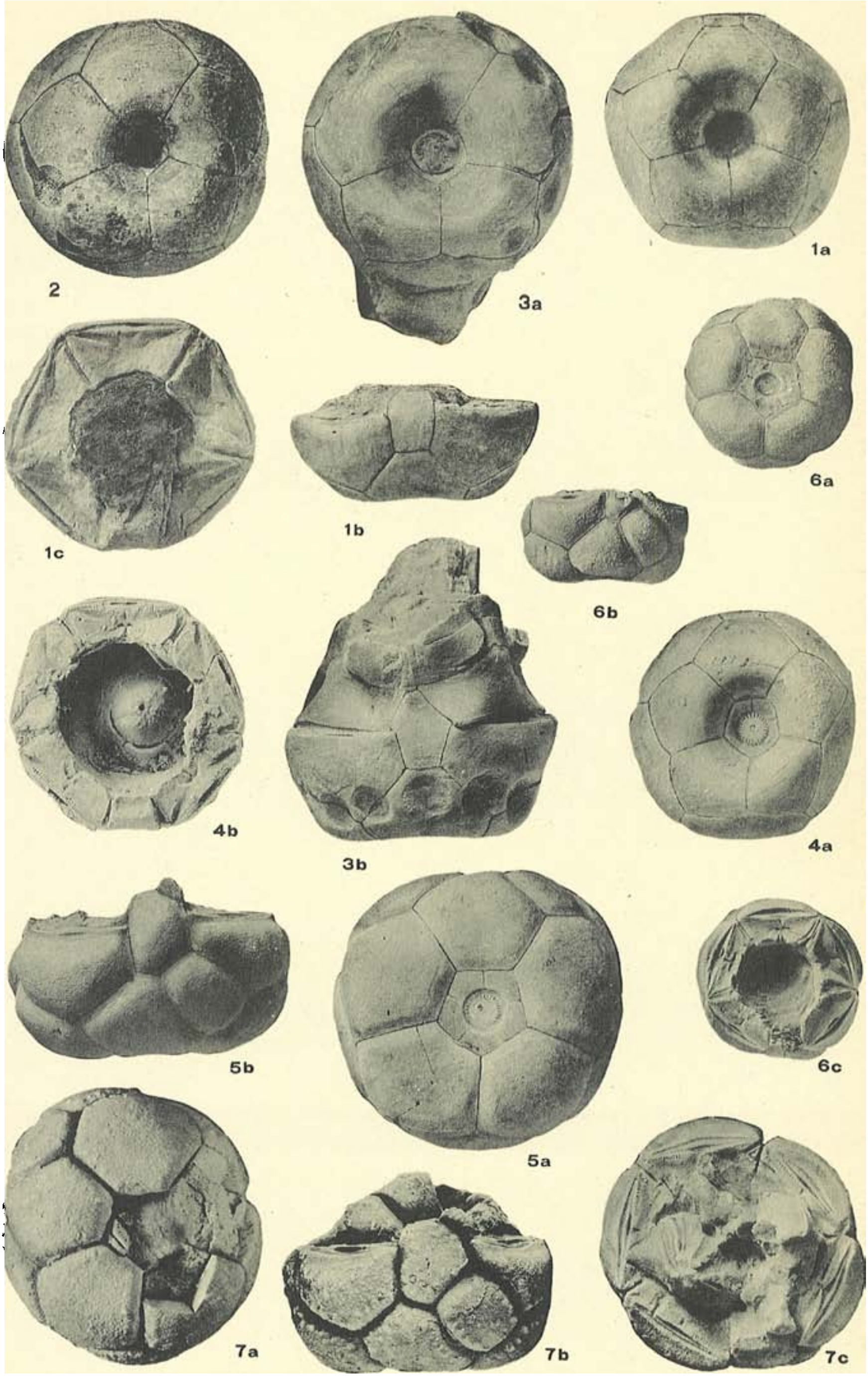
3. Holotype (K.U. 45871), from the Florena shale member of the Beattie limestone, Lower Permian, Grand Summit, Cowley County, Kansas. *a*, Dorsal view; *b*, posterior view, showing several pits that were probably formed by a boring gastropod.
4. Paratype (P–1581), from the Moran formation, Lower Permian, 1 mile northwest of Pueblo, Callahan County, Texas. *a*, Dorsal view; *b*, ventral view.

Parulocrinus compactus Moore and Plummer, n.sp. 369

5. Holotype (P–7885), from the Brad formation, 1.3 miles east of Pickwick, Palo Pinto County, Texas. *a*, Dorsal view, showing the nearly smooth appearance of the plates and the furrows along the sutures; *b*, posterior view.
6. Paratype (K.U. 60281), from the same horizon and locality. *a*, Dorsal view of an immature specimen; *b*, posterior view, showing the fine granulose ornamentation; *c*, ventral view.

Parulocrinus pustulosus Moore and Plummer, n.sp. 372

7. Holotype (K–424), from upper Mineral Wells shale, near Brownwood, Brown County, Texas. *a*, Dorsal view: *b*, posterior view, showing the row of low nodes near margins of the plates; *c*, ventral view.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Schistocrinus parvus Moore and Plummer, n.sp. 226

1. Holotype (M–6), from the Brannon Bridge limestone, Millsap Lake formation, southwest of Brock, Texas. *a*. View of crown from the posterior side, showing the reduced size of the basal plates and indicating arm structure clearly, x2; *b*. view from the anterior side, showing the girdle of projecting spines at the summit of the anal sac, x2.

Apollocrinus geometricus Moore and Plummer, n.sp. 104

2. Holotype (K.U. 45471), from the top of the Iola limestone, Kansas City group, Missouri series, at Iola, Kansas. *a*, Dorsal view, showing the prominent ridges that extend across suture lines between the basal and radial plates, x2; *b*, posterior view, indicating the steep outward inclination of the radial facets, only one of the three plates belonging to the anal series in the cup present, x2; *c*. ventral view, showing notches at summit of interradial sutures where the outer surface projects upward and inward around the edges of the facets, x2.

Pachylocrinus ogarai Moore and Plummer, n.sp. 140

3. Holotype (P–10752), from the Graford formation, Canyon group, on Kyle Mountain, Palo Pinto County, Texas. Enlargement of the right posterior radial and adjacent plates to show the surface ornamentation and the depressions along the sutures.

Erisocrinus typus Meek and Worthen 152

4. Hypotype (P–4938), from the Palo Pinto limestone, 3½ miles north of Strawn, Palo Pinto County, Texas. Side view, x2.

Paraulocrinus blairi (Miller and Gurley) 361

5. Holotype (Walker Mus. 6468), from beds of the Missouri series near McClellan Springs, Cass County, Missouri. *a*, Posterior view, showing two anal plates in the cup and indicating the flat base of the cup; *b*, dorsal view, x1.

Ulocrinus americanus (Weller) 338

6. Holotype (Walker Mus. 13369), from the Cibolo limestone (Wolfcamp), Lower Permian, near Shafter, Presidio County, Texas. Dorsal view, x1.

Apollocrinus florealis Moore and Plummer, n.sp. 106

7. Holotype (M–1), from the Brannon Bridge limestone, Millsap Lake formation, near Brock, Parker County, Texas. Dorsal cup and parts of the two rays, showing biserial structure of the arms, their wide isotomous branching, and very stout pinnules, x2. This unique specimen is the only representative of the genus yet discovered showing character of the arms.

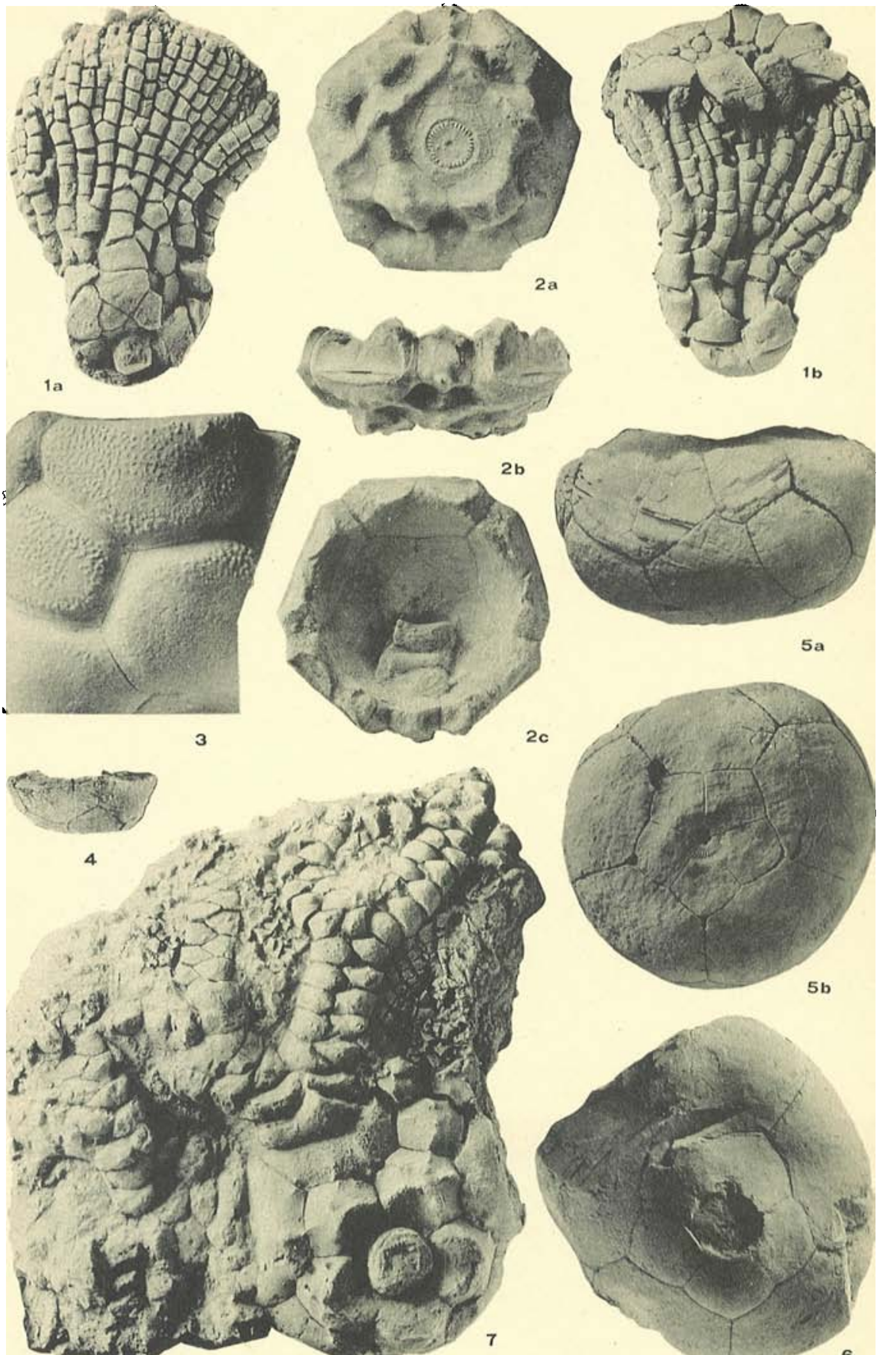
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PLATE 20

(All figures x1.5)

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Sellardsicrinus marrsae Moore and Plummer, n.sp. ... 358

1. Paratype (M–22), from the Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. Specimen showing the biserial arms that branch isotomously three times; dorsal cup lacking.
2. Holotype (M–23), from same horizon and locality. One side of the crown.

Delocrinus subhemisphericus Moore and Plummer, n.sp. ... 258

3. Paratype (K.U. 45441), from the Lane shale, Missouri series, at Kansas City, Missouri. *a*, Posterior view, showing low truncate bowl shape of the cup; *b*, ventral view.

Paradelocrinus obovatus Moore and Plummer, n.sp. ... 326

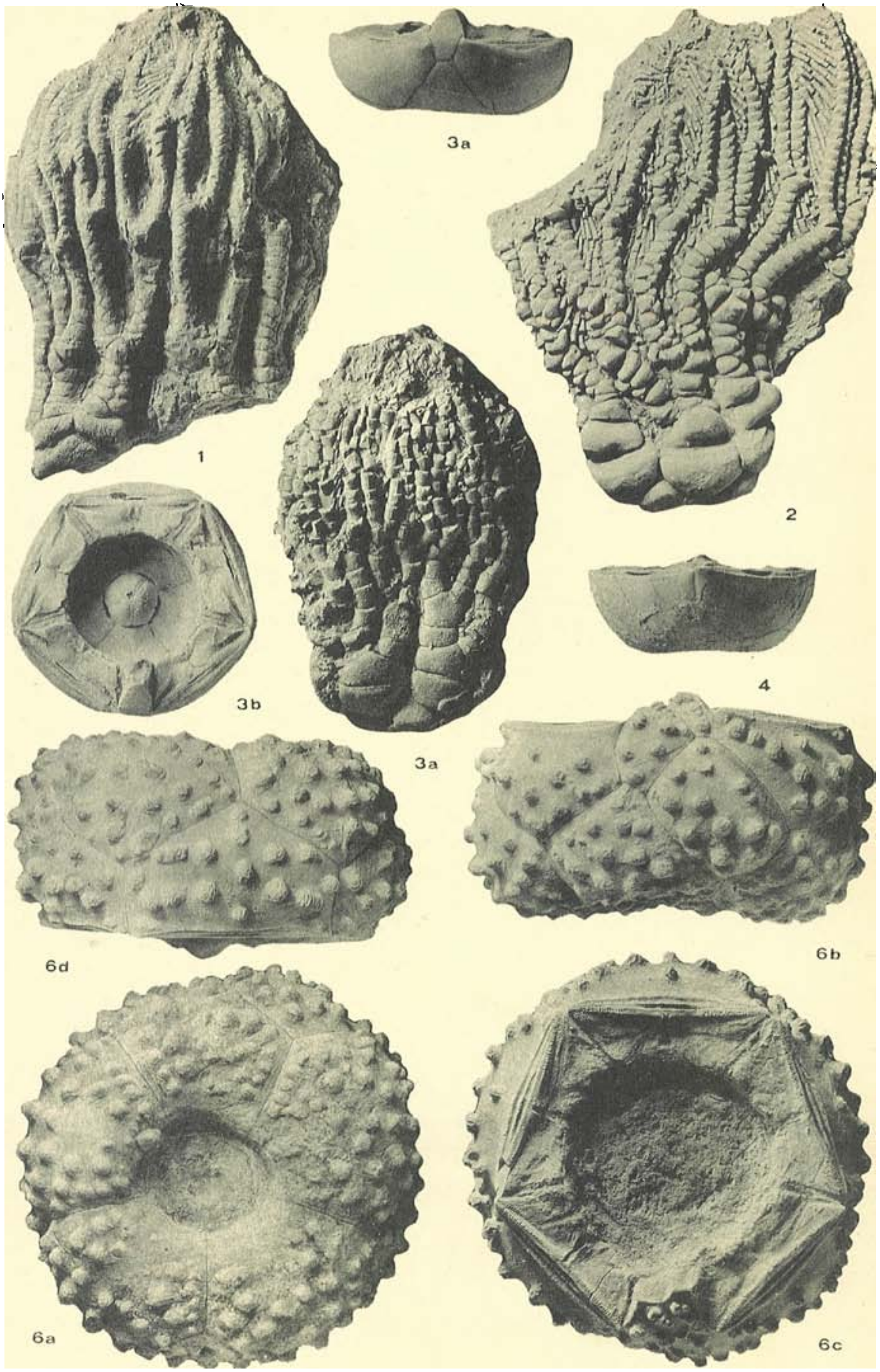
4. Holotype (P–10737), from the Graford formation, on the northwest side of Kyle Mountain, Palo Pinto County, Texas. Side view.

Neozeacrinus praecursor Moore and Plummer, n.sp. ... 165

5. Paratype (M–24), from the Brannon Bridge limestone member of the Millsap Lake formation, 3 miles southwest of Brock, Parker County, Texas. View of a somewhat flattened crown, a little smaller than average size.

Ethelocrinus texasensis Moore and Plummer, n.sp. ... 379

6. Holotype (P–11182), from the lower Marble Falls limestone, about 13 miles southwest of San Saba, San Saba County, Texas. This species is assigned to *Ethelocrinus*, characterized by presence of only two anal plates in the dorsal cup, even though the holotype and one of the paratypes show three anal plates in the cup, which indicates reference to *Eupachycrinus*; other paratypes have only two anal plates in the cup. The species is on the border line between these two genera, which because of stability of characters in practically all cases are considered valid genera. *a*, Dorsal view; *b*, posterior view; *c*, ventral view; *d*, anterior view.



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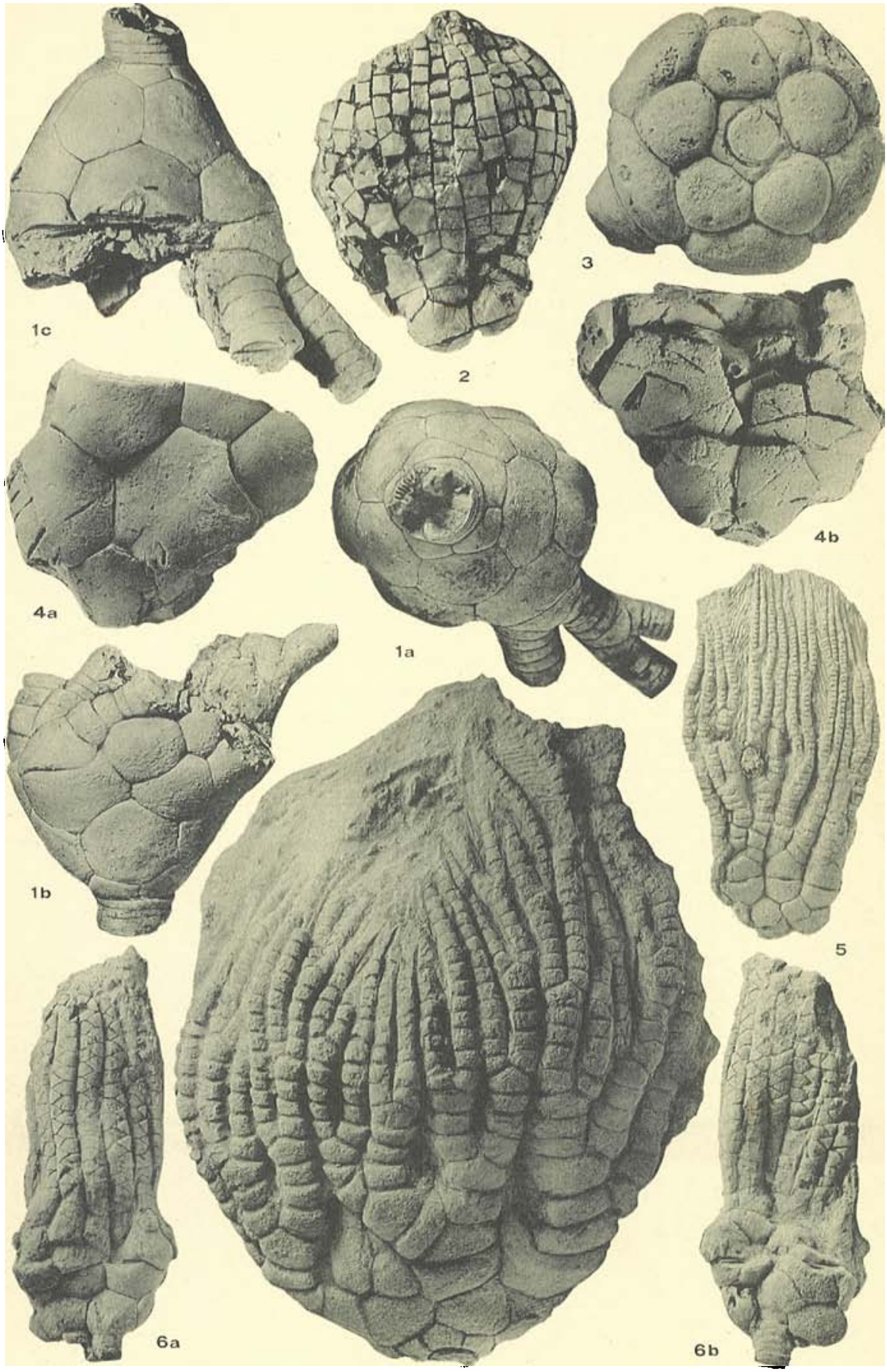
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Part I

Figures in boldface type refer to pages where genera and species are described.

CONTRIBUTIONS TO GEOLOGY, 1939

Part 2

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Part 2

ILLUSTRATIONS

Part 2

CONTRIBUTIONS TO GEOLOGY, 1939

Part 2

NORTH AMERICAN TEKTITES

Virgil E. Barnes

INTRODUCTION

During April, 1936, several curiously shaped black glass objects from Grimes County, Texas, were brought to the attention of the personnel of the Bureau of Economic Geology. Dr. H. B. Stenzel recognized them as being tektites. This is the first time, so far as can be found by scanning the literature, that tektites have been found in North America.[1]

Sporadic glasses from other places have been named after the locality in which they were found. The word "tektite," originated by Suess (194)[2] in 1900, is a group name used to cover the three known occurrences at that time. He states: "Als gemeinschaftlichen Namen für die ganze Gruppe habe ich nach der Eigenschaft der Körper, welche im Gegensatze zu den übrigen Meteoriten ganzlich durchgeschmolzene Massen sind, die Bezeichnung 'Tektite' gewählt. (τήχειν, Schmelzen von Metallen und anderen harten Massen; τηχτος, geschmolzen.)" It is desirable that the Grimes County tektites receive a name suggestive of their locale; therefore, the word "bediasite" is suggested. Bedias is a place name common in Grimes County, Texas, traceable to the Bedias Indians who formerly lived there.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. H. B. Stenzel for the original identification of this glass and for help in reading some of the foreign literature; to Mr. F. A. Gonyer for the additional work and time that he has given to this problem over and above that necessary for the routine analyses; and to The University of Texas Committee on Research Grants and Publications, Dr. J. T.

---

[1]La Paz (110a)[2] states: "Tektites are exhibited occasionally in placer mining camps in the United States. However, it is the author's experience that persistent questioning disclosed always that such specimens came originally from the tektite-sprinkled gold fields of Australia."

[2]Numbers in the text in parentheses, as (116a, 194), refer to entries under corresponding numbers in the bibliography.

Issued June, 1940.

Patterson, Chairman, for a grant to cover the cost of two analyses. He also wishes to express his appreciation to the people of the Grimes County area for their hospitality and their help in making the tektite collection which is the basis for this paper. The ink sketches are the work of Jack Graves, and the photography is mostly by Gale White. To these men the writer wishes to express his appreciation.

HISTORY OF TEKTITES

Tektites have been found in many parts of the world. The first ones of which there is a record are the moldavites, so called after the river Moldau, in Bohemia. These objects have also been known as bouteillenstein (bottlestone) and pseudochrysolite because of their fine green color. Billitonites are named after the island of Billiton, where they are found in tin-bearing gravels. This name also applies to tektites found in Borneo, Java, and other islands in this vicinity. Recently the name indochinite has been suggested for the tektites found in the Malay Federated States, French Indo-China, and adjoining parts of China. Koenigswald (102) states that the tektites of Solo, Java, are intermediate in character between the deeply etched ones of Billiton and the slightly etched ones of Indo-China. Tektites from the Philippines were described in 1930. Australites have been known since 1851 and are very widely distributed over the southern half of Australia. Walcott (225) suggested the name "obsidianites" for these objects, but this usage has now been largely abandoned. A local group of tektites from Tasmania has been named Darwin glass or queenstownite. Glasses found in Colombia and Peru, known as americanites, are still under question. They may be tektites. Lacroix (113) in 1935 described tektites from the Ivory Coast in Africa. The presence of tektites in North America, recorded here for the first time, makes them of world-wide distribution. They are now recorded from every continent, with the possible exception of South America.

Moldavites

The first recorded use of moldavites by man is that discovered by Dr. J. Bayer (Suess, 194) in loess of the paleolithic station of Willensdorf near Spitz on the Donau. He found, together with other worked stone flakes, three small worked flakes, which were identified by Professor Berwerth as moldavites. This culture is about 25,000 years old. Oswald (142) apparently makes reference to this same find in his statement: "Cave dwellers of paleolithic time used them for their implements."

The first printed word regarding moldavites is probably that of Joseph Mayer (129) written in 1787, more than a century and a half ago. He states: "In the vicinity of Thein on the Moldau, or Moldauthein, particularly handsome pieces of a green glassy mass are found which equal in hardness other garnets, are very pure and translucent, particularly have a beautiful dark green color, and are being sold as chrysoliths. I have not seen them in any other form than as amorphous, and as round pebbles and boulders; and to this day one finds them only in these forms in scattered pieces on the fields and in gullies excavated by the rain. The size of the pieces surpasses very often that of a dove's egg, and pieces have been found from which walking stick knobs have been cut which are one inch thick and up to two inches long." Mayer speaks of them as "supposed chrysolith" and classifies them as a glassy species of lava.

Johann Thaddaeus Lindaker (122) in 1792 noted the half moon-shaped grooves which he thought to be caused by percussion with the dropping out of small pieces along conchoidal fractures. He thought they might be of volcanic origin, or produced by burning coal, or of an artificial origin from a smelter or glass factory.

Klaproth (101) in 1816 made the first chemical analysis and decided "Thev belong neither to the chrysolith nor are they artificial glass." He named them pseudochrysolith.

August Breithaupt (21) in 1823 called them bouteillenstein and classified them with gemmy glassy obsidian. The cut stones of that time were known commercially as water chrysolith. He noted the delicate wavy play of light in the interior of the pieces (fluidal structure) and used this as a distinction from true chrysolith.

O. L. Erdmann (60) in 1832 emphasized that splinters can be melted only with difficulty to a colorless glass.

F. X. Zippe (241, 242) in 1836 (published 1840) first used the name moldavite and spoke of the material as being obsidian or empyrodoxic quartz. He states: "This mineral is found in flat, often extended, large grains and tuberous shapes, similar to those of amber, with a peculiar shriveled and rilled surface. The color is dark olive-green, occasionally verging into blackish green; on the outside they are nearly matt; on the inside on the excellent conchoidal fractures, which have a strong glassy lustre, they are translucent with wavy lines as in impure glass. This interesting variety of pyrodoxic quartz is distinguished through its color and high grade of translucency from the obsidians found in volcanic regions; also the shapes and surfaces have something peculiar about them, although similar pieces only with less flat shapes are found in Hungary, and pieces with similar surfaces are found in Mexico. Before the blowpipe this variety melts with difficulty and without foaming. The original rock from which the pieces are derived is not known. However, they are not boulders. They are found in the sands and soil of Moldauthein and Budweis."

Dr. Franz Dvorsky (53), a high school professor in Trebitsch, in 1878 found the first moldavites of Trebitsch in Moravia.

A. Makowsky (124, 125), in 1881 and 1882 stated the following distinctions between moldavites and common obsidian: The moldavites have a bottle-green color; they have no microscopic crystal inclusions; they are present as scattered large and small pebbles; they fuse quietly, although with difficulty, to a clear glass before the blowpipe; the surface is iridescent after continued glowing; and they occur in regions completely free of volcanic formations. He favors an artificial origin and compares them to the glass tears on artificially made glass plants.

A. Wenzliczke (231) in 1880 and J. Haberman (74) in 1881 emphasized that the moldavites of Trebitsch could not be artificial glass because the chemical analysis shows a high percentage of silica, alumina, and iron oxide in proportion to the percentage of alkalies, which has never been known in an artificial glass.

F. Dvorsky (53, 54) in 1883 defended the natural origin of moldavites. He pointed out that in the vicinity of the moldavites the well-known many-colored slags of old glass plants are absent and that moldavites are unknown in the vicinity of old well-known glass plants of that region. He emphasizes that moldavites are always found in quartz gravels having a thickness of 2 to 5 meters, which lie on the hilly plateaus at a height of 50 to 100 meters above the present flood plain of the river but are never found on the flood plain itself. The gravels belong to an ancient river system and were formed, without doubt, at a time when there was no glass industry.

A description of a moldavite locality near Trebitsch made by F. Dvorsky in 1883 and 1899 will be given in order to emphasize the character of these deposits.

> The small hill Malakrohota north of Kozichovitz to the east of Trebitsch is 451 meters in altitude. On its top there is a well-defined cap of fifteen hectar area. The gravel is so numerous that outcrops are poor. It consists chiefly of quartz, often of fist size, mostly, however, smaller; and of other hard minerals such as smoky quartz, clear quartz, and tourmaline, in well-rounded pieces. These minerals are derived from veins of the surrounding basement rocks.

At another place Dvorsky found a silicified fresh-water limestone with snail shells overlying the quartz gravels which contain the moldavites.

Frank Rutley (155) in 1885 compared the moldavites with fulgurites from Mont Blanc, Switzerland.

J. N. Woldrich (235, 236) in 1886 and 1888 reported the finding of three moldavites at Radomilitz near Budweis under a 50-centimeter thick loamy, humus, rich field-soil cover and in a 50-centimeter thick layer of brown-yellow, locally conglomeratic gravel which was lying on Tertiary sands of the upper brown coal formation. According to him, the gravels are Pleistocene or Tertiary in age.

Stelzner (187) in 1893 recognized the relationship between australites and moldavites. He states that the surfaces of several moldavites have a number of small circular grooves and largely ellipsoidal furrows and that some pieces have schlieren-like surface sculpture, which is very similar to the Australian material investigated by him. He states that the surface features of both kinds of tektites agree only in a matter of form. Stelzner concludes that because the moldavites are found in gravels they must have been transported by running water for long distances. Therefore, they could not have the fine ribs, edges, and other sculpture which they would have had before their transportation. Therefore, the surface sculpture must be due to corrosive processes of chemical or mechanical nature. This appears to be the first correct interpretation of the surface sculpture. Stelzner considers the grooves of australites to be of similar origin to the grooves of meteorites.

A. Rzehak (156) in 1897 defended the artificial origin of moldavites. He alleged that the melting points of some glass specimens change considerably in the course of time.

F. Dvorsky (54) 1899, is apparently the first writer to figure moldavites.

F. E. Suess (192, 193, 194) in 1898, following the thoughts of other workers on billitonites and australites, proposed the meteoritic origin for moldavites. He gave a very long discussion in his 1900 work on the surface features of moldavites and how such features could be formed by flight through the atmosphere.

In 1898 A. Rzehak (157) stated that if moldavites are meteoritic in origin they should be more common. He also points out that on

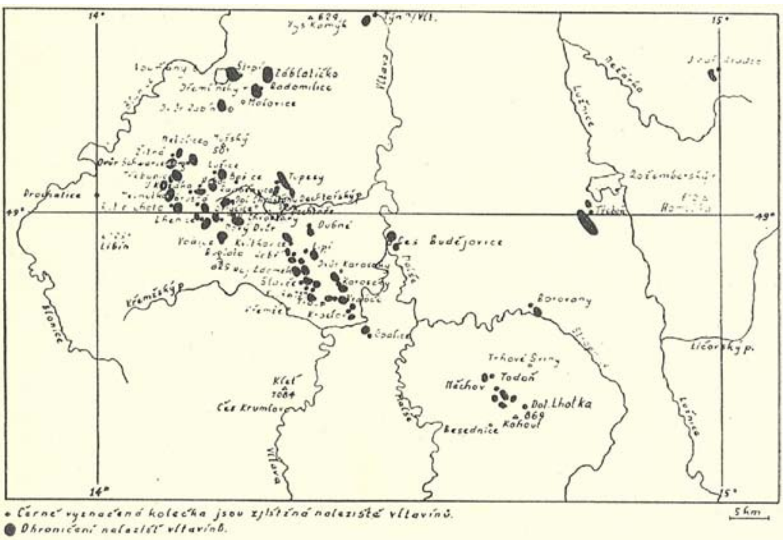

Fig. 79. Map showing exact localities of tektites in Bohemia (Oswald, 141).

old glass objects the same surface sculpture is found, which differs from that of the moldavites only in degree. He doubts their meteoritic origin.

After Suess's monographic work of 1900, the tektite problem assumed more of a world-wide character, and most papers thereafter incorporated material relating to all tektite occurrences. Other postulated origins will be mentioned in this paper in the sections on australites, billitonites, indochinites, and other occurrences. In 1914 Suess (197) brought the tektite question up to date, and in both his publications of 1900 and 1914 gives a complete bibliography. The meteoritic origin of tektites became popular in the late

1890's and has held sway until the present time with minor suggested origins springing up along the way but easily shown not to be applicable. The most serious challenge to the extraterrestrial origin, until the present, is that of Spencer's (179, 180, 182, 183, 184, 186) splash theory in which he postulates the formation and splashing outward of glass by meteorite impact. He substantiates this theory by glass found about large meteorite craters such as those of Henbury, Australia, and Wabar, Arabia. Suess (200, 201, 202) again from 1932 to 1935 reiterates and stands by the meteoritic

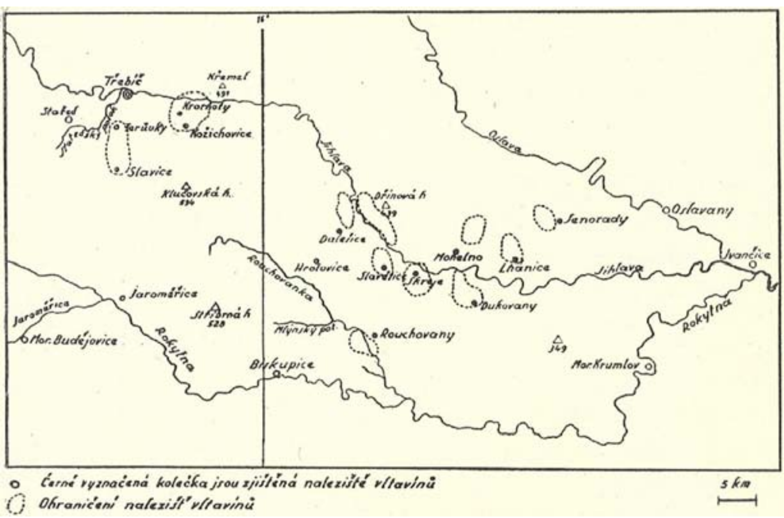

Fig. 80. Map showing exact localities of tektites in Moravia (Oswald, 141).

theory but weakens to the extent of excluding Darwin glass from the tektite glasses.

Janoschek (93) has determined that the moldavites are of Helvetien (middle Miocene) age.

In a translated article of Oswald's (142) there is the following statement: "Nowadays, there is no question as to the origin of tektites—most specialists in the subject being convinced that they are of meteoritic origin. The dispute concerns only the surface of the tektites." This is undoubtedly a misstatement but in general indicates the confusion of thought on the subject as it stands today. Oswald (141) has shown the distribution of moldavites in Moravia and in Bohemia. His maps are reproduced in this paper as figures

79 and 80. The distribution is definitely related to certain drainages and divide areas, as can be seen on these figures. Figures 1 to 5 of Plate 22 are protographs of moldavites.

The Moravian and Bohemian tektites, according to Oswald (141), are somewhat different. The ones from Moravia are in general larger and darker colored. The largest Moravian tektite weighs 235 grams, whereas the largest Bohemian tektite weighs 87.5 grams. The Moravian tektites have a fatty-glassy lustre, and the Bohemian ones have more the appearance of being lacquered. The Moravian tektites are simpler in form, being mostly spherical, rotation-ellipsoidal, or flattened-ellipsoidal in shape, and are without deep surface sculpture. The Bohemian tektites, on the other hand, have a very large range in shape and have a highly varied sculpture.

Australites

Walcott (225) in 1898 gave an excellent review of the australites. He mentions that Charles Darwin (39, 40) is probably the first to report them and that he assumed they were a type of volcanic bomb. Clarke (32) mentions the finding of other specimens in gold washers. The descriptive catalogue of the rock specimens and minerals in the National Museum, 1868, mentions an unusual obsidian ball. This ball had a specific gravity of 1.06. It was cut and found to be hollow, with the cavity having a beautiful polish. Tate (205) suggests that the australites may have been distributed by the aborigines. Streich (190) and Stelzner (187) believed them to be of volcanic origin. Stelzner states: "Again, others are of the opinion that the problem can only be solved if one ascribes to the so-called obsidian bombs a cosmic origin, in spite of the fact that they have characters entirely different from those of other known aerolites." He explained the rim through air resistance, and he compares the shapes with those of bullets shot into sand. Considerable argument as to whether the australites are basic or acid in character is settled by Walcott by the analyses available to him and by their behavior when heated. He states: "Tested for fusibility, the edges and corners of the fragments become rounded, and in thin splinters a light-coloured glass was obtained, whereas basic glasses fuse readily to a dark opaque glass." Walcott also points out the presence of flow structure and the presence of strain shown by a slight anisotropism between crossed nicols. Walcott discusses and discards the igneous origin of the australites. He believes that they are of meteoritic origin, that they were derived from comparatively large bodies, and that the shaping took place in the earth's atmosphere. He also believes that they did not all fall at the same time.

In 1908 and again in 1912 Dunn (48, 50) postulated the origin of australites to be volcanic. He believed that they are blebs of bubbles blown in the throats of volcanoes and that they were carried great distances by air currents. Dunn is probably the first to depict flow structure by photographs of sections between crossed nicols. One of his sections is reproduced in this paper as Plate 26, figure 6. He contends that the rim material flowed down the sides of the bubbles and accumulated around the central core. As can be seen by a careful study of these sections, the flow structure does not fit such a postulate. Dunn also questions whether some tektites could not have been formed by lightning fusing dust in the air.

Summers (204) has shown the bubble hypothesis of Dunn (48) to be impossible. He also points out that Merrill (130) must not have been familiar with australites; otherwise he would not have postulated that all tektites are rolled obsidian pebbles. Gregory's (73) hypothesis of aerial fulgurites caused by lightning fusing dust in the air is also shown to be untenable. Summers made a careful study of the analyses of australites and concluded that an artificial origin is impossible. He also points out that no igneous rocks of the correct composition are known in the area. Another point which he brings out is that the tektites of Australia have a provincial distribution by chemical composition.

Fenner (64, 65, 65e) has recently examined many of the australite collections in Australia. He has given much information on the numbers, distribution, forms, and classification of australites. Fenner records 7353 pieces in museums and 4593 in private collections, totaling 11,946 pieces. He estimates that at least as many more are in unrecorded collections. These australites have been found throughout an area estimated to be 2,000,000 square miles in extent. Fenner's map showing the distribution is reproduced here as figure 81 and gives a complete picture of the enormous area covered by these distinctive objects. Australites have been found in the alluvial gold-mining areas of Victoria and New South Wales, in the alluvial tin-mining areas of Tasmania, and on the surface elsewhere. Fenner has classified the australites into seven groups based on shape, namely, buttons (Pl. 26, fig. 6), lenses, ovals, boats, canoes, dumb-bells, and teardrops. Subdivisions of the classification are based on degree of preservation, presence and distribution of bubble cavities, surface sculpture or design, and size as expressed by some dimension. Fenner states: "Flanges and rims are among the most characteristic features of australites, and in well-developed forms they are very regular and beautiful." They are pitch-black by reflected

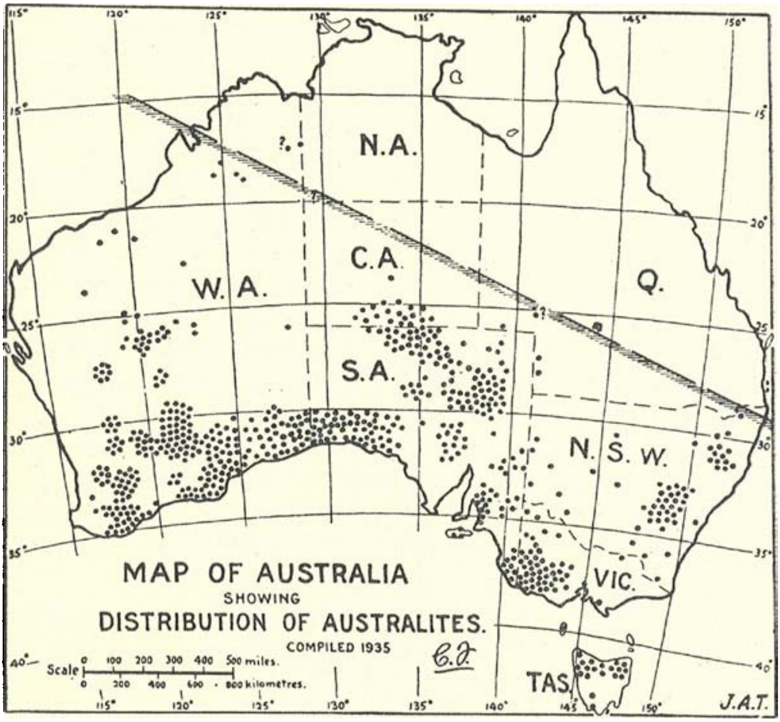

Fig. 81. Map showing distribution of australites (Fenner, 65).

light and amber-brown to bronze-green by transmitted light. The australites range in weight from 0.15 grams to 218 grams and average 0.934 grams in weight. Fenner gives a resumé of the theories of the origin of tektites, and of particular interest is his statement about the aboriginal legends and use of australites, which is as follows: "The first theorist on australites was not Charles Darwin; for the aborigines of the interior of Australia (Dieri and adjacent tribes) knew them by the names *ooga* and *muramura*, with accompanying legends concerning these 'staring eyes' and 'emu's eyes.' This might be taken as constituting stone-age man's theory of their origin. These objects would appear to have been known to the aborigines throughout Australia south of the line shown on figure 3 [fig. 81 of present paper], and to have been treasured as objects of mystery and magic, particularly for their use in the arts of healing and of rain-making."

Darwin Glass

Darwin glass, found in the Jukes-Darwin mining field of Tasmania, has been well described by David, Summers, and Ampt (41). This glass is distinct from the australites found on the same island and from all other tektites. The first description of this glass is by Suess (197). Hills (84) in the following year reviewed their occurrence. The glass is found associated with quartzite rubble and in many places underlies 9 to 18 inches of peat formed in post-glacial times. No glass has been found in the peat. Another interesting fact is the alleged absence of Darwin glass above an elevation of 1300 feet on Mount Darwin. This is explained by glacial action carrying and concentrating the material at lower levels. The amount of glass is estimated to range between one-quarter and one-half ounce per square foot of the rock rubble. This is a much greater concentration than is found in other tektite localities, except in Indo-China. Photographs of this material by David, Summers, and Ampt (41) and by Suess (197) could be duplicated from forms seen in most any heap of slaggy cinders. Darwin glass has the highest silica content of all the tektites (Libyan Desert glass excluded), and, consequently, the lowest specific gravity and index of refraction. This glass varies in color from dark smoky green to almost black; some is grayish green, and some very vesicular pieces are almost white. The vesicularity present in this glass is much greater than that in other tektites.

David, Summers, and Ampt used variation diagrams to show the genetic relationship of Darwin glass to other tektites. They also showed in 1927 that all tektite localities fall on a great circle and postulated a swarm of glassy meteorites for the whole. A photograph of Darwin glass by Suess is reproduced in Plate 22, figure 14.

Schonite

Eichstädt (58) and Wahl (223, 224) described a broken piece of glass from Hof Kälna in Starby Parish, province of Kristianstad, southern Sweden. This glass has a dark color and a specific gravity of 2.707, which is much higher than that of any other known tektite. Eichstädt was the first to describe it as "characteristically a meteorite consisting of pure glass." He recognized the varnish-like luster and the shagreen surfaces as being fused surfaces not unlike the confused interlacing fusion crust on the surface of the Stannern meteorite.

The microscopic examination by Wahl confirms this observation. The crust which in thin section presents an appearance of overlapping protuberances is filled with very small bubbles and is bounded sharply from the interior compact glass by a splintered alteration zone likewise filled with bubbles. Wahl states: "No other method for the melted crust can be thought of than that it was produced by the frictional resistance of the air by the flight of a meteorite through it."

No chemical analysis of this material is available, and only one piece of glass has been reported. Consequently the validity of schonite as a tektite must be questioned until more is known about it.

Billitonites and Associated Tektites

According to Mueller (138) the first tektite reported from Borneo was that reported by S. Mueller in 1836 at Pleihari, southeastern Borneo.

The first description and figure of tektites from Billiton are those of P. Van Dijk (218), 1879. He termed this material obsidian of Billiton. Billitonites are found in the old gravels of numerous tin pits in several districts, distributed over a large area. They are scarce at all localities, and the Chinese workmen considered them to be black diamonds. Van Dijk states that there are no volcanic rocks on the island of Billiton.

R. D. M. Verbeek (221, 222) in 1897 was the first to propose an extraterrestrial origin of billitonites. He believed them to be outcasts of moon volcanoes.

P. G. Krause (104, 105) in 1899 described similar glasses from Bunguran in the Natuna Archipelago and, in 1898, apparently was the first to use the furrows on the surface of billitonites as an argument for extraterrestrial origin.

In Java an unusual tektite has been found which is of a bright yellow color.

Koomans (103) notes the difference in amount of etching of the various tektite groups and the exceptionally strong etching of the billitonites. She states: "The billitonites are by far the most strongly etched and it seems to me that the presence of tin-ore, topaz, and tourmaline in Billiton is significant. All these minerals point to pneumatolitic influence, through which fluor is present in the ground and strongly diluted hydrofluoric acid would make the stronger etching of the billitonites clear." Some of the etch forms are remarkable and show a tremendous amount of loss through corrosion. Figures 12 and 13 of Plate 22 are reproductions of photographs of billitonites published by Lacroix (116).

Indochinites

Lacroix (106, 107, 108, 110, 111, 112, 114, 115, 116) has described in several papers the tektites of French Indo-China, the French territory of Kouang-tchéou-wan, and adjacent areas of China. Lacroix's map of the distribution is reproduced as figure 82. This map shows, in addition to the indochinites, the location of other tektites found about the South China Sea. A large number of tektite localities have been found. and, considering the inaccessibility of this area, this seems truly remarkable. They must be very common and probably will be found to be very much more widespread than now indicated.

The tektites of this region are uniformly black, yellow, or brownish in thin splinters. The tektites which are present in Indo-China have perfectly clear-cut forms, such as that of pears, long drops (tears), rods, plaques, spheres, ellipsoids, and discs. Figures 6–10 of Plate 22 are photographs of indochinites kindly furnished by Professor Lacroix, and figure 11 of Plate 22 is a reproduction of one he has already published (111). In some deposits tektites with enormous gas bubbles are in abundance, and in others innumerable microscopic gas bubbles only are present. Microscopic examination does not disclose any trace of crystallization. These tektites are more or less deeply corroded, and all of the usual forms of surface sculpture thus produced are present. According to Lacroix, the flow structure brought out by corrosion is probably better developed here than anywhere else. Lacroix adopts the meteoritic

Fig. 82. Map showing distribution of tektites about the South China Sea (Lacroix, 111).

hypothesis for the formation of these tektites as well as for all of the others in this general area.

Lacroix has also mentioned the type of rock upon which these tektite-bearing alluviums rest. These rocks are of very diverse character, and among those mentioned are granite, dacite, basalt, schist, gneiss, marble, and various sedimentary rocks of Siluro-Devonian and Triassic age. The age of these tektite deposits is thought to be Quaternary.

Patte (144) mentions that the tektites of Hai-nan are known by such names as "pierres de lune" and "excrèments d'étoile." No importance, however, seems to be attached to their occurrence in many localities. In Texas, for instance, the aborigines apparently disregarded them.

Philippine Island Tektites

The Philippine tektites from near Rosario were first mentioned by Selga (171). Beyer (17) during archeological investigations found tektites in the province of Rizal, which he termed rizalites. More than 300 specimens have been collected in this area. Lacroix (109) has described the Philippine tektites, and Koomans (103) has recognized, in addition, glasses which are not tektites, which are termed pseudo-tektites and pseudo-americanites.

The Philippine tektites are essentially the same as the rest of the tektites found about the South China Sea.

Malay Federated States Tektites

Damour (38) described an obsidian in 1844 which exploded while being cut. Lacroix has since established that this is in reality a tektite. Scrivenor (167, 168, 169, 170) lists the localities from which tektites are known in the Malay Federated States and described some of the occurrences. He also states that no tektite has yet been found containing partially fused rock or sand. He states that J. C. Shenton has found the presence of nickel in three Malayan tektites and concludes that Spencer's (179) meteoritic splash theory is probably the most likely for the origin of tektites. These tektites are very similar to others of this region already mentioned.

Ivory Coast Tektites

Lacroix's (113) description of Ivory Coast tektites is the most recent record, until the present, of a tektite find. The importance of this find lies chiefly in correcting a misconception based on the idea that all tektites are located on one great circle around the earth, as postulated by David, Summers, and Ampt (41). This postulate was used as additional evidence that tektites are meteorites. This find is about 40 degrees from the postulated great circle.

These tektites are very similar to those of Billiton both in sculpture and color. One having a deficiency of density was struck with a hammer. It exploded, and on the interior a bubble 1 centimeter in diameter was found. This is similar to the occurrence reported by Damour (38). The tektites are found in auriferous gravels and are used as an index of the richness of the deposits by the natives, who apparently have no views as to their origin.

South American Tektites

Codazzi (34a, 35, 36), Linck (117, 118, 119, 120, 121), and Stutzer (191) have described natural glasses from Peru and Colombia which they believe to be tektites. These glasses, however, vary considerably in chemical composition from that of other tektite glasses, and many of the components approach in amount that found in some igneous glasses. Linck (117, 118) also described inclusions in the Peruvian glass such as andalusite, sillimanite, wollastonite, scapolite, sanidine, oligoclase-andesine, zircon, aegirin augite, and basaltic augite. No other tektite has been found with recognizable crystalline minerals. The gas content, however, of these glasses is comparable to that found in tektites, and, on this basis, the origin probably can be assumed to be the same.

The name americanites has been proposed for these glasses by Martin (128), but in consideration of the wide geographical extent of the Americas, this name should be dropped.

Libyan Desert Glass

Clayton and Spencer (34) described in 1933 a high-silica glass from the Libyan Desert. This glass is found in lumps up to 10 pounds in weight scattered over the surface in an area of at least 80 by 25 kilometers. The masses are irregular in shape and are wind worn on all sides. The glass is pale greenish yellow and in part is quite clear and transparent. Some parts are clouded by minute bubbles. The specific gravity of this glass is 2.21. The index of refraction is 1.4624.

A thick section was made from a piece of this glass kindly furnished by Dr. L. J. Spencer. In this section a wavy type of flow structure is plainly visible. No particles similar to those present in tektites were seen. Since this is a high-silica glass (essentially lechatelierite), this lack of glassy particles of lechatelierite is easily explained.

Bediasites

Occurrence and Description

In consideration of the fact that these are the first tektites found in North America and that the origin of glasses of this type is a moot question, a description of a portion of those found will be given in order to present as much evidence as possible that may eventually help to solve the problem of their origin.

All of the bediasites, except one, were found in Grimes County, Texas, at approximately 30°33′ to 30°41′ N. Lat. and 96°03′ to 96°09′ W. Long. During the period from April, 1936, through December, 1938, a total of 482 bediasites have been acquired from this area. The distribution is outlined in figure 83. Each star indicates places where the residents of this area have pointed out the locality at which bediasites have been found. Many have been found elsewhere within this area, but since the exact spot is difficult to locate without an adequate map, no attempt has been made to place stars at the locale of all finds.

These bediasites have been known to the local residents for many years. They are called "black diamonds." Recently under the influence of petroleum geologists, who have been active in this area, they have received the name "volcanic glass." The residents know them by either name.

The first bediasites received were obtained in April, 1936, through the efforts of George D. Ramsey, who was supervising a Works Progress Administration mineral resource survey of Grimes County, sponsored by the Bureau of Economic Geology. Mr. Ramsey reported that: "The personnel of the mineral resource survey found a dozen obsidian spats in an area southwest of Keith, west of Carlos, and north of Lamb Spring. They were found in Jarvis, Elm, and Alum Creeks and in the tributary ravines along the watersheds of these creeks." Mr. Ramsey sent 14 specimens in for study. These were supplemented by another group of 21 chosen from the collection of Mr. W. O. Pyles. During 1938, the residents of the area were interviewed and most of their collections obtained. The following is a list of collections and the number of bediasites in each collection:

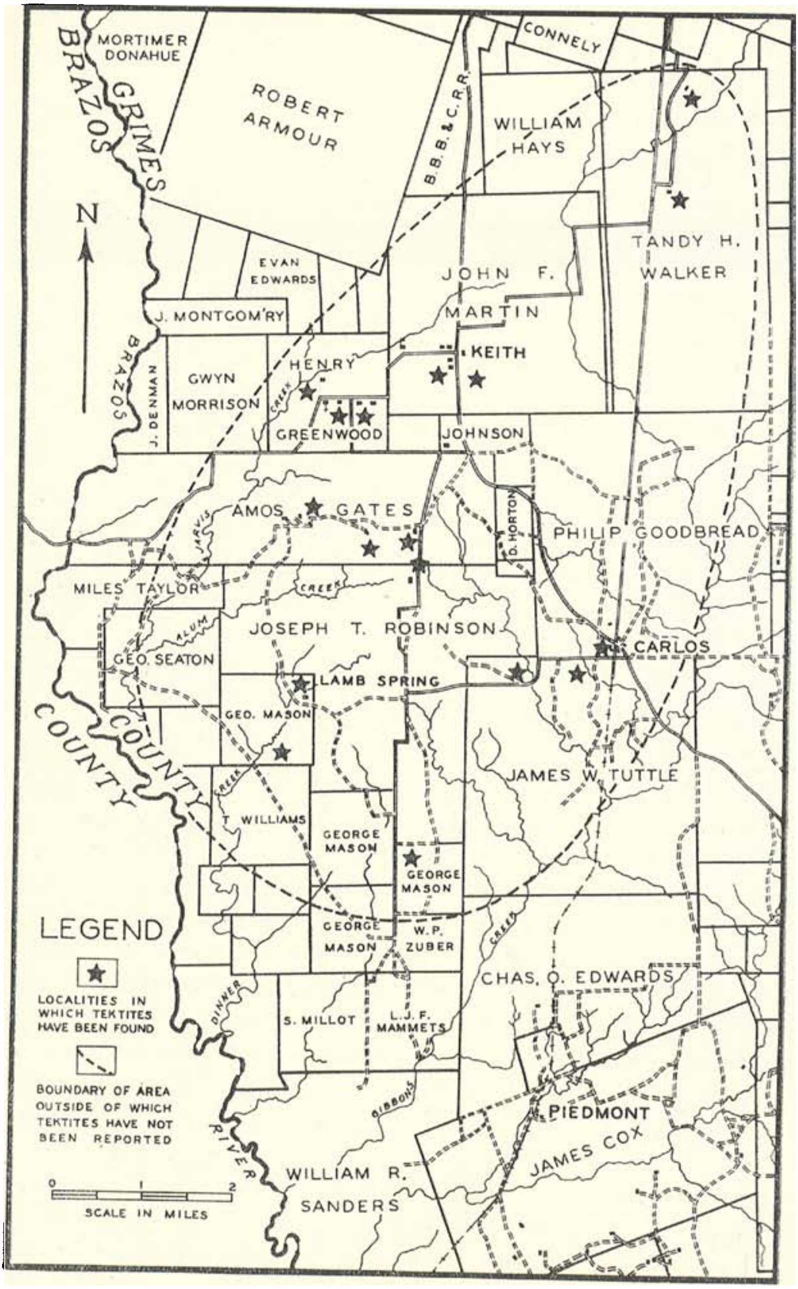

Fig. 83. Map showing distribution of bediasites in a portion of Grimes County, Texas.

ROUTE 2, IOLA, TEXAS:

W. O. Pyles, 164 (includes 21 already mentioned). These bediasites were picked up by Mr. Pyles on his farm southwest of Keith during the past 30 years or more.

E. R. Coneley, 112; found by Mr. Coneley since 1918, mostly while plowing on his farm west of Keith.

L. R. Lyons, 15; found during the past year southwest of Keith on the road which runs in front of the house.

Louise Lyons, 15; found during August, 1938, in creek at above locality.

Amanda and Jennie Stewart, 9; found near Lamb Spring and at their present home north of Carlos. This is the northernmost alleged occurrence.

A. L. Stewart, 5; found near his home southwest of Keith.

J. L. Cook, 6; found near his home southwest of Keith.

Anton Rice, 1; found August 15, 1938, near his home north of Carlos.

ROUTE 2, ANDERSON, TEXAS:

B. M. Mabry, 100; found over a rather wide area including Carlos and Lamb Spring.

W. L. Churchwell, 21; found west of Keith.

J. A. King, 8; found along Lake Creek, which is between Carlos and Lamb Spring.

Clifford Miller, 6; found southwest of Carlos. These are the southernmost bediasites recorded.

In addition to the above listed bediasites, Dr. H. B. Stenzel of the Bureau of Economic Geology found one on a gravel bar in Dinner Creek at Lamb Spring; Mr. Carl Chelf of the Texas Memorial Museum found 4 in Dinner Creek and 1 in Alum Creek; and the writer found 1 in Dinner Creek. One of those found by Mr. Chelf weighs 91.3 grams and is the largest bediasite on record. Many bediasite collections are reported to have been taken out of this area by tourists, by geologists, and by others interested in petroleum development. They have been known for probably 50 years, have been cut for jewelry sets, and apparently have received wide distribution, yet their true identity has remained unknown until recently. All available archeological collections from this area have been examined to determine if the Indians made use of these bediasites. So far no indication has been found that the Indians were even aware of the existence of the material.

The Grimes County bediasites are located in an elliptical area which is about 10 miles long by about 5 miles wide, figure 83. The bediasites in every case are reported to be found associated with gravels. In all the areas examined by the writer this was found to be true. The gravels are siliceous and do not contain limestone as does the gravel along the major water courses through this area. The following is a typical pebble count of the bediasite-bearing gravels:

Petrified wood, 11%: chert, flint, and cherty fossil aggregates, 56%: quartzite ranging from pebbles with grains easily visible to those in which the grain structure is barely detectable, 19%; vein quartz, 13%; and black siliceous pebbles in part traversed by minute quartz veins, 1%. Of this group only the petrified wood is of truly local derivation. Many of the cherty fossil aggregates contain recognizable fossils of Paleozoic age.

These gravels belong to the old siliceous gravels of the divide areas and are regarded by Renick (150) as probably belonging to the Uvalde gravels which are present farther to the west. He further states that they probably represent the up-dip facies of the Reynosa-Lissie deposits of the Gulf Coastal Plain to the southeast. They would, therefore, be Pleistocene in age.

The gravels were nowhere seen to be in layers over a few inches thick, and in several gullies where tektites were found only a bushel or two of gravel would be left at the bottom of a gully formed from the removal of a plot of soil as much as 150 by 50 feet in area. Beneath the gravel-bearing soil, rocks of Eocene age are present. Tektites have been found in the gravels resting on the formations listed in the following table, which is part of a table taken from Renick's report.

On May 21, 1937, after the study of the bediasites was well started, another tektite was received from Mr. C. J. Sigmund of Cuero. He obtained it from Mr. Henry Hoehne, who found it on a hill 300 yards north of Sandies Creek, 9 miles northwest of Cuero. DeWitt County. This find is located approximately at 29°10′ N. Lat. and 97°24′ W. Long. This locality is about 130 miles from Grimes County. The formation outcropping in the DeWitt County locality is the Oakville of Miocene age. Figure 84 is a map of Texas showing the bediasite localities and the trend of the Jackson group of Eocene age.

A group of 36 bediasites was originally chosen for study and included those found by the mineral resource survey, others selected from Mr. Pyles' collection, and the one from DeWitt County. This group was later supplemented by 43 others having an excess or deficiency of density over or under that of the original group of 36.

Table of formations in the Grimes County tektite area

	Formation	Member	No.	Surface Thickness in Feet	Lithology
JACKSON GROUP	Manning 250 to 350 feet		10	0 to 25	Chocolate-colored lignitic clay with interbedded tan sand and sandstone, with thin beds of lignite; some thin fossiliferous marine beds, but mostly nonmarine.
		Yuma sandstone	9	3 to 25	Massive and flaggy sandstone, locally containing fossiliferous marine beds.
			8	25 to 40	Same as 10.
		Dilworth sandstone	7	2 to 22	Massive sandstone, generally marine at top.
			6		Same as 10.
	Wellborn 25 to 150 feet	Carlos sandstone	5	5 to 12	Massive gray sandstone, with impressions of stems; locally semi-quartzitic.
		Middle Wellborn	4	10 to 120	Same as 10.
		Bedias sandstone	3	0 to 30	Massive gray sandstone, locally quartzitic; contains marine beds near top at some localities.
	Caddell (Moodys marl) 100 to 200 feet		2		Chocolate-colored shales and sands, locally lignitic; nonmarine beds and interbedded marine glauconitic shales.
			1	0 to 25	Gray calcareous sandstone, locally with ferruginous concretions and locally fossil-bearing.

There is a wide variation in the shape and surface configuration of these bediasites, as can be seen in the photographs shown on Plates 23 and 24. Table I was prepared in which the specific gravity, refractive index, specific refractivity, and weight are recorded. The bediasites are arranged in the order of decreasing specific gravity.

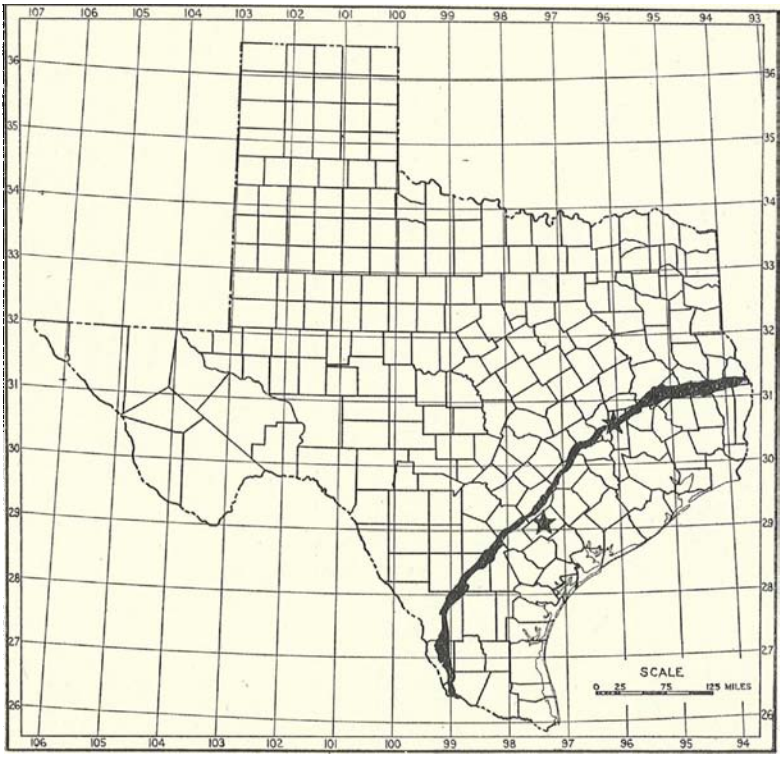

Fig. 84. Map showing bediasite localities in Texas (indicated by stars) and outcrop of the Eocene Jackson group of sedimentary beds across the State.

The index of refraction was determined by the immersion method in a series of oils varying by about 0.0010, and corrections were applied for temperature. The specific gravity was determined by suspension of the entire bediasite in Thoulet solution and reading the refractive index of the solution on an Abbé refractometer. The solution was checked before and after the bediasites had been suspended in it by obtaining the specific gravity of a quartz crystal free of inclusions and flaws. The temperature of the solution and that of the refractometer were recorded. In order to remove air films and bubbles from the bediasites, the solution containing the bediasites was placed under a vacuum. The true specific gravity of the bediasites was obtained by the use of Goldschmidt's (70) table.

Table I. Specific gravity, refractive index, specific refractivity, and weight of 79 bediasites.

No.	Mus. No.	Sp. Gr.	N_{Na}	K	Wt. in cm.
1	30764	2.433	1.511	.2100	7.5
2	30775	2.432	{1.512 / 1.483}	.2105	24.7
3	30781	2.423	1.509	.2101	7.0
4	30764	2.420	1.509	.2103	22.7
5	30774	2.418	1.510	.2109	11.4
6	30773	2.416	1.508	.2103	19.2
7	30763	2.416	1.506	.2094	11.3
8	30782	2.412	1.506	.2098	2.5
9	30764	2.412	1.506	.2098	35.2
10	30763	2.411	1.509	.2111	39.8
11	30774	2.410	1.506	.2100	22.7
12	30773	2.409	1.506	.2100	6.5
13	30774	2.408	1.506	.2101	12.5
14	30763	2.407	1.505	.2098	18.7
15	30763	2.406	1.505	.2099	10.3
16	30782	2.404	1.503	.2092	40.5
17	30775	2.402	1.505	.2102	34.4
18	30763	2.401	1.504	.2099	3.0
19	30764	2.400	1.503	.2096	6.4
20	30763	2.400	1.503	.2096	3.7
21	30246	2.397	1.502	.2094	13.9
22	30247	2.394	1.501	.2093	3.9
23	30780	2.392	1.500	.2090	33.9
24	30764	2.391	1.501	.2095	38.3
25	30247	2.391	1.500	.2091	53.0
26	30246	2.391	1.500	.2091	22.2
27	30246	2.390	1.500	.2092	2.5
28	30247	2.390	1.500	.2092	37.5
29	30247	2.387	1.499	.2090	8.5
30	30246	2.387	1.499	.2090	18.7
31	30767	2.385	1.498	.2088	22.4
32	30246	2.384	1.499	.2093	2.9
33	30247	2.384	1.498	.2089	13.8
34	30246	2.383	1.501	.2102	11.6
35	30247	2.381	1.497	.2087	7.8
36	30246	2.379	1.499	.2098	2.3
37	30246	2.375	1.497	.2093	3.0
38	30247	2.374	1.497	.2094	59.4
39	30246	2.374	1.497	.2094	12.5
40	30247	2.374	1.497	.2094	5.4
41	30246	2.373	1.499	.2103	16.9
42	30246	2.370	1.495	.2089	7.0
43	30247	2.367	1.496	.2095	34.1

No.	Mus. No.	Sp. Gr.	N_{N_1}	K	Wt. in gm.
44	30246	2.367	1.496	.2095	11.4
45	30247	2.367	1.497	.2100	9.4
46	30247	2.364	1.496	.2098	22.3
47	30247	2.364	1.495	.2094	0.5
48	30246	2.364	1.496	.2098	24.3
49	30247	2.364	1.497	.2102	20.7
50	30247	2.364	1.493	.2085	7.5
51	30247	2.363	1.494	.2091	15.7
52	30247	2.361	1.492	.2084	28.8
53	30247	2.357	1.492	.2087	23.6
54	30247	2.356	1.493	.2093	13.2
55	30774	2.354	1.491	.2086	18.4
56	30764	2.347	1.490	.2088	10.5
57	30774	2.347	1.490	.2088	7.8
58	30764	2.346	1.490	.2089	7.2
59	30775	2.345	1.490	.2090	15.8
60	30763	2.344	1.490	.2090	16.0
61	30763	2.342	1.489	.2088	1.0
62	30763	2.341	1.489	.2089	6.9
63	30247	2.341	1.490	.2093	9.8
64	30775	2.340	1.489	.2090	19.0
65	30774	2.340	1.489	.2090	13.5
66	30763	2.340	1.488	.2085	8.8
67	30763	2.340	1.489	.2090	11.7
68	30763	2.340	1.490	.2094	10.0
69	30782	2.340	1.488	.2085	28.5
70	30763	2.339	1.488	.2086	0.7
71	30774	2.339	1.488	.2086	6.8
72	30779	2.339	1.488	.2086	14.8
73	30773	2.339	1.488	.2086	5.8
74	30773	2.339	1.489	.2091	22.8
75	30775	2.337	1.488	.2088	5.9
76	30773	2.337	1.489	.2092	6.7
77	30775	2.336	1.490	.2098	22.0
78	30773	2.336	1.489	.2093	9.6
79	30763	2.334	1.488	.2091	2.7
Average		2.3742	1.4971	.20938	15.57

In summary: This group of bediasites ranges in weight from a half-gram to 59.4 grams and averages 15.57 grams. There is a rough correlation between specific gravity and weight. The first group of 26 tektites averages 19.4 grams, the next 27 tektites average 15.9 grams, and the last 26 tektites average 11.0 grams. The refrective indices range from 1.488 to 1.512 and average 1.4971. The refractive index of each bediasite also varies, though mostly through a smaller range than does the group as a whole. The value given in the table is that of a small chip removed from each bediasite; consequently it is not an average refractive index of the bediasite as a whole. However, the variation in average refractive index of the bediasites is real, as is shown by the correlative values of the refractive index to the specific gravity. That definite relations exist between specific gravity and refractive index has been shown in many cases. Gladstone and Dale (68) expressed this relationship by the following formula: $\frac{n - 1}{d}$ = constant (K), where n = the refractive index and d = the density. Using the average refractive index and the average specific gravity as measured for the entire group to obtain the constant, the theoretical index of refraction for each bediasite can be calculated. The refractive index calculated is 1.5094 and 1.4887 for the bediasites having the highest and the lowest specific gravities respectively, which checks very well with 1.512 and 1.488, the values actually measured. The range of specific gravities is 2.433 to 2.334, and the average specific gravity is 2.374. There are discrepancies in correlation between the refractive index and the specific gravity. These are explained by the fact that the refractive index reading obtained was not an average value. Porosity may account for some discrepancy in the specific gravity but is probably negligible as is shown by the percentage of porosity in Table II. The main factor accounting for this difference in refractive index is the variation in chemical composition of each tektite. The most outstanding example of this variation in composition of the glass is present in bediasite No. 2 (Table I and Pl. 26, fig. 1). In one chip from this bediasite, glass was present ranging in refractive index from 1.512 to 1.483, a range greater than that of the entire group of bediasites measured.

The type of furrowing produced by etching varies but in general readily falls into two distinct classes. The furrowing most conducive to an irregular shape is the V-type in which the furrows may extend to a depth of one-half the radius of the tektite, or even more. The other type is a broad U-shaped furrowing in which the depth of the furrow is much less than its width. In many of the tektites furrowing is not pronounced, and in a few both V- and U-shaped furrows are present. The U-shaped furrowed bediasites in general are of higher index than the V-shaped ones. Whether this is an accidental correlation or a real one is still a matter for conjecture.

The shape of these bediasites is highly varied, making it difficult to give a satisfactory description in a few words. Several factors control their present shape, among the most important of which are the original shape; the amount, kind, and depth of etching; and the amount of spalling. Etching is responsible for the surface texture, which may be classified as smooth, intermediate, rough, or very rough. Distinct forms such as lenses and teardrops are scarce. Many are ellipsoidal, some are nearly spherical, others are very long for their thickness, and a few are tabular. Many are so deeply etched and others are so much spalled that the shape can only be described as highly irregular.

Flow structure is recognizable on most of the bediasites, and in some it is very well developed. It does not conform to the surface and does not seem to have any regular relationship to the shape of the bediasites (Pl. 26, figs. 1–3). So far as can be seen on the exterior the flow structure varies from straight through curved to highly contorted. Selective etching along these very fine flow lines makes them visible. Low magnification aids in detecting the flow lines in many of the specimens.

Conical pits about 4 millimeters deep are present in a few of the bediasites. The shape of these pits is similar to ones which would be produced by sticking a lead pencil point into a plastic mass. "Lunar craters" are U-shaped circular furrows; consequently a small knob of glass is left in the center which at first sight is suggestive of a spherulite. A plate was cut from bediasite No. 53 (Pl. 23, 53a) in such a manner that the central part of one of these knobs is included. The knob is of glass, and the ring apparently is etched along flow structure. This, of course, is based on a two-dimensional study and might not hold for a three-dimensional observation.

Spalling is widely distributed with over half the specimens showing evidence of at least one spalled surface (Pls. 23 and 24, figs. 30, 38, 43, 81, 82, 85, 87), and a few of them are probably entirely bounded by spalled surfaces (Pl. 24, fig. 86). Several of the bediasites are spall fragments (Pls. 23 and 24, figs. 37, 85, 87). Some spalls are only a few millimeters thick and are concave on the side where they were attached. The concave side is very little etched, and the convex side shows the usual deep etching.

The furrows are for the most part curved and very irregular in trend. A photograph of tektite No. 31, Plate 23, the DeWitt County tektite, shows remarkably well the character of the U-shaped furrows. A lunar crater is shown in the photograph of bediasite No. 53

(Pl. 23). Many of the U-shaped furrows have a cross lining not unlike that produced by an engraving tool.

Bediasite No. 28, Plate 23, shows clearly the V-shaped type of furrowing. This specimen, incidentally, is the most irregular shaped and deepest etched of the entire group. The sides of the V-shaped furrows are in part smooth and in part etched, having irregular patterns.

Under slight magnification the areas between furrows are seen to be etched in various manners. Many are replicas in miniature of the larger U-shaped furrowed surfaces; some are pitted by shallow circular pits, others by elliptical pits; and in a few the pits are so close together that the intervening ridges are sharp, producing a surface not unlike that of a hammered metal.

Several crescentric markings on the surfaces of a few of the bediasites appear to be abrasion marks caused by blows (Pl. 24). In at least one place these marks are aligned in such a manner as to suggest the dragging of a rock across the surface, producing a series of crescentric marks similar to those found on some glaciated surfaces.

The explanation of tektite furrowing as due to fusion stripping has been shown by Wright (240) to be incorrect. He investigated the Icelandic obsidian of Hrafntinnuhryggur and found markings produced by etching that almost exactly duplicated the markings on moldavites. The surface markings of the bediasites have the same appearance as those found on both the Icelandic obsidian and the moldavites. Further proof that the rough surface is produced by etching is present on the bediasites. Many of these have spalled surfaces, the spalls of which are much later than the etching on the bediasite as a whole. For example, the unspalled portion of some of the bediasites is etched to a rather uniform depth of about 4 to 6 millimeters, whereas the spalled surfaces are etched in the same manner but only to a depth of a millimeter or less (Pl. 23, fig. 43). If the furrowing had been produced during flight, any subsequently spalled surfaces would be without furrowing.

In order to study the interior structure of the bediasites with greater facility, plates about a millimeter thick were cut out of bediasites Nos. 2, 10, 21. 23, 34, 50, and 53. These plates, which are of a brownish color, show flow structure very well. The flow structure viewed by transmitted light appears to the unaided eye much like arrested heat waves. In all seven glass plates the flow structure is contorted, and it does not conform to the exterior surface.

The glass plates contain bubbles and some lechatelierite (fused quartz) particles. Particle is used advisedly in this case for want of a more precise word. The bubbles are spherical, indicating that they formed or assumed their shape after the flow structure had been developed. A statistical study was made of both the bubbles and the lechatelierite particles in the plates from bediasites Nos. 34 and 50. The data are presented in Table II.

Table II. Estimates of amount of bubbles and inclusions contained in bediasites.

	No. 50		No. 34	
	Bubbles	Lechatelierite Particles	Bubbles	Lechatelierite Particles
Size in mm. Max.	.065	.48 x .06	.336	.35 x .19
Size in mm. Min.	.002–	.015– x .005–	.002–	.015 x .005–
Size in mm. Ave.	.015	.136 x .032	.058	.125 x .057
Number per cc.	1305	690	14,260	5980
Volume cc.	.0000023	.000048	.0015	.0012
Per cent by volume	.00023	.0048	.15	.12

The general variation in the number, size, and amount of bubbles and lechatelierite particles to be expected is well shown in this table. It is readily seen that No. 34 has about 650 times as much volume occupied by bubbles and about 25 times as much volume occupied by lechatelierite particles, as does No. 50. The average size of the lechatelierite particles does not vary widely between the two, whereas the average bubble size is much larger in No. 34. Bediasite No. 55, Plate 23, contains a very large bubble or, more strictly speaking, a compound bubble composed of three parts. The present shape of the hole is such that three bubbles must have been in contact except for very thin diaphragms of glass. These diaphragms have been broken, and all that is left are two raised rings at the point where the bubbles met. Four other bediasites have been found containing large bubbles, one of which is a centimeter in diameter. In each case the bubbles have been exposed by removal of material by weathering.

The lechatelierite particles are microscopic and vary widely in shape (Pl. 25). Most of them are linear, and most of them are aligned with the flow structure. Many have embayed surfaces, suggestive of fusion. Several are hooked at one end. Their color is a little deeper than that of the glass, and they have a definitely pinkish cast. The particles, however, are colorless when placed in an immersion liquid of nearly the same index, thus suggesting that the color seen is due to reflections from the enclosing glass. The index of refraction is near 1.464 and is definitely below 1.472 and above 1.453 as determined by the immersion method. To obtain lechatelierite particles for index determination a portion of one tektite was crushed. Very few particles were found, and only a very few of these were in such a position at the edge of the glass grain so that the Becke line between the liquid and the particle could be seen.

Between crossed nicols the lechatelierite particles are isotropic and rarely show extremely weak anisotropism. A few of the lechatelierite particles have an abnormal concentration of bubbles in and about them. Lechatelierite has an index of refraction of 1.458, which is slightly lower than the index of refraction determined for this mineral. Quartz is seldom pure, and any impurity contained would raise the index of refraction of the melt. Most quartz contains gaseous inclusions. These gases are retained in the melts from such quartz and are very difficult to remove. The abnormal concentration of gases, therefore, in and about some of these lechatelierite particles is a further indication helping to establish their identity. Anderson (3) in a study of fulgurites has noted groups of bubbles within partially fused grains of feldspar and quartz which he attributes to "expansion of gas or fluid cavities, or air spaces and cracks, preëxisting in quartz and decomposed feldspars." Lechatelierite is found mostly in fulgurites, and it is also known about volcanoes. It has also been found in the Canyon Diablo meteorite crater of Arizona.

Each of the lechatelierite grains shows strain effects. Each grain has both dilatational and compressional strains, situated in alternate quadrants. This strain, in combination with the general lenticularity of the grains, causes them to show interference figures between crossed nicols and without convergent light, Plate 25, figures 6 and 7.

The presence of these lechatelierite particles indicates limited liquid miscibility. Bowen (20) states: "There is only one kind of phenomenon which could be considered as definite proof of the occurrence of limited liquid miscibility and it would, without doubt, be very commonly observed if limited miscibility among rock-forming silicates were a fact. The observed phenomenon would be the occurrence in glassy, or partly glassy, extrusive lavas of distinct globules of material still partly glass. large or small, according to their opportunity for aggregation, and of composition different from that of the main mass. Here would lie indisputable proof of the formation of immiscible liquid globules." The above statement should be enlarged somewhat to cover the deformation of globules after they have formed. In the case of tektites, strongly developed flow structure is present (Pl. 26, figs. 1–6), and any globules that might have been present would have been deformed and drawn out in the direction of flow. The case for limited miscibility in these tektites is far from complete.

There is a more plausible explanation for the presence of these lechatelierite particles. If the original material contained quartz grains before it was melted and if fusion was rapid, followed by rapid cooling, it is possible that the quartz would be fused into lechatelierite, but because of its viscosity it would not be able to mix with the rest of the glass in the time available. This would be a case of limited miscibility of a type but not in the same sense as stated by Bowen, in which the enclosed globules are formed by aggregation while the material is molten.

The glass chip taken from the DeWitt County tektite contains two lechatelierite particles. On this basis it is probably safe to assume that the DeWitt County tektite and the Grimes County bediasites are of the same origin.

All glass plates cut from the bediasites show bands of anisotropism between crossed nicols. These bands correspond to the flow structure and are probably anisotropic because of strain. By the use of the sensitive tint plate the strain is better seen, and in areas where anisotropism is not recognized by crossed nicols strain is also observed. Strain is distributed irregularly throughout the plates with alternation of tensional and compression zones. Wright (240) has postulated the distribution of strain to be expected in rounded glass objects depending on the heat conditions through which they have passed. According to him three general conditions might be expected, namely: (1) the object might be without strain or only slightly strained, having been derived from the interior of a mass that cooled slowly and consequently had enough time to be annealed; (2) the object was extremely hot and cooled rapidly, such as would be true in the case of the formation of a volcanic bomb; or (3) the body was very cold and the exterior was heated very rapidly, such as would be the case with a glass meteorite. To these possibilities mentioned by Wright a fourth might be added, namely, that the objects have irregularly distributed strain. The tektite flow structure is probably due to non-homogeneity of the glass, and strain has developed because of a difference in coefficient of expansion of the various parts of the non-homogeneous glass.

The distribution of strain under these various conditions should be as follows: (1) none or very little strain; (2) an outside zone of dilatational strain and an inside zone of compressional strain separated by a zone of no strain; (3) an outside zone of compressional strain and an inside zone of dilatational strain separated by a zone of no strain; and (4) a condition of very irregular strain following flow structure.

According to Wright, the moldavites and obsidian bombs of Iceland show the same distribution of strain as called for under (2); consequently, he concludes that both are derived from very hot small bodies quickly cooled. The bediasites, on the other hand, show a condition of strain as postulated under (4) in which strain is parallel to the flow structure. A plate cut from a moldavite shows the same distribution of strain as is found in the bediasites; consequently, Wright's observation cannot be accepted.

A plate cut from one of the bediasites was repeatedly heated to a white heat and plunged into water. The only noticeable effect was the development of small microscopic cracks about the periphery of the plate. This treatment did not alter the residual strain nor did it produce a superimposed strain pattern. The temperature at which the flow structure formed must have been considerably higher than the temperature which can be obtained in a plate before the blowpipe. Only the thinnest of slivers show any evidence of rounding when placed before the blowpipe. Ordinary obsidian treated in this manner softens and develops into a frothy mass.

The bediasites have flow structure which is well developed. This flow structure resulted from rapid fusion of a non-homogeneous material followed by cooling before the glass became homogeneous in composition. The flow structure is made visible, therefore, by the difference in refractive index of adjacent glasses due to difference in composition. Figures 1–3 of Plate 26 were prepared to show the flow structure in relation to the shape of the tektite.

These photographs were taken with artificial transmitted light. A large auxiliary lens was placed between the thick section and the camera in order to give coverage on the photographic film to the section. The flow structure is best seen when the section is slightly out of focus. A Becke line effect is caused by the difference in refractive index of adjacent glasses. If a particular flow line is observed to be bright when the focus is above the section it will be dark when the focus is below the section.

Figures 1 and 1-a of Plate 26 are a photograph and sketch of a tabular or plate-like tektite. This specimen (No. 2 of Table I) is the most heterogeneous in composition of any of the bediasites examined. In this section rounded areas of colorless glass are present in addition to well-formed flow lines. In this section the flow structure is sharply truncated as if it had at one time continued much farther. The section shown in figure 53a of Plate 23 also shows the same relationship.

Figures 2 and 2-a of Plate 26 are a photograph and sketch of a smooth, lens-shaped bediasite. The flow lines in the photograph can be traced directly to the edge of the bediasite where they are sharply truncated.

Figures 3 and 3-a of Plate 26 are a photograph and sketch of a deeply etched, thick, lens-shaped bediasite. In this section the flow structure is truncated by the highly irregular surface. There is only slight indication of etching being controlled by flow structure.

The shape of the flow structure in a specimen can be used as a rough index of the amount of material which has been removed by erosion. The flow structure will mostly parallel the surface of a molten object unless it has been disturbed by some other factor, such as the escape of abundant gas, in which case it might be highly contorted. The way in which flow structure parallels the edge of a once molten mass is well demonstrated in figure 85-A, a drawing of material described in the next section. The manner in which flow structure might be contorted at the edge of a molten mass is suggested in figure 85-B. This figure shows the end of a tube fused by the passage of an electric current. The flow structure appears to have been distorted by ebullition caused by escaping gas, producing a very irregularly contorted structure. The same highly contorted type of flow structure is present in a section cut from a tektite from Muong Nong, French Indo-China. A photograph of this material was attempted, but the confusion of structure was too great to allow reproduction. Another section cut from a tektite from Dalat, French Indo-China, having a definite and original shape shows the flow structure paralleling the surface. Unfortunately this

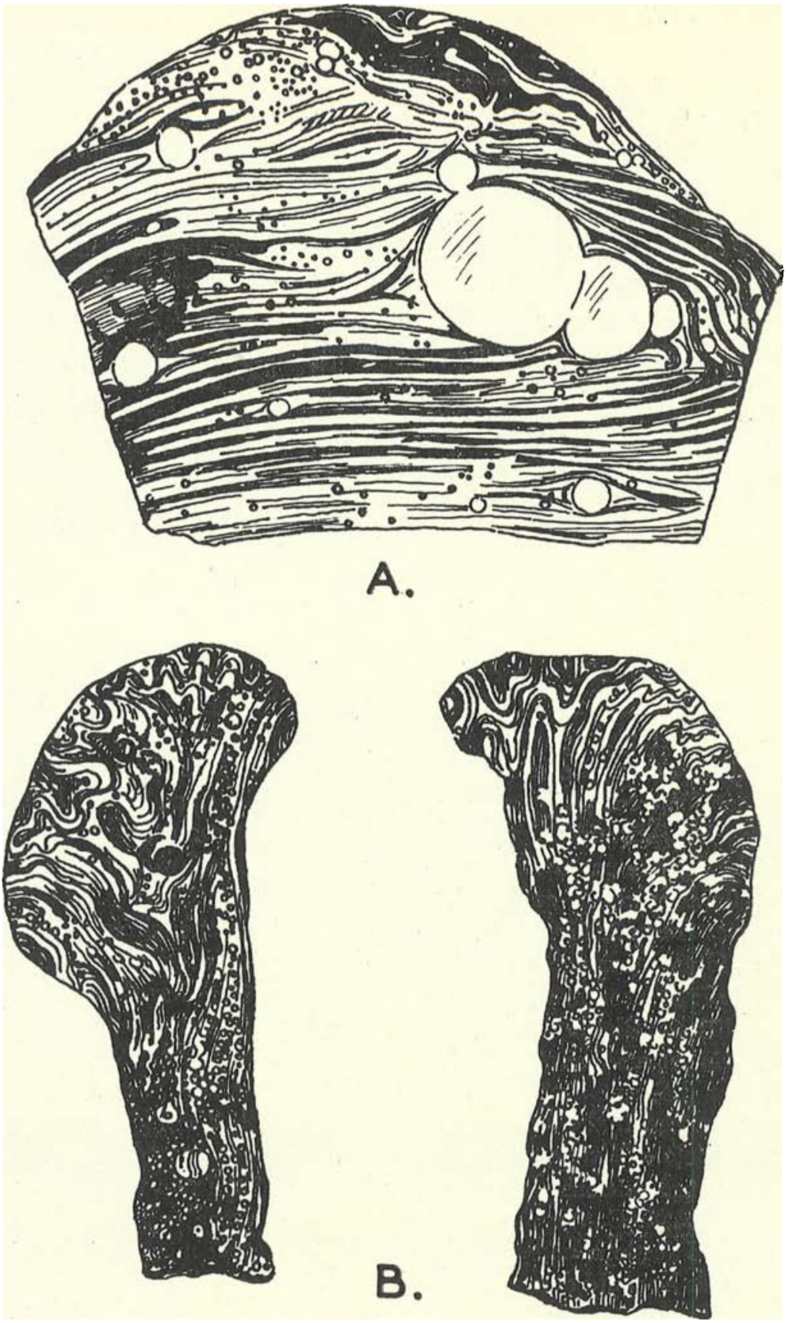

Fig. 85. Drawings of glass plates cut from material fused by a broken power line arcing through the soil. A, regular flow structure in glass that flowed along the ground. x4. B, contorted flow structure in a glass tube. x6.

flow structure was not in a position to show distinctly in a photograph. Plate 26, figure 5, is a photograph of a section from an australite from Charlotte Waters, Australia. In this section the flow structure is sharply truncated. One section cut from a moldavite shows the same type of truncation (Pl. 26, fig. 4).

Flow structure and strain in tektites as seen in thick sections have been pictured by several writers, and the illustrations by Dunn are probably the earliest and most instructive. Plate 26, figure 6, is a reproduction of a section photographed by Dunn (50).

All of the bediasites sectioned show sharp truncation of the flow structure. It must be concluded that considerable material has been removed from each specimen by weathering. The smooth bediasites have probably lost material mostly by corrasion, and any definitely shaped forms still remaining may be reflections of the former shapes. The rough bediasites have probably lost material mostly by corrosion. From a study of flow structure in the bediasites, it must be concluded that very few, if any, specimens remain having their original size and shape. Insufficient material has been examined from other localities to draw conclusions as to the average amount of removal of material. The australite and the moldavite examined have lost much material. Dunn has figured australite buttons in which the amount of material removed is slight. If the flow structure is carefully traced, however, it will be seen that some material has been lost. The indochinites examined have lost scarcely any material. The amount of material removed, as indicated by the truncation of flow structure, and the percentage of tektites having definite shapes are indications of the relative ages of various tektite groups, providing other factors have been approximately equal. From a superficial examination of the tektites from the few Indo-China localities available to the writer, it appears that considerable difference in the amount of material removed exists and that these tektites are of different ages. The same holds true for the australites, as can be seen if the sections by Dunn (50) (Pl. 26, fig. 6) and of the Charlotte Waters tektite (Pl. 26, fig. 5) are compared.

Polished sections were made at Harvard of the two tektites sent to Mr. F. A. Gonyer for analysis. Dr. E. B. Dane examined these polished sections under the high power reflecting microscope, and so far as he could determine they are homogeneous. The tremendous magnification available with this instrument should reveal any minute metallic particles present. There are none.

DESCRIPTION AND EXAMINATION OF OTHER GLASSES

Some perlites from Globe, Arizona, contained in the Bureau of Economic Geology collection, faintly resemble tektites in appearance. Their index of refraction varies between about 1.485 and 1.500, and their density varies between about 2.34 and 2.37. Under the microscope, however, they are easily distinguished from tektites by the large number of small lath-shaped crystallites. Before the blowpipe this perlite is very refractory, becoming vesicular only with prolonged heating. One phenomenon which is worthy of comment is that the original surfaces became frothy much more readily than did freshly broken surfaces. This suggests that changes have taken place at the surface of these perlites making them much less refractory. Another perlite from Arizona, received from Mr. A. R. Allen of Trinidad, Colorado, was examined. Mr. Allen remarked on its similarity to some of the tektites. This perlite has a specific gravity of 2.342, an index of refraction of 1.495, and contains lath-shaped crystallites.

A sample of glass from Freestone County, Texas, was submitted to the Bureau. This glass was formed by a broken power line arcing through the soil upon which it fell. The connotation of this glass was not immediately noted, and even the name of the donor is not remembered. This glass is in part similar to fulgurite tubes and is composed of an inner glassy surface surrounded by a highly vesicular glass with sand adhering to it. The sand is composed of quartz, feldspar, and a small amount of clay. The index of refraction of the glass is near 1.48. A drawing of a section through one of these tubes is reproduced as figure 85-B. In addition to these tubes, many pieces ranging in shape from spheres to teardrops are present, some of which have no sand adhering to them. Most of these pieces have a filament of glass extending from them. Another type in this collection was produced by glass flowing along the surface of the ground, forming rivulets and puddles. Fragments of this type have a flat base with adhering sand and a rounded, smooth upper surface without adhering sand. A drawing of a section cut from a fragment of this type is reproduced as figure 85-A. This drawing shows the flow structure as depicted by variation in the composition, color, and refractive index of the glass. Lechatelierite particles are present in this glass, but clear-cut photographs could not be obtained of them. The strain is irregularly distributed, exactly as it is in the bediasites and not as is postulated by Wright (240) for a small molten body cooled rapidly, namely, an outside zone of dilatational strain and an inside zone of compressional strain separated by a zone of no strain.

In consideration of the resemblance of tektites in composition to fused shaly sediments, a noncalcareous shale from the Carrizo formation was fused in the carbon arc. The glass which resulted had an index of refraction of 1.51. Lechatelierite particles are also present in this glass. Bubbles are rather abundant but not more so than in some of the more vesicular bediasites. The color of this glass is similar to that of the bediasites.

Volcanic ash beds are present in Grimes County in the general vicinity of the tektite area. Some of this ash was fused in the carbon arc. The resulting glass is nearly colorless, with a slightly greenish cast. It has an index of refraction ranging from slightly below to slightly above 1.485. Quartz and some feldspar are present in the ash as impurities. After fusion, the only impurities seen are lechatelierite particles.

Glassy material formed about a burning and cratered petroleum and gas well was examined. This material was collected and thin-sectioned by Dr. Duncan McConnell, of the geology department, The University of Texas, who very kindly allowed the writer to examine the slides. This material is mostly glassy, with some recognizable detrital grains scattered throughout. Some recrystallization has taken place with the development of crystallites somewhat resembling augite. The index of refraction of this glass is 1.55, which is much higher than that of the bediasites. This glassy material was re-fused in the carbon arc. The resulting glass has an index of refraction slightly under 1.54, is a clear, deep bottle-green, and has lechatelierite particles in it.

Another glass examined was formed in the fire box of a boiler at a creosoting plant. This glass contains no detrital minerals, has an index of refraction near 1.55, and has commenced to recrystallize. Recrystallization has taken place in that portion of the glass first deposited, while that last deposited is entirely glassy. The crystals in this glass also closely resemble augite.

Two australites were obtained from Mr. A. R. Allen of Trinidad, Colorado. These australites are from Charlotte Waters, Central Australia. The following data were obtained:

	Specific Gravity	N_{Na}	Weight
Australite No. 1	2.457	1.512	3.6 gm.
Australite No. 2	2.430	1.506	3.9 gm.

A thin plate was cut from australite No. 1. The color is somewhat darker than that of the average bediasite, and the flow structure, while present, is not so readily seen. The point of greatest interest is the presence of lechatelierite particles in this australite exactly similar to those found in bediasites and in the various fusion materials just described. Two sections cut from indochinites kindly furnished by Professor Lacroix contain lechatelierite particles. One of these is from Dalat, State of Annam, and the other specimen is from Muong Nong, lower Laos. Figures 1 and 2 of Plate 25 are photographs of lechatelierite particles in the former section.

A section was cut from a Bohemian moldavite kindly furnished by Mr. F. W. Cassirer of Paris. This section furnishes the most spectacular display of lechatelierite particles of any section yet examined. The size and shape of these particles vary greatly (fig. 86). Particles are present of similar shape to those figured in indochinites and bediasites. In addition, there are many which have been drawn out into fantastic shapes such as corkscrew-like spirals and serpentine-like threads (fig. 87). Some are like ribbon fluted in such a manner that with certain orientations they entirely resemble the segmented appearance of a tapeworm. These much drawn-out types grade into the more nearly equal dimensional forms and are undoubtedly of the same material. The process by which these particles became so contorted is difficult to visualize. The melt must have been very hot and very fluid, and possibly escaping gas produced an effect similar to that of boiling, causing a turbulency sufficient to deform these drawn-out particles. They might also be explained by a piling up or jamming effect following the development of the flow structure.

Rutley (155) in 1885 described the microscopic structure of bouteillenstein and noted these inclusions. His description follows: "The section contains numerous spherical gas-bubbles and irregular enclosures, some fusiform, others club-shaped, while many assume bulbous and slightly branching forms. They are frequently produced into, or from, delicate capillary rods, and they usually contain several, sometimes a dozen or more, spherical gas-bubbles.

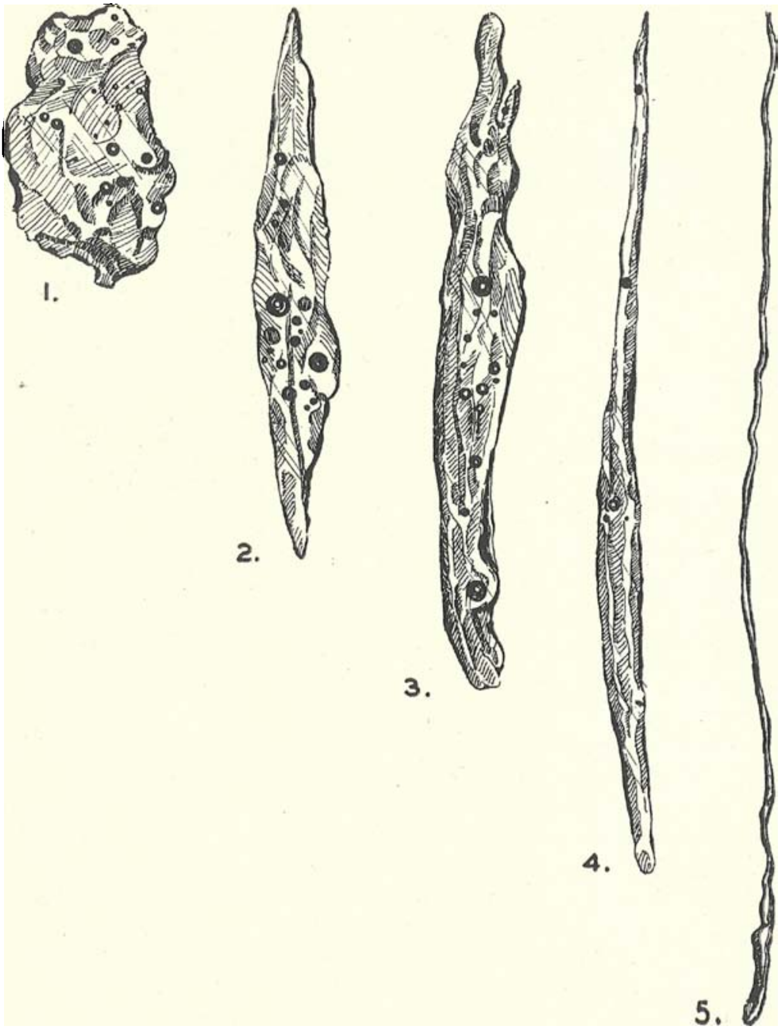

Fig. 86. Drawings of lechatelierite particles in a moldavite illustrating elongation during the development of flow structure. Assuming that the particles were originally about equidimensional, then the following ratio of elongation is shown: (1) 1–1.5; (2) 1–7; (3) 1–8; (4) 1–20; and (5) about 1–75. x100.

The surfaces of these glass enclosures do not, as a rule, appear to be smooth and cylindrical, but they more resemble those of flint cores from which flakes have been artifically struck, or the surfaces of prisms of starch. They depolarize strongly from strain, and

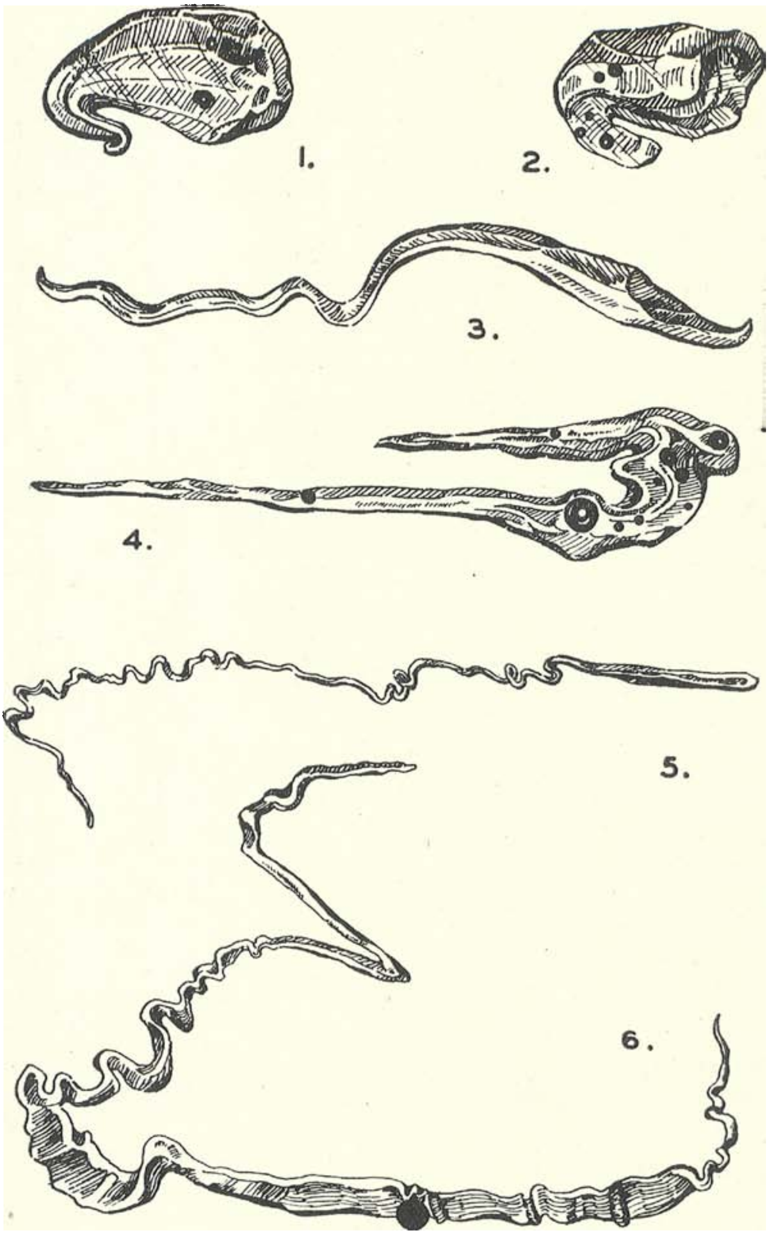

Fig. 87. Drawings of distorted lechatelicrite particles in a moldavite illustrating turbulency during or jamming following the development of flow structure. x120.

the glass immediately surrounding them is similarly affected, so that each glass enclosure is bordered by a nimbus which is traversed by dark brushes. The similarity of these glass enclosures to the one figured from the fulgurite of the Dom du Gouté is very striking." Rutley further states: "That bouteillenstein is an obsidian is denied by Makowsky; but (apart from its banded structure) its glass enclosures and numerous gas-bubbles and its almost perfect freedom from any products of crystallization, render its comparison with fulgurite not merely admissible, but possibly instructive."

Suess (194) in his 1900 work mentions these particles. The following is Suess' original statement:

In Dünnschliffen von allen Vorkommnissen finden sich in wechselnder menge und Grösse, längliche oder rundliche Linsen von schwächer lichtbrechendem Glase eingeschlossen; ihre Streckung fällt stets mit der Richtung der Fluidalstructur Zusammen und tritt am stärksten hevor bei dem böhmischen Stücken. Doch besitzen sie auch in dem australischen Schliffe, wo sie sich etwas spärlicher vorfinden, oft eine ausgesprochene, beiderseitig zugeschärfte Lancetform; daneben finden sich ober auch rundliche oder unregelmässig umgrenzte Blättchen; hie und da liegen sich shief im Schliffe, ohne denselben der ganzen Dicke nach zu durchsetzen.

Lacroix (116) has figured in a photomicrograph an object which has very much the appearance of a lechatelierite particle. He states:

Les fragments de tectites, à forme quelconque, de Séan-Tô (Hai-nan) renferment souvent non seulement des bulles à forme distincte, mais encore de petites ponctuations d'un blanc de lait, ne dépassant pas les dimensions d'une tête d'épingle: au premier abord, elles pourraient être prises pour des inclusions d'une minéral étranger, mais l'examen microscopique, sous diverses incidences, montre qu' il s'agit d'agglomération de tres petites bulles gazeuses, conduisant sur quelques dixiémes ou même centièmes de millimétre à une ebauche de texture ponceuse.

An examination of Plate 25 will be sufficient to convince one that these particles are not groups of gas bubbles producing a pumiceous texture.

It is apparent from an examination of these various fusion products that glass, even of the composition of the bediasites, would recrystallize to some extent if maintained near the fusion point for a considerable time, as would be the case if they were fused by burning petroleum, gas, or coal. On the other hand, quick fusion and cooling can be produced naturally by electricity (lightning); by meteorite impact, as exhibited by the glasses about the

Wabar, Henbury, and Canyon Diablo craters; and by passage of meteorites through the air.

DENSITY AND REFRACTIVITY OF TEKTITES

Most of the available data concerning specific gravity and index of refraction of tektites have been gathered into Table III. This supplements the data in Table I and is used to show the relation of these properties among tektite groups and between the tektites and igneous glasses. In addition, specific refractivity, K, has been calculated for those data for which it had not been previously recorded.

Table III. Density, index of refraction, and specific refractivity of tektites.

AUTHORITY	DENSITY	N_{Na}	K	LOCALITY
AUSTRALITES				
Lacroix[1]	2.380	1.5002	0.2102	Mount Williams, Victoria.
Ježek[2]	2.386	1.4981	0.2088	Unknown.
Tilley[3]	2.393	1.504	0.2106	Mount Williams, Victoria.
Lacroix	2.415	1.5043	0.2088	Hamilton, Victoria.
Barnes[4]	2.430	1.506	0.2082	Charlotte Waters, Central Australia.
Tilley	2.443	1.520	0.2128	Mount Williams, Victoria.
Tilley	2.453	1.519	0.2116	Unknown.
Barnes	2.457	1.512	0.2084	Charlotte Waters, Central Australia.
Lacroix	2.458	1.5178	0.2107	Charlotte Waters, South Australia.
Average	2.424	1.509	0.2100	
BEDIASITES				
See Table I.				
BILLITONITES				
Lacroix	2.457	1.5157	0.2099	Billiton.
Lacroix	2.498	1.526	0.2106	Martapoera, Borneo.
Lacroix	2.51	1.5241	0.2088	Mt. Moeriah, Java (noir).
Lacroix	2.512	1.5305	0.2112	Mt. Moeriah, Java (blanc jaunatre).
Average	2.494	1.5241	0.2101	
DARWIN GLASS				
Lacroix	2.275	1.4790	0.2105	Tasmania.
Ludwig[5]	2.2645	1.477	0.2088	Tasmania.
Ludwig	2.2921	1.479	0.2090	Tasmania.
Ampt[6]	2.296	1.474	0.2064	Tasmania.
Average	2.288	1.477	0.2087	

[1]Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 203, 1932.
———, Acad. sci. Paris Comptes rendus, tome 193, p. 265, 1931.
[2]Ježek, B., and Woldřich, J., Bull. Internat. Acad. sci. Bohême, vol. 15, pp. 232–245, 1910.
[3]Tilley, C. E., Mineralog. Mag., vol. 19, pp. 275–294, 1922.
[4]These determinations were made upon material obtained from A. R. Allen, Trinidad, Colorado.
[5]Quoted in (6).
[6]David, T. W. E., Summers, H. S., and Ampt, G. A., Royal Soc. Victoria, Proc., n.s., vol. 39, pt. 2, pp. 167–190, 1927.

INDOCHINITES

Authority	Density	N_{Na}	K	Locality
Lacroix[7]	2.404	1.4986	0.2074	Cambodge, Samrong, S. E. Kratié (Bloc).
Lacroix	2.413	1.4972	0.2061	Cambodge, Schmach (Bloc).
Lacroix	2.414	1.5053	0.2092	Annam, Dalat (Plaque allongée).
Lacroix	2.419	1.5035env.	0.2081	Hai-nan, Sim-San.
Lacroix	2.419	1.5045	0.2086	Kouang-Tchéou-wan, Potao.
Lacroix	2.421	1.5042	0.2083	Cambodge, Près Kratié (kilomètre 135.5 de la route coloniale).
Lacroix	2.421	1.5065	0.2092	Hai-nan.
Lacroix	2.422	1.5063	0.2090	Schmach.
Lacroix	2.425	1.5081	0.2095	Ban-Don-Phay.
Lacroix	2.428	1.5092	0.2097	Schmach.
Lacroix	2.429	1.5058	0.2082	Annam, Dalat (disque).
Lacroix	2.429	1.5076	0.2090	Tonkin, Dong Van.
Lacroix	2.429	1.5089	0.2095	Laos, Sud de Muong Nong (Bloc).
Lacroix	2.432	1.5089	0.2093	Tonkin, Beausite (Pia Oac).
Tilley[8]	2.433	1.505	0.2076	Pahang, Malay States.
Lacroix	2.438	1.5102	0.2093	Entre Kontoum et Dek-Tô.
Lacroix	2.440	1.5120	0.2098	Laos, Attopeu (Bloc).
Lacroix	2.440	1.5133	0.2104	Annam, Dan-Kia.
Lacroix	2.443	1.5148	0.2107	Malaisie (éch. Damour).
Lacroix	2.445	1.5146	0.2105	Tan-hai.
Average	2.427	1.5072	0.2089	

IVORY COAST

Lacroix	2.4	1.4991	0.2080	Akakoumoékrou (Échantillon á grosse bulle).
Lacroix	2.465	1.5178	0.2101	Akakoumoékrou.
Lacroix	2.487	1.5146	0.2069	Près Ouellé.
Average	2.451	1.5105	0.2083	

MOLDAVITES

Ježek[9]	2.303	1.4812	0.2089	Bohemia or Moravia
Ježek	2.304	1.4812	0.2089	Bohemia or Moravia
Ježek	2.305	1.4798	0.2081	Bohemia or Moravia
Ježek	2.309	1.4812	0.2084	Bohemia or Moravia
Ježek	2.317	1.4861	0.2098	Bohemia or Moravia
Ježek	2.321	1.4886	0.2105	Bohemia or Moravia
Ježek	2.321	1.4925	0.2122	Bohemia or Moravia
Ježek	2.323	1.4890	0.2105	Bohemia or Moravia
Ježek	2.325	1.4853	0.2087	Bohemia or Moravia
Ježek	2.326	1.4841	0.2081	Bohemia or Moravia
Ježek	2.326	1.4856	0.2088	Bohemia or Moravia

[7]Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 203, 1932.

————, Mus. nat. histoire nat., Archives, 6th ser., tome 12, p. 168, 1935.

————, Acad. sci. Paris Comptes rendus, tome 199, p. 1539, 1934.

————, Acad. sci. Paris Comptes rendus, tome 191, p. 893, 1930.

————, Acad. sci. Paris Comptes rendus, tome 193, p. 265, 1931

[8]Tilley, C. E., Mineralog. Mag., vol. 19, pp. 275–294, 1922.

[9]Ježek, B., and Woldřich, J., Bull. Internat. Acad. sci. Bohême, vol. 15, pp. 232–245, 1910. (This publication was not accessible to the present writer; consequently the exact locality for each specimen is unknown. Tilley (10) states ". . . from various localities in Bohemia and Moravia, . . .")

MOLDAVITES—Continued

Authority	Density	N_{Na}	K	Locality
Ježek	2.331	1.4893	0.2099	Bohemia or Moravia
Ježek	2.333	1.4834	0.2072	Bohemia or Moravia
Tilley[10]	2.337	1.488	0.2088	Bohemia or Moravia
Ježek	2.338	1.4858	0.2078	Bohemia or Moravia
Lacroix	2.339	1.4877	0.2085	Bohemia or Moravia
Ježek	2.339	1.4888	0.2090	Bohemia or Moravia
Lacroix	2.341	1.4875	0.2082	Bohemia or Moravia
Ježek	2.342	1.4863	0.2076	Bohemia or Moravia
Lacroix	2.342	1.4879	0.2083	Bohemia or Moravia
Lacroix	2.345	1.4928	0.2101	Bohemia or Moravia
Ježek	2.346	1.4901	0.2089	Bohemia or Moravia
Ježek	2.347	1.4880	0.2079	Bohemia or Moravia
Tilley	2.347	1.490	0.2088	Bohemia or Moravia
Ježek	2.348	1.4897	0.2086	Bohemia or Moravia
Tilley	2.350	1.489	0.2081	Bohemia or Moravia
Lacroix	2.350	1.4948	0.2106	Bohemia or Moravia
Tilley	2.352	1.492	0.2092	Bohemia or Moravia
Ježek	2.352	1.4920	0.2092	Bohemia or Moravia
Ježek	2.354	1.4917	0.2089	Bohemia or Moravia
Ježek	2.355	1.4920	0.2089	Bohemia or Moravia
Ježek	2.356	1.4930	0.2093	Bohemia or Moravia
Ježek	2.357	1.4921	0.2088	Bohemia or Moravia
Ježek	2.359	1.4917	0.2084	Bohemia or Moravia
Ježek	2.360	1.4961	0.2102	Bohemia or Moravia
Ježek	2.362	1.4917	0.2082	Bohemia or Moravia
Ježek	2.364	1.4956	0.2096	Bohemia or Moravia
Tilley	2.367	1.492	0.2079	Bohemia or Moravia
Average	2.3366	1.4888	0.2088	

PHILIPPINE ISLANDS

Authority	Density	N_{Na}	K	Locality
Lacroix[11]	2.447–2.451	1.5130	0.2097 0.2093	Rosario

LIBYAN DESERT GLASS

Spencer[12]	2.208	1.4624	0.2094	Libyan Desert

[10] Tilley, C. E., Mineralog. Mag., vol. 19, pp. 275–294, 1922.

[11] Lacroix, Alfred, Acad. sci. Paris Comptes rendus, tome 193, p. 265, 1931.

[12] Clayton, P. A., and Spencer, L. J., Mineralog. Mag., vol. 23, pp. 501–508, 1934.

Table III contains 80 density and refractive index determinations, of which 2 are new. Table I contains 79 new determinations on bediasites, making altogether 159 determinations on tektites. These have been plotted on figure 88. Lechatelierite (vitreous silica) is also plotted on this diagram since the chief variation in chemical composition of tektites is in silica. A straight line drawn through the point for lechatelierite and the point representing the average density and refractive index of the bediasites passes through all groups of tektites. All tektites fall very near to this line; especially when one considers that porosity and non-uniformity of composition in some of the individual tektites render the determinations liable to error.

This diagram shows the overlapping relationship of the various tektite groups. When the specific gravities and refractive indices of all tektite groups have been as well studied as they have been for the bediasite, moldavite, and indochinite groups this overlap will be still more marked. As it now stands, there is a slight gap between the moldavites and Darwin glass. The moldavites overlap the bediasites rather markedly, and the bediasites fill in the gap that until now existed between the moldavite and the australite-indochinite groups. The upper half of the bediasite group overlaps most of the indochinite group which, in turn, is completely overlapped by the australite group. The australite group barely overlaps the billitonites, but in both groups very little data are available. The tektites from the Ivory Coast, represented by only three points, completely overlap the indochinite group and substantially overlap the australite and bediasite groups. The one example from the Philippines falls near the upper end of the indochinites.

Attempts have been made to correlate the densities and refractive indices of volcanic glasses. Tilley (209), in addition, plotted some of the tektites quoted above on his diagram. He arrived at the conclusion that volcanic glasses occupy a field under, and adjacent to, that of the tektites. George (67) prepared a diagram of volcanic glasses only. These workers used different rocks and obtained different results. George has about an equal number of points falling above and below the tektite line shown in figure 88, whereas Tilley's points, except one, fall below this line. The points plotted by Tilley, which included tektites, cover roughly a wide band which extends directly away from vitreous silica. The curve George accepted is highly concave toward the specific gravity side of the diagram. It is believed that the tektite line, figure 88, more nearly represents the actual relationship of natural glasses and that the variation from this line found in volcanic glasses is caused largely by the water content and somewhat by the state of oxidation of the iron, as pointed out by Tilley. George explains that points above his curve are of alkalic rocks and those below represent partially crystalline rocks.

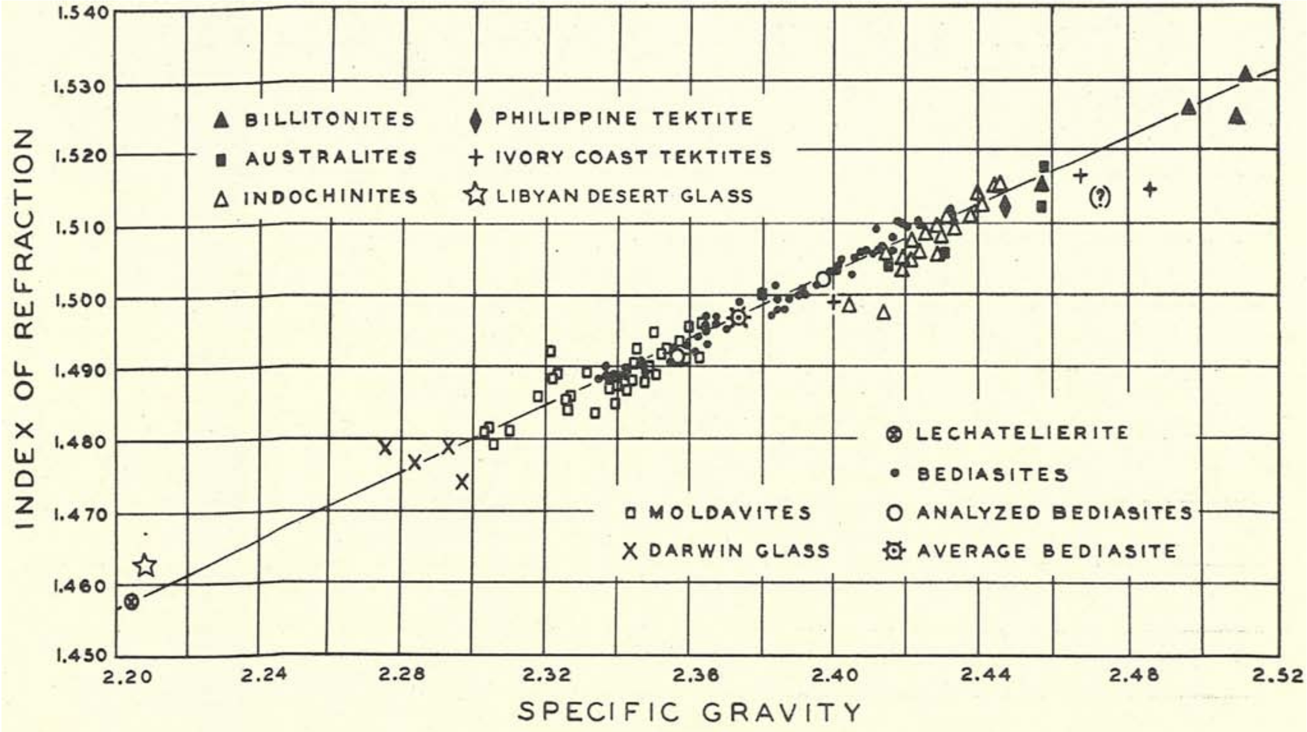

Fig. 88. Index of refraction–specific gravity curve illustrating the relationship of all tektites.

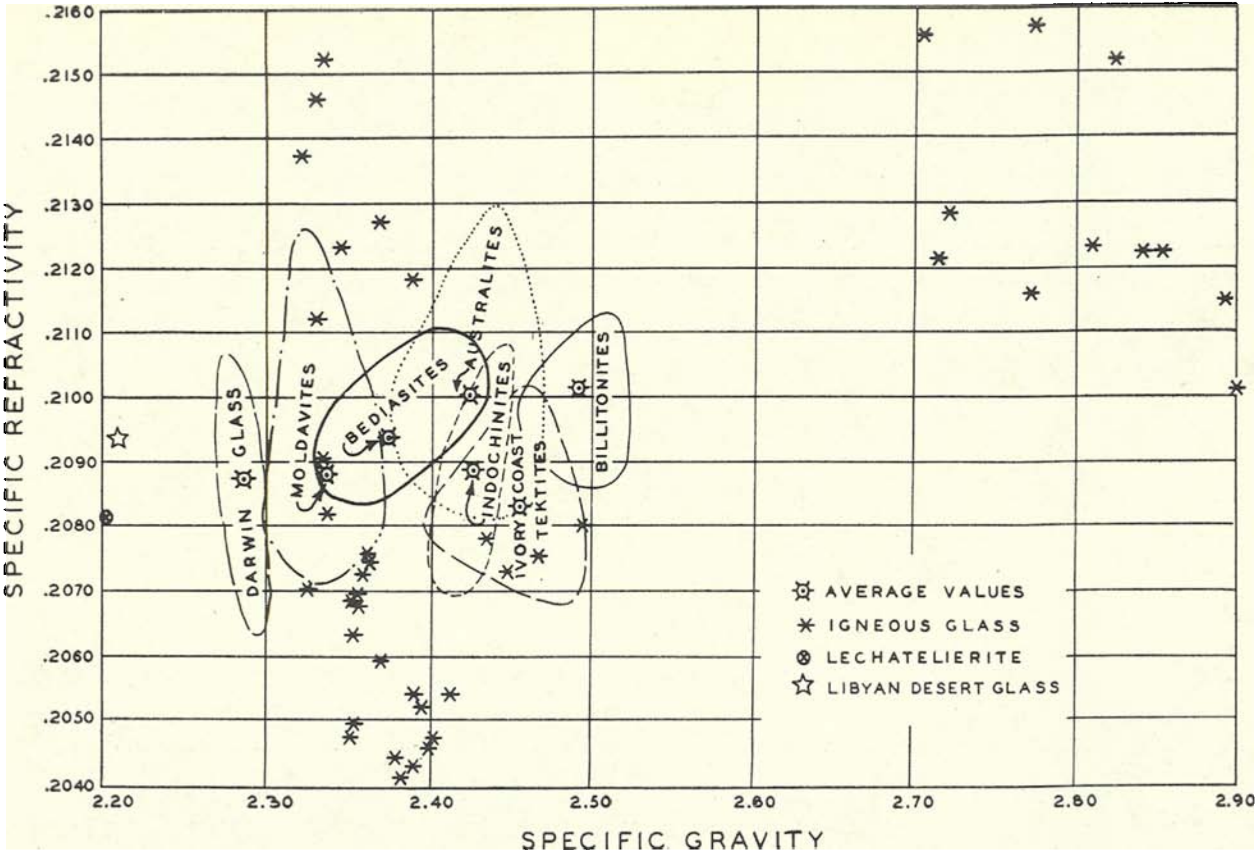

Fig. 89. Diagram to illustrate the specific refractivity–specific gravity relationship of the tektite groups and igneous glasses.

Tilley also plotted specific refractivity against specific gravity. Specific refractivity, or K as used by Tilley, is obtained from the relationship $(n - 1)/d = K$ stated by Gladstone and Dale (68). They have shown that "every liquid has a specific refractive energy composed of the specific refractive energies of its component elements, modified by the manner of combination, and which is unaffected by changes of temperature and accompanies it when mixed with other liquids. The product of this specific refractive energy and the density is, when added to unity, the refractive index." For crystalline solids the results are only approximate. Glasses should more nearly follow this law, but for each glass a slightly different value for K is obtained. In figure 89 all the data by Tilley, as well as most of those by George, are plotted on a diagram on which the areas occupied by the tektite groups have been placed. Tilley in his diagram found the tektite area to be distinct from the volcanic glass area. The present diagram shows that the volcanic glass area entirely overlaps the tektite area and that very little is accomplished by a study of specific refractivity. One point that is brought out, however, is that the tektites are confined to a relatively small area, whereas volcanic glasses are very widely spread over the diagram. A determination of specific refractivity might be contributory evidence helping to establish the identity of a glass suspected of being a tektite, but it would be far from infallible and should not be relied upon. The same holds true for the relationship of the specific gravity to the index of refraction.

These various glasses may be identified by their behavior before the blowpipe. Obsidian melts and froths readily, perlite becomes viscous and froths with difficulty, and only very thin splinters of tektites become rounded and there is no frothing.

CHEMISTRY OF TEKTITES

Bediasites

Chemical analyses were made by F. A. Gonyer of two bediasites. One of these has the highest index of refraction and the highest specific gravity and the other has the lowest specific gravity and close to the lowest index of refraction of the original group of 36 studied. The analyses are given in Table IV.

Table IV. Analyses of two bediasites from Grimes County, Texas.

	No. 21 PER CENT	No. 53 PER CENT
SiO_2	73.52	77.76
Al_2O_3	15.88	13.30
Fe_2O_3	.45	.37
FeO	4.64	3.36
CaO	.06	.04
MgO	1.38	1.19
Na_2O	1.30	1.41
K_2O	1.73	1.97
H_2O	.08	.02
TiO_2	.87	.76
MnO	.01	.01
NiO	none	none
CuO	none	none
CoO	none	none
Total	99.92	100.19
Specific gravity	2.397	2.357
N_{Na}	1.502	1.492
K calc. n–1/d	0.2094	0.2087
K calc. from analyses	0.2091	0.2087

These analyses unfortunately do not closely approach the limits of composition that will be found in the bediasites. As pointed out by Summers (203) the silica content varies with the specific gravity, that is, the higher the specific gravity, the lower the silica content. The most remarkable feature brought out by these analyses is the abnormally low lime content. The lime is lower than found in obsidian and much lower than is found in all other tektites, except Darwin glass. Soda and potash, as is true in other tektites, are lower than is normal for obsidian. The bediasites compare more closely to moldavites and Darwin glass than to any other tektites. One important point brought out by these analyses is the absence of nickel and cobalt. Spencer (183) postulates that glass formed by meteorite impact, such as that found about the Wabar and Henbury craters, usually contains nickel. He also implies that the presence of nickel indicates an origin by meteorite impact.

The specific refractivity K was calculated by using two methods, one by the relationship $N_{Na} - 1/\text{sp. gr.} = K$, and the other by the additive relationship $K = k_1\frac{p_1}{100} + k_2\frac{p_2}{100} + \text{etc.}$, where k_1, k_2, etc., equals the specific refractive energies $(\frac{n-1}{d} = K)$ of the constituents found by analysis and where p_1, p_2, etc., equals the percentage of the constituents found by analysis. K determined by these two methods checks within 0.15 per cent in one analysis and exactly for the other, which speaks well for the accuracy of the analyses.

Other Tektites

Silicate analyses are very complex, and in order to compare them it is necessary to devise some means of grouping or classifying them. Attempts at classification of the igneous rocks have been made by many people, and probably the most outstanding chemical classification is that known as the C.I.P.W. system of Cross, Iddings, Pierson, and Washington. The truly great achievement of this system is the assemblage and classification by Washington (226) of over 8000 analyses of igneous rock. If an endeavor had not been made to give names (many of which are difficult and confusing) to the various groups defined chemically, it is possible that this system would have been accepted more rapidly and generally.

In order to arrive at a better understanding of the chemical composition of tektites, they have been recalculated into their normative mineral composition and classified according to the C.I.P.W. system. In Table V, the analyses, the normative mineral composition, and the C.I.P.W. classification of the tektites are given, and, where available, the specific gravity and index of refraction.

Table V. Analyses of 66 tektites showing normative mineral composition and, if available, specific gravity and refractive index.

	DARWIN GLASS (QUEENSTOWNITES)				MOLDAVITES			
	1	2	3	4	5	6	7	8
SiO_2	86.34	87.00	88.76	89.81	77.69	82.68	82.28	78.61
Al_2O_3	7.82	8.00	6.13	6.21	12.78	9.56	10.08	12.01
Fe_2O_3	0.63	0.19	---	0.26	2.05			0.16
FeO	2.08	1.93	1.24	0.89	1.45	1.13	2.03	3.09
MgO	0.92	0.82	0.58	0.73	1.15	1.52	0.98	1.39
CaO	0.05	nil	0.17	---	1.26	2.06	2.24	1.62
Na_2O	0.15	0.14	0.13	0.01	0.78	0.63	0.28	0.44
K_2O	0.87	0.99	1.36	1.05	2.78	2.28	2.20	3.06
H_2O+	0.43	0.36	---	---	---	---	0.06	---
H_2O-	0.03			---	---	---	---	---
TiO_2	0.52	0.51	1.24	0.86	---	---	---	---
MnO	nil	nil	tr.	0.01	---	0.18		0.11
	99.95	99.94	99.61	99.83	99.94	100.04	100.15	100.49
Q	79.63	80.03	81.39	84.63	57.42	62.64	64.26	59.98
Or	5.15	5.86	8.04	6.22	16.68	13.34	12.79	18.35
Ab	1.27	1.19	1.10	0.09	6.81	5.24	2.62	3.67
An	0.25	---	0.85	---	6.12	10.29	11.12	8.06
C	6.53	6.69	4.13	5.05	6.12	2.35	3.16	5.00
Hy	4.56	4.57	1.75	1.83	3.82	6.18	6.20	9.31
Mt	0.91	0.28		0.38	3.02	---	---	0.23
Il	0.99	0.97	2.36	1.65	---	---	---	---
Sp. gr.	2.296	---	2.2921	2.2845	---	---	---	---
N_{Na}	1.474	---	1.479	1.477	---	---	---	---

1. I″.1″.1″.″2. David, T. W. E., Summers, H. S., and Ampt, G. A., Royal Soc. Victoria, Proc., n.s., vol. 39, pt. 2, p. 178, 1927. Analyst, Ampt. Minor constituents: ZrO_2, 0.11; P_2O_5, tr.; CO_2, Cr_2O_3, NiO, CoO, BaO, SrO, and SO_3, nil; Cl, nil (?).
2. I.1″.1.(1)2. David, T. W. E., Summers, H. S., and Ampt. G. A., Royal Soc. Victoria, Proc., n.s., vol. 39, pt. 2, p. 178, 1927. Analyst, Ampt. Minor constituents: ZrO_2, tr.; P_2O_5. CO_2, Cr_2O_3, NiO, CoO, BaO, SrO, SO_3, nil; Cl, nil (?).
3. I.1(2).(1)2.1(2). Suess, F. E., Geol. Gesell. Wien Mitt., Band 7, p. 104, 1914. Analyst, Ludwig. Mt. Darwin, Tasmania.
4. I.1″.1.1. Suess, F. E., Geol. Gesell. Wien Mitt., Band 7, p. 104, 1914. Analyst, Ludwig. Mt. Darwin, Tasmania.
5. I″.2″.2″.2. John, C. v., K. geol. Reichsanstalt Wien Jahrb., Band 39, p. 473, 1889. Analyst, C. v. John. Radomiltz, n. Budweis, Bohemia.
6. I.2″.3.2. John, C. v., K. geol. Reichsanstalt Wien Verh., p. 179, 1889. Analyst, C. v. John. Budweis, Bohemia.
7. I.2.3″.″2. John, C. v., K. geol. Reichsanstalt Wien Jahrb., Band 39, p. 473, 1889. Analyst, C. v. John. Radomiltz, n. Budweis, Bohemia.
8. I(II).2(3).″3.″2. John, C. v., K. geol. Reichsanstalt Wien Verh., p. 179, 1899. Analyst, C. v. John. Trebitsch, Bohemia.

	MOLDAVITES—continued						BEDIASITES	
	9	10	11	12	13	14	15	16
SiO_2	77.96	77.75	80.73	80.52	80.00	77.78	73.52	77.76
Al_2O_3	12.20	12.90	9.61	9.44	10.04	11.56	15.88	13.30
Fe_2O_3	0.14	----	----	----	----	----	0.45	0.37
FeO	3.36	2.60	1.93	1.98	2.27	2.54	4.64	3.36
MgO	1.48	0.22	1.59	1.73	1.46	1.52	1.38	1.19
CaO	1.94	3.05	2.13	1.84	1.76	1.34	0.06	0.04
Na_2O	0.61	0.26	0.37	0.52	0.51	0.68	1.30	1.41
K_2O	2.70	2.58	3.60	3.15	3.37	3.26	1.73	1.97
H_2O+	----	0.06	0.02	0.11	0.10	----	0.08	0.02
H_2O-	----	----		0.05	0.05	----		
TiO_2	----	----	0.32	0.72	0.74	1.40	0.87	0.76
MnO	0.10	----	0.07	0.09	0.06	0.15	0.01	0.01
	100.49	99.46	100.37	100.15	100.36	100.23	99.92	100.19
Q	54.66	57.12	56.45	57.71	56.82	54.90	54.30	57.84
Or	16.12	15.57	21.25	18.60	20.02	19.46	10.01	11.68
Ab	5.24	2.10	3.14	4.41	4.19	5.76	11.00	12.05
An	9.73	15.29	10.59	9.15	8.62	6.67	0.28	0.28
C	4.69	3.98	1.19	1.79	2.35	4.49	11.83	8.67
Hy	9.90	5.35	7.13	6.94	6.77	6.31	10.00	7.75
Mt	0.23	----	----	----	----	----	0.70	0.46
Il	----	----	0.61	1.37	1.37	2.74	1.67	1.37
Sp. gr.	----	----	2.343	----	----	----	2.397	2.357
N_{Na}	----	----	1.487	----	----	----	1.502	1.492

9. I(II).2(3).3.2. John, C. v., K. geol. Reichsanstalt Wien Verh., p. 179, 1899. Analyst, C. v. John. Trebitsch, Bohemia.
10. I.2.(3).(3)4.(1)2. John, C. v., K. geol. Reichsanstalt Wien Jahrb., Band 39, p. 473, 1889. Analyst, C. v. John. Radomiltz, n. Budweis, Bohemia.

11. I″.(2)3.3.1(2). Nováček, R., Casopis Národniho Musea Praha, vol. 106, p. 68, 1932. Lhenice, Bohemia.
12. I′.2(3).(2)3.2. Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 198, 1932. Analyst, Raoult. Trébic.
13. I′.2(3).′3.′2. Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 198, 1932. Analyst, Raoult. Radomélice.
14. I′.2(3).(2)3.2. Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 198, 1932. Analyst, Raoult. Skrey (Moravia).
15. I(II).2.1.3. Analyst, Gonyer. Minor constituents: NiO, CoO, CuO, none. Grimes County, Texas.
16. I(II).2.1.3. Analyst, Gonyer. Minor constituents: NiO, CoO, CuO, none. Grimes County, Texas.

INDOCHINITES

	17	18	19	20	21	22	23	24
SiO_2	72.12	73.14	73.74	72.48	70.40	76.64	74.56	73.48
Al_2O_3	12.88	12.48	12.71	12.84	13.65	11.36	12.60	12.50
Fe_2O_3		—	—	—	0.17	0.06	—	—
FeO	4.99	4.88	4.78	4.59	5.13	4.39	4.98	5.28
MgO	2.04	2.12	1.39	2.16	1.94	1.29	1.22	2.26
CaO	3.14	3.34	2.52	2.78	3.00	1.48	1.34	2.06
Na_2O	1.45	1.29	1.92	1.73	1.57	1.56	1.81	1.05
K_2O	2.28	1.84	2.20	2.63	2.72	2.30	2.21	2.32
H_2O+	tr.	0.21	—	0.14	—	0.22	—	—
H_2O-	0.04	0.09	0.26	0.05	0.16	—	0.14	0.05
TiO_2	1.00	0.95	0.84	1.01	1.03	0.99	0.88	1.01
MnO	0.13	0.16	0.10	0.11	0.15	0.10	0.12	0.10
	100.07	100.50	100.46	100.52	99.92	100.39	99.87	100.11
Q	41.94	44.88	43.32	39.96	38.10	50.88	47.52	47.22
Or	13.34	10.56	12.79	15.57	16.12	13.34	12.79	13.34
Ab	12.05	11.00	16.24	14.67	13.10	13.10	15.20	8.91
An	15.57	16.68	12.51	13.90	15.01	7.51	6.67	10.29
C	2.35	2.35	2.65	1.94	2.65	3.67	4.90	4.59
Hy	12.76	12.96	11.16	12.26	12.46	9.67	10.89	13.78
Mt	—	—	—	—	0.23	—	—	—
Il	1.98	1.82	1.52	1.98	1.98	1.98	1.67	1.98
Sp. gr.	2.432	2.429	—	2.429	2.440	2.413	2.404	—
N_{N_1}	1.5089	1.5076	—	1.5089	1.5120	1.4972	1.4986	—

Analyses 17–39 are from the following publication: Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 12, pp. 162–163, 1935. Analyst, Raoult.

17. (I)II.3.3.3. French Indo-China, Tonkin, Beausite (Pia Oac).
18. (I)II.3.3(4).3. French Indo-China, Tonkin, Dong Van.
19. (I)II.3.3.3′. Siam, Roi Eit.
20. (I)II.3.3.3. French Indo-China, Laos, Sud de Muong Nong (Bloc).
21. (I)II.3.3.3. French Indo-China, Attopeu (Bloc).
22. I(II).(2)3.2.(3).3. French Indo-China, Cambodge, Schmach (Bloc).
23. (I)II.′3.2′.3. French Indo-China, Cambodge, Samrong, S. E. Kratié (Bloc). Minor constituent: Cr_2O_3, 0.01.
24. ′II.′3.3.′3. French Indo-China, Cambodge, Khum de Varin.

INDOCHINITES, Continued

	25	26	27	28	29	30	31	32
SiO_2	72.62	72.22	72.08	72.00	73.74	73.30	72.78	72.62
Al_2O_3	12.20	12.55	13.21	12.41	12.35	11.98	12.20	12.12
Fe_2O_3	......	......	0.37	......	......	......	......	......
FeO	5.19	5.28	4.47	5.47	5.63	5.19	5.33	5.55
MgO	2.20	2.16	1.92	2.30	2.44	2.44	2.30	2.32
CaO	2.28	2.72	2.42	2.74	2.02	2.28	2.52	2.44
Na_2O	2.00	1.63	1.61	1.74	0.90	1.64	1.69	1.20
K_2O	2.17	2.36	2.80	2.47	2.38	2.25	2.09	2.38
H_2O+	......	......	0.13	......	......	0.12	......	0.18
H_2O-	0.17	0.06	0.13	0.06	......	0.14	0.07	0.07
TiO_2	0.94	1.01	0.78	0.94	0.96	0.99	0.90	0.99
MnO	0.11	0.11	0.13	0.11	0.10	0.32	0.12	0.14
	99.89	100.10	100.05	100.24	100.52	100.46	100.03	100.01
Q	40.92	41.16	40.80	39.36	46.98	43.32	42.42	43.80
Or	12.79	13.90	16.68	15.01	14.46	12.79	12.23	14.46
Ab	16.77	13.62	13.62	14.15	7.86	13.62	14.15	9.96
An	11.40	13.34	11.95	13.62	10.01	11.40	12.51	11.95
C	2.45	2.45	3.06	1.94	4.49	2.86	2.65	3.16
Hy	13.55	13.58	11.53	14.28	14.94	14.42	14.25	14.51
Mt	......	......	0.70	......	......	......	......	
Il	1.82	1.98	1.52	1.82	1.82	1.98	1.67	1.98
Sp. gr.	2.421	......	2.422	......	......	2.429	2.414	......
N_{Na}	1.5042	1.5063	......	......	......	1.5058	1.5053	......

INDOCHINITES, Continued

	33	34	35	36	37	38	39	40
SiO_2	72.26	74.56	73.96	70.58	74.82	74.60	74.14	72.40
Al_2O_3	13.18	12.34	12.16	13.23	11.62	11.59	12.73	12.68
Fe_2O_3	......	......	......	0.10	......	......	......	0.23
FeO	5.32	4.66	5.45	5.08	4.58	4.88	4.93	3.59
MgO	2.15	1.82	1.83	1.92	1.90	1.87	1.78	2.34
CaO	2.42	2.40	2.28	3.92	2.44	2.76	2.24	2.75
Na_2O	1.43	0.92	1.06	1.43	1.25	1.11	1.03	1.68
K_2O	2.15	2.47	2.51	2.59	2.51	2.32	2.41	3.16
H_2O+	0.14	0.07	tr.	0.20	0.08	0.09	0.08	0.43
H_2O-	0.06	......	0.11	......	0.08	0.04	......	......
TiO_2	0.99	0.92	0.98	0.99	0.98	0.95	0.90	0.74
MnO	0.10	0.10	0.13	0.13	0.12	0.15	0.11	0.06
	100.20	100.26	100.47	100.17	100.38	100.36	100.35	100.20*
Q	43.56	48.30	46.62	37.38	46.68	47.28	47.70	38.77
Or	12.79	15.01	15.01	15.57	15.01	13.34	14.46	18.66
Ab	12.05	7.86	8.91	12.05	10.48	9.43	8.91	14.23
An	11.95	11.95	11.40	19.46	12.23	13.62	11.12	13.[illegible]8
C	4.08	3.67	3.57	0.82	2.35	2.35	4.28	1.44
Hy	13.58	11.76	13.05	12.59	11.56	12.36	12.16	11.05
Mt		......	......	0.23	......			0.33
Il	1.98	1.67	1.98	1.98	1.98	1.82	1.67	1.41
Sp. gr.	2.440	2.419	......	2.445	......	......	2.419	2.409
N_{Na}	1.5133	1.5045	......	......	......	......	1.5035 (av.)	......

25. (I)II.3.'3.3'. French Indo-China, Cambodge, Prés Kratié (Kilomètre 135.5 de la route coloniale). Minor constituent: Cr_2O_3, 0.01.
26. (I)II.3.3.3. French Indo-China, Cambodge, Aur-Roum-Hak.
27. (I)II.3.'3.3. French-Indo China, Cambodge, Schmach.
28. 'II.3.3.3. French Indo-China, Cambodge, Prey-Chrok-Bal-Rollous
29. 'II.'3.3.2(3). French Indo-China, Annam, Lang Bian (Dalat).
30. 'II.3.3.3. French Indo-China, Annam, Dalat (disque). Minor constituent: Cr_2O_3, 0.01.
31. 'II.3.3.3. French Indo-China, Annam, Dalat (plaque allongée). Minor constituent: Cr_2O_3, 0.03.
    Le chrome n'a pas été recherché dans les autres échantillons.
32. 'II.3.3.'3. French Indo-China, Annam, Dalat.
33. (I)II.3.3.3. French Indo-China, Annam, Dam-Kia.
34. (I)II.3.3.2(3). French protectorate, Kouang-Tchéou-wan, Potao.
35. (I)II.'3.3.(2)3. French protectorate, Kouang-Tchéou-wan, Tan-Hai.
36. (I)II.3.3'.3. French protectorate, Kouang-Tchéou-wan, Tan-Hai.
37. (I)II.3.3.'3. China, Hai-nan, Séan-Tô.
38. (I)II.'3.3.'3. China, Hai-nan, Séan-Tô.
39. (I)II.'3.3.(2)3. China, Hai-nan, Sim-San.
40. (I)II.3.3.3. Koomans, Cath. M., Leidsche Geol. Meded., Deel 10, Afl. 1, p. 70, 1938. Analyst, Koomans. Siam, Dhupan Hill. *Includes P_2O_5, 0.14.

	MALAY PENINSULA	PHILIPPINES				BILLITONITES AND ASSOCIATED TEKTITES		
	41	42	43	44	45	46	47	48
SiO_2	70.08	71.64	71.32	71.20	70.66	70.62	70.90	69.32
Al_2O_3	13.61	12.53	12.16	13.52	12.08	12.34	13.50	12.27
Fe_2O_3	0.15	.....	2.03	0.59	1.78	2.25	0.32	0.06
FeO	4.81	5.32	3.03	3.89	4.52	3.17	5.47	6.81
MgO	2.16	2.79	2.94	2.23	3.65	3.61	2.45	4.05
CaO	3.48	3.42	2.95	3.40	2.97	2.99	2.35	3.72
Na_2O	1.99	1.21	1.66	1.59	1.62	1.68	1.46	0.77
K_2O	2.44	2.28	1.90	1.84	1.69	1.57	2.17	2.18
H_2O+	.....	0.19	0.51	0.63	0.15	0.75	.....	0.14
H_2O-	0.08	tr.	.....	.....	.....	.....	.....	0.14
TiO_2	0.79	0.98	1.04	0.92	0.63	0.62	1.00	1.01
MnO	0.15	0.10	0.11	0.08	0.16	0.10	.....	0.09
	99.74	100.46	99.78*	99.99†	100.09‡	99.82‡‡	99.62	100.53
Q	34.92	40.62	42.62	41.90	40.30	41.69	41.64	37.86
Or	14.46	13.49	11.23	10.89	10.00	9.28	12.79	12.79
Ab	16.77	10.25	14.08	13.48	13.72	14.23	12.58	6.29
An	17.51	17.00	14.66	16.90	14.76	14.86	11.68	18.35
C	1.22	1.82	2.01	2.69	2.14	2.39	4.39	2.04
Hy	13.06	15.29	9.50	10.72	14.89	11.96	14.15	20.79
Mt	0.23		2.95	0.86	2.59	3.27	0.46	0.23
Il	1.52	1.86	1.98	1.75	1.20	1.18	1.98	1.98
Sp. gr.	.....	.....	2.431	2.436	2.439	2.442	2.457	.....
N_{Na}	.....	.....	.....	.....	.....	.....	1.5097	.....

41. 'II.3'.3.3. Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 193, 1932. Analyst, Raoult. Malaisie (échantillon Damour). Une analyse de l'une des grosses tectites de M. Scrivenor faite par Salter a donné des résultats á peu prés semblables, mais avec Al_2O_3, 14.30; CaO, 2.61; Na_2O, 1.16; K_2O, 1.90.

42. 'II.3.3'.3. Same reference as 41. Analyst, Raoult. Philippines, Rosario.
43. (1)II.3.3.3". Koomans, Cath. M., Leidsche Geol. Meded., Deel 10, Afl. 1, p. 70, 1938. Analyst, Koomans. Philippines, Busuanga. *Includes P_2O_5, 0.13.
44. (1)II.3.3".3". Same reference as 43. Analyst, Koomans. Philippines, Bulakda. †Includes P_2O_5, 0.10.
45. "II.3.3.3". Same reference as 43. Analyst, Koomans. Philippines, Rizal (Rizalite). ‡Includes P_2O_5, 0.18.
46. "II.3.3.3(4). Same reference as 43. Analyst, Koomans. Java. ‡‡Includes P_2O_5, 0.12.
47. II.3.3.3. Müller, F. P., Geol. Mag. dec. 6, vol. 2, pp. 206–211, 1915, Analyst, Hinden. Borneo, Brunei, Tutong Station.
48. II.3.(3)4.2'. Same reference as 41. Analyst, Raoult. Borneo, Martapoera.

	BILLITONITES AND ASSOCIATED TEKTITES—continued				AUSTRALITES			
	49	50	51	52	53	54	55	56
SiO_2	70.92	70.30	70.28	71.14	76.25	77.72	73.59	72.39
Al_2O_3	12.20	12.77	12.67	11.99	11.30	9.97	12.35	13.12
Fe_2O_3	1.07	0.53	0.21	----	0.35	0.32	0.38	0.42
FeO	5.42	5.43	5.28	5.29	3.88	3.75	3.79	4.48
MgO	2.61	3.74	2.62	2.38	1.48	1.59	1.80	1.87
CaO	3.78	2.37	3.92	2.84	2.60	2.40	3.76	3.17
Na_2O	2.46	1.73	1.71	2.45	1.23	1.29	1.03	1.54
K_2O	2.49	2.48	2.32	2.76	1.82	1.96	1.93	1.92
H_2O+	----	----	----	----	0.32	0.15	0.53	0.11
H_2O-	----	0.08	0.05	----	0.02	0.04	0.27	0.02
TiO_2	----	0.50	1.10	tr.	0.65	0.86	0.70	0.76
MnO	0.14	0.13	0.19	0.32	0.06	tr.	0.15	0.05
	101.09	100.21*	100.35	99.17	99.99	100.05	100.29	99.91
Q	31.56	36.11	35.49	32.13	52.14	52.62	46.92	43.56
Or	15.01	14.68	13.73	16.32	10.56	11.68	11.68	11.12
Ab	20.96	14.65	14.49	20.75	9.96	11.00	8.38	13.10
An	14.73	11.80	19.46	13.43	12.79	11.95	18.63	15.85
C	----	2.88	0.21		2.75	1.33	1.73	2.65
Hy	13.72	18.04	14.67	16.01	9.64	9.15	10.31	11.30
Mt	1.62	0.77	0.31	----	0.46	0.46	0.46	0.70
Il	----	0.95	2.04	----	1.22	1.67	1.37	1.52
Di	3.50	----	----	0.54	----	----	----	----
Sp. gr.	----	----	----	----	2.398	2.385	2.428	2.427
N_{Na}	----	----	----	----	----	----	----	----

49. "II.3(4).3.3(4). Suess, F. E., K. geol. Reichsanstalt Wien Jahrb., Band 50, heft 2, p. 237, 1901. Analyst, C. v. John. Java, Tebrung, Dendang.
50. II.3.3.3. Dittler, Emil, Centralbl. Mineralogie, Abt. A, pp. 214–219. 1933. Mine Dendang, Java. *Includes P_2O_5, 0.06; BaO. 0.01; S_2, 0.08; C, trace; GeO_2, 0.0005; Ga_2O_3, 0.001; Sc_2O_3, 0.005; Y_2O_3, 0.001.
51. "II.3".3".3. Lacroix, Alfred, Mus. nat. histoire nat., Archives, 6th ser., tome 8, p. 193, 1932. Analyst. Raoult. Mine Dendang, Java.

52. "II.3(4)."3.3". Verbeek, R. D. M., Jaarb. mijnwezen Ned. Indïe, Jahrg. 20, p. 240, 1897. Analyst, Brunck. Mine Dendang, Java.

53. I(II).(2)3.3.3. Summers, H. S., Royal Soc. Victoria, Proc., n.s., vol. 21, pt. 2, p. 425, 1909. Analyst, Ampt. Hamilton, Victoria. Minor constituents: NiO, 0.03; P_2O_5, CO_2, SO_2, Cl, Cr_2O_3, BaO, SrO, none.

54. I(II).(2)3.3.3. Summers, H. S., Royal Soc. Victoria, Proc., n.s., vol. 21, pt. 2, p. 425, 1909. Analyst, Ampt. Peake Station, n. Lake Eyre, South Australia. Minor constituents: NiO, P_2O_5, trace; CO_2, SO_2, BaO, SrO, Ce, none.

55. I(II).3.(3)4."3. Clarke, F. W., U. S. Geol. Surv., Bull. 228, p. 276, 1904. Analyst, Hillebrand. Pieman, Tasmania. Minor constituents: ZrO_2, 0.01; Li_2O, BaO, SrO, trace; CuO, trace (?); NiO, none.

56. (I)II.3.3.3. Summers, H. S., Royal Soc. Victoria, Proc., n.s., vol. 21, pt. 2, p. 425, 1909. Analyst, Ampt. Mount Elephant, Victoria. Minor constituents: NiO, 0.06; P_2O_5, CO_2, SO_2, Cl, BaO, SrO, none.

	AUSTRALITES, Continued					IVORY COAST TEKTITES		
	57	58	59	60	61	62	63	64
SiO_2	71.22	70.62	69.80	68.91	79.51	68.00	68.60	76.56
Al_2O_3	13.52	13.48	15.02	15.42	10.56	16.46	15.80	11.54
Fe_2O_3	0.77	0.85	0.40	0.40	0.60	......	0.18	0.17
FeO	5.30	4.44	4.65	4.86	3.11	6.08	6.46	3.99
MgO	2.38	2.42	2.47	2.49	1.35	3.38	2.88	3.60
CaO	3.52	3.09	3.20	3.88	1.48	2.00	1.40	1.62
Na_2O	1.48	1.27	1.29	1.20	0.91	1.45	2.35	1.32
K_2O	2.28	2.22	2.56	2.50	1.25	1.84	1.92	0.82
H_2O+	......	0.01	......	0.01	0.19	0.13	......	0.22
H_2O-	......	0.06	......	0.13	nil	0.14	......	0.07
TiO_2	......	0.90	0.80	0.08	0.63	0.80	0.80	0.60
MnO	0.28	0.42	0.18	0.08	0.06	0.09	0.06	0.08
	100.75	99.78	100.37	99.96	99.65	100.37	100.45	100.59
Q	38.04	41.40	38.28	36.36	62.16	38.71	35.52	54.08
Or	13.90	12.79	15.57	15.01	7.78	10.87	11.34	4.84
Ab.	12.58	11.00	11.00	9.96	7.34	12.35	19.92	11.17
An	17.51	15.29	15.85	19.46	7.51	9.95	6.94	8.06
C	2.14	3.37	4.18	3.57	5.00	8.42	7.29	5.51
Hy	15.64	12.96	13.46	14.78	7.76	18.28	17.60	15.17
Mt	1.16	1.16	0.70	0.70	0.70	......	0.26	0.25
Il	......	1.67	1.57	0.15	1.22	1.52	1.52	1.14
Sp. gr.	2.443	2.454	2.454	......	2.370	2.517	2.487	2.4
N_{Na}	......	......	......	......	......	1.5178	1.5146	1.4991

57. "II.3.3.3. Suess, F. E., K. geol. Reichsanstalt Wien Jahrb., Band 50, heft 2, p. 238, 1901. Analyst, C. v. John. Between Everard and Frazer ranges, Australia.

58. "II.3.3.3. Ann. Rept. Secretary Mines, Victoria, 1907, p. 63, 1908. Analyst, not stated. Coolgardie, West Australia. Minor constituents: SO_2, Cl, NiO, trace; P_2O_5, CO_2, none.

59. (I)II.3.3.3. Hillebrand, W. F., U.S. Geol. Surv., Bull. 228, p. 276, 1904. Analyst, Hillebrand. Upper Weld, Tindrift, Tasmania. Minor constituents: Li_2O, trace; BaO, SrO, none.
60. II.3.3.3. Summers, H. S., Rept., Australian Assoc. Adv. Sci., vol. 14, p. 190, 1913. Analyst, Mingaye. Uralla, New South Wales. Minor constituents: SrO, Li_2O, nil.
61. I.2.3.2. Summers, H. S., Rept., Australian Assoc. Adv. Sci., vol. 14, p. 190, 1913. Analyst, Ampt. Curdie's Inlet, Victoria. Minor constituents: Li_2O, slight trace; P_2O_5, CO_2, SO_2, Cl, NiO, BaO, CoO, nil.
62. II.3.3.3. Lacroix, Alfred, Acad. sci. Paris Comptes rendus, tome 199, pp. 1539–42, 1934. Analyst, Raoult. Akakoumoekrou, Ivory Coast.
63. II.3.2.(3)4. Lacroix, Alfred, Acad. sci. Paris Comptes rendus, tome 199, pp. 1539–42, 1934. Analyst, Raoult. Prés d'Ouelle, Ivory Coast.
64. ″II.2.3.4. Lacroix Alfred, Acad. sci. Paris Comptes rendus, tome 199, pp. 1539–42, 1934. Analyst, Raoult. Akakoumoekrou, Ivory Coast.

	LIBYAN DESERT GLASS 65	JAVA TEKTITE[a] 66
SiO_2	97.58	73.73
Al_2O_3	1.54	11.33
Fe_2O_3	0.11	0.83
FeO	0.23	4.46
MgO	tr.	2.39
CaO	0.38	2.49
Na_2O	0.34	1.15
K_2O	none	2.32
H_2O+	0.10	0.25
H_2O-	------	0.06
TiO_2	0.21	0.87
MnO	tr.	0.11
	100.49	100.18*
Q	94.78	
Or	0	
Ab	2.88	
An	1.89	
Hy	0	
Mt	0.15	
Il	0.40	
Sp. gr.	2.208	2.436
N_{Na}	1.4624	1.5091

65. I.1.3″.5. Clayton, P. A., and Spencer, L. J., Mineralog. Mag., vol. 23, pp. 501–508, 1934. Analyst, M. H. Hey. Libyan Desert, Egypt. Minor constituent: NiO, trace.
66. Heide, F., Uber tektite von Java: Centralbl. Mineralogie, 1939, Abt. A., pp. 199–206. Analyst, P. Wagner. Solo, Java. *Includes P_2O_5, 0.19.

[a]This analysis was received too late to incorporate in the text and figures.

Inspection of these analyses reveals some facts that may be significant. Holmes (88) in a review of the chemical criteria of the parentage of metamorphic rocks gives the following criteria for suspecting a sedimentary origin. These criteria apply to detrital sediments and in particular to argillaceous types:

1. Excess of Al_2O_3 (corundum of the norm):
   Excess over 5 per cent—suspect a sedimentary origin.
   Excess over 10 per cent—almost surely of sedimentary origin.
2. $K_2O > Na_2O$, combined with $MgO > CaO$:
   These combined give a considerable degree of probability of a sedimentary origin.
3. Very great excess of SiO_2 (quartz of the norm):
   To count as evidence the excess should be greater than 50 per cent.

In Table VI criteria are applied to the several tektite groups.

Table VI. Application of criteria for sedimentary origin to tektites.

Sedimentary Criteria	Darwin Glass	Bediasites	Moldavites	Ivory Coast	Indochinites	Billitonites	Australites
5% excess of Al_2O_3 (norm)	X*	X		X			
10% excess of Al_2O_3		—					
$K_2O > Na_2O$	X	X	X	—	X	X	X
$MgO > CaO$	X	X		X			
Quartz, greater than 50%	X	X	X	—			

*X indicates compliance to a sedimentary origin and — indicates conflicting data.

From a chemical study alone there is a strong suggestion that Darwin glass, bediasites, and possibly the moldavites and Ivory Coast tektites are fused sediments. The indochinites, billitonites, and australites on this basis are most closely allied to the igneous rocks. As pointed out by Holmes, all these criteria must be applied with caution and with full examination of all other available facts. There are a few recorded igneous rock analyses which compare closely to some of the tektite groups. These are enumerated in Table VII in which the tektites are arranged according to the C.I.P.W. classification.

Table VII. Tektites tabulated according to C.I.P.W. classification showing for comparison the number of igneous rocks falling in each tektite group.

Tektites	C.I.P.W. Classification	No. Tektites	No. Igneous Rocks	Total	Per cent Tektites	General Type of Igneous Rock
Libyan Desert glass	I.1.3.5	1	3	8	62	Quartz veins
Darwin glass	I.1.1–2.1–2.	4				
Bediasites	I.2.1.3.	2	3	5	40	Greisen and nodules
Moldavite	I.2.2.2.	1	8	9	11	Quartz-mica rich granites
Australite	I.2.3.2	1	1	9	89	Felsite
Moldavites		7				
Moldavite	I.2.4.2.	1	0	1	100	----
Indochinite	I.3.2.3	1	96	97	1	Granites, rhyolites, and glasses
Moldavite	I.3.3.1.	1	0	1	100	----
Australites	I.3.3.3.	2	26	28	7	Granites and some glass
	I.3.4.3	1	2	3	33	Rhyolites and granite
Ivory Coast tektite	II.2.3.4.	1	0	1	100	----
Indochinite	II.3.2.3.	1	4	5	20	Granite types
Ivory Coast tektite	II.3.2.4.	1	2	3	33	Granite types
Indochinite	II.3.3.2.	2	1	3	67	Granite
Ivory Coast tektite	II.3.3.3.	1	6	43	86	Granite types
Indochinites		21				
Philippine Is. tektite		4				
Billitonites, etc.		6				
Australites		5				
Billitonite	II.3.4.2.	1	0	1	100	----
	Total	65	152	217	30	

The totals do not truly express the relative proportions of tektites and igneous rocks analyzed. The tektite analyses have been collected up to the present time, whereas the igneous rock analyses are those recorded through 1913. This table does show, however, that out of the many thousands of recorded igneous rock analyses, very few fall in the group occupied by tektites. Furthermore, it is seen that in 4 out of 15 tektite groups, no igneous rock of similar classification is present.

The type of igneous rock analyzed is indicated in the last column of the table. There is a preponderance of deep-seated rocks, some of which are extreme differentiation products and others of which are definitely altered through metamorphism. A few rocks belong to the intermediate zone, and a few are near-surface or surface rocks.

The main point brought out by this table is the scarcity of igneous rocks having a similar chemical composition to tektites and the scarcity of glassy rocks having a composition similar to tektites.

Various methods of diagrammatic representation have been used to portray analyses. Because of the large number of oxides involved it is impossible to portray composition graphically unless certain groupings are made or certain oxides are disregarded. Suess (197) and Dittler (43) used a triangular diagram representing the three oxides CaO, K_2O, and Na_2O.

This diagram has been amplified with the addition of MgO, which calls for four triangles representing the following groups of components: Na_2O–K_2O–MgO; Na_2O–K_2O–CaO; MgO–CaO–Na_2O; and MgO–CaO–K_2O. These are represented in figures 90 and 91. The bounded areas of these composite triangular diagrams are composed from 25 analyses of indochinites, 10 analyses of moldavites, 9 analyses of australites, 4 analyses of Philippine tektites, 4 analyses of Darwin glass, 3 analyses of Ivory Coast tektites, and 25 analyses of glassy igneous rocks taken from Iddings (90). Other analyses are represented by symbols for each analysis, and included are 2 analyses of bediasites, 1 analysis of Henbury glass, 1 of Wabar glass, 1 of a composite analysis of 371 sandstones used for building purposes, and 1 of a composite analysis of 51 Paleozoic shales. The last two analyses made by H. N. Stokes were taken from Clarke's "Data of Geochemistry" (31). The 25 analyses of acid igneous glasses are thought to be representative since they were selected by Iddings to represent the various rock types and ranges in composition.

The field of the igneous rocks in general is distinct from that of the tektites. One very noticeable overlap is that of the igneous field upon the Ivory Coast field on all four triangles. This overlap taken alone would suggest that the Ivory Coast tektites may be either of an igneous origin or that they are formed of a material little changed from that of an igneous rock. The igneous rocks also overlap a portion of the indochinite field on the Na_2O–K_2O–CaO triangle and a portion of the moldavite field on the MgO–CaO–K_2O triangle.

The similarity of the indochinites, australites, billitonites, and the Philippine tektites is well shown on the four diagrams by their overlapping positions. The moldavites, on the other hand, overlap other groups in only two of the triangles and are adjacent to four of the principal tektite groups in the other two triangles. Darwin glass is completely different from all other tektite groups and also

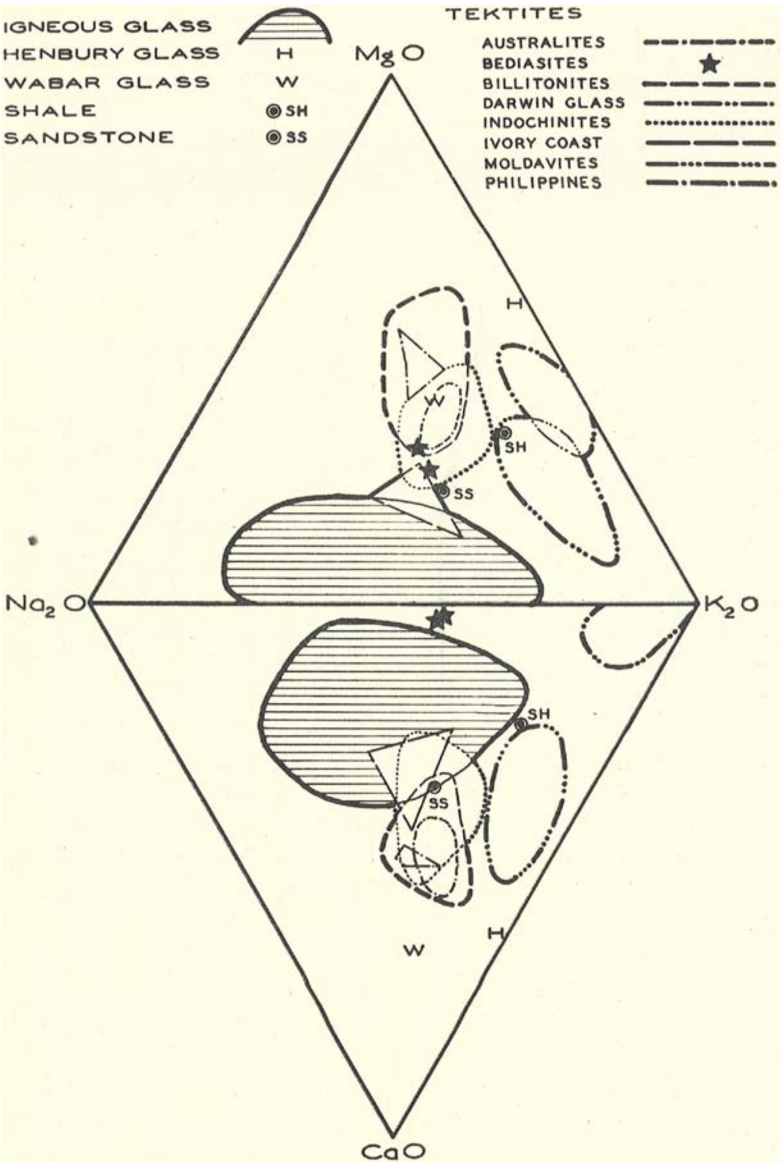

Fig. 90. Triangular diagrams using Na_2O–K_2O–MgO and Na_2O–K_2O–CaO to compare the tektite groups to the igneous glass group, two average sediments, and meteorite crater glasses.

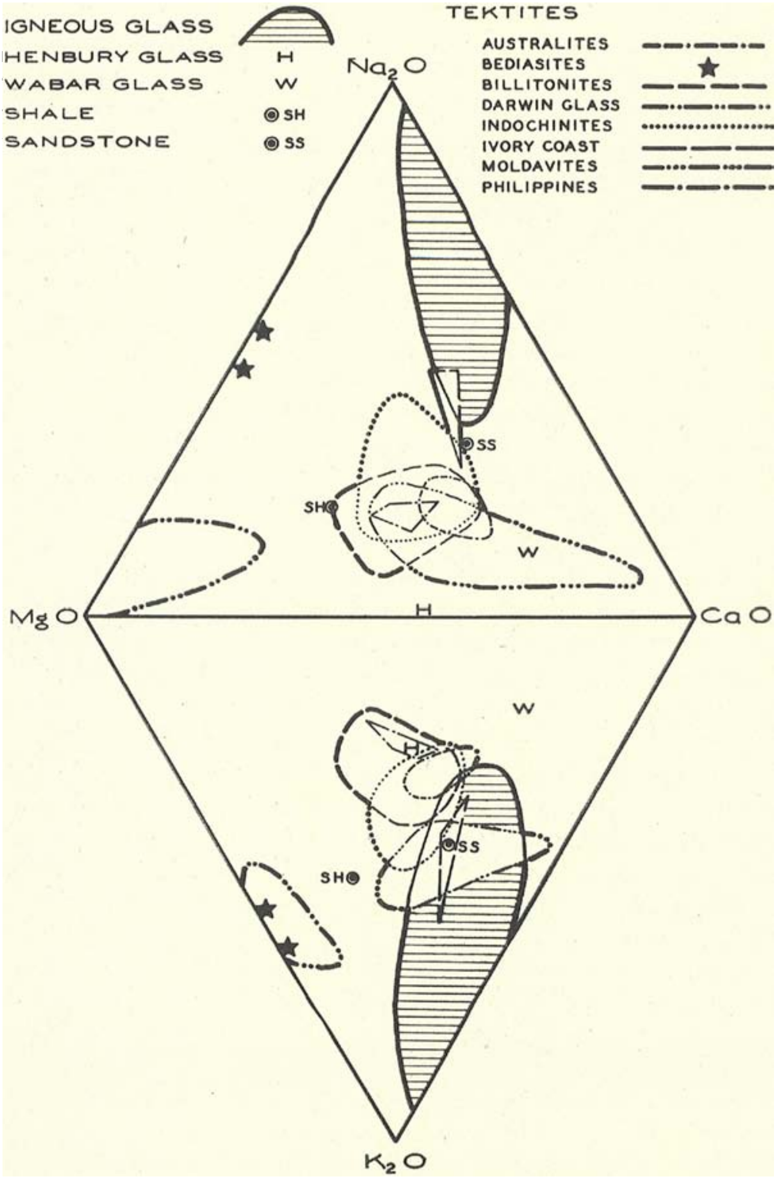

Fig. 91. Triangular diagrams using MgO–CaO–Na_2O and MgO–CaO–K_2O to compare the tektite groups to the igneous glass group, two average sediments, and meteorite crater glass.

occupies areas far distant from the igneous glass areas. The nearest approach in composition is to that of the moldavites. On one triangle, $MgO–Na_2O–K_2O$, there is a slight overlap. The bediasites are also unique and do not show any constant relationship throughout. On the $MgO–Na_2O–K_2O$ triangle they fall in the indochinite-billitonite-australite area; on the $MgO–CaO–K_2O$ triangle they fall in the Darwin glass area; and on the other two triangles they fall independent of any other group. The distinctive feature of the bediasites is the very low calcium which places them on the $Na_2O–K_2O–CaO$ triangle on the opposite side of the igneous area from the tektite area.

The points representing the analyses of Wabar and Henbury glass are, in general, farther removed from the igneous area than are the tektites. Only two points of the Wabar glass and one of the Henbury glass fall within the tektite area.

Tektites have always been compared to igneous rocks, and seldom has their relationship to sedimentary rocks been shown. To bring out their relationship to sedimentary rocks two analyses have been plotted, one of a composite analysis of 371 sandstones used for building purposes and the other a composite analysis of 51 Paleozoic shales. The close correlation of the tektites with these sediments is apparent. Furthermore, it is safe to predict that the analysis of any tektite yet analyzed can be duplicated by an analysis of a sedimentary rock.

A further comparison may be made between sediments and tektites by using these average analyses. These analyses were recalculated, disregarding volatiles, by the C.I.P.W. system. The average sandstone falls in the I.2.3.3 group, and the average shale falls in the II.3.2.2 group. An average of these analyses falls in the I.2.2.2. group. This average is the equivalent of a fused sandy shale or argillaceous sandstone. The sandstone group I.2.3.3. has only one classificatory correlative in Washington's compendium, namely, a granite. The sandstone group is also very close to the moldavite group I.2.3.2., which contains 5 analyses.

The shale group II.3.2.2 has three classificatory correlatives in Washington's compendium, namely, 2 granites and one dike rock. The Ivory Coast tektites probably come nearest to matching the average shale in composition. The sand-shale group I.2.2.2 represented by 8 igneous rocks contains one moldavite and is closely allied to the bediasites.

Another method of representation is used in figure 92, in which the oxides are grouped according to their valence, namely, as R_2O_3, RO, and R_2O, and the ratios shown. The RO_2 group is not used, since it is much the largest, and since any representation using this group would cause congestion in one corner of the diagram, it is advisable not to use it. In this diagram the various tektite

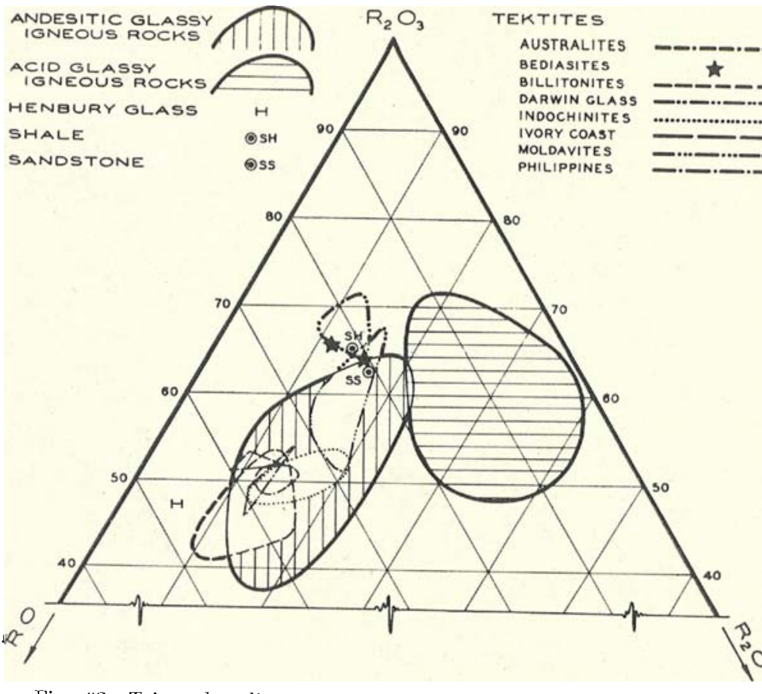

Fig. 92. Triangular diagram using R_2O_3–RO–R_2O to compare the tektite groups to andesitic glassy igneous rocks, acid glassy igneous rocks, Henbury glass, and two average sedimentary rocks.

groups are shown, as well as two areas of glassy igneous rocks. All of the tektites fall on the left half of the diagram and overlap to some extent, especially in the australite-billitonite-indochinite area. Also falling on this side of the diagram are 25 igneous rocks which are mostly andesitic pumice and andesitic ash. Included in this area are two andesitic obsidians, one perlite, and six pitchstones of andesitic, dacitic, or trachytic character. Even though this group of igneous rocks overlaps the tektite area there is a chemical difference that cannot be seen on this diagram. This difference is in the

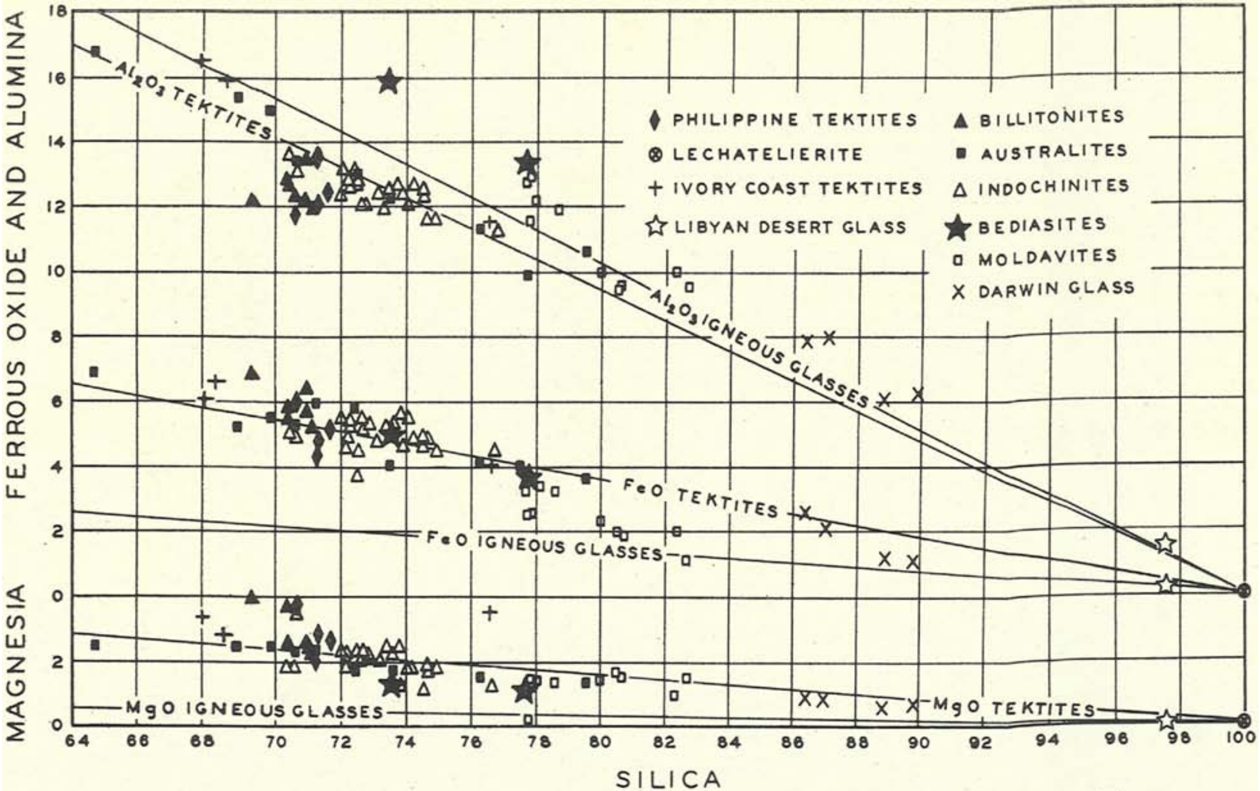

Fig. 93. Variation diagram of tektites and igneous glasses (alumina, ferrous oxide, and magnesia).

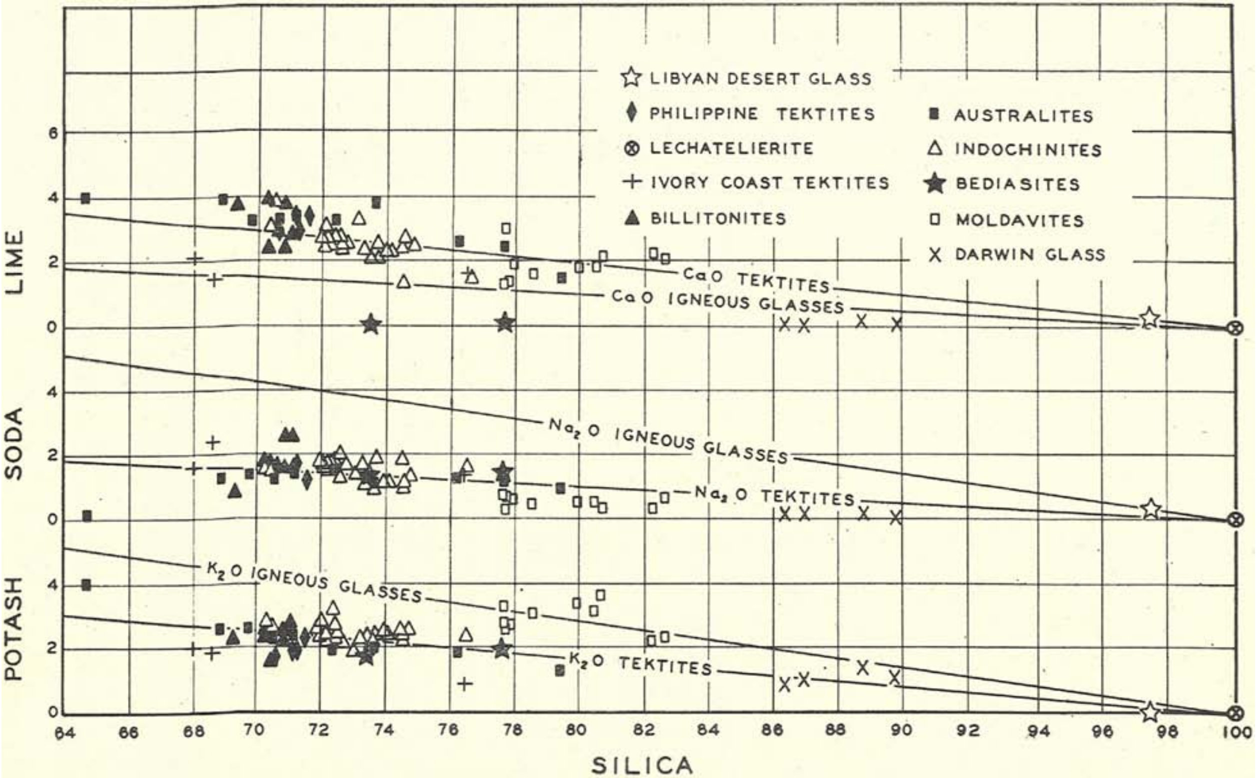

Fig. 94. Variation diagram of tektites and igneous glasses (lime, soda, and potash).

ratio of potash to soda. In all of the igneous glassy rocks represented, the potash content is less than the soda content, whereas in the tektites the opposite is true, with two exceptions. Two of the analyses of Ivory Coast tektites show less potash than soda. On the right half of this diagram is an area which represents 54 analyses of glassy igneous rocks. Included in these analyses are obsidian, perlite, pitchstone, and pumice chiefly of rhyolitic, dacitic, and trachytic character. This area is entirely distinct from that of the tektites and shows that there is a marked difference between the chemical composition of the tektites and that of the more acid glasses.

Variation diagrams have been used by Suess (197) and Summers (203) to show the relationship of the various tektite groups. A diagram of this type is usually constructed with one coördinate representing either the actual percentage of silica or the molecular number, which is obtained by dividing the actual percentage of silica by its molecular weight, and the other coördinate representing the percentages of other oxides or their molecular numbers. This has been done for all of the analyses in Table V, using actual percentages of the various oxides, and the results are shown in figures 93 and 94. In addition to all of the points used in the construction of these diagrams, a straight line is drawn from a point representing 100 per cent silica roughly through the center of the tektite field. The corresponding average line for the igneous glasses as derived from the analyses given by Iddings (90) is also placed upon the diagram. A difference is shown between tektites and igneous glasses in these diagrams. The Al_2O_3 difference is not great, perhaps being slightly higher in the igneous rocks. The FeO, MgO, and CaO content of the tektites is markedly higher than that of the igneous glasses, and Na_2O and K_2O are markedly lower in the tektites than in the igneous glasses.

The following discussion pertains to the variation line for the tektites and the distance of the various groups from this average line. The bediasites range much higher in Al_2O_3 than do the average tektite and are approached only by the moldavites and Darwin glass. These are counterbalanced by the billitonites and Philippine tektites which are somewhat low in Al_2O_3. The FeO line, which is a combination of all the iron oxides, passes centrally through all of the groups except the moldavites, which are remarkably low.

The MgO line passes through all groups, except that the billitonites and the Ivory Coast tektites are somewhat high. The CaO line shows the greatest departure for certain groups of any of the oxides. The bediasites and Darwin glass which are almost free of CaO are much below the average line. The Ivory Coast tektites are somewhat below the line, and the rest of the tektites are about average. The Na_2O line is above the moldavites and Darwin glass, and the K_2O line is below the moldavites and above the Ivory Coast tektites. Otherwise the various tektite groups are well balanced along these lines.

On figure 95, following the work by George (67), the indices of refraction and the specific gravities have been plotted against SiO_2 using the same SiO_2 scale as for the variation diagram figures 93 and 94. The curves for igneous glasses derived by George or modified from his curves are also shown. In each case the curve for the igneous glasses is lower than that for the tektites. Using these curves in conjunction with the variation diagrams, figures 93 and 94, the approximate composition of a tektite can be obtained by determining its specific gravity or its index of refraction. Having both determinations will make the results somewhat more accurate.

From all these comparisons of chemical compositions, and entirely from the chemical standpoint, the evidence points to re-fusion of sediments of a sand-shale composition to produce at least certain groups of tektites. Darwin glass, bediasites, and moldavites fall into this group of tektites. Undoubtedly if all the analyses of sediment were reviewed and adjusted for volatiles, at least one analysis would be found that would match any analysis of a tektite yet made, whether in the more acid moldavite group or the more basic billitonite group. The preponderance of analyses, however, would be near that of moldavitic composition.

As recently pointed out by Koomans (103), "Why should the material be supposed to have come from so great a distance, an hypothesis that cannot be verified, when products of the same chemical composition are to be found on earth?" Linck (119) noticed this similarity in composition to that of sediments and assumed that the tektites originated from a celestial body where clastic sediments occur. It is unfortunate that the glassy character of tektites has led most workers to compare them with igneous rocks and to overlook almost entirely the fact that they compare very closely to sedimentary rocks.

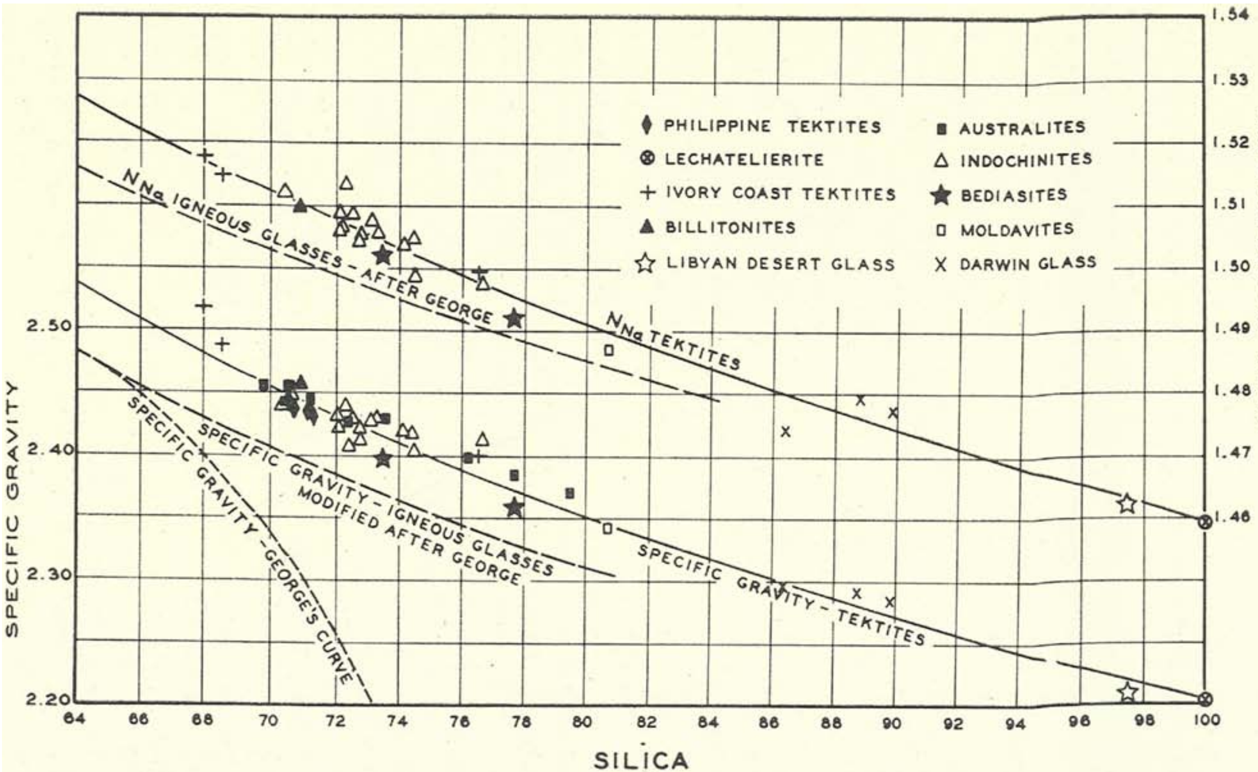

Fig. 95. Variation diagram of tektites and igneous glasses (index of refraction and specific gravity).

GAS IN TEKTITES

Some work has been done on the composition and amount of gas contained in tektites. The following work by Brun quoted by Beck (9) is taken from Suess (197). The results have been calculated for 1 kg. of material at 14 degrees and 738 mm. of pressure.

	BILLITONITE	MOLDAVITE
A. Solid sublimates obtained in the apparatus.		
NH_4Cl	5 mg.	KCl and chloride—Trace (?)
(Na,K)Cl	60 mg.	
B. Gas		
CO_2	98.0 cu. cm.	30.0
CO	100.4 cu. cm.	110.0
H	29.2 cu. cm. (14.22*)	35.0
N	trace	-------
SO_2	0.4 cu. cm.	-------
H_2S	absent	-------
O	absent	-------
Total	228.0 cu. cm. (213†)	175.0

*Correction for H evolved by platinum tube
†Calculated from one kg.

Doring and Stutzer (45) give the composition and amount of gas contained in a Colombian glass and in a moldavite as determined by Professor Henrich and also cite the composition of gas from a billitonite as determined by Brun. These determinations, given as volume percentages, are as follows:

	COLOMBIAN GLASS	MOLDAVITE	BILLITONITE
CO_2	27.1	12.6	46.00
CO	24.4	33.1	47.13
H_2	35.3	41.1	6.66
CH_4	2.2	trace	
O_2	1.1	0.6	

In the Colombian glass 8.3 ccm. of gas at 0° C. and 760 mm. was obtained from a 10-gm. sample, and in the moldavite 7.9 ccm. of gas was obtained from a 12-gm. sample. On the basis of the gas composition and content, the South American glasses may be tektites, even though their chemical composition is remarkably similar to that of an igneous rock.

These gases do not compare at all in composition with those found in igneous glasses nor is there nearly so large an amount of gas in the tektites as in the igneous glasses. The preponderance of gas present is CO_2 and CO. CO_2 is an abundant soil gas. When

CO_2 is heated it decomposes into CO and oxygen. If some of the oxygen escapes or is consumed, for instance, through oxidation of iron, then, upon cooling, CO as well as CO_2 would remain. Nitrogen should be more abundant if these gases are from fused sediments. Lacroix (111) mentions that some nitrogen is present. Enough work has not been done as yet on the gas content of tektites to warrant definite conclusions. This phase of the work deserves further research.

ORIGIN OF TEKTITES

The development of thought on the origin of tektites has been traced to some extent in the historical section of this paper. Many people have contributed ideas during the past 150 years, some of which were without foundation and many of which may contribute to the final solving of the problem. The meteoritic origin is probably accepted now by more students of the subject than any other origin. This manner of origin is unsupported by direct observation of a tektite fall, and until a fall of tektites has been observed this origin is without final proof. The meteoritic origin has been widely accepted mainly because certain misconceptions have crept into the literature and have not immediately been pointed out.

A misconception introduced which has held up progress for at least 35 years is the attempt to compare tektites with igneous glasses. Because of the inability to find an igneous glass of a composition similar to that of the tektites, it was assumed that tektites do not compare in chemical composition to that of terrestrial rocks. During this time no one attempted to compare them with other terrestrial rocks, but one worker did notice the similarity between the composition of tektites and that of certain sediments. The meteoritic origin was so firmly established, however, that he postulated that the celestial bodies from which tektites were derived must have had sedimentary rocks upon them. Within the past 5 years many workers on this subject have become fully aware of the fact that tektites are very similar in composition to certain sedimentary rocks. The present work bears out this fact.

Another argument advanced in support of the meteoritic theory, which is widely quoted, is the great circle postulate based on the four occurrences of tektites known in 1927. These four occurrences—moldavites, billitonites, australites, and Darwin glass—are aligned along one great circle of the earth. This gave room for considerable latitude of conjecture, but, needless to say, it has injured the standing of the theory of meteoritic origin in view of facts since brought to light. Both the Ivory Coast tektites and the bediasites are far from this great circle.

Considering the large number of papers on tektites, several of which are in languages not usually encountered in scientific work, it is difficult to ascertain all of the known facts and to be sure of what is fact and what is supposition. Some of the postulated origins have been treated adequately by other workers.

An artificial origin, as has been already pointed out by Suess (194), Lacroix (111), Loewinson-Lessing (123), Novaček (140), and Oswald (142), is impossible. In the first place, tektites were known befoie man was able to produce temperatures sufficient to melt glass of this composition, and furthermore Novaček has compaied the analyses of tektites with those of artificial glasses and found that they do not agree.

That they might be volcanic bombs thrown off the moon, as postulated by Verbeek (221, 222) and accepted by Linck (121), is shown by Oswald (142) to be unlikely. The moon, because of its much smaller size, would have cooled far more rapidly than the earth, and the last outcasts of "moon volcanoes" must have fallen while the earth was young. One of the arguments by Linck to support this theory is the postulate by David, Summers, and Ampt (41) that all tektites are located on a great circle. This great circle, according to Linck, was supposedly the equator at the time tektites from the moon landed on earth. Lacroix (113) has described tektites from the Ivory Coast which are 40 degrees from this postulated great circle. La Paz (116a) has recently treated the great circle distribution of tektites from a mathematical viewpoint. The result is two great circles, neither of which passes near North America. It is safe to predict that many other tektite localities will be found within the next few years, and if great circles are postulated to take care of every additional locality, the result will be a meaningless maze of great circles. The great circle idea is founded on fallacies and unproven assumptions, namely, (1) that tektites are meteorites, (2) that they all arrived in the same swarm; (3) that they landed along an equatorial line; and (4) that no more tektite localities would be found except along this great circle. The first assumption is still unproven. The second is decidedly a fallacy since tektites along this line range in age at least from the Miocene to the Quaternary. The third assumption is conceivable but not necessarily correct, and the fourth has been shown to be incorrect by the finding of tektites in Africa and North America.

In support of the contention that tektites will be found in many other localities, the following excerpts from letters recently received by the author of this paper are given. Dr. E. P. Henderson, of the U. S. National Museum, in a letter dated December 21, 1938, states: "Recently one of these [tektites] has come to light in Georgia. . . ." Mr. Oscar E. Monnig, of Fort Worth, Texas, who visited the U. S. National Museum states in letter dated March 15, 1939: "They have one tektite from our mutual acquaintance, J. C. Melcher." (Mr. Melcher lives in Fayette County, Texas.) In the same letter, Mr. Monnig refers to the tektite from Georgia: "The color is fully translucent green, like moldavites. The shape is a symmetrical one, like a double convex elliptical lens. The weathering, or markings, are relatively fine, numerous, and cover the whole surface, but are not deep."

During March, 1939, the writer had the opportunity to examine three complete tektites and two sets cut from tektites allegedly found in Lee County, Texas. Lee County and Fayette County are located between Grimes and DeWitt counties, from which the tektites described in this paper have been obtained.

That tektites are aerial fulgurites formed by lightning fusing dust in cyclonic storms has been suggested by Gregory (73) and Chapman (30). Spencer (179) and Fenner (62) discredit this postulate. As pointed out by Spencer, "No one has picked up an aerial fulgurite after a storm."

Van Lier (219) has postulated that tektites have formed from gel masses that have resulted from the drying up of low areas which left small pools of highly concentrated silicious waters. Again, as with aerial fulgurites, if this can happen, why has no one ever seen a tektite in the process of formation?

The discussion concerning a terrestrial volcanic origin of tektites has been so voluminous that it seems worthwhile to enumerate only a few of the arguments. Most tektites have been found in areas far removed from a possible volcanic source connected with the present terrain, and, so far as can be determined, from a possible volcanic source in past periods at the time the sediments on which the tektites rest were laid down. Transportation of tektites by aborigines or, as postulated for australites, by emus cannot be supported in Texas where large birds have never been known and where the aborigines have left no trace indicating that they were aware of material of this nature.

Dunn (52) has postulated that the australites were formed from molten lava upon which rain has fallen, thus producing by the expanding steam glass bubbles to which blebs of glass adhered. These postulated bubbles with their attached blebs were supposedly carried by atmospheric currents, thus accounting for their wide distribution. Even if this were possible, no lava has been found to have the same composition. Probably the most conclusive proof against a volcanic origin is that the chemical composition of tektites has never been approached by that of an obsidian yet analyzed. A publication by Summers (203) treats this phase of the origin with great clarity. The present work supports Summers' conclusions.

Another group of postulated origins which has received very little attention includes fusion of natural materials by forest fires, by burning coal seams, by burning petroleum seeps, and by burning gas seeps. The great objection to all of these types of fusion is that no tektite has ever been found with recognizable detrital grains, whereas in every example of this type of material that has come to the writer's attention detrital grains are readily recognizable. Scrivenor (170) has also noted that tektites do not contain fused rock particles or sand. Among the glassy materials examined during the present study are glasses produced in the crater of a burning petroleum and gas well, fulgurites produced by lightning striking sand, and glass formed in a fire box of an oil-fed boiler. In the first two cases detrital grains are recognizable, and great porosity is present. In fulgurites no recrystallization is seen, but in the other two types recrystallization is abundant. Products produced by burning coal seams to the north of the bediasite area have been described by Lonsdale and Crawford (123a). Nothing similar to a bediasite glass was found. Burning forests probably do not create a sufficiently high temperature to produce a glass having the high melting point of bediasites.

Spencer (179, 180, 182, 183) has recently suggested that tektites are formed by the impact of meteorites fusing the surface rocks and splashing them outward into droplets which solidify. This postulate should receive careful attention, since glass is actually found about some of the larger meteorite craters. Several facts must be explained, however, before this origin can be accepted in its entirety. Among these is the absence of meteorites and meteorite craters in the vicinity of tektite localities and the absence of nickel in most tektites so far analyzed. As pointed out by Spencer, the glasses about the Wabar and Henbury craters contain appreciable nickel caused by the mixing of molten meteoritic material with the fused rocks. Most tektites, including the bediasites, are free from nickel, and the greatest amount recorded in any tektite yet analyzed is only 0.06 per cent nickel. With the meteorite impact hypothesis it is an inescapable fact that a border zone would exist in which products of fusion and detrital material would be mixed. No material of this type has yet been found in a tektite, unless the lechatelierite particles identified here for the first time can be so considered.

The theory that tektites are glass meteorites presents fully as many difficulties as does the meteoritic impact theory. The tektites are entirely different in composition from even the most siliceous stony meteorite. All known meteorites may be arranged into a well-defined chemical series, and if tektites are added to this same series an enormous gap is left between meteorites and tektites without an extraterrestrial representative. Suess (192–202), Lacroix (106–116), and Fenner (62–65e) are three of the most active supporters of this theory, and many other writers agree with them. Lacroix (111,114) has summarized the tektite question in recent papers, and his summary and conclusions are as follows:

I. Tektites are natural glasses, comparable to rhyolites, of monzonitic and shoshonitic character; they are exceptionally rich in total silica, as well as in free silica, and always contain at least a small quantity of free alumina. Always more potassic than sodic, they are distinguished from terrestrial volcanic glasses of analogous silica content by the proportion of iron, lime, and magnesia which they contain. They are much poorer in gas, CO_2 and CO dominating. They are also distinguished, from the physical point of view, by the complete absence of crystallization.

II. Tektites are known to occur only in fragments having, or having had, most often definite shapes (pears, teardrops, spheres, discs, rods, etc.); they are very often fractured, by reason of their state of strain.

III. The surface of tektites is always more or less carved out with deep and characteristic sculptures.

IV. Tektites are found only in a very few regions of the earth, but they are there distributed over vast spaces and at times in very large quantities. No relationship exists between their composition and that of the substratum upon which they lie. They are always found in alluvials of Quaternary or

Tertiary age, where they have been concentrated by the flow of superficial streams.

Conclusions I to IV are the result of concordant observations; they must be considered as definite facts.

V. Tektites are of extra-terrestrial origin. Their forms and their folded internal structure are of primary origin; they were formed on their journey through the terrestrial atmosphere from molten, viscuous matter raised to a high temperature.

VI. The tektite sculptures are of secondary origin, and were produced by chemical corrosion, effected in the alluvials where they are concentrated, and where their delicate sharp-edged decorations remain intact among the harder materials which surround them.

Conclusion V can only be demonstrated by observing a fall of tektites, a fact which has not been realized up to the present; conclusion VI up to the present depends upon experimental reproductions.

VII. From a geological point of view tektites belong to the extra-terrestrial rocks, homologous to granitic rocks, which constitute the principal material of the terrestrial crust, just as meteorites are homologous to the rocks constituting the depths of the earth.

VIII. However, contrary to meteorites which possess all of their principal lithologic characteristics from the moment that they enter the terrestrial atmosphere, tektites must have been formed in the latter by violent oxidation and at a high temperature, from a type of meteorite wholly metallic not directly proven in the intact state, composed essentially of silicon and of light metals, unstable in the presence of oxygen. Oxidation, which implys the evolution of an enormous amount of heat, must have caused the volatization of a part of the products of this reaction and have made of it another product, the spatters of which are tektites. They are entirely vitreous on account of their rapid cooling.

This last conclusion does not appear susceptible to direct demonstration.

The bediasites will now be discussed in the light of the review just given. Bediasites have been found in a localized area in Grimes County, Texas, which may be defined as an elliptical area about 10 miles long and 5 miles wide. The major axis of this area is in the same direction as the local drainage. The major axis lies almost parallel to the strike of the Jackson formation of Eocene age. The Jackson is composed of several members ranging from sandstone to shale in composition, containing locally petrified wood but no conglomerate. On the surface and above the Jackson old siliceous gravels are found, and associated with these gravels are the bediasites. Chemically the bediasites differ from all obsidian and all other tektites which have been analyzed. The chief difference from other tektites is an extremely low CaO content. Nickel is not present. The bediasites contain a small number of spherical bubbles and a small number of mostly elongated lechatelierite particles. They have a contorted flow structure and a surface which ranges from slightly roughened to very deeply etched. They vary in index of refraction from about 1.488 to about 1.512 and in specific gravity from 2.334 to 2.433. This variation is directly correlative with the chemical composition. The melting point of the bediasites is apparently higher than could be attained by any natural heat, except that from lightning, that from meteorite impact, and that caused by meteorites passing through the atmosphere. No bediasites were found with recognizable inclusions of rock material, unless the lechatelierite particles are to be so considered.

One bediasite has been found in DeWitt County, 130 miles southwest of Grimes County. Unless this find is substantiated by more finds in the same area, it must be looked upon as a possible case of transportation by man during the past 50 years. Notice has been received of two other localities in Texas, but as yet specimens have not been received from these localities.

Other relevant facts are as follows: No volcanic activity is known within many hundreds of miles of this locality during the time interval from the Jackson to the present. There is no evidence that aborigines transported this material. Similar gravels are found over wide areas elsewhere in the State, but bediasites, so far as the writer is aware, have not been found in them, with two possible exceptions, mentioned earlier in this paper. No meteoritic material has been found in this area, and no craters have been recognized. Coal, petroleum, and gas are found in, or adjacent to, this area. A salt dome underlies the western part of this area. Glasses examined which were formed by burning petroleum and gas contain detrital material and abundant bubbles. They are also partially recrystallized.

With this array of facts the following can be immediately eliminated: glasses formed by burning coal seams, burning petroleum and gas seeps, burning forest, volcanic activity, artificial processes, and meteorite impact. A volcanic origin from the moon, gels, and aerial fulgurites has been shown by others to be untenable.

This leaves two postulates to discuss, namely, that bediasites are meteorites or that they are fused sediments. Figure 83 is a map showing the area in which bediasites are known to have been found in Grimes County. This area is outlined by a smooth flowing line, and the result is an ellipse, or more nearly an egg-shaped area. If it were desirable to support the meteorite theory it could be concluded that a body traveling from the south-southwest shed tektites as it went. This preliminary outline of the area no doubt will be changed as the information increases. Furthermore, the two northernmost stars on this map represent a small number of bediasites. The more northern star represents a collection of bediasites obtained from two very old women who lived at one time near Lamb Spring; the other star represents a find made by Mr. Rice who at one time had a large collection picked up toward Carlos and Keith. It seems highly possible that these older collections were in part lost and the same bediasites were picked up again in these locations. If these localities were disregarded, the boundary would outline a nearly circular area. However, as can be noted by studying this map, the drainage is in the direction of the long axis of this ellipse, and any bediasites that may have been in a very local area to the north would have been widely spread to the south, especially when the length of time they have been here is taken into consideration. Furthermore, the fact is not established that these bediasites did not come from one of the lower Jackson beds and become distributed by stream action. In this area it is quite evident that considerable erosion has taken place since the older gravels were deposited and that the older gravels have been lowered and moved somewhat in the direction of drainage. One fact mentioned before that may be significant is the variation in sculpture from northwest to southeast in this area. The Coneley collection, which is represented by the most westerly star west of Keith, consists of 112 bediasites, practically all of which are rounded forms without deep sculpture. The Pyles collection of 164 bediasites and the Mabry collection of 100 bediasites, all of which were collected to the south of Keith, are predominantly sculptured, and many are deeply sculptured. There is always the possibility that a collector's eyes might become atuned to a certain shape and that one might overlook sculptured forms, whereas other collectors might overlook the non-sculptured forms. If, however, this is not true, this variation of sculpture is suggestive, to say the least. The formations strike about northeast-southwest, and if unsculptured bediasites were being derived from some bed in the Jackson formation they would be distributed in the direction of drainage. Those most recently excavated from the bed would be unsculptured, whereas those that have been exposed the longest and traveled the farthest would be the most highly sculptured. However, plates cut from smooth bediasites show that the flow structure is sharply truncated, indicating that much material has been removed. Whether these bediasites are derived from some bed in the Eocene Jackson formation or whether they are of Pleistocene age makes very little difference as to their ultimate origin, except that the presence or absence of a Jackson meteor crater could not very well be checked.

If the meteoritic theory is considered for the origin of the bediasites, several things must be explained, among which are the large number present in this limited area, whether these came from space as individuals or as one mass, whether their character changed after hitting the earth's atmosphere, and how material of such character could originally have been formed.

If one mass of glass entered the earth's atmosphere, very little fusion stripping could take place in the time available. The small amount of expansion, as shown by lack of fracture when a white-hot plate is plunged into water, suggests that explosions such as are common with stony meteorites could not happen. If the mass hit the ground it might be shattered, but in any event large fragments would remain. If, as has been suggested by Michel (132) and accepted by Suess (201), the material which entered the atmosphere was composed of elemental silicon, sodium, magnesium, and such easily oxidizable elements, then the formation of tektites could possibly be explained. The presence of lechatelierite particles would necessitate the presence of quartz particles in the original material. If material of this type has a common origin with that of meteorites, it would seem likely that elemental material other than iron, nickel, and a few more of the stable elements would be found at least in some of the more siliceous meteorites.

From the present study, certain relevant facts have been ascertained. Tektites contain lechatelierite particles, which are nothing more nor less than fused silica (quartz). Glasses formed by burning petroleum and gas wells where heat is maintained for a considerable time show some recrystallization as well as some unfused sand grains. Lechatelierite particles were found in glass formed by a broken power line which arced through the soil, and no recrystallization was seen. Lechatelierite particles were found in glass fused from shale in the electric arc. The presence of lechatelierite particles suggests that fusion was rapid, that the heat was very intense, and that cooling was rapid. Only three natural modes of rapid and intense heating combined with rapid cooling can be mentioned. These are rapid heating caused by meteorites passing through the earth's atmosphere, rapid heating due to large meteorites fusing the soil upon striking the earth, and rapid heating caused by lightning striking the earth. The first mode is incapable of being demonstrated and rests upon an insecure footing of postulates, many of which have been proven incorrect. The second mode will undoubtedly be found to account for certain of the tektites, but contributing evidence will support this origin such as the presence of nickel, association with meteorites, presence of meteorite craters, and presence of detrital fragments in some of the border phase glasses.

The last mode of formation postulated, namely, that of lightning fusing the soil, has many points in its favor and also has several points that are difficult to explain. The chief advantages of this origin is that there is no necessity for a basis of nebulous postulates for either the chemical composition or the mode of fusion. The material necessary for the formation of tektites is present on earth, and the mode of fusion can readily be seen on any unsettled day. The chief disadvantage to this origin is self evident. So far as the writer is aware, glass masses formed by lightning have not been found. All lightning-produced glasses so far recognized, except some of the glazed surfaces such as are reported on peaks of the Alps, are found in sand and are fragile, thin-walled tubes with detrital grains on the exterior.

To justify an origin by lightning almost as many unsubstantiated postulates would have to be made as for the meteoritic origin. The writer hesitates to enter this field of supposition by reason of the fact that the subject may be encumbered by some ideas which may be incorrect and which may cloud the issue for those who do not go deeply into the subject. If one accepts the lightning origin, the question arises as to why no one has found glasses formed from shales by lightning. It is possible that no one has thought about examining shale areas for these glasses. Another consideration must be taken into account. In wooded areas lightning mostly strikes trees or other vegetation with little chance of striking the ground directly. In a wooded area one would scarcely expect to find tektites being formed at present. In areas without vegetation the population is usually very sparse, and there is a chance that such glasses would be overlooked.

The composition of the sedimentary rocks also has a bearing upon the distribution of such postulated glasses. Limestone, if struck by lightning, would not be fused but would be calcined. Sand, as is well known, allows the lightning charge to penetrate, fusing tubes, some of which are several feet long. The lack of porosity in shales and clay is probably a factor mitigating against the development of tubes. It is possible that in shales the effect would be concentrated in a much smaller area with the production of masses of glass rather than tubes.

The chief stumbling block to the lightning origin of tektites, and probably the hardest to explain, is some of the definite shapes found in some tektites such as those of Australia and Indo-China. Some of these forms, however, were accidentally reproduced in Freestone County, Texas, by a broken power line which arced through a sandy soil. Apparently some of the molten glass was propelled into the air and assumed shapes similar to the pears, tears, flattened pears, spheres, and various deformed shapes of these tektites that are figured by Lacroix (111). Some of these forms were in the air sufficiently long to cool below the point where sand would adhere to them after coming in contact with the ground. These forms are the most symmetrical in shape. Those to which sand adheres are usually somewhat flattened. To each of these shapes a drawn-out filament is attached. In some of these the filament is curved as if the spurted glass were projected no more than an inch or so and the filament remained attached to the source, thus producing a graceful curving arc. Among this material are many filaments, some of which have swellings and thinnings which are suggestive of the development of the dumb-bell type of tektite. Another form developed is that of the plate, plaque, or tabular type in which the glass flowed along the surface, adapting itself to the surface irregularities but in general maintaining a thickness considerably less than its width. A few tubes were developed with glassy shapes at one end in the form of a torus. The size of holes through the torus varies widely. In two specimens the hole is entirely closed, and the form becomes more nearly that of a very oblate spheriod. These forms are the nearest approach to that of the Australian buttons but, needless to say, fall far short of having the button form. The length of time that it took to form this glass is unknown, but presumably the power line arced for an appreciable time, whereas lightning is almost instantaneous. The effects of lightning are, therefore, not entirely comparable with the effects produced by an arcing power line.

The presence of tektites above formations of very diverse character can easily be explained. Limestone rock from which tektites could not be directly formed contains other materials in addition to calcium carbonate. These materials are left behind as the limestone is dissolved during the course of time. The result is a residual mantle of clay which may be very low in calcium carbonate and which may be within the range of chemical composition found in tektites. In other words, even above limestone, materials exist from which tektites could be formed.

This discussion is not intended as a dogmatic endeavor to support an origin by lightning but is an endeavor to create enough interest to cause the investigation of all the terrestrial possibilities before accepting the meteoritic origin with all of its unproven and unprovable postulates. It is hoped that enough has been said that other persons will spend some time in search and thought and possibly in experimentation to determine if the objections, pointed out above, to an origin by lightning are valid. A line of research of interest would be the production of glass from some of the shales of the area in which bediasites are found, using quick methods of heating such as high intensity electrical current or an oxyacetylene torch. This should be followed by chemical analyses, specific gravity determinations, index of refraction determinations, and etching experiments to see if the typical tektite surface can be produced. Experimentation of this type may not settle the question beyond dispute, but the writer is of the opinion that much could be learned by this procedure. It is also hoped that careful observations will be made in the more arid portions of the world to see what the effect of lightning is upon shales and clays. So far as the writer is aware, the effect of lightning upon these materials has not been recorded. Lightning must strike these materials, and there must be some observable effect.

If tektites are meteorites, they should be preserved in formations throughout the geologic column. Glass is a durable substance and unlike meteorites would not be destroyed in a short time by oxidation. If, on the other hand, tektites are formed by lightning, they will always be formed on land, and the chances of these brittle glasses surviving transportation and being incorporated in most sedimentary formations is almost nil. Those few which might survive would be found only in conglomerates or in terrestrial deposits.

Spencer's meteorite splash origin, as mentioned before, is valid for the formation of certain glasses. Glasses of this type will be distinguished in general from most of those now included under tektites. These meteorite splashes should be given a distinctive name such as "impactites." This name was suggested by Dr. H. B. Stenzel.

The names pseudo-tektite and pseudo-americanite have been introduced into the literature. These names appear to be unnecessary since the materials to which they apply are definitely igneous glasses, some of which are of perlitic character. The material from Arizona listed by Koomans (103) as pseudo-tektites is probably perlite. The fact that they resemble tektites is not a legitimate reason for changing their name.

Lacroix (111), on the basis of the meteoritic origin of tektites, has proposed an expanded classification of meteorites as follows:

I. Meteorites
   - a. Holometallites
     - holosiderites (observed meteorites composed of stable metals.
     - microsiderites (assumed meteorites composed of unstable metals)
   - b. Sysiderites (metallic meteorites with some stony matter)
   - c. Sporado-siderites (stony meteorites with scattered grains of iron)
   - d. Asiderites (stony meteorites without metallic iron)

II. Tektites (formed by oxidation from holometallic microsiderites)

In this classification is the term microsiderite, proposed to cover the supposed source material of tektites. This is a purely hypothetical type of meteorite, never yet observed and postulated only on the insecure basis of tektites being meteorites. This classification should be held in abeyance until the origin of tektites is finally settled beyond dispute.

If, as practically all the evidence now indicates, tektites actually are proven to be fulgurites, then the word tektite should not be used for these objects but should be held in reserve in case a glass meteorite is ever found. Fulgurites formed from various materials might be designated by the material from which they are formed, such as sand fulgurites, clay fulgurites, and shale fulgurites. If tektites prove to be of so prosaic an origin, then locality names will lose their value except to designate certain types which are of value for ornamentation.

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PLATE 22

Photographs of moldavites, indochinites, billitonites, and Darwin glass illustrating characteristic forms and sculpture. Approximately natural size.

1, 2. Plaque and teardrop-like forms of moldavites.

3–5. Rounded forms of moldavites (after Suess).

6. Khum de Varin indochinite.

7. Kouang-tchéou-wan indochinite; fragment of bubble.

8–10. Pia Oac indochinites; elongated drops and fragment of a drop.

11. Lang-Bian indochinite, illustrating spalling (after Lacroix).

12, 13. Two views of a billitonite illustrating characteristically deep sculpture and flow structure (after Lacroix).

14. Darwin glass illustrating slaggy appearance (after Suess).

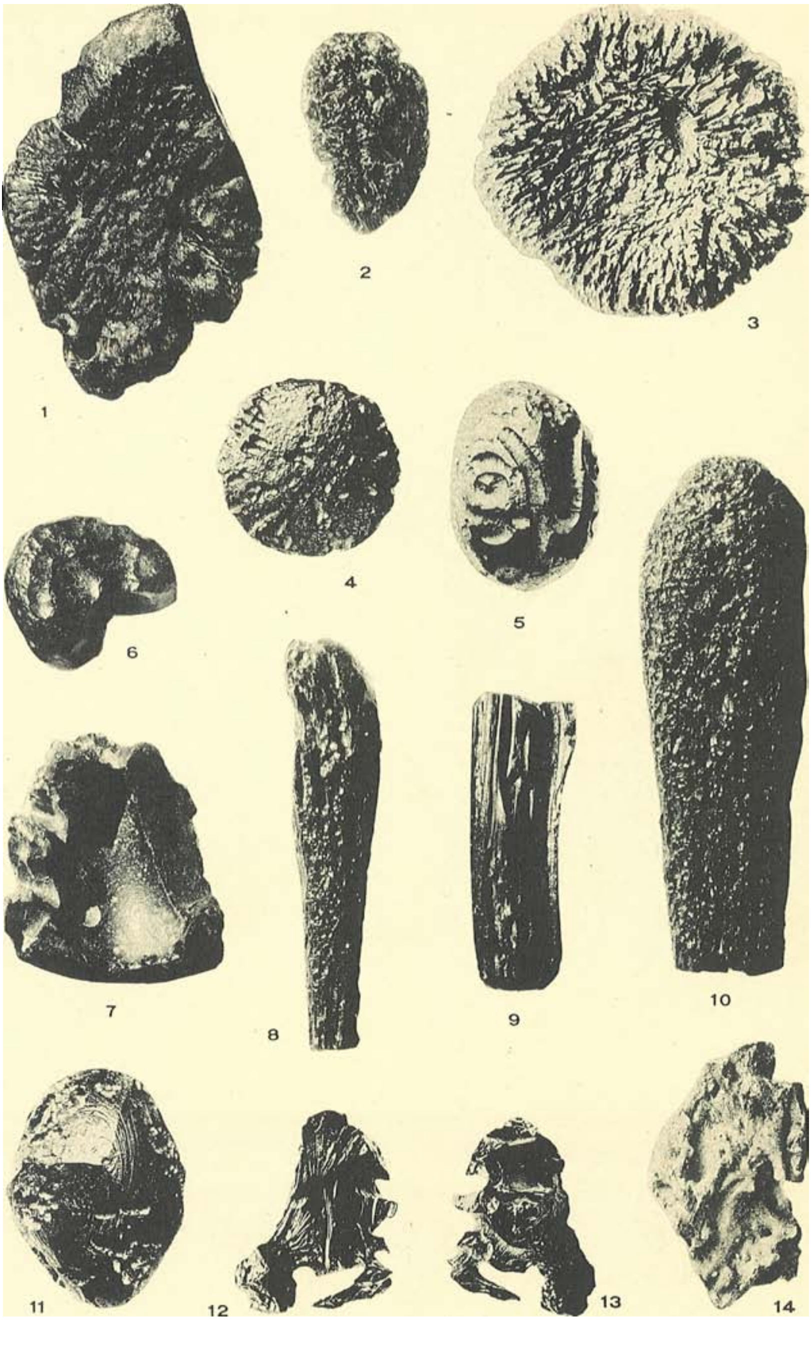
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PLATE 23

Photographs of bediasites (numbers correspond to those in Table I, pp. 499–500). Natural size.

21. U-shaped furrows.
26. Spherical bediasite with deep V-shaped furrows.
28. Deeply V-shaped furrowed and the most irregular bediasite found.
30. Deep V-shaped furrows, point to left formed by spalling.
31. DeWitt County lens-shaped tektite, U-shaped furrows.
37. Thin flake; may be a spall.
38. Spalled smooth surfaces at lower right.
43. Spalled slightly etched surfaces lower right; deep V-shaped furrows left.
46. Edge view of smooth lens.
48. Smooth with little surface sculpture.
52. Long cylindrical type.
53. Slightly etched form exhibiting lunar crater.

53a. Flow structure, in thick plate cut from No. 53.

55. Smooth type with large bubble.

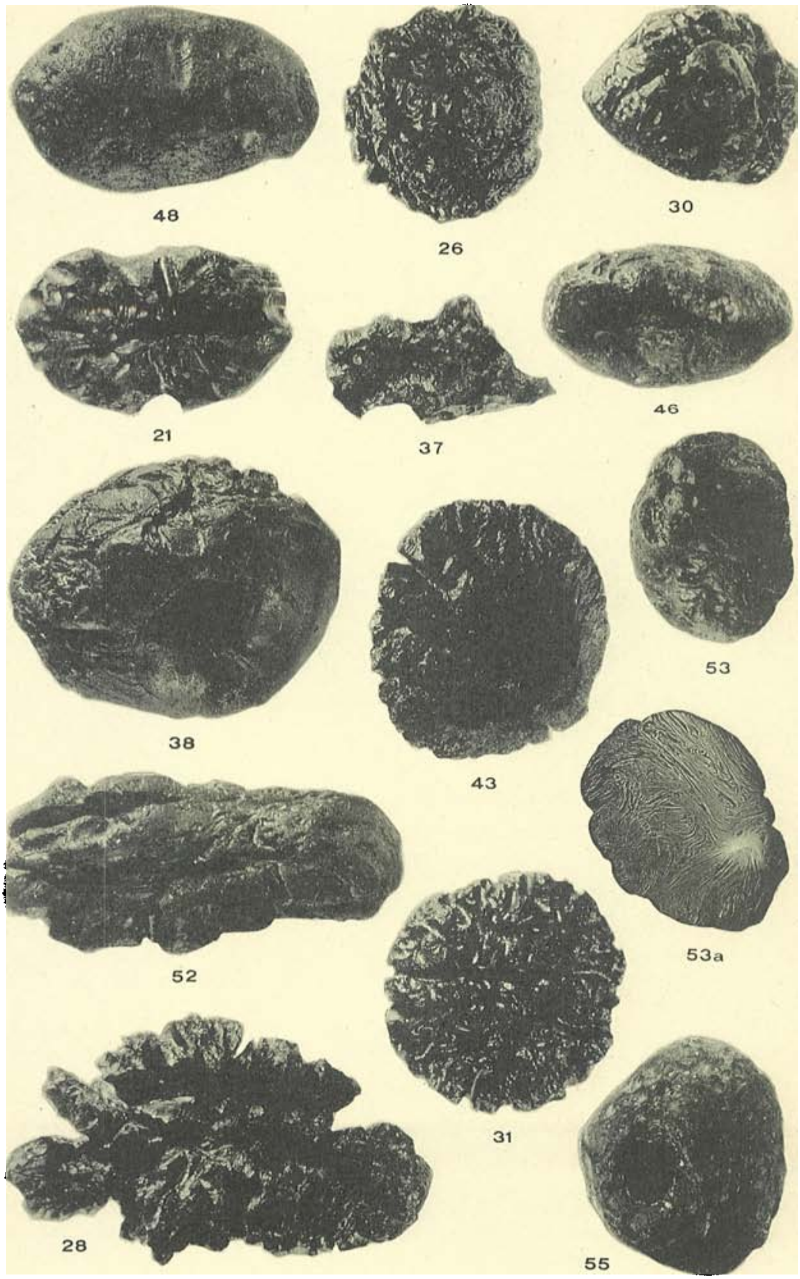
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PLATE 24

Photographs of bediasites coated with ammonium chloride to bring out surface features. (Numbers correspond to those in Table I, pp. 499–500). Natural size.

5. Long deeply pitted form.
80. Pear-shaped with well developed flow structure.
81. Spall fragment.
82. Smooth spall surfaces contrasted with deeply etched surfaces.
83. Smallest tektite in collection.
84. Long smooth form.
85. Spall fragment.
86. Largest tektite in collection; also most highly spalled.
87. Spall fragment illustrating excellent flow structure.
88. Smooth spherical type.
89. Gumdrop type.
90. U-shaped furrows.

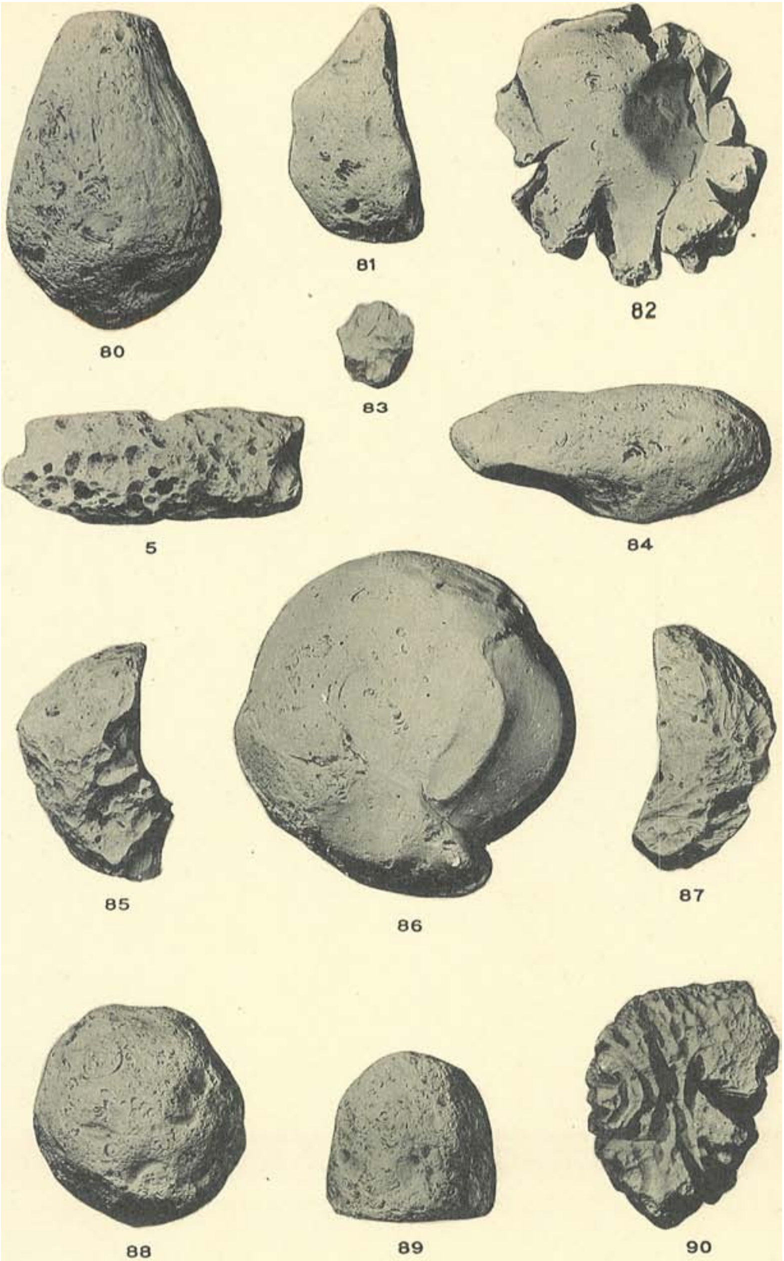
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PLATE 25

Photomicrographs of lechatelierite particles and bubbles in tektites. x70.

1, 2. Lechatelierite particles in indochinites. The black spherical objects are bubbles, some of which are included in the lechatelierite.

3. Lechatelierite particles in a bediasite.

4. Elongated lechatelierite particle in a bediasite parallel to the flow structure.

5. Hook-shaped lechatelierite particle and elliptical lechatelierite particle in a bediasite.

6, 7. Lechatelierite particle between crossed nicols illustrating nimbus quartered by brushes. Figure 7 is rotated 45° from the position shown in figure 6.

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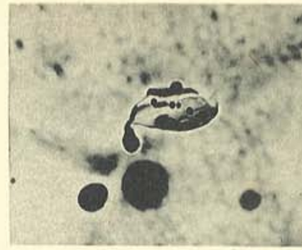

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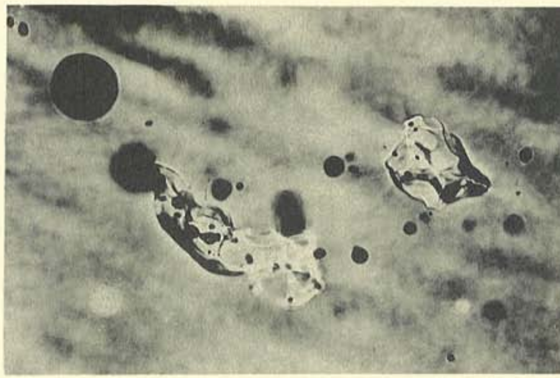

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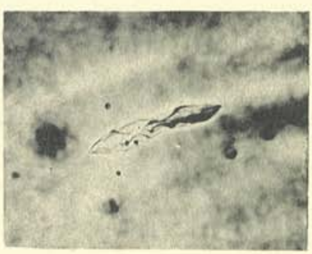

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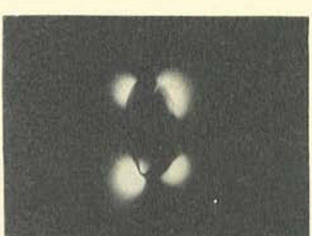

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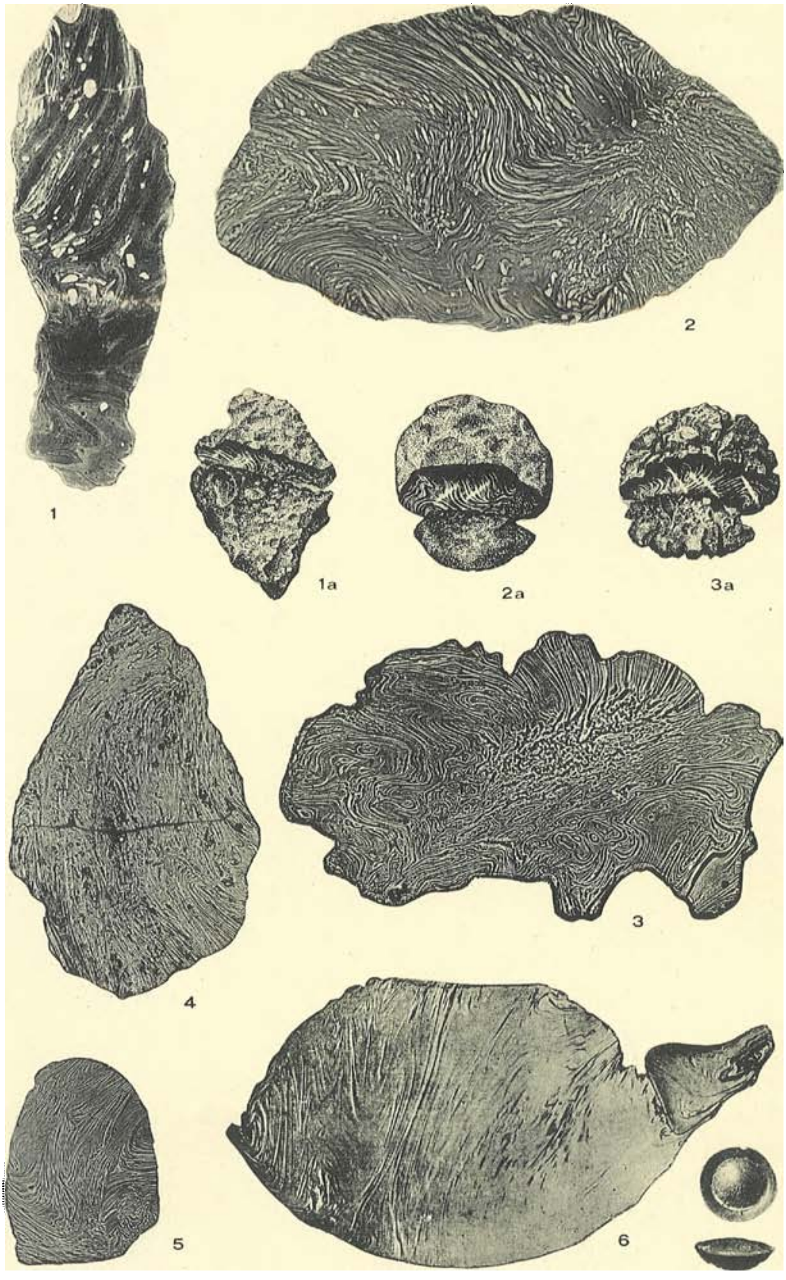
PLATE 26

Illustrations of flow structure in tektites, photographed by transmitted light.

1. Flow structure in a tabular bediasite. The white areas are globular masses of colorless glass, not present in any of the other sections examined. x2.
2. Flow structure in a smooth lens-shaped bediasite. x2.
3. Flow structure in a much corroded lens-shaped bediasite. x2.

1a, 2a, 3a. Sketches showing the shape of the tektites of which sections are represented by figures 1, 2, and 3. These sections illustrate sharply truncated flow structure which indicates that much glass has been removed.

4. Flow structure in a moldavite. The horizontal crack developed across a large lechatelierite particle and then slowly extended outward. x2.
5. Flow structure in an australite from Charlotte Waters. x2.
6. Flow structure in an Australian button (after Dunn). x9. The central large mass illustrates sharply truncated flow structure at the upper side and some indication of the flow structure's having been bent toward the left at the lower left side. The rim illustrates flow structure that is essentially parallel to the surface and shows that little material has been removed from this portion of the button. At the right are two views of an Australian button (after Fenner).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CATALOGUE OF TEXAS METEORITES

Virgil E. Barnes

Seventy meteorite falls have been found within the borders of Texas, and Texas now far surpasses any other state in the Union in the number of known falls. On the basis of the size of the State alone this should be true. In addition, much of the land surface is free of rocks and dense vegetation that might mask and hide meteorites. A factor mitigating against the finding of meteorites, however, is a sparse population in a large area of the State in which the surface conditions are the most favorable. A glance at the map, figure 96, shows that most of the meteorites have been found in the central and most heavily populated portions of the State. An exception to this is in the northwestern plains area of Texas where numerous finds have been made recently, chiefly due to the efforts of Dr. H. H. Nininger and Mr. Oscar E. Monnig. In the flat coastal plain area, no meteorites have been found, yet such centers of population exist as the Houston-Galveston area, the Beaumont-Port Arthur area, the Corpus Christi area, and the Brownsville area. Outside of the larger cities in this belt, however, much of the area is sparsely populated. A factor which probably contributes to the lack of meteorite finds in the coastal plain is the low relief and the lack of erosion. Many meteorites bury themselves to a depth greater than tillage will reach, and in an area of practically no erosion they are not uncovered. Another factor that may be operating in this area is the rapid destruction of the meteorites by salts blown inland from the Gulf. The most favorable area for locating meteorites in the future appears to be the more arid portions of west Texas where the vegetation cover is very sparse and where large areas are devoid of rocks. As the population increases in this area, many more meteorites should be found.

The University Centennial Exposition of 1936, which has culminated in a Texas Memorial Museum at The University of Texas, displayed the few meteorites that were available. Texas meteorites were very meagerly represented in the exhibit, and those available for display were the main masses of the falls known as Wichita County, Tulia, and small portions of Odessa, Deport, and Ballinger.

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To correct this deficiency, Dr. H. B. Stenzel, Supervisor for the Division of Geology of the Centennial Exposition, undertook to acquire more material. A complete iron of the Deport fall was

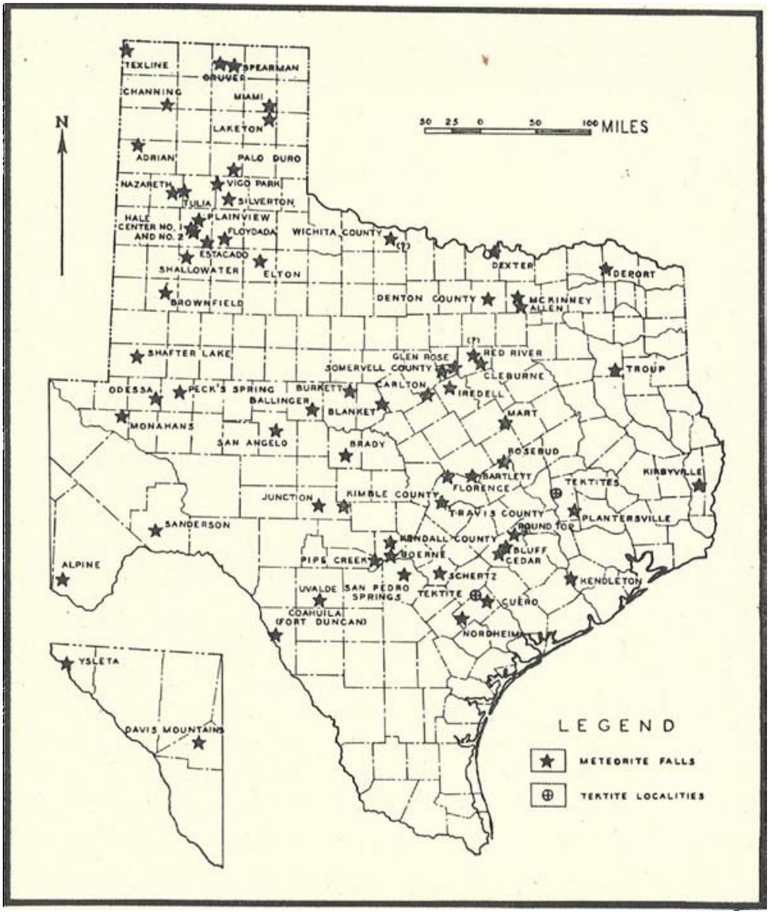

Fig. 96. Map of Texas showing the location of meteorite falls and tektite localities. (This zinc etching block for this figure was made prior to the discovery of the Concho and Ozona meteorites; hence their locations are not shown on the map.)

purchased, and since other more spectacular material was needed which was not available from described falls, Dr. Stenzel and his staff investigated all reports and rumors of meteorites about the State. As a result, the Nordheim iron was purchased, and the

Cuero stone was secured as a loan. The Cuero stone is now on deposit with the Bureau of Economic Geology.

During this same year, the Works Progress Administration started a mineral resource survey of the State by county units, sponsored by the Bureau of Economic Geology of the University. The supervisors of these surveys were instructed to inquire for meteorites and to investigate all rumors and all old falls in the areas in which they worked.

Mr. J. J. Sedlmeyer, supervisor of the Fayette County project, obtained two stony meteorites and located one other. One of these stones weighs 25 pounds and 7 ounces and is part of the Cedar fall described by Merrill.[1] The other two stones, one of which weighs 17 pounds and 1 ounce and the other weighing about 30 pounds, are parts of the Bluff fall described by Whitfield and Merrill.[2] Since these falls have already been described, only new data will be given here. The Cedar stone was donated to the Bureau of Economic Geology by Mr. C. Rainosek of LaGrange. This is the largest stone known of the Cedar fall. The 17-pound 1-ounce Bluff stone was donated to the Bureau of Economic Geology by Mr. Louis Hausmann of LaGrange. The other Bluff stone, except for one thin section in the collection of the Bureau of Economic Geology, has been acquired by the Texas Observers, of Fort Worth, Texas.

Mr. Sedlmeyer made very careful inquiries about the location where these meteorites were found as well as where those obtained in 1878 and 1890 were found. He marked these locations on a map which is reproduced as figure 97. Two discrepancies between this map and that published by Merrill[3] will be pointed out. The large Bluff stone found in 1878 by Rainosek was shown on Merrill's map to have been found where the present Cedar stone was found. Mr. Sedlmeyer traced the old find to another Rainosek whose property is located to the northeast and this find is designated as No. 1 on the map. The other discrepancy is the interchanging of the Knappe, No. 4, and Sanders, No. 5, localities. This point is unimportant since these two stones are of the same fall.

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[1]Merrill, G. P., On the Fayette County Texas, meteorite finds of 1878 and 1890, and the probability of their representing two distinct falls: U. S. Nat. Mus.. Proc., vol. 54, pp. 557–561, 1918.

[2]Whitfield, J. E., and Merrill C. P., The Fayette County, Texas, meteorite: Amer. Jour. Sci., 3d ser., vol. 36, pp. 113–119 1888.

[3]Merrill, G. P., *op. cit.*, p. 560.

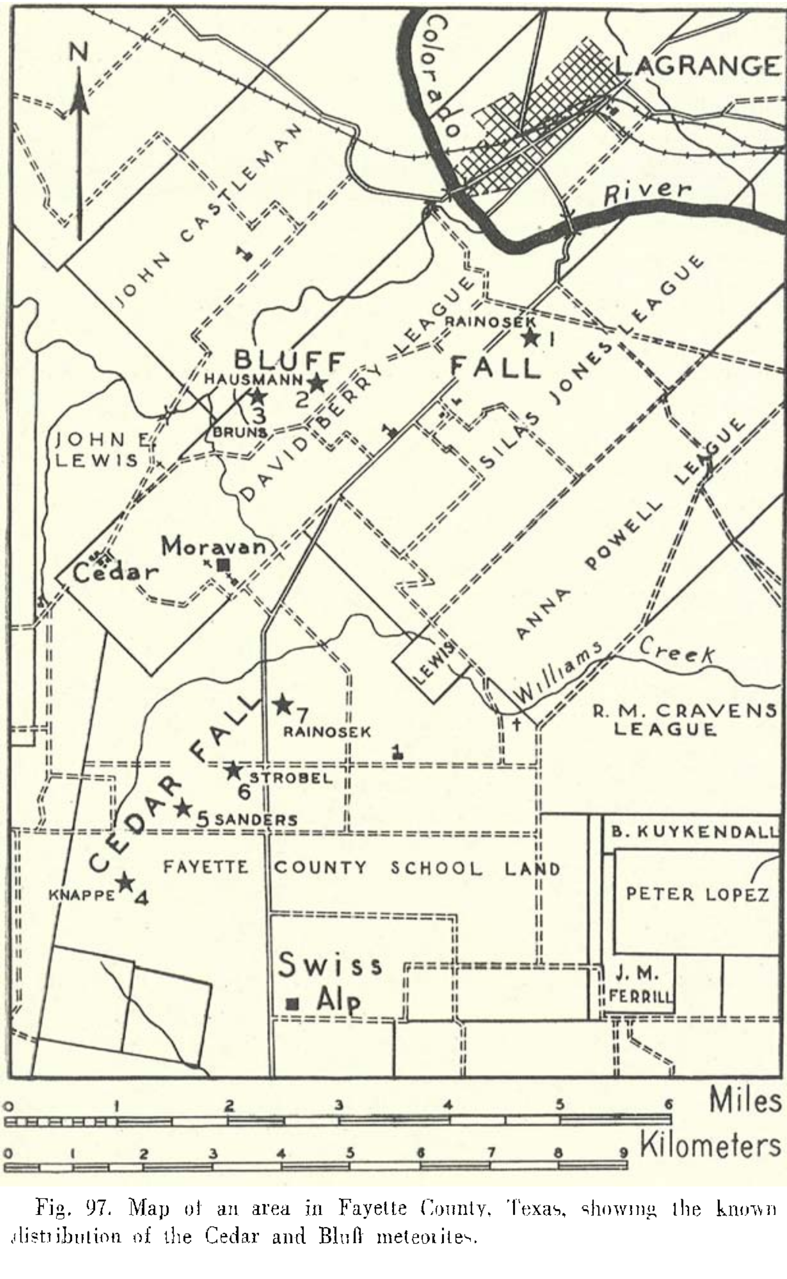

Fig. 97. Map of an area in Fayette County, Texas, showing the known distribution of the Cedar and Bluff meteorites.

The following list gives the locality number on the map, figure 97, and the stones found at each locality:

No. 1, Bluff (1878), Hensoldt find of 1888 (Rainosek); about 320 pounds
No. 2, Bluff, Sedlmeyer find of 1936 (Hausmann); 17 pounds, 1 ounce
No. 3, Bluff, Sedlmeyer find of 1936 (Bruns); 30 pounds
No. 4, Cedar, Melcher find of 1890 (Knappe); 16 pounds, 9¾ ounces
No. 5, Cedar, Melcher find of 1890 (Sanders); 2 pounds, 12 ounces
No. 6, Cedar, Melcher find of 1890 (Strobel); 12 pounds, 3½ ounces
No. 7, Cedar, Sedlmeyer find of 1936 (C. Rainosek); 25 pounds, 7 ounces

As the mapping of these finds now stands, each fall is grouped. The above information was obtained by Mr. Sedlmeyer before a thin-section study was undertaken and the identity of these stones determined.

In order that no mistake would be made in the identification of these stones, the thin sections made by Merrill of the Bluff and Cedar falls were borrowed from the U. S. National Museum for direct comparison. In the thin section of the Bluff (Hausmann) stone, black veinlets are present, which are entirely the same as those described by Merrill.

All three of these stones were found many years ago. The manner in which the Rainosek (Cedar) stone and the Hausmann (Bluff) stone were found is best expressed in the following excerpt from Mr. Sedlmeyer's report:

> One day while travelling on the old Flatonia-LaGrange road, I noticed a mail box of Henry Rainosek's. This man is a distant kin to the Bluff Rainosek. After talking and explaining the character of these stones to him, he remembered picking one up in a field on his father's place about 30 years ago. This old homestead is on the new Schulenburg-LaGrange highway 7 miles south of LaGrange. We went to his home that day and made inquiries of his father about this stone. The old gentleman could not remember a thing until a young woman told him in Bohemian (a language which I speak) that they had a very heavy rock that they had been using to hold sauerkraut in the barrel. I asked that I be allowed to see this rock. This is the No. 7 which you now have.
>
> Another day, coming from LaGrange, I cut back west just at the place where the original Rainosek stone fell and headed for the location where George Bruns found one which he now has in his possession. We stopped at Mr. Louis Hausmann's place and he told me that he had plowed up a stone like the one Bruns has about 40 years ago, but that it lay around the house and had been thrown around so much that he did not know just where it was. I asked permission for myself and my crew of men to make

a search. We found it in some weeds. He readily agreed to part with it and you now have it as No. 2. Mr. Hausmann is a pleasant old German—(German is a language I also speak)—and he told me all about the Rainosek stone.

George Bruns sent a fragment of his meteorite to the Bureau of Industrial Chemistry in 1917. Mr. J. E. Stullken[4] made a determination for iron and nickel and found 20.80 per cent and 0.28 per cent respectively, whereas the analysis by Whitfield and Merrill[5] for the Bluff stone shows 21.99 per cent and 1.78 per cent respectively.

A Works Progress Administration project in Gillespie County, on which supervision was furnished by both the University Centennial and the Bureau of Economic Geology, resulted in Mr. W. S. Strain's obtaining information about a meteorite in an adjoining county. This meteorite, a stone weighing 339 pounds, was secured in Kimble County and is described later.

In April, 1938, Mr. Glen Evans, supervisor of a Works Progress Administration mineral resource survey of Dickens County, obtained a 4.35-pound iron from Mr. E. T. Varnell of Route 1, Afton, Texas. Mr. Varnell presented this meteorite to the Bureau of Economic Geology. This iron has not been cut or examined in detail as yet, but, from an old fractured surface, it appears to be a medium octahedrite containing rather large troilite nodules. This iron will probably receive the name Elton from the village nearest to where it was found. This iron will be described as soon as funds are available for an analysis.

Included in the acquisitions for the 1936–1938 period are 483 tektites. Tektites probably are not meteorites, but since they have been so considered for a long time, they will be included in this paper. Mr. George Ramsey, supervisor of a Works Progress Administration mineral resource survey in Grimes County, brought these tektites to the attention of the personnel of the Bureau of Economic Geology during April, 1936. On May 21, 1937, Mr. C. J. Sigmund sent a tektite to the Bureau from DeWitt County.

Enough additional meteorite finds have been made since Monnig's list of 1934[6] was published that a new catalogue of Texas meteorites

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[4]Schoch, E. P. Chemical analyses of Texas rocks and minerals: Univ. Texas Bull. 1814, p. 256, 1918.

[5]Whitfield J. E., and Merrill, G. P., *op. cit.*

[6]Monnig O. E., Preliminary check list of Texas meteorites *in* The Geology of Texas, Vol. II, Structural and Economic Geology. Univ. Texas Bull. 3401, pp. 220–223, 1934 [1935].

is warranted. The following list is presented with as much significant information as can be obtained with the time and opportunity available.

A sketch map of the State, figure 96, is given to show the location of all the falls listed in the catalogue.

The writer wishes to express his appreciation to Dr. E. P. Henderson of the United States National Museum, Washington, D. C.; to Mr. Oscar E. Monnig of Fort Worth, Texas; and to Dr. H. H. Nininger of Denver, Colorado, for coöperation they have given toward completing this catalogue. They very kindly checked the lists which the writer prepared, making corrections and additions, especially of new meteorites in their possession which have not been previously recorded. Many other meteorite enthusiasts have furnished information. Two additional falls are recorded here for the first time by the permission of Dr. F. M. Bullard, of The University of Texas, and Mr. W. S. Strain, of the College of Mines and Metallurgy, El Paso. To all these people the writer wishes to express his appreciation and thanks.

CATALOGUE OF TEXAS METEORITES AND TEKTITES

The names adopted for the meteorites are printed in black type (bold-face); those in italics are synonyms. Under "specimens," an asterisk (*) before the weight indicates that the specimen has been exchanged. The Texas Observers Collection is in the care of Oscar E. Monnig, 312 West Leuda Street, Fort Worth, Texas.

METEORITES

Adrian, Deaf Smith County. (The town of Adrian is in Oldham County.)
Found: 1936.
Weight: One broken stone, 14 lb. (6.3 kg.); another stone, 36 lb. (16.3 kg.).
Stone. Chondrite.
Described: Not yet described.
Specimens: Mainly in Nininger Collection; U. S. Nat. Mus., 1077 gm.; Field Museum, 140 gm.

Allen, Collin County.
Found: About 1923. Recognized: 1938.
Weight: 3.1 lb. (1.4 kg.).
Stone. Chondrite, veined (?).
Described: Not yet described.
Specimen: Texas Observers Collection, 1409 gm.

Alpine, Brewster County; "Chico" Mountain.[7]

Found: 1915.

Weight: About 2 tons.

Iron. Nickel-poor ataxite.

Described: Merrill, G. P., U. S. Nat. Mus., Proc., vol. 61. art. 4. 4 pp., 2 figs., 1922. (Analyzed by J. E. Whitfield.)

Specimens: U. S. Nat. Mus., 173 gm.; rest on south side of "Chico" Mountain (Chisos Mountains).

Austin. See Denton County.

Austina. See Wichita County.

Avoca. See Tulia.

Ballinger, Runnels County.

Found: 1927.

Weight: 2.7 lb. (1.25 kg.).

Iron. Granular hexahedrite.

Described: Nininger, H. H., Jour. Geol., vol. 37, pp. 88–90. 1929. (Analysis by F. G. Hawley.)

Specimens: U. S. Nat. Mus., 470 gm.; Bureau of Economic Geology, The University of Texas, 80 gm.; Harvard Min. Mus., complete slice; Am. Mus. Nat. Hist., 73.4 gm.; Field Museum, 53 and 70 gm.; Nininger Collection, 120 gm.

Bartlett, Bell County.

Recognized: 1938.

Weight: 18.94 lb. (8.59 kg.).

Iron. Octahedrite.

Described: Not yet described.

Specimen: Dept. of Geology, The University of Texas.

Blanket, Brown County.

Fell: 10:30 P.M., May 30, 1909.

Weight: 11.25 lb. (5.1 kg.).

Stone.

Described: Not yet described. Two stones figured in Catalogue of Meteorites of the Field Museum, 1916.

Specimens: Field Museum, two stones, 1557 and 1516 gm.: U. S. Nat. Mus., 1 stone, 1815 gm.; Nininger Collection, 185 gm.; Texas Observers Collection, 75 gm.

Bluff, Fayette County.

Found: 1878.

Weight: 320 lb. (145 kg.), find of 1878. Two additional stones since found, about 30 lb. (13.5 kg.) and 17.1 lb. (8 kg.).

Stone. Veined or brecciated, crystalline hypersthene-chondrite.

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[7]Mr. R. W. Miller, supervisor of a unit of the Works Progress Administration paleontologic-mineralogic survey sponsored by the Bureau of Economic Geology, has seen the main mass of this meteorite upon two different occasions. It is located in Juniper Canyon of the Chisos Mountains of southern Brewster County, about 80 miles south of Alpine. There is a possibility that this meteorite is now covered by talus and will not be relocated.

Described: Whitfield, J. E., and Merrill, G. P., Amer. Jour. Sci., 3d ser., vol. 36, pp. 113-119, 1888. (Analysis by J. E. Whitfield.)

Specimens: British Museum, 12,401, 132, and 6 gm.; Field Museum, 10,985, 2934, 5556, 7483, and 8619 gm.; Amer. Mus. Nat. Hist., 1108.3, *415, *347, 12,318, 48.8, 3176, 194.7, 121.3, 80.6, and 18.3 gm.; Bureau of Economic Geology, The University of Texas, 8 kg.; Vienna Nat. Hist. Mus., 258 gm.; Univ. of Minn. Mus., 7.25 kg.; U. S. Nat. Mus., 8953 gm.; Harvard Min. Mus., 8040 gm.: Weidhaas Collection, 816, 32, and 28 gm.; Texas Observers Collection. 13.5 kg. and 174 and 5 gm.

Boerne, Kendall County.

Found: 1884.

Weight: 2.5 lb. (1.1 kg.) known. (Two stones said to have been found weighing 34 and 22.7 kg.)

Stone. Chondrite.

Described: Not yet described.

Specimen: U. S. Nat. Mus., 800 gm.

Borne. See Kendall County.

Brady, McCulloch County.

Found: 1937.

Weight: 2 lb. (0.9 kg.), one stone.

Stone.

Described: Not yet described.

Specimen: Nininger Collection.

Brazos. See Red River.

Brazos River. See Wichita County.

Brownfield, Terry County.

Found: 1937.

Weight: 0.72 lb. (325 gm.), two stones.

Stone.

Described: Net yet described.

Specimen: Nininger Collection; U. S. Nat. Mus., 25 gm.

Burkett, Coleman County.

Found: October, 1913.

Weight: 18.4 lb. (8.4 kg.).

Iron. Coarse octahedrite.

Described: Not yet described.

Specimens: Amer. Mus. Nat. Hist., 3071, 2773, 833, *826, *324, and 182 gm.; specimen in Nininger Collection; U. S. Nat. Mus., 823 gm.

Carlton, Hamilton County.

Found: 1887.

Weight: 179 lb. (81.4 kg.).

Iron. Fine octahedrite (Cohen: finest octahedrite).

Described: Howell, E. E., Amer. Jour. Sci., 3d ser., vol. 40, pp. 223–226, 1890. (Analysis by L. G. Eakins.)

Specimens: Field Museum, 3406, 3175, and 2721 gm.; Vienna Nat. Hist Mus., 7½ kg. (Brezina lists 131, 147, 413, 277, and 5 gm.); Harvard

Min. Mus., 3284 gm.; U. S. Nat. Mus., 1420 gm.; British Museum, 6180 gm. (Cohen lists Vienna, 6986 gm.; Ward, 5592 gm.; Chicago, 3406 gm., and Brezina, 500 gm.); Amer. Mus. Nat. Hist., 4256.9, *3853, 5570, 654.5, 52.3, *19.8, 9.5, and 4.5 gm.; Nininger Collection, 1305 gm.; Texas Observers Collection, 50 gm.

Carlton-Hamilton. See Carlton.

Cedar, Fayette County.

Found: 1890 or 1900.

Weight: Originally described, 3 stones, 16.6 lb. (7.53 kg.), 12.2 lb. (5.53 kg.), and 2.75 lb. (1.25 kg.). Find of 1936, 25.44 lb. (11.54 kg.).

Stone. Veined spherulitic chondrite.

Described: Merrill, G. P., U. S. Nat. Mus., Proc., vol. 54, pp. 557–561, 1918.

Specimens: U. S. Nat. Mus., 2.8 kg. of 5.53-kg. stone; Baylor University, Waco, Texas, 1.64 kg.; main mass Ward's Nat. Sci. Estab.; Bureau of Economic Geology, The University of Texas, 11.54 kg., one stone; Nininger Collection, slice.

Channing, Hartley County.

Found: 1936.

Weight: 33.75 lb. (15.3 kg.), one broken stone.

Stone.

Described: Not yet described.

Specimens: In Nininger and Gillespie Collections; U. S. Nat. Mus., 1528 gm.; Field Museum 623 gm.; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, 81 gm.

Chico Mountain. See Alpine.

Clarendon. See Palo Duro.

Cleburne, Johnson County.

Found: About 1907. Recognized: 1934.

Weight: 14.6 lb. (6.6 kg.).

Iron. Octahedrite.

Described: Not yet described.

Specimen: Texas Observers Collection.

Coahuila, Mexico (Fort Duncan, Maverick County).

Found: 1882.

Weight: 97 lb. (44 kg.).

Iron. Hexahedrite.

Described: Hidden, W. E., Amer. Jour. Sci., 3d ser., vol. 32, pp. 304–306, 1886.

Specimens: Vienna, 13,029 gm.; British Museum, 4520 gm.; v. Braun, 3025 gm.; Amer. Mus. Nat. Hist., 291 gm.; Vienna Nat. Hist. Mus. (Brezina reports) 99 and 183 gm.; U. S. Nat. Mus., 258 and 116 gm.; Harvard Min. Mus., 331 and 56 gm.; Field Museum, 104, 434, and 12 gm.; Nininger Collection, 383-gm. slice.

NOTE: This mass originally described as Fort Duncan is now considered as a portion of the Coahuila fall which includes such names as Bonanza iron, Butcher iron, and Sancha (Sanchez) Estate.

Collin County. See McKinney.

Concho, Glasscock County.

Recognized: 1939 (original discovery date unknown).

Weight: 206 lb. (93.5 kg.).

Stone. Chondrite.

Described: Not yet described.

Specimen: Bureau of Economic Geology, The University of Texas.

Cross Timbers. See Red River.

Cuero, DeWitt County.

Found: May 16, 1936.

Weight: 102.5 lb. (46.5 kg.).

Stone. Very dark green, veined or brecciated, spherical hypersthene-chondrite.

Described: Barnes, V. E., Univ. Texas Pub. 3945, pp. 613–622, 1939 [1940]. (Analysis by F. A. Gonyer.)

Specimen: Bureau of Economic Geology, The University of Texas.

Cut Off. See Schertz.

Davis Mountains, Jeff Davis County.

Found: 1903.

Weight: 1520 lb. (690.9 kg.).

Iron. Medium octahedrite.

Described: Farrington, O. C., Field (Col.) Mus. Nat. Hist., Pub. 178, g.s., vol. 5, no. 1, pp. 4–9, 1914. (Analysis by H. W. Nichols.)

Specimens: Field Museum, 689,460 and 460 gm.; British Museum, 41 gm.; Amer. Mus. Nat. Hist., 27.5 gm.; U. S. Nat. Mus., 28 gm.; Nininger Collection, slice.

Denton County.

Found: About 1856.

Weight: Probably about 40 lb. (18 kg.). Recovered about 12 lb. (5.4 kg.).

Iron. Medium octahedrite.

Described: Shumard, B. F., Acad. Sci. St. Louis, Tr., vol. 1, pp. 622–624, 1860. (Analysis by W. P. Riddell.)

Specimens: British Museum, 122 gm.; Amer. Mus. Nat. Hist., 13 gm.; U. S. Nat. Mus., 7.97 gm.; Harvard Min. Mus., 49 gm.; Field Museum, 3, 25, and 17 gm.; main mass removed without authorization many years ago from a Texas State museum collection and present location unknown.

Deport, Red River County. (The town of Deport is in Lamar County. The meteorite was found just across the county line in Red River County.)

Found: 1926 and later. Recognized: 1932.

Weight: At least 90 irons totaling over 66 lb. (30 kg.).

Iron. Coarse octahedrite.

Described: Palache, Charles, and Gonyer, F. A., Amer. Min., vol. 17, pp. 357–359, 1932. (Analysis by F. A. Gonyer.)

Specimens: Texas Memorial Museum, Austin, 776 gm., one complete mass; Bureau of Economic Geology, The University of Texas, one mass, 1100 gm.; Harvard Min. Mus., 2- and 6 lb. masses; U. S. Nat. Mus., 5783 gm.; Field Museum, 315 gm.; Texas Observers Collection, 65 pieces, total weight 14.3 kg.; Nininger Collection, 2661 gm.

Dexter, Cooke County.

Found: 1889.

Weight: 3.8 lb. (1724 gm.).

Iron. Coarse octahedrite.

Described: Mentioned by Reeds, C. A., Amer. Mus. Nat. Hist., vol. 73, art. 6, p. 556, 1937.

Specimen: Amer. Mus. Nat. Hist., entire mass.

Elton, Dickens County.

Found: About 1936. Recognized: April, 1938.

Weight: 4.35 lb. (1.973 kg.).

Iron. Probably medium octahedrite.

Described: Not yet described.

Specimen: Bureau of Economic Geology, The University of Texas, Austin.

Estacado, Hale County. (The town of Estacado is in the northwest corner of Crosby County. The meteorite was found in the southeast corner of Hale County.)

Found: 1883.

Weight: One stone, 640 lb. (290 kg.); another stone, 270 lb. (122.5 kg.).

Stone. Crystalline bronzite-chondrite.

Described: Howard, K. S., and Davison, J. M., Amer. Jour. Sci., 4th ser., vol. 22, pp. 55–60, 1906; also Amer. Jour. Sci., 4th ser., vol. 21, p. 186, 1906. (Analysis by J. M. Davison.)

Specimens: Field Museum, 103,200 and 15,402 gm.; British Museum, 17,103 gm.; Amer. Mus. Nat. Hist., 122.5 kg., 419.6 and 148.2 gm.; U. S. Nat. Mus., 9.9 kg.; Harvard Min. Mus., 17,800 and 230 gm.; Nininger Collection, 13,750 and 1085 gm.; Texas Observers Collection, 802, 380, 71, and 43 gm.

Fayette County. See Bluff and Cedar.

Florence, Williamson County.

Fell: About 8 P.M., Jan. 21, 1922.

Weight: 8.02 lb. (3640 gm.).

Stone. Gray breccia-like chondrite.

Described: Lonsdale, J. T., Amer. Min., vol. 12, pp. 398–404, 1927. (Analysis by E. V. Shannon.)

Specimens: U. S. Nat. Mus., 1405 gm.; Dept. of Geology, The University of Texas, one-half; Nininger Collection, 50 gm.

Floydada, Floyd County.

Found: 1938.

Weight: 27.8 lb. (12.6 kg.)

Iron. Octahedrite.

Described: Not yet described.

Specimens: Texas Observers Collection, 12.5 kg.; Nininger Collection, one fragment.

Fort Duncan. See Coahuila.

Gibb's Meteorite. See Red River.

Glen Rose, Somervell County.

Found: About 1934. Recognized: 1936.

Weight: About 24½ lb., one mass.

Iron.

Described: Not yet described.

Specimen: Texas Observers Collection.

Glen Rose iron. See Glen Rose.

Glen Rose stone. See Rosebud.

(The name Glen Rose was used by mistake for Rosebud. "Glen Rose stone" should be dropped even as a synonym.)

Gruver, Hansford County.

Found: 1934.

Weight: 24.4 lb. (11.1 kg.).

Stone. Chondrite.

Described: Not yet described.

Specimens: Main mass in Nininger and Gillespie collections; Field Museum, 780 gm.; U. S. Nat. Mus.. 1107 gm.; Texas Observers Collection, 948 gm.

Hale Center No. 1, Hale County.

Found: 1936.

Weight: 1.53 lb. (695 gm.), one stone.

Stone. Chondrite.

Described: Not yet described.

Specimens: U. S. Nat. Mus., 188 gm.; specimen in Nininger Collection; Wichita University and the Bingham Collection have main masses.

Hale Center No. 2, Hale County.

Found: 1936.

Weight: 1.34 lb. (610 gm.), one stone.

Stone. Chondrite.

Described: Not yet described.

Specimens: U. S. Nat. Mus., 326 gm.; specimen in Nininger Collection.

Hale County. See Plainview.

Hamilton County. See Carlton.

Hill's Stone. See Travis County.

Iredell, Bosque County.

Found: June, 1898.

Weight: 3.3 lb. (1.5 kg.). Only about 0.5 kg. preserved.

Iron. Hexahedrite.

Described: Foote, W. M., Amer. Jour. Sci., 4th ser., vol. 8, pp. 415–416, 1899. (Analysis by J. E. Whitfield.)

Specimens: Amer. Mus. Nat. Hist., 179.4 gm.; U. S. Nat. Mus., 99 gm.; Vienna Nat. Hist. Mus., 6 gm.; Field Museum, 11 gm.

Junction, Kimble County.[8]

Found: About 1932. Recognized: 1938.

Weight: 0.53 lb. (241 gm.), fragment.

Stone.

Described: Not yet described.

Specimen: Texas Observers Collection.

Kendall County.

Known: 1887.

Weight: 46.3 lb. (21 kg.).

Iron. Granular hexahedrite.

Described: Cohen, E., Meteoritenkunde, Heft 3, p. 241, 1905. (Analysis by Fahrenhorst.)

Specimens: Vienna, 10,702 gm.; Budapest, 582 gm.; British Museum, 556 gm.; Prague, 345 gm.; Paris, 270 gm.; Amer. Mus. Nat. Hist., 170.4, *44.5, *307, 368, *494, 629.5, 625, and 11.5 gm.; Vienna Nat. Hist. Mus., 299 gm.; U. S. Nat. Mus., 1165 and 767 gm.; Harvard Min. Mus., 494 gm.; Nininger Collection, 118 gm.; Field Museum, 118, 286, and 410 gm.

Kendleton, Fort Bend County.

Fell: 7.25 P.M., May 2, 1939.

Weight: Several pounds.

Stone. Gray chondrite, possibly brecciated.

Described: Account of fall given by Fouts, F. F., and King, J. J., The University of Texas Pub. 3945, pp. 657–664, 1939 [1940]. See also Monnig, O. E., The Sky, vol. 3, no. 10, pp. 6–7, 24–26, 1939.

Specimens: J. J. King, 1588 gm. (on display at Texas Memorial Museum); Texas Observers Collection, 12 stones. (Six additional stones are known.)

Kimble County.

Found: 1918. Recognized: 1936.

Weight: 339 lb. (153.8 kg.).

Stone. Dark greenish-gray, veined, crystalline hypersthene-chondrite.

Described: Barnes, V. E., Univ. Texas Pub. 3945, pp. 623–632, 1939 [1940]. (Analysis by F. A. Gonyer.)

Specimen: Bureau of Economic Geology, The University of Texas.

Kirbyville, Jasper County.

Fell: About 3.30 P.M., Nov. 12, 1906.

Weight: 0.21 lb. (97.7 gm.).

Stone. Achondrite (?).

Described: Not yet described.

Specimen: Texas Observers Collection.

LaGrange. See Bluff.

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[8]Mr. O. E. Monnig states: "This has not been cut or sectioned, but from an outside examination looks somewhat different from Kimble County. I believe it is distinct."

Laketon, Gray County.
Found: 1937.
Weight: 8 lb. (3.6 kg.), 2 fragments.
Stone.
Described: Not yet described.
Specimens: In Nininger Collection; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, 20.5 gm.

Lipan Flats. See San Angelo.

Louisiana. See Red River.

Mart, McLennan County.
Found: 1898.
Weight: 15.7 lb. (7.2 kg.).
Iron. Finest octahedrite.
Described: Merrill, G. P., and Stokes, H. N., Washington Acad. Sci., Proc., vol. 2. pp. 41–68, 1900. (Analysis by H. N. Stokes.)
Specimens: Baylor University, Waco, Texas, 3.74 kg.; British Museum, 430 gm.; U. S. Nat. Mus., 458 gm.; Amer. Mus. Nat. Hist., 202.4 gm.; Field Museum, 1132 gm.; Nininger Collection, 473 gm.

Maverick County. See Coahuila.

McKinney, Collin County.
Found: 1870.
Weight: 334 lb. (152 kg.). Two stones; larger one, 100 kg.
Stone. Black hypersthene-chondrite.
Described: Merrill, G. P., Amer. Jour. Sci., 4th ser., vol. 35, p. 520, 1913; also Nat. Acad Sci., vol. 14, mem. 4, pp. 5–6, 1919. (Analysis by J. E. Whitfield.)
Specimens: Field Museum, 52, 163, 2491, 2610, and 72 gm.; Vienna, about 40 kg.; British Museum, 999 and 290 gm.; Amer. Mus. Nat. Hist., 1686.3, 632.5, 2750, 326.9, *65, and *60 gm.; Vienna Nat. Hist. Mus. (Brezina reports), 300, 250, 351, 301, 280, 260, and 300 gm.; U. S. Nat. Mus., 1.4 kg.; Harvard Min. Mus., 594 gm.; Witte Museum, San Antonio (Collin County), 350 gm. (est.); Nininger Collection, 14 kg.; Weidhaas Collection, 81.5 gm.; Texas Observers Collection, 2450 gm. and 1.8 kg.

Miami, Roberts County.
Found: 1930. Recognized: 1937.
Weight: 127 lb. (57.7 kg.), one stone.
Stone.
Described: Not yet described.
Specimens: Nininger Collection, main mass; U. S. Nat. Mus., 1160 gm.; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, 53 gm.

Midland County. See Peck's Spring.

Monahans, Ward County.
Found: 1938.
Weight: 61.5 lb. (27.9 kg.), one mass.
Iron. Ataxite.

Described: Nininger, H. H., Popular Astronomy, vol. 47, pp. 268–271, 1939.

Specimens: Nininger Collection; U. S. Nat. Mus., 873 gm.; Texas Observers Collection, 577 gm.

Nazareth, Castro County.

Found: 1938.

Weight: 43.9 gm.

Stone.

Described: Not yet described.

Specimen: Texas Observers Collection.

Nordheim, DeWitt County.

Found: August, 1932.

Weight: 33.4 lb. (15.15 kg.).

Iron. Nickel-rich ataxite under present classification.

Described: Barnes, V. E., Univ. Texas Pub. 3945, pp. 633–644, 1939 [1940]. (Analysis by F. A. Gonyer.)

Specimen: Texas Memorial Museum, Austin, entire mass.

Odessa, Ector County.

Found: Before 1922 and since.

Weight: Unknown.

Iron. Coarse octahedrite.

Described: Merrill, G. P., Amer. Jour. Sci., 5th ser., vol. 3, pp. 335–337, 1922. (Analysis by E. V. Shannon.)

Specimens: Bureau of Economic Geology, The University of Texas, 206 and 123.5 gm., 11 specimens, 47 kg.; Nininger Collection, 27 masses; Gillespie Collection, 18 masses; U. S. Nat. Mus., 2345 gm.; H. A. Ward, 453.6 gm. (1933); Field Museum, 11 and 6.2 gm.; Lona O'Neal, Odessa, 1125 gm. (1933); Stuart H. Perry Collection, Adrian, Michigan, 3270 gm.; Texas Observers Collection, 3780 gm.; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, 991 gm.

Ozona, Crockett County.

Found: 1929. Recognized: 1939.

Weight: 281 lb. (127.5 kg.).[58a]

Stone. Chondrite.

Described: Not yet described.

Specimen: College of Mines and Metallurgy, El Paso, Texas.

Palo Duro, Armstrong County.

Found: 1934.

Weight: 6.3 lb. (2853 gm.)

Iron. Octahedrite.

Described: Not yet described.

Specimens: Texas Observers Collection, 2826 gm.; Texas A. & M. College, 27 gm.

[58a] An additional 130 pound stone from this area may be part of this fall.

Peck's Spring, Midland County.

Found: May 15, 1926.

Weight: 3.52 lb. (800 gm. recovered; an equal amount distributed).[9]

Stone. Black, crystalline enstatite-chondrite.

Described: Merrill, G. P., U. S. Nat. Mus., Proc., vol. 75, art. 16. 2 pp., 1929. (Analysis by F. A. Gonyer.)

Specimens: U. S. Nat. Mus., 628 gm.; Nininger Collection. 39 gm. The portion distributed was scattered among many individuals and is probably mostly lost to record.

Pipe Creek, Bandera County.

Found: 1887.

Weight: 30 lb. (13.6 kg.).

Stone. Veined, crystalline bronzite-chondrite.

Described: Ledoux, A. R., New York Acad. Sci., Tr., vol. 8. pp. 185–187. 1889. (Analysis by G. F. Kunz.)

Specimens: Field Museum, 3855 and 368 gm.; British Museum, 766. 87, and 56 gm.; Amer. Mus. Nat. Hist., 336 and 34 gm.; Vienna Nat. Hist. Mus., 87 gm.; Univ. of Minn. Mus., 24.6 gm.; U. S. Nat. Mus., 163 gm.; Harvard Min. Mus., 195 and 99 gm.; Weidhaas Collection. 38 and 19 gm.

Plainview, Hale County.

Found: 1913 and later.

Weight: Known (1918) about 68 lb. (31 kg.), dozen stones; known (1938) more than 500 individuals.

Stone. Veined, intermediate chondrite.

Described: Merrill, G. P., U. S. Nat. Mus., Proc., vol. 52, pp. 419–422, 1917; and vol. 54, pp. 503–505, 1918. (Analysis by J. E. Whitfield.)

Specimens: Field Museum, 1602 gm.; Amer. Mus. Nat. Hist., 1947. 1461, and 595.5 gm.; Lazard Cahn, about 7 kg.; U. S. Nat. Mus., 4770, 5467, and 4592 gm.; Nininger Collection at one time contained about 500 individuals, now contains 200 individuals; British Museum, 2.8 kg.; Harvard Min. Mus., 1.25 kg.; Stuart H. Perry Collection, Adrian, Michigan, 2.5 kg.; Philadelphia Acad. Nat. Sci., 175 gm.; Texas Observers Collection, 9 kg.; 5890. 3400. 1980, 1415, 976, 761. 718, 673, 366, 153, 127, 17.8, and 9.5 gm.; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum. 1359 gm.

Plantersville, Grimes County.

Fell: 4 P.M., Sept. 4, 1930.

Weight: 4.596 lb. (2084.9 gm.).

Stone. Between white chondrite veined and intermediate chondrite.

Described: Lonsdale, J. T., Amer. Min., vol. 22. pp. 877–888, 1937. (Analysis by F. A. Gonyer.)

Specimen: U. S. Nat. Mus., 1965 gm.

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[9]In some catalogues the decimal point has been misplaced thus giving an erroneous weight of 35.2 lb.

Red River, north-central or possibly northeast Texas.
Found: 1808.
Weight: 1638 lb. (743.2 kg.).
Iron. Medium octahedrite.
Described: Silliman, Benjamin, Jr., and Hunt, T. S., Amer. Jour. Sci., 2d ser., vol. 2, pp. 370–376, 1846.
Specimens: Yale University Mus., main mass; British Museum, 424, 83, and 0.5 gm.; Amer. Mus. Nat. Hist., 79.7 and 168.2 gm.; U. S. Nat. Mus., 77 gm.; Harvard Min. Mus., 1740 and 22 gm.; Nininger Collection, 96 gm.; Field Museum, 55, 32, and 22 gm.

Red River. See also Wichita County.

Rockport. See McKinney.

Rosebud, Milam County. (The town of Rosebud is in Falls County. The meteorite was found near Burlington, Milam County, but this name was already in use for a fall in the State of New York, so it became necessary to use the name of the next closest town, even though it is in an adjoining county.)
Found: About 1905.
Weight: 125 lb. (56.8 kg.).
Stone. Black chondrite.
Described: Bullard, F. M., Amer. Min., vol. 24, pp. 242–254, 1939. (Analysis by F. A. Gonyer.)
Specimens: Dept. of Geology, The University of Texas, main mass; Nininger Collection, 15 gm.

Round Top, Fayette County.[10]
Found: 1934. Recognized: 1937.
Weight: 17 lb. (7.7 kg.).
Stone.
Described: Not yet described.
Specimen: Texas Observers Collection.

San Angelo, Tom Green County.
Found: 1897.
Weight: 194 lb. (88.2 kg.).
Iron. Medium octahedrite.
Described: Preston, H. L., Amer. Jour. Sci., 4th ser., vol. 5, pp. 269–272, 1898. (Analysis by Mariner and Hoskins, Chicago.)
Specimens: Field Museum, 1501, 1814, and 2551 gm.; British Museum, 771 gm.; Amer. Mus. Nat. Hist., 610 and 227.7 gm.; Vienna Nat. Hist. Mus., 184 gm.; U. S. Nat. Mus., 2725 gm.; Harvard Min. Mus., 295 gm.; Dept. of Geology, The University of Texas, one-third of mass; Nininger Collection, 528 gm.; Texas Observers Collection, 2123 and 72 gm.; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, specimen.

San Antonio. See Kendall County.

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[10] Mr. O. E. Monnig tentatively lists this meteorite as being different from Bluff and Cedar.

Sanderson, Terrell County.

Found: March, 1936.

Weight: 14.87 lb. (6.75 kg.).

Iron.

Described: Not yet described.

Specimen: College of Mines and Metallurgy, El Paso, Texas.

San Pedro Springs, Bexar County.

Found: 1887.

Weight: 0.16 lb. (72 gm.).

Stone. White chondrite.

Described: Not yet described.

Specimens: Amer. Mus. Nat. Hist., 49.7 gm.; Vienna Nat. Hist. Mus., 4 gm.

Schertz, Guadalupe County.

Found: Prior to changing the village name "Cut Off" to Schertz.

Weight: 0.68 lb. (308 gm.).

Iron.

Described: Not yet described.

Specimen: George F. Kunz Collection; now in possession of Ernest Weidhaas, New York.

Shafter Lake, Andrews County.

Found: About 1933. Recognized: 1936.

Weight: About 6.62 lb. (3.00 kg.), one stone.

Stone. Chondrite.

Described: Not yet described.

Specimen: Texas Observers Collection.

Shallowater, Lubbock County.

Found: 1936.

Weight: 10.3 lb. (4.7 kg.), one stone.

Stone. Crystalline chladnite.

Described: Not yet described.

Specimens: Harvard Min. Mus., slice; H. G. Fales Collection, slice; British Museum, slice; U. S. Nat. Mus., 1189 gm.; Nininger Collection, main mass; Field Museum, 290 gm.; Texas Observers Collection, 291 gm.

Silverton, Briscoe County.

Found: 1938.

Weight: 3.03 lb. (1.37 kg.).

Stone.

Described: Not yet described.

Specimen: Texas Observers Collection.

Somervell County.

Found: About 1919. Recognized: 1937.

Weight: About 44 lb. (20 kg.); 3 pieces of this mass recovered, 26 lb. (11.8 kg.).

Stony-iron. Pallasite.

Described: Not yet described.

Specimen: Texas Observers Collection.

Spearman, Hansford County.

Recognized: 1934.

Weight: 23 lb. (10.4 kg.).

Iron. Medium octahedrite.

Described: Not yet described.

Specimens: Nininger Collection has some; U. S. Nat. Mus., 877 gm.; Field Museum, 764 gm.; W. F. Bingham Collection, one-half of mass; Texas Observers Collection, 2010 gm.

Stratford. See Tulia. Dr. H. H. Nininger reports that he was deliberately misled as to the location from which this material was obtained. Stratford should be dropped even as a synonym and is only included here in hope that this mistake will be entirely eliminated.

Texas. See Red River.

Texline, Dallam County.

Found: July, 1937.

Weight: 41.8 lb. (19 kg.), two stones.

Stone. Chondrite.

Described: Not yet described.

Specimens: Nininger and Gillespie collections; U. S. Nat. Mus., 423 gm.; Texas Technological College, two fragments; Floyd V. Studer Collection, Panhandle Plains Historical Society Museum, 163 and 54.5 gm.; Texas Observers Collection, one stone, 1786 gm.

Toyah. See Davis Mountains.

Travis County.

Found: 1889.

Weight: 5.86 lb. (2.77 kg.).

Stone. Black chondrite.

Described: Eakins, L. G., Amer. Jour. Sci., 3d ser., vol. 39, pp. 59–61, 1890. (Analysis by L. G. Eakins.)

Specimens: U. S. Nat. Mus., main mass, 1996 gm., Amer. Mus. Nat. Hist., 10.7 gm.; Nininger Collection, 185 gm.

Troup, Smith County.

Fell: 8:30 A.M., April 26, 1917.

Weight: 2.2 lb. (1 kg.).

Stone. Intermediate chondrite.

Described: Udden, J. A., U. S. Nat. Mus., Proc., vol. 59, pp. 471–476, 1921. Also Merrill, G. P., U. S. Nat. Mus., Proc., vol. 59, pp. 477–478, 1921. (Analysis by E. P. Schoch.)

Specimens: Bureau of Economic Geology, The University of Texas, 625 gm.; U. S. Nat. Mus., 114 gm.; Field Museum, 43.2 gm.; Texas Observers Collection, 187.5 gm.

Tulia, Swisher and Castro counties.

Found: February and July, 1917.

Weight: Original find, 2 stones, 32.8 lb. (14.88 kg.) and 19.5 lb. (8.86 kg.); additional finds, at least 330 lb. (150 kg.).

Stone. Veined crystalline chondrite.

Described: Palache, Charles, and Lonsdale, J. T., Amer. Jour. Sci., 5th ser., vol. 13, pp. 353–359, 1927. (Analysis by E. V. Shannon.)

Specimens: Bureau of Economic Geology, The University of Texas, 14.88 kg. (1 stone); Harvard Min. Mus., 8.86 kg.; U. S. Nat. Mus., 7.2 kg.; also 819 gm. labeled Avoca: Texas Observers Collection, 157 pieces totaling 311 lb. (141 kg.); Nininger Collection, 15 individuals, plus 5438 gm. (Stratford).

Uvalde, Uvalde County.

Found: About 1915. Recognized: 1938.

Weight: 18.5 lb. (8.4 kg.).

Stone. Veined chondrite.

Described: Not yet described.

Specimen: Texas Observers Collection.

Vigo Park, Briscoe County. (The town of Vigo Park is in Swisher County. The meteorite was found across the county line in Briscoe County.)

Found: 1934. Recognized: 1938.

Weight: About 3 lb.; 35.2 gm. is all of this meteorite that has been recovered.

Stone.

Described: Not yet described.

Specimen: Texas Observers Collection.

Wichita County. (This meteorite may be from some other county. Baylor County and Parker County have been suggested as possible locations.)

Found: 1836.

Weight: 320 lb. (145.4 kg.).

Iron. Coarse octahedrite.

Described: Mallet, J. W., Amer. Jour. Sci., 3d ser., vol. 28, pp. 285–288, 1884.

Specimens: Bureau of Economic Geology, main mass, 101.2 kg.; British Museum, 1377 and 20.5 gm.; Amer. Mus. Nat. Hist., 1424 and 1663.5 gm.; Vienna Nat. Hist. Mus., 428, 168, and 44 gm.; U. S. Nat.

Mus., 2361 gm.; Philadelphia Acad. Nat. Sci.. 406 gm.; Harvard Min. Mus., 1800 gm.; Field Museum, 1396, 2466, and 115 gm.

Young County. See Wichita County.

Ysleta, El Paso County.

Known: 1914.

Weight: 310 lb. (140.7 kg.).

Iron. Fine octahedrite.

Described: Not yet described.

Specimens: Amer. Mus. Nat. Hist., main mass, 140.6 kg., and 115.9 gm.

TEKTITES

Bediasites, Grimes County.

Found: During the past quarter to half century. Recognized: April, 1936.

Weight: Given in the following table:

Accession Number	Original Collection Number of Specimens	Original Collection Weight in Grams	Material Exchanged Number of Specimens	Material Exchanged Weight in Grams	Retained in Collection Number of Specimens	Retained in Collection Weight in Grams
30246	14	155	0	0	14	155.0
30247	21	398	2	23.4	19	374.6
30763	143	1489	78	752.8	65	736.2
30764	25	417	8	169.0	17	248.0
30765	9	132	0	0	9	132.0
30766	1	26	0	0	1	26.0
30773	112	1980	54	926.2	58	1053.8
30774	69	603	22	238.5	47	364.5
30775	21	350	0	0	21	350.0
30776	8	192	0	0	8	192.0
30777	14	187	2	39.0	12	148.0
30778	6	116	0	0	6	116.0
30779	5	70	0	0	5	70.0
30780	6	70	0	0	6	70.0
30781	1	7	0	0	1	7.0
30782	15	187	1	18.5	14	168.5
30783	1	6	0	0	1	6.0
30784	1	16	0	0	1	16.0
30785	4	121	0	0	4	121.0
30787	6	90	6	90.0	0	0
	482	6612	173	2257.4	309	4354.6

These specimens range from 0.585 gm. to 91.3 gm. in weight and average 13.7 gm.

Glass: Refractive index, 1.488 to 1.512; specific gravity, 2.334 to 2.433.

Described: Barnes, V. E., Univ. Texas Pub. 3945, pp. 477–582, 1939 [1940].

Specimens: Bureau of Economic Geology, The University of Texas, 309 specimens, 4355 gm., of which 63 gm. has been used for chemical analyses and 7 glass sections. Specimens sent as exchange material listed in the following table:

Specimens Sent in Exchange to	Accession No.	No. of Specimens	Weight in Grams
A. R. Allen, Trinidad, Colorado	30773	1	7.5
British Museum of Natural	30763	1	9.5
History, London, England	30764	2	36.0
	30773	4	54.5
	30774	3	34.5
F. W. Cassirer, Paris, France[a]	30763	25	195.8
	30773	11	178.2
	30774	3	34.5
Charles Fenner, Adelaide, South Australia	30763	6	37.5
	30764	1	24.0
	30773	7	103.5
	30774	3	21.0
Field Museum of Natural History, Chicago, Illinois	30763	2	19.5
Geophysical Laboratory, Washington, D. C.	30247	2	23.4
Museum d'Histoire Naturelle,	30763	36	438
Paris, France	30764	5	109
	30773	21	436
	30774	8	110
	30777	1	34
Rijksmuseum van Geologie en Mineralogie,	30763	3	12.0
Leiden, Holland	30773	3	61.5
	30774	1	6.0
	30777	1	5.0
	30782	1	18.5
L. J. Spencer, London, England	30773	1	13
	30774	3	23
Texas Memorial Museum, Austin, Texas	30787	6	90
University of Melbourne, Geological	30763	3	22.5
Museum, Melbourne, Australia	30773	3	29.0
	30774	1	9.5
U. S. National Museum,	30763	2	18
Washington, D. C.	30773	3	43
Total		173	2257.4

[a] Includes 163 gm. to be exchanged for tektites from Java and the Philippine Islands.

Bediasite, DeWitt County.

Found: Prior to 1937.

Weight: 1 specimen, Mus. No. 30767, 22.4 gm.

Glass. Refractive index, 1.498; specific gravity. 2.385.

Described: Barnes, V. E., Univ. Texas Pub. 3945, pp. 477–582, 1939 [1940].

Specimen: Bureau of Economic Geology, The University of Texas, 22.4 gm.

OUT-OF-STATE METEORITES IN TEXAS COLLECTIONS

In view of the interest shown in meteorites by the people of the State, the writer has compiled the following list which gives the location in Texas museums and institutions of higher learning of meteorites which have fallen outside of Texas and which are designated as out-of-State meteorites. This list is of value to persons who wish to see many of the different types of meteorites in existence.

Agricultural and Mechanical College, College Station, Texas:
- Cañon Diablo, Arizona, small fragment
- Henbury, Central Australia, small fragment

Baylor University, Waco, Texas:
- Brenham, Kiowa County, Kansas, 820 gm.

College of Mines and Metallurgy, El Paso, Texas:
- Brenham, Kiowa County, Kansas, large fragment
- Cañon Diablo, 31-lb. mass and 50 gm.
- Holbrook, Navajo County, Arizona, number of fragments
- St. Michel, Finland, 17.5 gm.
- Unidentified, 50 gm.

East Texas State Teachers College, Commerce, Texas:
- Unidentified (listed as Pike, New York), 113 gm.
- Unidentified, 139 gm.

Panhandle Plains Historical Society Museum, Floyd V. Studer Collection of Meteorites, Canyon, Texas:
- Adams County, Colorado
- Admire, Kansas
- Allegan, Michigan
- Bjurböle, Finland
- Brenham, Kansas
- Cañon Diablo, Arizona
- Covert, Kansas, 30 gm.
- Henbury, Australia
- Holbrook, Arizona
- Huizopa, Mexico
- Melrose, New Mexico
- Molong, New South Wales, 18 gm.
- Richardton, North Dakota
- Vaca Muerta (Llano del Inca), Chile, 12 gm.
- Xiquipilco (Toluca), Mexico, 39 gm., 637 gm.

Southern Methodist University, Dallas, Texas:
- Cañon Diablo (?), fragments

Texas Christian University, Fort Worth, Texas:
- Xiquipilco, Mexico, 280 gm.

Texas Observers, Fort Worth, Texas:
- Adams County, Colorado, 96 gm.
- Admire, Lyon County, Kansas, 152 gm.
- Alfianello, Brescia, Italy, 13 gm.
- Allegan, Allegan County, Michigan, 179 gm.
- Arispe, Sonora, Mexico, 330 gm.

Beardsley, Rawlins County, Kansas, 248 gm.
Bendego, Bahia, Brazil, 13 gm.
Bethany, Great Namaqualand, South Africa, 902 gm.
Bishopville, Sumter County, South Carolina, 5.5 gm.
Bitburg, Trier, Rhenish Prussia, 7 gm.
Bjurbole, Borga. Nyland, Finland, 85 gm.
Braunau, Trutnov, Bohemia, 9.5 gm.
Brenham Township, Kiowa County, Kansas, 54 lb.
Butler, Bates County, Missouri, 394 gm.
Cañon Diablo, Coconino County, Arizona, 46 pieces totaling 109 lb.
Carthage, Smith County, Tennessee, 30 gm.
Chupaderos, Jiminez, Chihuahua, Mexico, 125 gm.
Coldwater, Comanche County, Kansas, 92 gm.
Cosby's Creek, Cocke County, Tennessee, 100 gm.
Covert, Osborne County, Kansas, 193 gm.
Crescent, Logan County, Oklahoma, 80 gm. (entire amount recovered)
Dhurmsala, Kangra district, Punjab, India, 21 gm.
Durango, Mexico (probably Cacaria), 84 gm.
Ergheo, Brava, Italian Somaliland, East Africa, 166 gm.
Estherville, Emmet County, Iowa, 96 gm.
Farmington, Washington County, Kansas, 243 gm.
Forest City, Winnebago County, Iowa, 487 gm.
Four Corners, San Juan County, New Mexico, 775 gm.
Gilgoin Station, Brewarrina, County Clyde, New South Wales, 269 gm.
Hainholz, Minden, Westphalia, Germany, 3.5 gm.
Harriman, Roane County, Tennessee. iron 67 lb. (name tentative; heretofore neither reported nor described)
Harrisonville, Cass County, Missouri, 428 gm.
Henbury, Central Australia, 703 gm.
Holbrook, Navajo County, Arizona, 304 stones totaling 1,849 gm.
Homestead, Iowa County, Iowa, 4.5 gm.
Hugoton, Stevens County, Kansas, 517 gm.
Imilac, Desert of Atacama, Chile, 51 gm.
Karoonda, South Australia, 22.5 gm.
Knyahinya, Nagy-Bereszna, Czechoslovakia, 50 gm.
Krasnojarsk, Yeniseisk, Siberia, 95 gm.
La Grange, Oldham County, Kentucky, 141 gm.
L'Aigle, Orne, France, 8 gm.
Lake Labyrinth, South Australia, 156.5 gm.
Long Island, Phillips County, Kansas, 53 gm.
Magura, Arva, Czechoslovakia, 150 gm.
Marion, Linn County, Kansas, 24 gm.
Melrose, Curry County, New Mexico, 101 gm.
Mighei, Olviopol, Kherson, Ukraine, 1 gm.
Mocs, Kluj, Transylvania, 16 gm.
Molong, County Ashburnham, New South Wales, 265.5 gm.
Morita, Chihuahua, Mexico, 405 gm.

Mount Joy, Adams County, Pennsylvania, 81 gm.
Nashville, Kingman County, Kansas, 24 gm. (This stone is neither described nor announced and the name is tentative.)
Ness County, Kansas, 574 gm.
Pacula, Jacala, Hidalgo, Mexico, 2 gm.
Pasamonte, Union County, New Mexico, 56 gm.
Piñon, Otero County, New Mexico, 783 gm.
Pultusk, Warsaw, Poland, 302.5 gm.
Richardton, Stark County, North Dakota, 1577 gm.
Roy No. 1, Harding County, New Mexico, 125 gm.
Roy No. 2, Harding County, New Mexico, 54 gm.
Sacramento Mountains, Eddy County, New Mexico, 493 gm.
Santa Catharina, Brazil, 427 gm.
Serra de Mage, Pesquiera, Brazil, 108 gm.
Stannern, Iglau, Moravia, Czechoslovakia, 4.5 gm.
St. Michel, Finland, 153 gm.
Tatum, Lea County, New Mexico, stone 3 lb. 15 oz. (entire find; not described)
Tazewell, Claiborne County, Tennessee, 368 gm.
Toluca, Mexico State, Mexico, 144 pieces totaling 807 lb.
Tombigbee River, Choctaw County, Alabama, 34 gm.
Trenton, Washington County, Wisconsin, 26 gm.
Vaca Muerta, Sierra de Chaco, Toltal, Atacama, Chile, 293 gm.
Waconda, Mitchell County, Kansas, 17 gm.
Wauneta, Wray Co., Colorado, stone 8 lb. 6 oz. (heretofore undescribed and unreported
Willamette, Clackamas County, Oregon (shale, several ounces)
Zacatecas, Mexico, 100 gm.
Unidentified:
  Iron: 25 gm.; 6 gm.; 67 gm.; and 163 gm.
  Stone: 19 gm.; 69 gm.; 21 gm.; and 1 gm.
  Five freshly fallen stones: 44 gm.; all related (Forest City, Winnebago County, Iowa?)
  Iron: 86 gm. (Toluca?)
  Iron: 60 gm. (Magura, Arva, Czechoslovakia?)
  Iron scraps: 25 gm.
  Iron scraps: 45 gm. ("Tennessee")

THE UNIVERSITY OF TEXAS:

BUREAU OF ECONOMIC GEOLOGY:
  Bethany, Great Namaqualand, South Africa, 231 gm.
  Brenham, Kiowa County, Kansas, 608 gm.
  Sacramento Mountains, Eddy County, New Mexico, 183.5 gm.
  Saline, Sheridan County, Kansas, 52 gm.
  Toluca, Mexico State, Mexico, 2410 gm.

DEPARTMENT OF GEOLOGY:
  Cañon Diablo, Coconino County, Arizona, 100 lb.

OUT-OF-STATE TEKTITES IN BUREAU OF ECONOMIC GEOLOGY COLLECTION

The material listed in the following table has been obtained in exchange for bediasites sent from the Bureau of Economic Geology collection as shown on pages 604–605. Some of the exchange material had not been received at the time this paper was sent to press.

In addition to the tektites, 25.9 gm. of Wabar, Arabia, silica glass (Mus. No. 30975) has been received from the Field Museum of Natural History, Chicago, Illinois, and 0.5 gm. of Wabar, Rub'al Ishali, Arabia, silica glass (Mus. No. 31003) has been received from the British Museum of Natural History, London, England.

Kind of Material and Sender	Accession No.	No. of Specimens	Weight in Grams	Specific Gravity	Remarks
Australites—					
University of Melbourne, Geological Museum, Melbourne, Australia	30954	1	2.855	-------	Part of flanged button. Tasmania?.
	30955	1	2.769	2.459	Boat form. Coolgardie, Western Australia.
	30956	1	6.202	2.454	Core of round form. Charlotte Waters, Central Australia.
	30957	1	8.148	2.380	Core of oval form. Mulka, Southern Australia.
	30958	1	6.910	2.433	Core of round form. William Creek, Southern Australia.
	30959	1	6.719	2.418	Dumb-bell form. Mulka, Southern Australia.
	30960	1	2.313	2.414	Button with part of flange, Mulka, Southern Australia.
	31012	1	0.800		Boat. Transcontinental Line, Western Australia.
	31013	1	1.605		Half button. ?Long Plains, Tasmania.
	31014	1	1.430		Lens (two-thirds). ?Long Plains, Tasmania.
	31015	1	20.845		Large core. ?Long Plains, Tasmania.
	31016	1	0.600		Worn oval. Ooldea, Southern Australia.
A. R. Allen, Trinidad, Colorado	30846–1	1	3.6	2.457	Charlotte Waters, Central Australia.
	30846–2	1	3.9	2.430	Charlotte Waters, Central Australia.
Charles Fenner. Adelaide, South Australia	30976*	1	5.7		Flanged button, almost perfect.
	30977	1	2.2		Lens, average size and shape.
	30978	1	17.1		Lens core, medium sized.
	30979	1	8.9		Lens core, thicker than usual.
	30980	1	7.0		Lens core, similar to above.
	30981	1	11.7		Lens core, flatter, medium sized.
	30982	1	15.4		Oval type, large, well preserved.
	30983	1	13.0		Oval type, similar to above.
	30984	1	4.9		Oval type, smaller and with broken flange.
	30985	1	4.0		Oval type, small.
	30986	1	12.7		Boat type, large specimen.
	30987	1	8.8		Dumb bell, part missing.
	30988	1	12.8		Dumb bell, part missing.
	30989	1	3.5		Teardrop type.
	30990	1	14.2		Large fragment.

*Numbers 30976–30992 inclusive were all collected from a locality in the region of Lake Eyre, South Australia, particularly to the northwest of that place.

Kind of Material and Sender	Accession No.	No. of Specimens	Weight in Grams	Specific Gravity	Remarks
	30991	1	5.5		Lens type, fragment showing bubble.
	30992	1	9.8		Lens core, broken.
British Museum of Natural History, London, England	31004	6	45.5		Button types, Lake Eyre district, South Australia.
	31005	2	17.5		Dumb-bell types, Lake Eyre district, South Australia.
	31006	1	8.2		Either Oodradatta, South Australia, or 200 miles northeast of Coolgardie, Western Australia.
Total australites		40	297.1		
Billitonites—					
Rijksmuseum van Geologie en Mineralogie, Leiden, Holland	30996–30998	3	35.3		Island of Billiton.
	30999–31001	3	6.0		Island of Billiton. Very remarkable etched forms.
British Museum of Natural History, London, England	31007	1	7.5		Billiton Island, East Indies.
Darwin glass—					
U. S. National Museum, Washington, D. C.	30942	13	15		Western Tasmania.
British Museum of Natural History, London	31008	1	1.5		Ten Mile, Mt. Darwin, Tasmania.
University of Melbourne, Geological Museum, Melbourne, Australia	31017	1	1.76		Darwin, Tasmania.
Total Darwin glass		15	18.26		
Indochinites—					
Museum d'Histoire Naturelle, Paris, France	30847	13	378		Island of Tan Hai, Kouang tchéou wan.
	30848	16	273		Dalat, Annam, French Indo-China.
	30848–B, –G, and –H	3	104		Pia Oac, Annam, French Indo-China.
	30849	9	26		Khum de Varin, Cambodge, French Indo-China.
	30850	2	337		Muong Nong, Bas Laos, French Indo-China.
Total indochinites		43	1118		

Kind of Material and Sender	Accession No.	No. of Specimens	Weight in Grams	Specific Gravity	Remarks
Libyan Desert glass—					
L. J. Spencer, London, England	30922	2	34.5		Libyan Desert, Egypt.
Moldavites—					
F. W. Cassirer, Paris, France	30874	1	4.8		Koroseky.[a]
	30875	1	1.7		Koroseky.
	30876	1	3.3		Koroseky.
	30877	1	2.4		Koroseky.
	30878	1	6.0		Koroseky.
	30879	1	14.2		Habry.[b]
	30880	2	18.6		Habry.
	30881	1	2.7		Koroseky.
	30882	2	3.8		Habry.
	30883	2	4.9		Koroseky.
	30884	1	10.8		Habry.
	30885	1	6.0		Koroseky.
	30886	1	8.9		Habry.
	30887	1	23.7		Habry.
	30888	1	23.6		Habry.
	30889	1	23.5		Habry.
	30890	2	7.5		Koroseky.
	30891	2	12.4		Koroseky.
	30923	27	59.1		Second-grade material for cutting; Southern Bohemia.
U. S. National Museum, Washington, D. C.	30943	1	2.4		Bohemia
Total moldavites		51	240.3		
Rizalites—					
Rijksmuseum van Geologie en Mineralogie, Leiden, Holland	30993	1	31.0		Philippine Islands.
	30994	1	9.3		Philippine Islands.
	30995	1	6.7		Philippine Islands.

[a]Specimens indicated as coming from Koroseky and Habry are from near Ceske Budejovice (Budweis), Southern Bohemia.

[b]Also spelled Hraby in list of material sent.

THE STONY METEORITE FROM CUERO, TEXAS

Virgil E. Barnes

On May 16, 1936, Mr. C. J. Sigmund, of Cuero, and a troop of Boy Scouts discovered a 102.5-pound (46.5-kilogram) stony meteorite in Chisholm Creek 1 mile upstream from the Clinton road and about 3 miles south of Cuero, DeWitt County, Texas. This fall was found at approximately 29°01′ N. Lat. and 97°17′ W. Long. The stone was exposed by erosion. It was 4 or 5 feet beneath the surface with the fluted side up and the nose buried in the bank. A piece estimated to weigh between 5 and 10 pounds had been broken off the exposed portion of the meteorite several years before Mr. Sigmund found it, but there is no indication as to what happened to this piece.

The meteorite is 44 centimeters across in the longest direction, which is approximately at right angles to the direction of fluting. It is 20 centimeters thick near the brustseite or nose and slopes back from this point, thinning to a wedge.

This stone is much weathered and cracked, and the original glassy crust has almost lost its identity. Some of the original features created during flight are preserved, and the point that was forward is easily recognized. In the nose of this stone (Pl. 27, fig. 2) is one equidimensional pit about 4 centimeters across, and radiating from this pit are numerous flutings. These flutings are not so well developed as those which extend to the end of the wedge (Pl. 27, fig. 1). The side of the meteorite not photographed is undulating without fluting.

All surfaces of the stone show open cracks arranged in a somewhat symmetrical manner, giving the surface a polygonal pattern not unlike that of a sun-cracked mud flat. Some of these open cracks are as much as 5 millimeters wide and 2 centimeters deep. Any polished surface of this meteorite reveals a network of cracks and veinlets. The cracks are widest at the surface and extend as much as 6 centimeters into the stone (Pl. 27, fig. 3), where they continue as filled, black veinlets similar to those found in meteorites

Issued June, 1940.

such as the Bluff[1] and Kimble County.[2] Surfaces of the cracks have well developed slickensides along them, indicating that they are fault surfaces (Pl. 27, fig. 4). The movement along them undoubtedly took place before the meteorite entered the earth's atmosphere; otherwise, if the slickensiding had been produced by the shock of hitting the atmosphere or the ground, the stone would have been shattered into many pieces. The filled portion of the cracks is probably a myolinite which is coherent enough to hold the meteorite together. This myolinitic material weathers much faster than the rest of the stone, thus accounting for the open cracks near the surface. This stone is a breccia in which the fragments have shifted little in respect to each other.

Neither the weathered surface nor the freshly-broken surface of the meteorite shows any evidence of chondritic structure, but any polished surface shows numerous round, dark greenish-black, uniformly colored chondrules up to 3 millimeters in diameter. The color of the surface is a very dark green or greenish black, but somewhat mottled, probably largely due to differential weathering. The polished surface (Pl. 27, fig. 3) shows innumerable irregularly-shaped, uniformly-distributed particles of troilite and nickel-iron, mostly less than a millimeter in diameter. A few large nickel-iron plates are present ranging up to 9 millimeters in length.

The chemical analysis reveals considerable phosphorous in the metallic portion of this meteorite, which suggests the presence of schreibersite. Polished samples were examined by reflected light before and after etching, and four metallic substances can be recognized. Two of these are nickel-iron constituents and can be distinguished only after etching. One of these constituents is unaffected by the dilute nitric acid and is probably taenite. The other constituent tarnishes and darkens and may be kamacite. The two bronzy-colored minerals can be distinguished with certainty only by etching. The troilite darkens and evolves gas bubbles, whereas the other constituent is entirely unaffected. The latter is schreibersite.

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[1]Whitfield, J. E., and Merrill, G. P., The Fayette County, Texas, meteorite: Amer. Jour. Sci., 3d ser., vol. 36, pp. 113–119, 1888.

[2]Barnes, V. E., The stony meteorite from Kimble County, Texas: Univ. Texas Bull. 3945, pp. 623–632, 1939 [1940].

The taenite is present as thin layers situated at the periphery of some of the nickel-iron particles. The troilite is associated either with the nickel-iron or with the silicates. In one of the plates of nickel-iron, a spherical nodule of troilite is present, while in other plates the troilite is marginal to the nickel-iron. The schreibersite is present as irregularly-shaped particles associated with the silicates and is rarely in contact with the troilite or the nickel-iron. In no place was schreibersite seen as needles in the nickel-iron or as layers separating the nickel-iron from the silicates, as is so common in the pallasites. If all the phosphorous is combined as schreibersite, then about 0.8 per cent of the mineral should be present.

A thin-section examination shows olivine and orthorhombic pyroxene to be the main silicate minerals present. The orthorhombic pyroxene has an index for Np of approximately 1.669 and for Ng of approximately 1.679. The mineral is positive in optical character. Using Winchell's[3] diagram for the enstatite-hypersthene series, this indicates that 2V should be about 86°, and the specific gravity should be about 3.31. An endeavor was made to check 2V by the use of the universal stage. The readings obtained did not check among themselves, largely because of wavy extinction and the low birefringence of the mineral. Most of the readings were within a few degrees of 90°; some were positive and others negative. On one crystal which extends into an opening in the thin section, 2V was found to be 78° and the mineral negative. Considering the tuffaceous nature of this stone, the minerals might well vary considerably in composition and therefore in optical properties. If this optical angle variation is real, it indicates that both enstatite and hypersthene are present.

The indices of the olivine were only approximately determined on some of the fresher-looking material, and Ng is near 1.71 and Np is near 1.67. 2V measured on a universal stage is 89°, and the mineral is negative. According to Winchell's[4] diagram for the forsterite-fayalite series, this gives a value for the specific gravity of 3.44. The specific gravity of the stone as a whole is 3.41, which is lower than should be expected from one containing so large a percentage of nickel-iron and troilite and which is composed largely

[3]Winchell, A. N., Elements of Optical Mineralogy, Part II, Description of Minerals, p. 168, John Wiley & Sons, New York, 1927.

[4]Idem, p. 177.

of olivine and hypersthene having specific gravities of at least 3.44 and 3.31 respectively.

The chemical analysis, when calculated into a normative mineral composition, shows that the normative olivine and the normative hypersthene are much more ferriferous than is indicated by the petrographic examination. It is possible that these minerals vary widely in composition and that the low iron minerals are more favorable for optical work, thus accounting for the discrepancy between the modal and normative mineral composition.

One thin section was leached by hydrochloric acid to remove the metallic minerals and the olivine. The remaining portion is mostly hypersthene. A very small amount of material is present which has a birefringence near that of olivine and an extinction angle of 37° or more. This mineral is probably either augite or diopside. No maskelynite, merrillite, or feldspar was found.

The central part of the freshly polished surface exuded droplets which, after a few days exposure, turned to a limonitic-appearing material. This is suggestive of the mineral lawrencite. A test for chloride was negative; however, the fragment tested was from near the surface and was probably leached. Gonyer in his analysis of this meteorite also failed to find chlorine.

This stone has many spherical polysomatic and monosomatic chondrules and chondroidal forms in it, as well as many that are crushed and sheared. Some of the chondrules are composed entirely of radiating hypersthene. A few of these are clouded by minute inclusions, others are clouded in part, and the rest are free from clouding.

Many other chondrules are composed entirely of olivine, some of which are clouded, barred forms, and others are clear, non-barred forms. Some of these are monosomatic, composed of olivine having synchronous extinction, and others are polysomatic, composed of olivine particles having random extinction. Two olivine chondrules were seen which have barred and cloudy centers surrounded by clear olivine. Both parts of these chondrules extinguish at the same time. Some non-barred forms were found with cloudy centers and clear borders.

Chondroidal[5] forms composed of olivine and hypersthene? with some metal are present. In this type the olivine is in clear euhedral crystals surrounded by finely fibrous hypersthene?. The euhedral olivine is not strained, as is shown by a lack of wavy extinction. This lack of deformation seems rather unique, especially when the amount of metamorphism shown by the stone in general is taken into consideration. The olivine may have escaped metamorphism because of the surrounding felted hypersthene? which acted as a buffer.

Other chondroidal forms are present in which fragmental olivine and some metal are the main materials present. In this type the olivine shows distinct evidence of metamorphism. In general the chondroidal forms contain metal, whereas the chondrules do not. A few of the hypersthene chondrules do, however, contain finely disseminated metal on the portion of their periphery farthest away from the initial point of crystallization. This may be a growth phenomenon in which the hypersthene continued to grow after the chondrule was incorporated with the rest of the meteoritic material. This stone is undoubtedly of a tuffaceous origin in which chondrules of olivine, chondrules of hypersthene, chondroidal forms, and fragments of chondrules and chondroidal forms have been incorporated with considerable nickel-iron and sulphide to form a rock. The material to form this meteorite must have been deeply buried in order to make it as compact as it now is. The depth of burial must have been sufficient to cause metamorphism. This is shown by the strain effects seen in the minerals between crossed nicols and by the shearing which is indicated by the presence of crushed chondritic fragments drawn out along definite breaks or shearing planes.

The following analysis was made by F. A. Gonyer.

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[5]Chondrules of a compound holocrystalline nature, and those porphyritic through the development of olivine or pyroxene phenocrysts in a more or less glassy base, are lacking in smooth exteriors; and, though often quite spherical in outline, are, as a rule, more or less irregular. In many instances these show unmistakable evidences of an origin of form through mechanical attrition. These should be designated chondroidal forms, rather than true chondrules. (Merrill, G. P., Composition and structure of meteorites U. S. Nat. Mus.. Bull. 149, p 39, 1930.)

Analysis of Cuero meteorite

	Combined Analyses	Soluble Silicate 45.17%	Insoluble Silicate 30.12%	Sulphide 3.01%	Metal 21.70%
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
SiO_2	30.95	32.31	54.32		
Al_2O_3	2.54	1.87	5.63		
Fe_2O_3	0.41	0.91	none		
FeO	16.61	30.02	10.14		
MgO	21.06	30.20	24.62		
CaO	1.13	0.75	2.64		
Na_2O	0.27		0.91		
K_2O	0.05		0.16		
H_2O	1.99	4.19	0.32		
SO_4	none	none	none		
CO_2	0.09	0.19			
TiO_2	0.02	none	0.08		
Cr_2O_3	0.26		0.87		
MnO	0.20	0.19	0.37		
NiO	0.05	0.11	trace		
CoO	0.01	0.02	none		
Cl	none				
Fe	19.81				91.27
Ni	1.69				7.78
Co	0.11				0.51
Cu	0.01				0.04
P	0.13				0.60
Mn	none				none
FeS	3.01			100.00*	
	100.40	100.76	100.06	100.00	100.20

*Sulphur was determined, and sufficient iron to make FeS was deducted from the metal.

This stone is much more basic than the average for sixty-three stony meteorites as given by Merrill.[6] Merrill's average meteorite and the Cuero meteorite recalculated to 100 per cent are given in the following table:

[6]Merrill, G. P., Composition and structure of meteorites: U. S. Nat. Mus., Bull. 149, p. 47, 1930.

	Average Per cent	Cuero Per cent
SiO_2	38.41	30.83
Al_2O_3	2.86	2.53
Fe_2O_3	0.92	0.41
FeO	13.60	16.54
MgO	23.66	20.98
CaO	1.88	1.12
Na_2O	0.82	0.27
K_2O	0.16	0.05
H_2O	0.47	1.98
CO_2		0.09
TiO_2	0.16	0.02
Cr_2O_3	0.40	0.26
MnO	0.23	0.20
NiO	0.40	0.05
CoO	0.05	0.01
Cl	0.03	0.00
Fe	12.35	21.63
Ni	1.09	1.68
Co	0.10	0.11
Cu	0.01	0.01
P_2O_5	0.34	-
P	-	0.13
S	1.89	1.10
C	0.16	
	100.00	100.00

The chief differences brought out by this table are that the Cuero meteorite is noticeably low in silica and somewhat low in magnesia, ferric oxide, lime, soda, potash, and sulphur and is very high in iron and somewhat high in nickel, ferrous oxide, and water.

The high water content suggests weathering, and this in turn suggests that a high content of ferric oxide should be found. Instead, the ferric oxide is very low. Apparently the conditions of atmospheric weathering were such that part of the olivine was changed to minerals such as antigorite, ferroantigorite, and possibly brucite without much oxidation of the metal. The water that penetrated this meteorite must have been low in oxygen and carbon dioxide, or possibly oxygen and carbon dioxide were consumed at the surface of the meteorite. With deeper penetration, then, only serpentinization could take place. The small amount of carbon dioxide suggests either that some mineral developed other than the usual carbonates formed during weathering or that some magnesium was removed in solution. If the chemical equation, combining two molecules of chrysolite (Mg_2SiO_4) and three of water, is balanced with an end product of one molecule of antigorite, then enough constituents are left over to form one molecule of brucite. If the same process is carried out for the fayalite molecule (Fe_2SiO_4), with the addition of some oxygen, then a possible result is ferroantigorite and limonite.

The following is the normative mineral composition of this meteorite, disregarding all products of weathering except calcite.

	Per cent
Orthoclase	0.29
Albite	2.29
Anorthite	4.93
Corundum	0.23
Hypersthene	15.91
Olivine	48.48
Magnetite	0.59
Chromite	0.38
Ilmenite	0.04
Metal	20.82
Schreibersite	0.83
Troilite	3.00
Calcite	0.22
	98.01

If the 1.99 per cent water is considered to be part of such minerals as antigorite, ferroantigorite, brucite, and limonite, then about 10 per cent of weathering products are present.

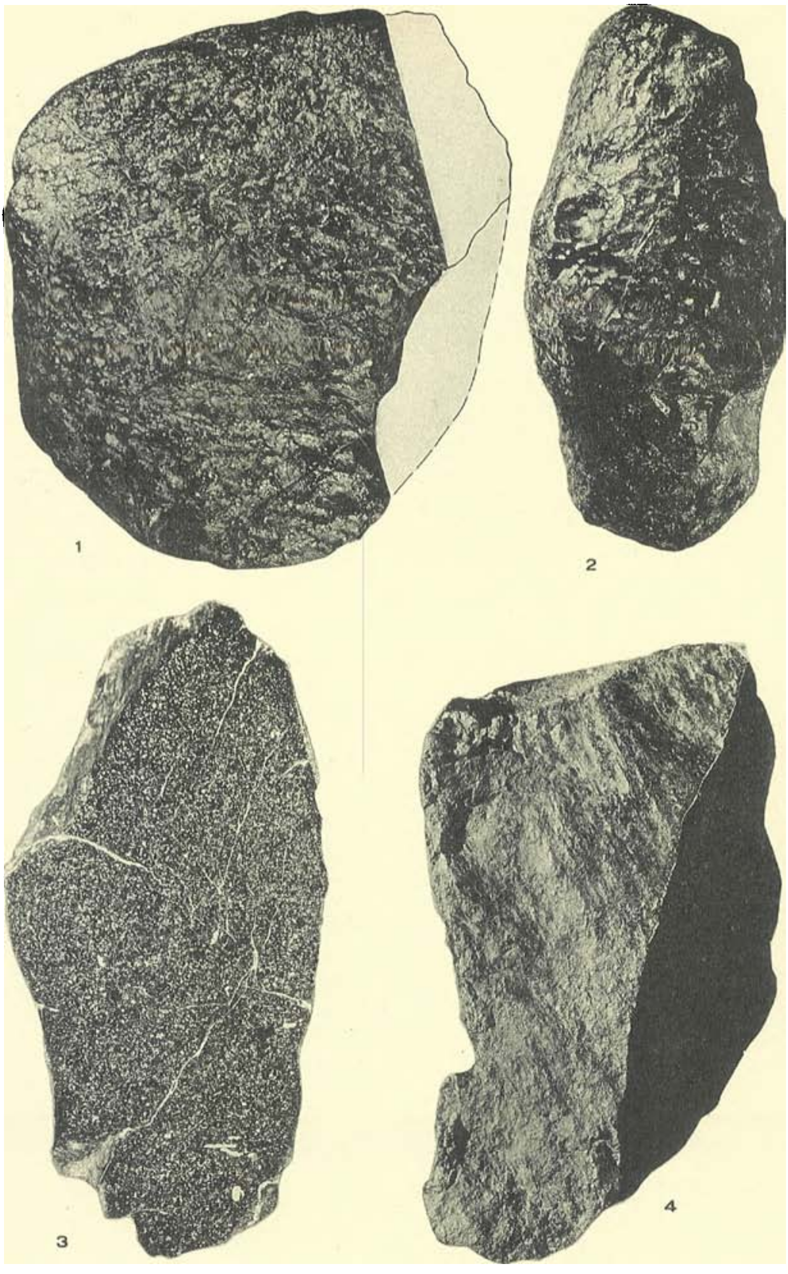
In résumé: The Cuero stone is a very dark green, veined (or brecciated), spherical, hypersthene chondrite, weighing 102.5 pounds. Even though it is an old fall, some of the fluting produced during flight is still preserved. This is a rather common type of meteorite, the chief features of interest being well-developed slickensides, a high content of iron, both as the metal and as ferrous oxide, and a low content of silica.

The writer wishes to express his appreciation to The University of Texas Committee on Research Grants and Publication, Dr. J. T. Patterson, chairman, for a grant to cover the cost of the analysis. He also wishes to express appreciation to Mr. C. J. Sigmund for the kind interest and coöperation he has shown and for his donation to the Bureau of Economic Geology.

PLATE 27

Photographs of Cuero meteorite.

1. Fluted surface and polygonal areas outlined by cracks. The solid line outlines portion sawed off and not photographed. The broken line indicates generalized outline of portion broken off before the meteorite was found by Mr. Sigmund. 1/5 natural size.
2. Nose (brustseite) with thumb-mark pitting, some fluting, and a few cracks. 1/5 natural size.
3. Polished surface of fragment sawed from meteorite showing abundant small bright points of metal, troilite, schreibersite, and a few larger plates and masses of metal. Black chondrules are visible and can be detected by noting small, mostly circular, areas free from metallic points. Open cracks are present at the edges of the polished surface and narrow down to thread-like lines near the center where they are filled by a myolinite-like material. The surface of a crack appears at the upper left and is reproduced in figure 4. ½ natural size.
4. Slickensided surface from along fault in the Cuero meteorite. The black area at the right is a portion of the polished surface shown in figure 3. Natural size.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THE STONY METEORITE FROM KIMBLE COUNTY, TEXAS

Virgil E. Barnes

During August, 1936, a large meteorite was brought to the attention of Mr. W. S. Strain by Mr. B. L. Enderle, head of the science department of the Fredericksburg high school. Mr. Strain, a representative of the University Centennial Exposition, at the time was supervising the excavation of a fossil elephant by a Works Progress Administration mineral resource survey in Gillespie County, sponsored by the Bureau of Economic Geology, The University of Texas. He secured this meteorite, which weighed 339 pounds (153.8 kilograms), on September 5, 1936.

The location of this find is on land owned by Mr. A. S. Parker north of Noxville, in eastern Kimble County, close to Little Devils River (also called East Fork of James River), and near the north side of Sec. 607 of the S. A. & M. G. Railroad Company survey. This fall was found at approximately 30°25′ N. Lat. and 99°24′ W. Long. Since no other meteorite has been found in this county, it is proposed that this be called the Kimble County meteorite.[1]

This stone was first seen in 1918 by Mr. A. S. Parker, who recognized the possibility of its being a meteorite. He had seen the meteor of the year before, and the direction in which he observed the flight fitted the location of this find. He claims that the hill on which this meteorite was found, and which is now wooded, was covered only by grass previous to 1918. He grazed sheep all over this hill and believes that if an object of this size had been present he would have seen it. Although he, therefore, concludes that this is a stone of the October 1, 1917, fall described by Udden,[2] it seems logical upon investigation to conclude that this stone fell long before the meteor described by Udden was seen. Mr. Parker's description of the stone as it was when he first saw it in 1918 indicates it had already been subjected to more than one year's weathering. He stated that it looked then exactly as it does at present and that at a short distance he mistook it for a rusty,

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[1]Since this paper was written Mr. O. E. Monnig, of Fort Worth, has obtained a 241-gram fragment of a stony meteorite from near Junction, Kimble County, which he believes is a distinct fall and which he has named the Junction meteorite.

[2]Udden, J. A., The Texas meteor of October 1, 1917. Univ. Texas Bull. 1772, 56 pp., 1917.

Issued June 1940.

cast-iron washing kettle. It is unlikely that one year's weathering in the semi-arid Kimble County region would have removed the fused crust and would have produced by spalling the rounded appearance described.

This meteorite was broken at the time Mr. Strain secured it, a 19.1-kilogram mass having been either cracked off by someone or broken off by weathering. Numerous shell-like spalls also surrounded the stone. The main mass of this stone weighs 132.7 kilograms and measures roughly 34 by 63 centimeters. In a median direction it is 41 centimeters thick. This stone has one broad face that is slightly concave, and the center of the face is depressed about 4 centimeters. The next largest face intersects this concave face at right angles. Two other facet-like faces meet the concave face at lower angles, as does a third face represented on a detached fragment. A photograph of the spalled side of the stone (Pl. 28, fig. 1) shows remnants of facet-like faces, but spalling has much reduced them in area. This side of the stone presents much the appearance, as stated by Mr. Parker, of a rusty, cast-iron washing kettle (Pl. 28, fig. 2).

The 19.1-kilogram fragment is roughly tetrahedral in shape and measures about 33 by 25 by 18 centimeters. Three irregular fragments weigh 519, 454, and 294 grams respectively, and other small fragments and spalls total 756 grams. The 19.1-kilogram fragment has been cut into two parts weighing 10.6 and 7.1 kilograms.

The surface of this meteorite has been devoided of the fused crust by weathering. Some of the surfaces retain the shape they originally had while others have been altered by exfoliation and spalling. The original surfaces (those not created by spalling) are of a rusty color and are studded with little projections from 1 to 5 millimeters in diameter. These projections are of nickel-iron which, in this meteorite, withstands weathering much better than do the sulphide and enclosing silicates. On these surfaces are numerous chondrules that are remarkably well outlined by the limonitic brown. One vein is visible on the surface and is traceable entirely around the meteorite by the raised hummocks of nickel-iron elongated in the plane of the vein. There is some evidence that other veins are present.

On a freshly fractured surface this meteorite is of a dark greenish-black color not unlike many basalts and trap rocks. Chondritic structure is scarcely discernible. On a polished surface the aggregate color is a very dark greenish-gray which, when viewed at a distance, approaches black. The color intensity varies slightly, giving a clouded effect. On this surface (Pl. 28, fig. 3) are present many irregularly-shaped, brightly reflecting areas of white nickel-iron and of bronzy troilite, ranging from the size of a pin point up to 8 millimeters in diameter. Some of the large areas are composed entirely of troilite. In the rest, troilite occupies the central portion with nickel-iron partly or entirely surrounding it. Chondrules are numerous on the polished surface (Pl. 28, fig. 3) and range in color from white through shades of gray and greenish-gray to dense black. One light-colored chondrule has numerous dark green fragments scattered through it.

Visible on the polished surface, but not visible in the photograph, is a small group of very narrow black veinlets that trend without apparent relationship to the shape of the stone. Two of these veinlets, which dip at an angle of 70° to 80° to the plane of the cut, are parallel and roughly intersect a third ramifying veinlet at an angle of about 70°. This ramifying vein has a dip varying between vertical and 55°. Centrally located in the photograph is an open crack which is rather irregular and dips from near vertical to 45°. Along this crack weathering has penetrated, slightly darkening the stone for a width of 4 or 5 millimeters. A zone of weathering is present along the spalled edges on the right side of the photograph, but the two original faces at the bottom and left of the photograph do not show penetration by weathering. The zone of weathering is indicated by a slight darkening, a few open cracks, and by many minute cracks which are, in general, parallel to the outer face of the meteorite.

This is a chondritic stone containing chondrules of olivine and hypersthene. Well-shaped chondrules are not abundant, but it is seen from a study of thin sections that chondrules were originally the main components and that they have since been so crushed and distorted that it is difficult to recognize many of them as such.

Many of the chondritic areas of olivine show a rough outline, within the borders of which are several sizable fragments and many smaller ones of varied optical orientation. The olivine is of negative optical character, indicating that the FeO content ranges above 13 per cent. A rough determination was made of the greater and lesser indices of refraction by using a liquid having an index of refraction of 1.6947. This happened to be the same index as the average olivine when it was rotated 45° from extinction. Using Winchell's[3] diagram for the forsterite-fayalite series and the above figure as a mean index, approximate values of 1.714 and 1.676 are obtained for Ng and Np respectively. These values indicate that 2V is about 87°, that the mineral is negative, and that the specific gravity is about 3.48.

The indices for hypersthene, as determined from a series of immersion liquids of known index, are about 1.688 for Ng and 1.673 for Np. By using Winchell's[4] diagram for the enstatite-hypersthene series, it is seen that the mineral should be negative with 2V near 87°, and that it should have a specific gravity of about 3.34. With these properties the mineral should have an FeO content of about 11 per cent which, according to some writers, would classify it as bronzite. In this paper, the usage by Winchell will be followed, namely, that negative minerals in the enstatite-hypersthene series are hypersthene and that positive minerals are enstatite. The name bronzite is a variety name used for an intermediate mineral having a bronzy luster.

Upon calculating the analysis to a normative mineral composition, the normative olivine and the normative hypersthene are found to be considerably more ferriferous than is indicated by the optical data. This discrepancy may possibly be accounted for by the normative mineral composition not representing closely the modal mineral composition. It is also possible that the crystals favorable for optical study are lower in ferrous oxide and that the confused groundmass material is high in ferrous oxide.

Between chondrules and recognizable chondritic areas much fragmented olivine and enstatite are present, with some interstitial material that is semi-opaque. The metallic portion of the meteorite, which consists of nickel-iron and troilite, is associated with these areas. A clear, colorless, uniaxial, negative mineral is present which has a low birefringence and has an index of refraction which is lower than that of the surrounding minerals. This mineral is probably merrillite. It has extremely irregular extinction and in most sections gives flash interference figures suggestive of a biaxial

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[3]Winchell, A. N., Elements of Optical Mineralogy, Part II, Description of Minerals, p. 168, John Wiley & Sons, New York, 1927.

[4]Idem, p. 177.

mineral. Its true uniaxial character was determined by orientation on the universal stage. The merrillite is mostly associated with the metallic portion, which suggests an interstitial position and a late date of crystallization.

From the chemical analysis only about 0.5 per cent of merrillite can be present, but in thin section it, or some mineral resembling it, appears to be more abundant. It is possible that much of this clear, colorless material is feldspar which is little removed from maskelynite (fused feldspar). The chemical analysis indicates the presence of considerable feldspar. On freshly polished surfaces of this meteorite, drops of exudation soon form, which within a few days turn into a brown substance. This indicates the presence of the deliquescent mineral lawrencite. The chemical analysis, however, shows chlorine to be absent.

A section was treated with hydrochloric acid to remove the olivine. The remaining material was hypersthene, with some monoclinic pyroxene. This material was oriented on the universal stage and $Z \wedge c$ found to vary between about 27° and 34°. The values obtained for 2V were very unsatisfactory due to the low birefringence, wavy extinction, and brown color. 2V appears to be near 75°, and the mineral is positive. From the optical data, this mineral should be clinohypersthene. Though the norm indicates that some diopside may be present, it was not found microscopically.

The specific gravity of the meteorite is 3.43, as obtained by the average of several readings on fragments up to 522 grams in weight. This figure is rather low, considering that the olivine has an indicated specific gravity of 3.48, the enstatite 3.34 or higher, and the metallic portion much higher. The apparently low density of the stone may be accounted for by porosity. On the polished surfaces numerous small pits are present, which show well under magnification. They have an interior configuration that would be unlikely to have been produced by plucking during grinding. The solution of some soluble mineral during grinding could, of course, account for the pits, but considering the low density this seems improbable.

Schistosity planes have been developed through most of the olivine crystals. No matter what the orientation of the crystals may be, these planes are roughly parallel, which suggests metamorphism and shearing. They are, in places, much better developed than the olivine cleavage. The olivine is much clouded by very fine inclusions, which are chiefly concentrated along the schistosity planes and cleavages. This material is probably very finely divided magnetite. The degree of clouding varies between chondrite areas but seems to be fairly uniform within an area.

Some of the olivine chondrules have been crushed and much altered. In these chondrules fragments of olivine showing good outlines and clear interference colors are surrounded by material which is variously oriented and has hazy, indistinct interference colors. Under high magnification this surrounding material is seen to be composed of islands of olivine of various orientation having hazy interference colors and grading into a somewhat homogeneous groundmass which exhibits aggregate polarization. The chondrule has apparently been subjected to a crushing force strong enough to produce a myolinite composed of olivine which almost reached its melting point, thus changing markedly its optical character.

The hypersthene chondrules have not suffered so much distortion as the olivine. Many of them are complete, and those that are fractured do not show an optical change in the character of the hypersthene.

Veinlets are present in four of the sections studied. These veinlets are of a black, opaque substance, and contain islands of a colorless mineral which remain light during rotation between crossed nicols. At the edges of the veinlets the same mineral is found, and at a short distance it can be traced into unaltered olivine. It is assumed, consequently, that the islands are olivine which has almost reached the fusion point and has thus been changed markedly in optical character. By reflected light, nickel-iron and troilite can be seen in the veinlets, and the whole surface has a somewhat bronzy luster. The Bluff stone from Fayette County, Texas, described by Whitfield and Merrill[5] has a vein that exhibits the same characteristics.

This meteorite was analyzed by F. A. Gonyer, and the results of the analysis are given in the following table:

[5]Whitfield, J. E., and Merrill, G. P. The Fayette County, Texas, meteorite: Amer. Jour. Sci., 3d ser., vol. 36, pp. 113–119, 1888.

Analysis of Kimble County meteorite

	Analyses Combined	Soluble Silicate 43.88%	Insoluble Silicate 40.96%	Sulphide 3.74%	Metal 11.42%
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
SiO_2	37.33	33.14	55.63		
Al_2O_3	3.06	0.46	6.98		
Fe_2O_3	0.09	0.21	none		
FeO	14.47	30.21	10.27		
MgO	23.24	34.01	20.32		
CaO	1.67	0.41	3.64		
Na_2O	0.67		1.63		
K_2O	0.20		0.49		
H_2O	0.43	0.98			
P_2O_5	0.19	0.43			
TiO_2	0.11	none	0.26		
Cr_2O_3	0.17		0.41		
MnO	0.14	0.17	0.18		
NiO	0.17	0.39	none		
CoO	0.02	0.04	none		
Cl	none				
Fe	10.63				93.09
Ni	0.69				6.02
Co	0.06				0.56
Cu	0.01				0.08
P.	trace				0.03
Mn	none				none
FeS	3.74			100.00*	
	100.09	100.45	99.81	100.00	99.78

*Sulphur was determined, and sufficient iron to make FeS was deducted from the metal.

Nothing unusual is brought out by this analysis. It is very close to the average of that for stony meteorites as given by Merrill.[6] The absence of chlorine in a 3-gram sample was unexpected after having observed exudations on the polished surfaces. It is quite possible that some other deliquescent constituent may be present.

The normative mineral composition of this meteorite is as follows:

	Per cent
Orthoclase	1.18
Albite	5.00
Anorthite	5.11
Diopside	1.62
Hypersthene	19.93
Olivine	50.60
Merrillite	0.50
Magnetite	0.13
Chromite	0.25
Ilmenite	0.21
Metal	11.39
Troilite	3.74
	99.66

[6]Merrill, G. P., Composition and structure of meteorites: U. S. Nat. Mus., Bull. 149, p. 47, 1930.

Of these minerals, olivine, hypersthene, merrillite, metal, and troilite were identified petrographically. Another mineral, clino-hypersthene, corresponding in composition to hypersthene was also identified. The feldspathic constituents were not directly identified, and the material suspected of being feldspar has the appearance of maskelynite.

In summarization, the Kimble County stone is classified as a dark, greenish-gray, veined, crystalline, hypersthene chondrite. It weighs 339 pounds and belongs to a group of rather common stones. Its chief features of interest are probably the veins and the metamorphism. The date of fall is a controversial point, and it is hoped that enough evidence has been presented to show that this stone fell prior to the appearance of the October 1, 1917, meteor.

The writer wishes to express his appreciation to The University of Texas Committee on Research Grants and Publication, Dr. J. T. Patterson, chairman, for a grant to cover the cost of the analysis. He also wishes to express appreciation and thanks to Mr. A. S. Parker for his welcome donation to the Bureau of Economic Geology.

PLATE 28

Photographs of Kimble County meteorite.

1. Rounded spalled surface with one spall at the upper left corner barely attached. Lichens which have grown on the meteorite are numerous at the right and top. 1/7 natural size.
2. One flat surface and outline of the round spalled surface. The flat surface appears to be an original surface from which the crust has been removed by weathering. A vein crosses this surface and is outlined by raised elongated hummocks. The white areas at the left are caliche (calcium carbonate) which accumulated during the time the meteorite remained on the ground prior to its discovery. 1/7 natural size.
3. Polished surface showing chondrules ranging in color from porcellaneous white (right center) through gray to black; the metal and troilite are white. In this photograph it is difficult to distinguish the metal from some of the light gray chondrules. 2/5 natural size.

1 2 3

THE IRON METEORITE FROM NORDHEIM, TEXAS

Virgil E. Barnes

During 1936, the University Centennial Exposition secured a much-corroded iron weighing 34 pounds from Hugo Schlosser, a farmer who lives 3 miles south of Nordheim, DeWitt County, Texas. This fall is located at approximately 28°52′ N. Lat. and 97°37′ W. Long. Figure 98 is a map showing its location.

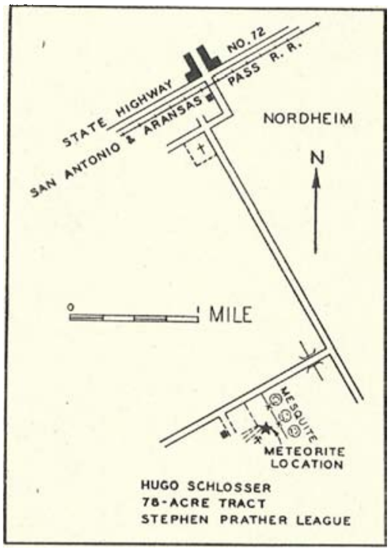

Fig. 98. Map showing the location where the Nordheim iron meteorite was found.

The meteorite was found in a cotton field on Mr. Schlosser's farm during August, 1932, and apparently had been brought to the surface by a plow earlier that year. This field was cultivated for the first time during the 1932 season, and evidently the meteorite had lain just beneath the surface for many years. Mr. Fred Oehler of San Antonio was the first to identify this find as a meteorite. He secured it as a loan for about three years before Mr. Schlosser disposed of it to the University Centennial Exposition. This iron

Issued June, 1940.

was brought to the attention of the University authorities by Mr. E. H. Sternberg, principal of the Nordheim high school.

When received, the meteorite was covered by loosely attached magnetic scale from 2 to 4 millimeters thick, most of which came off in the course of handling. Two small pieces of metal weighing probably less than a total of 20 grams were removed before the specimen was received. A 13-gram piece was taken for analysis, and an equal amount was removed for study under the metallographic microscope. The remaining mass weighs 33.3 pounds (15.11 kilograms). This iron is easily cut by a hacksaw and is malleable.

The meteorite measures about 21 centimeters long, 13 centimeters thick, and 19 centimeters in a median direction. It has the usual type of surface found on much-corroded irons that are free of troilite nodules. The shape is irregular sub-polyhedral with most of the faces concave and the angles between them sharp. One point is rounded, but oxidation has obliterated all other evidence that might have been present to indicate that this is the brustseite, providing, of course, that the meteorite remained oriented during flight. A photograph of the meteorite (Pl. 29, fig. 1) shows one side from which all the pieces for study have been removed. The cut surfaces have been polished and etched, yet in this photograph the etched structure can hardly be seen. The polishing was carried past the edges of one cut to give more surface area so that the orientation of the structure could better be determined. Plate 29, figure 2, is a photograph of the meteorite taken from another direction showing, in addition to the shape, some of the scale which still adheres.

This iron can be polished to a bright mirror-like surface. A few barely visible schreibersite plates are present, but no troilite or other minerals are recognizable. At least two sets of parallel cracks are present. One of these can be seen in figures 3, 4, and 5 of Plate 29. After being cut, and upon standing for a while, a few small, barely visible spots of exudation appeared upon the surface, indicating the presence of lawrencite.

Etching, using 6 per cent nitric acid, brings out several sets of schlieren-like streaks or bands. These streaks are visible only when the incidence of the light is in certain directions. With certain other directions of illumination, the etched surface appears structureless and has an appearance suggestive of the presence of a thin coat of varnish. Only a few of the schlieren-like directions are visible at the same time. For this reason the three photographs, figures 3, 4, and 5 of Plate 29, are used to show all the directions present upon one of the surfaces. The streaks, depending upon the direction of lighting, either have a sheen or are dark. In Plate 29, figure 4, the lighting is so arranged that the groundmass reflects with a slight silvery sheen, and most of the streaks are dark. Altogether, ten different structural directions can be seen in these three photographs. In Plate 29, figure 3, two parallel lines, one reflecting light (extreme right) and the other dark, are present. The two sets, even though parallel in section, dip at different angles.

These streaks are not sharply bounded as are the lamellae of the octahedral irons. In the photographs it is seen that they vary in width within a set and in some places entirely disappear. The edges of the streaks have a slightly frayed appearance when observed with a hand lens. The several sets vary in width, depending upon the angle at which they intersect the etched surface.

Under the microscope at low magnification, the etched iron appears structureless. Using 200 diameters magnification, a structure can be seen which stands out even more clearly at higher magnifications. The fragment studied has two surfaces intersecting at about 30°. On one of these surfaces in Plate 30, figure 3, four directions of microscopic structure can be seen. Two directions are nearly parallel, and the other two directions are at a very slight angle to each other. These two sets of directions are roughly at right angles to each other. The other surface of this fragment shows slightly more divergence between the lines. One direction was traced on both surfaces, and the fragment cut parallel to the plane designated in this manner. The etch pattern of the new surface reveals three microscopic structural directions at nearly 60° to each other. The microscopic structure, therefore, must be octahedral, but, unlike that of the normal octahedral iron, the structure is invisible to the unaided eye.

The visible schlieren-like streaks do not coincide with this structure. One streak, so situated that its orientation could be reasonably well ascertained, appears to intercept the axes of the microscopic structure in the relationship (210) that is parallel to the face of a tetrahexahedron. If this is correct, then it is possible to cut a random section through the meteorite in such a manner that twelve sets of structural directions could be recognized. As previously pointed out, at least ten sets can be recognized in the surface photographed.

Under magnification a few schreibersite plates or needles up to 1 millimeter long and 0.15 millimeter thick are visible and apparently are of random orientation. One twin was seen, the two members of which are crossed at near right angles. Under high magnification some lens-shaped forms were seen, a few of which were connected side by side in parallel arrangement. One microscopic nodule of troilite is all that was found on the several square inches of surface examined. This nodule has a schreibersite crystal extending entirely through it. In the photomicrographs, Plate 30, figures 1 to 4, some of the forms taken by the schreibersite crystals are shown. These photographs were taken at 350 diameters magnification and are reproduced in the plate at about 230 diameters magnification. Surrounding the crystals are thin layers of nickel-iron, possibly taenite, which is continuous with the same type of material that depicts the octahedral structure. The other less bright constituent between the taenite plates may be kamacite.

Another constituent may be present which makes up part of the schlieren-like streaks. This constituent, which would normally be considered plessite, is of about the same color as the taenite but is of lower relief. If this constituent is plessite, it is abnormal in that it is brighter than the kamacite, whereas the reverse is usually true. Furthermore, plessite is usually considered to be a mixture of taenite and kamacite, possibly as an eutectic, and no evidence of this is seen even under the highest magnification. This third constituent may be taenite with a low nickel content. Plate 30, figure 5, shows a portion of one of the schlieren-like streaks and some evidence that the bright equigranular material forming it may be of a different composition from the taenite. In the upper part of Plate 30, figure 1, a portion of another streak is shown. Stray grains of the intermediate constituent are also shown in Plate 30, figure 4.

The two most common constituents are designated for convenience as taenite and kamacite, and these outline the octahedral structure. The taenite is in thin plates and is the constituent that gives the direction to the octahedral structure. The kamacite is of a more granular equidimensional character and occupies the space between the taenite plates. The intermediate constituent has apparently separated out along planes parallel to the faces of a tetrahexahedron and takes the form of more or less equidimensional grains which are separated in places by irregular thin taenite layers. The orientation and irregular distribution of this constituent causes the schlieren-like appearance observed without magnification.

Upon weathering, the kamacite is first removed, leaving a delicate network of taenite. As the weathering progresses the network is broken, and with more weathering only small, brightly reflecting points are left. In detached pieces of scale, areas are present in which the taenite forms a network. It also outlines areas originally occupied by schreibersite crystals. Plate 30, figure 6, is a photomicrograph of a polished surface on a 3-millimeter thick piece of scale showing the taenite network preserved in the oxidation products of the other constituents. The magnetic properties of meteoritic scale may be due in part to the presence of finely divided taenite rather than to the presence of magnetic iron oxide formed during oxidation, as suggested by Shannon.[1] In Shannon's paper the problem is attacked from the chemical standpoint, and the scale was not polished and examined under high magnification using a reflecting microscope. Until this is done it will be uncertain whether the magnetic properties of the scale that he examined are due to magnetic iron oxide or to minute particles of unoxidized nickel-iron.

F. A. Gonyer analyzed 13 grams of the Cuero meteorite, freed as nearly as possible from rust, and reports the following composition:

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[1]Shannon, E. V., The oxidation of meteoric irons with comparative descriptions of two new examples of magnetic iron oxide from terrestrial sources: U. S. Nat. Mus., Proc., vol. 72, art. 21, pp. 1–15, 1927.

	Per cent	
Fe	87.79	
Ni	11.69	
Co	0.51	
Cu	trace	
Mn	none	
Cl	0.02	
C	none	
P	0.04	
S	trace	
Insoluble	0.01	(mostly Fe_2O_3)
Total	100.06	

This analysis is calculated to the following mineral constituents:

	Per cent
Fe-Ni-Co-Cu	99.74
Schreibersite (Fe, Ni, Co) $_3$P	0.22
Lawrencite ($FeCl_2$)	0.04
Troilite (FeS)	trace
	100.00

The specific grâvity of this iron is 7.84.

This meteorite, on the basis of meteorites described previously, for the present will be included under the nickel-rich ataxites of the Rose-Tschermak-Brezina[2] classification and in the Cape group (Dc). The Cape group is defined as being nickel-rich and having "sharp (hexahedral?) etch bands in a dull groundmass." Cohen[3] combines this group with the Shingle Springs (Dsh) group of Rose-Tschermak-Brezina, which contains etch bands and spots that are not sharply bounded, defines this entire group as "granular to dense ataxites with (?) hexahedral schlieren," and designates this group as the Cape iron group with symbol (DsC). The classification of Rose-Tschermak-Brezina is the one usually accepted, but in this case the modification by Cohen appears more logical. Meteorites falling into the DsC group of Cohen are the Cape of Good Hope, Kokomo, and Iquique (Dc); and Shingle Springs and Ternera (Dsh).

The analyses of these irons are compared with that of the Nordheim in the following table:

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[2]Brezina, Aristides, The arrangement of collections of meteorites. Proc. Amer. Phil. Soc., pp 211–247, 1904.

[3]Cohen, E. W., Meteoritenkunde, Heft 3, pp. 138–161, Stuttgart. E. Schweizerbart'sche Verlagshandlung (E. Nagele), 1905.

	(Dc)			(Dsh)		
	I CAPE OF GOOD HOPE	II KOKOMO	III IQUIQUE	IV SHINGLE SPRINGS	V TERNERA	VI NORDHEIM
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Fe	82.87	83.24	83.49	82.21	82.17	87.79
Ni	15.67	15.76	15.41	16.69	16.22	11.69
Co	0.95	1.07	0.94	0.65	1.42	0.51
Cu	0.03	0.01	0.02	0.02	trace	trace
Cr.	0.04	0.00	trace	0.02		n.d.
C	0.03	n.d.	0.03	0.03		0.00
Cl	0.01	n.d.	n.d.	0.00		0.02
P	0.09	0.08	0.07	0.34	0.11	0.04
S	0.00	trace	0.02	0.05	0.13	trace
	96.69	100.16	99.98	100.01	100.05	100.05
Sp. Gr.	7.8543	7.8606	7.8334	7.8943	7.694	7.84

I. Analysis by Fahrenhorst, p. 87; E. Cohen, Meteoreisen-Studien 10th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 15, pp. 79–88, 1900.
II. Analysis by Sjöström, p. 153; E. Cohen, Meteoreisen-Studien 8th: Ann. k. k. Naturhist, Hofmus., Wien, Bd. 13, pp. 150–153, 1898.
III. Analysis by Sjöström, p. 156; E. Cohen, Meteoreisen-Studien 8th: Ann k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 153–156, 1898.
IV. Analysis by Sjöström, pp. 479–480; E. Cohen, Meteoriesen-Studien 9th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 477–481, 1898.
V. Analysis by Lindner; C. Klein, Die Meteoritensammlung der Königlichen Friedrich-Wilhelms Universitat zu Berlin am 21 January 1904, Sitzungsberichte der Konigl. preussi Akademie der Wissen-schaften zu Berlin, Bd. 4, p. 151, 1904.
VI. Analysis by F. A. Gonyer.

The chief difference is that Nordheim is lower in nickel and cobalt and higher in iron. The minor constituents do not vary appreciably, except that the Dsh group has a higher phosphorous and sulphur content. The average nickel-cobalt in the first five meteorites is 16.96 per cent, compared with 12.20 per cent in the Nordheim, a difference of 4.76 per cent. The nickel-cobalt content of Nordheim is below that of the schlieren-containing ataxites and is near the boundary for that of the structureless nickel-rich ataxites. Several of the fine and finest octahedrites have a higher nickel content than does the Nordheim iron.

In discussing the Kokomo iron, Cohen[4] makes the following statement:

Under a moderately strong magnifying power Kokomo appears as an entirely homogeneous mass, with the exception of extraordinarily small,

[4]Cohen, E. W., Meteoreisen-Studien 8th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 150–153, 1898.

strongly reflecting points. At first, by the employment of a magnifying power of about 200 diameters, one sees a succession of dark, faint, and bright, glistening particles; since one cannot distinguish a distinct line of demarcation between one and another of them, it is not possible to determine definitely whether the structure is granular or whether the appearance is due to etching pits. I consider the former the more probable.

He also mentions that the "stripes" are darker or brighter according to the position of the plate with reference to the light; that with a certain position of lighting the entire surface is uniform; and that upon etching, the iron takes on a varnish-like luster. These properties are also found in the Nordheim meteorite. Under magnification, the same effect was obtained as noticed by Cohen of "extraordinarily small, strongly reflecting points" when the Nordheim was etched to bring out the schlieren-like lines. It was found that 3 per cent nitric acid acting for about 1 or 2 seconds is sufficient to bring out the microscopic structure, whereas 6 per cent nitric acid acting for 15 to 20 seconds is necessary to bring out the schlieren-like structure. A slight burnishing after etching helps to make a more distinct surface for study.

Cohen's[5] description of Cape of Good Hope, Iquique, and Shingle Springs contain very similar statements to the above, and he thinks that the separation of these meteorites into two groups is not advisable. He states:

If no especial weight be given to the kind of edging of the bright portions, this meteoric iron [Shingle Springs] may be included in a well-defined group with the following common characteristics: high percentage of nickel; bright etching bands and spots; dense structure of the nickel-iron. Such a grouping appears to me more natural than the division into two groups by Brezina. The latter unites the Cape, Iquique, and Kokomo irons in the Cape group, and arranges Shingle Springs and Ternera under the Chesterville group, which, in consequence of this, acquires quite a heterogeneous composition.

Considering the octahedral structure of the Nordheim, which is visible under high magnification, it seems that it should be placed in a new division of microscopic-structured octahedrites rather than with the ataxites. It is possible that a restudy of the meteorites

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[5]Cohen, E. W., Meteoreisen-Studien 9th: Ann. k. k. Naturhist. Hofmus., Wien, Bd. 13, pp. 477–481, 1898.

of Brezina's Dc and Dsh groups under high magnification and with properly etched surfaces might reveal a similar structure. If they do have an octahedral structure they should be removed from the nickel-rich ataxites and should be placed with the octahedrites in a new group defined as microscopic-structured octahedrites with schlieren-like streaks. If the schlieren-like streaks can be correlated with a definite crystallographic direction—for example, if they are parallel to the face of a tetrahexahedron—then the qualifying word "tetrahexahedral" can be inserted before "schlieren-like streaks." If, however, the present terminology is retained, in which octahedral structure visible without magnification denotes an octahedrite, then, under the Rose-Tschermak-Brezina classification, the Nordheim will have to be classified as a nickel-rich ataxite, group Dc.

The writer wishes to express his appreciation to Dr. H. B. Stenzel and the Committee on Geological Exhibits for the University Centennial Exposition for the opportunity to examine this iron, and to The University of Texas Committee on Research Grants and Publication, Dr. J. T. Patterson, chairman, for a grant to cover the cost of an analysis.

PLATE 29

Photographs of Nordheim meteorite.

1. View showing character of surface and parallel cracks in the polished areas. x4/10.
2. End view showing character of surface and some loosely-attached scale. x4/10.

3, 4, 5. Polished and etched surfaces lighted in each photograph from a different direction to bring out the large number of structural directions. The type of reflection depends on the direction of lighting. In figure 4 the two prominent directions are lighted to bring out the reverse of the effect seen in figure 3. About x1.5.

1

3

4

2

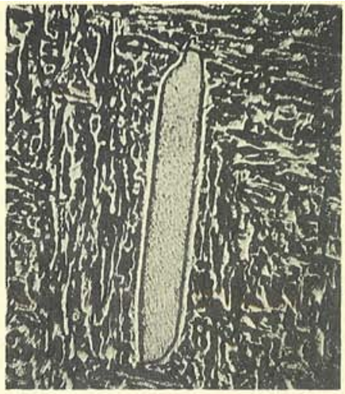
5

PLATE 30

Photomicrographs of polished and etched surface of Nordheim iron and scale. About x230.

1. A schreibersite crystal surrounded by taenite which is continuous with the taenite that forms the octahedral structure. In the upper part of the photograph is a portion of a schlieren-like line.
2. A schreibersite crystal parallel to one direction of the microscopic structure.
3. A schreibersite crystal group and four definite directions of microscopic structure.
4. A peculiar type of schreibersite crystal and a few grains of the intermediate constituent which forms the schlieren-like bands.
5. A portion of a schlieren-like line. The bright granular material of this line is probably a material intermediate in composition between taenite (long bright plates) and kamacite (black). In the upper right corner taenite borders some of the intermediate material. In the lower right and upper left corners normal octahedral structure is present.
6. A polished surface of scale in which taenite is preserved in the oxidation products of other constituents. This surface shows three prominent structural directions.

1



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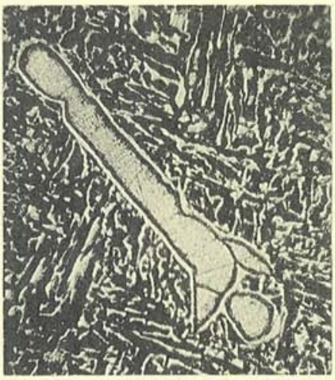

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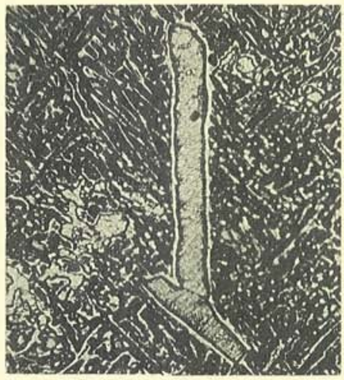

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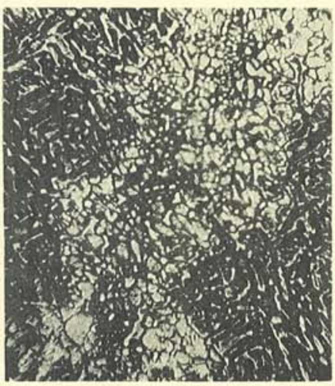

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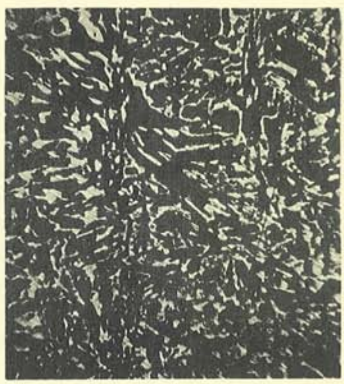

6

PSEUDOTACHYLYTE IN METEORITES

Virgil E. Barnes

In a paper by Hall and Molengraaff[1] describing the geology of the Vredefort Mountain Land, an extensive discussion of pseudotachylyte is given. The similarity of this material to veins found in the Kimble County[2] and Bluff[3] meteorites is striking. With this in mind the writer restudied and made other thin sections of the Kimble County meteorite and borrowed the U. S. National Museum's thin sections of the Bluff veins described by Merrill.[4] For comparison the writer also prepared thin sections of pseudotachylyte and myolinite found recently in the pre-Cambrian area of central Texas.

Shand[5] was the first to use the word *pseudotachylyte.* He states ". . . the name pseudotachylyte has been adopted in recognition of the fact that these rocks have a great similarity to tachylyte, also that such rocks have been mistaken for trap and tachylyte in Scotland and India as well as in South Africa, and for the further reason that no more suitable name is in existence."

The pseudotachlyte described by Shand is in granite. It is dense, black, and contains inclusions of quartz and feldspar derived from the granite. Shand recognized microscopically three types of pseudotachylyte ranging from a type that is dense, clouded with magnetite, and slightly isotropic; through one that shows an incipient crystallization of small grains and scales which are pleochroic from yellowish green to pale grass-green; to a type consisting either of a honeycomb of polygonal spherulites of a dark brown color, or of a felt of feldspar-microlites with a subordinate amount of magnetite dust and a few green scales in the interstices.

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[1]Hall, A. L., and Molengraaff, G. A. F., The Vredefort Mountain Land in the Southern Transvaal and the northern Orange Free State: Verh. der Koninklijke Akad van Wetenschappen te Amsterdam, vol. 24, no. 3, pp. 93-114, 1925.

[2]Barnes, V. E., The stony meteorite from Kimble County, Texas: Univ. Texas Bull. 3945, pp. 623-632, 1939 [1940].

[3]Whitfield, J. E., and Merrill, G. P., The Fayette County, Texas, meteorite: Amer. Jour. Sci., 3d ser., vol. 36, pp. 113–119, 1888.

[4]Idem.

[5]Shand, S. J., The pseudotachylyte of Parijs (Orange Free State) and its relation to "trap-shotten gneiss" and "flinty crush-rock": Quar. Jour. Geol. Soc. London, vol. 72, pp. 198–221, 1916.

Issued June, 1940.

Shand places pseudotachylyte in the following continuous series of crushed to recomposed rocks: myolinite, fritted myolinite or flinty crushrock, fused myolinite or pseudotachylyte, and recrystallized pseudotachylyte.

In an appendix to his paper he states: "The pseudotachylyte has originated from the granite itself through melting, caused not by shearing but by shock, or alternatively by gas-fluxing."

Hall and Molengraaff[6] in a more extended examination of this same area (Parijs and the Vredefort Mountain Land of South Africa) found pseudotachylyte in all of the old rocks of the area including the metamorphosed sediments. They note also that magnetite separates out in the wall rocks and that crushing next to the veins is prevalent with few exceptions. They concluded that the pseudotachylyte was produced by crushing without much shearing and that shock and gas-fluxing were probably not operative. Shand, as well as Hall and Molengraaff, shows by chemical analyses that the pseudotachylyte is very similar in composition to that of the enclosing rocks and concludes that it is derived from these rocks and that it has not migrated far.

Crickmay[7] in a study of myolinites in Georgia notes that:

> The myolinite is similar to pseudo-tachylite (Hall and Molengraaff, 1925) in being pseudo-eruptive, but there has been no fusion in its development. If the presence of glass is taken as distinctive of a pseudo-tachylite, the name is not applicable here. However, if the term is used to denote a myolinite with pseudo-eruptive relations to the parent rock, it is certainly descriptive of the myolinite near Neel's Gap.

Waters and Campbell[8] have made an excellent review of myolinites and, more to the point, have restudied a few samples of the South African pseudotachylyte using a different method of attack. They failed to find true glass either in this or similar material from California. The index of refraction of the isotropic-appearing pseudotachylyte is considerably higher than that of the same material when fused into a true glass by the oxy-acetylene torch. Furthermore, under high magnification, 250x, they find that much of the pseudotachylyte that appears isotropic at low magnification

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[6]*Op. cit.*

[7]Crickmay, G. W., The occurrence of myolinites in the crystalline rocks of Georgia: Amer. Jour. Sci., 5th ser., vol 26, pp. 170, 1933.

[8]Waters, A. C., and Campbell, C. D., Myolinites from the San Andreas fault zone: Amer. Jour. Sci., 5th ser., vol. 29, pp. 473–503, 1935.

is resolvable into definite particles. The inferred conclusion, therefore, is that pseudotachylyte is in reality a very finely divided myolinite.

Black veinlets are very common in meteorites, and probably more than half of all stony meteorites are veined. The only veins examined for this discussion, however, are those found in the Kimble County, Bluff, and Cuero meteorites. The latter is not truly veined but is faulted with myolinite along the faults. The veinlets in the Kimble County meteorite are narrow, being less than a millimeter thick. Figure 99 is a tracing showing the veinlets present on a

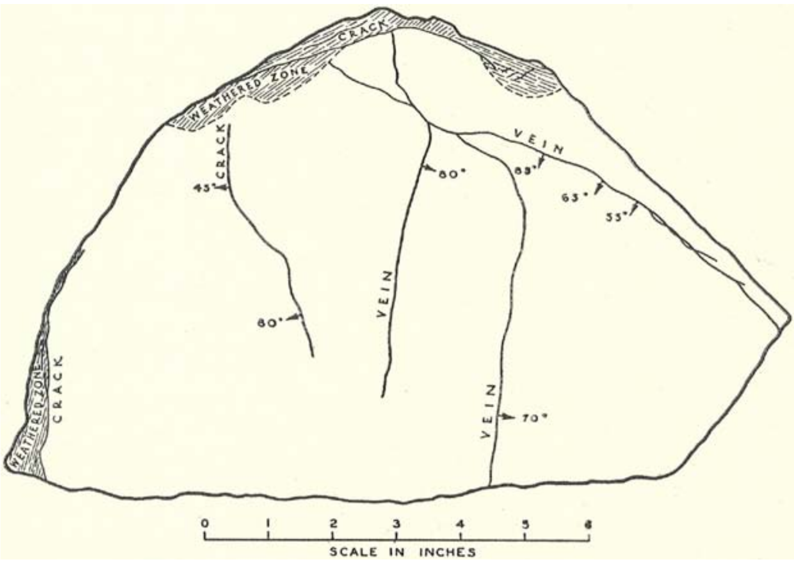

Fig. 99. Tracing of veins on a polished surface of the Kimble County meteorite.

polished surface of the Kimble County meteorite. Two prominent directions intersecting at about 70° are present. On another polished section one of these veins cuts across a light-colored chondrule, and so far as can be seen there has been no offsetting of the chondrule. By reflected light the veins of both the Kimble County and Bluff meteorites have a bronzy appearance and have some metal distributed throughout. In the Bluff meteorite studied by Whitfield and Merrill,[9] a vein about 2 millimeters thick was found. A chemical

[9]*Op. cit.*

analysis was made of the vein which compares rather closely to that of the meteorite as a whole. Individual stones of Pultusk and Mocs seem to be made up wholly of vein material.[10] Analyses of veins more than an inch in thickness in the Orvinio[11] and Ställdalen[12] meteorites have also been made, and in each case the veins are similar in composition to that of the meteorites as a whole. These analyses are given in the following table:

	Bluff (1)		Orvinio (2)		Ställdalen (3)	
	Stone	Vein	Stone	Vein	Stone	Vein
	Per cent		Per cent		Per cent	
SiO_2	37.70	38.96	38.01	36.82	35.71	38.32
Al_2O_3	2.17	1.89	2.22	2.31	2.11	2.15
FeO	23.82	22.98	6.55	9.41	10.29	9.75
MgO	25.94	27.52	24.11	21.69	23.16	25.01
CaO	2.20	trace	2.33	2.31	1.61	1.84
Na_2O	----	----	1.46	0.96	----	----
K_2O	----	----	0.31	0.26	----	----
MnO	----	----	----	----	0.25	1.00
NiO	----	----	----	----	0.20	0.42
Fe	4.41	2.30	22.34	22.11	21.10	17.47
Ni+Co	1.75	3.26	2.15	3.04	1.78	1.02
S	1.30	0.26	1.94	2.04	2.27	2.51
P_2O_5	----	----	----	----	0.30	0.31
	99.29	97.17	101.42	100.95	98.78	99.80
Sp. gr.	3.510	3.585	3.675	3.600	3.733	3.745

(1) Whitfield, J. E., Amer. Jour. Sci., 3d ser., vol. 36, pp. 113–119, 1888.
(2) Sipöcz, L., Tschermarks Min. Mitt., p. 244, 1874.
(3) Lindström, G., Ofvers. Vetensk.—Akad. Förhand. Stockholm, no. 4, p. 35, 1877.

In thin sections the veinlets are entirely opaque except for colorless inclusions which remain bright during rotation between crossed nicols. The edges of some of the larger olivine crystals where they contact the veins have the same appearance. The inclusions are, therefore, mostly altered olivine, with possibly some altered hypersthene being present. In both the Kimble County and Bluff meteorites the olivine and hypersthene are clouded by minute black specks. In the olivine of the Kimble County meteorite, especially, these black specks are arranged mostly in parallel zones without respect to the orientation of the olivine crystal but with a more

[10]Farrington, O. C., Meteorites, p. 85, R. R. Donnelley & Sons Company, Chicago, 1915.
[11]Described by Tschermak, Gustav, Sitzungsber. Akad. Wiss. Wien, Math.-naturwiss. kl., vol 70, Abt. 1, p. 459, 1875.
[12]Described by Nordenskiöld, A. E., Geol. Fören. Förhand., Stockholm, vol. 4, p. 46, 1878.

or less parallel orientation throughout the thin section. This is suggestive of incipient shearing with magnetite separating from the femic minerals along the shearing direction. This may be similar to the separation of magnetite reported by Hall and Molengraaff[13] in the wall rocks adjacent to pseudotachylyte. Some of the colorless inclusions in the meteorite veinlets are practically free of these black specks. From the rounded and embayed outline of these inclusions and their changed optical character, they must have been near their melting point and possibly plastic enough for the magnetite to migrate into the vein proper.

In Plate 31, microphotographs of these veins are shown. Figure 1 of this plate is a photograph by plane-polarized light of a vein in the Bluff meteorite taken from one of Merrill's thin sections. Figure 2 is the same except that crossed nicols were used. Figures 3 and 4 are photographs of a vein in the Kimble County meteorite using plane-polarized light and crossed nicols respectively. Figures 5 and 6, using plane-polarized light and crossed nicols respectively, are photographs of pseudotachylyte from an outrop in the bed of Sandy Creek near the base of Enchanted Rock in Llano County, Texas.

It was hoped that the difference in character of the altered and normal olivine could be clearly shown by photographs, but unfortunately this is not possible at present. In Plate 31, figure 2, many of the inclusions in the vein remain bright during 360° of rotation, and in Plate 31, figure 4, the inclusion in the thickened portion of the vein at the right does the same. The photographs do not show this characteristic well but do show something of the character of the narrow veins. A portion of the vein wall situated at the lower side of the vein in Plate 31, figures 3 and 4, is sharply defined even though the wall rock is of heterogeneous material. This is indicative of a clean-cut shear, but, as already mentioned, a chondrule is crossed by one of these veins, and no displacement can be seen. The amount of movement to produce this shearing must be minute; therefore, the containing pressure must have been very high for friction to produce enough heat to change the optical properties of the inclusions.

In Plate 31, figures 1 and 2, a veinlet is shown which extends almost through the pseudotachylyte and into the wall rock on one

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[13] *Op. cit.*, p. 99.

side. Quartz veinlets having a similar appearance have been pictured by Waters and Campbell.[14] The pseudotachylyte from Llano County shows many of the characteristics of the normal nonrecrystallized pseudotachylyte described from South Africa. In thin sections and in the accompanying photographs of a thin section (Pl. 31, figs. 5 and 6), the black, dense material is pseudotachvlyte which has islands of microcline and quartz distributed throughout. The extreme crushing and shearing and "milling out" of the minerals are shown clearly in this section. The edge of the large feldspar crystal is frayed and drawn out. Using crossed nicols, the deformation of the crystal is shown by the bent lamellae and the undulatory extinction. In this section there is some material which remains bright during 360° of rotation between crossed nicols, thus indicating a common genetic relationship between the pseudotachylytes of meteorites and of earthly rocks.

The veins in the meteorites differ considerably from those in the granite. However, other than the fact that the granite contains a larger number of fragments, the difference is chiefly due to the great dissimilarity in mineralogical and chemical composition of the two. Hall and Molengraaff,[15] in describing pseudotachylytes from much less basic rocks, state: "The groundmass or matrix of the pseudotachylyte is generally crowded with small black specks, taken to be magnetite, which may be so abundant that the rock becomes only very little transparent and not resolvable under the microscope even with high powers." It is believed that the greater opacity of the veins found in the Kimble County and Bluff meteorites may be accounted for by the high iron content of the meteorite minerals, which has separated out as magnetite.

In consideration of the small number of pseudotachylytes described from North America, the field relations of this rock will be given. This pseudotachylyte is from a few hundred feet within the Enchanted Rock granite mass and was collected from a shear zone of dull brick-red, fritted myolinite or flinty crush rock 20 feet thick which strikes N. 33° E. and has a vertical dip. The pseudotachylyte, which constitutes less than 1 per cent of the shear zone, is present as dense, flinty-appearing, black, narrow, resistant streaks. Pseudotachylyte from the type locality is not available

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[14]*Op. cit.*, p. 492.
[15]*Op. cit.*, p. 105.

for comparison, but nevertheless the Llano material is easily identified when compared with the microphotographs of pseudotachylyte in Hall and Molengraaff's memoir.

In the Llano pseudotachylyte, and as pointed out by Crickmay[16] for Georgia and by Waters and Campbell[17] for California and South Africa, no material is present that can be definitely identified as glass. Much entirely opaque material is present in which glass might be contained but in which it would be difficult to prove the presence of glass since light cannot be transmitted through it. The extremely small translucent particles all appear to be anisotropic, even though some of them are weakly so and do not show definite extinction. It is possible that these particles are altered in the same manner as the much larger olivine fragments observed in meteorite veins. It is thought that enough heat has been created to disorder somewhat the molecular structure but not to destroy it entirely. This may be the characteristic noted by Hall and Molengraaff[18] and called "incipient melting." Minerals during such disordering might be plastic enough to migrate and at the same time not be a glass. Likewise it seems that recrystallization of this material could take place if the temperature remained high enough for a sufficient length of time, but if the original thesis that heat is developed by crushing and shearing is correct, then it would be expected that the heat would dissipate rapidly into the uncrushed rock before recrystallization could take place.

The word pseudotachylyte should probably be reserved for a myolinite in which the character of the minerals has been changed through crushing and heating, with a separating of dark material and the development of very small particles, many of which are molecularly disordered. These latter are then neither glass nor are they definitely mineral, and, therefore, pseudotachylyte, or "false tachylyte," seems entirely appropriate. "Pseudotachylyte vein" should be retained for that pseudotachylyte which shows definitely an intrusive relationship. In discussing meteorites, however, it is difficult to think of the pseudotachylyte as being other than veins since this type of material has always been referred to as veins. If a certain amount of interchangeable usage is noticed in this

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[16] *Op. cit.*, p. 170.
[17] *Op. cit.*, p. 495.
[18] *Op. cit.*, p. 100.

paper, let it be understood that veins, unless otherwise qualified, mean pseudotachylyte.

Veins have been described in the Cuero[10] meteorite which probably corresponds more closely to a myolinite. In this case the veins are along slickensided faults of small displacement. The Cuero is an old fall on which the fluted surface is preserved, yet open cracks extend to a depth of at least 6 centimeters along the faults, indicating that the filling is a myolinite which, because of its granularity, weathered easily and was removed.

If all veined meteorites were examined, undoubtedly all gradations from myolinite barely aggregated sufficiently to hold the meteorite together, to the densest of pseudotachylyte would be found. That these veins were formed after the meteorite entered the atmosphere or that they formed upon hitting the ground can probably safely be disregarded. It is true that these veins resemble somewhat the crust of a meteorite, but upon one moment's reflection it is seen that, even though the surface of the meteorite may become incandescent, it is in the atmosphere only for a few seconds; and that due to slow conduction the interior during this time must remain at a temperature near that of interplanetary space. Under these conditions a surface melt would immediately congeal and would not be able to penetrate cracks deeper than a few centimeters at most.

Another possible origin of these veins that should be mentioned is an origin by shock such as would be caused by the disaggregation of a celestial body during a close approach or collision. With this origin, however, it is difficult to understand how myolinite along faults such as is found in the Cuero could form and the meteorite not be parted along these weak zones.

Recognition of the fact that vein material in meteorites is similar to material found on the earth leads to the substantiation of the postulate that meteorites are derived by the disaggregation of celestial bodies. Some idea of the size of such a body might be obtained if the magnitude of the forces necessary to produce pseudotachylyte were known. This material has been found on the earth only in metamorphosed rocks and must have formed at depths of several miles below the surface and consequently under rather high pressures. In a celestial body a certain minimum size would

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[10] Barnes, V. E., The stony meteorite from Cuero, Texas: Univ. Texas Bull. 3945, pp. 613–622, 1939 [1940].

be necessary before deformative movements could take place. Furthermore, if the body were zoned with nickel-iron in the center, followed in succession by zones of pallasitic material and stone containing some iron, then the pseudotachylyte would have been in the outer stony part and not near the center of the body. This gives an additional size below which the body could not have been and still have the pseudotachylyte formed within it. This indicates that the body would have to be at least of a minimum size of several hundred miles in diameter.

Some indication of the upper limit of size possible for such a body can be obtained if it is assumed that the meteorites seen to fall on earth are samples of a body from which they were originally derived and that pseudotachylyte has a maximum pressure limit above which it cannot form. According to the available sample,[20] using the 60 falls observed in North America up to January 1, 1909, as given in the following table, an indication of the proportion of veined meteorites can be obtained.

	Per cent
Iron	5
Stony iron	1
Achrondrites veined	1
Achrondrites not veined	6
Chondrites veined or brecciated	42
Chondrites not veined	45
	100

Veined meteorites make up nearly half of all the meteorites observed to fall in North America. The figures for the entire earth will differ somewhat from these but in general will be comparable. A factor that may be significant and may tend to nullify the above averages is the possibility that meteorites are derived from many different bodies. Also many of the more friable chondrites may not have reached the ground, thus giving a too high proportion for the veined stones. However viewed, if the present sample is at all reliable, a considerable portion of the meteorite source body (or bodies) is composed of veined rocks. If there are limits to the conditions under which these veins form, then the size of the body would also have to be limited probably at the most to a few thousand miles in diameter.

[20]Farrington O. C., Catalogue of the meteorites of North America to January 1, 1909: Nat. Acad. Sci., Mem., vol. 13, pp. 16–20, 1915.

The identification of pseudotachylyte in meteorites confirms Hall and Molengraaff's belief that gas fluxing is not operative in the formation of such material found on earth. Meteorites are poor in gases and in minerals suggestive of a gaseous or aqueous origin. It becomes very unlikely, therefore, that gases could be operative in forming these veins in the bodies from which meteorites are derived. Crushing and shearing under a considerable load seem to be the logical source for the heat which modified the minerals into the substances found in these veins. The intrusive nature of this material is undoubtedly due to differential movement set up during crushing. A rock mass cannot be deformed without developing tensional strain in some direction. If this strain is sufficient to cause fractures and if these fractures penetrate to a crush zone in which the products of crushing are under high containing pressures, then the crushed material will flow toward the point of lowest pressure, providing the differential pressure is sufficient to overcome the frictional resistance. In this manner the presence of intrusive crush rocks can be explained.

The main attempt in this paper is to show that the black veins in meteorites are very similar to pseudotachylyte found in some of the metamorphosed rocks of the earth and that their origin is probably similar. This, in combination with the proportion of veined meteorites observed to fall over a given length of time, leads to the tentative conclusion that the source of meteorites must be from a body (or bodies) of the order of magnitude of several hundred to a few thousand miles in diameter.

PLATE 31

Microphotographs of pseudotachylyte in meteorites and in granite.

1. Pseudotachylyte vein (black) in the Bluff meteorite. Photographed with plane-polarized light. The inclusions in the vein are mostly altered olivine. A small veinlet which cuts the pseudotachylyte and the inclusions penetrates the wall rock. About x24.
2. Pseudotachylyte vein (black) in the Bluff meteorite (same view as fig. 1). Photographed with crossed nicols. A few of the inclusions are so altered that they remain bright during 360° of rotation between crossed nicols. About x20.
3. A complex vein of pseudotachylyte in the Kimble County meteorite which shows intrusion of pseudotachylyte into cross fractures at the left. Photographed with plane-polarized light. About x24.
4. A complex vein of pseudotachylyte in the Kimble County meteorite (same view as fig. 3). Photographed with crossed nicols. The inclusion in the thickened portion of the vein, at the right, remains bright during 360° of rotation between crossed nicols. About x20.
5. Pseudotachylyte from the Enchanted Rock granite mass, Llano County, Texas. Photographed with plane-polarized light. The light-colored bands in the upper part of the photograph are composed largely of finely divided fragments of quartz and feldspar. The black material is pseudotachylyte which is so opaque that light cannot penetrate it in sections 0.03 mm. in thickness. About x38.
6. Pseudotachylyte from the Enchanted Rock granite mass, Llano County, Texas (same view as fig. 6). Photographed with crossed nicols. This photograph brings out more clearly the fine state of division of the fragmented quartz and feldspar. The large feldspar crystal at the bottom is highly strained as is shown by the undulatory extinction and the bent twinning lamellae. About x32.

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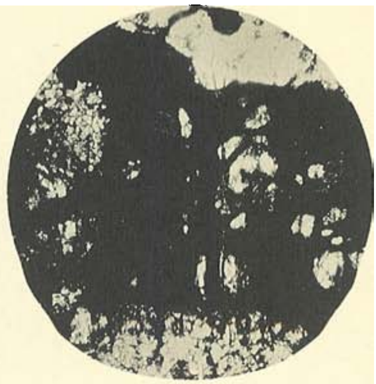

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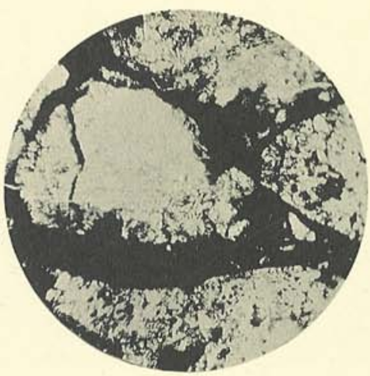

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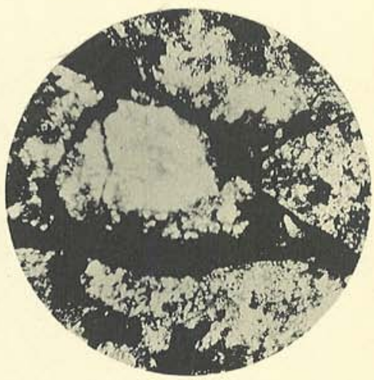

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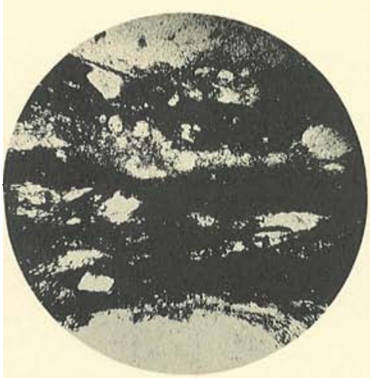

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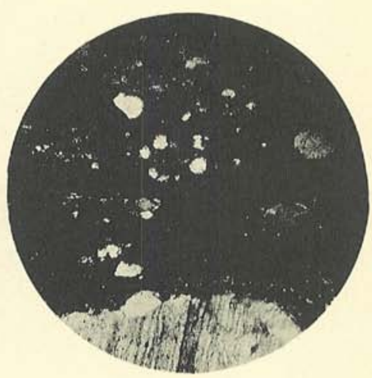

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THE KENDLETON, TEXAS, METEORITE FALL OF MAY 2, 1939[1]

F. F. Fouts and J. J. King

During the early evening of May 2, 1939, a fireball streaked southward across the Texas sky. Many people observed this spectacular phenomenon, and newspapers the following day carried eyewitness accounts of this rare event. The writers attempted to collect all the reliable information about this fireball, and this information is presented in this paper.

Vertical and horizontal angle readings were made from a point about 7 miles southeast of the center of the city of Houston, Harris County, Texas, at longitude 95° 15′ 44″ W. and latitude 29° 41′ 6″ N. This position is in an uncongested district and therefore permitted viewing the meteor during its entire luminous passage.

The meteor appeared at 7:25 P.M., plus or minus 30 seconds C. S. T., May 2, 1939. Slightly in excess of 3 seconds elapsed from the time the body first became visible until it vanished.

The trail appeared to be yellowish in color and began to disperse within 15 seconds after the meteor had vanished. At the expiration of 5 minutes, the trail was so completely distorted and dispersed as to be no longer recognizable. Five photographs of this train are shown in Plate 32.

The meteor was first observed at azimuth N. 47° W.; altitude 40°. The point of disappearance was at azimuth, S. 80° W., altitude 18°.

While the meteor was bright when first observed, it seemed to become more brilliant as it advanced, and then vanished instantly without any previous perceptible diminution in brightness.

[1]This article appeared in the Texas Observers Bulletin of June, 1939, and with the permission of Oscar E. Monnig, the bulletin's editor, and the authors, it is being reproduced here in a somewhat modified form. Mr. Oscar E. Monnig makes the following statement in his foreword: "The article is based on an actual observation of the meteor from Houston, Texas, by F. F. Fouts, and on several field trips and other prompt work done by him and J. J. King, also of Houston. Mr. King modestly fails to state that he was the actual finder of the largest meteorite so far recovered from the fall. Through the kind coöperation of these parties, the editor was enabled to undertake the collecting of meteorites from this field at an early stage; active work on this phase is continuing, and will be the basis of a future detailed description of the distribution of the fall and the character of the pieces recovered. Most of the meteorites found to date are in the collection of the Texas Observers at Fort Worth."

Issued June, 1940.

An investigation was made in the area where the meteorite fell. The meteor exploded almost directly overhead at Kendleton, Fort Bend County, Texas. Meteorites were found within an area of approximately 4 square miles surrounding Kendleton.

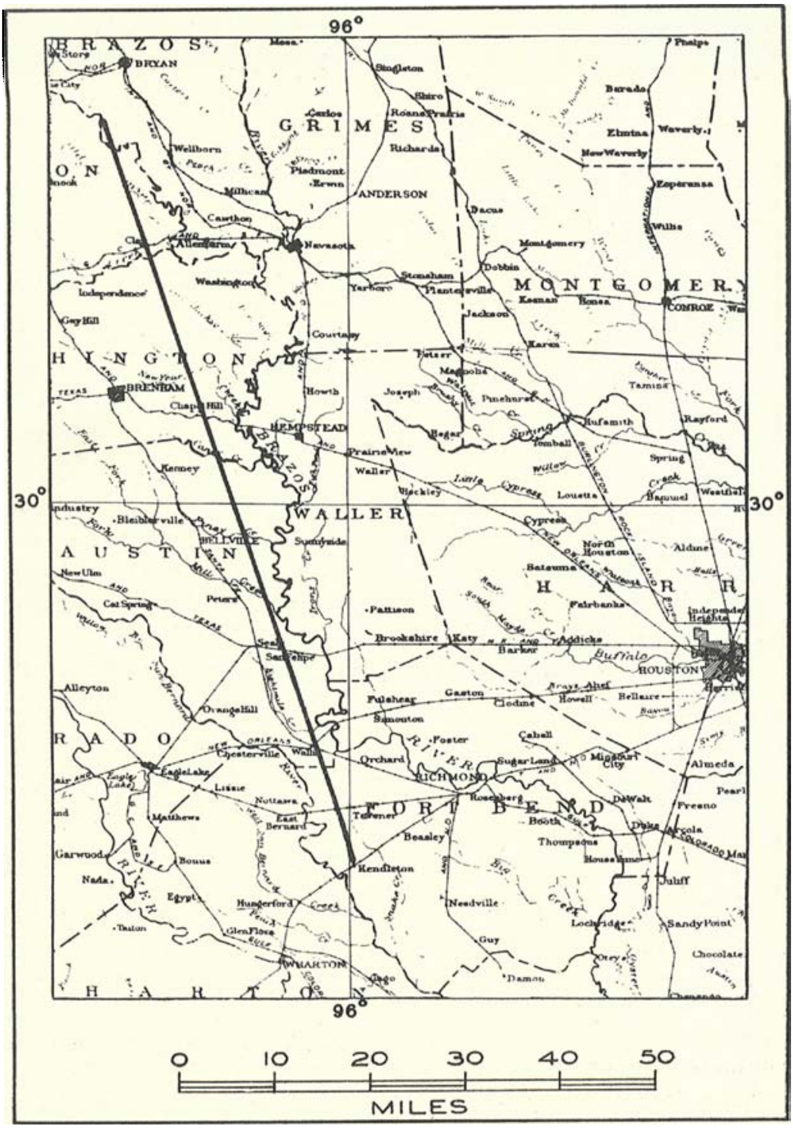


Fig. 100. Map showing the projected path of the Kendleton meteorite.

Witnesses at Orchard, Fort Bend County, stated that the luminous body passed to the west of them but at a very high maximum altitude of about 70°. At Wallis, Austin County, it was reported that the path of the meteor was directly overhead. All witnesses interviewed at this town were in agreement on this point. Reliable information at Sealy, Austin County, indicated that the meteor passed to the east of the town but at a very high maximum altitude averaging

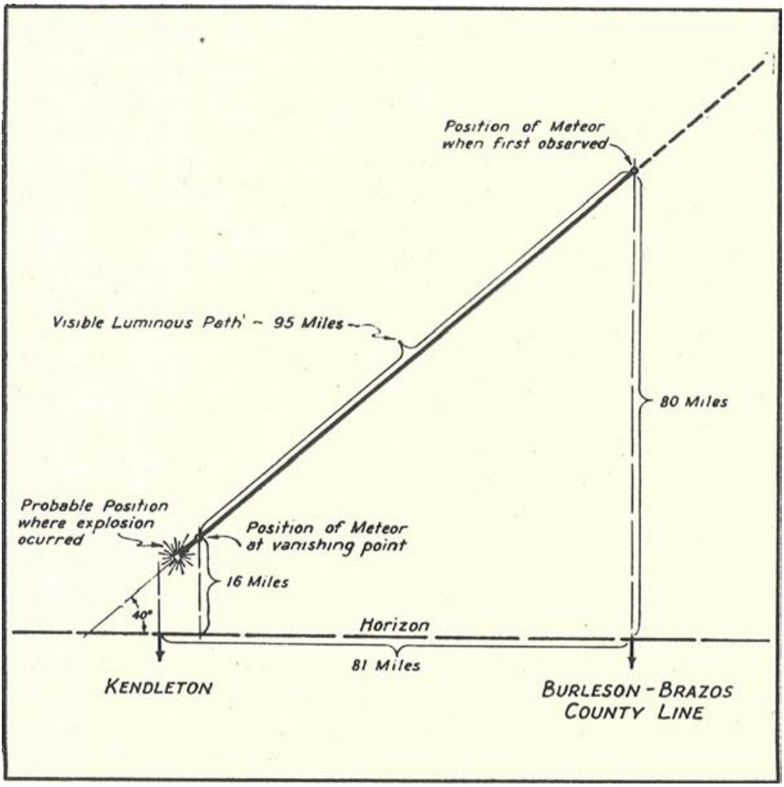


Fig. 101. Diagram showing angle of descent and visible length of luminous path of Kendleton meteorite.

about 85°. Residents of Bellville, Austin County, saw the brilliant body pass high and to the east of the town. The angle of greatest altitude indicated by reliable witnesses was approximately 85°. A reliable report from a witness at Bryan, Brazos County, indicated that the meteor came into view slightly south of the zenith and a few degrees west of south and that it then traveled away from the observer.

Using the above information, the projected path of the meteor is shown in figure 100. Applying the observations taken at Houston to this projected path, the calculated elevation of the meteor when first observed is 80 miles. The end-point is calculated to be at an elevation of 16 miles. Corrections for earth curvature were not made. The calculated side view of the path of the meteor is shown in figure 101.

Two witnesses a short distance south of Kendleton, on whose farms or adjacent thereto two of the larger meteorites were found, gave very similar versions of what happened when the meteor exploded. The first warnings that they had of the passage of a meteor were two terrific explosions, one immediately after the other, followed by a number of weaker reports. One of the witnesses stated that the explosions seemed to come from above, and upon looking up a "ball of yellow smoke" was observed. The other witness reported that the sound of the explosions appeared to come from the nearby highway; however, his attention was directed upward and he, too, saw a "ball of smoke." Both witnesses stated that "it seemed 8 or 10 minutes" after the explosions before the fragments reached the earth. One witness re-enacted his movements between the time of the explosions and the time the fragments landed near him, and upon timing him it is indicated that a period of 5 to 7 minutes might be more nearly correct.[2] The fractured faces of the meteorites which fell near these two witnesses had the appearance of freshly broken stone.

No one in or near Kendleton, who was close to a fragment when it landed, saw the meteor at the instant it exploded; therefore, no check on real altitude calculated from the light-sound interval is available. A number of witnesses at Kendleton who saw the body as it approached stated that it "seemed twice as big as the moon."

All witnesses near fragments when they landed gave the same description of the sound produced by the falling bodies as they approached the earth. The noise produced was not described as a

[2]Editor's note: Mr. Oscar Monnig, of Fort Worth, in a letter states: "I feel that the intervals at Kendleton between the first sound of the shock-wave and the impact of stones was not as long as witnesses thought, since I took two of them through their paces with a stop watch and got 1 min., 10 sec., and 2 min., 32 sec., respectively."

whistling or screaming sound but a "roaring like an airplane falling." The conception of the noise produced by a falling airplane was probably gained from sound motion pictures.

One witness at Wharton, Wharton County, about 14 miles airline from Kendleton, saw the meteor at the instant it burst and heard two loud explosions. His estimate of the time interval between the explosion and the reports was not sufficiently accurate to be of value for real altitude calculations.

Several people at Orchard, a direct distance of about 10 miles from Kendleton, saw the meteor explode and later heard the two loud reports. All the witnesses at this point agreed that the meteor was not brilliant white when it ruptured but that it was reddish in color. Red particles were seen to fly in all directions when the body exploded. No reliable information is available as to the elapsed time between the instant it was seen to explode and the time the sound was heard.

At Wallis, approximately 13 miles airline from Kendleton, no one saw the meteor explode nor were any loud reports heard. The passage of the meteor at this point was accompanied by a terrific roar, and the meteor was brilliant white. The failure of witnesses at this point to see the meteor explode and hear the reports may be accounted for by the excitement caused by the nearness of the body as it passed overhead.

The sound of the passage of the meteor near Sealy, about 24 miles airline from Kendleton, was described by several reliable witnesses as similar to heavy, distant thunder. Many reported that windows vibrated as the body passed.

At its nearest approach, the meteor was approximately 48 miles from the observation point in Houston, and at this distance the luminous disc at its brightest position appeared to subtend an angle equal to that of the full moon. Competent observers in Houston are in agreement on this point.

Long distance electric power transmission lines serve all the towns along the calculated path of the meteor, but the power company had no report of interruptions or surges on the lines. The telephone company at Houston had two toll circuits in use on national radio hook-ups but had no indication of interference when the meteor passed. However, radio receiving sets in Houston did reveal a very pronounced static disturbance when the body appeared.

While some people in Houston stated that the passage of the meteor was heard in the city, it seems now definitely established that no sound whatever was perceptible there.

The largest meteorite of this fall so far found weighs 1,588 grams (3.5 pounds). This fragment landed in hard, dry ground alongside a public road and hit the earth with a wide, fractured face down. The upper, fused face extended slightly above the surrounding ground level. The hard, dry ground probably kept the fragment from penetrating more deeply.

Particles of green grass were found lodged in the crevices on the under side of this meteorite; therefore, it must have been fairly cool upon reaching the earth. None of the witnesses who were near fragments when they fell saw anything come to the earth. The appearance of the fractured faces indicated that the fragment did not become appreciably heated after the explosion which produced these last fractures. The meteorite is of the stony type, and a rough, preliminary analysis reveals silicates, iron, and nickel in appreciable quantities.

Two additional meteorites of unusual interest were discovered on May 22 about half a mile south of the center of Kendleton. The larger weighs approximately 1 pound 12 ounces, and the other weighs less than 1 pound. These meteorites do not have freshly fractured surfaces but do have crusts produced by fusion except for minute spots where the crust has been jarred loose. The larger fragment which is roughly elliptical in shape was found with one tip fractured from the main body; however, the two pieces were in perfect contact when found. The larger fragment has a fusion crust of about the same thickness on all faces and is fairly smooth all over. The smaller piece, however, is quite rough and irregular and some of the faces still show fracture marks underneath a very thin film of fused material or secondary crust.

Witnesses near whose houses these fragments fell heard the explosions and also heard the particles as they reached the earth.

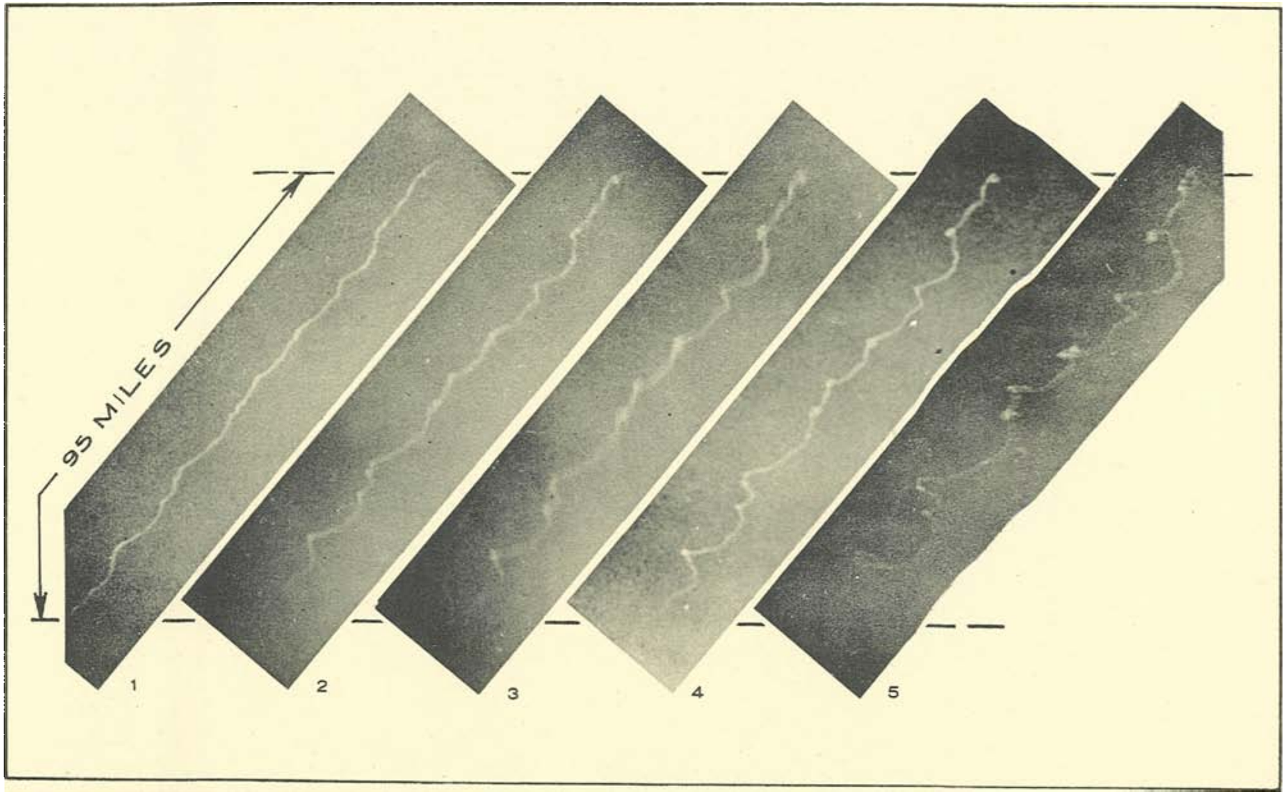
They stated that 20 to 30 minutes elapsed between the time of the explosion and the time when "something hit the ground." An attempt was made to obtain a check on this time estimate but with little success. It is impossible, therefore, to determine how accurate this information is.

PLATE 32

Photographs of train of Kendleton meteorite.

1, 2, 3. First three of a group of four photographs taken by Mr. Paul Peters, staff photographer for the Houston Post. The exposures were made within the city limits of Houston, and the following values for the time interval between the passage of the meteor and the instant the exposures were made appear to be as accurate as will ever be determined: Figure 1, 25 seconds; figure 2, 45 seconds; figure 3, 50 seconds, after the disappearance of the meteor. It should be brought out at this time that the camera was not held entirely level when these photographs were made; therefore, the angle of the path appears to be about 50° instead of 40° as was actually the case. The meteor, taking into account altitude, at its nearest approach to Houston was approximately 44 miles from the point where the photographs were made. The camera used by Mr. Peters was a 2¼ by 3¼ Speed Graphic equipped with an f-3.5 lens of 105 mm. focal length. The exposures were made with an f-3.5 diaphragm setting and a time of one-tenth of a second.

4, 5. Photographs made by Mr. Fred L. Trube within the city limits of Houston at a point about 1 mile west of the position from which Mr. Peters made his exposures. First exposure was made approximately 60 seconds after the passage of the meteor and second exposure about 105 seconds after the passage. The camera was not held completely level, and the indicated angle appears excessively steep. The camera used by Mr. Trube was a 2¼ by 2¼ Rolleiflex with an f-3.5 lens of 75 mm. focal length. The exposures were made with an f-3.5 diaphragm setting and a time of one-fifth of a second.


95 MILES
1
2
3
4
5

DREIKANTERS[1] FROM THE BASAL HICKORY SANDSTONE OF CENTRAL TEXAS

Virgil E. Barnes and G. A. Parkinson

A sand-blasted pebble was found on a granite outcrop by Mr. Parkinson in June, 1938, during an investigation of building stone near Katemcy, Mason County, Texas. This pebble is shown in the upper right corner of figure 102. Continued search by Mr. Parkinson led to the discovery of countless numbers of these pebbles in the basal Hickory sandstone less than a quarter of a mile from the original find. The rest of the dreikanters shown in figure 102 are from this locality.

A hurried examination was made of this find, but no attempt was made to define the lateral distribution of the dreikanters or their position in the Hickory. This locality is on the eastern side of the large Katemcy granite mass and may be reached by going in an easterly direction from Katemcy post office a distance of 0.73 mile, turning south through a gate, and following a little-used road 0.67 mile to a very small gully which drains in a westward direction. The dreikanters are located less than a hundred steps up the gully to the east of the road. They are from the Hickory sandstone and presumably are from near the base. Twenty feet east of the road and a few hundred feet north of the gully is an outcrop of Hickory sandstone which has been down-faulted against the granite. The displacement on this fault is not known.

The dreikanters are all of quartz which is predominantly of a milky variety. A few were found that are almost colorless and transparent; some are smoky; and others have a parallel structure of alternating milky and semi-transparent bands. The shape and size of the pebbles are represented in figure 102. The maximum size may be slightly greater than represented, and the minimum pebble size on which facets were noticed is about half an inch in diameter. The number of facets varies greatly. Some long pebbles

[1]Dreikanters as here used is to be interpreted as faceted pebbles, the facets of which have been produced by the cutting action of sand carried by wind. The number of edges, faces, or corners is immaterial. Other names which have been used are sand-blasted pebbles, ventifacts, glyptoliths, windkanter, einkanter, and zweikanter. The last two names are used allegedly to cover certain special forms of dreikanters and probably should be dropped.

Issued June, 1940.

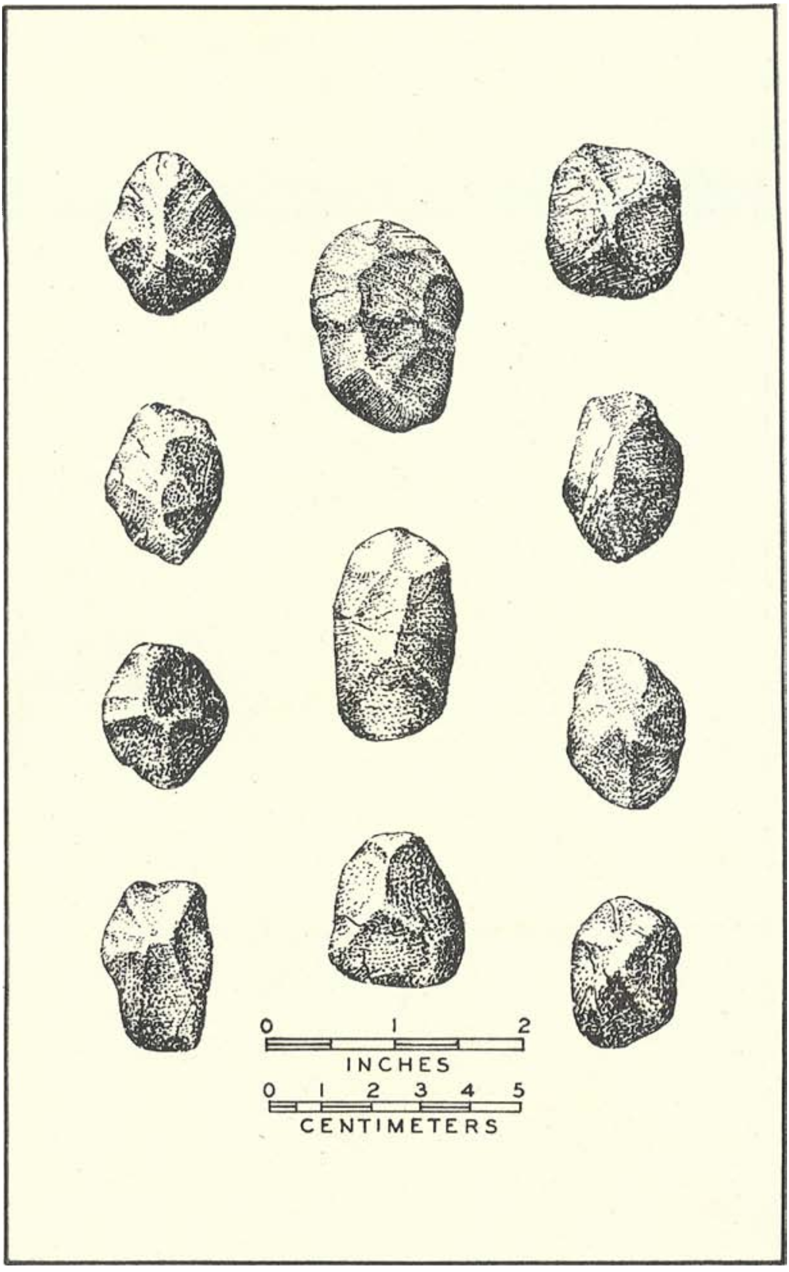


Fig. 102. Dreikanters from near Katemcy, Mason County, Texas.

have only one facet. Most, however, have three or more facets. A very striking type, several of which were seen, is like the first one found. In this type four facets of equal size have developed, forming a pyramid. Some facets were noticed that are slightly concave. The abraded facets mostly have a dull lustre and are somewhat frosted. A few of the facets have a slight polish, and all are smooth to the touch.

This is the first reported occurrence of dreikanters in the basal Hickory sandstone. The finding of dreikanters at one place, however, could be fortuitous and not prove widespread distribution.

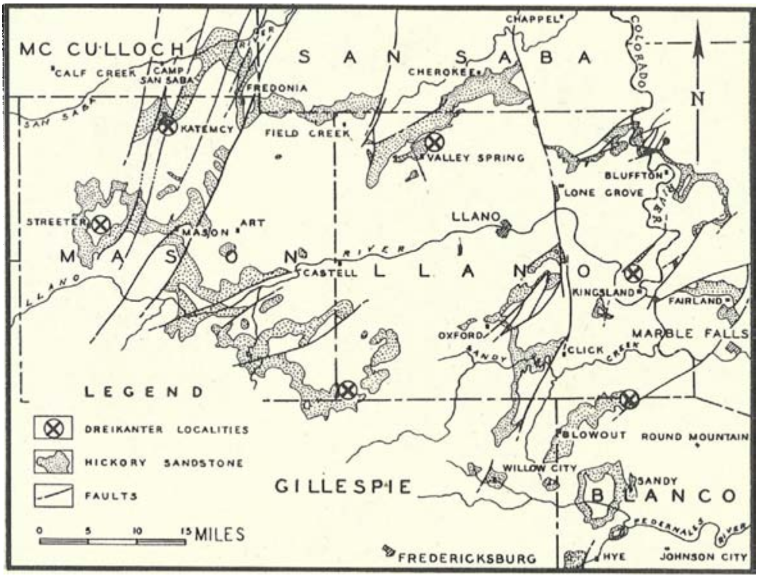


Fig. 103. Map of Hickory sandstone outcrop in central Texas, showing dreikanter localities.

Basal Hickory outcrops were examined when convenient during the time allotted to an investigation of building stone in central Texas. Out of nine localities examined, dreikanters were found in six, which are shown on the map, figure 103. The other three localities, one north of Pontotoc, one west of Burnet, and the other west of Nigger Head in Burnet County, were in areas where the pre-Cambrian surface is rugged and the basal conglomerates are composed of angular pebbles and large boulders. North of Pontotoc the pre-Cambrian Valley Spring gneiss forms a hill which is so high that Cap Mountain limestone is deposited directly on gneiss. At the foot of this hill Hickory overlaps the gneiss and is full of large gneiss boulders.

The dreikanters in the Streeter area, in the southwest corner of Llano County, and near Valley Spring are in the basal few feet of the Hickory. The Valley Spring occurrence will be described since the dreikanters were found at least 4 feet above the base of the

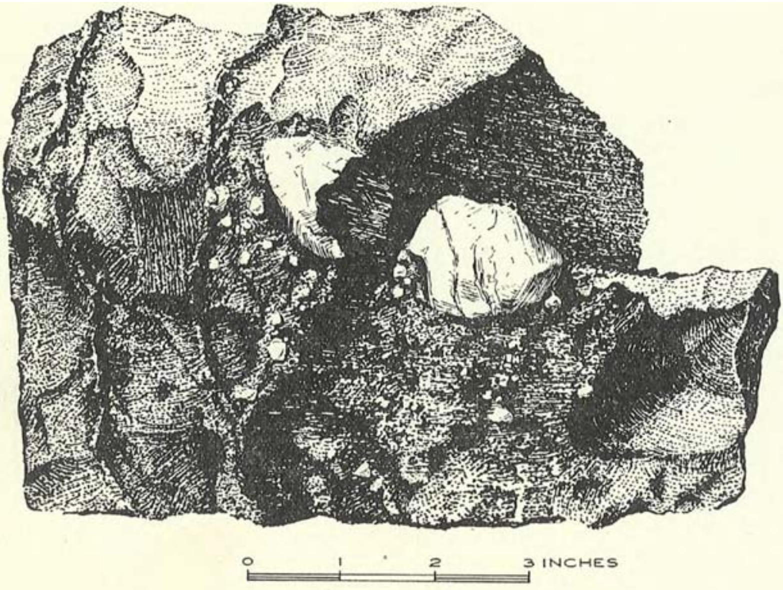


Fig. 104. Drawing illustrating faulting, raised ridges of firmly cemented sandstone along fractures, and mold of a dreikanter in Hickory sandstone.

Hickory. The basal 1 foot of the Hickory, which is in contact with granite at this point, is composed of unabraded angular white quartz fragments varying widely in size and shape. Above this is a zone of cross-bedded coarse sand with some layers of small pebbles. The first dreikanters in this section are about 4 feet above the base. This outcrop demonstrates that dreikanters continued to form after the deposition of Hickory was well under way, and that they were not all formed on the old pre-Cambrian surface and then incorporated in water-laid sediments.

In the southwestern corner of Llano County the dreikanters are in the basal few inches of the Hickory sandstone, which at this point lies directly upon granite. The Hickory has the typical veined appearance so common to it in the vicinity of faults, and many of the dreikanters now lying on the surface are broken, having been faulted while in the Hickory. One well-faceted pebble was found upon the surface registering a fault having a displacement of about one-eighth of an inch. The halves of the pebble are so well cemented that weathering has not separated them since the pebble became exposed at the surface. Another pebble in a slab of sandstone which was collected is offset $1\frac{1}{4}$ inches by faulting. A drawing of this slab, figure 104, illustrates the faulting. In addition to the offset quartz pebble, raised ridges of more firmly cemented sandstone indicate fracture planes. Wherever outcrops of Hickory sandstone are covered by networks of these raised ridges, a fault will be found nearby.

Many of the dreikanter of this locality are exceptionally large, some of which range up to 4 inches across. These dreikanters are mostly faceted on the surfaces which were upward during basal Cambrian time. They lay upon bed rock and apparently were not subject to much change in position as is so common where pebbles lie upon sand. Consequently the typical Brazil nut-like dreikanter shape has not been developed. The dreikanters were not disturbed while finally being covered by sand as is attested by their present position with the faceted faces upward. The sand which incorporated them must have been wind blown rather than water borne, otherwise many of the pebbles would have been turned over onto their faceted faces. These dreikanters are found in place by turning over basal sandstone slabs. The conglomerate thus exposed is almost devoid of abraded faces, but in slabs from which the pebbles have fallen out, perfect molds of dreikanter shapes are present (fig. 104). These molds also preserve the minute irregularities caused by faulting.

The four-sided pyramidal form usually has some undercutting along the edges of the base but otherwise does not have facets cut on this side. This is an indication that pebbles of this type were not turned over during the time that they were subjected to abrasion. The pebbles did not rotate about horizontal axes, and it seems impossible that they could rotate about the vertical axis, stopping each time at near a 90° position. It seems likely that four major wind directions may have been responsible for the shaping of these dreikanters.

The pre-Cambrian surface of this area, as pointed out above, was not entirely peneplained at the time Hickory deposition began. The amount of relief in the area was considerable, but the character of the surface of the more easily eroded formations is not well shown. It is reasonable to assume, however, that some relief existed, that the dreikanters found are not all from exactly the same level, and that conditions favorable to wind deposition may have existed for a considerable length of time.

The writers will not attempt to give an exhaustive treatment of conditions during basal Cambrian time, but the similarity between this occurrence and some other occurrences should be pointed out. In Twenhofel's "Treatise on Sedimentation," dreikanters and dune deposits are mentioned as occurring in Sweden in the Eophyton sandstone, which is basal Cambrian. In a personal communication, Dr. Josiah Bridge mentioned that Dr. E. O. Ulrich has found dreikanters in the Potsdam of Wisconsin. From these examples one might suspect that wind deposits are more common in the basal Cambrian than has hitherto been recognized.

A PLIOCENE VERTEBRATE FAUNA FROM HIGGINS, LIPSCOMB COUNTY, TEXAS[1]

Curtis J. Hesse

INTRODUCTION

In the fall of 1928, Mr. C. L. Baker, then Chief Geologist of the Rio Bravo Oil Company, sent to the University of California a small collection of vertebrate fossils. The specimens had been collected by O. M. Longnecker and L. C. Reed, of the Rio Bravo Oil Company, while investigating the geology of Hemphill County, Texas. The area was visited that fall by Dr. C. L. Camp and Dr. V. L. VanderHoof, of the University of California, who in company with Reed and Longnecker made collections at various localities.

The locality from which the Higgins collection was taken had been shown to Reed and Longnecker by Mr. Rudolph Goettsche of Higgins, Texas. During the subsequent visit of the California party, the three rhinoceros skulls described in the following pages were found, along with many other specimens. In the summer of the following year (1929), a small collection was made there by VanderHoof and J. H. Cress, and in 1930 the locality was again visited by Mr. R. A. Stirton and A. J. Greer.

Credit for the discovery of this material, as well as that of the large Hemphill fauna, must go entirely to Reed and Longnecker. Although they were engaged in economic work, they were encouraged by C. L. Baker to promote the purely scientific side of their investigation in every possible way. The University of California was exceptionally fortunate in having the information gathered by these men at its disposal. From the widely scattered localities in Hemphill and adjacent counties, a large collection of vertebrate fossils has been made.

ACKNOWLEDGMENTS

The Higgins collection referred to in this report is housed in the Museum of Paleontology at the University of California. All specimen and locality numbers appear in the records of this institution

[1]A contribution from the Museum of Paleontology, University of California.

The author is now assistant curator of the Museum of the Agricultural and Mechanical College of Texas at College Station.

Issued June, 1940.

unless otherwise indicated. The drawings are by the staff artist, Mr. Owen J. Poe.

The writer wishes to acknowledge the assistance given him by the staff of the Museum in the preparation of this and other reports. His thanks are especially due to Mr. R. A. Stirton for constructive criticism of the subject matter of this paper. The United States Government SERA project operating in the Museum has been of assistance in preparing and cataloguing specimens and in typing parts of this manuscript.

LOCALITY AND STRATIGRAPHIC POSITION

The Higgins locality is situated in the southeastern corner of Lipscomb County, Texas, about 1½ miles south of the town of Higgins. There are two main localities, which may be termed quarries, or rather fossiliferous areas, perhaps old channels or small lakes. The first of these localities, and the most important of the two, is U. C. Loc. no. V2824 (Reed and Longnecker's locality 24A). It lies one-fourth mile from the east line and 3 miles north of the south line of Lipscomb County. It is on the west side of a small creek, paralleling the east county line. The second locality, and least important, is about a mile south of U. C. Loc. no. V2825 (Reed and Longnecker's locality 24B). Both localities are on the Sibet ranch. The fossils of each are similar in preservation, and so far as the writer is able to determine from a study of the specimens, they are both of the same age. Certain forms are present in one locality and not in the other, but it seems best to regard this negative evidence as due to chance. The fauna, as far as representing the life of that area, is very incomplete; no small forms are represented at all. The specimens that were obtained, except the rhinoceros skulls, are incomplete and frequently specifically indeterminate. Skeletal elements, fragments of proboscidean and rhinoceros jaws make up the larger part of the Higgins fauna.[2]

The regional Cenozoic geology of the Panhandle has been summarized recently by the Bureau of Economic Geology of The University of Texas.[3] There have been many articles written regarding

[2]Since the above was written, the late Mr. C. Stuart Johnston, formerly of the West Texas State Teachers College, Canyon, Texas, had made extensive collections at the Higgins localities.

[3]Sellards, E. H., Adkins, W. S., and Plummer, F. B., The geology of Texas, Vol. 1, Stratigraphy: Univ. Texas Bull. 3232, p. 763, 1932 [1933].

the Tertiary formations of the Texas Panhandle, but in most cases the work was done in local areas only. This has led to the introduction of several sets of names for minor subdivisions, many of which do not exist as mappable stratigraphic units.[4]

The Tertiary sediments of northwest Texas were deposited as a broad alluvial apron, lying unconformably upon rocks of Cretaceous, Triassic, and Permian age. In its general relations, distribution, lithology, and fossil faunas, this blanket of sediment is similar to beds that occur in New Mexico, Oklahoma, eastern Colorado, Kansas, and Nebraska. This extensive formation was named the Ogallala[5] and was mapped[6] as far south as the 37th parallel. Later work[7] has shown that Tertiary sediments, in all respects similar to those mapped by Darton, extend through the western part of Oklahoma. Darton[8] and the recent correlation tables of the U. S. Geological Survey[9] also refer the Tertiary of northwest Texas to the Ogallala.

The recent volume of "The Geology of Texas,"[10] follows the usage of Matthew[11] who recognizes the name "Panhandle formation" for

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[4]Gould, C. N., The geology and water resources of the eastern portion of the Panhandle of Texas: U. S. Geol. Surv., Water-Supply Paper 154, pp. 25–30, 1906.

Gould, C. N., and Lonsdale, J. T., Geology of Texas County, Oklahoma: Oklahoma Geol. Surv., Bull. 37, 62 pp., 1926.

Sellards, E. H., Adkins, W. S., and Plummer, F. B., *op. cit.*, p. 766.

Wilmarth, M. G., Tentative correlation of the named geologic units of Texas: U. S. Geol. Surv., Chart 1, 1930.

[5]Darton, N. H., Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: U. S. Geol. Surv., 19th Ann. Rept., Pt. IV, pp. 178–179, 1898. Also printed as Prof. Paper 17, 69 pp., 1903.

[6]Darton, N. H., Preliminary report on the geology and underground water resources of the central Great Plains: U. S. Geol. Surv., Prof. Paper 32, Pl. 35, 1905.

[7]Gould, C. N., Geology and water resources of Oklahoma: U. S. Geol. Surv., Prof. Paper 148, p. 79, 1905; and The geology and water resources of the eastern portion of the Panhandle of Texas: U. S. Geol. Surv., Prof. Paper 154, pp. 25–30, 1906.

Rothrock, E. P., Geology of Cimarron County, Oklahoma: Oklahoma Geol. Surv., Bull. 34, p. 68, 1925.

Gould, C. N., and Lonsdale, J. T., Geology of Beaver County, Oklahoma: Oklahoma Geol. Surv., Bull. 38, pp. 23–41, 1926; and Geology of Texas County, Oklahoma: Oklahoma Geol. Surv., Bull. 37, 62 pp., 1926.

[8]Darton, N. H., "Red Beds" and associated formations in New Mexico, with an outline of the geology of the State: U. S. Geol. Surv., Bull. 794, p. 58, 1928 [1929].

[9]Wilmarth, M. G., Tentative correlation of the named geologic units of Texas: U. S. Geol. Surv., Chart 1, 1930.

[10]Sellards, E. H., Adkins, W. S., and Plummer, F. B., *op. cit.*, p. 767.

[11]Matthew, W. D., Observations on the Tertiary of the Staked Plains: MS. submitted to the American Museum of Natural History, 1924.

these Tertiary grits.[12] This name was proposed by Gidley[13] for the general Tertiary rocks of the Panhandle and is in common usage among geologists working in that area.[14] There seems little reason to believe that the above names apply to separate and distinct stratigraphic units, so future usage and work must decide the academic question of which name shall be used.

Unfortunately the exact position of the Higgins localities in the generalized section of that area is not known. However, certain conclusions may be drawn from the fauna itself, as to its age, relative to other discoveries in the region.

DESCRIPTION OF GENERA AND SPECIES

Order CARNIVORA

In the collection made at the two localities described, the order Carnivora was represented by members of the families Canidae and Machairodontidae. The absence of other families of this order is due, the writer believes, to the vagaries of collecting and should not be looked upon as indicating that this area was outside their normal range in Pliocene time.

Family CANIDAE

OSTEOBORUS CYONOIDES (Martin)

Referred material in the University of California Museum of Paleontology.—From U. C. Loc. no. V2824: proximal end of scapula, proximal end of radius, distal ends of two femora, calcaneum and fragments of a lower jaw with the alveoli of M_{2-3}, all no. 30295; a tibia and astragalus, no. 30569; from U. C. Loc. no. V2825: fragment of a lower jaw with heavily worn P_2 to M_1, no. 30626; an axis and a dorsal vertebrae, no. 30627.

On the evidence of this material, the presence of *O.* cf. *cyonoides* is established in Loc. no. V2825 and probably in Loc. no. V2824, but none of the specimens collected in the latter are specifically determinable. The lower jaw fragment, no. 30626 from locality V2825, is more heavily worn than any of those figured by Matthew

[12]Matthew, W. D., Blanco and associated formations of northern Texas (abst.): Bull. Geol. Soc. Amer., vol. 36, p. 221, 1925.

[13]Gidley, J. W., The fresh-water Tertiary of northwestern Texas: American Museum Expeditions of 1899–1901: Bull. Amer. Mus. Nat. Hist., vol. 19, p. 634, 1903.

[14]Personal communication from F. B. Plummer to the writer.

and Stirton,[15] but its wear is not greater than that shown by other Hemphill specimens. This worn lower jaw falls well within the size range of the series collected at Hemphill and also within the series of the topotypes from the Edson fauna of Kansas. In the type of this species,[16] P_1 is lost and P_2 was a single-rooted tooth, but topotype material indicates that these two characters are subject to variation. The lower jaw from Higgins has a two-rooted P_2; P_3 is slightly larger than in the type with a better developed cingulum on the posterior margin of the tooth; P_4 is not as wide across the posterior half of the crown as in the type; and M_1 is similar in both specimens. The topotype material and the excellent series of jaws from the Hemphill fauna show that no important distinction exists between Higgins jaw fragment and *O. cyonoides;* though additional material from Higgins may show that it averages smaller than those from Hemphill.

The skeletal material from both the Higgins localities corresponds in size and structural detail to that collected at Hemphill and referred to this species. Matthew and Stirton[17] figured several elements similar to those listed above. The detailed description of the skeleton is left until the large Hemphill series may be treated.

OSTEOBORUS VALIDUS (Matthew)*

Aelurodon haydeni validus Matthew and Cook, 1909, Bull. Amer. Mus. Nat. Hist., vol. 24, p. 371, fig. 2.

Cf. *Aelurodon* Matthew, 1932, in The Geology of Hemphill County, Texas: Univ. Texas Bull. 3231, p. 67.

Referred material in the University of California Museum of Paleontology.—From. U. C. Loc. no. V2824: left lower jaw, incomplete, P_2 to M_1; right lower jaw fragment alveoli of I^{1-2}, I^3 present; fragment of the right maxillary with part of the alveoli of the canine and P^1, P^2 present; the tip of a lower canine; an atlas and a metacarpal, all no. 30294; from U. C. Loc. no. V2825:

[15]Matthew, W. D., and Stirton, R. A., Osteology and affinities of *Borophagus*: Univ. California Pub., Dept. Geol. Sci., Bull. 19, Pls. 29–30, 1930.

[16]Martin, H. T., Two new carnivores from the Pliocene of Kansas: Jour. Mamm., vol. 9, p. 235, Pl. 21, 1928.

[17]Matthew, W. D., and Stirton, R. A., *op. cit.*, Pls. 32–34.

*As this paper goes to press, a posthumous paper by C. Stuart Johnston, "A skull of *Osteoborus validus* from the early middle Pliocene of Texas," appeared in the Journal of Paleontology for September, 1939 (vol. 13, pp. 526–530).

zygomatic process of the squamosal, no. 30312; a lower carnassial tooth, no. 30178; a fragment of the posterior part of the right lower jaw, with alveoli of M_{1-3}, no. 30177.

The genus *Osteoborus* was defined by Stirton and VanderHoof[18] primarily on the basis of the canid specimens in the Hemphill fauna. These specimens had all been referred to *Borophagus cyonoides* by Matthew and Stirton,[19] but additional material and a restudy of the entire series indicated that this reference was in error. Stirton and VanderHoof were able to clarify the relationship of several species of late Tertiary canids by placing them in the new genus *Osteoborus*. Prior to this work, many of these species had been of questionable systematic position and were most confusing to anyone trying to identify similar forms.

Aelurodon haydeni validus was described and figured by Matthew and Cook,[20] who, by designating it as a subspecies, recognized that it was not a typical *A. haydeni*. This subspecies remained more or less unnoticed by those not working on the Snake Creek collections, until Stock[21] pointed out that *A. haydeni* was similar to *A. aphobus* of the Ricardo fauna. Stirton and VanderHoof[22] referred the Ricardo *A. aphobus* Stock (not the type *A. aphobus* Merriam)[23] to their new genus *Osteoborus* and suggested the specific name be changed to *O. ricardoensis* to avoid confusion. They also noted that *A. haydeni validus* was not a true *Aelurodon*, and, as Stock suggested, this subspecies was allied to *O. ricardoensis*. On the basis of the observations of these authorities and on the characters shown by the Higgins specimen, the writer refers both the Higgins jaw and the type of *Aelurodon haydeni validus* to the genus *Osteoborus* under the specific name of *O. validus*.[24]

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[18]Stirton, R. A., and VanderHoof, V. L., *Osteoborus*, a new genus of dogs, and its relations to *Borophagus* Cope: Univ. California Pub., Dept. Geol. Sci., Bull. 23, p. 175, 1933.

[19]Matthew, W. D., and Stirton, R. A., Osteology and affinities of *Borophagus*: Univ. California Pub., Dept. Geol. Sci., Bull. 19, pp. 171–216, Pls. 21–34, 1930.

[20]Matthew, W. D., and Cook, H. J., A Pliocene fauna from western Nebraska: Bull. Amer. Mus. Nat. Hist., vol. 24, p. 371, 1909.

[21]Stock, Chester, Canid and proboscidean remains from the Ricardo deposits, Mohave Desert, California: Carnegie Inst., Pub. 393, p. 42, 1928.

[22]Stirton, R. A., and VanderHoof, V. L., *op. cit.*, p. 178.

[23]Merriam, J. C., Tertiary mammalian faunas of the Mohave Desert: Univ. California Pub., Dept. Geol. Sci. Bull. 11, p. 535, 1919.

[24]In the collection of the West Texas State Teachers College at Canyon, Texas, there is additional material of this form. The late Mr. C. Stuart Johnston, of that institution, had in manuscript descriptions of this and other Higgins material. It is probable that some of this work will be published.

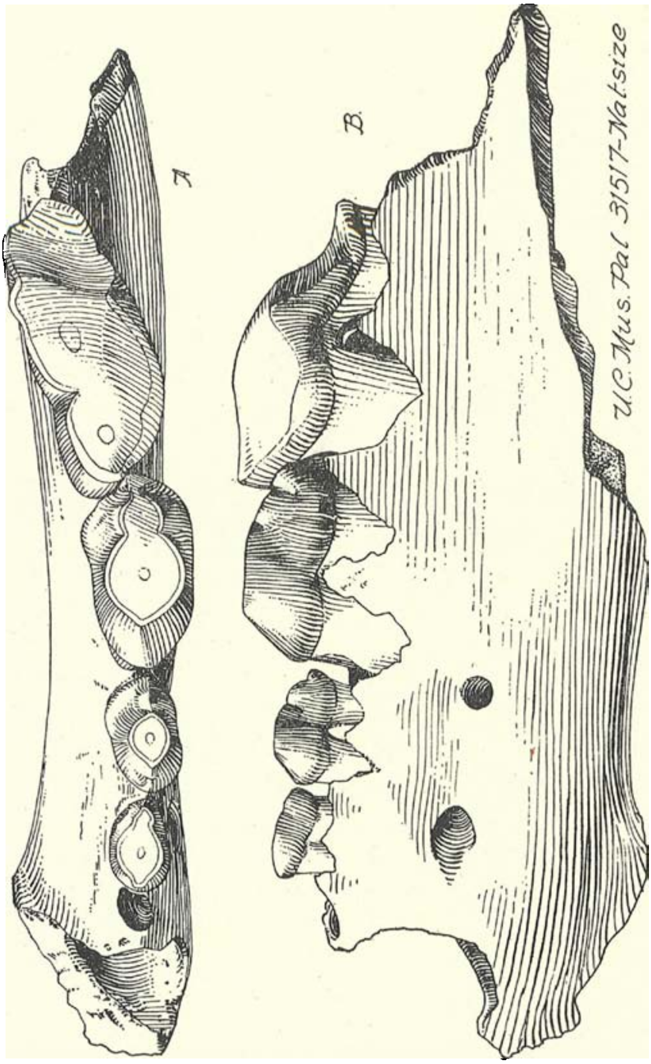

Fig. 105. Left lower jaw of *Osteoborus validus* (Matthew). A, superior view of teeth. B, external view of jaw. Natural size.

Description of the referred material.—The heavily worn left lower jaw, no. 31517 (fig. 105), cannot be distinguished from the figure of the type of *O. validus.* This specimen is large, with a deep massive ramus. The alveolus of the canine shows it to have been a heavy tooth standing almost upright in the jaw. The alveolus of P_1

is crowded between the posterior edge of the canine and P_2; it seems to have held a single-rooted tooth. P_2 is a two-rooted, oval (11.9 mm. by 8.5 mm.) tooth, which bore, in an unworn state, a single main cusp and a smaller posterior one. It is not placed at an angle, as the alveoli of P_2 indicate in Matthew's figure of *A. haydeni validus.* P_3 is crowded against P_2; the main body of each tooth is in perfect alignment; P_3 has an oval crown (15.2 mm. by 9.2 mm.), slightly wider across the posterior half of the tooth, no anterior cusp, but has a large median cusp and a small posterior one. P_3 is against P_4, with which it is aligned. P_4 has a much larger crown (25.3 mm. by 14.2 mm.), no anterior cusp, but has a very large protoconid and a well developed posterior cusp. The posterior, inner corner of P_4 is projected outward, forming a part of a broad, cingulate "heel." P_4 seems to correspond in detail to P_4 in *A. haydeni validus.* M_1 is a large (36.9 mm. by 16.5 mm.), massive, heavily worn tooth. Little may be told about its crown, but a left M_1 from Loc. no. V2825, no. 30178, has a high paraconid and protoconid, well developed metaconid, and a broad heel (heel shown in no. 31517). In its details, this tooth resembles a very large *Aelurodon* and was regarded as such by Matthew.[25] The ramus in no. 31517 is 37 mm. deep beneath P_2 and 43 mm. deep beneath P_4; the jaw is very massive throughout. Another jaw fragment, no. 30177, from Loc. no. V2825, contains the alveoli and roots of M_{1-3}. M_2 was an oval tooth (16 mm. by 8.5 mm.), and M_3 seems to have been small and single rooted. The condition of M_{2-3} is the same as that described by Matthew.[26] Two large foramina are present on the outer, anterior surface of the maxillary. The larger, or anterior mental foramen, is immediately below the posterior root of P_2, and the smaller of the two is in a line with the most anterior root of P_4. Although these foramina seem to vary in position in mammalian lower jaws, these two are consistently placed in the type of *O. validus* and the material referred to this species from Texas. An edentulous lower jaw fragment, no. 30294, has lost all trace of P_1, another character which seems to vary.

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[25]Reed, L. C., and Longnecker, O. M., The geology of Hemphill County, Texas: Univ. Texas Bull. 3231, p. 67. 1932.

[26]Matthew, W. D., and Cook, H. J., A Pliocene fauna from western Nebraska: Bull. Amer. Mus. Nat. Hist., vol. 26, p. 372, 1909.

The premaxillary, no. 31518, shows that the upper incisors were heavy and appressed to a slight degree. There was a small diastema (9.5 mm.) between I^3 and the canine. Another fragment of the right maxillary shows a part of the upper canine alveolus, the alveolus of P^1 crowded against it on the inner side, and P^2 as a double-rooted tooth with an oval (13.8 mm. by 8.2 mm.), heavily worn crown.

The fragment of a zygoma, no. 30312, referred to this form does not seem to be distinct from either *Osteoborus* or *Aelurodon* except in its size. The skull of *O. validus,* estimating on the basis of this zygoma, must have been at least 7 inches across at its widest point. The atlas is of proportionate size. The left fourth metacarpal is typically canid in all its characters; it is large, but in its proportions might be either a large *Aelurodon* or *Osteoborus.*

Comparison with other forms.—Stirton and VanderHoof[27] have set forth the characters of the genus *Osteoborus. Aelurodon haydeni validus* and the material discussed in the paragraphs above are referred to *Osteoborus* on the following characters:

1. First three premolars reduced in size.
2. Premolar series crowded together and shortened, more so than in *Aelurodon.*
3. First three premolars with prominent central cusp, but with reduced anterior and posterior accessory cusps.
4. P_4 with a posterior accessory cusp above talonid, and considerably larger than P_3.
5. Teeth heavily worn, as in many species of *Osteoborus.*

Of the six species of *Osteoborus, O. cyonoides, O. littoralis, O. secundus,* and *O. pugnator* are small and not likely to be confused with *O. validus. O. ricardoensis (Aelurodon aphodus),*[28] is however, quite close in size and detail to *O. validus,* a fact noted by Stock as well as Stirton and VanderHoof. It may be distinguished from *O. validus* on the following points:

1. *O. ricardoensis* smaller in size.
2. P_2 small, conical round tooth in *O. ricardoensis,* but is oval with a posterior cusp in *O. validus.*

[27]Stirton, R. A., and VanderHoof, V. L., *op. cit.*, p. 175.

[28]Stock, Chester, *op. cit.*, p. 41.

3. P_3 in *O. ricardoensis* does not have a posterior accessory cusp, but in *O. validus* it is well developed.
4. P_4 with posterior accessory cusp proportionally heavier in *O. validus.*
5. M_1 proportionally much wider in comparison to its length in *O. validus.*
6. M_2 more elongate and oval in *O. validus* (as suggested by alveoli).

Family MACHAIRODONTIDAE

MACHAERODUS CATOCOPIS Cope

Referred material in the University of California Museum of Paleontology.—From U. C. Loc. no. V2824: the occipital region of a skull, no. 32756; anterior part of left lower jaw, with canine in place, no. 30296; an atlas, no. 20567; distal ends of two humeri, no. 20565; proximal end of three ulnae, nos. 30296, 20561, 30562; the distal end of a femur, no. 30296; the distal end of a tibia, no. 30566; a calcaneum, no. 30563; four astragali, no. 30564; right metatarsal IV, no. 30568; phalanges, and one distal phalanx, no. 30296; from U. C. Loc. no. V2825: the anterior one-third of a left lower jaw, with the broken root of a canine in place; two lower carnassial teeth; a fragment of a canine; an atlas; an axis; the distal end of a femur; a complete tibia and the distal end of another; a calcaneum; an astragalus; an incomplete metatarsal; and a phalanx; all of this material no. 30625.

The material is, of course, very incomplete and contains a few elements that are specifically determinable. Nevertheless, it compares in detail with the much larger series of *M. catocopis* specimens in the Hemphill fauna and can, in the writer's opinion, be referred to that species.

The *Machaerodus catocopis* material from the Hemphill fauna was described by W. H. Burt,[29] who included in his paper some of the material from the two Higgins quarries.

[29]Burt, W. H., *Machaerodus catocopis* Cope from the Pliocene of Texas: Univ. California Pub., Dept. Geol. Sci., Bull. 20, pp. 263–268, 1931.

EXPLANATION OF FIG. 106

Fig. 106. *Machaerodus catocopis.* A, B, superior and external views of anterior part of left lower jaw, no. 30296. C, external view of anterior part of left lower jaw, no. 30625. Natural size.

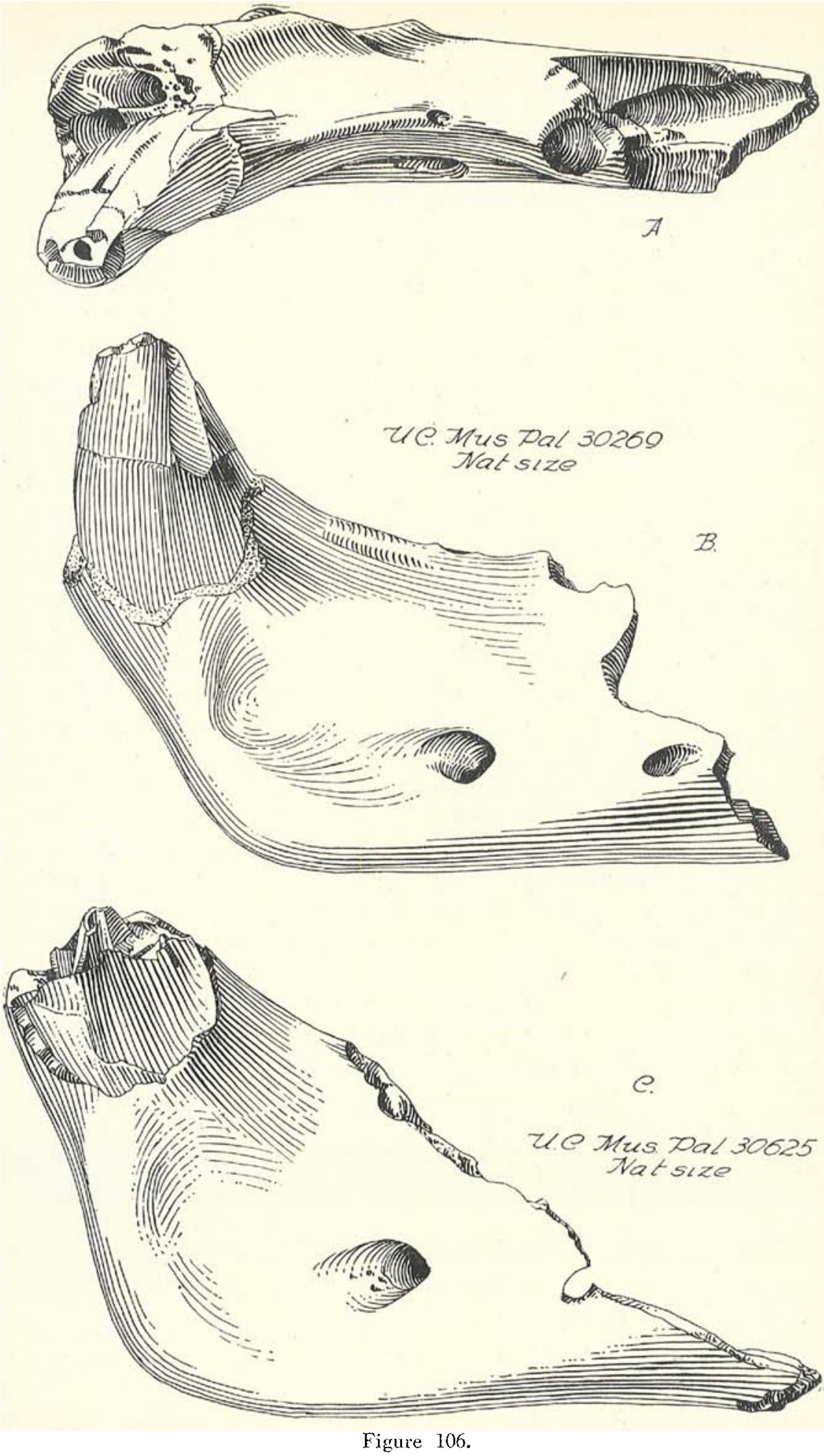

Figure 106.

Description of the referred material.—The most important specimen in this collection is that of the occipital region of a skull from Loc. no. V2824. This consists of the basioccipital, exoccipitals, supraoccipitals, and the posterior part of the temporal and parietal bones. Unfortunately the tympanic bulla have been destroyed, and many of the other characters of the basioccipital region are obscure. Although this basicranium is approximately the same size as that of a young *Smilodon californicus* skull, it is strikingly different in certain proportions. The condyles of the two are nearly the same size, and the distance from the base of the foramen magnum to the occipital crest is also about the same. However, any measurement across the back of the skull, from one lamboidal crest to the other, shows *M. catocopis* to be slightly larger. In other respects this specimen agrees with that described by Burt[30] and substantiates the characters noted by him.

The anterior one-third of the left lower jaw, no. 30296 (fig. 106, A, B), from locality V2824, and a similar specimen, no. 30625 (fig. 106, C), from locality V2825, deserve special consideration. These two specimens, though incomplete, show the heavy, flanged symphyseal region, stump of the canine, alveoli of the incisors, and external foramina of the jaw. The smaller of these two, no. 30296, was discussed by Burt[31] as *Machaerodus*, sp.indet., because it seemed to be somewhat different in its characters from the Hemphill specimens. The additional fragment, no. 30625, is almost a duplicate of the former specimen and exhibits many of the same characters. Both these jaws were heavy, slightly more so than any of those from Hemphill. No. 30625 is larger than any of the lower jaws in the University of California collection, exceeding no. 30296 to a slight degree. Burt pointed out that the canine of no. 30296 was relatively larger and the incisors of this specimen relatively smaller than any of the machaerodonts from Hemphill. These facts also hold true for the second Higgins jaw (no. 30625), but it is less complete, and other characters listed by Burt cannot be verified. It seems wise, therefore, to place all this material under one specific name until its status can be definitely determined.

M_1 no. 30625 is a large sectorial tooth, easily referable to any of the *M. catocopis* lower M_1 in the Hemphill fauna. It carries a suggestion of a metaconid. P_4 no. 30625 is the anterior half of the

[30]Burt, W. H., *op. cit.*, p. 263.
[31]Burt, W. H., *op. cit.*, p. 263.

tooth. Although this specimen is incomplete—only the metacone and a part of the paracone are preserved—it resembles very closely the P^4 of *M. catocopis* figured by Burt.[32]

The skeletal material represented in this collection is by no means as complete as that described by Burt[33] from the Hemphill fauna. Where it has been possible to check the statements of Burt on this less complete collection, the characters pointed out by him are substantiated. On the basis of the Higgins *M. catocopis* skeletal elements, and the additional material of the Hemphill fauna, the range of size seems somewhat greater than that indicated by Burt's descriptions.

Order UNGULATA

Suborder PERISSODACTYLA

Family EQUIDAE

The North American species of later Tertiary horses have, for some years, been in a confusing state. There are three generally recognized genera of Pliocene equids and two subgenera. Of these five groups, material referable to the genus *Hipparion* is the most common of all in collections made from the Pliocene of the High Plains. This wealth of material is probably the explanation of the two subgenera and twenty-seven species that have been based upon it. Gidley[34] suggested that the genus *Hipparion* was confined to the Old World and that the North American forms were, on the basis of characters listed by him, worthy of separate generic rank. For the North American types, he used the name *Neohipparion*, with the type species of *N. whitneyi*. Gidley's classification was not followed by other writers nor was it followed completely by him, for in a later paper[35] he recognized the probability of certain of the North American forms belonging to the genus *Hipparion*. Since this time, other writers have either disregarded *Neohipparion* or treated it as a subgenus. In 1926, Matthew[36] discussed the evolution of the horse at some length and recognized two groups or subgenera

[32]Burt, W. H., *op. cit.*, Pl. 45.

[33]Burt, W. H., *op. cit.*, pp. 265–268.

[34]Gidley, J. W., A new three toed horse: Bull. Amer. Mus. Nat. Hist., vol. 19, p. 466, 1903.

[35]Gidley, J. W., Revision of the Miocene and Pliocene Equidae of North America: Bull. Amer. Nat. Hist., vol. 23, p. 905, 1907.

[36]Matthew, W. D., The evolution of the horse; a record and its interpretation: Quart. Rev. Biol., vol. 1, p. 165, 1926.

in the genus *Hipparion.* The first of these subgenera *H. (Neohipparion)* was of large size with wide flattened protocones and the metaconid and metastylid separated by a broad, flat-bottomed valley. The second subgenus, named by Matthew *H. (Nannippus),* was smaller, very high crowned, and had oval protocones. This scheme of classification was discussed at greater length by Matthew and Stirton,[37] in describing the equids of the Hemphill fauna.

In the papers covering the above genus and subgenera it is often difficult, if not impossible, to decide how an author regards them. The use of these names is quite variable even in the same paper, but there seems to be a tendency in the literature, at present, to recognize all three as separate and distinct genera. This usage is followed by the writer in discussing the Higgins specimens.

NEOHIPPARION OCCIDENTALE (Leidy)

Referred material in the University of California Museum of Paleontology.—From U. C. Loc. no. V2824: eleven upper cheek teeth, no. 30602; thirteen lower cheek teeth, no. 30603; the distal end of a humerus, no. 30597; from U. C. Loc. no. V2825: one lower and three upper cheek teeth, no. 30628; a proximal phalanx, no. 30630.

Description of referred material.—Similar in size to the types of *N. occidentale*, *N. affine*, or *N. whitneyi.* In height of crown, these teeth are similar to the type of *N. occidentale.* The crowns are straight, parastyle and mesostyle very heavy, and the hypoconal groove is open to the base of the crown. The enamel borders of the pre- and post-fossette are, on the inner sides, moderately complicated. This complication is greater than that of either *N. affine* or *N. whitneyi*, and in some cases greater than in the types of *N. occidentale.* The protocone is separate to the base of the crown in these teeth, and in all cases its anterior-posterior length is in excess of its transverse width. In shape it varies from an ellipse, elongate oval, to a round oval with its buccal side flattened. Some of this variation in shape is due to wear and some to the position of the tooth in the maxillary, but the series represented by this collection is not large enough to determine these points definitely. In most of their characters, these upper teeth resemble the type of *N. occidentale* and less so the types of *N. affine* and *N. whitneyi.*

[37] Matthew, W. D., and Stirton, R. A., Equidae from the Pliocene of Texas: Univ. California Pub., Dept. Geol. Sci., Bull. 19, p. 353, 1930.

This writer is fully in accord with Matthew[38] who suggests that all of the above species are synonymous.

Unfortunately there were no lower cheek teeth described with the types of either *N. occidentale* or *N. affine*, but the type of *N. whitneyi* offers good comparative material. The lower teeth, from the Higgins localities, are large, heavy, and moderately high crowned. They are approximately the same size as those of the figured type of *N. whitneyi.* The metaconid and metastylid are

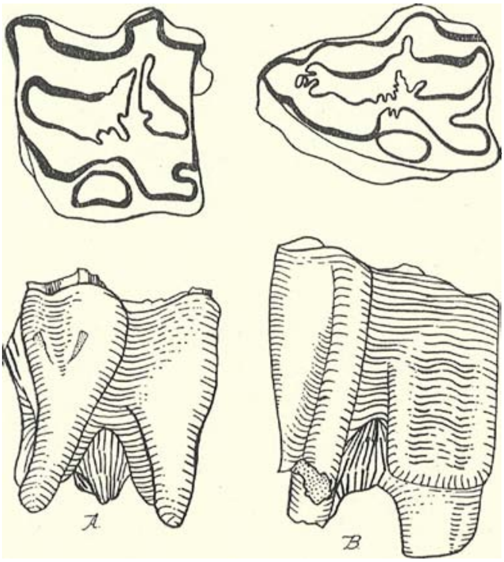

Fig. 107. *Neohipparion occidentale.* A, crown and external view of P^4. B, crown and external view of M^3. No. 30628. Natural size.

rounded and separated by a deep valley, which shows on the inner surface of the tooth as a flat-bottomed groove. In the premolar teeth, the external enamel borders of the protoconid and hypoconid tend to become flattened.

Skeletal material referable to the Hipparion group.—Two proximal phalanges and the distal end of a humerus are, on the basis of size and slenderness, referred to the *Hipparion*-like genera. The humerus, no. 30597, and one of the proximal phalanges, no. 30600,

[38] Matthew, W. D., Third contribution to the Snake Creek fauna. Bull. Amer. Mus. Nat. Hist., vol. 50, p. 174, 1924

are both small—too small for the skeleton of *Neohipparion occidentale*. They are the size of the *Nannippus lenticularis* specimens in the Hemphill fauna and may be regarded as some species of *Nannippus*. The remaining proximal phalanx is larger but is typically *Hipparion*-like in its slender proportions. It may be referred to *Neohipparion occidentale*, but its size is not as great as one would expect in that form.

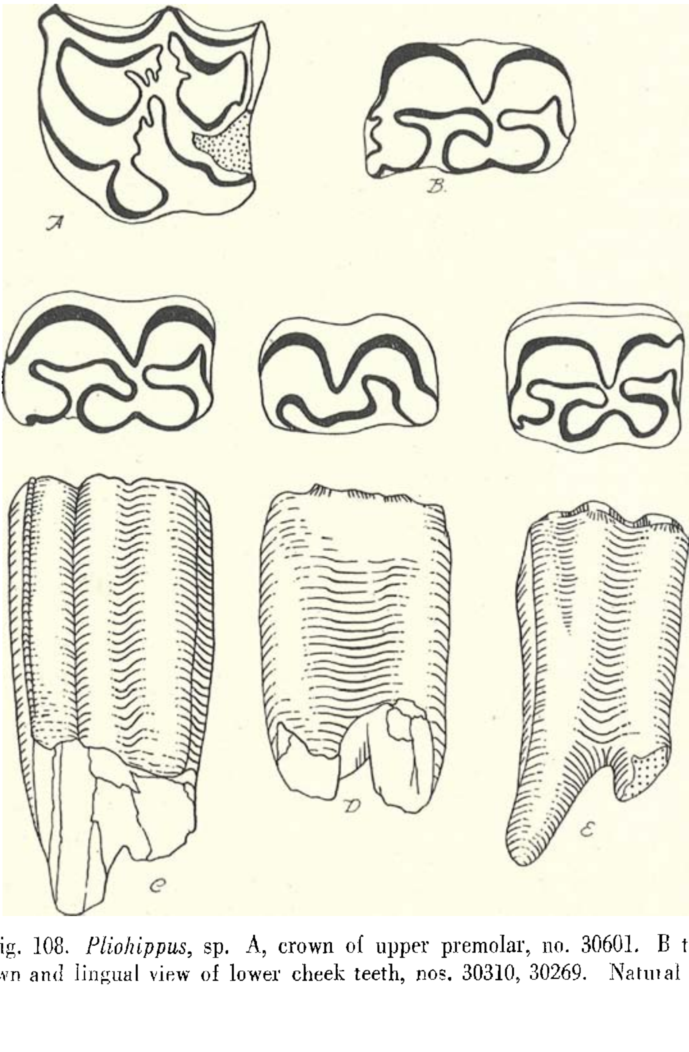

Fig. 108. *Pliohippus*, sp. A, crown of upper premolar, no. 30601. B to E, crown and lingual view of lower cheek teeth, nos. 30310, 30269. Natural size.

PLIOHIPPUS, sp.

Although teeth of the genus *Pliohippus* are present in the Higgins fauna, they are by no means as common as those of *Neohipparion occidentale*. There are only nine teeth which may be referred to the former genus, and only six of these, three uppers and three lowers, are complete enough to offer any characters. A left P^3 is the best specimen for determination, but an identification based upon such scanty material is of little value. In its crown pattern and size, it resembles most closely the type of *P. robustus*, but the curvature of the crown of *P. robustus* is a little greater than in this Higgins specimen. The remaining upper teeth are either heavily worn or deciduous. Two lower teeth seem to be slightly less high crowned than the lowers of *P. interpolatus* of the Hemphill fauna. In other characters, they are typically pliohipped but seem specifically indeterminate. This material is insufficient to give any clear idea of the species of *Pliohippus* represented in the fauna. It does, however, show that it was a less high-crowned form and specifically different from the *P. interpolatus* material of the Hemphill fauna.

Equid skeletal elements.—The remainder of the material referred to the Equidae is made up of skeletal elements. These were quite common in Loc. no. V2824 and much less so in Loc. no. V2825. In this writer's opinion, it is at present impossible to place even a generic determination upon most of these elements. Matthew and Stirton[39] referred many skeletal elements of corresponding size to *P. interpolatus*, but this assumption seemed quite safe since there were no large Hipparions in the Hemphill fauna. In the case of the Higgins fauna, the limb elements of *Pliohippus* and those of *Neohipparion occidentale* would be nearly the same size, and except in the cannon bones and proximal phalanges, no characters are known upon which they might be separated. It seems best, then, to regard this part of the equid material as generically undeterminate.

Family RHINOCEROTIDAE

The most important and best preserved of all finds made at the Higgins localities was that of three rhinoceros skulls. With these there were many fragments, incomplete lower jaws, and skeletal elements. It was this material, along with that from the Hemphill

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[39]Matthew, W. D., and Stirton, R. A., *op. cit.*, p. 395, Pl. 52.

fauna, that occasioned the two papers on this family by the late Dr. Matthew.

There have been many papers written by various authors dealing with the phylogeny and classification of the later Tertiary rhinoceroses, but there are many questions as yet unanswered. The genus *Teleoceras* seems well defined and quite common in faunas of this age. *Aphelops* and *Peraceras* are less well separated, and their relations to the Old World *Chilotherium* are apparently very close.[40]

The two most common late Tertiary genera, *Aphelops* and *Teleoceras*, are both represented in the Higgins fauna. *Teleoceras* was less common than *Aphelops* and was found only at locality V2825, while the latter genus was fairly common in both V2825 and V2824.

TELEOCERAS cf. FOSSIGER

Referred material in the University of California Museum of Paleontology.—From U. C. Loc. no. V2825: an incomplete skull, left maxillary, palate, and right maxillary from M^2 forward all missing, the cranium frontals, nasals, and most of the right maxillary well preserved, no. 30646; conjoined nasal bones, no. 30308: a right tibia, no. 30640; an astragalus, no. 30308; and a single IV metatarsal, no. 30645.

The genus *Teleoceras* was described by Hatcher[41] in 1894, and up to the present time seven species have been referred to it. *T. mendicornutus* and *T. minor* are more primitive species of the upper Miocene, while *T. fossiger* and *T. hicksi* are more advanced Pliocene forms. The type species, *T. major*, is now considered a synonym of *T. fossiger*, and the remaining two species, *T. felicis* and *T. proterus*, seem to be of doubtful status. It seems certain that the material referred to *T. fossiger* does not all represent that species. The large series of skulls from the Long Island, Kansas, locality has never been adequately described. It is certain that any species of animal as large as a rhinoceros is bound to show a wide individual variation, but the variation shown by the specimens

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[40]Matthew, W. D., A review of the rhinoceroses with a description of *Aphelops* material from the Pliocene of Texas: Univ. California Pub., Dept. Geol. Sci., Bull. 20, p. 433, 1932.

[41]Hatcher, J. B., On a small collection of vertebrate fossils from the Loup Fork beds of northwestern Nebraska; with note on the geology of the region: Amer. Naturalist, vol. 28 p. 241, 1894.

referred to *T. fossiger* is, this writer believes, too great to be accounted for as individual. The species *T. fossiger* is, therefore, a catch-all for most of the Pliocene *Teleoceras* material but probably does not represent a true species.

Description of the referred material.—The incomplete skull, no. 30646, is probably that of a male. It is not exceptionally large and falls well within the size limits of a series of *Teleoceras* skulls in the University of California Museum of Paleontology. The tip of the nasals bears a low non-rugose prominence, suggesting that if a nasal horn were present at all, it was small. The nasals are not reduced and must have projected out over the premaxilla. Immediately behind the orbits, the frontals suddenly flare into the postorbital processes, the widest point on the superior surface of the skull. The posterior orbital crests are united into a sagittal crest beginning at a point in line with the jugal process of the squamosal. The supraoccipital crests are semicircular, broad and flaring, but do not project backward out over the occipital condyles. In outline the top of the skull is slightly concave, with its lowest point just back of the orbits. There is not the sudden upward pitch of the occipital region as there is in *Aphelops*, nor is the back of the skull slanted forward as in *Peraceras*. The teeth are heavily worn and shattered, so little may be told about them. In outline and structural details, this incomplete skull is distinctly teleocerne, but it offers only the most general characters of that genus.

The conjoined nasal bones figured and described by Matthew[42] are slightly larger than those of this skull. The horn prominence is not marked in this specimen as it is in the nasals of the skull, although the former is a larger individual. The tibia, listed above, is short and stocky and is in all respects similar to a tibia of *T. fossiger* from the Long Island quarry. The astragalus and fourth metatarsal are readily placed in this genus and are similar in detail to like elements from other localities.

Genus APHELOPS

To this genus may be referred the larger part of the rhinoceros material collected in the Higgins localities. It is a large form close in size to the contemporary genus *Teleoceras* but differing from it in certain marked characters. It is characterized by: unreduced

[42]Matthew, W. D., *op. cit.*, p. 436, fig. 10.

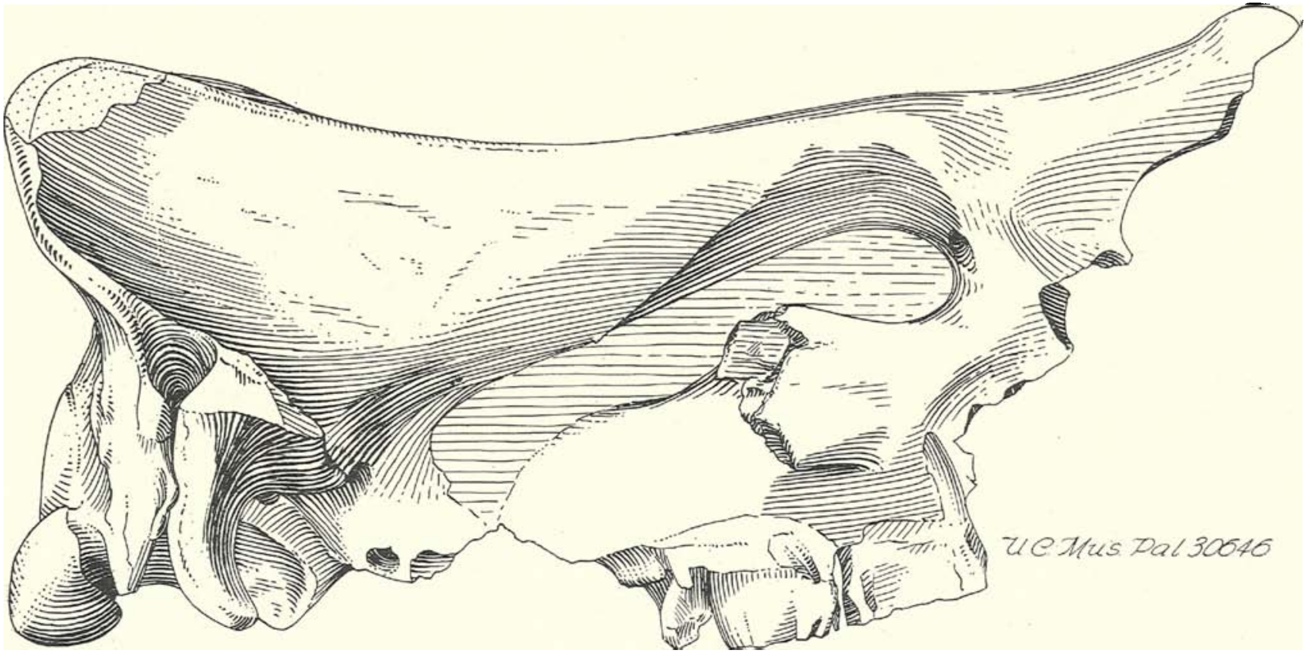

Fig. 109. *Teleoceras* cf. *fossiger*. Side view of skull no. 30646 from U. C. Loc. no. V2825. One-third natural size.

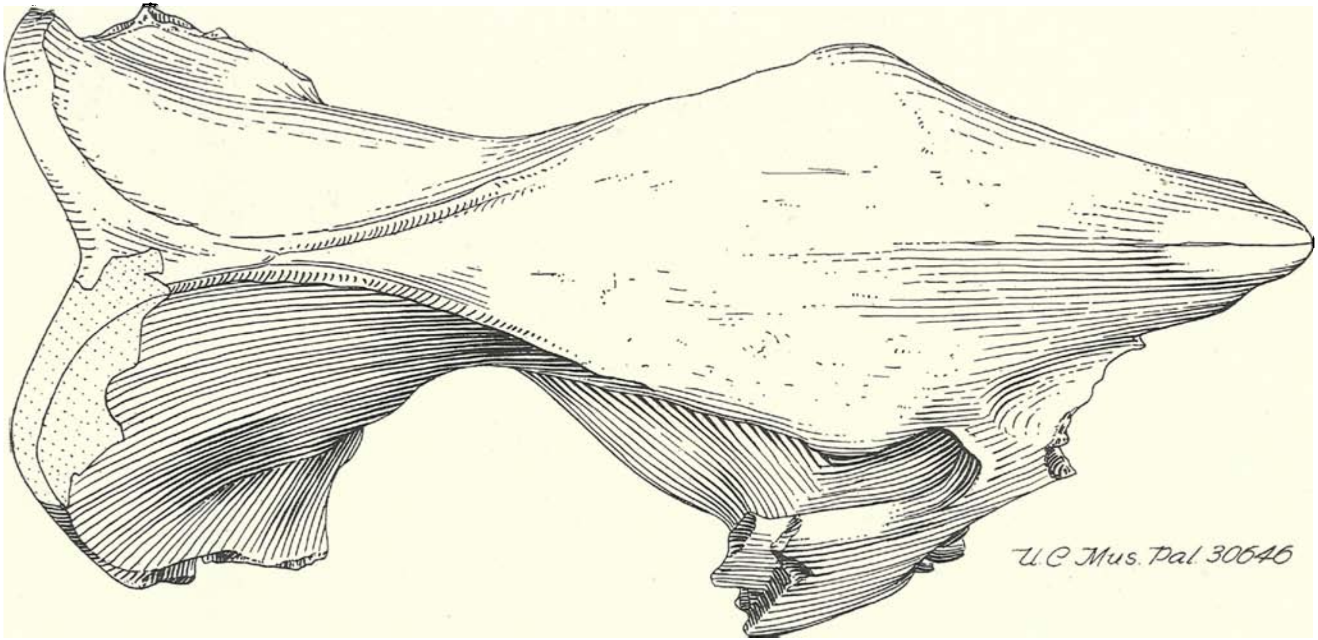

Fig. 110. *Teleoceras* cf. *fossiger*. Doisal view of skull no. 30646. One-third natural size.

premolars, cheek teeth brachydont in comparison to those of *Teleoceras*, narrow occipital region, narial notch extended far back, nasals reduced in some species but similar to *Teleoceras* in others, and limbs and feet normal, not shortened. This genus has been summarized by various authors and is now known from thirteen North American species. The Eurasian genus *Chilotherium*, recently described by Ringstrom,[43] was regarded as very close to *Aphelops* by Matthew.[44] Unfortunately Ringstrom did not compare his new genus directly with *Aphelops* so the value of Matthew's observations must await further study.

The Higgins *Aphelops* material and that from the Hemphill fauna (locality 20) was discussed at length by Matthew.[45] In his discussion of the Higgins skulls, he noted that in certain characters they did not resemble the large skull from Hemphill, but this difference was not regarded as specific by him. Most of Matthew's discussion was based upon the large Hemphill skull (no. 30252) which is much closer in its detailed characters to the type of *A. mutilus*, the species to which all the Texas material was referred. This species, *A. mutilus*, was originally described as a subspecies of *A. malacorhinus*.[46] It has not yet been adequately distinguished from *A. malacorhinus*, and additional topotype material may show the two to be synonymous.[47] In view of this evidence, it seems to the writer that it is more likely that the older Higgins skulls represent the original *A. malacorhinus*, and that the more advanced *A. mutilus* is represented in the Upper Snake Creek and Hemphill faunas. Certainly this will account for the differences between the two Texas forms and will allow, also, emphasis on the suggestion of Matthew[48] that *A. mutilus* be regarded as a subspecies or a progressive mutation of *A. malacorhinus*.

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[43]Ringstrom, Torsten, Nashorner der *Hipparion*-fauna Nord-Chinas. Paleon. Sinica, ser. C, vol. 1, fas. 4, p. 26. 1924.

[44]Matthew, W. D., *op. cit.*, p. 433.

[45]Matthew, W. D., A review of the rhinoceroses with a description of *Aphelops* material from the Pliocene of Texas: Univ. California Pub., Dept Geol. Sci., Bull. 20, pp. 411–480, 1932.

[46]Matthew, W. D., Third contribution to the Snake Creek fauna: Bull. Amer. Mus. Nat. Hist., vol. 50, Bull. 50, p. 150, 1924.

[47]Matthew, W. D., A review of the rhinoceroses with a description of *Aphelops* material from the Pliocene of Texas: Univ. California Pub., Dept. Geol. Sci., Bull. 20, p. 432, 1932.

[48]Idem.

APHELOPS MALACORHINUS Cope

Referred material in the University of California Museum of Paleontology.—From U. C. Loc. no. V2824: three excellent skulls, incomplete in minor details, nos. 30300, 30301, 30302; from U. C. Loc. no. V2825: posterior part of left lower jaw M_{1-3}, no. 30637; posterior part of left lower jaw with alveoli of P_4, M_{1-3}, no. 30638; right femur, no. 30641; astragalus, no. 30307; part of hyoid and miscellaneous carpal and tarsal elements.

Description of the referred material.—SKULL, NO. 30300: A large (greatest length 534 mm.; greatest breadth 345 mm.), well-preserved skull, nasals, premaxillaries and both P^1 missing. Narial notch above P^4; postorbital region wide (213 mm.) and flat; postorbital ridges narrowly separate for three-fourths distance to occipital crest; they then fuse to form a short sagittal crest; occipital region narrow in comparison to that of *Teleoceras;* also rises more steeply from postorbital area. Upward pitch of occiput not as sharp as in *A. mutilus* skull from Hemphill fauna. Occipital crest overhangs occipital condyles slightly. Greatest width across paraoccipitals 195 mm. Postglenoid process heavy and curved forward. Entire basicanium shallow and elevated above plane of palate. Broken posterior border of nasals only 90 mm. wide, indicating that they were reduced. Palate narrow (75-100 mm.), deeply arched transversely. Posterior narial opening opposite middle of M_2; P_3M_3 all same size; P_2 slightly smaller than P_3; P_1 and entire anterior part of palate missing; medifossettes on premolars; skull throughout massive, heavy, and giving impression of being wide and flat.

SKULL, NO. 30301: Large skull, within a few mm. of size of no. 30300; nasals, premaxillaries, left P^2 missing; postorbital ridges narrowly separated to occipital crest, no true sagittal crest; nasal and frontal region more convex transversely than in no. 30300; greatest width across broken nasals 82 mm.; teeth heavily worn; left P^2 one-half the size of P^3; skull throughout slightly more massive and heavy in its construction than was no. 30300; otherwise the same in its general characters; wear of teeth and heavy rugosity of occipital region suggest the slight difference may be due to age.

SKULL, NO. 30302: Same size as the other two skulls but less well preserved; nasals, left zygoma, P^1-P^2 on both sides missing; postorbital region crushed slightly, teeth shattered and incomplete;

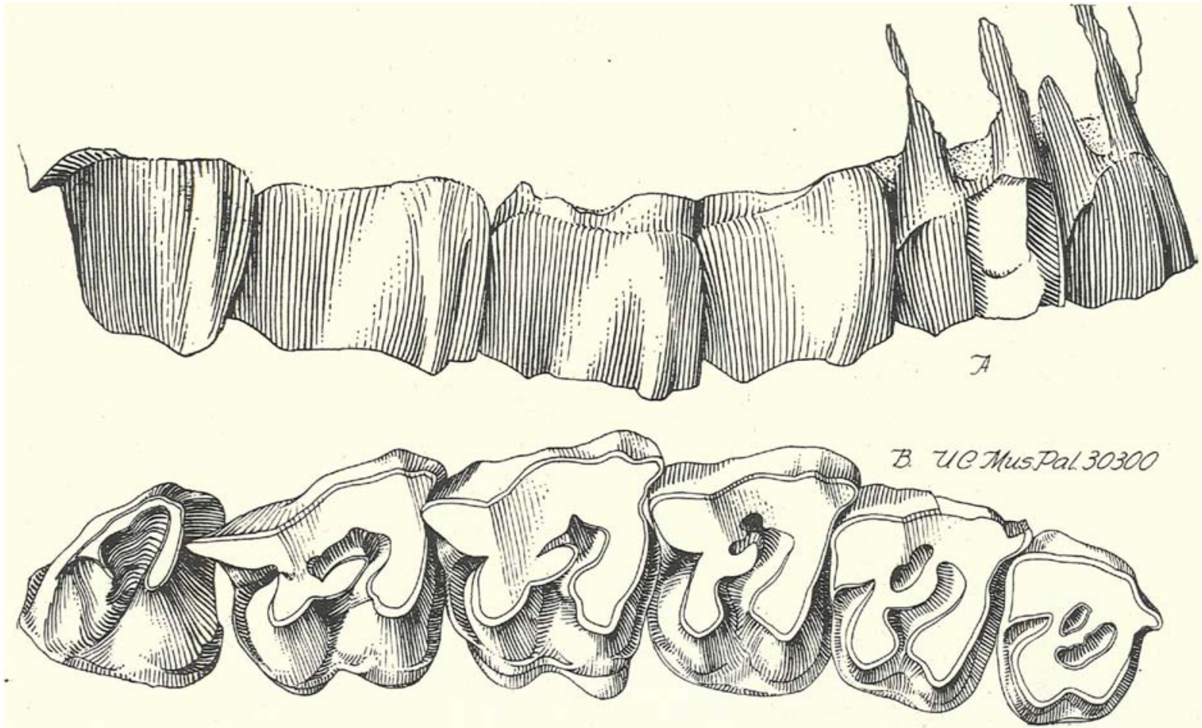

Fig. 111. *Aphelops malacorhinus.* External (A) and crown (B) views of upper right dentition of skull no. 30300 from U. C. Loc. no. V2824. One-half natural size.

postorbital crests imperfectly united—represented by deep groove in surface of cranium; entire top of skull seems somewhat flattened by crushing; lack of prominent occipital crest and rugosities indicate animal was young; characters otherwise same as other two skulls.

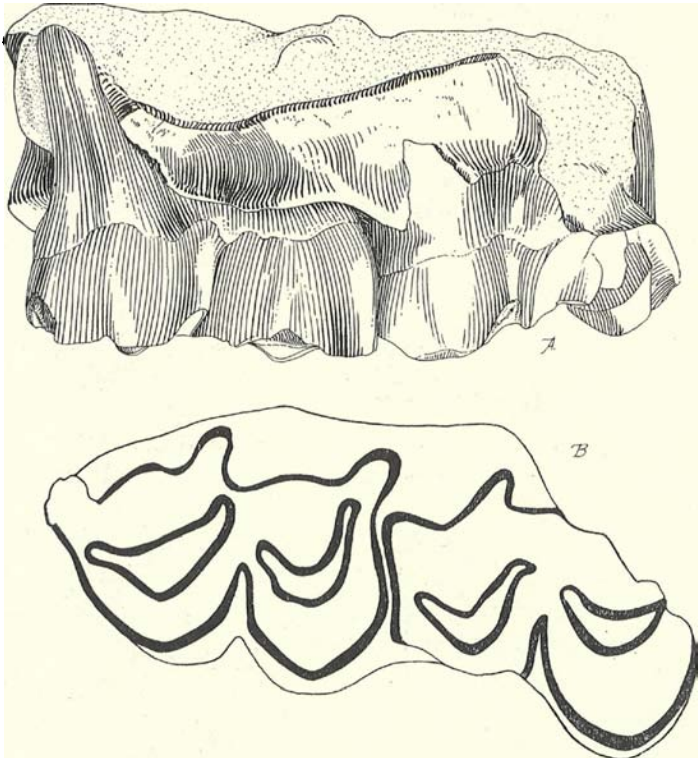

Fig. 112. Cf. *Megatylopus*. A, external view of maxillary fragment. B, crown view of teeth. Natural size.

LOWER JAWS: The two incomplete lower jaws offer no characters of specific value. They are of the size one would expect in a Pliocene *Teleoceras* or *Aphelops* and on the basis of the height of crown of the molar teeth (in no. 30637), they are referred to the latter genus.

SKELETAL ELEMENTS: The few skeletal elements preserved in this fauna offer no characters not already discussed by Matthew.[49] The

[49]Idem, pp. 427–430.

astragalus is, as noted by him, very characteristic in its structure and may be easily distinguished from the same element in *Teleoceras.*

Suborder ARTIODACTYLA

Genera MERYCODUS-CAPROMERYX

A navicular-cuboid (no. 30315) of a small artiodactyle probably belongs either to the genus *Merycodus* or the genus *Capromeryx.* It is from U. C. Loc. no. V2825 and represents the smallest animal in the collection. *Capromeryx* was common in the Hemphill fauna and is known from other localities in the same region. On the basis of its size, this specimen might fit well into either of the two forms.

Family CAMELIDAE

The remains of fossil camels were common in both of the localities at Higgins. Unfortunately neither quarry yielded sufficient material of the skulls or jaws so that the genera might be determined. The fragments of limbs, metapodials, and astragali are not as large as those customarily referred to *Megatylopus,* but they are much more massive than the average of the *Procamelus-Pliauchenia* group. A fragment of the right maxillary with M_{1-2} in place shows the teeth to be rather brachydont with prominent external styles. These teeth are similar to a form in the Hemphill fauna which is regarded as a new, slightly smaller species of *Megatylopus.* They are slightly less high crowned, and the limb material does not range as large in size as that from Hemphill.

There are, besides these specimens, a few fragments which indicate a camelid of much smaller size, probably belonging in the *Procamelus-Pliauchenia* group.

Order SUBUNGULATA

Suborder PROBOSCIDEA

The fragmentary remains of members of the Proboscidea group were among the most common of the fossils at both the Higgins localities. Unfortunately there are few specimens complete enough to determine with accuracy; they consist of teeth, limbs, and fragments. Considering the voluminous literature on these forms, the writer feels it to be a hopeless task to try to identify this material even as far as the genus.

CORRELATION OF THE VERTEBRATE FAUNA OF HIGGINS, TEXAS

The fauna described in the preceding pages does not represent the entire list of animals inhabiting this area in Pliocene time. Also, due to the paucity of genera, correlations based upon the fauna are likely to be somewhat in error. Nevertheless, there are certain conclusions as to age and general relationships that may be drawn from this assemblage.

Of the Carnivora represented in this fauna, the genus *Osteoborus* is confined to the Pliocene in all save one instance. The species *O. cyonoides* has been recorded from the Edson fauna of Kansas, Hemphill fauna of Texas, and probably Optima fauna of Oklahoma, as well as from the Higgins fauna. *O. validus* is known only from the Upper Snake Creek and the Higgins faunas, but it is closely related to *O. ricardoensis* of the Pliocene of California. *Machaerodus catocopis* is known chiefly from the Hemphill fauna and other scattered occurrences of Pliocene age. Little may be said of the equids in the Higgins quarries except that they are well advanced over any merychippines but appear to be less advanced (*Pliohippus* at least) than those of the Hemphill. *Teleoceras fossiger* is of little help since it has a wide stratigraphic range, and in all probability the forms referred to it do not represent one species. The original type of *Aphelops malacorhinus* is again from beds of lower Pliocene age, while the species *A. mutilus* is recorded from the Upper Snake Creek and Hemphill faunas.

From the foregoing records, one may conclude that the assemblage of genera and species in the Higgins fauna represents a Pliocene stage slightly older than the Hemphill or Upper Snake Creek faunas. It has many elements in common with these two, but other no less important elements are not as advanced as they are in these younger faunas. Direct comparison with either the Clarendon or Beaver material is difficult, since Higgins produced so few forms. In the elements they do have in common, Higgins is distinctly more advanced.

One may, then, consider the Higgins faunas as late lower Pliocene or early middle Pliocene, occurring in the Ogallala formation. In the generalized European section, it would fall into the late Pontian or early Plaisancian. It is, of course, impossible to state its European position exactly, and the above is at best approximate.

SUMMARY

A vertebrate fauna made up of eight mammalian genera was collected near Higgins, Lipscomb County, Texas. It is probably from a southern extension of the Ogallala formation. The carnivores of this collection are allied to those of the Upper Snake Creek and Hemphill faunas. The equids are of the type that inhabited the northern part of the Great Plains in early Pliocene time. Three rhinoceros skulls from this locality are reassigned to the species *Aphelops malacorhinus* and are not as closely allied to the Upper Snake Creek and Hemphill forms as Matthew indicated. On this evidence the Higgins fauna is placed as intermediate in position between the more primitive Clarendon, Burge, and Beaver faunas and the more advanced Upper Snake Creek and Hemphill faunas. It is considered as late lower Pliocene or early middle Pliocene, later probably than the Pikermi or Samos faunas of the Old World.

THE BORGER, TEXAS, EARTHQUAKE OF JUNE 19, 1936

E. H. Sellards

A small earthquake centering in or near Borger, Texas, occurred on June 19, 1936. In the region of maximum intensity, the earthquake was of sufficient severity to cause buildings to sway perceptibly. Some persons were frightened and ran out of houses. The principal shock, which occurred at or near 9:24 P.M., was felt over the greater part of the Panhandle regions of Texas and Oklahoma and in adjoining counties in Kansas and Colorado. The accompanying map, figure 113, indicates the approximate area over which this earthquake was perceptible without instrumental records. The earthquake was recorded by seismographs at Austin, Texas; St. Louis and Florissant, Missouri; Des Moines, Iowa; Tucson, Arizona; and probably at other stations. From the seismograph records, Rev. James B. Macelwane of Saint Louis University has determined the time of origin of the earthquake as follows: first shock, 9:13:37; second shock, 9:18:27; third shock, 9:24:06 P.M., Central Standard time, June 19 (letter of July 8, 1936). The time of first recorded arrival of the three shocks at several stations as given by Dr. Macelwane was as follows, Central Standard time:

First shock:	Florissant, Missouri—9:17:21
	St. Louis, Missouri—9:17:28
Second shock:	Florissant, Missouri—9:22:11
Third shock:	Florissant, Missouri—9:26:11
	St. Louis, Missouri—9:26:13
	Des Moines, Iowa—9:27:34

The time of first arrival of the second and third shocks at Tucson, Arizona, was as follows: 9:22 and 9:27 P.M., Central Standard time (U. S. Coast and Geodetic Survey).

The following account of the earthquake is based on observations and inquiries made in the area affected on June 25, 26, and 27, 1936, supplemented by news items from the press and by information obtained from circulars sent out by the Bureau of Economic Geology. The United States Coast and Geodetic Survey has likewise made available the non-instrumental records obtained by the United States Weather Bureau.

Issued June 1940.

Of the three shocks recorded by seismograph only two, the second and third, were recognized by observers in the earthquake region. That the first shock should not have been felt is unexpected inasmuch as it was recorded on seismographs as far away as St. Louis,

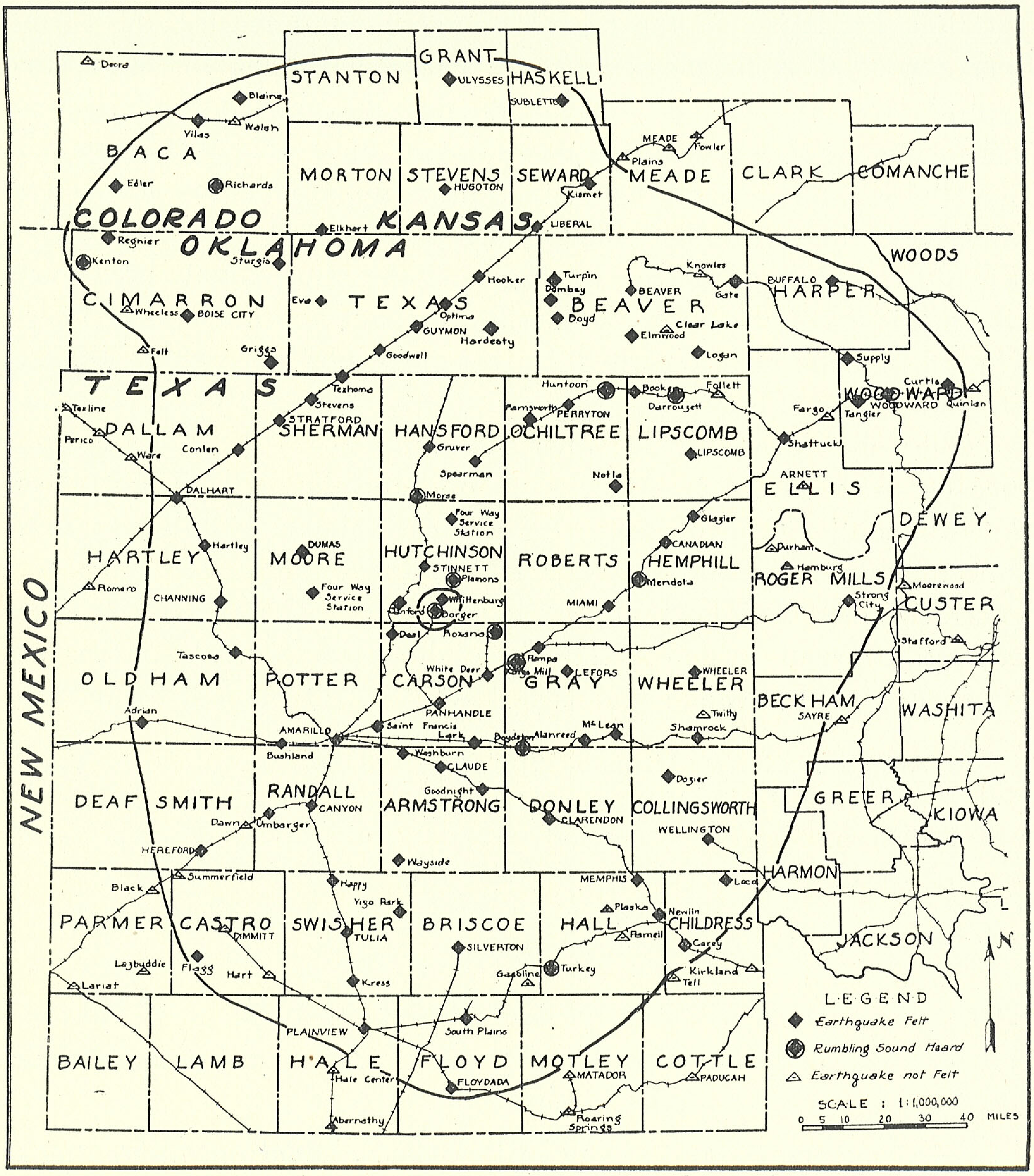

Fig. 113. Map to show extent of sensible shock of earthquake of June 19, 1936.

Missouri. Of those who felt the third shock, several recognized two parts separated by a few seconds—the first part a severe shock and the second part a prolonged tremor. The following comments indicate reactions to the earthquake.

COMMENTS BY THOSE WHO FELT THE THIRD SHOCK ONLY

Some of the observers refer to two shocks which were, in fact, the two parts of the third shock, the first and second shocks not having been felt by these persons.

Guymon, Oklahoma.—"Two shocks just an instant apart. First was the shorter, but the second of longer duration. Recognizing what was taking place, I anticipated the second shock and was interested to see if I could determine the direction of second shock, but the earth seemed only to move up and down. The characteristic peculiar earth rumble or moan was absent as far as I could ascertain. I spent 3½ years in the South Sea Islands, where quakes are almost a daily affair, and the shock was similar save for the strange roaring sound. I was standing facing west, listening to band concert at time."

Shattuck, Oklahoma.—"Did not hear any sound as the band was playing at the time, but the stone building seemed to sway from north to south, then back again."

Sanford, Texas.—"A shock and then a tremor felt by all persons of the community. The first shock gave the effect of the house being run into, then the tremors were noticeable for perhaps 40 seconds. It seemed that the tremors ran from north to south."

Memphis, Texas.—"Came running into my room and said that someone was pulling the house over. Another tremor less violent followed immediately."

Lefors, Texas.—"It seemed that something hit the house and shook it."

Liberal, Kansas.—"The shock appeared to me as though a very strong gust of wind hit the house, but with rather a circular motion tending to make me dizzy." "I had just moved my bed near the window and was reading when the bed began to quiver. I thought at first it was the wind, then I felt a dizziness and a sensation similar to sea sickness—others from adjoining apartment reported chairs rocked and such reports came in from many persons in Liberal—others reported water in wells around Liberal being red and muddy. One of our employees reported he was picnicking on the Cimarron River and the tremors were strong enough to cause the Victrola needle to jump up and down on the Victrola they were playing." One observer recognized two shocks; interval estimated at five seconds (U. S. Coast and Geodetic Survey record).

Boise City, Oklahoma.—"Observer on third floor of brick building recognized two distinct trembles very near together, the last probably being a little heavier of the two. . . . Rumbling sound heard by some persons on Flagstone Hill, 10 miles north of Boise City." (U. S. Coast and Geodetic Survey records.)

COMMENTS BY THOSE WHO FELT THE SECOND AND THIRD SHOCKS

Pampa, Texas.—"I felt a distinct tremor. Walked out into the yard to see what had happened. Returned to the house and resumed reading, and then a second and harder shock came. I looked at my watch and found that the second shock was at 9:25 P.M."

White Deer, Texas.—"The first quake was slight, but the second one felt as though the house would come to pieces if it had lasted any longer."

Elmwood, Oklahoma.—"Felt a shock. Some of the listeners thought it was thunder and we were just talking and wondering about what it was when we felt second shock. I did not notice any rumbling sound, neither did I think of there being more than two shocks, but there were crackling sounds in the house, rattling of dishes, and window glass, much as if a clap of thunder had pealed."

Gruver, Texas.—"I knew the first was an earthquake shock, so by the time the second came, I was well prepared. My family and I were in our old rock house which has stood in this Panhandle Country for fifty years, and we all were frightened to death. The walls, ceiling, and floor just quivered, and seemed as though these old thick walls would never stand. It seemed as though the whole house was waving up and down. It certainly was a shock to this entire community."

Panhandle, Texas.—"My wife and I were in bed reading when the first shock occurred about 9:22. We did not recognize it for an earthquake as neither of us had ever had experience with them. We both remarked that the wind was rising. About three minutes later it seemed like someone caught our bed on each side and began to shake it with quick jerks; the windows rattled and the window curtains and pictures flapped against the walls. This latter shock was divided into two sections, separated by about two or three seconds. Altogether the last shock lasted about ten seconds."

SOUNDS ACCOMPANYING THE EARTHQUAKE

A rumbling sound accompanying the earthquake was reported at several localities. The rumbling sound, commonly described as resembling distant thunder, was heard not only in the region of maximum intensity but also seemingly quite as often in the region of somewhat lesser intensity. Many observers report hearing no sound at all other than that incidental to rattling of dishes, doors, or furniture. Localities from which the rumbling sound was reported are indicated on the map.

The following are some of the comments on sound:

Boydston, Texas.—"Like a train passing over a bridge. After the first sound was heard we were sitting at the dining room table when the floor seemed to shake under our feet; then the articles on the stove commenced to shake."

Hunton, Texas.—"Sounded like thunder and woke me."

Darraugett, Texas.—"Sounded like distant thunder."

Mendato, Texas.—"A low rumble, thought it a train. Shook the house or it seemed to sway to the north."

Kenton, Oklahoma.—"A faint rumble, somewhat like a heavily loaded truck crossing a bridge at a distance."

Richards, Colorado.—"I distinctly felt the tremor, heard a noise which I took to be distant thunder. I stood up listening for other noises and heard what I took to be a stiff wind coming. I stepped out in the yard and found everything perfectly quiet. No wind, no thunder, all perfectly quiet."

"By inquiry, I have found three other persons who felt a distinct tremor and heard a sound which they described as very distant thunder, followed by a sound of a high wind approaching or coming. They say they thought surely a high wind would strike very soon. The sound as of a high wind approaching lasted for thirty seconds or a very little more."

Plainview, Texas.—"A deep rumbling sound as distant thunder."

Turkey, Texas.—"A deep sound and felt the tremor very much."

Morse, Texas.—"Low thunder-like rumble."

Kingsville, Texas.—"Rumble like distant thunder."

Roxanna, Texas.—"The sound was that of heavily loaded truck or train passing."

Farnsworth, Texas.—"A roaring sound which was quite pronounced and which frightened many."

RELATION OF THE EARTHQUAKE TO STRUCTURAL FEATURES

The controlling underground structural feature of the Panhandle region is the buried Amarillo mountain chain which trends approximately east-west. The place of maximum intensity of this earthquake was on the north flank of this mountain structure and in part in the accompanying syncline of the Anadarko basin to the north. The known lines of faulting in this region trend WNW-ESE.[1] So far as can be judged from available records it does not appear that this earthquake represents slippage on any known line of faulting.

Three previous earthquakes have been recorded in the Panhandle region. The first of these is reported to have occurred in April, 1907. The second earthquake of which there is more definite record occurred on March 24, 1917. The third earthquake of this region, which has been fully described by Udden, occurred on July 30, 1925.[2] It thus appears that this region since 1907 has been affected by mild earthquake shocks at intervals of from 9 to 11 years.

[1]See structural map accompanying Univ. Texas Bull. 3401, The Geology of Texas, Vol. II, Structural and Economic Geology 1934 [1935].

[2]Udden, J. A., The Southwest earthquake of July 30, 1925. Univ. Texas Bull. 2609, 32 pp., 1926.

GASTROPODA OF THE KIAMICHI SHALE OF THE TEXAS PANHANDLE

Merrill A. Stainbrook

From well records and scattered outcrops the Kiamichi shale is known to have a widespread distribution over much of the southern half of the Texas Panhandle. In a few places only is the shale exposed in any considerable area as in the deep basins of Lakes Guthrie, Tahoka, Montezuma, Bull, and Yellowhouse. In these localities, collecting over a period of years has yielded a fauna of some eighty species. Most of them are mollusks and, contrary to the usual mode of preservation in the Comanche as molds and casts, they generally have well-preserved shells. Gastropods form a small portion of the fauna as only twelve species have been recovered, five of them undescribed. The majority of the gastropods occur also in the Kiowa shale of southern Kansas and further substantiate the correlation of that formation with the Kiamichi shale.

Class GASTROPODA

Family PHASIANELLIDAE

PHASIANELLA ESTACADOENSIS Stainbrook, n.sp.

Pl. 33, Fig. 7

Description.—Shell small, nonumbilicate, elongate subovate in outline with moderately high acute spire and large body whorl, the spire making about a third of the total height; whorls numbering about three, inflated and regularly convex from back to front; body whorl more inflated than the others; suture strongly impressed; aperture semiovate, broadly rounded anteriorly, a little contracted posteriorly, the outer lip thin; surface smooth, marked by a few fine striae of increment. Dimensions of the holotype, a small but complete specimen, are: height, 8.1 mm., diameter of body whorl, 4.8 mm. A paratype measures 11.7 mm. in height and 6.9 mm. in diameter. Larger specimens are at hand but are so badly preserved that accurate measurements are impossible.

Remarks.—This species may not be properly placed in *Phasianella,* but it resembles members of that genus. It is quite

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unlike any other species of gastropod in the Texas Comanche known at the present time.

Horizon and locality.—Kiamichi shale in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—The holotype and paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family TROCHONEMATIDAE

AMBERLEYA MUDGEANA (Meek)

Pl. 33, figs. 1–3

Turbo mudgeanus Meek, F. B., 1871, Preliminary paleontological report, *in* Hayden, F. V., Preliminary report of the United States Geological Survey of Wyoming, and portions of contiguous territories, Pt. IV, No. 1, p. 313.

Margarita mudgeana Meek, 1876, U. S. Geol. Geog. Surv. Terr. (Hayden), Vol. 9, p. 300, pl. 2, figs. 9a–b; Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, p. 55, Pl. VIII, figs. 8, 9.

Description.—The author's specimens occur in a hard sandy limestone and are extracted with difficulty, few of them completely. They offer, however, few differences from the features noted in Meek's description. The spiral carinae are high, narrow, somewhat irregular along the summit, and on some specimens number three instead of four. On other examples there are several small spiral costae paralleling the carinae on the lower portion of the body whorl, and there may be a single costa in each or in any one of the intercarinal furrows. The growth lines are slightly lamellose, crowded, and oblique.

A small, complete specimen measures 16.3 mm. in height and 12.8 mm. in breadth. A large example measures 16.7 mm. in diameter.

Remarks.—The shell seems to have the characters of the genus *Amberleya* and has been placed therein. *Turbo chihuahuensis* Böse resembles this form to some extent but seems to be umbilicate and should probably be placed in the genus *Calliomphalus*. *Amberleya graysonensis* Adkins does not differ to any great extent from this form. A species which seems to be identical, though larger, occurs in the Comanche Peak limestone near Lubbock.

Horizon and locality.—Kiamichi shale, in the Guthrie shell bed at Guthrie Lake, near Tahoka, Texas, in which it is moderately common and in the *Desmoceras* zone at North Double Lake near the same town.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family TROCHIDAE

TROCHUS TEXANUS Roemer

Pl. 33, figs. 10–11

Trochus texanus Roemer, 1888, Paleont. Abhandl., vierter Band, heft 4, p. 15, taf. 1 (XXXI), fig. 13; Cragin, 1894, Amer. Geol., vol. 14, p. 11; Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, p. 57, Pl. IX, fig. 4; Adkins, 1928, Univ. Texas Bull. 2838, p. 174.

Description.—Shell small, trochoid in shape with high pointed spire and straight sides; whorls number from four to five, slightly flattened dorsally, rounded ventrally, slightly inflated at the shoulder, separated by a distinct, shallow, narrow furrow; aperture subcircular, with the outer lip thin and inner lip slightly calloused. Dorsal portion of each whorl marked by five spiral lirae of which the lowermost is the largest, and the others equal in size. Each lira is composed of a single row of subequal, dorso-ventrally elongated, slightly oblique and laterally flattened, beadlike tubercles; those of the peripheral lira are longer, flatter, and closer together. The narrow linear spaces between the lirae and the intervals between the tubercles are marked by numerous fine spiral costae. The lower anterior portion of the body whorl is marked by from seven to ten spiral ridges; of these the largest is peripheral and with the large one immediately above gives the whorl a keeled appearance; the remainder of the ridges are smaller than the lirae on the upper side of the whorl and are not as strongly tuberculate, the tubercules being smaller and less elongated. The whorl is also marked by numerous lines of growth.

A well-preserved example, a complete shell, measures 11.9 mm. in height and 9.6 mm. across the greatest diameter. The apical angle is about 60°.

Remarks.—*Trochus texanus* to some extent, especially in the ornamentation, resembles members of the genus *Calliomphalus* from the Coon Creek beds of Tennessee. It does not seem to belong to that genus, however, as it is nonumbilicate and has differently shaped whorls.

The author has not seen examples of *Trochus texanus* from the type area, and the reference of his form to that species is tentative and to some extent based on Cragin's recognition of it in the Kiowa shale of Kansas. Adkins mentions that *Trochus texanus* has a tooth on the lower margin of the outer lip. The condition of this portion of the shells at hand is such that neither the presence nor the absence of this feature can be demonstrated. Twenhofel mentions in his description of examples from the Kiowa shale that each tubercle has a small hole in or near its apex; none of the author's specimens has such a feature.

Horizon and locality.—Kiamichi shale, in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas. Reported from the Kiowa shale of Kansas. The Edwards limestone at Austin is the type locality.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family NERITIDAE

NERITA? SEMIPLEURA Twenhofel

Pl. 33, fig. 19

Nerita? semipleura Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, p. 56, Pl. VII, fig. 2.

Description.—The author has a single incomplete specimen which lacks a portion of the outer lip and has the shell of the anterior portion of the body whorl partly eroded. It differs in no particular from the description given by Twenhofel. The aperture seems to have been ovate and somewhat contracted posteriorly and has a smooth callous on the inner lip. The shell is imperforate. This example measures 5.9 mm. in height and 9.1 mm. in diameter.

Remarks.—This species agrees with Cragin's description of *Neritoma marcouana* of the Kiowa shale, except that it is not as high as indicated by him, and may belong to that species. The presence of short oblique costellae on the upper portion of the whorls and their absence on the lower part is very suggestive that this is the case. However, until comparison can be made with the types of *Neritoma marcouana* it may be best to regard the two species as distinct.

Horizon and locality.—Kiamichi shale, in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—The plesiotype is in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family NATICIDAE

NATICA SMOLANENSE Twenhofel

Pl. 33. figs. 12–13

Natica? smolanense Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, p. 56, Pl. VII, fig. 6.

Description.—Shell small, consisting of about three whorls, of which the body whorl comprises about three-fourths of the whole shell; subovate in outline, inflated, the spire obscure and but little elevated about the body whorl; suture linear and sharply impressed; whorls strongly and regularly curved from front to back; aperture semicircular, broadly rounded in front, acutely angular posteriorly; outer lip apparently thin; umbilicus open and deep. Surface of the shell smooth, marked by numerous fine transverse growth striae. Dimensions of the largest specimen, which is partially exfoliated, are: height, 22.3 mm.; diameter, 20.2 mm.

Remarks.—This form resembles *Natica collina* Conrad and may be identical with it.

Horizon and locality.—Kiamichi shale in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

GYRODES PATTONI Stainbrook, n.sp.

Pl. 33, fig. 14

Description.—Shell small, depressed, comprising about three and a half whorls; spire small, elevated about a millimeter above the remainder of the shell; body whorl large, gradually expanding and anteriorly flaring; the posterior portion next to the suture flattened or gently concave, and set off from the remainder by a distinct ridge; peripheral part of the whorl gently convex anteriorly and strongly curved posteriorly; suture deep, narrow; umbilicus distinct, infundibuliform; aperture semi-elliptical, broader in the posterior portion than anteriorly with outer lip thin. Surface marked by numerous transverse growth lines which are slightly more prominent on the posterior portions of the whorls. Dimensions of the holotype, a complete shell, are as follows: height, 8.8 mm.: diameter, 11.8 mm. A paratype, a large internal mold, measures 12.5 mm. in height (spire missing) and 18.7 mm. in diameter.

Remarks.—The low-spired, flat-topped shell with large, gradually expanding body whorl is characteristic of the genus. Thus far no other species of *Gyrodes* has been noted from the Lower Cretaceous (Comanche) beds of Texas.

Horizon and locality.—Kiamichi shale in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—The holotype and two paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family TURRITELLIDAE

TURRITELLA BELVIDERII Cragin

Pl. 33, figs. 15–16

Turritella belviderii Cragin, 1890, Bull. Washburn Lab. Nat. Hist., vol. 2, no. 11, p. 75; Cragin, 1897, Science, n.s., vol. 6, p. 134.

Turritella seriatim-granulata var. *belviderii* Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, pp. 58–59, Pl. VIII, figs. 1–2.

Description.—*Turritella belviderii* as developed in the area under consideration is a shell of moderate size with nearly straight or slightly convex whorls. The lirae, six in number, are subequal in size, the posterior one being slightly larger. The tubercles are well developed; those on the posterior lirae are elongate parallel to the axis of the shell, those on the remaining lirae are square or elongate in the direction of the ribs. On the earlier portion of the spire, the lirae are usually seven in number, linear, crowded, and moderately tuberculate. A typical example at hand, the spire absent, measures 42.6 mm. in height, with probably two-fifths of the shell missing, and 17.8 mm. in diameter.

Remarks.—*Turritella belviderii* differs from *Turritella seriatim-granulata* in having six spiral ribs, of which the posterior-most is considerably larger than the rest, instead of five equal ones, in that the middle one does not have a fine rib on either side and in that the tubercles are numerous and close together instead of few and remote. For these reasons it seems best not to regard *T. belviderii* as a variety of *T. seriatim-granulata.*

Turritella belviderii as shown by Kansas and Texas examples differs from *T. kansasensis* in that the spiral ribs of the former are wider and composed of tubercles and those of the latter are narrow, linear, sharply erect ridges; the intercostal furrows of the latter species are wider and flatter along the bottom. *T. kansasensis* has not as yet been found in the Panhandle area, and the above comparison is based on examples of the species collected in the type region in Kansas. Some of these are well preserved and show tubercles on the posterior rib of the larger whorls.

Horizon and locality.—Kiamichi shale in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas; Kiowa shale of southern Kansas.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

TURRITELLA LYNNENSIS Stainbrook, n.sp.

Pl. 33, fig. 18

Description.—Shell small in size, elongate, turreted, straight sided, possessing ten or more whorls in complete shells; whorls slightly arched from back to front, separated by a sharply depressed linear suture. Surface of the whorls marked by a pair of rather small tuberculated lirae on the posterior slope next to the suture; of these the posterior one is the larger; each is bordered anteriorly by a deep furrow; some specimens show a fine lira between these two. The anterior slope near the suture is marked by three or four rounded, low, plain lirae of variable width and convexity; the remainder of the surface of the whorls is marked by very fine spiral costae; on worn specimens the latter are usually missing so that at the first glance the ornamentation of this form appears to consist of a pair of beaded lirae posteriorly, a plain, smooth area centrally and several plain lirae anteriorly. On the anterior portion of the whorls covered by the succeeding whorl there are about ten fine, plain costae. Fine undulant striae of growth cross the whorls, being concave posteriorly and convex anteriorly. Aperture oval, broadest toward the front.

Measurements of a specimen consisting of three complete whorls and lacking a spire are as follows: height, 21.1 mm.; diameter, 7.7 mm.

Horizon and locality.—Kiamichi shale, in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—The holotype and paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

TURRITELLA MACROPLEURA Stainbrook, n.sp.

Pl. 33, figs. 17, 20–21

Description.—Shell large, elongate, turreted with ten or more whorls in a complete specimen, the earlier whorls with straight sides, the later ones slightly convex and with a posterior shoulder due to the strong development of the hindmost revolving lira; each whorl marked by four large revolving strongly tuberculated lirae of which the posterior is considerably larger; the other three are nearly equal in size but some specimens may show a slightly progressive decrease in magnitude toward the front; posterior to each lira and in the middle of the flat-bottomed furrows is a small fine tuberculated lira, making eight in all on each whorl. The tubercles of the four large lirae are strongly developed, erect, elongated parallel to the axis of the shell or slightly oblique; tubercles of the smaller lirae are much shorter. On the anterior part of the body whorl there are usually six lirae untuberculated or slightly so. Fine transverse striae of growth cross the whorls, being concave on the posterior slope and convex toward the aperture on the anterior. Aperture suboval in outline, broadest anteriorly.

Dimensions of an incomplete specimen are: height, 58.5 mm., with perhaps one-fourth missing; diameter, 20.1 mm.

Remarks.—In worn examples some or all of the smaller lirae may appear to be missing, but close examination of well-preserved specimens will show these characteristic features of this species. *Turritella macropleura* differs from *Turritella belviderii* in its larger size, in having eight ribs of unequal size instead of six subequal ones, and in having straight-sided whorls which have a distinct shoulder posteriorly.

Horizon and locality.—Kiamichi shale in the Guthrie shell bed and the *tucumcari* zone, at Guthrie Lake, near Tahoka, Texas.

Type.—The holotype and paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family CERITHIIDAE

CERITHIUM LAEVICULUM Stainbrook, n.sp.

Pl. 33, fig. 23

Description.—Shell large, elongate ovate in outline with the sides gently convex; whorls numbering six or more, flat or gently convex from back to front, in some examples depressed a little on the posterior slope and inflated correspondingly on the anterior slopes of the upper whorls; body whorl elevated along the middle with two narrow shallow grooves in front; aperture ovate, slightly canaliculate posteriorly and apparently so anteriorly, but the loss of that portion of the shell makes this uncertain; the outer lip is thick with a distinct spout-like indention which is reflected away from it; inner lip thick, reflected and touching the body whorl for a short distance posteriorly. Surface smooth for the most part except in the early stages which show deep spiral grooves and narrow costae. Numerous growth lines cross the whorls, each making in the middle of the whorls a distinct swing away from the aperture corresponding to the notch in the outer lip.

Dimensions of the holotype are: height, 68.5 mm. (incomplete); diameter, 33.1 mm. *Cerithium laeviculum* differs from *Cerithium proctori* Cragin in having fewer but larger and thicker whorls.

Type.—The holotype and paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family APORRHAIDAE

ANCHURA KIOWANA Cragin

Pl. 33, figs. 4–6

Anchura kiowana Cragin, 1894, Colorado Coll. Studies. 5th Ann Pub., pp. 66, 67; Twenhofel, 1924, Kansas Geol. Surv., Bull. 9, pp. 53–54; Pl. IX, figs. 2–3.

Description.—The author's examples of this species agree well with Cragin's description. They are usually embedded in a hard, tough sandstone and can seldom be extracted with any degree of completeness. The shell is easily recognized even in fragmentary condition by its fusiform shape and conspicuous ornamentation. The spire is high, forms about half the height of the shell, and merges gradually with the body whorl. Whorls are moderately convex, most strongly so anteriorly, and are separated by a distinct, deeply indented suture. The transverse ribs are strongly developed, regularly spaced, narrow, angular along the summit, and extend completely across the whorls. They are also concave toward the aperture instead of being straight as noted by Twenhofel. Specimens from the Belvidere area also agree with the author's specimens in this development. Numerous, fine, crowded lirae cross the ribs and are larger and farther apart on the anterior portion of the body whorl. None of examples shows the wing. Two specimens from Kansas Kiowa shale have this feature well preserved, and each shows a distinct keel in the middle which becomes indistinct at the back and merges with the smooth periphery of the body whorl. An example, with a part of the spire and the anterior portion of the body whorl absent, measures 28.5 mm. in height and 13.7 mm. in diameter. A portion with the body whorl complete is 15.8 mm. in diameter.

Remarks.—Comparison of these forms with examples of *Anchura kiowana* from the type area show them to be identical. Several of the author's are, however, distinctly larger than the dimensions given by Cragin. *Anchura kiowana* differs from *A. mudgeana* in having a proportionately smaller and less inflated body whorl, in that the ribs of the body whorl do not extend as far anteriorly, and in having a very indistinctly or scarcely developed callous on the inner lip.

Horizon and locality.—Kiamichi shale, moderately common in the *Turritella* zone at Guthrie and Tahoka lakes, near Tahoka, Texas.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

Family RINGICULIDAE

AVELLANA TEXANA Shumard

Pl. 33, figs. 8–9

Avellana texana Shumard, 1859, Trans. Acad. Sci. St. Louis, vol. 1, p. 597.
Cinulia texana Adkins, 1928, Univ. Texas Bull. 2838, p. 197.

Description.—Shell small, subglobose, oval in outline, higher than wide, having about two and a half whorls; spire low, oblique, about one-fifth the height of the spire; body whorl making up the greater part of the shell, expanding toward the front, regularly curved from back to front; aperture semicircular, narrow, expanded and rounded anteriorly, acutely angular posteriorly; outer lip greatly thickened, reflected exteriorly, crenulate internally; inner lip strongly calloused, bearing two small oblique teeth, situated near the anterior end. Exterior of the shell marked by narrow spiral lirae, variable in number, twenty in one specimen at hand; those on the anterior slope tending to be slightly larger. Transverse growth striae cross the lirae and are most prominent in the furrows between them.

Remarks.—The presence of two teeth on the inner lip and the crenulate inner surface of the outer lip place this form in the genus *Avellana.*

Horizon and locality—Kiamichi shale, in the Guthrie shell bed and in the *Turritella* zone at Guthrie Lake, near Tahoka, Texas.

Type.—Plesiotypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin.

PLATE 33

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Amberleya mudgeana (Meek), x2 ... 706

1–3. Lateral, apical, and apertural views of three hypotypes from Guthrie Lake.

Anchura kiowana Cragin, x1 ... 713

4. Lateral view of an incomplete specimen from Tahoka Lake.

5, 6. Views of two examples from Belvidere, Kansas.

Phasianella estacadoensis Stainbrook, n.sp., x2 ... 705

7. Lateral view of holotype from Guthrie Lake.

Avellana texana Shumard, x2 ... 714

8, 9. Dorsal and ventral views of a well-preserved specimen from Guthrie Lake.

Trochus texanus Roemer, x2 ... 707

10, 11. Ventral and dorsal views of a nearly complete shell from Guthrie Lake.

Natica smolanense Twenhofel, x2 ... 709

12, 13. Dorsal and ventral views of a hypotype from Guthrie Lake.

Gyrodes pattoni Stainbrook, n.sp., x2 ... 709

14. Apical view of the holotype from Guthrie Lake.

Turritella belviderii Cragin, x1 ... 710

15. Lateral view of a typical example.

16. Lateral view of a portion of the spire of another example showing linear lirae of that part of the shell. Both from Guthrie Lake.

Turritella macropleura Stainbrook, n.sp., x1 ... 712

17. Lateral view of a part of a spire of a paratype.

20. Ventral view of the holotype.

21. Lateral view of a paratype. All from Guthrie Lake and natural size.

Turritella lynnensis Stainbrook, n.sp., x2 ... 711

18. Lateral view of the holotype from Guthrie Lake.

Nerita? semipleura Twenhofel, x2 ... 708

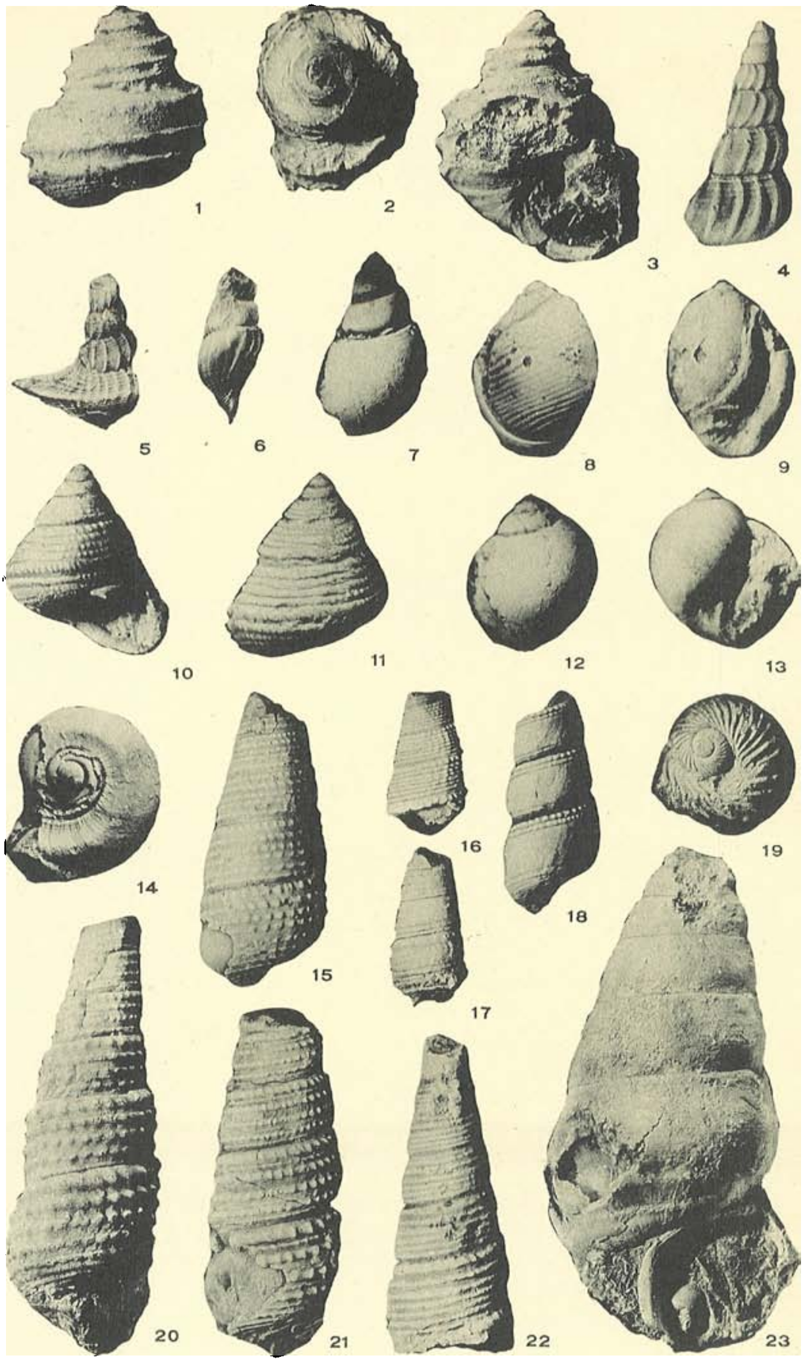
19. Apical view of the only specimen collected; from Guthrie Lake.

Turritella kansasensis Meek, x1 ... 711

22. Lateral view of a specimen from Belvidere, Kansas, introduced for comparison with other species of *Turritella*.

Cerithium laeviculum Stainbrook, n.sp., x1 ... 713

23. Ventral view of the holotype from Guthrie Lake.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NEW EOCENE BRACHIOPODS FROM THE GULF AND ATLANTIC COASTAL PLAIN

H. B. Stenzel

Brachiopods constitute a very inconspicuous element of the Tertiary fauna in the Coastal Plain. Very few species have been described, and it is not expected that the number of known species will increase much in the future. The genus which is represented by the greatest number of species is *Argyrotheca*. However, the species of even this genus are rare and usually restricted to one locality only. Two new species of this genus are described in this paper. Additional new species of *Argyrotheca* and other genera are present in the Salt Mountain limestone of Alabama. These are being prepared for publication by Dr. Lyman Toulmin in a paper on the fauna of that limestone.[*]

The species described below were collected by the writer in the course of his field studies in the Coastal Plain. It seems advisable to record them now so that the new species be made available for comparative paleontologic studies.

Class BRACHIOPODA

Order TELOTREMATA

Family TEREBRATELLIDAE

Genus ARGYROTHECA W. H. Dall, 1900

Some names which must be discarded: The Nautilus, vol. 14, p. 44. Genotype.—*Terebratula cuneata* Risso, by original designation.

This is the best represented brachiopod genus in the Gulf and Atlantic Coastal Plain Tertiary. The following species have been reported:

A. schucherti Dall,[1]	Choctawhatchee formation, upper Miocene	Florida
A. wegemanni Cole,[2]	Meson formation, middle Oligocene	Mexico

[*]Toulmin, L. D., Eocene brachiopods from the Salt Mountain limestone of Alabama: Jour. Pal., vol. 14, pp. 227–233, pl. 28, 1940.

This paper has been published in the meantime.

[1]Dall, W. H., Contributions to the Tertiary fauna of Florida with especial reference to the Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Trans., Wagner Free Inst. of Sci., vol. 3, pt. 6, p. 1539, pl. 58, fig. 8, Philadelphia, 1903.

Cooke, C. W., and Mossom, Stuart, Geology of Florida: Florida State Geol. Surv., 20th Ann. Rept., pp. 142, 143, 1929.

[2]Cole, W. S., A new Oligocene brachiopod from Mexico: Bull. Am. Pal., vol. 15, no. 57a, pp. 117–122 of vol., pl. 17, 1929.

Muir, J. M., Geology of the Tampico region, Mexico, p. 134, Amer. Assoc. Petr. Geol., Tulsa, Oklahoma, 1936.

Issued June, 1940.

A. akymatophora Stenzel, n.sp., Crockett formation, Claiborne group, middle Eocene	Texas
A. dalli Aldrich,[3] Hatchetigbee formation, Wilcox group, lower Eocene	Alabama
A. hatchetigbeensis Stenzel, n.sp., Hatchetigbee formation, Wilcox group, lower Eocene	Alabama
A. n.sp. Toulmin, Salt Mountain limestone, Wilcox group, lower Eocene	Alabama
A. beecheri (Clark),[4] Vincentown formation, Rancocas group, lower Eocene	New Jersey
A. plicatilis (Clark),[5] Vincentown formation, Rancocas group, lower Eocene	New Jersey
A. powersi Gardner,[6] Wills Point formation (?), Midway group, Paleocene	Texas

ARGYROTHECA AKYMATOPHORA, n.sp.

Pl. 34, figs. 1–4

Description.—The type material consists of four loose valves, two brachial and two pedicle valves.

Exterior of brachial valve devoid of plications or ribs, ornamented only with growth lines and the punctae. Hinge line straight. Growth lines and outline of valve almost semicircular. However, the greatest width of the valve is attained in front of and not at hinge line. Syntype 1 has a very faint median radial furrow.

Interior of brachial valve with a prominent nose-like median septum. An inconspicuous low ridge extends diagonally across each corner of the valve. Parallel with the hinge line extend the groove-like dental sockets, each bounded by a ridge. The groove-like dental sockets and ridges and the median septum radiate from a roughly pentagonal area located in the center of the hinge line.

Exterior of pedicle valve devoid of plications or ribs, ornamented only with growth lines and punctae. Growth lines nearly semicircular. Cardinal area triangular; beak prominent but rounded. Delthyrium large triangular.

Aldrich, T. H., New Eocene fossils from the southern Gulf States: Bull. Am. Pal., vol. 5, no. 22, pp. 13–14. pl. 5, figs. 9–10, 1911.

[4]Clark W. B., Two new brachiopods from the Cretaceous of New Jersey. Johns Hopkins University Circulars, vol. 15, no. 121, p. 3, pl., fig C, 1895.

[5]Clark W. B., *op. cit.*, p. 3. pl., fig. D.

[6]Gardner Julia, A new Midway brachiopod, Butler salt dome, Texas. Amer. Jour. Sci., 4th ser., vol. 10, pp. 134–138, figs. 1–8. 1925.

———, The Midway group of Texas: Univ. Texas Bull. 3301, pp. 113–115 pl. 5, figs. 1–8, 1933.

Interior of pedicle valve with a low median septum. This septum is thin and narrow in the posterior half of the valve. It is low and wide in the middle and tapers out to the front. Teeth of hinge inconspicuous, merely slightly thickened corners.

Brachial valve almost flat, pedicle valve slightly inflated.

Dimensions.—Syntype 1 (brachial valve), length 3.85 mm., width 4.88 mm. (Pl. 34, figs. 1–2); syntype 2 (brachial valve), length 2.57 mm., width 2.95 mm.; syntype 3 (pedicle valve), length 5.12 mm., width 5.09 mm.; syntype 4 (pedicle valve), length 3.75 mm., width 3.72 mm. (Pl. 34, figs. 3–4).

Remarks.—This is the first and only species of *Argyrotheca* known from the Claiborne group of the Gulf Coastal Plain.

Due to its distribution which is limited to the type locality it can hardly be confused with other species. However, the following characteristics distinguish it from its congeners: both valves are devoid of plications and the growth lines are semicircular to oval. *Argyrotheca schucherti* Dall, *A. wegemanni* Cole, *A. gardnerae* Cooke,[7] *A. dalli* Aldrich, *A. beecheri* (Clark), *A. plicatilis* (Clark), and *A. hatchetigbeensis* Stenzel are plicate on both valves and differ therein markedly from this species. *Argyrotheca powersi* Gardner has no plications on the brachial valve, but has well developed plications on the pedicle valve. On the other hand, *A. berryi* Olsson[8] from the upper Eocene Saman formation of Peru is consistently devoid of plications on both valves and very similar in general appearance to *A. akymatophora* Stenzel. In addition, *A. berryi* is near to *A. akymatophora* in stratigraphic age. Differences between these two species are slight. The chief difference is in the outline of the valves. The valves of *A. berryi* are consistently wider in proportion to their length than the corresponding valves of *A. akymatophora*. For instance, the pedicle valves of *A. berryi* are much wider than long; the same valves of *A. akymatophora* are about as wide as they are long.

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[7]Cooke, C. W. *Argyrotheca gardnerae*, new name Jour., Washington Acad. Sci., vol. 25, p. 31, 1935.

— — Contributions to the geology and paleontology of the West Indies: Carnegie Inst. Washington, Pub. 291, p. 152, pl. 16, figs. 5a–5c, 1919.

[8]Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru, pt. 2. Upper Eocene Mollusca and Brachiopoda: Bull. Am. Pal. vol. 15, no. 57, pp. 100–101, pl. 1, figs. 9–11, 1929.

The specific name is derived from the Greek α (not), κυμα (wave, plication), φορος (bearing).

Types.—The four types are in the writer's collection at Austin, Texas.

Type locality.—Stone City (or Moseley's Ferry) on Brazos River, that is, the bluff on the right or south bank of the river at the bridge of the new State highway No. 21 and the bridge of the Houston & Texas Central (Southern Pacific) Railroad, 11.3 miles west of Bryan, Brazos County, as measured by speedometer along highway No. 21, Burleson County, Texas.

Geologic horizon.—Basal beds of Wheelock member, Crockett formation, Claiborne group, middle Eocene. Syntype 1 comes from bed (ad) of the Stone City bluff as described by the writer in a previous paper.[9] This bed is 4.2 feet thick and is 4.2 to 8.4 feet above the base of the Crockett. Syntypes 2, 3, and 4 come from bed (ab) of the bluff. This bed is 3.7 feet thick and is 0.2 to 3.9 feet above the base of the Crockett.

In keeping with the near-shore and transgressional character of the basal Crockett beds the deltidial plates of the pedicle valves are missing, all types are found as loose single valves, and the types found in bed (ab) are slightly rounded by wave action.

ARGYROTHECA HATCHETIGBEENSIS, n.sp.

Pl. 34, figs. 5–9

Description.—The type material consists of 8 loose pedicle valves and 2 loose brachial valves.

Exterior of the brachial valve ornamented with approximately 13 low and very indistinct radial ribs. Hinge line straight. Growth lines and outline of valve nearly semicircular. The greatest width of the valve is attained at the hinge line.

Interior of brachial valve with a prominent nose-like median septum. There is no ridge extending across the corners of the valve. Parallel with the hinge line extends a dental groove and a ridge on each side. The grooves and ridges and the median septum radiate from an area located at the center of the hinge line. This

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[9] Stenzel, H. B., A new formation in the Claiborne group: Univ. Texas Bull. 3501, pp. 267–279, 1936.

area is wide from left to right but narrow in antero-posterior direction, the proportion in these two directions being about 3 to 1.

Exterior of pedicle valve with approximately 13 to 17 well defined radial ribs which begin a short distance from the point of the beak. As the shell grows the number of ribs increases by intercalation of new ribs. In old specimens the ribs become obsolete so that the valve is smooth along the margin. Cardinal area triangular and steep. Beak prominent but rounded. Delthyrium large, but not extending to the beak.

Interior of pedicle valve with a low median septum. This septum is very thin in the posterior half of the shell and broad and low in the anterior half and disappears toward the front margin. Teeth of hinge inconspicuous, merely slightly thickened.

Brachial valve flat, pedicle valve slightly inflated and of the shape of a low half-cone.

Dimensions.—The three figured types have the following dimensions in millimeters:

Valve	Syntype	Length	Width	
Brachial	1	2.64	4.13	(See Pl. 34, figs. 5–6.)
Pedicle	2	3.34	4.12	(See Pl. 34, fig. 7.)
Pedicle	3	3.14	4.2	(See Pl. 34, figs. 8–9.)

Remarks.—This is the second species described from the same locality, that is, Hatchetigbee bluff. The other species is *Argyrotheca dalli* Aldrich. These two species are the only ones known from the Wilcox group of the Gulf Coastal Plain. *Argyrotheca* n.sp. Toulmin is a third but as yet undescribed species from that group.

The differences between these two species concern only the brachial valve because the pedicle valve of *A. dalli* Aldrich is as yet unknown. The brachial valve of *A. dalli* has well marked radial plications; the same valve of *A. hatchetigbeensis* has very indistinct radial plications. The outline of the valve in *A. dalli* is oval because the greatest width is at the middle of the valve and not at the hinge line; the outline of the valve in *A. hatchetigbeensis* is semicircular and the hinge line is the widest part of the valve. In the interior of the valve *A. dalli* has a large round area occupying the center of the hinge line; the same area in *A. hatchetigbeensis* is wide from left to right but narrow from anterior to posterior. The dental grooves and ridges, which are to both sides of this area and parallel with the hinge, are short in *A. dalli* and long in *A. hatchetigbeensis*.

Argyrotheca hatchetigbeensis and *A. powersi* Gardner are somewhat similar in one respect, namely, the discrepancy in ornamentation of brachial and pedicle valve. In *A. hatchetigbeensis* the brachial valve has very feeble plications, but the pedicle valve has well developed plications. In *A. powersi* the brachial valve has no plications, but the pedicle valve has well developed plications.

Types.—The 10 syntypes are in the writer's collection at Austin, Texas.

Type locality.—Bluff at Hatchetigbee landing on the right bank of Tombigbee River, by road 4.25 miles east-northeast of Frankville, Washington County, Alabama.[10]

Geologic horizon.—Hatchetigbee formation, Wilcox group, lower Eocene.

Family TEREBRATULIDAE

Genus TEREBRATULINA A. d'Orbigny, 1847

Sur les Brachiopodes ou Palliobranches (deuxième mémoire): Compte rendu hebdomaires des séances de l'Académie des Sciences (Paris), vol. 25, p. 268.

Genotype.—*Anomia caput-serpentis* Linné of authors = *Anomia retusa* Linné.

TEREBRATULINA LOUISIANAE, n.sp.

Pl. 34, figs. 10–16

Description.—Shell large for the genus. Both valves about equally convex, thin, and punctate. Pedicle valve elongate oval and with a straight beak which is slightly obliquely truncated by the foramen. Foramen large, semicircular. Deltidial plates missing. The hinge teeth are strong, high, and compressed. Brachial valve is subcircular in outline, but the anterior margin has a short stretch in the middle which is straight. There are small *Pecten*-like ears at the hinge. These ears are developed in youth but disappear in maturity. Both valves ornamented with numerous, fine, dichotomous or intercalating ribs. The ribs are roundly arched in cross section, the interspaces being narrower than the ribs. The ribs are slightly wider along the midline than to both sides of each

[10]Best available map is map No. 13 in Semmes, D. R. Oil and gas in Alabama. Geol. Surv. Alabama, Special Rept. 15, p. 364, 1929.

valve. The ribs are crossed by numerous fine growth lines which produce very fine wrinkles upon the ribs. Average width of a rib is 1/6 to 1/7 mm.

Dimensions.—The largest type specimen is 21.6 mm. long. Other types are

19.2 mm. long, 14.4 mm. wide	(See Pl. 34, fig. 12.)
15.6 mm. long, 14.7 mm. wide	(See Pl. 34, figs. 10–11.)
14.5 mm. long, 13.2 mm. wide	
15.2 mm. long, 13.0 mm. wide	
16.4 mm. long, 12.7 mm. wide	
18.9 mm. long, 17.1 mm. wide	

All specimens measured are pressure-flattened. This flattening has increased the width but has left the length almost unchanged.

Remarks.—There are six species of this genus known from the Tertiary beds of the Gulf and Atlantic Coastal Plain of North America. The other five known species are *T. brundidgensis* Aldrich[11] from the Nanafalia formation of the Wilcox group, lower Eocene, of Alabama; *T. innovata* De Gregorio[12] from the "*Scutella*" bed, Claiborne group, middle Eocene, or the Ocala limestone, Jackson group, upper Eocene, of Alabama; *T. lachryma* (Morton)[13] from the Santee limestone of the Jackson group, upper Eocene, of South Carolina; *T. manasquani* Stenzel from the Manasquan formation, middle Eocene, of New Jersey; and *Terebratulina* n.sp. Toulmin from the Salt Mountain limestone of the Wilcox group, lower Eocene, of Alabama. Comparison of the new species with these five is difficult on account of the crushed nature of the new species.

Terebratulina louisianae Stenzel is about twice as large as *T. lachryma* (Morton) and *T. brundidgensis* Aldrich and about the same size as *T. manasquani* Stenzel. *Terebratulina lachryma* (Morton) and *T. brundidgensis* Aldrich are also in outline more elongate-oval than *T. louisianae*. *Terebratulina manasquani* Stenzel has a median sinus and fold at the anterior margin of the valves.

[11]Aldrich, T. H., Some new Eocene fossils from Alabama: The Nautilus, vol. 21, pp. 8–9, pl. 1, figs. 1, 2, 3, 1907.

[12]de Gregorio, A., Monographie de la faune Éocénique de l'Alabama et surtout de celle de Claiborne de l'étage Parisien: Annales de Géologie et de Paléontologie, livr. 7 and 8, p. 238, pl. 39, figs. 4–6, 1890.

[13]Morton, S. G., Supplement to the "Synopsis of the organic remains of the ferruginous sand formation of the United States": Amer. Journ. Sci. and Arts, vol. 24, art. 11, p. 130, pl. 10, fig. 11, 1833.

This feature is absent in the other species. *Terebratulina* n.sp. Toulmin is a tiny species about one-sixth the size of *T. louisianae* and is characterized by nodulated ribs. *Terebratulina innovata* De Gregorio is a tiny species of subtriangular outline.

Types.—Numerous syntypes are in the writer's collection, Austin, Texas.

Type locality.—Cut on west side of gravelled State highway No. 12, Chestnut-Creston road, 1.47 miles south of railroad depot at Chestnut, near center of sec. 7, R. 6 W., T. 12 N., Natchitoches Parish, Louisiana. This part of the highway is the road bed of an abandoned railroad. This is Bureau of Economic Geology locality No. La-6.

Geologic horizon.—Glauconite marls in lower part of Cane River formation, Claiborne group, middle Eocene. The brachiopods occur about 10 to 20 feet above the base of the Cane River formation. Other fossils found there are

Aturia laticlavia Stenzel
Ostrea lisbonensis Harris
Ostrea ludoviciana Harris
Ostrea, sp.
Anomia, sp.
Venericardia natchitoches Harris
Corbula smithvillensis Harris?
Madracis ganei Vaughan

This locality is presumably also the type locality of *Ostrea lisbonensis* Harris and *Ostrea ludoviciana* Harris.

TEREBRATULINA MANASQUANI, n.sp.

Not *Terebratula atlantica* Morton, S. G., Description of some new species of organic remains of the Cretaceous group of the United States: Acad. Nat. Sci. Philadelphia, Jour., vol. 8, pt. 2, p. 214, 1842.

Not *Terebratulina Halliana* Gabb, W. M., Synopsis of American Cretaceous Brachiopoda: Acad. Nat. Sci. Philadelphia, Proc. 1861, p. 19, 1862.

Not *Terebratulina Halliana* Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formation, including the geographical and stratigraphical range and synonymy: Amer. Phil. Soc., Proc., vol. 8, pp. 250, 256, 1861.

Not *Terebratula glossa* Conrad, T. A., *in* Cook, G. H., Geology of New Jersey, p. 377, 732, and text fig., 1868.

Not *Terebratula glossa* Conrad, T. A., Descriptions of Miocene, Eocene, and Cretaceous shells: Amer. Jour. Conchology, vol. 5, pt. 1, pp. 42–43, pl. 1, fig. 22, 1869.

Terebratulina atlantica (in part) Whitfield, R. P., Brachiopoda and Lamellibranchiata of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Surv., Mon. 9, pp. 9–11, pl. 1, figs. 10, 13, not figs. 11, 12, 1885.

Not *Terebratulina atlantica* Hollick, C. A., The paleontology of the Cretaceous formation on Staten Island: New York Acad. Sci., Trans., vol. 11, p. 98, pl. 1, fig. 8, 1892.

Terebratulina atlantica (in part) Weller, S., A report on the Cretaceous paleontology of New Jersey: New Jersey Geol. Surv., Pal. ser., vol. 4, pp. 360–361, pl. 28, figs. 9–12, 1907.

Remarks.—There has been a great deal of confusion concerning this little brachiopod. In order to remove this confusion it is necessary to straighten out all the brachiopod species which have been confused.

Terebratulina atlantica (Morton) was described from "the ferruginous sand at Woodward's Farm, New Jersey, where it was found by Mr. Conrad."[14] Another fossil described from this same locality is *Terebratella sayi* (Morton) which "occurs in the marl of Burlington County, New Jersey, more particularly at Woodward's Farm, near Walnford, from whence it was first brought by Mr. Samuel R. Wetherill."[15] In addition, Morton[16] lists *Exogyra costata* Say, Gryphaeas, and Belemnites from Woodward's farm. According to Cook[17] "in Upper Freehold the Lower Marl Bed [Navesink marl, Upper Cretaceous], was first opened and the first marl dug in 1805, by Benjamin Woodward, on farm now owned by Nimrod Woodward" and "Nimrod Woodward's pits at Cream Ridge, expose about 12 feet of blue marl [Navesink marl, Upper Cretaceous], and the sand-marl beneath [Mount Laurel sand, Upper Cretaceous]." The settlement of Walnford is 5 miles north of New Egypt or 3 miles north by west of Hornerstown in Upper Freehold, Monmouth County, on the bank of Crosswicks Creek. Cream Ridge is located nearby. The north-facing slope south of Walnford exposes the Mount Laurel sand overlain by Navesink marl; as mapped the nearest Eocene

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[14]Morton, S. G., Description of some new species of organic remains of the Cretaceous group of the United States. Acad. Nat. Sci. Philadelphia, Jour., vol. 8, pt. 2, p. 214, 1842.

[15]Morton, S. G., Synopsis of the organic remains of the Cretaceous group of the United States, p. 71, Philadelphia, 1834.

[16]Morton, S. G., Description of the fossil shells which characterize the Atlantic Secondary Formation of New Jersey and Delaware; including four new species Acad. Nat. Sci. Philadelphia, Jour., vol 6, pt. 1, p. 87, 1829.

[17]Cook, G. H., Geology of New Jersey, pp. 468 and 266, Newark, 1868.

outcrops are 2½ miles south of Walnford.[18] The genus *Terebratulina* is known to occur in the Upper Cretaceous of North America, and *Terebratella sayi* and *Exogyra costata* are well known and widespread fossils of the Upper Cretaceous Navesink marl. The type locality of *Terebratulina atlantica* (Morton) is therefore in the Upper Cretaceous, in particular in the Mount Laurel sand, which is the sand-marl subdivision of the Lower Marl Bed of Cook or the ferruginous sand of older authors.

Terebratulina halliana Gabb was described under peculiar circumstances. In 1861 Gabb found in the collections of the Academy of Natural Sciences of Philadelphia a tray of Terebratulinas from New Jersey labelled "*lachryma*" by Morton.[19] Gabb recognized correctly that these fossils could not be *Terebratulina lachryma* (Morton), because this is an Eocene species from South Carolina and is more slender than the New Jersey specimens. At the same time Gabb[20] made the fundamental mistake of referring *Terebratulina atlantica* (Morton) to the young stage of *Terebratula harlani* Morton. Morton stated clearly that *Terebratulina atlantica* has fine ribs, while *Terebratula harlani* is devoid of ribs. This feature alone makes it impossible to confound these two species. However, as Gabb considered these two species identical he knew of no species of *Terebratulina* from New Jersey to which one could assign the specimens in the tray at the Philadelphia Academy. Therefore, he described the specimens in that tray as new under the same *Terebratulina halliana* giving as their locality only New Jersey.[21]

Morton never reported *Terebratulina lachryma* as occurring in New Jersey. The only *Terebratulina* he ever reported from there is *T. atlantica*. It is probable that the specimens which he labelled *lachryma* and left at the Philadelphia Academy and which Gabb saw so labelled were at first thought to be *lachryma* by Morton but were later recognized as distinct and described as new under the name

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[18]Stephenson, L. W., letter to H. B. Stenzel April 1 1939.

[19]Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formation including the geographical and stratigraphical range and synonymy. Amer. Phil. Soc. Proc. vol 8 footnote, p. 256 1861.

[20]Gabb, W. M., Synopsis of the Mollusca of the Cretaceous formation, including the geographical and stratigraphical range and synonymy. Amer. Phil. Soc. Proc., vol. 8, p. 250, 1861, and Synopsis of American Cretaceous Brachiopoda Acad. Nat Sci. Philadelphia Proc. 1861, p. 18, 1862.

[21]Gabb, W. M., Synopsis of American Cretaceous Brachiopoda: Acad. Nat. Sci Philadelphia, Proc. 1861, p. 19, 1862.

T. atlantica. Morton may have neglected to correct the name on the label. This assumption explains why Gabb found no specimens labelled by Morton as *T. atlantica* but found nevertheless specimens of a *Terebratulina* from New Jersey labelled by Morton. Therefore, the writer assumes that the types of *T. halliana* Gabb are the same as the types of *T. atlantica* (Morton). This assumption could be proved definitely if one were to collect topotypes of *Terebratulina atlantica* (Morton) on Woodwård's farm near Walnford in New Jersey and compare them with the syntypes of *Terebratulina halliana* Gabb in Philadelphia. Obviously it is not possible for the writer to do this part of the work.

The next species to consider is *Terebratula glossa* Conrad. This species was described from the green marl of the Upper Bed [Manasquan marl, middle Eocene] by Conrad in 1868 and redescribed in 1869. Although Whitfield[22] and Weller[23] considered *Terebratula glossa* Conrad as a synonym of *Terebratulina atlantica* (Morton), it is clear that *Terebratula glossa* Conrad can not be a *Terebratulina.* Conrad[24] did not mention any fine ribs as occurring on *Terebratula glossa* and compared this species with *Terebratula biplicata* from the Cretaceous of western Europe. Conrad's descriptions and comparisons make it highly improbable that he would mistake a *Terebratulina* for a *Terebratula.* If this species of Conrad's is not a *Terebratulina* it need not be considered here anymore. To make this conclusion certain Conrad's type specimen of *Terebratula glossa* should be restudied, if it can be located.

Definition.—After having disposed of the Cretaceous *Terebratulina atlantica* (Morton) [= *T. halliana* Gabb] and of the Tertiary *Terebratula glossa* Conrad we are left with those specimens of a *Terebratulina* which were described from the middle Eocene Manasquan marl by Whitfield and Weller under the erroneous name of *Terebratulina atlantica.* These specimens came from the marl pits along Manasquan River, 1 mile south of Farmingdale, Monmouth County, New Jersey, out of the middle Eocene Manasquan marl.

[22]Whitfield, R. P. Brachiopoda and Lamellibranchiata of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Surv. Mon. 9, p. 19, 1885.

[23]Weller, S. A report on the Cretaceous paleontology of New Jersey: New Jersey Geol. Surv. Pal. ser. vol. 4, p. 360, 1907.

[24]Conrad, T. A., Descriptions of Miocene, Eocene, and Cretaceous shells: Amer. Jour. Conchology, vol. 5, pt. 1, pp. 42–43, 1869.

The specimens represent a hitherto unnamed species. The name *T. manasquani* Stenzel, n.sp., is herewith proposed for them. The type specimen is the one figured by Whitfield.[25]

Description.—Shell outline subpentagonal and comparatively broad. The anterior margin of the shell is truncated. Pedicle valve with a short and broad beak, the angle of convergence of the sides being about 80 degrees. Brachial valve with short *Pecten*-like ears. Both valves ornamented with radial striae. The anterior margin of the shell has a gentle fold.

Dimensions.—Length 23.0 mm., width 17.5 mm.

Type.—The holotype was, according to Whitfield, in the collection of Miss F. M. Hitchcock, of New York. It is not known where the type is now.

Type locality.—Marl pits along Manasquan River, 1 mile south of Farmingdale, Monmouth County, New Jersey.

Geologic horizon.—Manasquan marl, middle Eocene.

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[25] Whitfield, R. P., *op. cit.*, pl. 1, fig. 13.

PLATE 34

PAGE

Argyrotheca akymatophora Stenzel, n.sp., x7 718

1, 2. Outside and inside views of brachial valve, syntype 1.

3, 4. Outside and inside views of pedicle valve, syntype 4.

From Stone City (or Moseley's Ferry) on right bank of Brazos River, Burleson County, Texas; basal beds of Wheelock member, Crockett formation, Claiborne group, middle Eocene.

Argyrotheca hatchetigbeensis Stenzel, n.sp., x7 720

5, 6. Outside and inside views of brachial valve, syntype 1.

7. Inside view of pedicle valve, syntype 2.

8, 9. Outside and inside views of pedicle valve, syntype 3.

From bluff at Hatchetigbee landing on right bank of Tombigbee River; by road 4.25 miles east-northeast of Frankville, Washington County, Alabama; Hatchetigbee formation, Wilcox group, lower Eocene.

Terebratulina louisianae Stenzel, n.sp., x2 722

10, 11. Ventral and dorsal views of shell, syntype 1.

12. Dorsal view of shell, syntype 2.

13, 14. Inside and outside views of brachial valve, syntype 3.

15, 16. Inside and outside views of pedicle valve, syntype 4.

From cut on west side of gravelled State highway No. 12, Chestnut-Creston road, 1.47 miles south of railroad depot at Chestnut, near center of section 7, R. 6 W., T. 12 N., Natchitoches Parish, Louisiana; glauconite marls in lower part of Cane River formation, Claiborne group, middle Eocene.

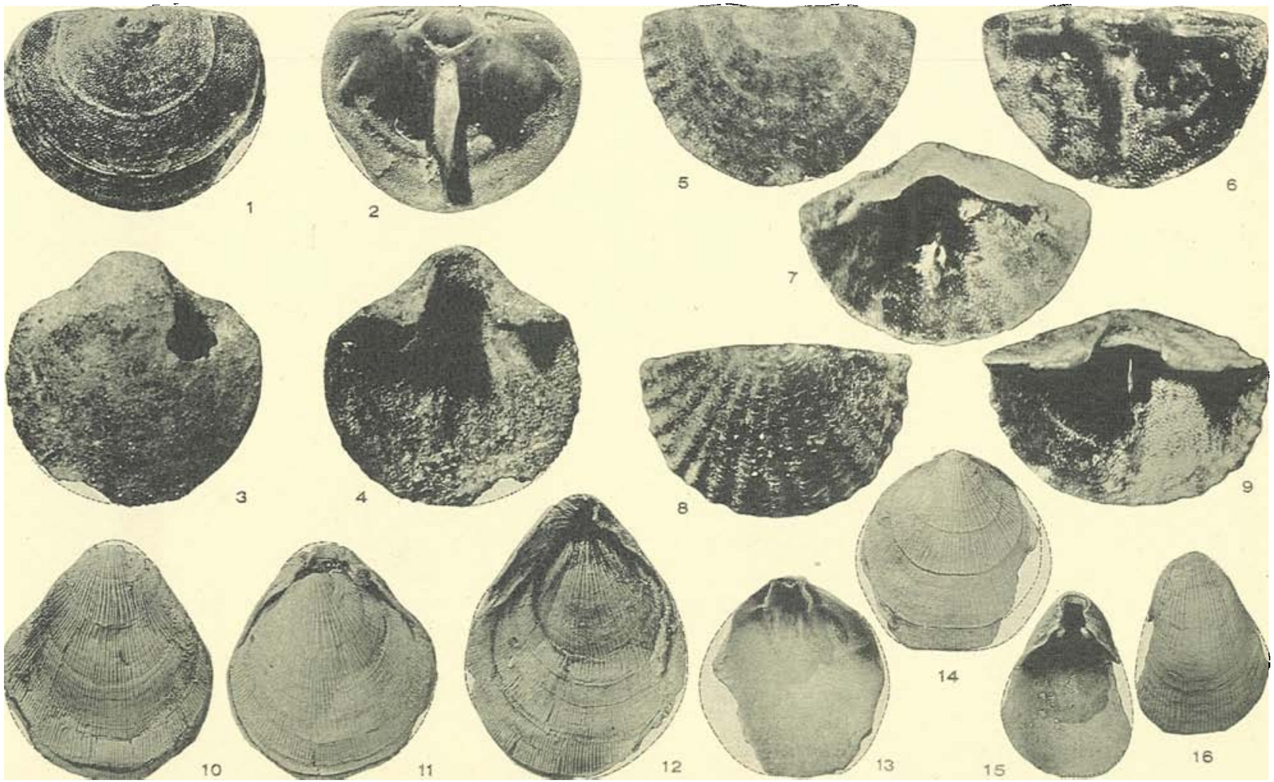


Plate 34

TERTIARY NAUTILOIDS FROM THE GULF COASTAL PLAIN

H. B. Stenzel

The number of nautiloid cephalopods known from the Tertiary deposits of the Atlantic and Gulf Coastal Plain of North America is small. Only 21 species have been described so far. This is indeed a very small number if one considers the circumstances, for the Coastal Plain extends from Cape Cod in Massachusetts to Mexico and is several hundred miles wide in many places. Tertiary beds of several thousand feet thickness are exposed in this region and fossil mollusks other than nautiloids are exceedingly abundant in many localities. Under these circumstances it is remarkable that so few specimens and so few species of nautiloids have been found. Evidently nautiloids are rare in number of specimens and species except for some of the Midway forms which may be found in abundance at some localities.

On account of the rarity of nautiloids in this region very little was known about them until recently. For instance, the local stratigraphic range of the genus *Aturia*, a comparatively abundant genus, was entirely unknown until 1935. Even today large extensions of this range are possible. Therefore, any addition to our knowledge, be this addition a new species or not, becomes important. For this reason, the lists and descriptions given below include all material known or available to the writer.

The material has come from many different sources. The writer wishes to acknowledge his indebtedness to Dean E. W. Berry for the loan of the type specimen of *Aturia berryi*, to Dr. Ralph Chaney and Dr. Bruce L. Clark for the loan of the monotype of *Woodringia simiensis* (Vokes), to Dr. Henry V. Howe for the loan of the type specimen of *Aturia garretti*, to Dr. F. E. Turner for the gift of the type specimen of *Aturia turneri*, to Dr. H. E. Vokes for the loan of a topotype specimen of *Eutrephoceras cookanum*, to Mr. L. Willis Clark for pointing out the *Aturia* locality near Laredo, to Mr. A. C. Elliott and Mr. R. E. McAdams for the gift of specimens of *Deltoidonautilus elliotti* and the pointing out of their type locality. Dr. L. Castex, of Bordeaux, France, and Dr. F. L. Spath, of the British Museum of Natural History, have kindly supplied specimens of *Aturia aturi*, which were much needed for comparison. The

Issued June 1940.

EAST COAST TERTIARY NAUTILOIDS

GENUS	SPECIES	TYPE LOCALITY	AGE
ATURIA	alabamensis (Morton)	Claiborne, Alabama	Ocala limestone, Jackson group, upper Eocene
	berryi Stenzel	Vicksburg, Mississippi	Vicksburg group, Oligocene
	brazoensis Stenzel	Stone City, Texas	Stone City beds, Claiborne group, middle Eocene
	garretti Stenzel	St. Maurice, Louisiana	Crockett formation, Claiborne group, middle Eocene
	laticlavia Stenzel	Bald Mound, Texas	Weches formation, Claiborne group, middle Eocene
	triangula Stenzel	Bald Mound, Texas	Weches formation, Claiborne group, middle Eocene
	turneri Stenzel	Bastrop County, Texas	Reklaw formation, Claiborne group, middle Eocene
	vanuxemi (Conrad)	Long Branch, New Jersey	Shark River marl, middle Eocene
ATUROIDEA	paucifex (Cope)	Glassboro, New Jersey	Hornerstown marl, Rancocas group, lower Eocene
	pilsbryi Miller & Thompson	Medford, New Jersey	Vincentown lime-sand, Rancocas group, lower Eocene
CIMOMIA	haltomi (Aldrich)	Black Bluff, Alabama	Sucarnochee shale, Midway group, Paleocene
	marylandensis Miller & Thompson	Popes Creek, Maryland	Nanjemoy formation, lower Eocene
	subrecta Miller & Thompson	Starkville, Mississippi	Clayton formation, Midway group, Paleocene
	vaughani (Gardner)	Uvalde County, Texas	Kincaid formation, Midway group, Paleocene
	vestali Miller & Thompson	Starkville, Mississippi	Clayton formation, Midway group, Paleocene

East Coast Tertiary Nautiloids—Continued

Genus	Species	Type Locality	Age
DELTOIDONAUTILUS	elliotti Stenzel	Bastrop County, Texas	Reklaw formation, Claiborne group, middle Eocene
EUTREPHOCERAS (?)	bryani (Gabb)	Vincentown, New Jersey	Vincentown lime-sand, Rancocas group, lower Eocene
EUTREPHOCERAS	cookanum (Whitfield)	Shark River and Squankum, New Jersey	Shark River marl, middle Eocene
	carolinense Kellum	Wilmington, North Carolina	Castle Hayne marl, Jackson group, upper Eocene
	reesidei Stenzel	Leon County, Texas	Crockett formation, Claiborne group, middle Eocene
	sloani Reeside	Perkins Bluff, South Carolina	Black Mingo formation, Midway group, Paleocene
	jonesi Miller & Thompson	Clarke County, Alabama	Formation unknown; Midway group, Paleocene
HERCOGLOSSA	mcglameryae Miller & Thompson	Lowndes County, Alabama	Clayton formation, Midway group, Paleocene
	orbiculata Tuomey	Allenton, Alabama	Clayton formation, Midway group, Paleocene
	tuomeyi Clark & Martin	Popes Creek, Maryland	Nanjemoy formation, middle Eocene
	ulrichi (White)	Little Rock, Arkansas	Basal Midway lime section, Midway group, Paleocene
	gardnerae Stenzel	Maverick County, Texas	Kincaid formation, Midway group, Paleocene
	n.sp. Stenzel	Kickapoo Shoals, Texas	Weches formation, Claiborne group, middle Eocene
WOODRINGIA	splendens Stenzel	Navarro County, Texas	Wills Point formation, Midway group, Paleocene

writer is grateful for important information or help received from Mr. W. S. Adkins, Dr. K. Van W. Palmer, Mr. W. A. Reiter, Dr. L. F. Spath, Dr. T. H. Withers, and Mr. A. Wrigley. Mr. Carl Chelf had the kindness to prepare some of the specimens studied and to make casts of important types. The photographs were made by Mr. Gale White, the drawings by Mr. J. S. Graves and Mr. Jerry Wilson.

The tables on pages 732, 733, and 735 summarize occurrences of Tertiary nautiloids in the Coastal Plain.

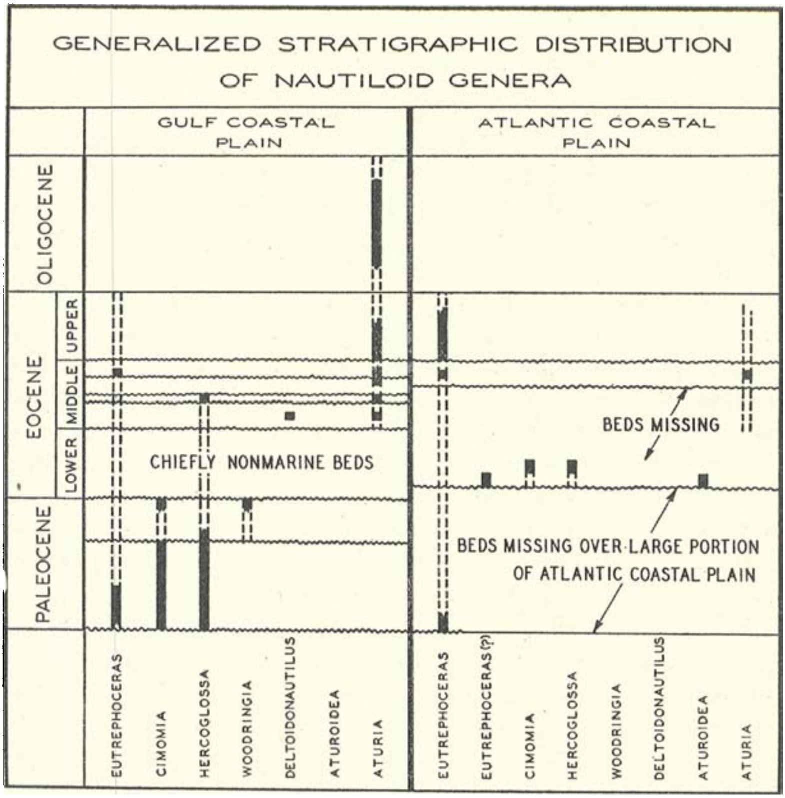
The stratigraphic distribution of nautiloids in this region is peculiar in some ways. For instance, only fragments of two indeterminate nautiloids have been found in Miocene deposits. A "Nautilus sp." is reported from the middle Miocene Calvert formation at Plum Point, Maryland.[1] A "Nautilus (fragments)" is reported from the lower Miocene Chipola formation of Bailey's Ferry, Calhoun County, Florida, by Maury.[2] These are the only references to Miocene nautiloids the writer has been able to find in the American literature dealing with east coast faunas. The fragments referred to by Maury are unfortunately misplaced, and K. Van W. Palmer was unable to locate them in the collections at Ithaca, New York. The writer's own collections from the same locality and from other localities of the same formation do not contain anything of this sort. J. Gardner also has not seen any nautiloid material in the Miocene collections of the U. S. National Museum.

This extreme rarity of nautiloids in the Miocene can hardly be explained through lack of intensive collecting because the Miocene of Maryland, Virginia, and Florida has been described by many authors, and large collections of marine invertebrates have been assembled by various institutions. Therefore, it seems fairly well established that Miocene nautiloids are either extremely rare in this region or even absent in most portions of the region. This is surprising because Miocene nautiloids are, although rare, well represented on the other side of the Atlantic. For instance, *Aturia aturi* (Basterot) occurs, besides several other localities, in the Burdigalian of St. Paul de Dax, Department of Landes, near Bordeaux in France. Topotype specimens of this species can be found in

[1]Martin, G. C., Systematic paleontology. Miocene, Mollusca Cephalopoda, *in* The Miocene deposits of Maryland, Maryland Geol. Surv., p. 130, pl. 39, fig. 1, 1904.

[2]Maury, C. J., A comparison of the Oligocene of western Europe and the southern United States: Bull. Am. Pal., vol. 3, no. 15 p. 370 of vol., 1902.

many collections in Europe, although the species is now considered a rarity. This discrepancy either in the abundance or perhaps even in the actual stratigraphic range of nautiloids to both sides of the Atlantic should enjoin people from making hasty intercontinental stratigraphic correlations based on nautiloid species.



Oligocene nautiloids had not been described previously from the Gulf and Atlantic Coastal Plain. However, they were known to be present because T. H. Aldrich[3] stated: "Among the material collected at Vicksburg, Miss., is a Nautilus—sp.? which, I believe, is the first instance of this cephalopod occurring in the Oligocene of this country." This specimen, a new species of *Aturia*, is described

[3]Aldrich, T. H., Notes on the distribution of Tertiary fossils in Alabama and Mississippi: Jour., Cincinnati Soc. Nat. Hist., vol. 8, p. 257, 1886.

below. It is the only specimen of a nautiloid known from the Oligocene of the Coastal Plain.

Knowledge of the Eocene and Paleocene nautiloids is still very imperfect. Many new species and extensions of the ranges of known species and genera are to be expected in the future. However, such results can be obtained only by extensive and careful collecting.

It is hoped that future collecting be done with an eye toward exact stratigraphic work. In the future no formal naming of new species should be attempted unless their detailed and exact locality and horizon are known. Unfortunately, new species published even as recently as 1933 have had occurrence data no more detailed than, for instance, Midway group of Clarke County, Alabama. Many difficulties are introduced into paleontologic work by inexact occurrence data. For example, paleontologists who work with Tertiary nautiloids are well aware of the difficulties which arose from M. Tuomey's insufficient description of *Nautilus orbiculatus* as coming from the "Cretaceous of Alabama."

At the present state of the knowledge of the Eocene and Paleocene nautiloids of this region it appears well established that the genus *Aturia* appeared first in the Reklaw formation. This formation is near the base of the middle Eocene Claiborne group. From this level on up the genus *Aturia* occurred sporadically in nearly all marine layers up into the Oligocene Vicksburg group.

The genus *Aturoidea* has been found only in the lower Eocene Rancocas group of New Jersey.

The genera *Cimomia* and *Hercoglossa* are found in the Gulf Coastal Plain in the Paleocene Midway group where they are very common in some localities. They are not known from the lower Eocene of the Gulf Coastal Plain presumably because that portion of the Eocene is largely nonmarine. Surprisingly, a specimen of a new *Hercoglossa* species was found recently in the Weches formation, which is one of the formations of the middle Eocene Claiborne group. In the Atlantic Coastal Plain they occur in the Nanjemoy formation of Maryland. This formation is generally considered middle Eocene in age. However, Gardner and Bowles have recently pointed out that the Venericardias of the Nanjemoy formation have Wilcox affinities. Therefore, these two authors place the Nanjemoy formation in the lower Eocene.[1] This correlation seems to be borne

[1]Gardner, Julia, and Bowles, Edgar, The *Venericardia planicosta* group in the Gulf Province: U. S. Geol. Surv., Prof. Paper 189-F, Chart 1 facing p. 114, 1939.

out by the nautiloids, because the two genera, *Cimomia* and *Hercoglossa,* are present in the Nanjemoy formation, but *Aturia* is not known from it.

The genus *Deltoidonautilus* is known so far only from the Reklaw formation which is the lowest marine formation included in the middle Eocene Claiborne group.

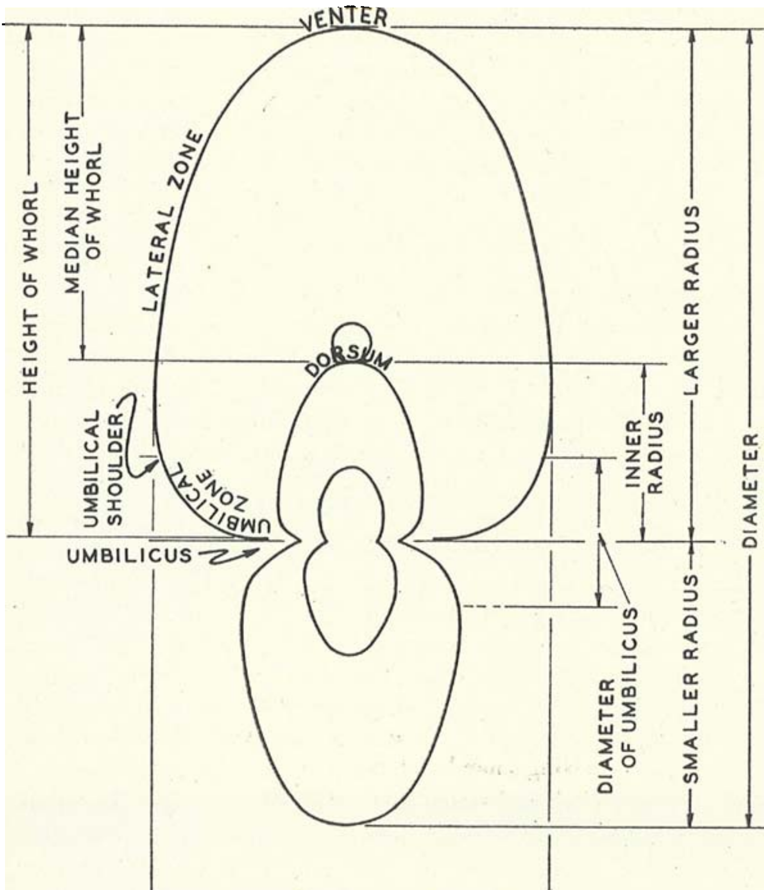


Fig. 114. Diagrammatic representation of terms used in description of nautiloids.

Whorl increase ratio is the ratio of larger radius over inner radius.

The genus *Eutrephoceras* is known throughout the Eocene and Paleocene.

The genus *Woodringia* is so far known only from one locality in the uppermost beds of the Paleocene Midway group.

Class CEPHALOPODA

Subclass TETRABRANCHIATA

Order NAUTILOIDEA

Family NAUTILIDAE

Genus EUTREPHOCERAS A. Hyatt, 1894

Phylogeny of an acquired characteristic: Amer. Phil. Soc., Proc., vol. 32, no. 143, p. 555, 1894.

Genotype.—*Eutrephoceras dekayi* (Morton) of Meek from the Upper Cretaceous of the western interior of North America by original designation.

The designation of the genotype is somewhat questionable. It is discussed fully in Reeside, J. B., A new nautiloid cephalopod, *Eutrephoceras sloani*, from the Eocene of South Carolina: Proc., U. S. Nat. Mus., vol. 65, art. 5, p. 2 of separate, 1924; and Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, pp. 300–301, 1933.

EUTREPHOCERAS REESIDEI, n.sp.

Pl. 35, figs. 5–7; text fig. 115 (7)

Eutrephoceras n.sp., Stenzel, H. B., The Geology of Leon County, Texas: Univ. Texas Pub. 3818, pp. 132, 156, 1939.

Description of monotype.—The type specimen is small. It is composed of the interior air chambers of a shell which must have been originally much larger. It is apparent that the outer air chambers and the living chamber have been broken off because a remnant of these missing chambers is preserved in form of a pillar-shaped shell mass. This mass is situated at one of the umbilici (compare left side of fig. 7 on Pl. 35). It is composed of the tightly coiled umbilical parts of the missing whorls. One side of the specimen has the original shell preserved. This side carries the pillar-shaped shell mass at the umbilicus and was embedded in the matrix (compare fig. 6 and left side of fig. 7 on Pl. 35). The other side is somewhat eroded so that the casts of the air chambers stand out like ribs and the eroded septa make grooves in between. This is the side which was exposed.

The largest preserved diameter is 14.6 mm. The cross section of the whorls is depressed and nephritic. The median height is about one-half of the width of the whorl at the last preserved septum. Therein it differs much from *Eutrephoceras sloani* Reeside[5] which has a median height of two-thirds of the width of the whorl. Therefore, *Eutrephoceras reesidei* must have been more globose than *Eut. sloani*, although this is not readily seen in the type of *Eut. reesidei* on account of the erosion of one side. The siphuncle is small and nearly central in the septum. The septa are closely spaced and numerous; 15 are present in the last preserved whorl. The umbilicus is deep and narrow, filled with matrix. The shell surface is devoid of ribbing. Growth lines are not preserved.

The sutures are visible on one side but are much eroded. They are nearly straight. The apparent concave outline of the septa on Plate 35, figure 5, is misleading in this respect. The septa are there so deeply etched out between the casts of the air chambers that they show their concave shape in the interior of the shell.

Dimensions.—Last preserved whorl, median height 5.0 mm.; greatest thickness 9.9 mm.; diameter of entire shell at the last preserved whorl 14.6 mm.

Remarks.—This species can be compared with other species of the genus (compare fig. 115) only with difficulty because the monotype is so small and the other species have been described from larger specimens only. It differs from *Eut. sloani* chiefly by its more globose shell and the proportionately lower median height of the septa. The proportion of median height to width in the east coast Tertiary species of this genus is as follows:

bryani (Gabb)[6]	0.70 to 0.68
cookanum (Whitfield)[7]	0.63 to 0.55
sloani Reeside[8]	0.65 to 0.59

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[5]Reeside, J. B., A new nautiloid cephalopod, *Eutrephoceras sloani*, from the Eocene of South Carolina: Proc., U. S. Nat. Mus., vol 65, art. 5, 1924.

[6]Gabb, W. M., Notes on American Cretaceous fossils with descriptions of some new species: Acad. Nat. Sci. Philadelphia, Proc. 1876, p. 277 [1877].

[7]Whitfield, R. P., Gasteropoda and cephalopoda of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Surv., Mon. 18, pp. 285–286, pl. 48, fig. 1, pl. 49, figs. 4–5, and text fig. 2, 1892.

[8]Reeside, J. B., *op. cit.*

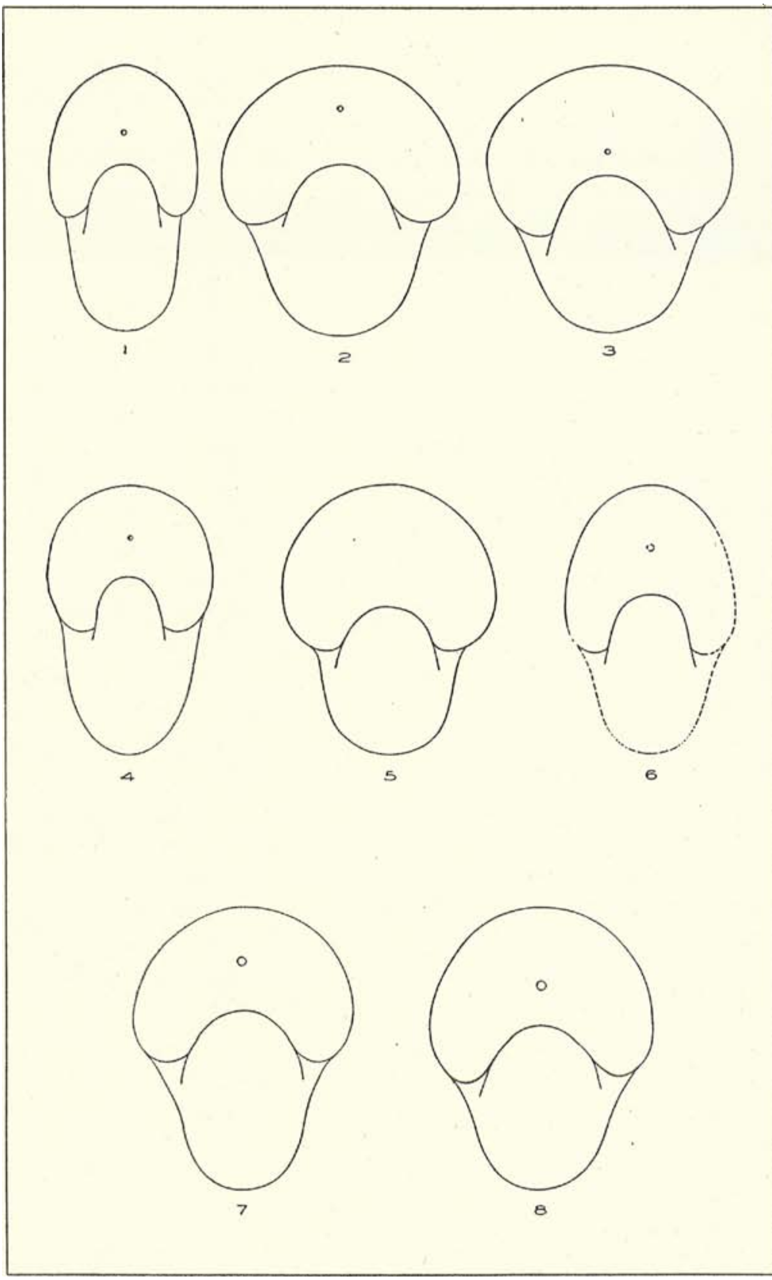

Fig. 115. Diagrammatic cross sections of North American species of *Eutrephoceras*.

carolinense Kellum[9]	0.54 to 0.53
jonesi Miller & Thompson[10]	0.58 to 0.53
reesidei Stenzel	0.50 to 0.47

However, these proportions must be used with caution because some of the species were described from pressure-deformed specimens and the measurements do not refer to the same stage of growth in every species. *Eutrephoceras cookanum* (Whitfield), for instance, seems always pressure-deformed; at least, all specimens figured by Whitfield and the one topotype (specimen No. 9775/2 in the American Museum of Natural History) seen by the writer are badly deformed.

[9]Kellum, L. B., Paleontology and stratigraphy of the Castle Hayne and Trent marls in North Carolina: U. S. Geol. Surv., Prof. Paper 143, pp. 32–33, pl. 7, figs. 5–7, 1926.

[10]Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, p. 303, pl. 34, figs. 1–2, 1933.

Explanation to Figure 115

(1) *Eutrephoceras* (?) *bryani* (Gabb); Gabb's holotype, diameter 89 mm. Based on Weller, S., A report on the Cretaceous paleontology of New Jersey: New Jersey Geol. Surv., Pal. ser., vol. 4, pl. 101, figs. 1–2, 1907.

(2) *Eutrephoceras dekayi* (Morton); Morton's holotype, diameter 85 mm. Based on Whitfield, R. P., Gasteropoda and cephalopoda of the Raritan clays and greensand marls of New Jersey: U. S. Geol. Surv., Mon. 18, pl. 37, figs. 2–3, pl. 38, fig. 1, 1892.

(3) *Eutrephoceras dekayi* (Meek) non (Morton); Meek's figured specimen, diameter 46 mm. Based on Meek, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Surv. Terr., vol. 9, pl. 27, fig. 1a–1b, 1876.

(4) *Eutrephoceras cookanum* (Whitfield); syntype, diameter 220 mm. Based on Whitfield, R. P., *op. cit.*, pl. 48, fig. 1.

(5) *Eutrephoceras jonesi* Miller & Thompson; monotype, diameter 225 mm. Based on Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, pl. 34, figs. 1–2, 1933.

(6) *Eutrephoceras sloani* Reeside; monotype, diameter 120 mm. Based on Reeside, J. B., A new nautiloid cephalopod, *Eutrephoceras sloani*, from the Eocene of South Carolina: U. S. Nat. Mus., Proc., vol. 65, art. 5, pls. 1–3, 1924.

(7) *Eutrephoceras reesidei*, n.sp.; monotype, diameter 14.6 mm.

(8) *Eutrephoceras carolinense* Kellum; syntype, diameter 20.7 mm. Based on Kellum, L. B., Paleontology and stratigraphy of the Castle Hayne and Trent marls in North Carolina: U. S. Geol. Surv., Prof. Paper 143, pl. 7, fig. 7, 1926.

Eutrephoceras (?) bryani (Gabb) is an interesting species. It clearly does not belong to the genus *Eutrephoceras*, notwithstanding Miller and Thompson's statement to that effect.[11] The writer has left it provisionally in *Eutrephoceras (?)* because he has seen illustrations only, but not the type specimen of that species. Exact generic assignment will have to await an examination of the type specimen. *Eutrephoceras (?) bryani* (Gabb) has an unusual whorl cross section (compare fig. 115) entirely different from the whorl cross section of typical *Eutrephoceras*. Furthermore, the species has a wavy suture line with an annular lobe in its dorsal part. This feature is entirely unknown in typical *Eutrephoceras*. Annular lobes are present in the genus *Nautilus* to which this species probably belongs.

Type.—The monotype is in the collection of the Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Small draw tributary to a branch which flows northward along the east line of P. L. Reinhardt 200-acre tract and enters Boggy Creek; the small draw is north of a wagon road of N. 68° E. direction and in the northeast part of the tract, in Nathaniel M. Allen and Fernando del Valle surveys, where these surveys overlap; about 3.5 miles airline distance east of Leona, Leon County, Texas (Bureau of Economic Geology locality No. 145–T–50).

For exact location compare also the map accompanying the report by H. B. Stenzel on The Geology of Leon County, Texas, The University of Texas Publication 3818, 1939.

Geologic horizon.—Basal conglomerate of the Wheelock member of Crockett formation, Claiborne group, middle Eocene.

Preservation.—The fragmentary character of the fossil is in keeping with the conglomeratic nature of the matrix in which it was found. The shell was broken before or during the deposition of the conglomerate. The conglomerate is brown in color and composed of flat pebbles of brown clay-ironstone in a richly fossiliferous and glauconitic marl matrix.

The air chambers are calcite-filled and more resistant to erosion than the shell matter itself.

The specimen was found by H. B. Stenzel. Carl Chelf skillfully removed it from the matrix and prepared it. The species is named in honor of Dr. John B. Reeside, Jr., of Washington, D. C.

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[11]Miller, A. K., and Thompson, M. L., *op. cit.*, p. 302.

Family HERCOGLOSSIDAE

Genus HERCOGLOSSA T. A. Conrad, 1866

Observations on recent and fossil shells, with proposed new genera and species: Amer. Jour. Conchology, vol. 2, pp. 101-102.

Genotype.—*Hercoglossa orbiculata* (Tuomey) from the Clayton formation of the Midway group (Paleocene) of Alabama, by subsequent designation in Hyatt, Alpheus, Genera of fossil cephalopods: Proc., Boston Soc. Nat. Hist., vol. 22, p. 270, 1883.

The genotype species of *Hercoglossa* has recently been discussed by A. K. Miller and M. L. Thompson.[12] These authors have investigated in a thorough manner the question of the geologic age of Tuomey's species. Tuomey[13] had stated that this nautiloid came from the Cretaceous of Alabama, but Miller and Thompson have shown convincingly that it probably came from the lower Midway. The lower Midway Clayton formation of Alabama contains a layer which is known as the Nautilus rock[14] on account of the abundance of nautiloids in it.

Tuomey's species unfortunately was never figured and his description is too short. The original type specimen is lost. For these reasons Miller and Thompson have described and figured a nautiloid specimen which they obtained from the Clayton formation of Alabama. These authors have designated their specimen as the neotype of *Nautilus orbiculatus* Tuomey. It is most unfortunate that the Clayton formation of that area contains more than one species of nautiloid fitting Tuomey's description. Therefore, Miller and Thompson's selection of one particular species as *Nautilus orbiculatus* is not necessarily correct and by no means convincing. However, this question is at present irrelevant for the understanding of the genus because most of the species from the Clayton formation which fit Tuomey's description are near related.

HERCOGLOSSA GARDNERAE, n.sp.

Pl. 36, figs. 1, 2; text figs. 116 (3) and 117 (1)

Description.—Shell large involute, widest at the umbilical shoulder. Cross section of shell compressed oval. Umbilical

[12] Miller, A. K. and Thompson, M. L., *op. cit.*, pp. 313-315.

[13] Tuomey, Michael, Description of some new fossils from the Cretaceous rocks of the Southern States: Proc., Acad. Nat. Sci. Philadelphia, vol. 7 pp. 167-168, 1851.

[14] Compare Smith, E. A., and others, Report on the Geology of the Coastal Plain of Alabama, pp. 192-193, 1894.

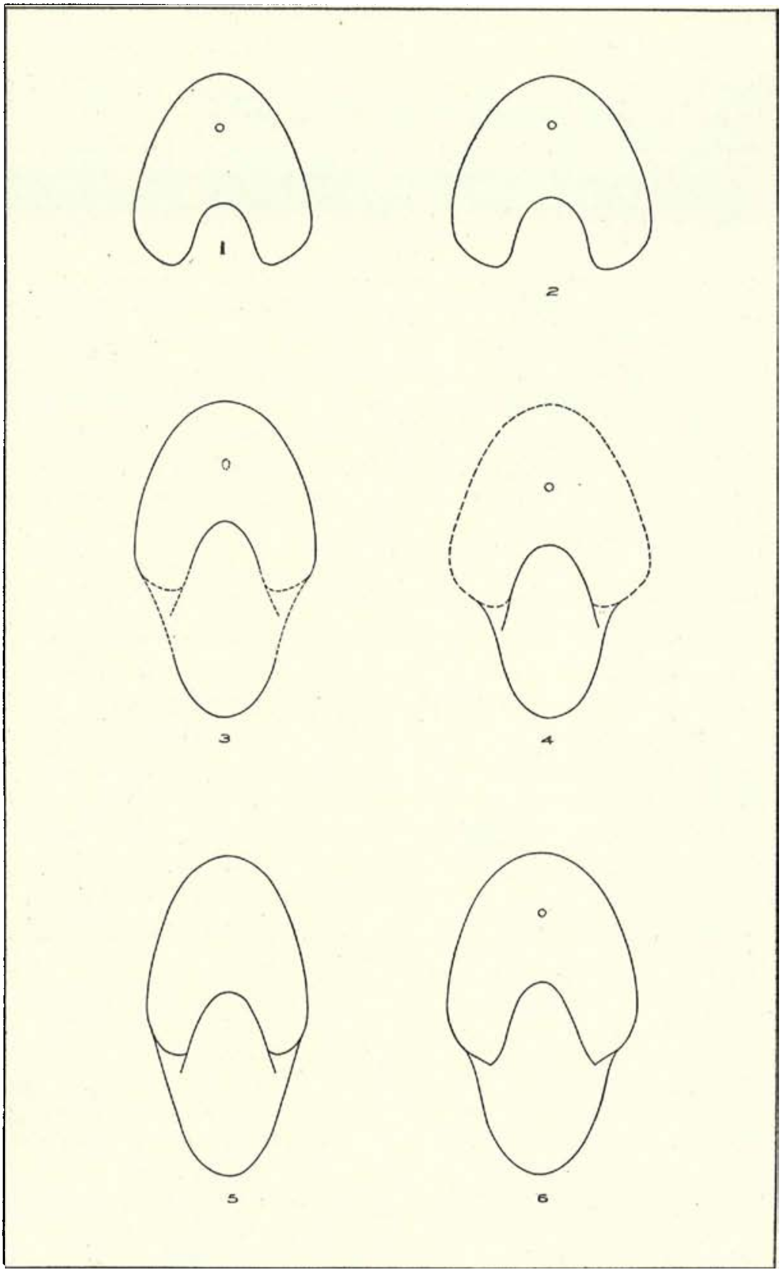

Fig. 116. Diagrammatic cross sections of some species of *Hercoglossa.*

shoulder fairly well defined; umbilical zone narrow, descending at an angle of 40 degrees into the umbilicus and occupying about one-fourth of the total height of the whorl. Umbilicus narrow and perforate. Lateral zones converge toward the venter at an angle of 40 degrees and are only very gently curved. Venter evenly rounded and comparatively narrow.

Septa convex apicad, widely spaced, 12 in the last preserved whorl. Siphuncle small and subventral in position. It is about three-eighths of the median height of the whorl removed from the venter. The siphuncular collar is short and oval in outline.

Sutures have a high, broad ventral saddle which is gently arched on top. The lateral lobe is deep and narrow at first but is deep and broad in the last few sutures. It is placed far over toward the venter. The lateral saddle is symmetrical, high, wide, and prominent. It is placed with its apex ventrad of the umbilical shoulder. There is a lobe at the umbilicus. The dorsal portion of the suture contains a broad lateral saddle and a deep, narrow lobe in the middle of the dorsum.

Dimensions.—Diameter of holotype 14.5 cm.

Remarks.—This species of *Hercoglossa* is obviously related to *H. ulrichi* (White) and *H. orbiculata* (Tuomey) as figured by Miller

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Explanation to Figure 116

(1) *Hercoglossa orbiculata* (Tuomey); neotype, height 176 mm. Based on Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, text fig. 4, 1933.

(2) *Hercoglossa clarki* Miller; monotype, height 156 mm. Based on Miller, A. K., The "Paleocene" nautiloid cephalopods of Landana, Portuguese West Africa: Jour. Pal., vol. 9, p. 173, text fig. 2, 1935.

(3) *Hercoglossa gardnerae*, n.sp.; holotype, diameter 145 mm.

(4) *Hercoglossa ulrichi* (White); holotype, diameter 170 mm. Based on White, C. A., On Mesozoic fossils: U. S. Geol. Surv., Bull. 4, pls. 8, 9. 1884.

(5) *Hercoglossa mcglameryae* Miller & Thompson; monotype, diameter 175 mm. Based on Miller, A. K., and Thompson, M. L., *op. cit.*, pl. 38, fig. 1.

(6) *Hercoglossa harrisi* Miller & Thompson; holotype, diameter approximately 100 mm. Based on Miller, A. K., and Thompson, M. L., Some Tertiary nautiloids from Venezuela and Trinidad: Eclogae Geol. Helvetiae, vol. 30, pl. 7, fig. 2, 1937.

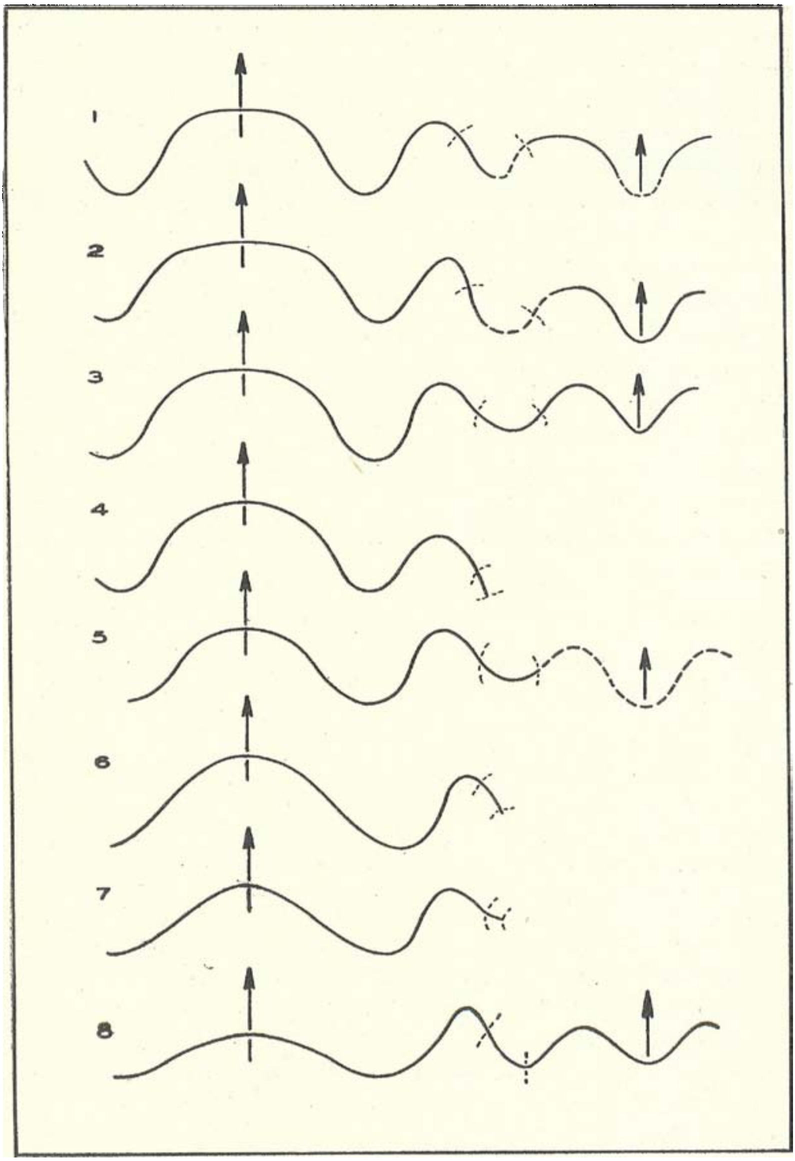

Fig. 117. Sutures of some species of *Hercoglossa*.

and Thompson.[15] In these two species the umbilical shoulder is better defined; therefore, the cross section of the whorl is more clearly triangular and less oval than in *H. gardnerae.*

The suture of *H. gardnerae* is characterized by a high, somewhat rectangular-appearing ventral saddle. In *H. orbiculata* (Tuomey) this saddle is much less rectangular in shape and broader. In other North American species of this genus the ventral saddle is not so conspicuous and not so clearly rectangular in shape but tends more to a semicircular or triangular shape. The lateral lobe of *H. gardnerae* is deeper and narrower than in *H. ulrichi* (White) and of about the same shape as in *H. orbiculata* (Tuomey). The lateral saddle of *H. gardnerae* does not differ greatly from those of *H. ulrichi* (White) and *H. orbiculata* (Toumey).

Types.—The holotype and 8 paratypes are in the collection of the Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—South side of Cuero Creek about 4½ miles up from San Antonio outpost, southern Maverick County, Texas. San

[15]Miller, A. K., and Thompson, M. L., *op. cit.*, pp. 315–319, pl. 37, figs. 1–2.

Explanation to Figure 117

(1) *Hercoglossa gardnerae*, n.sp.; holotype, x0.42.
(2) *Hercoglossa clarki* Miller; monotype, x0.2. Based on Miller, A. K., The "Paleocene" nautiloid cephalopods of Landana, Portuguese West Africa: Jour. Pal., vol. 9, p. 170, text fig. 1-C, 1935.
(3) *Hercoglossa orbiculata* (Tuomey); neotype, x0.19. Based on Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, text fig. 2-F, 1933.
(4) *Hercoglossa ulrichi* (White); figured specimen, x0.55. Based on Miller, A. K., and Thompson, M. L., *op. cit.*, text fig. 2-E.
(5) *Hercoglossa ulrichi* (White); holotype, x0.35. Based on White, C. A., On Mesozoic fossils: U. S. Geol. Surv., Bull. 4, pl. 7, fig. 1, 1884.
(6) *Hercoglossa mcglameryae* Miller & Thompson; monotype, x0.42. Based on Miller, A. K., and Thompson, M. L., *op. cit.*, text fig. 2-D.
(7) *Hercoglossa tuomeyi* Clark & Martin; syntype, x0.24. Based on Clark, W. B., and Martin, G. C., The Eocene deposits of Maryland, Maryland Geol. Surv., pl. 18, pl. 19, fig. 1, 1901.
(8) *Hercoglossa harrisi* Miller & Thompson; holotype, x0.52. Based on Miller, A. K., and Thompson, M. L., Some Tertiary nautiloids from Venezuela and Trinidad: Eclogae Geol. Helvetiae, vol. 30, text fig. 1, 1937.

Antonio outpost is about 0.4 mile from the Rio Grande and northeast of San Antonio crossing opposite the town of Guerrero in Mexico. (Holotype and 7 paratypes, No. 30443.)

About 1 mile north of Lopez tank on McFarland windmill road, southern Maverick County, Texas. (One paratype, No. 30448.)

Best map of this region is War Department, Corps of Engineers, U. S. Army, tactical map, Blocker's Ranch quadrangle, 1/125000, 1922.

Geologic horizon.—Upper part of Kincaid formation, Midway group, Paleocene. The fossils are found in a series of red-weathering beds of glauconitic marl which occur about 30 to 55 feet below the top of the Midway group[16] in that region. Here, the entire group is about 200 feet thick and consists of the Kincaid formation.

Preservation.—The specimens are not deformed. The shell is preserved in some cases but usually overgrown with worm tubes. Most of the specimens are interior molds, the air chambers being filled with fibrous calcite or glauconitic marl.

HERCOGLOSSA ULRICHI (White)

Text figs. 116 (4) and 117 (4, 5)

Nautilus texanus White non Shumard, U. S. Nat. Mus., Proc., vol. 4, p. 137, 1882.

Enclimatoceras ulrichi (White) in Hyatt, Boston Soc. Nat. Hist., Proc., vol. 22, p. 270, 1883.

Enclimatoceras (Nautilus) ulrichi (White), U. S. Geol. Surv., Bull. 4, pp. 16–17, pl. 7, figs. 1–3; pl. 8, fig. 1; pl. 9, fig. 1, 1884.

(?) Enclimatoceras hyatti? (White) in Aldrich, Alabama Geol. Surv., Bull. 1, p. 60, 1886.

Hercoglossa ulrichi Foord and Crick, Annals and Mag. Nat. Hist., ser. 6, vol. 5, p. 392, 1890.

Enclimatoceras (Nautilus) ulrichi Harris, Arkansas Geol. Surv., Ann. Rept. 1892, pp. 36–39, pl. 2, figs. 1–3, [1894].

Enclimatoceras ulrichi Harris, Bull. Am. Pal., vol. 1, no. 4, pp. 122–125, pl. 13, figs. 1–3; pl. 14, fig. 1; pl. 15, fig. 1, 1896.

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[16]Information obtained from a detailed structure map of Indio ranch, Maverick County, Texas, kindly supplied by W. A. Reiter.

Mesalia mavericki Gardner was described from the same "red beds" of southern Maverick County. Compare Gardner, Julia, The Midway group of Texas. Univ. Texas Bull. 3301, pp. 295–296, 1933 [1935]. The geologic horizon of this species was given by Gardner as Wills Point formation, but Bowles gave Kincaid formation for it. Compare Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, p. 325, 1939. The Geologic Map of Texas, 1937, shows in southern Maverick County, Kincaid formation only.

Hercoglossa (Enclimatoceras) ulrichi Grabau and Shimer, North American Index Fossils, vol. 2, pp. 111–112, text fig. 1343, 1910.

Enclimatoceras ulrichi Deussen, U. S. Geol. Surv., Water-Supply Paper 335, pl. 3, figs. 1-1b, 1914: Idem, U. S. Geol. Surv., Prof. Paper 126, p. 41, pl. 14, figs. 1a, 1b, 1924.

Hercoglossa ulrichi Miller and Thompson, Jour. Pal., vol. 7, pp. 319–322, text fig. 2–E, 1933.

Hercoglossa ulrichi Gardner, Univ. Texas Bull. 3301, pp. 320–322, 1933.

Specimens referable to this species are in the collection of the Bureau of Economic Geology. Their localities are as follows:

Specimen no. 3615; Seco Creek in Wenselado Pacheco survey, 10 miles south of D'Hanis, Medina County, Texas, Bureau of Economic Geology locality No. 162–T–7; W. F. Bowman coll., Sept. 18, 1923; Rio Bravo Oil Company Collection T 592; Kincaid formation, Midway group.

Specimens no. 11239 (many specimens); in cotton field one-eighth of a mile south of an east-west road, 5.2 miles N. 4½° W. of the Missouri, Kansas and Texas Railroad depot at Lockhart (airline distance) or 2.7 miles southeast of Rogers Ranch School (airline distance; compare, San Marcos Quadrangle of the U. S. Geological Survey), Caldwell County, Texas; Bureau of Economic Geology locality No. 28–T–3; F. B. Plummer coll., glauconite lentil at base of Wills Point formation, Midway group.

Specimens from west fork of Walnut Creek, three-eighths of a mile east of Lockhart–Lytton Springs road, Caldwell County, Texas; glauconite lentil at base of Wills Point formation, Midway group.

Specimens from northwest bank of Cedar Creek a short distance below the influx of Halfway Creek, 3½ miles southeastward and hence 2⅛ miles northeastward (airline distance; compare Austin Quadrangle of the U. S. Geological Survey) from westernmost corner of Bastrop County, in western Bastrop County, Texas; station No. 69 of H. J. Plummer, Foraminifera of the Midway formation in Texas: Univ. Texas Bull. 2644, p. 60, 1926; Hugh Duval coll.; Texas Memorial Museum Collection; glauconite lentil at base of Wills Point formation, Midway group.

Specimens no. R2227 and R2228; Wimpee farm, Jos. Williams survey, near town of Ola, Kaufman County, Texas; Bureau of Economic Geology locality No. 129–T–8; P. L. Applin coll.; Rio Bravo Oil Company Collection T 447; from a black sandy clay between two limestones, upper part of Kincaid formation, Midway group.

Specimen from Lone Oak limestone quarry, west of Lone Oak, Hunt County, Texas; M. N. Broughton coll.; Lone Oak limestone lentil, Kincaid formation, Midway group.

HERCOGLOSSA n.sp.

Remarks.—The monotype of this species was found in October 1939, after the manuscript and plates of this paper had gone to press. Therefore, it was not possible to include illustrations and a

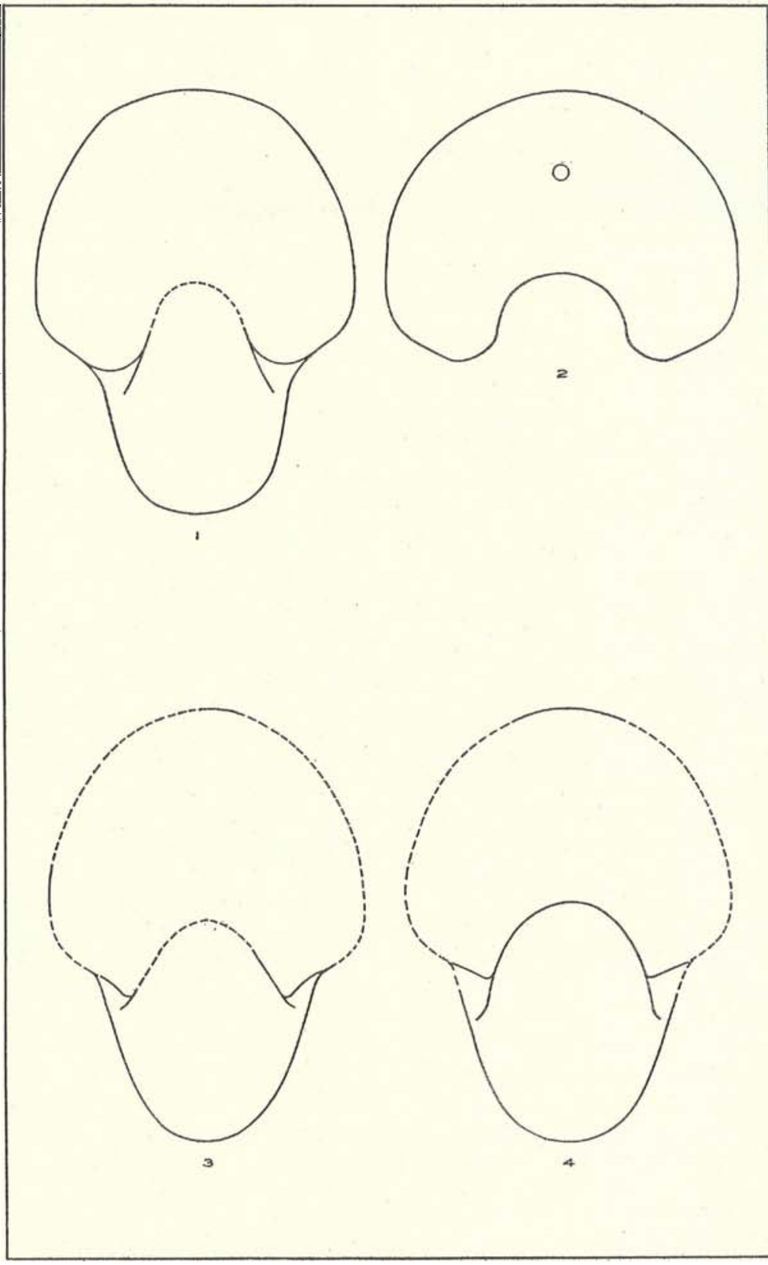

Fig. 118. Diagrammatic cross sections of North American species of *Cimomia*.

description of this species. However, the species is mentioned here for sake of completeness and because it is an important extension of the range of the genus in the Gulf Coastal Plain.

Type.—The monotype is in the collection of the Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Kickapoo Shoals, flat bench in bed of Trinity River at sharp bend 1.72 miles upstream from toll bridge, as measured along the course of the stream, Ramon de la Garza survey, western Houston County, Texas. This is Bureau of Economic Geology locality No. 113–T–16.

Geologic horizon.—Tyus member of Weches formation, Claiborne group, middle Eocene.

Genus CIMOMIA[17] T. A. Conrad, 1866

Observations on recent and fossil shells, with proposed new genera and species: Amer. Jour. Conchology, vol. 2, p. 102.

Genotype.—*Cimomia burtini* (Galeotti) from the Eocene of Brussels, Belgium, by original designation.

CIMOMIA VAUGHANI (Gardner)

Pl. 37, figs. 1, 2; text figs. 118 (1) and 119 (3)

Enclimatoceras vaughani Gardner, U. S. Geol. Surv., Prof. Paper 131–D, p. 115, pl. 33, figs. 1–3, 1923.

Hercoglossa vaughani Berry, Amer. Jour. Sci., ser. 5, vol. 6, p. 429, 1923.

Eutrephoceras? vaughani Olsson, Bull. Am. Pal., vol. 14, no. 52, p. 100, 1928.

Enclimatoceras vaughani Gardner, U. S. Geol. Surv., Bull. 837, pl. 32, fig. 1; pl. 33, figs. 1, 2, 1932.

Cimomia vaughani Miller and Thompson, Jour. Pal., vol. 7, p. 307, 1933.

Hercoglossa vaughani Gardner, Univ. Texas Bull. 3301, pp. 322–323, pl. 27; pl. 28, figs. 1, 2, 1933.

[17] This genus has been discussed recently in Spath, L. F., On the classification of the Tertiary Nautili: Annals and Mag. Nat. Hist., ser. 9, vol. 20, p. 424, 1927; and Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, pp. 305–307, text fig. 1, 1933.

Explanation to Figure 118

(1) *Cimomia vaughani* (Gardner); specimen No. 9516, diameter 59 mm.

(2) *Cimomia haltomi* Aldrich; topotype, height 53 mm.
Based on Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, p. 310, text fig. 3, 1933.

(3) *Cimomia vestali* Miller & Thompson; holotype, diameter 126 mm.
Based on Miller, A. K., and Thompson, M. L., *op. cit.*, pl. 36, fig. 2.

(4) *Cimomia subrecta* Miller & Thompson; holotype, diameter 120 mm.
Based on Miller, A. K., and Thompson, M. L., *op. cit.*, pl. 35, fig. 2.

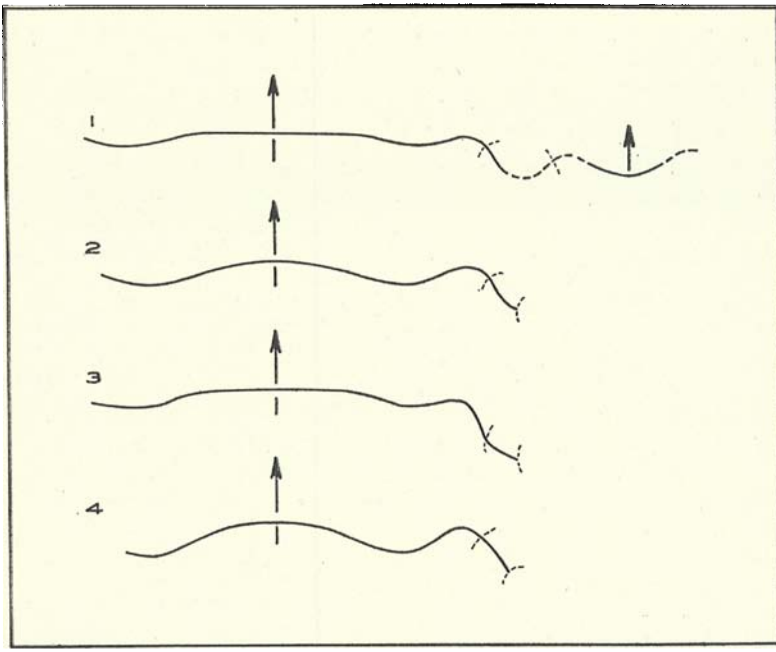

Fig. 119. Sutures of North American species of *Cimomia.*

(1) *Cimomia haltomi* (Aldrich); topotype, x0.5. Based on Miller, A. K., and Thompson, M. L., The nautiloid cephalopods of the Midway group: Jour. Pal., vol. 7, text fig. 2–A, 1933.

(2) *Cimomia subrecta* Miller & Thompson; holotype, x0.53. Based on Miller, A. K., and Thompson, M. L., *op. cit.*, text fig 2–B.

(3) *Cimomia vaughani* (Gardner); specimen No. 9516, x0.61.

(4) *Cimomia vestali* Miller & Thompson; holotype x0.44. Based on Miller, A. K., and Thompson, M. L., *op. cit.*, text fig. 2–C.

Specimens referable to this species are in the collection of the Bureau of Economic Geology. Their localities are as follows:

Specimen no. 17; M. L. River's farm near fence separating it from Solomon farm, on Solomon Branch,[18] about 6 miles S. 25° W. of

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[18]For description of outcrops in this vicinity, see Plummer, H. J., Foraminiferal evidence of the Midway-Wilcox contact in Texas: Univ. Texas Bull. 3201, pp. 60–61, Sta. 11-T 3, 1932.

Elgin, Bastrop County, Texas; Bureau of Economic Geology locality No. 11-T-3; E. H. Sellards and Julia Gardner coll., July 7, 1922; uppermost part of Wills Point formation, Midway group.

Specimen no. 34038; Tehuacana Creek, 4 miles north of Mexia or 3 miles south of Wortham and 2000 feet west of Mexia-Wortham road, Limestone County, Texas; Sta. 41 of H. J. Plummer, Foraminifera of the Midway formation in Texas: Univ. Texas Bull. 2644, p. 41, 1926; Wender coll.; at boundary between Kincaid and Wills Point formations, Midway group.

Specimens no. 9513, 9514, and 9516; exposure on west side of Lacy Creek, 10 miles northwest of Maybank and 2 miles southeast of Kemp on Maybank-Kaufman road, Kaufman County, Texas; H. J. Plummer Sta. 123, Bureau of Economic Geology locality No. 129-T-1; Plummer Collection; in top of Kincaid formation; below the base of Tehuacana limestone shell bed, Midway group.

Specimen from Lone Oak limestone quarry, west of Lone Oak, Hunt County, Texas; M. N. Broughton coll.; Lone Oak limestone lentil, Kincaid formation, Midway group.

Genus WOODRINGIA, n.gen.

Genotype.—*Woodringia splendens* Stenzel, n.sp., from the uppermost beds of the Wills Point formation, Midway group (Paleocene), of Navarro County, Texas.

Generic definition.—Shell nautiloid, completely involute, nonumbilicate, and subglobular. The cross section of the whorls becoming relatively wider and lower in the later stages of growth. Sutures with a broad and shallow ventral lobe lying between two small ventral saddles; medium deep lateral lobe succeeded by a medium high lateral saddle which lies ventrad of the umbilical shoulder; a lobe on the umbilicus; a saddle on the impressed lateral face; a deep dorsal lobe in the middle of the dorsum. Siphuncle subventral in position.

Remarks.—The family *Hercoglossidae* includes some Mesozoic and the following Cenozoic genera: *Cimomia, Hercoglossa, Woodringia, Deltoidonautilus,* and *Aturoidea. Deltoidonautilus* and *Aturoidea* are only distantly related to the new genus and can not be confounded with it. These two genera need not be discussed here. *Cimomia, Hercoglossa,* and *Woodringia* form a closely related group. *Cimomia* and *Woodringia* have in common the subglobular shape of the shell, whereas *Hercoglossa* is more compressed laterally and has a thick lenticular shell shape. However, even in the shell shape there is a slight difference between *Cimomia* and

Woodringia. The whorl cross section of *Woodringia* grows broader and lower in the later stages of growth. Such change in the shape of the whorl cross section has not been observed in *Cimomia,* and *Hercoglossa* does not become noticeably broader with age.

The sutures of *Woodringia* agree with those of *Hercoglossa* in all points but one. *Hercoglossa* has a high and broad ventral saddle; in *Woodringia* this same saddle is split in two by the appearance of the broad and shallow ventral lobe. Of particular importance is the position of the lateral saddle. This saddle lies ventrad of the umbilical shoulder in *Woodringia* and *Hercoglossa* but lies on or almost on the umbilical shoulder in *Cimomia.* The general similarity in the shape of the suture lines and the position of the lateral saddle indicate clearly the close relationship between *Hercoglossa* and *Woodringia.* Some species of *Cimomia* have a faint ventral lobe similar to the one of *Woodringia,* but their lateral lobes are much shallower than in *Woodringia* or *Hercoglossa.*

Although *Woodringia* has features of both *Hercoglossa* and *Cimomia,* it is not in the line of evolution from *Cimomia* to *Hercoglossa.* Species transitional in evolution between the two latter genera are known. Such species do not have a ventral lobe. On the contrary, the evolution from *Cimomia* to *Hercoglossa* proceeds by a gradual increase in the height of the ventral saddle. This saddle is very low and broad in *Cimomia* and becomes gradually more pronounced, higher, and narrower as evolution proceeds from this genus to *Hercoglossa.* Step in step with this change in the sutures goes the change in the shape of the shell. As evolution proceeds from *Cimomia* to *Hercoglossa* the shell shape becomes more compressed laterally. The shell shape of *Woodringia* does not fit into this evolutionary sequence because it is by far not enough compressed for the evolutionary stage of its suture which is in general agreement with fully developed *Hercoglossa* sutures except for its ventral portion.

Woodringia is presumably an independent offshoot developed from a *Hercoglossa* ancestor. This offshoot gradually acquired a ventral lobe in its suture and at the same time obtained a subglobular shell shape. Were *Woodringia* a link transitional in the evolution from *Cimomia* to *Hercoglossa* a new generic name would be superfluous; but *Woodringia* represents an offshoot easily separated from its parent stock. The genus *Woodringia* is presumably restricted to the Paleocene.

Beside the genotype species there is only one species known in this genus. This species is *W. simiensis* (Vokes)[19] from the Martinez stage (Paleocene) of Simi valley, Ventura County, California. *Woodringia simiensis* (Vokes) is transitional from typical *Woodringia* to *Hercoglossa* because it has a very shallow ventral lobe which barely indents the broad ventral saddle. Vokes has pointed out already that his species is distinguished from typical *Hercoglossa* by the great width of the shell in proportion to its height. Compare Plate 35, figure 4, and text figures 120 (2) and 121 (2).

The genus is named in honor of Dr. W. P. Woodring of Washington, D. C.

WOODRINGIA SPLENDENS, n.sp.

Pl. 35, figs. 1–3; text figs. 120 (1) and 121 (1, 3)

Hercoglossa ulrichi H. J. Plummer non (White), Plummer, H. J., Foraminiferal evidence of the Midway-Wilcox contact in Texas: Univ. Texas Bull. 3201, p. 62, 1932.

Hercoglossa vaughani F. B. Plummer non Gardner, Plummer, F. B., Cenozoic systems in Texas, Univ. Texas Bull. 3232, fig. 53, p. 817, 1932.

Description.—Shell inflated, involute, and medium sized. Cross section of whorls nephritic.

Umbilicus closed. Umbilical zones steep, descending at an angle of about 60 degrees into the umbilicus. Umbilical zones occupy about one-eighth of the total height of the whorl. Umbilical shoulder sharply rounded and well defined. Lateral zones gently curved, converging toward the venter at 52 degrees, and merging imperceptibly into the broadly rounded venter.

Ornamentation consisting of very faint ribs parallel with the growth lines. The growth lines (compare fig. 121 (3)) retreat for a deep, but broad hyponomic sinus and arch forward at the sides. The hyponomic sinus is more sharply curved in the early part of the last preserved whorl and becomes successively broader. The lateral arch of the growth lines is not evenly curved but tends to

[19]Vokes, H. E., Nautiloid cephalopods from the Eocene of California: Jour. Pal., vol. 11, p. 8, pl. 1, figs. 3, 4, and text fig. 1, 1937.

show a higher curvature toward the umbilicus. The growth lines retreat very slightly as they cross the umbilical shoulder so that there is a very slight sinus, which may represent the ocular sinus.

Septa convex apicad, closely spaced. It is estimated that there are about 15 in the last whorl of the specimen. Siphuncle small and subventral in position, continuous from one septum to the

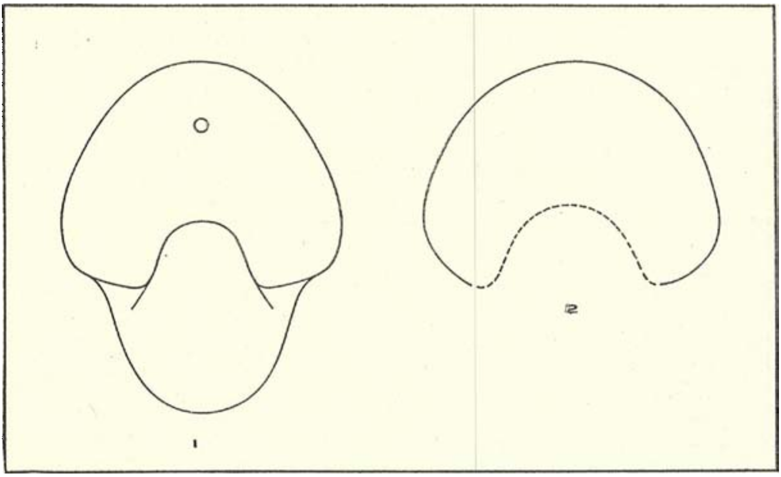

Fig. 120. Diagrammatic cross sections of North American species of *Woodringia*.

(1) *Woodringia splendens*, n.sp.; monotype, diameter 73 mm.
(2) *Woodringia simiensis* (Vokes); monotype, height 37 mm. Based on monotype specimen.

other (compare Pl. 35, fig. 3). The siphuncle curves down and narrows rapidly apicad from the septum at which it originates; then it swells up again to its original size and continues so in a straight line to the preceding septum.

Sutures have a broad shallow ventral lobe flanked by small shallow ventral saddles, which descend steeply into the narrow round lateral lobe; a round saddle follows and terminates against the umbilical shoulder. At the umbilicus there is a broad lobe. The dorsal portion of the suture has a wide broad saddle on the impressed lateral face and a deep dorsal lobe in the center of the dorsum.

Dimensions.—Greatest diameter 7.38 cm., thickness 5.63 cm., larger radius 4.74 cm., smaller radius 2.64 cm.

Remarks.—This species differs from *Woodringia simiensis* (Vokes) of the Paleocene of California by its deeper ventral lobe. It differs from other nautiloids of the Midway group of Texas in several generic characteristics which have already been discussed.

Type.—The monotype is in the collection of the Bureau of Economic Geology, The University of Texas, Austin, Texas.

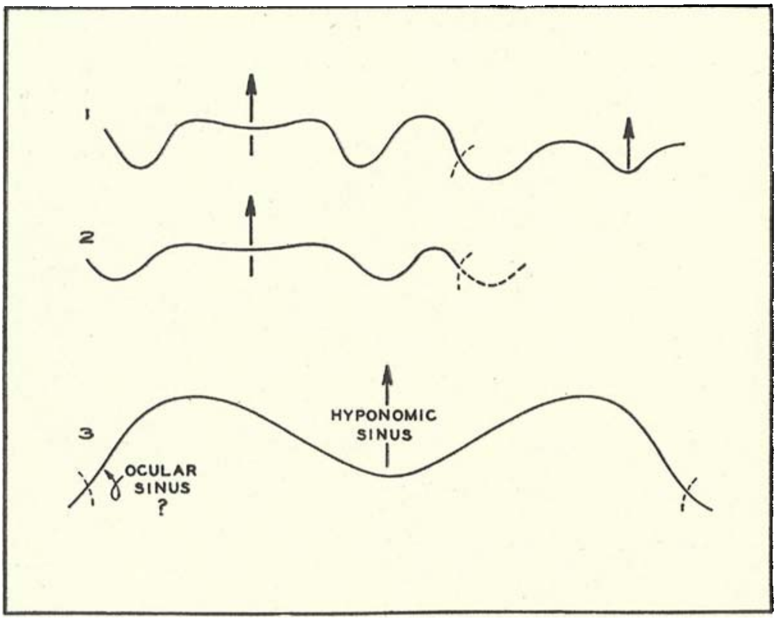

Fig. 121. Sutures and growth lines of North American species of *Woodringia*.

(1) Suture of *Woodringia splendens*, n.sp.; monotype, x1.
(2) Suture of *Woodringia simiensis* (Vokes); monotype, x0.68. Based on monotype specimen.
(3) Growth line of *Woodringia splendens*, n.sp.; monotype, x0.85.

Type locality.—South side of Foggyhead Creek in Smith's pasture and about 0.15 mile west of the bridge on Kerens–Round Prairie road, 3.8 miles by road south-southeast of the depot in Kerens, Navarro County, Texas (Bureau of Economic Geology locality No. 174–T–6).

Geologic horizon.—Uppermost beds of the Wills Point formation, Midway group, Paleocene.

The microfauna accompanying this species and the stratigraphy of the type locality have been presented in a thorough manner by H. J. Plummer.[20]

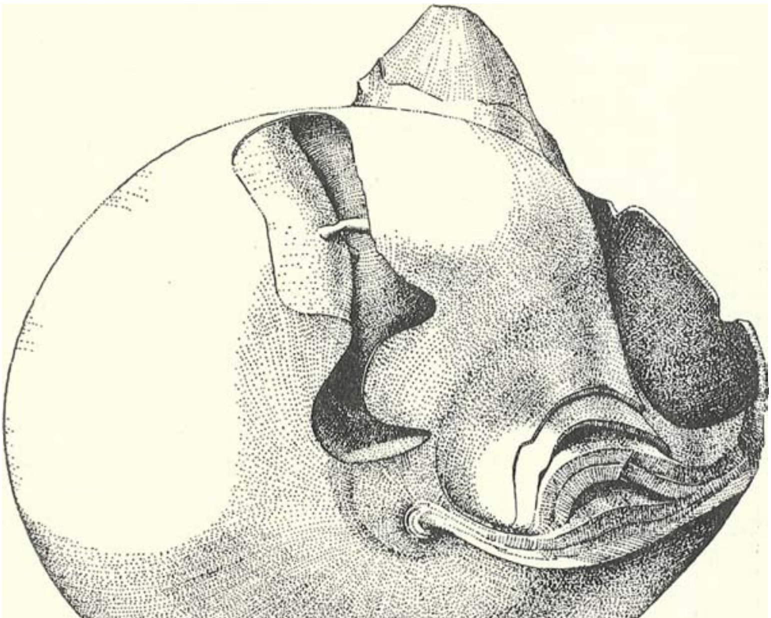

Fig. 122. Oblique view of monotype of *Woodringia splendens*, n.sp., natural size; drawn by J. S. Graves.

Preservation.—The original shell of the specimen is preserved and is free of any deformation by pressure. The last air chambers of the shell are lined with a layer of fibrous calcium carbonate which has enlarged the septa, shell walls, and siphuncle of the specimen. The siphuncle on figure 1, Plate 35, is enlarged by fibrous calcite to twice its original size, but on figure 3 it is only

[20]Plummer, H. J., Foraminiferal evidence of the Midway-Wilcox contact in Texas: Univ. Texas Bull. 3201, pp. 51-68, Pl. V, 1932

slightly enlarged. The air chamber visible at the top of figure 3, Plate 35, and text figure 122 is nearly devoid of secondary mineral deposits.

Credit for finding this interesting specimen belongs to Miss Gene Ross (Mrs. J. S. Kellough), formerly of the Bureau of Economic Geology.

Genus DELTOIDONAUTILUS L. F. Spath, 1927

Revision of the Jurassic cephalopod fauna of Kachh (Cutch): Paleontologia Indica, n.s., vol. 9, memoir no. 2, pt. 1, p. 22.

Genotype.—*Deltoidonautilus sowerbyi* (Wetherell) from the Eocene London clay of England, by original designation.

DELTOIDONAUTILUS ELLIOTTI, n.sp.

Pl. 38, figs. 1-6; Pl. 39, figs. 1, 2; text figs. 123 (2) and 124 (2)

Description.—Shell large, the largest specimen attaining a diameter of about 17 cm. Shell thick lenticular in shape and involute. Cross section of earlier whorls is truncate-triangular with a nearly flat and truncate venter and nearly straight and short lateral zones (compare Pl. 38, fig. 5). The cross section of the later whorls gradually becomes high-triangular in outline with gently curved and converging sides and sharply rounded venter; the whorls are widest at the umbilical shoulder.

Umbilical shoulder well defined; umbilical zone narrow, descending nearly vertically into the umbilicus and occupying only about one-fifteenth of the total height of the later whorls. Umbilicus narrow and perforate, filled with matrix in all figured specimens. Lateral zones converge toward the venter at an angle of 48 degrees and are gently curved to flat and very long, extending from the umbilical shoulder very nearly to the venter. Venter narrowly but evenly rounded.

Ornamentation absent, except for growth lines and very indistinct spiral lines. The growth lines are highly arched forward at the sides and retreat deeply for the sharply curved hyponomic sinus. The spiral lines are present only on paratype 2 and in this specimen only where the original shell surface is preserved. The lines are very fine obsolete wavy raised spirals best developed on the lateral zone near the umbilicus.

Septa convex apicad, closely spaced, presumably about 25 in the last air-chamber whorl of the holotype. Siphuncle extracentrodorsan in position, that is, slightly less than one-quarter of the median height of the whorl removed from the dorsum. The invagination of the septa which forms the siphuncular collar is small in diameter and restricted to the immediate vicinity of the siphuncle. Siphuncular collar tubular and long, extending certainly from one septum to the preceding one, presumably even to the next.

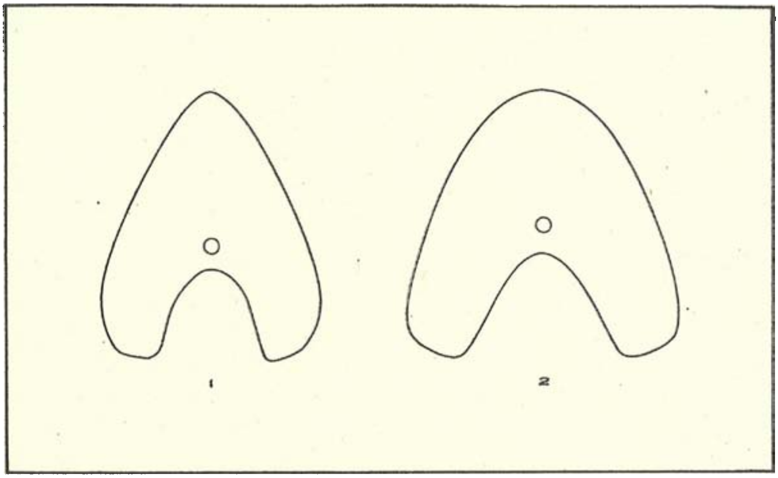

Fig. 123. Diagrammatic cross sections of some species of *Deltoidonautilus.*

(1) *Deltoidonautilus sowerbyi* (Wetherell); figured specimen, height 79 mm. Based on Edwards, F. E., A monograph of the Eocene Mollusca or descriptions of shells from the older Tertiaries of England, Pt. 1, Cephalopoda: Paleont. Soc., pl. 8, fig. 3, 1849.

(2) *Deltoidonautilus elliotti,* n.sp.; paratype 2, height 100 mm.

Sutures have a prominent, rounded-triangular ventral saddle, which is higher than any other saddle or lobe. The lateral lobe is broad and gently curved; the lateral saddle is relatively deep and narrow and lies a short distance ventrad from the umbilical shoulder; a medium-sized lobe lies on the umbilicus; a broad and shallow saddle lies on the lateral side of the impressed region opposite to the lateral saddle of the outside of the shell; at the dorsum there is a broad lobe.

The holotype (Pl. 38, figs. 1–4) is a mature specimen whose living chamber was removed in order to expose the septa. The shell is broken open at one place at the venter. Within there are visible the broken ends of several septa and the siphuncular collars. These are bent to one side and partly covered by shell fragments which are firmly cemented by pyrite (see Pl. 38, fig. 3).

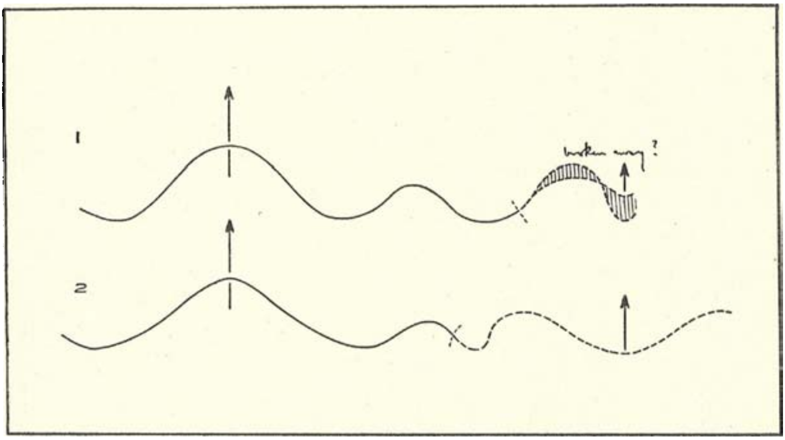

Fig. 124. Sutures of some species of *Deltoidonautilus.*

(1) *Deltoidonautilus sowerbyi* (Wetherell), x0.4. Based on specimen B. M. no. 71001 A in British Museum of Natural History, being the original to Edwards, F. E., A monograph of the Eocene Mollusca or descriptions of shells from the older Tertiaries of England, Pt. 1, Cephalopoda: Paleont. Soc., pl. 8, fig. 3, 1849, drawn by L. F. Spath.

(2) *Deltoidonautilus elliotti,* n.sp.; holotype, x0.63.

Paratype 2 (Pl. 39, figs. 1, 2) is a nearly complete shell which is only slightly crushed. The cross section of the chamber (fig. 123 (2)), is taken from this specimen at a place where it is not crushed.

Paratype 3 is a fragment of a living chamber showing the original aperture.

Paratype 4 was a complete but very badly crushed shell. It has been broken open and perfect molds of several air chambers were removed from its interior. These molds are fillings of air chambers by calcite. These interior air chambers are small. Their cross section is rather broad; the venter is nearly flat and truncate; the sides are almost straight; the siphuncle is subdorsal in position, one-sixth of the median height of the chamber removed from the dorsum. The suture at this early stage is less curved than later; the ventral saddle is broader and flatter on top. See figures 5–6, Plate 38.

Paratype 5 is the adapical part of a living chamber, showing the last septum. The lateral zones of the living chamber are nearly flat and the cross section is pronounced triangular. The specimen is considerably crushed.

Additional paratypes are crushed beyond use for description.

Dimensions.—Holotype, diameter 8.4 cm.; greatest width 4.8 cm.; median height 3.2 cm. and 2.1 cm., taken on opposite sides of the above measured diameter. Paratype 2, height of whorl of living chamber 9.7 cm.; greatest width in same cross section 8.7 cm.; diameter of umbilicus 1.2 cm. Paratype 3, height of whorl of living chamber 9.2 cm.; greatest width at same cross section 7.3 cm. + (measurement slightly too small on account of pressure deformation of specimen). Paratype 4, median height of one of the early air chambers 0.66 cm.; greatest width 1.14 cm.; total height 0.9 cm.

Remarks.—This species is the first of the genus discovered in North America. The genus is apparently rare not only in North America but also throughout the world. L. F. Spath[21] mentions only five species by name. These are *D. sowerbyi* (Wetherell), *D. deluci* (d'Archiac), *D. hazaraensis* (Das-Gupta), *D. somaliensis* (Newton), and *D.* sp. nov. aff. *sowerbyi* (Wetherell) Spath. To these should be added *D. cassinianus* (Foord and Crick) which is a *Deltoidonautilus.* Spath had left this species in the genus *Hercoglossa* and considered it transitional between *Hercoglossa* and *Deltoidonautilus.* Although Spath did not claim to have listed all known species of *Deltoidonautilus,* it is evident that the total number of known species is not very far from that figure.

Deltoidonautilus elliotti differs from the type of the genus, *D. sowerbyi* (Wetherell), by the shorter distance of the lateral saddle from the umbilical shoulder and by the more curved lateral zones in adult *D. elliotti,* which consequently does not appear as clearly triangular in cross section as *D. sowerbyi.*

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[21]Spath, L. F., On the classification of the Tertiary Nautili: Annals and Mag. Nat. Hist., ser. 9, vol. 20, p. 424 etc., 1927.

Deltoidonautilus elliotti falls among the species transitional from *Hercoglossa* to typical triangulate *Deltoidonautilus*, but it nevertheless is a true *Deltoidonautilus* rather than an "advanced" *Hercoglossa*. It differs from *Hercoglossa* by the prominent ventral saddle of its suture, the nearly triangular cross section of its whorls, and the subdorsal position of the siphuncle.

It is interesting to note that *D. sowerbyi* (Wetherell), *D.* sp. nov. aff. *sowerbyi* (Wetherell) Spath, and *D. cassinianus* (Foord and Crick) occur in the London clay which is considered Ypresian[22] in age and that *D. elliotti* occurs in the Reklaw formation, which is the lowest fossiliferous layer of the Claiborne group. However, it is dangerous to base correlations on the occurrence of so sporadic and rare a genus because this one occurrence may not represent its true and full stratigraphic range.

Types.—The types are in the writer's collection at Austin, Texas.

Type locality.—Bluffs along Ridge Creek about 1 mile above the Missouri, Kansas and Texas Railroad trestle and the county road bridge, 6.2 miles west of Smithville or 0.8 mile east of Upton, in east part of R. Andrews survey, Bastrop County, Texas (Bureau of Economic Geology locality No. 11–T–7). This locality is also the type locality of *Aturia turneri* Stenzel.

Geologic horizon.—Marquez shale member, Reklaw formation, Claiborne group, middle Eocene. These nautiloids occur approximately at the level of a concretionary, discontinuous, fossiliferous, lenticular, impure limestone, which is about 44 feet below the top of the Marquez shale.

Preservation.—These fossils are preserved with their original shell. The shell material is highly nacreous and has a color play of red, purple, and bluish green so that even small fragments of the shell can readily be distinguished from fragments of gastropod or pelecypod shells. The living chamber is usually filled with sediment, a gray or brown, argillaceous silt in part richly fossiliferous or brown, earthy clay-ironstone. The air chambers are unfilled or only partly filled; therefore, the specimens are usually crushed or at least cracked by the weight of the overlying sediments. The air

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[22]Wrigley, Arthur, and Davis, A. G., The occurrence of *Nummulites planulatus* in England, with a revised correlation of the strata containing it: Proc. Geol. Assoc., vol. 48, pt. 2, pp. 203–228, 1937.

chambers are lined with pyrite crystals having a golden-brown tarnish.

The first specimen was discovered by Mr. A. C. Elliott, geologist, Shell Petroleum Corporation, in whose honor the species is named. The specimens were kindly donated by Mr. R. E. McAdams and Mr. A. C. Elliott.

Family ATURIIDAE

Genus ATURIA H. G. Bronn, 1838

Lethaea Geognostica, first edition, vol. 2, pp. 1122–1123, pl. 42, figs. 17a–c.

Genotype.—*Aturia aturi* (Basterot) from the Burdigalian of St. Paul de Dax, Department Landes, France; by virtual tautonymy and subsequent designation in A. N. Herrmannsen, Indicis generum Malacozoorum primordia, vol. 1, p. 90, 1847.

ATURIA (ATURIA) BERRYI, n.sp.

Pl. 40, figs. 1–3; text figs. 125 (7) and 126 (2)

Nautilus—sp.? Aldrich, T. H., Notes on the distribution of Tertiary fossils in Alabama and Mississippi: Cincinnati Soc. Nat. Hist., Jour., vol. 8, p. 257, 1886.

Description of monotype.—Shell involute, compressed, discoidal. Cross section of whorl high and narrow, widest near the middle of the lateral zones. Umbilical shoulder very indistinct or absent; umbilical zones merging imperceptibly into the lateral zones and occupying approximately one-fifth or one-sixth of the total height of the whorl. Umbilicus closed, forming merely a shallow dell. Lateral zones gently arched, converging at an angle of 25 degrees; venter narrow and rounded.

Septa convex apicad, broadly invaginated at the lateral lobes and the siphuncle. Septa 12 in the last preserved whorl. Sutures slightly wavy across the venter so that there is a very shallow ventral lobe in the center flanked on either side by a very shallow ventral saddle; a small and narrow, but prominent saddle at the ventral corner of the base of the lateral lobe; lateral lobes slender, tapering abruptly to a pinched-in and only very slightly recurved end; lateral saddle highly arched with the sharpest curvature at the turning point to the lateral lobe. Successive sutures touch with the point of the lateral lobe onto the preceding saddle at the base of the lateral lobe.

Dimensions.—Greatest preserved diameter 2.8 cm.; greatest thickness 1.15 cm.; larger radius 1.74 cm.; smaller radius 1.06 cm.; whorl increase ratio 2.69; ratio thickness over diameter 0.411.

Remarks.—This species is the stratigraphically youngest *Aturia* known from the Gulf and Atlantic Coastal Plain of North America. Its young stratigraphic age is shown by its "advanced" evolution. The features which indicate its "advanced" evolution are the

narrow and high cross section
shallow dell-like umbilici
fairly large siphuncular invaginations
shallow ventral lobe of the suture

The cross sections of the various species of *Aturia* show considerable differences. (Compare fig. 125.) As a rule early Eocene Aturias are broader and have deeper umbilici than late Eocene and Miocene Aturias. *Aturia berryi* is one of the more compressed forms of the genus and has very shallow umbilici; it is in these respects a very advanced form.

Another feature of the evolution of the genus *Aturia* is the progressive increase in size of the siphuncular invaginations. Eocene species, that is, those belonging to the subgenus *Brazaturia,* have only moderately large siphuncular invaginations. Among the Miocene species, that is, those belonging to *Aturia,* s.s., large invaginations of the septa around the siphuncle are the rule. *Aturia berryi* is in that respect advanced but has not reached the extreme stage of Miocene species.

The suture of this species has a very shallow yet distinct lobe at the venter. This lobe occupies the same position as the ventral lobe of *Aturia narica* Cox[20] non Vredenburg. However, in the latter species the ventral lobe is quite large and conspicuous. This type of suture is very unusual for Aturias. It has so far been described only in *Aturia narica* Cox non Vredenburg and *Aturia berryi* Stenzel, n. sp. This difference is in the writer's opinion important enough to segregate *Aturia narica* Cox non Vredenburg from the other Aturias as a separate subgenus. However, pending a direct study of the type material the writer refrains from proposing a formal name for this subgenus.

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[20] Cox, L. R., Neogene and Quaternary mollusca from the Zanzibar Protectorate, *in* Report on the Paleontology of the Zanzibar Protectorate, pp. 19-20, pl. 19, figs 6, 7, 1927.

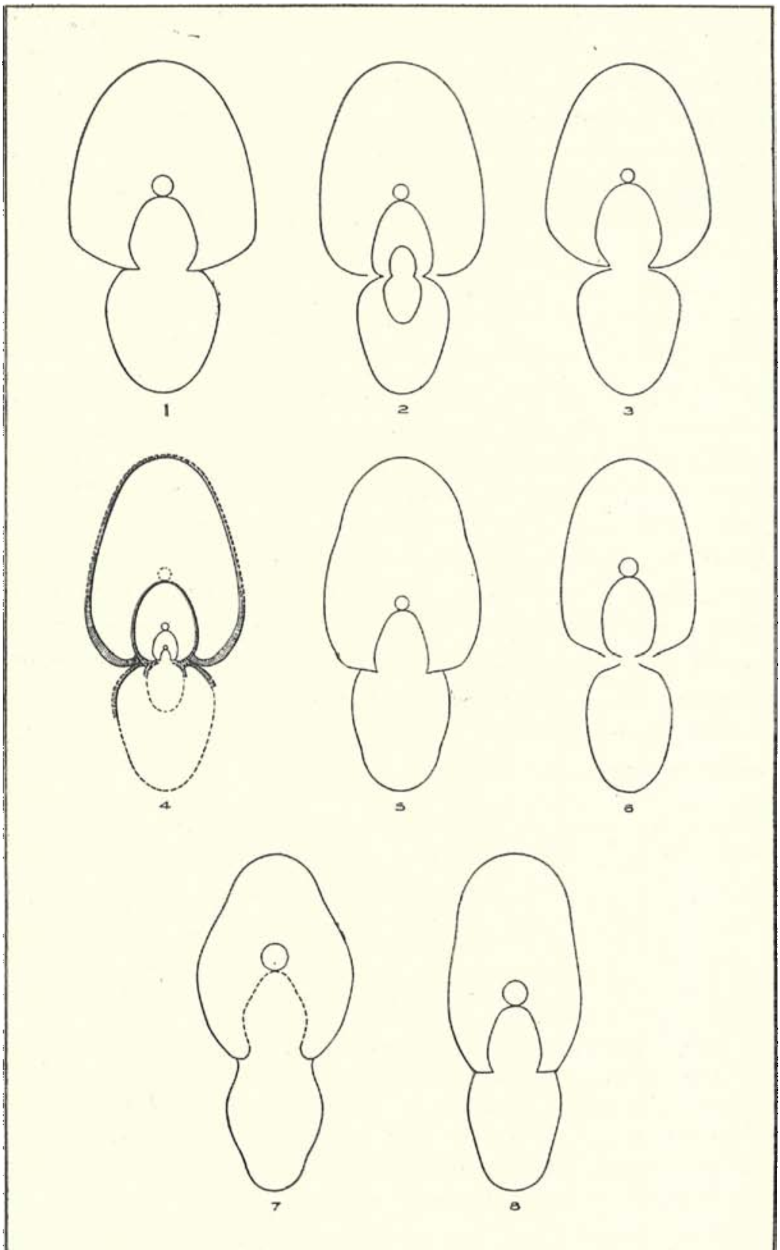

Fig. 125. Diagrammatic cross sections of some species of *Aturia.*

Cox described and figured two specimens of *Aturia* under the name *Aturia narica* Vredenburg. Each of his two specimens came from a different locality in the Zanzibar Protectorate. Only one of these specimens has the deep ventral lobe; it is specimen (C.28500) shown on Plate 19, figure 7, of Cox's publication. This specimen came from locality Loc. P. 75c on the Island of Pemba in the Chake Chake beds of the Pemba series, lower Miocene (upper Aquitanian to Burdigalian). The other specimen described by Cox is (C.28499) and came from locality Loc. P. 92 on Pemba Island and the same beds. According to Cox the suture of this specimen seems to have crossed the venter almost normally, although possibly with a very slight concave curve.

In view of the presence of that deep ventral lobe in specimen (C.28500) it seems that this specimen at least does not belong to *Aturia narica* Vredenburg.[24] The latter species came from near the base of the Nari beds, near Rádak, 7 miles south-southwest of Bhagothoro, and 10 miles south-southeast of Jhángára, close to the western side of the Dharan pass near Lakki, northwestern India. In typical *Aturia narica* Vredenburg the sutures cross the venter almost normally or with a slight orad convexity which is bordered on either side by a slight lobe situated close to the junction with the ventral base of the deep lateral lobe. This is a type of suture which is common among Aturias.

[24]Vredenburg, E., Description of mollusca from the post Eocene Tertiary formation of northwestern India · Memoirs, Geol. Surv. India, Vol. L, pt. 1, pp. 6-10, pl. 8, figs. 1 and 2, 1928.

Explanation to Figure 125

(1) *Aturia (Nilaturia) praeziczac* Oppenheim; metatype, diameter 23 mm.
(2) *Autria (Brazaturia) turneri*, n.sp.; monotype, diameter 67 mm.
(3) *Aturia (Brazaturia) laticlavia* Stenzel; monotype, diameter 93 mm.
(4) *Aturia (Brazaturia) triangula* Stenzel; monotype, diameter 132 mm.
(5) *Aturia (Brazaturia) brazoensis* Stenzel; holotype, diameter 99 mm.
(6) *Aturia (Brazaturia) garretti* Stenzel; monotype, diameter 169 mm.
(7) *Aturia (Aturia) berryi* Stenzel; monotype, diameter 40 mm.
(8) *Aturia (Aturia) aturi* (Basterot); topotype, diameter 30 mm.

The cross section (7) is drawn too broad; it should be corrected with the aid of the ratio of thickness over diameter given in the text.

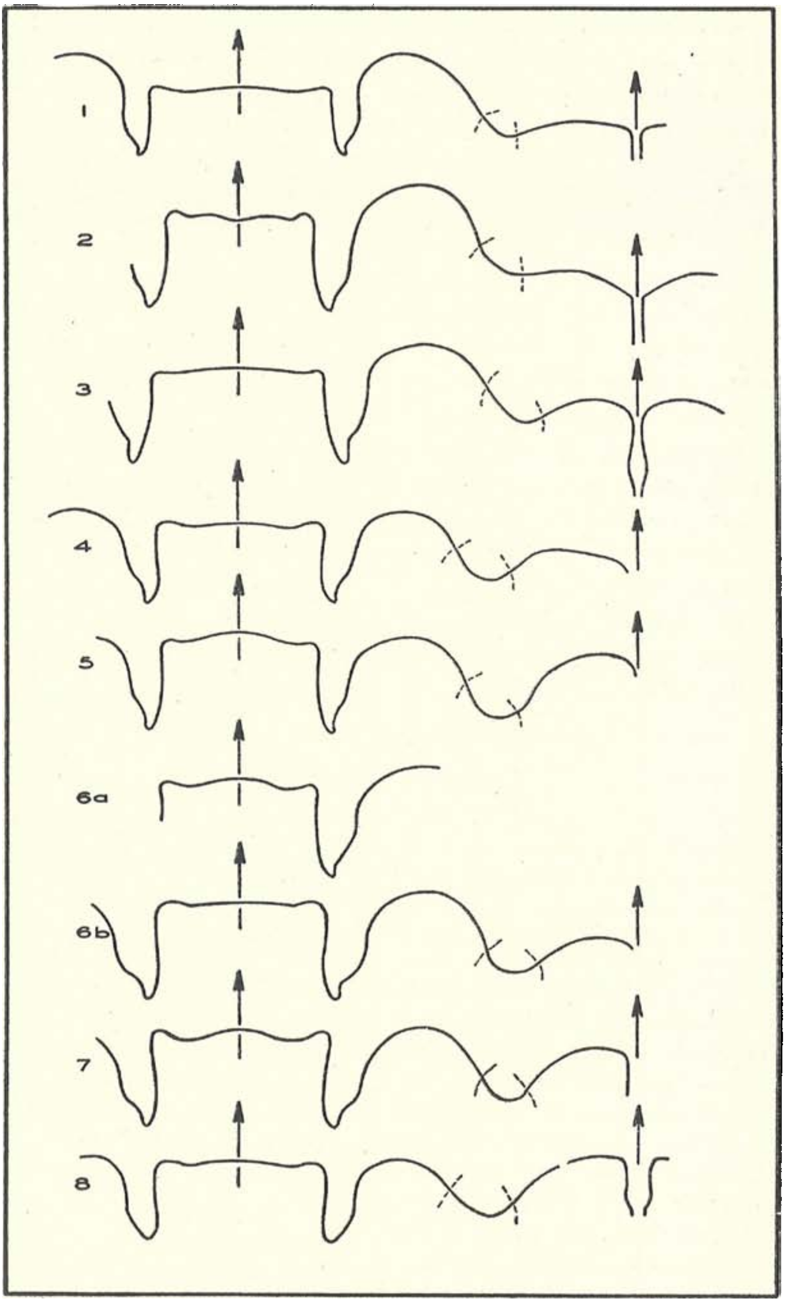

Fig. 126. Sutures of some species of *Aturia*.

A further characteristic of *Aturia berryi* is the position of the thickest place in the shell. Aturias are usually thickest at or near the umbilical shoulder. However, *Aturia berryi* has its greatest thickness about halfway between venter and umbilicus.

Type.—The monotype is in the collection of the Geological Department, The Johns Hopkins University, Baltimore, Maryland.

Type locality.—Vicksburg, Warren County, Mississippi.

Geologic horizon.—Vicksburg group, Oligocene. The particular horizon within the Vicksburg group from which the specimen was collected by T. H. Aldrich is not known. Small pieces of matrix adhering to the shell consist of speckled, yellow-gray, glauconitic limestone or indurated marl.

Preservation.—The specimen is entirely replaced by calcite. All the air chambers except one are filled with translucent, light yellow calcite crystals. The last preserved air chamber is broken open at one side so that one can see the calcite crystals filling it; compare Plate 40, figures 1 and 3.

The shell itself is also replaced by translucent calcite; it is nearly entirely removed except for some very thin slabs and skins adhering to the surface. Matrix fills part of the present aperture orad of the

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Explanation to Figure 126

(1) *Aturia aturi* (Basterot); topotype, x0.95. Based on topotype specimen from the Burdigalian of St. Paul de Dax, Department of Landes, France.

(2) *Aturia berryi*, n.sp.; monotype, x2.22.

(3) *Aturia garretti*, n.sp.; monotype, x0.33.

(4) *Aturia brazoensis* Stenzel; metatype, x0.95. Based on topotype specimen from the Stone City beds of Stone City, Burleson County, Texas, now in British Museum of Natural History, London, England.

(5) *Aturia triangula* Stenzel; monotype, x0.37.

(6a) *Aturia laticlavia* Stenzel; metatype, x0.70. Based on a specimen from the Cane River formation of a road cut along State highway No. 12, 1.47 miles south of depot at Chestnut, near center of sec. 7, R. 6 W., T. 12 N., Louisiana Meridian, Natchitoches Parish, Louisiana.

(6b) *Aturia laticlavia* Stenzel; monotype, x0.57.

(7) *Aturia turneri*, n.sp., monotype, x1.43.

(8) *Aturia praeziczac* Oppenheim; metatype, x1.45. Based on one of the topotype specimens collected by Schweinfurth 1902/03 and identified by P. Oppenheim, from Schech-Abd-el Ourun near Thebes, Egypt.

last preserved septum, which seems to indicate that the living chamber had its end there. One of the air chambers is filled with matrix instead of calcite crystals.

The species is named in honor of Dean E. W. Berry of The Johns Hopkins University whose numerous paleobotanical papers have contributed much to the knowledge of the Gulf Coast Tertiary.

Subgenus BRAZATURIA H. B. Stenzel, 1935

Nautiloids of the genus *Aturia* from the Eocene of Texas and Alabama: Jour. Pal., vol. 9, pp. 555–556.

Genotype.—*Aturia (Brazaturia) brazoensis* Stenzel from the Stone City beds (middle Eocene) of Stone City, Burleson County, Texas, by original designation.

ATURIA (BRAZATURIA) TURNERI, n. sp.

Pl. 41, figs. 1–6; text figs. 125 (2) and 126 (7)

Description of monotype.—Part of the type specimen was found enclosed in a limestone layer. The specimen had to be broken out of this hard limestone matrix. This could be done piece by piece only. Thereby the interior whorls of the specimen became available for study.

Shell involute, compressed, and flat lenticular in shape. Cross section of whorls triangulate-oval in the early whorls, becoming gradually broader at the venter and resulting in a subrectangular cross section of the last preserved whorl. Early whorls widest at or near the umbilical shoulder, but last preserved whorl widest in the region from the vicinity of the umbilical shoulder to the middle of the lateral zones. Umbilical shoulder not well defined; umbilical zone occupying about 1/8 of the total height of the earlier whorls, and 1/9 of the total height of the last preserved whorl. Lateral zones are only gently curved in the earlier whorls and converge at an angle of 29 degrees; lateral zones of the last preserved whorl gently curved and nearly parallel from the vicinity of the umbilical shoulder to their middle, but converging at an angle of 32 degrees from their middle on toward the venter. Venter broadly and evenly rounded.

Septa convex apicad, invaginated for the lateral lobes and the comparatively narrow siphuncular funnels. Septa 13 in the last preserved whorl.

Sutures slightly wavy across venter; a small narrow saddle at the ventral corner of the base of the lateral lobe; lateral lobes rapidly tapering and pinched in at the point which is recurved dorsally; lateral saddle evenly arched.

Growth lines with a deep and narrow, but well rounded hyponomic sinus.

Dimensions.—Greatest preserved diameter 8.5 cm. (in part calculated). At a diameter of 6.65 cm. the following measurements were obtained: larger radius 4.3 cm., smaller radius 2.35 cm., inner radius 1.5 cm., greatest thickness 3.3 cm., whorl increase ratio 2.87, ratio thickness over diameter 0.496.

Remarks.—*Aturia turneri* differs from other members of the genus occurring in the Claiborne group of the Gulf Coast region by its unusual cross section. It is rather broad near the venter of the last whorl so that the cross section of that whorl is subrectangular. All other Aturias from the Eocene of the Gulf Coastal Plain have more converging lateral zones, which give the cross section a more triangulate or ovate shape.

Another feature characteristic of *Aturia turneri* is the dorsal lobe of the suture. Plate 41, figure 5, is a photograph of the interior mold of an air chamber and shows the dorsal portion of the suture as it appears in interior molds. The dorsal lobe is comparatively wide and large for a middle Eocene Aturia. This lobe is similar to the dorsal lobe of *Aturia (Nilaturia) praeziczac* Oppenheim. In the latter species the dorsal lobe is even wider. *Aturia (Nilaturia) praeziczac* is a "primitive" species of the genus and *Aturia turneri* is somewhat transitional to *Nilaturia* in that feature. However, *Aturia turneri* differs clearly from *Atuia (Nilaturia) praeziczac* by the lateral, tongue-shaped lobes. In *Aturia praeziczac* the ends of these lobes are rounded; in *At. turneri* they are pointed and hooked toward the dorsum as is the case in typical *Brazaturia* and *Aturia*.

Type.—The monotype is in the writer's collection at Austin, Texas.

Type locality.—Bluffs along Ridge Creek about 1 mile above the Missouri, Kansas and Texas Railroad trestle and the county road bridge, 6.2 miles west of Smithville or 0.8 mile east of Upton, in east part of R. Andrews survey, Bastrop County, Texas (Bureau of Economic Geology locality No. 11–T–7). This locality is also the type locality of *Deltoidonautilus elliotti* Stenzel.

Geologic horizon.—Marquez shale member, Reklaw formation, Claiborne group, middle Eocene. This specimen was found in a concretionary, discontinuous, fossiliferous, lenticular, impure limestone, which is about 44 feet below the top of the Marquez shale.

Preservation.—The specimen was found in a piece of a hard limestone layer. One side of the shell was exposed. This side is considerably eroded. The remainder of the shell was embedded in the limestone and is well preserved. There is no pressure deformation. Some of the last preserved air chambers are filled with rock matrix. Nearly all of the inner air chambers are filled or lined with yellow calcite crystals.

The rock matrix is in the fresh state a dark gray dense limestone containing some glauconite grains and minute fossils in layers. Most of the minute fossils are pteropods of the genus *Limacina.* Other fossils found are *Pinna, Natica, Volutospina.* On weathering the limestone turns into a brown clay-ironstone, because it is very impure.

The specimen was discovered and donated by Dr. F. E. Turner of the Agricultural and Mechanical College of Texas.

ATURIA (BRAZATURIA) GARRETTI, n.sp.

Pl. 42, figs. 1–3; text figs. 125 (6) and 126 (3)

Description of monotype.—The type is a large internal mold composed of brown clay-ironstone. Shell involute, compressed, and flat lenticular in shape. Cross section of whorl high and narrow, widest near the umbilical shoulder. Umbilical shoulder indistinct. Umbilical zone narrow, occupying about one-eighth of the total height of the whorl. Lateral zones almost flat from the umbilical shoulder to the region of the lateral lobes, converging at an angle of 30 degrees; venter regularly rounded. Umbilicus deep and narrow in the mold; whether it was closed in the original shell can not be determined.

Septa convex apicad, broadly invaginated at the lateral lobes, less so at the large siphuncle. Septa 13 in the last preserved whorl. Sutures fairly straight across the venter; a small narrow saddle at the ventral corner of the base of the lateral lobe; lateral lobes stout but tapering to a slender, pinched-in, and recurved end; lateral saddle highly arched with the sharpest curvature at the turning point to the lateral lobe. Successive sutures touch with the point of the lateral lobe onto the preceding saddle at the base of the lateral lobe.

Dimensions.—Greatest preserved diameter approximately 17 cm. At a diameter of 12.4 cm. the following measurements were obtained: larger radius 7.6 cm., smaller radius 4.8 cm., greatest thickness 5.2 cm., whorl increase ratio 2.49, ratio thickness over diameter 0.423.

Remarks.—*Aturia garretti* differs from other members of the genus occurring in the Claiborne group of the Gulf Coast region by its very much more compressed cross section and to a certain extent also by its very low whorl increase ratio. It differs from *Aturia alabamensis* (Morton) from the Jackson group of the Gulf Coast by its much lower whorl increase ratio, 2.49, in comparison with 3.40 to 3.262 for *Aturia alabamensis*, but it is somewhat similar to the latter species through its low ratio of thickness over diameter.

Type.—The monotype, No. 2001, is in the Geology Museum, Louisiana State University, Baton Rouge, Louisiana.

Type locality.—Left bank of Saline Bayou, at railroad trestle of Louisiana Railway & Navigation Company at St. Maurice, southwestern Winn Parish, Louisiana, sec. 15, R. 6 W., T. 9 N., Louisiana Meridian.

Geologic horizon.—Crockett formation, Claiborne group, middle Eocene. Louisiana geologists prefer Cook Mountain over Crockett formation as a name for these beds.

Credit for finding this rare *Aturia* belongs to Mr. J. B. Garrett, Jr., in whose honor the species is named. Although the type locality has been visited by the writer several times, no additional material was found at this well known fossil locality.

ATURIA (BRAZATURIA) LATICLAVIA Stenzel

Aturia (Brazaturia) laticlavia Stenzel, H. B., Nautiloids of the genus *Aturia* from the Eocene of Texas and Alabama: Jour. Pal., vol. 9, pp. 558–559, pl. 63, figs. 4a–b, text fig. 1, 1935.

A second specimen of this species was found by the writer in Louisiana. It consists of a sectoral fragment of two whorls agreeing closely with the type.

Dimensions.—Diameter 6.6 cm. (in part calculated); larger radius 4.1 cm.; smaller radius 2.5 cm. (calculated); inner radius

1.5 cm.; greatest thickness at that diameter 3.1 cm.; whorl increase ratio 2.73; ratio thickness over diameter 0.471.

Remarks.—The specimen is an interior cast composed of impure, gray-green, calcareous, granular phosphorite.

Specimen.—The metatype is in the writer's collection at Austin, Texas.

Locality.—Road cut along State highway No. 12, 1.47 miles south of depot at Chestnut, near center of sec. 7, R. 6 W., T. 12 N., Louisiana Meridian, Natchitoches Parish, Louisiana. This locality is also the type locality of *Terebratulina louisianae* Stenzel and presumably also of *Ostrea lisbonensis* Harris and *Ostrea ludoviciana* Harris.

Geologic horizon.—Oyster bed of *Ostrea lisbonensis* Harris in the lower Cane River glauconitic marl, Claiborne group, middle Eocene. Other fossils found at the same place are as follows:

Ostrea lisbonensis Harris
Ostrea ludoviciana Harris
Ostrea, sp.
Anomia, sp.
Venericardia natchitoches Harris
Corbula smithvillensis Harris?
Terebratulina louisianae Stenzel
Madracis ganei Vaughan

ATURIA (BRAZATURIA) BRAZOENSIS Stenzel

Aturia (Brazaturia) brazoensis Stenzel, H. B., Nautiloids of the genus *Aturia* from the Eocene of Texas and Alabama: Jour. Pal., vol. 9, pp. 559–561, pl. 64, text fig. 1, 1935.

Two specimens referable to this species have recently been collected. Both were found at the well known Weches locality of Smithville, Bastrop County, Texas. The smaller, but more complete, specimen (catalogue no. 17239) came from the upper part of the Tyus member of the Weches. The larger, but fragmentary, specimen (catalogue no. 17240) was found loose on the outcrop. Apparently it is derived from the upper part of the Viesca member of the Weches.

Dimensions.—Specimen no. 17239: diameter 8.3 cm.; larger radius 5.3 cm.; smaller radius 3.0 cm.; inner radius (calculated)

1.7 cm.; thickness 4.5 cm.; whorl increase ratio 3.14; ratio thickness over diameter 0.542. These measurements refer to a cross section which is 27 degrees back of the outermost preserved portion of the shell.

Specimen no. 17240: diameter 21.9 cm.; larger radius 13.9 cm.; smaller radius 8.0 cm. (calculated); inner radius 4.6 cm.; thickness 9.3 cm.?; whorl increase ratio 3.02; ratio thickness over diameter 0.425.

Remarks.—The smaller specimen (no. 17239) is somewhat broadened by pressure deformation near its present aperture. A nearly undeformed cross section is found about 27 degrees apicad of that place. This cross section served for the measurements.

The cross section agrees in shape very closely with the type material of *At. brazoensis.* This species is characterized by a shell rather broad for this genus.

The larger specimen (no. 17240) is filled with a yellow and brown, glauconitic clay-ironstone matrix. This matrix apparently expanded inside the shell because the latter is traversed by a network of gaping cracks. For this reason the measurements given are somewhat uncertain. The measurement of the thickness in particular is uncertain. Therefore, the ratio of thickness over diameter is also uncertain.

Specimens.—The smaller specimen (no. 17239) is in the collection of the Bureau of Economic Geology, The University of Texas; the larger specimen (no. 17240) is in the writer's collection, Austin, Texas.

Locality.—Bluff on right bank of Colorado River upstream from steel bridge at Smithville, Bastrop County, Texas.

Geologic horizon.—Specimen no. 17239: limestone in upper part of Tyus member, Weches formation, Claiborne group, middle Eocene. The specimen was found in bed 2 of C. O. Nickell's section of the bluff. This bed is the lowest of the hard layers of that bluff. Credit for finding this specimen belongs to a Works Progress Administration crew and grant. It was collected under the supervision of Mr. C. O. Nickell.

Specimen no. 17240 was found loose on the upper part of the extensive hard bench at the Smithville bluff. Apparently it came from the upper clay-ironstone ledges in the Viesca glauconite member, Weches formation, Claiborne group, middle Eocene. The specimen was collected by H. B. Stenzel.

ATURIA (BRAZATURIA) cf. AT. BRAZOENSIS Stenzel

The material described under this name presents an interesting question important for the classification of Tertiary nautiloids.

All the specimens were found crowded in a single yellow calcareous septarian concretion of about 2 to 3 feet diameter. Other concretions nearby in the same layer do not contain any nautiloids, although the concretions are otherwise exactly alike. Many of the specimens are unfortunately penetrated by calcite veins which were deposited in the septarian shrinkage cracks and had produced a large amount of distortion in the specimens. Only 7 of the specimens are free of calcite veins and therefore free of deformation. These specimens are perfectly preserved. The original shell is not damaged and is well preserved, showing the growth lines. The air chambers are filled with matrix or white crystalline calcite deposits These 7 specimens are small; their diameters range between 4.5 and 2.8 cm.

One would presume that all the specimens belong to one and the same species because they were found crowded in so small and circumscribed a locality. Nevertheless, the specimens are not alike. On the contrary, they can be sorted easily into two separate groups. The separation can be made on the basis of general shape of the shell, one group having a narrow, the other a wide cross section. The differences are so pronounced that even at so early a stage of shell growth as at a diameter of only 2.55 cm. the separation into the two groups can be made. The separation can even be made by sight without one having to resort to tedious measurements.

Table of measurements (in cm.)

Specimen No.	1	2	3	4	5	6	7
Diameter	3.2	4.45	3.55	2.88	3.82	2.55	2.89
Thickness	1.61	2.52	2.0	1.345	1.78	1.405	1.313
Larger radius	2.0	2.90	2.30	1.67	2.3	1.64	1.75
Smaller radius	1.2	1.55	1.25	1.21	1.52	0.91	1.14
Whorl increase ratio	2.778	3.501	3.386	1.904	2.29	3.25	2.356
Thickness/diameter	0.503	0.5664	0.563	0.467	0.466	0.551	0.4544
Cross section	narrow	broad	broad	narrow	narrow	broad	narrow

The group with a narrow cross section has involute, compressed, and flat lenticular shells. Cross section is high and narrow, widest near the umbilical shoulder. Umbilical shoulder indistinct. Umbilical zone narrow, occupying about one-eighth of the total height of the whorl. Lateral zone almost flat from the umbilical shoulder to the region of the lateral lobes, converging at an angle of about 25 degrees; venter regularly rounded. Umbilicus deep, closed. The ratio of thickness over diameter varies between 0.454 and 0.503; the whorl increase ratio between 1.904 and 2.778.

The group with a wide cross section has involute and thick lenticular shells. Cross section is compressed oval, widest near the umbilical shoulder. Umbilical shoulder indistinct. Umbilical zone narrow, occupying about one-eighth of the total height of the whorl. Lateral zone nearly flat, slightly concave in the region of the lateral lobes, converging at an angle of about 42 degrees; venter comparatively broad, regularly rounded. Umbilicus deep, closed. The ratio of thickness over diameter varies between 0.551 and 0.5664; the whorl increase ratio between 3.25 and 3.501. This group is very similar to typical *Aturia brazoensis* Stenzel from Stone City, Burleson County, Texas.

The chief difference between these two groups lies in the shape of the cross section. This difference is, of course, evident in the ratio of thickness over diameter. Of great help in distinguishing the two groups is also the presence of a spiral depression or concavity in the region of the lateral lobes in the group with the broader cross section.

As stated before, one would presume that all the specimens belong to one and the same species. In that case the two groups might represent the two sexes.

It is a well known fact that the shape of the shell is dependent to a certain degree on the sex of the animal in *Nautilus pompilius* Linné which is one of the few present-day nautiloid species. Concerning the sexual dimorphism of *Nautilus pompilius* Bashford Dean[25] states:

> In examining fresh specimens I noticed that there appeared to be sexual differences in the shells. That of the female was wider at the sides of the oval aperture and here showed a somewhat angular contour. This peculiarity I have expressed in the accompanying Fig. 4, B, and it may be contrasted with the condition of the shell of a male shown in the same figure, A. This difference was clear in the case of the six specimens I examined; but I later found that there must be considerable variation, for in looking over the shells obtained at Maniuyod I was unable to distinguish those of the females from those of the males in as many instances as three out of ten.

[25] Dean, Bashford, Notes on living *Nautilus*: Amer. Naturalist, vol. 35 pp. 824–825 fig. 1, 1901.

This statement clearly indicates the difficulties encountered in separating female from male shells. Some paleontologists seem to overestimate the importance of sexual dimorphism in nautiloids, particularly in the genus *Aturia*. It is claimed often that some of the different species of *Aturia*, which have been described, are possibly nothing else but different sexes. This attitude is in opposition

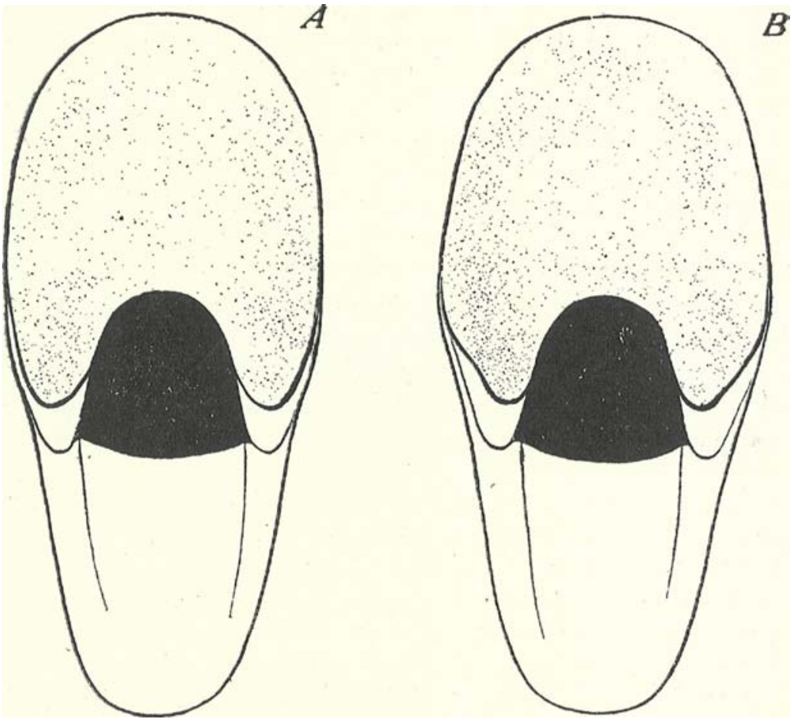

Fig. 127. Male (A) and female (B) shells of *Nautilus pompilius* Linné, extremes of sexual dimorphism of the shell. (From Bashford Dean.)

to the fact that the sexes of *Nautilus pompilius* shells are hard to distinguish and that even today several species of *Nautilus* occur side by side.

The differences observed between the broad and the narrow *Aturia* specimens from the Laredo locality are not of the same kind as the sexual dimorphism noted by Bashford Dean in *Nautilus pompilius*. Also these differences are noticeable at a very early stage of growth in this *Aturia*, whereas it is impossible to detect any differences in the young shells of *Nautilus pompilius*. However, one might argue that *Aturia* need not have had sexual dimorphism of the same kind as *Nautilus*. After all the two are different genera and are even classed in different families. Unfortunately sexual dimorphism has never been reported from a fossil nautiloid species. It would be interesting to study a fossil nautiloid species from this point of view. Such a species should be abundant at one locality and in only one stratum; it should be preserved so that pressure deformation is excluded. The *Aturia* material from Laredo is by far not sufficient to solve this problem.

If the two groups of *Aturia* from Laredo do not represent sexual dimorphism of one species, they would presumably represent two separate species occurring together at one locality. In that case only the broad specimens would belong to *Aturia brazoensis* Stenzel. The narrow specimen would presumably represent a new species.

Dimensions.—For dimensions of these specimens, compare table of measurements on page 776.

Specimens.—All of the material is in the collection of the Bureau of Economic Geology, The University of Texas, Austin, Texas. The material consists of 16 specimens of which only seven are sufficiently well preserved to be useful.

Locality.—Bluff on left bank of Chacon Creek, about one-fourth of a mile upstream from the intersection of Chacon Creek with U. S. highway No. 96 (Laredo–Corpus Christi road), at the eastern city limits of Laredo, Webb County, Texas. Best map of this region is War Department, Corps of Engineers, U. S. Army, Training Map, Fort McIntosh and vicinity, 1/20,000, 1932.

Geologic horizon.—Crockett formation, Claiborne group, middle Eocene. The horizon containing the yellow calcareous septarian concretions of which one carried the Aturias is about 30 feet above the dry bed of Chacon Creek.

Credit for the discovery of these specimens belongs to Mr. L. Willis Clark, of the Amerada Petroleum Corporation.

PLATE 35

PAGE

Woodringia splendens Stenzel, n.sp., x1 755

1–3. Three views of monotype.

From south side of Foggyhead Creek in Smith's pasture and about 0.15 mile west of bridge on Kerens-Round Prairie road, 3.8 miles by road south-southeast of the depot in Kerens, Navarro County, Texas; Bureau of Economic Geology locality No. 174–T–6; uppermost beds of the Wills Point formation, Midway group, Paleocene.

Woodringia simiensis (Vokes), x1 755

4. Ventral view of monotype.

From Simi Valley, Santa Susana quadrangle, Ventura County, California; locality 7016; Univ. California Mus. Paleont. 15985; Martinez stage, Paleocene.

Eutrephoceras reesidei Stenzel, n.sp., x2.5 738

5–7. Three views of monotype.

From tributary of Boggy Creek, 3.5 miles east of Leona, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–50; basal conglomerate of Wheelock member of Crockett formation, Claiborne group, middle Eocene.

Plate 35

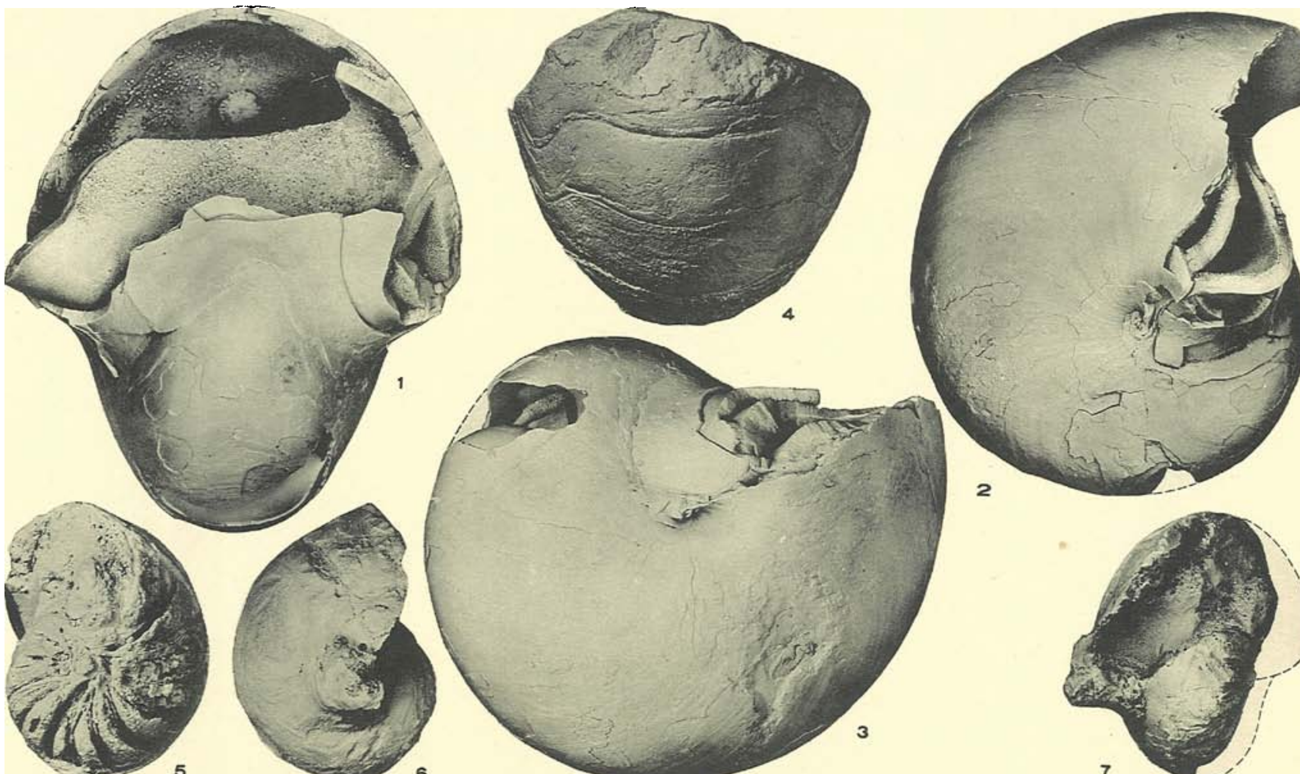

PLATE 36

1, 2. Two views of holotype.

From south side of Cuero Creek about 4½ miles up from San Antonio outpost, southern Maverick County, Texas; upper part of Kincaid formation, Midway group, Paleocene.

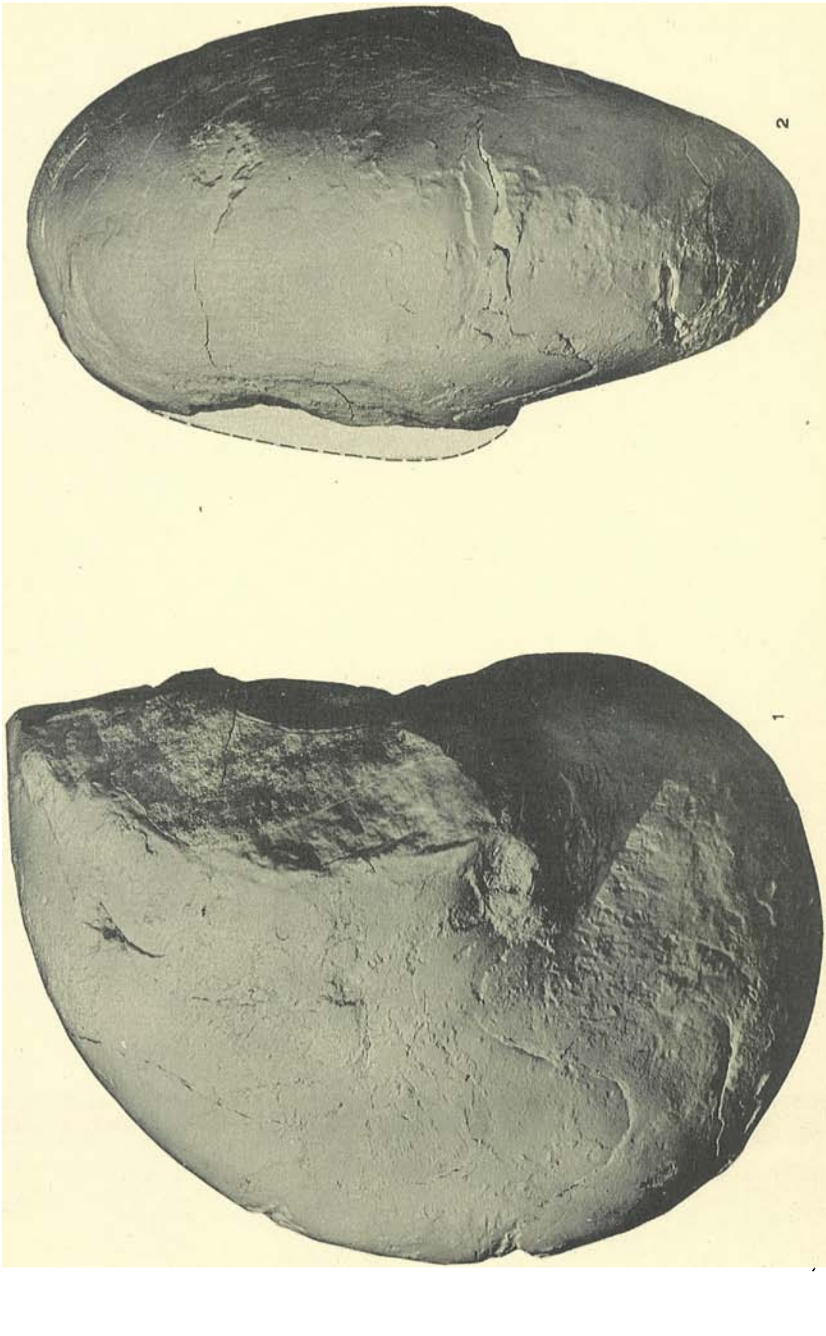
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PLATE 37

1, 2. Two views of specimen No. 9516.

From exposure on west side of Lacy Creek, 10 miles northwest of Maybank and 2 miles southeast of Kemp on Maybank-Kemp road, Kaufman County; top of Kincaid formation, below the base of Tehuacana limestone shell bed, Midway group, Paleocene.

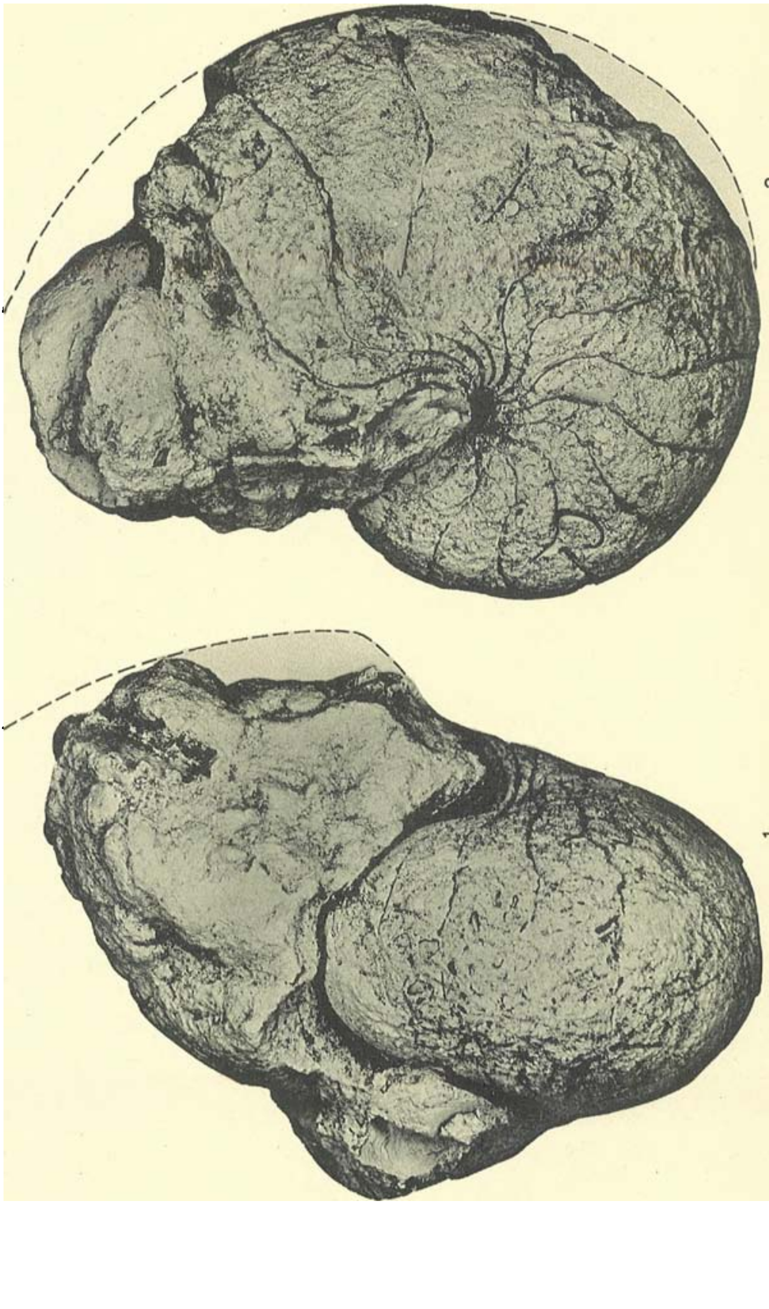

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PLATE 38

PAGE

Deltoidonautilus elliotti Stenzel, n.sp. 759

1–4. Four views of holotype, x1.

5, 6. Two views of a mold of an early air chamber of paratype 4, x2.5.

From bluffs along Ridge Creek about 1 mile above the Missouri, Kansas and Texas Railroad trestle and the county road bridge, 6.2 miles west of Smithville or 0.8 mile east of Upton, in east part of R. Andrews survey, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–7; concretionary limestone 44 feet below top of Marquez shale member, Reklaw formation, Claiborne group, middle Eocene. This locality is also the type locality of *Aturia turneri* Stenzel.

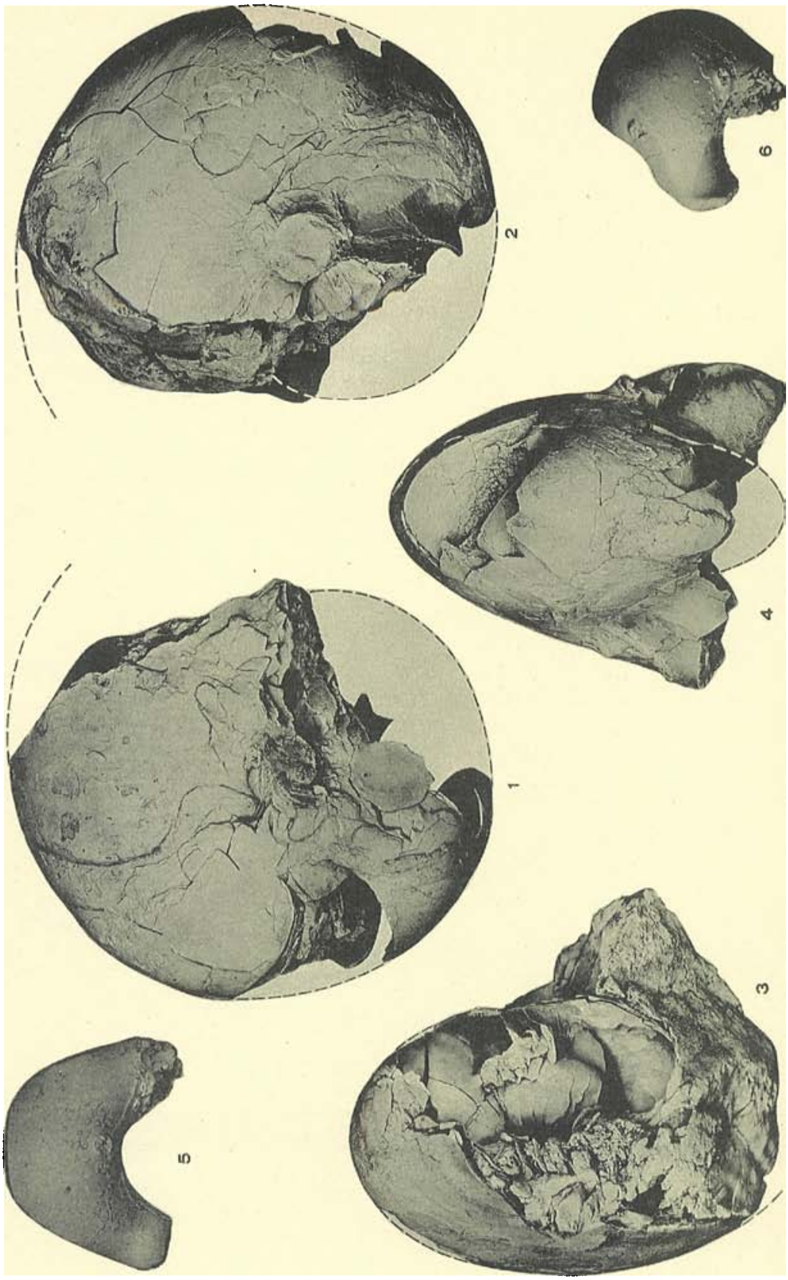


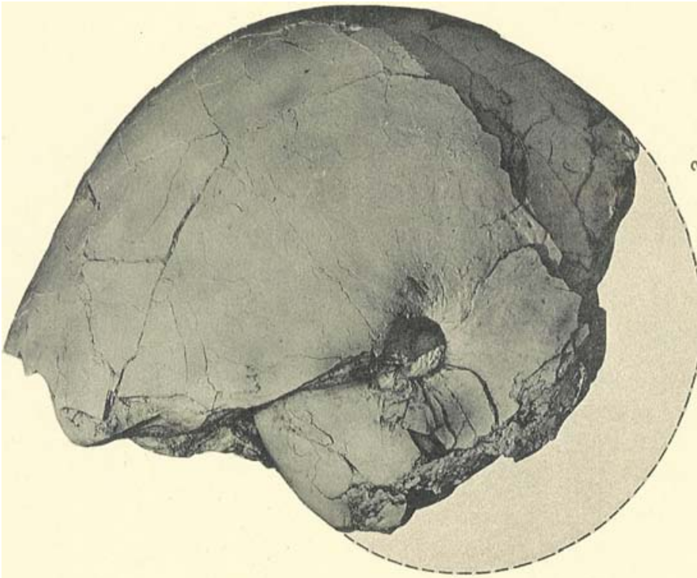
PLATE 39

PAGE

Deltoidonautilus elliotti Stenzel, n.sp., x0.5 759

1, 2. Two views of paratype 2.

From bluffs along Ridge Creek about 1 mile above the Missouri, Kansas and Texas Railroad trestle and the county road bridge, 6.2 miles west of Smithville or 0.8 mile east of Upton in east part of R. Andrews survey, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–7; concretionary limestone 44 feet below top of Marquez shale member, Reklaw formation, Claiborne group, middle Eocene. This locality is also the type locality of *Aturia turneri* Stenzel.



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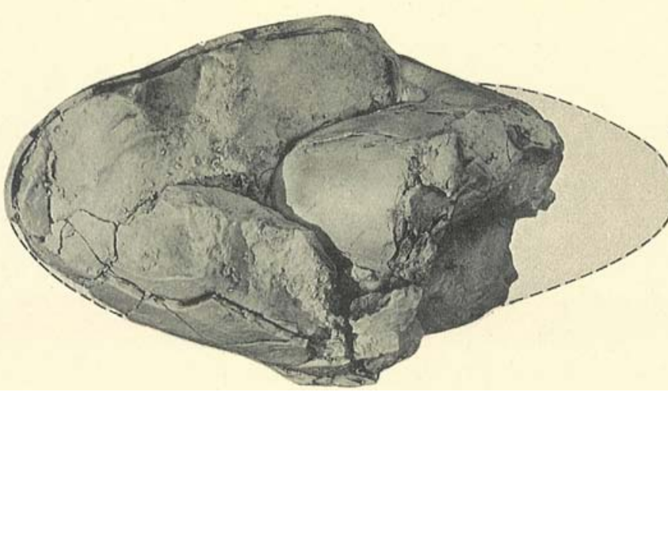

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PLATE 40

	PAGE
Aturia (Aturia) berryi Stenzel, n.sp., x3	764

1–3. Three views of monotype.

From Vicksburg, Warren County, Mississippi; Aldrich Collection, Geological Department, The Johns Hopkins University, Baltimore, Maryland; Vicksburg group, Oligocene. The monotype was coated with ammonium chloride for figures 1 and 3, but figure 2 was photographed immersed in water to bring out the semitransparent sutures.

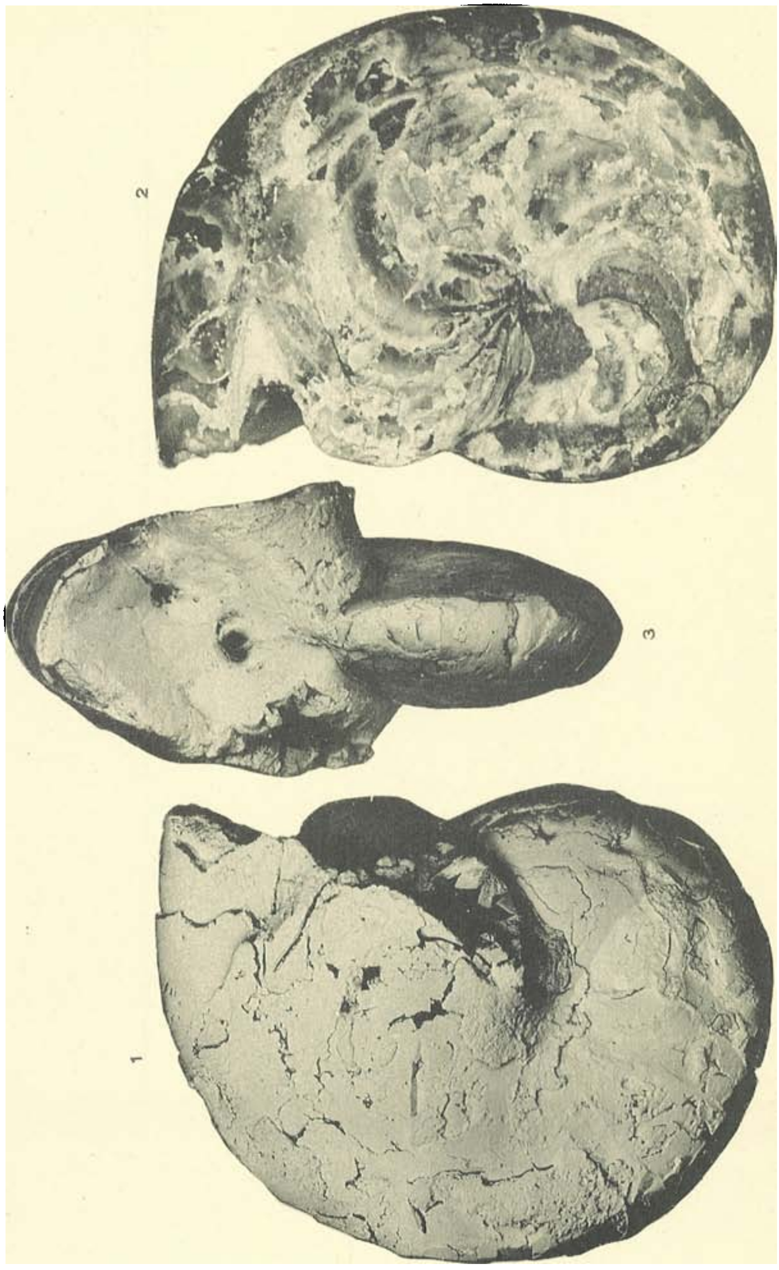

PLATE 41

1, 2. Two views of the entire monotype, x0.9.

3, 4. Two views of the monotype with 5/8 of the last volution removed, x1.2.

5. Cross-sectional view of monotype in same position as figure 3 but with the front half volution removed so that the inner volution is visible, x1.2.

6. Suture of monotype, x1.0.

From bluffs along Ridge Creek about 1 mile above the Missouri, Kansas and Texas Railroad trestle and the county road bridge, 6.2 miles west of Smithville or 0.8 mile east of Upton, in east part of R. Andrews survey, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–7; concretionary limestone 44 feet below top of Marquez shale member, Reklaw formation, Claiborne group, middle Eocene.

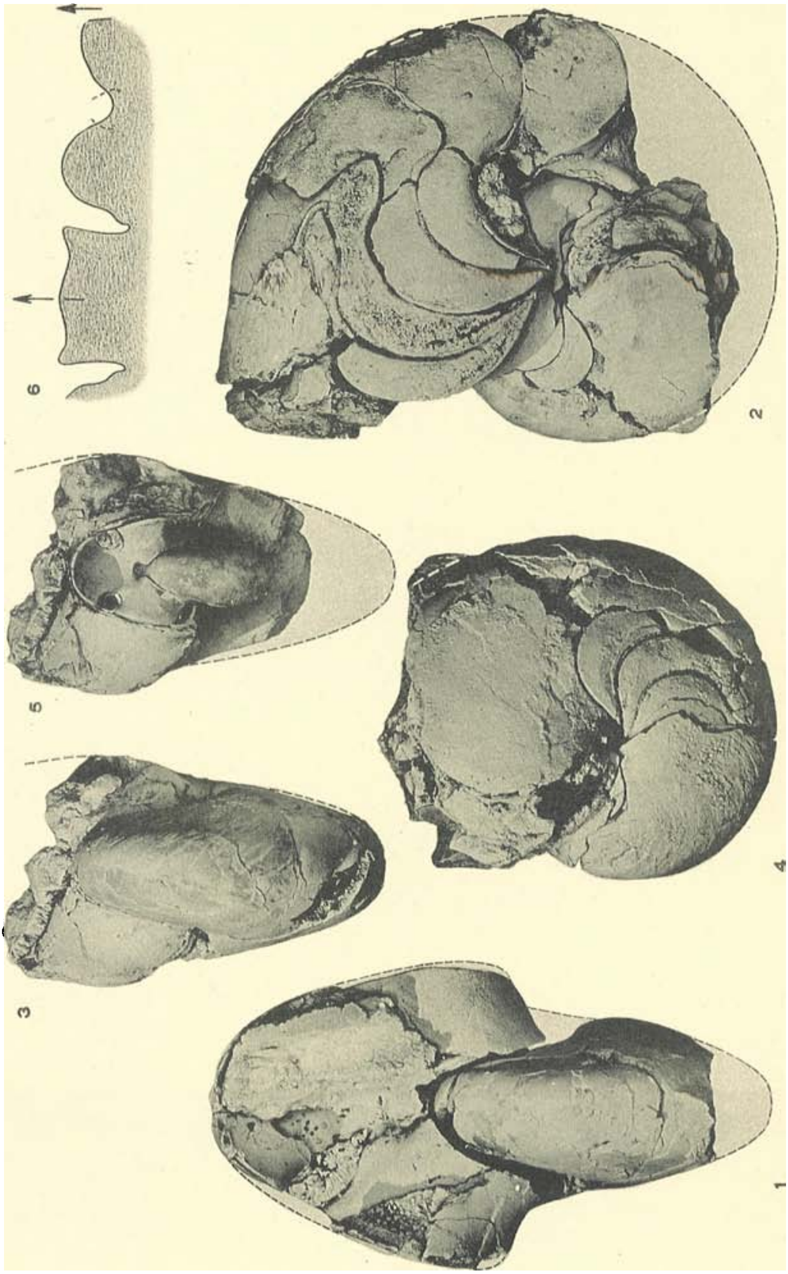
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PLATE 42

PAGE

Aturia (Brazaturia) garretti Stenzel, n.sp., x0.5 772

1, 2. Two views of the entire monotype.

3. Cross-sectional view of part of the monotype.

From left bank of Saline Bayou, at railroad trestle of Louisiana Railway & Navigation Company at St. Maurice, southwestern Winn Parish, Louisiana, section 15, R. 6 W., T. 9 N., Louisiana Meridian; No. 2001 Geology Museum, Louisiana State University, Baton Rouge, Louisiana; Cook Mountain formation, Claiborne group, middle Eocene.

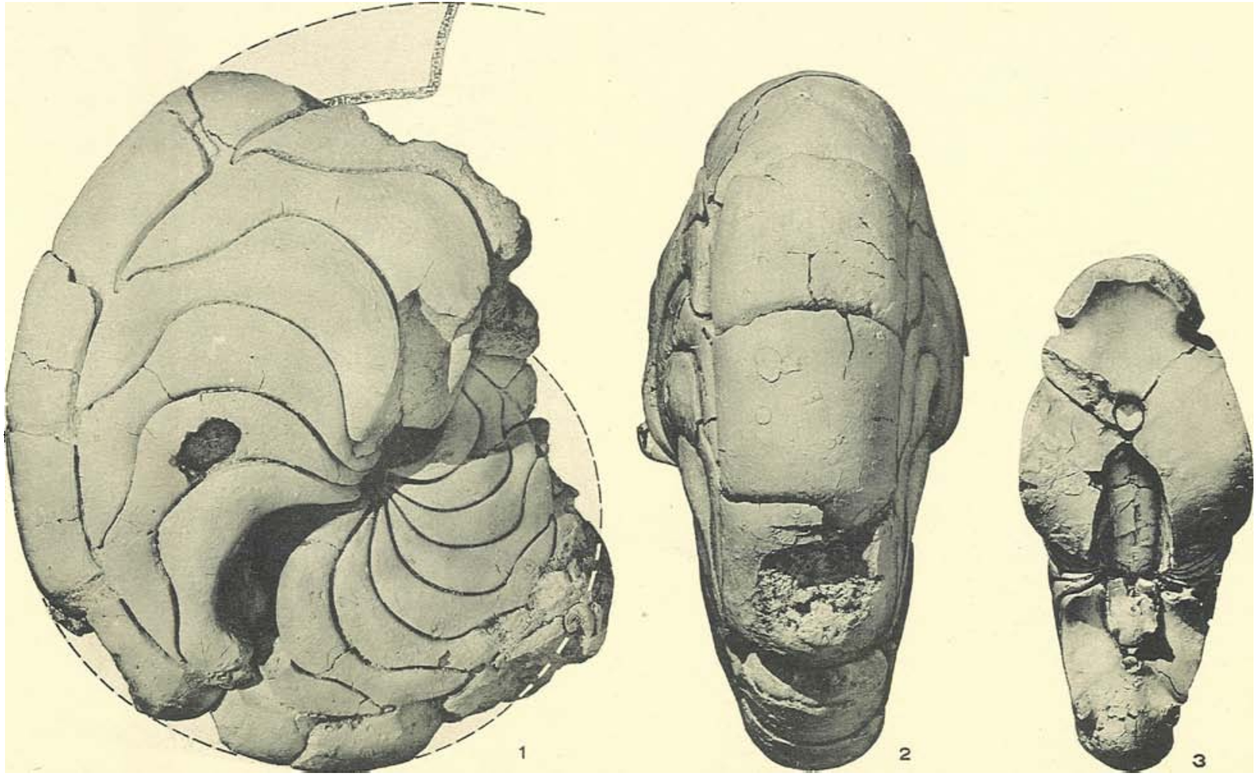

Plate 42

THE GASTROPOD GENERA CRYPTOCHORDA AND LAPPARIA IN THE EOCENE OF THE GULF COASTAL PLAIN[1]

H. B. Stenzel and F. E. Turner

In the course of the preparation of a comprehensive card index of the older Tertiary fossils from the Coastal Plain the two genera *Cryptochorda* and *Lapparia* were investigated. Both genera seemed of particular interest because each is a compact group in itself and because the stratigraphic range of each genus is comparatively short.

The genus *Cryptochorda* is restricted in the Claiborne group to the Weches formation and its stratigraphic equivalents. The genus is an immigrant in the Gulf Coastal Plain. It appeared here with the widespread transgression of the Weches sea and disappeared with the withdrawal of that sea, which inaugurated widespread nonmarine deposition resulting in the delta deposits of the Sparta sand. Later marine invasions did not return the genus *Cryptochorda* to this region. Therefore, the genus is one of the best time markers in the Gulf Coastal Plain and may be used to tie the stratigraphy of the Gulf Coast with that of the Pacific Coast.

On the Pacific Coast of North America, the genus *Cryptochorda* occurs in middle Eocene rocks referred to the Capay and Domengine stages. One species has been described; it is *Cryptochorda californica* (Cooper).[1a] *Cryptochorda eureia* Stenzel & Turner, n.sp., from the Weches formation of east Texas corresponds in general proportions and shape most closely to Cryptochordas referred to *Cr. californica* (Cooper) occurring in the Capay stage (Umpqua formation) of Oregon. Both Oregon and Texas specimens are less heavily calloused than the specimens found at Marysville Buttes in beds of the Capay stage. Cryptochordas from the Domengine portion of the Llajas formation in southern California are distinctly more elongate with a straighter outer lip than either of the above and in this respect resemble *Cr. stromboides* (Herman) from Frésville, Department Manche, France. The California and Oregon specimens all have numerous, broad, well marked spirals on the

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[1]Much of the material used in this article was collected by H. B. Stenzel under a grant-in-aid from the National Research Council. Grateful acknowledgment of this aid is made.

[1a]Cooper, J. G., Catalogue of California fossils: California State Mining Bureau, Bull. 4, p. 43, pl. 1, figs. 6–11, 1894.

Issued June, 1940.

anterior portion of the body whorl adjacent to the canal contrasting with the Gulf Coast and European species which have few if any faintly marked spirals in that place.

The genus *Lapparia* has a larger stratigraphic range. In the Gulf Coastal Plain it appeared suddenly with the widespread transgression of the Weches sea; but after the regression of the Weches sea it remained living in the Gulf Coast region and reappeared with every succeeding transgression throughout the later Eocene. With the end of the Eocene it disappeared from Gulf shores.

In the evolution of the genus *Lapparia* in the Gulf Coastal Plain the original stock of the genus was armed with spines at the shoulder of the whorl. From this spinose stock evolved short-lived branches, which were species devoid or nearly devoid of shoulder spines. In the late Claibornian Gosport sand a spineless branch appeared as *Lapparia pactilis* (Conrad). In the early Jacksonian Moodys marl another spineless branch appeared; it was the *Lapparia dumosa exigua* Palmer. It has been pointed out by De Gregorio[2] that the spineless *Lapparia pactilis* (Conrad) is quite similar to *Mitreola labratula* (Lamarck).

Although the genus *Lapparia* is obviously an immigrant in the Gulf Coastal Plain Eocene, it is not known from any other region except California. Dickerson[21] described one specimen of a *Lapparia* from the Tejon Eocene of Live Oak Canyon, California, as *Voluta martini.* This species corresponds in size, proportions, nature of coiling, trace of growth lines, columella and columella folds, siphonal fasciole, and resorption of the parietal wall almost exactly to *Lapparia elongata* Stenzel & Turner, n.sp., of the Weches formation of the Gulf Coast. Spiral ornamentation is obscure or lacking as on *L. nuda* Stenzel & Turner, n.sp., from the Weches formation. Unfortunately the protoconch and much of the spire is lacking from Dickerson's monotype specimen so the identity with *Lapparia* cannot be final.

The stratigraphic range of the genus as known in the Gulf Coast could mean either Jackson or Claiborne equivalence for the portion

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[2]De Gregorio, A., Monographie de la faune Éocénique de l'Alabama et surtout de celle de Claiborne de l'étage Parisien. Annals de Géologie et Paléontologie, livr. 7 and 8, p. 73, 1890.

See p. 818 of this paper.

[21]Dickerson, R. E., Fauna of the Type Tejon etc.: California Acad. Sci., Proc., ser. 4, vol. 5, no. 3, p. 76, pl. 11, figs. 14a, b, 1915.

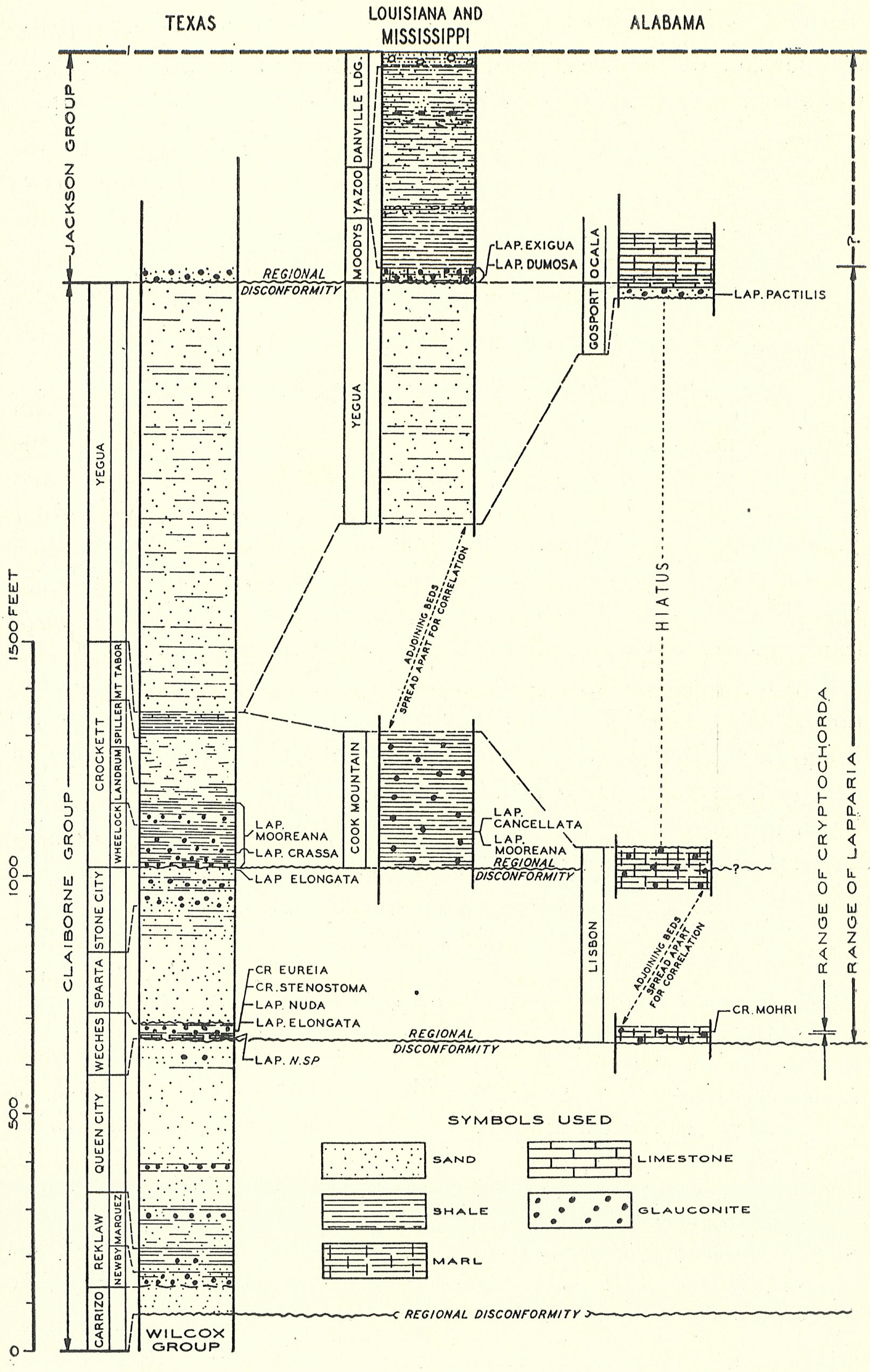

Fig. 128. Stratigraphic distribution of the genera *Cryptochorda* and *Lapparia* in the Gulf Coastal Plain.

of the Tejon in which *Voluta martini* occurs. However, the closest comparison of the west coast species seems to be with the lower Claiborne forms rather than with those higher in the stratigraphic section.

Class GASTROPODA

Order CTENOBRANCHIATA

Family HARPIDAE

Genus CRYPTOCHORDA O.A.L. Mörch, 1858

Note sur le genre *Volutoharpa* Fischer: Jour. de Conchyliologie, ser. 2, vol. 3, p. 43.

Genotype.—*Buccinum stromboïdes* Hermann from the Eocene of the Paris Basin, by original designation. (See Pl. 43, fig. 1.)

Deshayes[3] and Cossmann[4] mention that the Cryptochordas from the Eocene of the Paris Basin retain traces of coloration. This is also the case in specimens from Texas when freshly removed from their matrix. Such specimens are brownish in color except for the following portions which are nearly white: the protoconch, but not its sutures, which are outlined in brown; some hair-thin growth lines on the body whorl; a thin band along the outside edge of the parietal enamel; and the inside of the outer lip. The Paris Basin specimens are said to be brownish in color except for the parietal enamel which is white.

CRYPTOCHORDA MOHRI (Aldrich)

Pl. 43, fig. 2

Buccinum mohri Aldrich, T. H., Preliminary report on the Tertiary fossils of Alabama and Mississippi: Alabama Geol. Surv., Bull. 1, p. 26, pl. 3, figs. 16, 16a, 1886.

Cryptochorda mohri, Cossmann, M., Notes complémentaires sur la faune éocénique de l'Alabama: Annales de Géologie et Paléontologie, livr. 12, p. 38, 1893.

Cryptochorda mohri, Cossmann, M., Essais de paléoconchologie comparée, livr. 3, p. 78, 1899.

Not *Cryptochorda (Buccinum) mohri*, Stenzel, H. B., *in* Renick, B. C. and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, p. 106, 1931.

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[3]Deshayes, G. P., Description des coquilles fossiles des environs de Paris, vol. 2, mollusques, p. 647, 1824.

[4]Cossmann, M., Catalogue illustré des coquilles fossiles de l'Eocène des environs de Paris, fasc. 4: Soc. royale Malacologique de Belgique, Annales, vol. 24, p. 192, 1889.

Cryptochorda mohri, in part, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, p. 399, 1937. Not pl. 65, figs. 9, 10=*Cr. stenostoma* Stenzel & Turner.

Original description.—Shell rather solid; spire high; apex obtuse; whorls seven, rounded; suture rather shallow; surface smooth. Lines of growth coarse, showing on the body whorl. Outer lip strongly reflected. slightly shouldered at its junction with the body whorl. Aperture semi-lunate nearly two-thirds the length of the shell, smooth internally, terminating in a short, excised canal.

Locality.—Lisbon, Ala.

This species has some resemblance to *Buccinum stromboides*, Herm., from the Calcaire Grossier, of Grignon, but lacks the striations on the lower part of the body whorl, is less swollen in outline, and has a more strongly reflected outer lip. Named in honor of Dr. Chas. Mohr, of Mobile, Ala.

Revised description.—Shell solid, slender ovoid; spire medium, more than one-third of the length of the shell. Tip of protoconch broken in monotype specimen; remaining whorls smooth, convex, naticoid. Spire whorls convex, polished, covered on the anterior part by an extension of the parietal enamel. Body whorl ovoid, excavated at base, polished. Monotype specimen has no impressed spirals at the base of the body whorl. Aperture wide, oval, broadly emarginate at the base, extending into an anal canal at posterior end; outer lip slightly decorticated in monotype specimen, vertical except for the basal part which is recurved into the canal, smooth within, thickened and slightly reflected at the outside, nearly uniformly arched in outline, ending at the posterior into a slight, obtuse shoulder point, which is separated from the body whorl by the shallow anal canal; base of aperture broadly and only medium deeply notched at the base of an ill-defined, wide canal. Siphonal fasciole flat and well defined toward the body whorl by a narrow ridge. Columella with a slight vertical swelling. Parietal callus heavy, spreading over the entire apertural face of the body whorl, extending in posterior direction beyond the suture onto the preceding whorl.

Dimensions.—Monotype, length without tip of protoconch 47 mm.; width 23 mm.

Observations.—*Cryptochorda mohri* (Aldrich) has a longer and slenderer spire than either *Cr. eureia* Stenzel & Turner or *Cr. stenostoma* Stenzel & Turner. The aperture of *Cr. mohri* is wider than in the two new species, particularly so at its posterior end. The outer lip of *Cr. mohri* has less of a shoulder at its posterior junction and is not sigmoid in outline when viewed onto the apertural face.

A small amount of matrix remains in a hole of the monotype shell on the face opposite to the aperture. The matrix is a light sand with a few dark green glauconite grains.

The writers were able to examine the monotype specimen through the courtesy of Dean E. W. Berry, whom the writers wish to thank.

Type data.—Monotype in Aldrich Collection, Geological Department, The Johns Hopkins University, Baltimore, Maryland.

Type locality.—Lisbon bluff, about 1 mile south of Lisbon Landing on right bank of Alabama River, Monroe County, Alabama.

Geologic horizon.—Lisbon formation, Claiborne group, middle Eocene.

Distribution.—Known only from type locality.

CRYPTOCHORDA EUREIA, n.sp.

Pl. 43, fig. 3

Cryptochorda (Buccinum) mohri, Stenzel, H. B., *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, p. 106, 1931.

Description.—Shell solid, ovoid; spire low, nearly one-third the length of the shell. Protoconch consists of 3 smooth, convex, naticoid whorls. Spire whorls convex, polished, and covered on the anterior part by an extension of the parietal enamel. Body whorl ovoid, excavated at the base, polished. Some specimens, but not the holotype, have four impressed spirals at the base of body whorl. Aperture wide, oval, deeply emarginate at the base, extending into an anal canal at the posterior end; outer lip only slightly retractive, smooth within, thickened and slightly reflected at the outside, slightly sigmoid in outline, ending at the posterior in an obtuse shoulder point, which is separated from the body whorl by the shallow anal canal; base of aperture deeply notched at the base of an ill-defined canal. Siphonal fasciole flat and well defined toward the body whorl by a narrow ridge. Columella with a slight vertical ridge which shows the contour of the siphonal fasciole buried under the enamel. Parietal callus heavy, spreading over nearly the entire apertural face of the body whorl, extending in posterior direction beyond the suture onto the preceding whorl.

Dimensions.—Holotype, length 37 mm.; width 20 mm.

Observations.—This species has a shorter spire and thicker and wider spread parietal callus than *Cr. stenostoma* Stenzel & Turner. The specific name is the feminine gender of the Greek adjective εὐρύς, broad, and refers to the broad shape of the species.

Type data.—Holotype and fragmentary paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Gully 0.15 mile north of Concord-Centerville county road, 2.11 miles east of Robbins crossroads, right tributary of McDaniel Creek, 0.1 mile east of a fence and 0.15 mile west of east line of J. E. Morris 89-acre tract, International & Great Northern Railroad Company survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–36.[5]

Geologic horizon.—Viesca glauconitic marl member of Weches formation, Claiborne group, middle Eocene.

Distribution.—This species is widespread, though not common, in the Viesca member of east Texas. Fragmentary paratypes were found at the following additional localities:

Bluff on right bank of Cobb Branch near its head, 0.6 mile northwest of Camp Creek schoolhouse, on Buck McBride's 134-acre tract; Jose Maria Viesca survey, eastern Robertson County, Texas. Compare Marquez quadrangle, 1/62500, U. S. Geol. Survey.

Field on hill slope 0.1 mile south of Spring Creek, 3.2 miles southeast of Cullinan station, airline distance; near south corner of Bass Brothers 320-acre tract, Jefferson Reed survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–16.

Bluff between house and Spring Creek, southwest of the creek, about 1.4 miles east of Cullinan station, on Dr. E. O. Boggs 250-acre tract, west part of A. M. Halmark survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–19.

North ditch of Concord-Centerville county road, 5.2 miles west of Centerville, between left tributary of McDaniel Creek and Sparta nose, 0.3 mile west of Redland Methodist Church, east part of J. T. Smith 290-acre tract, Jos. Walker survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–38.

Road ditches at bottom of hill on Grapeland-Daily road, 8.2 miles west of the railroad at Grapeland, G. Greenwood survey, Houston County, Texas; Bureau of Economic Geology locality No. 113–T–15.

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[5]Compare Stenzel, H. B., The Geology of Leon County, Texas: Univ. Texas Pub. 3818, p. 266 and map. 1939. The description of the locality on p. 266 of this bulletin contains two misprints; replace 1.5 miles by 0.15 mile and Railway by Railroad.

CRYPTOCHORDA STENOSTOMA, n.sp.

Pl. 43, Fig. 4

Cryptochorda mohri, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, p. 399 in part, pl. 65, figs. 9, 10, 1937.

Description.—Shell solid, slender ovoid; spire low, less than one-third the length of the shell. Protoconch consists of 4 smooth, convex, naticoid whorls, of which the first 2 are much smaller than in *Cryptochorda eureia* Stenzel & Turner. Spire whorls slightly convex, polished, and covered on the anterior half by an extension of the parietal enamel. Body whorl slender ovoid, excavated at the base, polished. Aperture narrow, widest near the anterior end, deeply emarginate at the base, extending into an anal canal at the posterior end; outer lip only slightly retractive, smooth within, thickened and sharply reflected at the outside, slightly sigmoid in outline, ending at the posterior in a rectangular shoulder point, which is separated from the body whorl by the distinct anal canal; base of aperture deeply notched at the end of an ill-defined canal. Siphonal fasciole flat and well defined toward the body whorl by a narrow ridge. Columella with a pronounced, humpy, vertical ridge which is in part responsible for the narrowness of the aperture. Parietal callus thin, spreading over part of the apertural face of the body whorl, extending to about halfway between the posterior suture and the posterior end of the aperture. In the type specimen the parietal callus has numerous small holes arranged in lines presumably caused by boring sponges.

Dimensions.—Monotype, length 39 mm., width 19 mm.

Observations.—The specimen figured by Palmer belongs to this species. This species is characterised by the pronounced vertical ridge along the columella. This ridge is present in every member of this genus, even in the type species, *Cr. stromboides* (Hermann); but in no other species is it so high and well developed. The outer lip of this species is more nearly vertical if viewed on the apertural face of the body whorl (see Pl. 43, fig. 4); but when seen from the side it is more sigmoidal in outline than in any other species. The spire differs from that in other known species of *Cryptochorda* by its slightly convex profile and the lesser inflation of the whorls.

The specific name of the species is derived from the Greek adjective *στενός*, narrow, and noun *στόμα*, mouth or opening, and refers to the narrow aperture of the species.

Type data.—Monotype in Bureau of Economic Geology, The University of Texas, Austin, Texas. The type was collected by Mr. Carl Chelf of the Texas Memorial Museum.

Type locality.—Bluff on right bank of Colorado River upstream from highway bridge at Smithville, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–2.

Geologic horizon.—Viesca glauconite marl member of Weches formation, Claiborne group, middle Eocene.

Distribution.—Known only from type locality.

Family MITRIDAE

Genus LAPPARIA T. A. Conrad, 1855

Observations on the Eocene deposit of Jackson, Miss., with descriptions of thirty-four new species of shells and corals: Acad. Nat. Sci. Philadelphia, Proc. for 1855, p. 260.

Genotype.—*Mitra dumosa* Conrad from the upper Eocene Moodys marl of Jackson, Hinds County, Mississippi, by monotypy. (See Pl. 45, fig. 2.)

The genus was placed in the family Volutidae by Dall,[6] Cossmann,[7] and Palmer.[8] However, its true relationships are with the Mitridae. Dall based his decision entirely on the character of the protoconch. He stated that "No true *Mitra* exhibits such a nucleus, and they [the Lapparias] are beyond doubt properly referred to the Volutidae, where their peculiar characters entitle them to generic rank." On the other hand he admitted that *Lapparia* has "a very *Mitra*-like aspect, apart from the protoconch."

It remains, therefore, to be seen what this protoconch is. Dall classed *Lapparia* in the "*Scaphelloid Series*" of the Volutidae, a

[6]Dall, W. H., Contributions to the Tertiary fauna of Florida, with especial reference to the Miocene Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci., Trans., vol. 3, pt. 1, pp. 71, 79, 1890.

[7]Cossmann, M., Essais de paléoconchologie comparée, livr. 3, pp. 102, 111–112, 1899, and livr. 8, pp. 205–218, 1909.

[8]Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States Bull. Am. Pal., vol. 7, pp. 384–385, 1937.

name which he later[9] changed to Caricellinae. The Scaphelloid Series is characterized, according to its author, by a deciduous horny protoconch which becomes filled with limy matter only partially. The horny portion of the protoconch falls later into shreds and is lost leaving a scar which has a central spine or point at the apex in some cases. This scar is distinguished from the rest of the protoconch by the lack of distinct sutures and a dull, unpolished surface while the rest of the protoconch is polished and sutured. Such a protoconch is easily observable in forms such as *Scaphella (Aurinia) gouldiana* Dall, *Sc. (Au.) robusta* Dall, *Sc. junonia* Hwass, *Sc. (Caricella) demissa* Conrad, and *Sc. floridana* Heilprin, all figured by Dall. Eocene and Oligocene Caricellas in the collection of the Bureau of Economic Geology exhibit this type of protoconch clearly, for instance, *Caricella texana* (Gabb), *C. cherokeensis* Harris, *C. pyruloides* (Conrad), *C. bolaris* (Conrad), *C. praetenuis* (Conrad), and *C. demissa* Conrad. Notwithstanding Dall's statement to the contrary, not a single specimen of the genus *Lapparia* has such a protoconch. All *Lapparia* specimens before the writers of this article have protoconchs free of scars and well sutured from the beginning. There seems to be no reason for maintaining that the nature of the protoconch forces the inclusion of *Lapparia* in the Caricellinae or Scaphelloid Series.

Cossmann based his decision on his observation that all the exterior characters of the shell approach more the Volutidae than the Mitridae.[10] This is not the case and is in direct opposition to Dall's observation quoted above. Even Cossman contradicted himself in this observation because later[11] he declared *Lapparia* to be mitriform, that is, of the shape of a mitrid. Spinose species of *Lapparia* have exterior characters of the shell not far removed from such a characteristic genus of the Mitridae as *Vexillum*,[12] for

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[9]Dall, W. H., Notes on some Upper Cretaceous *Volutidae* with descriptions of new species and a revision of the groups to which they belong: Smith. Misc. Coll., vol. 50, pt. 1, No. 1704, 23 p., 1907.

————, A review of the American *Volutidae:* Smith. Misc. Coll., vol. 48, No. 1663 pp 311–373, 1907.

[10]Cossmann, M., *op. cit.*, p. 112.

[11]Cossmann, M., *op. cit.*, p. 217.

[12]*Vexillum* ("Bolten") Roeding, 1798, Museum Boltenianum, pt. 2 p. 138; genotype species: *Vexillum plicatum* ("Bolten") Roeding = *Voluta plicaria* Linné, Recent. Indo-Pacific, designated by W. P. Woodring. Miocene Mollusks from Bowden, Jamaica, pt 2: Carnegie Inst. Washington, Pub. 385, p. 244, 1928.

instance. Nonspinose species of the genus *Lapparia* have exterior characters not far removed from the genus *Mitreola*[13] of the Mitridae. (Compare Pl. 45, figs. 3, 5, 7.) Cossmann also claimed that the anterior columellar fold of *Lapparia* is nearly equal to the other three and that this feature is also present in some Volutes. Nevertheless, he called these columellar folds "presque mitriforme" 10 pages before,[14] clearly contradicting himself. It is, of course, a matter of opinion what would constitute "nearly equal" or unequal size in these columellar folds, but comparison of the four columellar folds of *Lapparia* with those of the Mitridae discloses certainly no significant difference, if any. Cossmann's classification of *Lapparia* in the Volutidae is not logical because he stated[15] that the Volutidae may be distinguished from the Mitridae in the following manner:

> Du côté des Mitridae, la délimitation est aussi bien tranchée, quoique la forme de certains représentants de ces deux Familles soit quelquefois très semblable; le caractére invariable et certain, à l'aide duquel on peut reconnaître une Mitre d'une Volute, c'est l'ordre de décroissance graduelle de l'épaisseur des plis columellaires; tandis que ces plis décroissent d'avant en arrière chez les Volutidae, ils croissent en sens inverse chez tous les Genres de Mitridae.

By these standards of distinction the genus *Lapparia* belongs to the family Mitridae, because its four columellar folds are of mitrid character. This feature has been noted by Cossmann who said that *Lapparia* has "4 plis presque mitriformes." In this statement the word *presque* seems superfluous. In addition it seems that the genera *Lapparia* and *Mitreola* are related. If *Mitreola* is classed with the mitrids—as it always has been classed—the genus *Lapparia* will have to be classed in the same family.

Traces of coloration are retained in some Texas specimens of this genus. Such specimens are brownish in color over their entire outside surface; the inside of the aperture is white except for the brown parietal wall and a broad brown band along the inside edge

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[13]*Mitreola* W. Swainson, 1833, Zoological Illustrations, ser. 2, vol. 2 pl. 128. Only two species mentioned, *Mitreola monodonta* (Lamarck) and *Mitra terebellum* Lamarck. Genotype designated by Herrmannsen, A. N., Indicis generum malacozoorum primordia, vol. 2, p. 45, Cassel, 1849, "Mitra monodonta (Lamck.?) Swains." Cossmann states in several of his books that *Mitreola labratula* Lamarck is the genotype; Cossmann's statement is apparently erroneous as that species is not among the two original species of the genus.

[14]Cossmann, M. *op cit.*, pp. 102, 112.

[15]Cossmann, M., *op cit.*, p. 102.

of the outer lip. This band is about 4 mm. wide in the figured paratype of *Lapparia crassa* Stenzel & Turner and forms the margin of the entire outer lip and the anterior canal. The columella, from the anterior tip of the canal to the last and largest columellar fold, is white. These color traces are observable in most species of the genus.

LAPPARIA, n.sp.

A large, coarse, new species of this genus occurs in the Tyus member of the Weches formation in Leon County, Texas. Specimens of this species are too fragmentary for formal description. However, the species is important, because it is the oldest known representative of this genus. The Tyus member is the basal portion of the Weches formation.

LAPPARIA ELONGATA, n.sp.

Pl. 44, figs. 3, 5

Lapparia mooreana, Cossmann, M., Essais de paléonconchologie comparée, livr. 3, p. 112, pl. 8, fig. 9, 1899.

Mitra cf. *dubia*, Stenzel, H. B., *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, p. 106, 1931.

Lapparia mooreana, in part, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 387–388, pl. 62, figs. 8, 12, 13 only, 1937.

Description.—Shell heavy, slender; apical angle 32° to 35°, spire nearly one-half of the length of the shell. Protoconch consists of 4 whorls of which the first two are polished, convex, and naticoid with deeply channelled sutures; the next two have very faint spiral ribs and deeply channelled sutures; the last of the 4 whorls is smaller than the preceding whorl; outline of protoconch ovoid. First nepionic whorl with about 15 retractive axial ribs which develop nodes and become shouldered after half a volution. The nodes gradually develop into flattened spines and the axial ribs disappear in later spire whorls. Spire whorls with a slight, wrinkled subsutural collar and steeply sloping spinous shoulder placed at the anterior third of the whorl; spines generally 7 to 10 per whorl, their tips flattened parallel with the direction of coiling; numerous fine wavy spirals overrun the whorls and are usually alternating in size. Body whorl ovoid with a steeply sloping spinous shoulder and excavated base;

fine, wavy spirals well developed posterior to and at the spines, but obsolete toward the base; growth lines strong and numerous. Aperture narrow, deeply emarginate at the base; outer lip not retractive, smooth within, and sharp-edged; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up in the shell; the 4 folds are arranged according to increasing strength and decreasing inclination, the most anterior fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Holotype, length 48 mm., width 17 mm.; figured paratype, length 45 mm., width 16 mm.

Observations.—This Weches species is the slenderest of all Lapparias. It differs from the Crockett species *Lapparia mooreana* (Gabb) by its larger protoconch, slenderer spire, and wider zone between the shoulder spines and the anterior suture on the spire whorls. It differs from the Weches species *L. nuda* Stenzel & Turner by the more pronounced spirals on the body whorl, the early disappearance of the axial ribs, and the slenderer shape. The specific name is chosen to emphasize the slender shape of the shell.

Cossmann figured this species under the name *Lapparia mooreana* (Gabb), stating erroneously that it came from the Paleocene Midway stage.

Type data.—Holotype and numerous paratypes in Stenzel Collection, Bureau of Economic Geology, Austin, Texas.

Type locality.—Bluff on right bank of Colorado River upstream from highway bridge at Smithville, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–2.

Geologic horizon.—Viesca glauconitic marl member of Weches formation, Claiborne group, middle Eocene.

Distribution.—Aside from the type locality, where the species is common, it was found at the following locality:

Collier's ferry or Burleson shell bluff on right bank of Brazos River, in W. H. Jenkins Estate $41\frac{1}{3}$ acre tract and J. R. Sadberry Estate 147-acre tract, J. C. Robertson survey, northeastern Burleson County, Texas; Bureau of Economic Geology locality No. 26–T–6.

One specimen of the genus *Lapparia* has been collected from the Stone City formation at Stone City, Burleson County, Texas, in the glauconitic marl 2.5 feet below the top of the Stone City formation. The spiral lines, axial ribbing and spines of this specimen are identical in development to *L. elongata;* the apical angle is intermediate between that of *L. elongata* and *L. mooreana;* the protoconch is small and the body whorl inflated anteriorly as in *L. mooreana.* This specimen is indicated in the Stone City formation on figure 128 as *Lap. elongata.*

LAPPARIA NUDA, n.sp.

Pl. 44, figs. 6, 9

Lapparia mooreana, in part, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda, and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 387–388, pl. 62, fig. 10 only, 1937.

Description.—Shell heavy; apical angle 41° to 44°, spire about one-half the length of the shell. Protoconch consists of 3½ whorls which are polished, convex, and naticoid with deeply channelled sutures; the last quarter volution of the protoconch and the succeeding half volution of the juvenile whorls is smaller than the preceding whorl; outline of protoconch ovoid. First nepionic whorl with about 19 retractive axial ribs which develop nodes and become shouldered after half a volution. The nodes gradually develop into slightly flattened, inconspicuous spines and the axial ribs persist to the last whorl. Spire whorls with a slight subsutural collar much wrinkled with growth lines, a steeply sloping noded shoulder placed usually near the middle of the whorl; ribs and nodes generally 9 to 11 per whorl, the node tips slightly flattened parallel with the direction of coiling; fine spiral lines usually lacking; if present they are developed best on the posterior shoulder slope. Body whorl ovoid with a steeply sloping noded shoulder and excavated base; axial ribs much narrower than the interspaces extend to the base where they gradually die out in the excavated portion. Aperture narrow, deeply emarginate at the base; outer lip not retractive, smooth within, and sharp-edged: deeply notched base of aperture extends into a short twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up the shell; the 4 folds arranged according to increasing strength and decreasing inclination, the most anterior fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Holotype, length 31 mm., width 14 mm.; figured paratype, length 21 mm., width 10 mm.

Observations.—This Weches species occurs together with *L. elongata* Stenzel & Turner. It may be distinguished from the latter by its greater apical angle, stouter outline, lack of spiral threads, more strongly wrinkled subsutural collar, and the persistence of the axial ribs even to the last whorl.

The specific name *nuda* refers to the absence of the spiral threads, a feature which distinguishes this species from other, ribbed Lapparias.

Type data.—Holotype and 14 paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Bluff on right bank of Colorado River upstream from highway bridge at Smithville, Bastrop County, Texas; Bureau of Economic Geology locality No. 11–T–2.

Geologic horizon.—Viesca glauconitic marl member of Weches formation, Claiborne group, middle Eocene.

Distribution.—This species is rare and was found at one additional locality only:

Spring Creek, dry branch of Spring Creek about one mile south of Cedar Creek School, airline distance, 5.5 miles southwest of Centerville, airline distance; near southeast line of J. E. Wilkinson 288-acre tract, J. A. Halmark survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–23. Viesca member of Weches formation, *Ostrea smithvillensis* Harris zone.

LAPPARIA MOOREANA (Gabb)

Pl. 44, figs. 4, 7, 8

Mitra mooreana Gabb, W. M., Descriptions of new species of American Tertiary and Cretaceous fossils: Acad. Nat. Sci. Philadelphia, Jour., ser. 2, vol. 4, p. 383, pl. 67, fig. 24, 1860.

Lapparia mooreana, Conrad, T. A., Catalogue of the Eocene and Oligocene Testacea of the United States: Am. Jour. Conchology, vol. 1, p. 24, 1865.

Lapparia mooreana, Conrad, T. A., Check list of the invertebrate fossils of North America; Eocene and Oligocene: Smith. Misc. Coll., vol. 7, no. 200, p. 16, 1866.

Not *Lapparia mooreana*, Cossman, M., Essais de paléoconchologie comparée, livr. 3, p. 112, pl. 8, fig. 9, 1899 = *L. elongata* Stenzel & Turner.

Mitra mooreana + *Mitra mooreana* var., Stenzel, H. B., *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, pp. 95, 101, 1931.

Lapparia mooreana, in part, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 387–388, pl. 62, figs. 9, 11, 14, and 15 only, 1937.

Original description.—Shell subfusiform, whorls eight, apex mamillated, suture distinct; mouth about half the length of the shell, outer lip sharp, inner lip heavy, four large folds on the columella: surface marked by short spinous nodes on the angle of the whorls (about eight on the body whorl), and by numerous fine revolving lines, crossed by prominent lines of growth.

Dimensions.—Length 1.05 in.; length of mouth 0.6 in.; width of body whorl, including spines, 0.5 in.

Revised description.—Shell heavy, slender; apical angle 38° to 44°; spire nearly one-half the length of the shell. Protoconch ovoid in outline, comparatively small, consists of 2 to 2½ polished, convex, and naticoid whorls with deeply channelled sutures; the last quarter volution of the protoconch and the succeeding half volution of the juvenile whorls is smaller than the preceding whorl. First nepionic whorl with about 21 retractive axial ribs which develop nodes and become shouldered after about half a volution. The nodes gradually develop into flattened spines and the axial ribs disappear in later spire whorls. Spire whorls with a slight, wrinkled subsutural collar and steeply sloping spinous shoulder placed at the anterior third of the whorl; spines generally 8 to 9 per whorl on adults, their tips flattened parallel with the direction of coiling; numerous fine wavy spirals overrun the whorls and are usually alternating in size. Body whorl ovoid with steeply sloping spinous shoulder and exvacated base; fine, wavy spirals well developed posterior to and at the spines, but obsolete toward the base in some specimens; growth lines strong and numerous. Aperture narrow, deeply emarginate at the base; outer lip not retractive, smooth within, and sharp-edged; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up in the shell; the 4 folds are arranged according to increasing strength and decreasing inclination, the most anterior fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Larger figured specimen, length 35 mm., width 16 mm.; smaller figured specimen, length 18 mm., width 8 mm. (see Pl. 44, figs. 4, 7). Holotype, length 27 mm.

Observations.—This species is characterized by the comparatively small protoconch having few volutions and by the disappearance of the axial ribs in the later whorls. *Lapparia crassa* Stenzel & Turner, which occurs with *L. mooreana* (Gabb) at the type locality of the former, is readily distinguished by the much larger protoconch, the persistence of ribs to the last whorl, and its heavier outline; *L. nuda* Stenzel & Turner is readily differentiated from *L. mooreana* by the lack of the spiral threads, the larger protoconch, the persistence of the ribs to the last whorl, and its slightly stouter appearance; *L. elongata* Stenzel & Turner differs from *L. mooreana* by its larger protoconch, more elevated spire, and larger size. *Lapparia nuda* and *L. elongata* are not found in the same beds as *L. mooreana.*

Type data.—Holotype, No. 13273, in Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. Figured specimens (Pl. 44, figs. 4, 7) in Stenzel Collection, Austin, Texas.

Type locality.—Gabb gave as type locality Wheelock and Caldwell County, Texas. This species is restricted to the Crockett (or Cook Mountain) formation in which it is very abundant. This formation does not occur in Caldwell County as that county was bounded in 1860 or today. Therefore, Gabb's statement is erroneous. It is possible that he meant the town of Caldwell which lies in Burleson County, Texas. This is the more probable because Caldwell and Wheelock are only 32 miles apart and lie both on the Old Spanish Road, which was at that time a main route of travel. There are numerous Crockett formation localities near both towns and along the Old Spanish Road between them. One of these localities is presumably the type locality where Dr. Francis Moore obtained the specimens. Kennedy[16] stated that many of Gabb's types came from Town Branch of Cedar Creek near Wheelock.

[16]Kennedy, William, The Eocene Tertiary of Texas east of the Brazos River: Acad. Nat. Sci. Philadelphia, Proc. for 1895, p. 122, 1896.

The locality on this branch was visited by Stenzel and was found to be exceedingly poor collecting. Unless this locality was much better 45 to 80 years ago it is doubtful that this is Gabb's locality. Other localities, on the Old Spanish Road, are much better.

Geologic horizon.—Wheelock marl member of Crockett formation, Claiborne group, middle Eocene.

Distribution.—This species is widespread in the Crockett formation of Texas or its stratigraphic equivalents in Louisiana and Mississippi. It was found at the following additional localities:

Stone City (Moseley's Ferry), bluff on right bank of Brazos River at bridge of State highway No. 21 and bridge of Southern Pacific Railroad, Burleson County, Texas; Bureau of Economic Geology locality No. 26–T–1. At this place *Lapparia mooreana* is found in the beds above the basal conglomerate (bed aa) of the Crockett formation; compare Stenzel, H. B., A new formation in the Claiborne group: Univ. Texas Bull. 3501, p. 269, 1936.

Little Brazos River upstream from bridge of State highway No. 21, 9.4 miles west of Bryan, Brazos County, Texas; Bureau of Economic Geology locality No. 21–T–1; Wheelock member of Crockett formation.

Two-Mile Creek, five bluffs at the steel bridge of Leona–Two-Mile School county road near Two-Mile Negro School, 5.24 miles from Leona. One of the bluffs is on right bank immediately east of bridge, another on right bank a few feet west of bridge, the other three are upstream from bridge but below the next fence line; on Emma and E. J. Houston land, near north corner of J. L. Landrum survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–52; lower Landrum member of Crockett formation.

Middleton, west ditch of Middleton–Spiller's Store county road, 0.15 mile northeast of steel bridge over Boggy Creek or 0.7 mile south of Middleton post office; in southeast corner of W. W. Hill 48-acre tract, Fernando del Valle survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–53; upper Wheelock member of Crockett formation.

Flat Branch, banks of branch about 200 feet above its confluence with Bear Branch, about 0.35 mile from entrance gate on Middleton–Guy's Store county road; near south corner of James Fleming 536-acre pasture, Fernando del Valle survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–58; lower Landrum member of Crockett formation.

Bear Branch, banks about 300 feet above its confluence with Flat Branch and about 0.35 mile from entrance gate on Middleton–Guy's Store county road; near south corner of James Fleming 536-acre pasture, Fernando del Valle survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–59; lower Landrum member of Crockett formation.

Two-Mile Creek, left bank at first ford above Two-Mile Church; between the fence of Emma and E. J. Houston land and fence of Gary D. Woods 300-acre tract but in west corner of land of Emma and E. J. Houston (said to belong to Mr. King), J. L. Landrum survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–71; marine lentil in lower Landrum member of Crockett formation.

Two-Mile Creek, left bank above the first ford of locality 145–T–71 and about halfway between this ford and the disused ford; between the fence of Emma and E. J. Houston land and fence of Gary G. Woods 300-acre tract but in west corner of Emma and E. J. Houston land (said to belong to Mr. King), J. L. Landrum survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–72; lower Landrum member of Crockett formation.

Alabama Ferry, on left bank of Trinity River 0.3 mile downstream from abandoned ferry, 7.5 miles west-southwest of Porter Springs, Houston County, Texas; Bureau of Economic Geology locality No. 113–T–9; lower Landrum member of Crockett formation.

Hurricane or Three-Mile bayou, bluff on right bank, 0.3 mile upstream from bridge on Crockett-Rusk county road, or mail route No. 1, 3.35 miles from courthouse at Crockett, in southeast corner of Young-Murchison 553½-acre tract and H. F. Craddock 277.4-acre tract, southeast corner of Newell C. Hodge survey, Houston County, Texas; Bureau of Economic Geology locality No. 113–T–2; lower Landrum member of Crockett formation.

Saline Bayou at St. Maurice, above and within sight of L. R. & N. C. R. R. trestle, on left side of bayou, 0.25 mile west of St. Maurice depot, Winn Parish, Louisiana; Bureau of Economic Geology locality No. La–15; Cook Mountain formation.

Quitman, in gullies north of old Quitman–Liberty Hill road on Mrs. J. M. Turner's place, and west of Madden Creek, sec. 15, T. 16 N., R. 3 W.; 3.60 miles west on road from Quitman railroad crossing, Jackson Parish, Louisiana; Bureau of Economic Geology locality No. La–7; Cook Mountain formation.

Indian Mound, cut of Alabama & Vicksburg Railroad on Indian Mound in pasture of Mr. A. H. Edwards, 3 miles east of Newton, Newton County, Mississippi; Bureau of Economic Geology locality No. Miss–1; Wautubbee formation.

LAPPARIA CRASSA, n.sp.

Pl. 44, fig. 1; Pl. 45, fig. 1

Mitra n.sp. aff. *mooreana*, Stenzel, H. B., *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, pp. 95, 101 in part, 1931.

Description.—Shell heavy; apical angle 47°; spire less than one-half the length of the shell. Protoconch large, ovoid, consists of 3 polished, convex, and naticoid whorls with deeply channelled sutures. First nepionic whorl with about 20 retractive axial ribs which develop nodes after about one volution. The nodes gradually develop into flattened, prominent spines and the axial ribs persist usually to the last whorl. Spire whorls with a slight, wrinkled subsutural collar and steeply sloping spinous shoulder placed near the anterior suture; spines generally only 7 to 8 per whorl, their tips flattened parallel with the direction of coiling; numerous fine, wavy spirals overrun the whorls and are alternating in size occasionally. Body whorl ovoid with a steeply sloping spinous shoulder and excavated base; spines usually buttressed anteriorly by narrow axial ribs extending to the excavated base; fine, wavy spirals well developed at and posterior to the spines, less well developed toward the base; growth lines strong and numerous. Aperture narrow, deeply emarginate at the base; outer lip not retractive, smooth within, and sharp-edged; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up in the shell; the 4 folds are arranged according to increasing strength and decreasing inclination, the most anterior fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Some specimens of this species lose the axial ribs suddenly. The holotype has well developed and large axial ribs on the body whorl, but the last two shoulder spines do not have any axial ribs.

Dimensions.—Holotype, length 57 mm., width 24 mm.; figured paratype, length 39 mm., width 20 mm.

Observations.—This species occurs with *Lapparia mooreana* (Gabb) and is distinguished from it by the much larger protoconch and the buttress-like axial ribs which give it a swollen appearance. This is the largest and heaviest *Lapparia* species with the exception of *Lapparia*, n.sp., from the basal Weches formation.

The specific name *crassa*, fat, is chosen to emphasize the swollen shape of the shell.

Type data.—Holotype and 8 paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Little Brazos River upstream from bridge of State highway No. 21, 9.4 miles west of Bryan, Brazos County, Texas; Bureau of Economic Geology locality No. 21-T-1.

Geologic horizon.—Wheelock marl member of Crockett formation, Claiborne group, middle Eocene. The stratigraphic section at the type locality is from 22 to 52 feet above the base of the Crockett. The lower half of this section carries the *Lapparia crassa.*

Distribution.—Known only from type locality, where it is much rarer than *Lapparia mooreana* (Gabb).

LAPPARIA CANCELLATA, n.sp.

Pl. 44, fig. 2

Description.—Shell heavy, comparatively short; apical angle 43°; spire nearly one-half the length of the shell. Protoconch stubby ovoid in outline, comparatively small, consists of 2½ polished whorls with deeply channelled sutures; the first 2 whorls are depressed and bluntly keeled and their slopes posterior to the keel are concave, the last half volution of the protoconch has slightly convex and vertical sides. First nepionic whorl with 14 retractive axial ribs which develop nodes and become shouldered after about half a volution. The nodes gradually develop into flattened spines and the axial ribs disappear in later spire whorls. Spire whorls with a slight subsutural collar and steeply sloping spinous shoulder placed immediately behind the suture; spines 10 on last preserved whorl of monotype, their tips slightly flattened parallel with the direction of coiling; suture distinct and wavy due to its position near the spines of the preceding whorl, numerous fine wavy spiral threads overrun the whorls and make a cancellate pattern with the raised threads of the growth lines. Body whorl ovoid with steeply sloping spinous shoulder and excavated base; fine wavy threads over entire body whorl but somewhat wider spaced in the excavated basal portion. Growth lines numerous and raised producing a cancellate pattern with the spirals over entire body whorl except the excavated base. Aperture narrow, deeply emarginate at the base; outer lip broken; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which are badly decorticated in the monotype. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Monotype, length of broken specimen, 21 mm., width 10 mm.

Observations.—This species is near related to *Lapparia mooreana* (Gabb). It differs from that species by the concave protoconch whorls, the more sunken spire, and the prominently cancellate ornamentation.

The specific name refers to the cancellate ornamentation, which is much more striking in this species than in any other *Lapparia.*

Type data.—Monotype in Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Cut and ditch on east side of Negreet-Columbus road on steep, wooded blackland hill, 7.15 miles from the school at Negreet, Sabine Parish, Louisiana; Bureau of Economic Geology locality No. La-19.

Geologic horizon.—Cook Mountain formation, Claiborne group, middle Eocene.

Distribution.—Known only from type locality.

LAPPARIA PACTILIS (Conrad)

Pl. 45, figs. 3, 5

Mitra pactilis Conrad, T. A., Fossil shells of the Tertiary formations of North America, p. 46, 1833.

Mitra pactilis, Conrad, T. A., *in* Morton, S. G., Synopsis of the organic remains of the Cretaceous group of the United States, appendix, p. 5, Philadelphia, 1834.

Mitra pactilis, Conrad, T. A., [republication of Conrad 1833], p. 43, pl. 16, fig. 21, 1835.

Voluta dubia Lea, H. C., Descriptions of some new species of fossil shells, from the Eocene at Claiborne, Alabama: Am. Jour. Sci., ser. 1, vol. 40. p. 103, pl. 1, fig. 23, 1840.

Mitra pactilis, Lea, H. C., Catalogue of the Tertiary Testacea of the United States: Acad. Nat. Sci. Philadelphia, Proc., vol. 4, p. 101, 1848.

Mitra pactilis, D'Orbigny, A., Prodrome de paléontologie. . . . , p. 355, 1850.

Mitra clabornensis Conrad, T. A., Descriptions of new species of Cretaceous and Eocene fossils of Mississippi and Alabama: Acad. Nat. Sci. Philadelphia, Jour., ser. 2, vol. 4, pl. 47, fig. 6, 1860, figure only, no description.

Lapparia pactilis, Conrad, T. A., Catalogue of the Eocene and Oligocene Testacea of the United States: Am. Jour. Conchology, vol. 1, no. 1, p. 24, 1865.

Lapparia pactilis, Conrad, T. A., Check list of the invertebrate fossils of North America; Eocene and Oligocene: Smith. Misc. Coll., vol. 7, no. 200. p. 16, 1866.

Mitra (Lapparia) pactilis + Mitra dubia, De Gregorio, A., Monographie de la faune Éocénique de l'Alabama et surtout de celle de Claiborne de l'étage

Parisien: Annales de Géologie et de Paléontologie, livr. 7 and 8, pp. 72–73, 75, pl. 5, figs. 39, 49, 56–60, 1890.

Lapparia pactilis, in part, Dall, W. H., Contributions to the Tertiary fauna of Florida, with especial reference to the Miocene Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci., Trans., vol. 3, pt. 1, p. 79, 1890.

Turricula dubia, in part, + *Mitra (Mitreola) pactilis,* Cossmann, M., Notes complémentaires sur la faune éocénique de l'Alabama: Annales de Géologie et de Paléontologie, livr. 12, pp. 37, 38, 1893.

Lapparia pactilis, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 385–386, pl. 62, figs. 4, 6, 7, pl. 89, fig. 4, 1937.

Original description.—Subfusiform, with seven volutions, a single row of nodes on each except the two from the apex, which are smooth: apex papillated; spire elevated; columella with four folds: aperture nearly half the length of the shell.

Revised description.—Shell heavy, slender; apical angle 38° to 45°; spire one-half the length of the shell. Protoconch ovoid in outline, large, consists of 2½ whorls which are worn or etched in all specimens at hand. Nepionic spire whorls with numerous weak retractive axial ribs which develop obscure nodes and become obscurely shouldered. The nodes may gradually disappear or remain to the last whorl and the axial ribs disappear gradually. Spire whorls with a slight subsutural collar and very steeply sloping slightly concave, nodose shoulder which is placed near the anterior suture; nodes generally 15 per whorl, obscure, and elongate in the direction of the growth lines; a few obsolete spiral threads occur on the subsutural collar; spire profile straight-sided. Body whorl ovoid with a very steeply sloping shoulder which is ill-defined if the specimen has no nodes on the body whorl or obscurely defined if it has; spirals missing in most specimens but some have a few obsolete threads on the obscure subsutural collar; growth lines smooth and numerous. Aperture narrow, deeply emarginate at the base; outer lip slightly retractive, smooth within, and sharp-edged; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up in the shell; the 4 folds are arranged according to increasing strength and decreasing inclination, the most anterior fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Figured topotype (Pl. 45, fig. 3), length 33 mm., width 13 mm.; figured topotype (Pl. 45, fig. 5), length 30 mm., width 12 mm.

Observations.—This species is farthest in evolution from the original spinose stock of the genus. It is characterized by the absence of spines, the nearly complete absence of a shoulder, and the nearly complete absence of spiral threads on the body whorl. The nodes of *L. pactilis*, if present, are elongate in the direction of the growth lines while in other Lapparias they are elongate parallel with the direction of coiling.

As pointed out by De Gregorio and confirmed by Cossmann, *Lapparia pactilis* is very similar to *Mitreola labratula* Lamarck (see Pl. 45, fig. 7). This similarity is indeed quite remarkable. Nevertheless, the differences between these two species are large enough and significant enough to separate them in different, although related, genera. *Mitreola labratula* has a thickened and slightly reflected outer lip, the parietal and columellar callus are thick in comparison with *Lapparia*. The outer lip of *Mitreola labratula* is slightly swollen at one place forming an indistinct tooth which is more pronounced in other species of the genus. The protoconchs of *Mitreola* and *Lapparia* are very similar. The chief differences between these two genera lie in the apertural characters. However, it should be pointed out that species of the genus *Lapparia* other than the extreme species, *L. pactilis* (Conrad), are not at all similar to *Mitreola* species in general appearance.

Type data.—Five syntypes, No. 13576, in Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. Figured topotypes (Pl. 45, figs. 3, 5) in Stenzel Collection, Austin, Texas.

Type locality.—Claiborne Bluff on left bank of Alabama River, Monroe County, Alabama.

Geologic horizon.—Gosport sand, Claiborne group, middle Eocene.

Distribution.—Presumably widely distributed in the Gosport sand of Alabama. Reported by Gardner[17] from the Gosport sand of

[17]Gardner, Julia, Recent collections of upper Eocene Mollusca from Alabama and Mississippi: Jour. Pal., vol. 13, p. 343, 1939.

Little Stave Creek, in sections 8 and 9, T. 7 N., R. 2 E., 4½ miles north of Jackson, Clarke County, Alabama.

LAPPARIA DUMOSA (Conrad)

Pl. 45, fig. 2

Mitra dumosa Conrad, T. A., *in* Wailes, B. L. C., Report on the Agriculture and Geology of Mississippi, p. 289, pl. 15, fig. 4, 1854.

Mitra (Lapparia) dumosa, Conrad, T. A., Observations on the Eocene deposit of Jackson, Miss., with descriptions of thirty-four new species of shells and corals: Acad. Nat. Sci. Philadelphia, Proc. for 1855, p. 260, 1855.

Lapparia dumosa, Conrad, T. A., Catalogue of the Eocene and Oligocene Testacea of the United States: Am. Jour. Conchology, vol. 1, p. 24, 1865.

Lapparia dumosa, Conrad, T. A., Check list of the invertebrate fossils of North America; Eocene and Oligocene: Smith. Misc. Coll., vol. 7, no. 200, p. 16, 1866.

Lapparia pactilis, in part, Dall, W. H., Contributions to the Tertiary fauna of Florida, with especial reference to the Miocene Silex beds of Tampa and the Pliocene beds of the Caloosahatchie River: Wagner Free Inst. Sci., Trans., vol. 3, pt. 1, p. 79, 1890.

Lapparia dumosa, Cossmann, M., Essais de paléoconchologie comparée, vol. 3, p. 111, 112, text fig. 14, pl. 8, fig. 8, 1899.

Lapparia dumosa, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, p. 286, pl. 62, figs. 1, 3, 1937.

Original description (Conrad, 1855).—Short-fusiform, volutions seven, direct, obliquely flattened above, with a series of transversely compressed, distant spines on the two largest whorls; on the contiguous whorl they become nodules; two whorls below the apex papillary, smooth; the next two longitudinally ribbed, and the others longitudinally striated or with prominent lines of growth; whole surface with revolving wrinkled lines; plaits four; beak profoundly ridged.

Revised description.—Shell heavy, slender; apical angle 37° to 40°; spire nearly one-half the length of the shell. Protoconch ovoid in outline, large, consists of 2½ polished, convex, and naticoid whorls with deeply channelled sutures. First nepionic whorl with about 20 retractive axial ribs which develop nodes and become shouldered after about one volution. The nodes gradually develop into flattened spines and the axial ribs disappear in later spire whorls. Spire whorls with a slight subsutural collar and steeply sloping spinous shoulder placed at the anterior third of the whorl; spines generally 11 per whorl, their tips flattened parallel with the direction of coiling; numerous fine wavy spirals overrun the whorls. Body whorl ovoid with steeply sloping spinous shoulder and excavated base; fine wavy spirals well developed over entire body whorl but somewhat wider spaced in the excavated basal portion. Growth lines smooth and numerous. Aperture narrow, deeply emarginate at the base; outer lip not retractive, smooth within, sharp-edged; deeply notched base of aperture extends into a short, twisted canal. Siphonal fasciole convex, wrinkled with growth lines, and spirally twisted. Columella bears 4 strong folds, which spiral all the way up in the shell; the 4 folds are arranged according to increasing strength and decreasing inclination, the anteriormost fold being the weakest and steepest of the four. Parietal wash thin; the parietal wall is slightly resorbed at the aperture.

Dimensions.—Figured topotype, length 27 mm., width 11 mm.

Observations.—This species is the genotype of the genus *Lapparia.* There is a complete gradation between typical *Lapparia dumosa* (Conrad) and *L. dumosa exigua* Palmer, both forms being end members of variation in the same species. *Lapparia dumosa* is easily distinguished from *L. dumosa exigua* by its prominent spines. The figured topotype of *L. dumosa* is not quite typical being not very prominently spinose. Specimens like the figured topotype are very similar to *Lapparia mooreana,* but have a larger protoconch, a thicker columella, a siphonal fasciole and columellar folds more nearly at a right angle to the vertical axis, and more subdued spiral threads, and lack the wrinkles on the subsutural collar. The latter two features make *L. dumosa* appear much smoother-surfaced than *L. mooreana.*

Type data.—Syntypes, No. 13575, in Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. Figured topotype (Pl. 45, fig. 2) in Stenzel Collection, Austin, Texas.

Type locality.—Moody's Branch, cliff on right bank of branch, near intersection of Peachtree Street and Poplar Boulevard, in northern part of Jackson, Hinds County, Mississippi.

Geologic horizon.—Moodys marl, Jackson group, upper Eocene.

Distribution.—Reported from the Moodys marl of Louisiana and Mississippi.

LAPPARIA DUMOSA var. EXIGUA Palmer

Pl. 45, figs. 4, 6, 8, 9

Lapparia dumosa var. *exigua* Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 386–387, pl. 62, figs, 2, 5.

Original description.—Shell stout; nucleus typical; general characters shown by the illustration.

The variety differs from *L. dumosa* in the absence of large spines and in having slightly coarser spiral threads over the entire surface. Some specimens have incipient nodes or poorly developed spinose nodes on the body whorl or lower whorls of the spire. While *dumosa* has 6–8 spines, *exigua* has 10 or more nodes.

Although the young *L. pactilis* is spirally striate, the adult is smooth. Some specimens are nodose. *L. exigua* differs from *pactilis* in being coarsely striate, and in the character of the obscure nodes. The nodes in *L. exigua* when present are incipient spines and are situated as in *L. dumosa*, near the midline of the whorls. In *L. pactilis* they are longitudinal and extend from the midline to the suture below. They are the remnants of longitudinal folds which are stronger in the adolescent stages.

Dimensions.—Syntype, No. 3202, length 31 mm., width 13 mm.; syntype, No. 3203, length 32 mm., width 14 mm.; figured specimen (Pl. 45, fig. 4), length 30 mm., width 13 mm.; figured specimen (Pl. 45, fig. 6), length 26 mm., width 10 mm.

Observations.—There is a complete gradation between typical *Lapparia dumosa* (Conrad) and *L. dumosa exigua* Palmer, both forms being end members of variation in the same species. *Lapparia dumosa* is easily distinguished from *L. dumosa exigua* by its prominent spines.

Type data.—Two syntypes, Nos. 3202 and 3203, at Paleontological Research Institution, 126 Kelvin Place, Ithaca, New York. Figured specimens in Stenzel Collection, Austin, Texas.

Type locality.—One-half mile below Gibson's landing on right bank of Ouachita River, approximately 6 miles airline distance below Columbia, Caldwell Parish, Louisiana.

Geologic horizon.—Moodys marl, Jackson group, upper Eocene.

Distribution.—The following additional locality is represented by material collected by H. B. Stenzel in 1933:

Moody's Branch, cliff on right bank of branch near intersection of Peachtree Street and Poplar Boulevard in northern part of Jackson, Hinds County, Mississippi; Bureau of Economic Geology locality No. Miss-15; Moodys marl, Jackson group.

LAPPARIA GEORGIANA (Conrad)

Mitra georgiana Conrad, T. A., Descriptions of one new Cretaceous, and seven new Eocene fossils: Acad. Nat. Sci. Philadelphia, Jour., ser. 2, vol. 2, pt. 1, p. 39, pl. 1, fig. 4, 1850.

Original description.—Fusiform; spire turreted; volutions five or six, tuberculated, tubercles acute and extending over the inferior half of each volution; upper portion contracted and angulated; suture impressed; aperture elliptical, about half as long as the shell; columella with four plaits.

Observations.—Lack of material from Georgia makes it impossible to add to the original description of the species. Until additional material is found in Georgia or until the type becomes available for study the species remains doubtful.

Type data.—Unknown.

Type locality.—Georgia. It is not known in which part of Georgia this fossil was collected. Some of the other Eocene fossils described by Conrad in the same article and collected by the same collector, J. Hamilton Couper, are said to come either from white limestone or Burr-stone of Palmyra, Lee County, or limestone of Brainbridge, Baker County.

Geologic horizon.—Unknown.

PLATE 43

PAGE

Cryptochorda stromboides (Hermann), x2 802

1. Specimen, Bureau of Economic Geology No. 12631.

   From Frèsville, Manche, France; formerly Collection Chantegrain, Maintenon, France; Lutetian, middle Eocene.

Cryptochorda mohri (Aldrich), x2 798

2. Monotype.

   From Lisbon bluff, Monroe County, Alabama; Aldrich Collection, Geological Department, The Johns Hopkins University, Baltimore, Maryland; Lisbon formation, Claiborne group, middle Eocene.

Cryptochorda eureia Stenzel & Turner, n.sp., x2 800

3. Holotype.

   From gully tributary to McDaniel Creek, Leon County, Texas; Bureau of Economic Geology locality No. 145-T-36; Viesca glauconitic marl member of Weches formation, Claiborne group, middle Eocene.

Cryptochorda stenostoma Stenzel & Turner, n.sp., x2 802

4. Monotype.

   From Smithville, Bastrop County, Texas: Bureau of Economic Geology locality No. 11-T-2; Viesca glauconitic marl member of Weches formation, Claiborne group, middle Eocene.

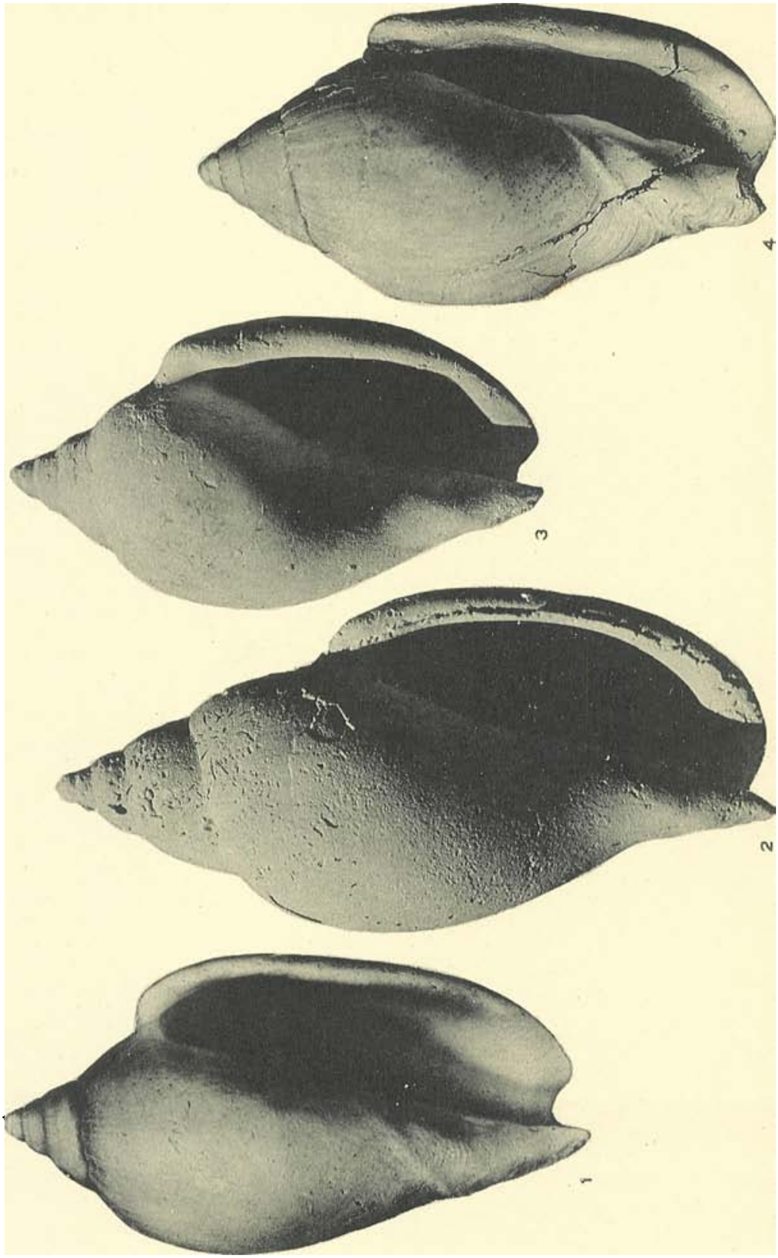

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PLATE 44

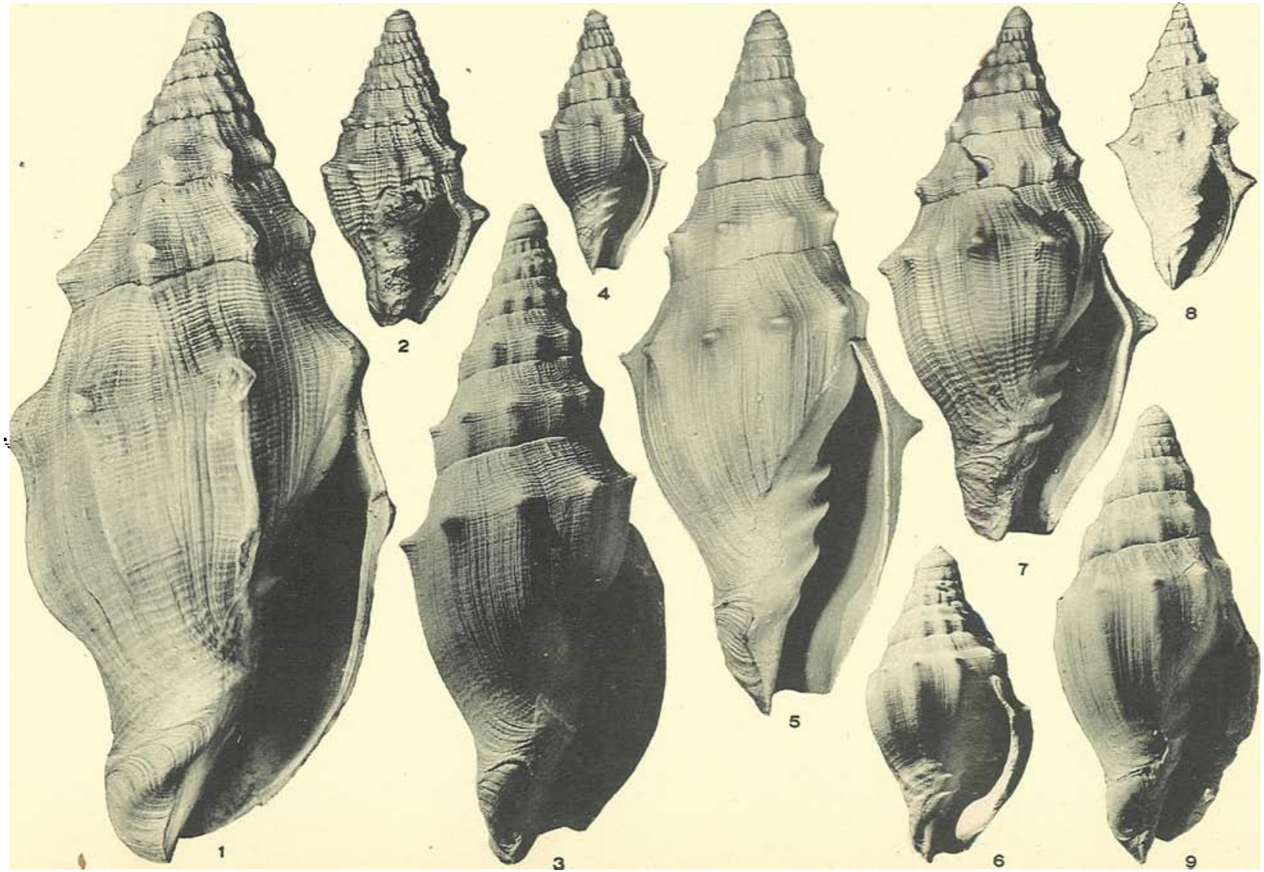
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PLATE 45

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Lapparia crassa Stenzel & Turner, n.sp., x2	813

1. Paratype.

   From Little Brazos River, Brazos County, Texas: Bureau of Economic Geology locality No. 21–T–1; Wheelock member of Crockett formation, Claiborne group, middle Eocene.

Lapparia dumosa Conrad, x2 819

2. Topotype.

   From Jackson, Hinds County, Mississippi; Bureau of Economic Geology locality No. Miss–15; Moodys glauconitic marl, Jackson group, upper Eocene.

Lapparia pactilis (Conrad), x2 816

3, 5. Topotypes.

   From Claiborne bluff, Monroe County, Alabama; Gosport sand, Claiborne group, middle Eocene.

Lapparia dumosa var. *exigua* Palmer 821

4, 6. Specimens, x2.

   From Jackson, Hinds County, Mississippi; Bureau of Economic Geology locality No. Miss–15; Moodys glauconitic marl, Jackson group, upper Eocene.

8. Syntype as figured by Palmer (Pl. 62, fig. 2), x1.2.

   From near Gibson's landing, Caldwell Parish, Louisiana; Moodys marl, Jackson group, upper Eocene.

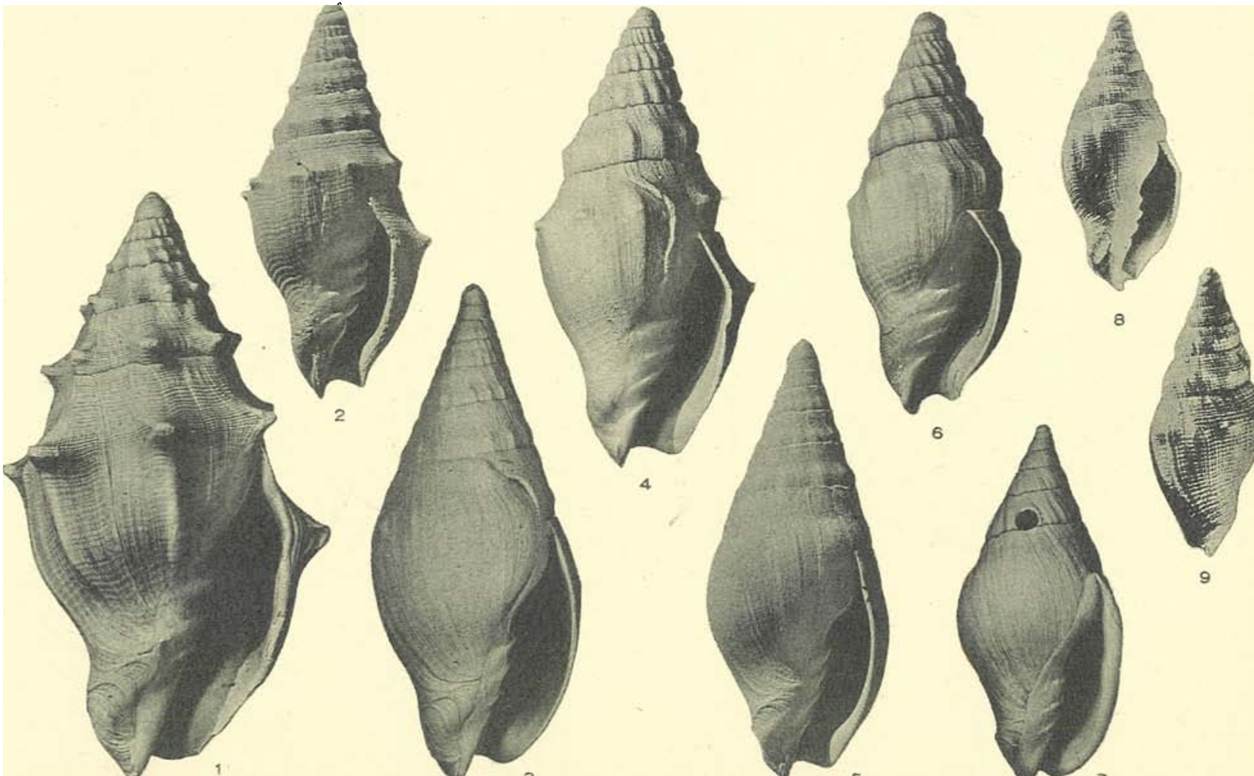
9. Syntype as figured by Palmer (Pl. 62, fig. 5), x1.2.

   From Creole Bluff near Montgomery, Grant Parish, Louisiana; Moodys marl, Jackson group, upper Eocene.

Mitreola labratula (Lamarck), x2 805

7. Specimen, Bureau of Economic Geology No. 12294.

   From Grignon, Seine & Oise, France; formerly Collection Chantegrain, Maintenon, France; Lutetian, middle Eocene.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TURRITELLIDAE FROM THE PALEOCENE AND EOCENE OF THE GULF COAST

H. B. Stenzel and F. E. Turner

In the course of studies in the Tertiary of the Texas Coastal Plain the need of a comprehensive compilation of all species described from the Gulf and Atlantic Coastal Plain became very much apparent. Such a compilation was begun in 1938. It is intended to make this compilation available to the public in the form of a card index similar to the Devonian portion of the "Type Invertebrate Fossils of North America" published by the Wagner Free Institute of Science, Philadelphia, Pennsylvania. Among the groups of fossils which have been compiled already[1] are the gastropod family Turritellidae. During the examination of this family the writers recognized several new species and added observations to species already known. These species are presented in this paper.

The Turritellidae are one of the most prolific groups of Tertiary fossils. The number of species discernible is large, and almost every species is represented by numerous individuals. Some species are so prolific of variants that it is necessary to have very large collections in order to be able to comprehend the full scope of variation possible within a species even at one locality. The outstanding example of such variability is *Turritella carinata* Isaac Lea from the Gosport sand of Alabama. Such variable species present considerable difficulties to the paleontologist.

On the other hand, some of the species are important as guide fossils. For instance, at the present time *Turritella arenicola* Conrad is in the center of interest as a guide fossil. This species had hitherto been known only from the upper Eocene Jackson group and was considered a reliable guide fossil for that group. However, recently its range has been extended;[2] it has been recognized in marine lentils of the Creola member of the Yegua formation. This discovery extends its range to the uppermost beds of the Claiborne group. Such discoveries have added greatly to the interest in the Turritellidae.

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[1]Other groups which are already compiled are the nautiloids, the brachiopods, and the gastropod genera *Cryptochorda* and *Lapparia*.

[2]Stenzel, H. B., The Yegua problem Univ. Texas Pub. 3945, pp. 847–901, 1939 [1940].

Issued June, 1940.

The Turritellidae have recently been treated comprehensively by Edgar Bowles.[3] This excellent paper has been of great value to the present work and is of great importance for the study of the Tertiary faunas.

Some of the material used in this paper was collected by H. B. Stenzel under a grant-in-aid from the National Research Council. Grateful acknowledgment of this aid is made.

Class GASTROPODA

Order CTENOBRANCHIATA

Family TURRITELLIDAE

Genus TURRITELLA J.B.A.P.M. de Lamarck, 1799

Prodrome d'une nouvelle classification des coquilles: Soc. d'Histoire Nat. Paris, Mém., p. 74.

Genotype.—*Turbo terebra* Linné, living in the western Pacific Ocean, by monotypy.

TURRITELLA FEMINA Stenzel

Pl. 46, figs. 11–13

Turritella femina Stenzel, *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, pp. 87, 89, 107, pl. 6, fig. 14, 1931.

Turritella femina, Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas: Univ. Texas Bull. 3232, pp. 644, 647, 815, 1933.

Turritella femina, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, p. 203, pl. 26, fig. 5, 1937.

Turritella dutexata, Bowles, Edgar, The Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, p. 285, pl. 31, fig. 2, 1939. Not *T. dutexata* Harris.

Description.—Apical angle 13° juvenile, 14° to 22° adult; spire profile concave near the apex. First two apical whorls smooth; at end of second volution appear 2 lirae of which the anterior appears slightly earlier and is slightly higher; these two primaries are prominent in the juvenile stage and remain larger than any other

[3]Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, pp. 267–336, 1939. In this paper Bowles follows a correlation recently proposed by C. W. Cooke (Cooke, C. W., Equivalence of the Gosport sand to the Moodys marl: Jour. Pal., vol. 13, pp. 337–340, 1939). The upper Claibornian Gosport sand is correlated with the lower Jacksonian Moodys marl and the name Gosport sand is suppressed. This correlation has not been accepted by other stratigraphers.

rib during the entire growth of the shell, giving even the adult whorls a slightly bicarinate appearance. One-half volution later a third, weaker, primary lira appears posterior to the two; on sixth whorl a secondary lira appears next to the posterior suture; on eighth whorl a secondary lira appears between the two posterior primaries and another secondary between the anterior suture and the most anterior of the 3 primaries; on ninth whorl appears a fourth secondary lira between the two anterior primaries. Additional spirals are added on the whorl chiefly posterior of the 2 prominent primaries and some of these spirals may reach the size of the secondaries, so that the adult whorls may have up to 9 larger ribs and numerous fine threads between them. The ribs and threads are usually arranged by alternating sizes.

The adult whorl shape is highly inflated with the greatest width at the 2 major primary lirae.

Observations.—This species is related to *T. dutexata* Harris from which it is readily distinguished by the much greater number of ribs; *T. femina* differs from *T. dutexata lisbonensis* Bowles by the concave spire profile and the inflated whorls.

Turritella femina Stenzel and *T. femina oligoploka* Stenzel are end members of a continuous series of variants.

Type data.—Holotype and numerous paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Bluff on right bank of Cobb Branch near its head, 0.6 mile northwest of Camp Creek schoolhouse, on Buck McBride's 134-acre tract; Jose Maria Viesca survey, eastern Robertson County, Texas. Compare Marquez quadrangle, scale 1/62500, U. S. Geological Survey.

Geologic horizon.—Viesca member, Weches formation, Claiborne group, middle Eocene.[4]

Distribution.—Weches formation of central and east Texas.

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[4]For stratigraphic terms used, compare:

Stenzel, H. B., The Yegua problem: Univ. Texas Pub. 3945, pp. 847–904, 1939 [1940].

————, The geology of Leon County, Texas: Univ. Texas Pub. 3818, 1939.

————, A new formation in the Claiborne group. Univ. Texas Bull. 3501, pp. 267–279, 1936.

Plummer, F. B., Cenozoic systems in Texas *in* The geology of Texas, Univ. Texas Bull. 3232, pp. 519–818, 1933.

TURRITELLA FEMINA OLIGOPLOKA Stenzel, n.subsp.

Pl. 46, figs. 7–10

Description.—Apical angle 20° juvenile, 12° adult; spire profile convex. Adult whorls with 3 equal spiral ribs of which the two anterior ones are a little closer together; these 3 spiral ribs are the primaries; late in the adult stage a fourth rib develops out of and remains near the posterior suture; in old age the whorls become a little loosely coiled; through this loose coiling a rib is bared at the anterior suture; normally this rib marks the edge of the body whorl base; early in the adult stage of many specimens a secondary spiral appears between the 2 posterior primary spirals. Adult whorl shape convex, but not inflated.

Observations.—This subspecies is represented by numerous specimens at the type locality, but there are a few specimens which are transitional to typical *T. femina* Stenzel. Therefore, *T. femina oligoploka* and *T. femina* are end members of a series.

The subspecies has essentially the same rib pattern as *T. femina,* but it has fewer ribs, a slenderer spire, a convex spire profile, and a less inflated whorl shape. In general appearance *T. femina oligoploka* resembles *T. dutexata* Harris, with which it has been confounded. In *T. dutexata* there are two primary spirals which are prominent in the juvenile and adult stages; also its whorls are broader and lower in comparison with those of *T. femina oligoploka.*

The subspecific name is derived from the Greek ὀλίγος, few, and πλόκος, braid, and refers to the ribbing of the species.

Type data.—Numerous syntypes in Stenzel Collection, Austin, Texas.

Type locality.—North ditch of Concord-Centerville county road, 0.6 mile southeast of Robbins crossroads, in south corner of J. M. Powell 100-acre tract, in south corner of R. M. Tyus survey, Leon County, Texas; Bureau of Economic Geology locality No. 145–T–1; compare H. B. Stenzel, The Geology of Leon County, Texas: Univ. Texas Pub. 3818, 1939.

Geologic horizon.—Viesca member, Weches formation, Claiborne group, middle Eocene.

Distribution.—Weches formation of east Texas.

TURRITELLA DUTEXATA Harris

Pl. 46, figs. 4–6

Turritella dutexata Harris, G. D., New and otherwise interesting Mollusca from Texas: Acad. Nat. Sci. Philadelphia, Proc. for 1895, p. 82, pl. 9, fig. 8, 1895.

Turritella dutexata, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, pp. 198, 199, pl. 26, figs. 2, 3, 4, 1937. Not figs. 1, 8, 9.

Not *T. dutexata,* Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, pp. 285–286, pl. 31, fig. 2, 1939 = *T. femina* Stenzel.

Original description.—Whorls (in a complete specimen) about 15; all marked by two subcentral carinal lines together with one small one just below and one just above the suture.

Besides the ornamentation shown on the specimen figured, there are usually about four spiral striae on each whorl between the upper carinal and subsutural line; between the two strong carinal lines there is often a faint stria; likewise one often appears just below the lower carina. When fully striated this species bears a general resemblance to *T. arenicola* and *T. arenicola* var. *branneri,* but may be distinguished at once by the persistency of the bicarinate feature of the whorls to the very apex. The apical whorls of *T. arenicola* and variety are unicarinate somewhat as in *T. carinata* H. C. Lea (*T. apta* De Greg.). It will be observed that in Meyer's carefully drawn figure of *T. carinata* H. C. Lea, in the Proc. Acad. Nat. Sci. Phila., 1887, p. 54, pl. 3, fig. 1, 1a, two carinae are represented on each whorl, but it is the upper one which predominates on the apical whorls; in *dutexata* it is the lower.

Revised description.—Apical angle 20°; shell profile straight. First 2½ whorls smooth and convex, next half whorl unicarinate at anterior third of whorl; a second primary carina is added posterior to the first on the third whorl. The two primary carinae are equal in size and continue prominent on all later whorls. A secondary lira is added on the sixth or seventh whorl just anterior to the suture; one or two secondary lirae are added next to the first secondary on later whorls. Adult whorls have 2 strong and equal primary carinae in the anterior half of the whorls, 1 to 3 weak secondary lirae near the posterior suture, perhaps one weak secondary lira at the anterior suture, and numerous obsolete threads covering the entire whorl; whorls slightly inflated, inflation increasing with age. Characteristic of this species is the bare appearance of the adult whorls save for the two conspicuous primary spirals.

Observations.—The second paragraph of Harris' description includes other species besides *T. dutexata.*

Secondary ribs and less conspicuous primary carinae are present on *T. dutexata lisbonensis* Bowles; trilirate adolescent whorls are present on *T. nasuta brazita* Stenzel & Turner; adult whorls of *T. femina* Stenzel are more inflated and have many secondary lirae.

Turritella dutexata does not occur together with *T. femina* Stenzel or *T. femina oligoploka* Stenzel.

Type data.—Holotype, No. 1974, in Geology Department, The University of Texas, Austin, Texas.

Type locality.—From Orell's to Price's Crossing over Elm Creek, Lee County, Texas.

Geologic horizon.—Basal Landrum member, Crockett formation, Claiborne group, middle Eocene.

Distribution.—Crockett formation of Texas and Cook Mountain formation of Louisiana, both in Claiborne group, middle Eocene.

TURRITELLA OLA Plummer

Pl. 46, fig. 3

Turritella ola Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas: Univ. Texas Bull. 3232, p. 815, pl. 10, fig. 2, 1933.

Turritella ola, Gardner, J. A., The Midway group of Texas: Univ. Texas Bull. 3301, p. 291, 1935.

Turritella ola, Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, pp. 320, 321, 1939.

Original description.—Apical angle 18°, sculpture consisting of 2 narrow high spirals and faint posterior spiral line, whorls separated by a fine nearly invisible lira.

Observations.—Apical angle is 20° instead of 18°. A spiral rib separates the base from the sides of the body whorl; this rib is almost entirely covered on the spire and is the nearly invisible lira referred to by Plummer. This species is very similar to *T. dutexata* Harris but has an apical angle 2°–3° greater and maximum inflection of growth lines on or anterior to posterior spiral line instead of posterior to it.

Type data.—Holotype, No. P5387, in Plummer Collection, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Quarry and creek approximately 1 mile south of Ola, eastern Kaufman County, Texas.

Geologic horizon.—Rocky Cedar Creek limestone lentil of Kincaid formation, Midway group, Paleocene.

Distribution.—Known only from type locality.

TURRITELLA NASUTA BRAZITA Stenzel & Turner, n.subsp.

Pl. 46, figs. 1, 2

Description.—Apical angle, juvenile 14°–17°, adult 10°–12°; shell long, slender; spire profile very slightly convex. Adolescent whorls trilirate, the 2 anterior lirae slightly stronger and remaining so throughout the shell. Adult whorls usually with 4–5 sharp spiral ribs, the fourth rib appearing near the suture posterior to the 3 primary ribs; occasionally a fifth and even sixth secondary are added between the primary ribs. Many fine striae between the ribs. Whorls vary in shape from straight-sided to slightly convex; greatest diameter at the anterior primary rib. Growth lines sinuous with maximum inflection slightly posterior to middle primary rib. Base of body whorl sharply set off from the sides by a flange. On the spire this flange is hidden by the suture.

Turritella nasuta brazita resembles *T. dutexata* Harris and *T. femina oligoploka* Stenzel in the adult ribbing; it is distinguished from *T. dutexata* by the trilirate adolescent whorls, the greater number of ribs on adult whorls, and lesser convexity of its whorl shape; it is distinguished from *T. femina oligoploka* by the greater number of ribs on the adult whorls, the lesser convexity of its whorl shape, and the more sharply raised spiral ribs. It differs from typical *T. nasuta* Gabb in the much greater strength of ribbing, particularly of the two anterior primaries.

Type data.—Holotype and numerous paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Little Brazos River, upstream from bridge of State highway No. 21, 9.4 miles west of Bryan, Brazos County, Texas; Bureau of Economic Geology locality No. 21–T–1.

Geologic horizon.—Wheelock member, Crockett formation, Claiborne group, middle Eocene.

Distribution.—Crockett formation of central and east Texas.

TURRITELLA TURNERI Plummer

Pl. 47, figs. 16, 17

Turritella turneri + *Turritella*, n.sp. Plummer, F. B., Cenozoic systems, *in* The Geology of Texas: Univ. Texas Bull. 3232, pp. 625, 815, pl. 10, figs. 10, 10a, not p. 583, 1933.

Turritella mortoni turneri, Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States: Bull. Am. Pal., vol. 7, p. 195, pl. 23, figs. 4, 5 (only), 1937.

Turritella dumblei turneri, Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, p. 304, 1939.

Original description.—Apical angle 17½°, sculpture consisting of 5 unequal spirals, anterior spiral the largest, shape of whorl strongly convex, posterior whorl slope slightly longer than anterior.

Observations.—Three spirals developing from primary lirae usually show stronger on the adult whorls than subsequently developed lirae of which there may be either 1 or 2. Major spirals may be either 4 or 5 in number and are usually finely beaded. Fine revolving striae appear between the lirae early in the development of the shell. Shell profile straight to slightly concave. The whorls are not strongly convex as stated by Plummer, but rather angulated near the posterior suture, making the suture appear deeply channelled. Distinguished from *T. infans* Stenzel & Turner, n.sp., by the concave profile of the shell, narrower apical angle, and more pronounced striation between the 4 or 5 major revolving ribs.

Type data.—Four syntypes, No. P5419, in Plummer Collection, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Old copper prospect 4½ miles northeast of Harwood, Alsabrook place, Pullen survey, Caldwell County, Texas.

Geologic horizon.—Marquez shale member, Reklaw formation, Claiborne group, middle Eocene.

Distribution.—Marquez shale member and lower and middle part of Queen City formation in central Texas.

TURRITELLA POLYSTICHA Stenzel & Turner, n.sp.

Pl. 47, fig. 11

Turritella turneri, in part, + *Turritella* cf. *T. abrupta* Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas: Univ. Texas Bull. 3232, pp. 583, 815, pl. 10, fig. 6, 1933.

Description.—Shell small; apical angle 28° juvenile, 20° adult; spire profile convex; first three whorls smooth; sculpture consisting of several fine spiral threads begins on fourth whorl. Adult whorls with a rounded angulation near the anterior as well as near the posterior suture, making the sutures deeply channelled. Anterior angulation more conspicuous and one-third whorl height removed from the suture, posterior angulation about one-fourth of the whorl height removed from the other suture. The broad band between the angulations is slightly concave. Sculpture of adult whorls 17 spiral threads partly alternating in strength; three of the threads on some individuals are slightly stronger than the remainder; the lower one of the three is located on the anterior angulation of the whorl. Growth lines forming nearly a perfect, gently curved sigmoid; greatest retraction located between posterior angulation and the middle of the whorl, reflection beginning on the anterior angulation and continuing to the anterior suture.

Observations.—Plummer in 1933 referred this species to *T. abrupta* Conrad, which name seems to be a typographical error for *T. obruta* Conrad. Typical *T. obruta* Conrad is a middle Eocene Gosport sand fossil and has very little similarity to *T. polysticha.*

The specific name is derived from the Greek πολύς, many, and στίχος, line, and refers to the ornamentation.

Type data.—Syntypes in Plummer Collection Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Solomon's Branch in bank of creek 100 yards west of road, 6 miles southwest of Elgin, Bastrop County, Texas.

Geologic horizon.—Seguin formation, Wilcox group, lower Eocene.

Distribution.—Known only from type locality.

TURRITELLA INFANS Stenzel & Turner, n.sp.

Pl. 47, figs. 12–15

Turritella dumblei n.var. Stenzel, *in* Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, p. 102, 1931.

Description.—Shell small; apical angle juvenile 20°–27°, adult 15°–20°; profile of early portion of shell convex. Whorls angulated near the anterior suture making the suture appear deeply channelled. First 3 whorls smooth, 3 primary lirae begin faintly on fourth whorl and increase rapidly in strength and persist as strong lirae on adult whorls, a fourth lira appears commonly immediately anterior to the suture. The anterior one of the 3 strong lirae is situated on the angle of the whorl. Additional lirae are rare. Beading on lirae very faint. Revolving striae between the strong lirae usually obsolete.

Distinguished from *T. turneri* Plummer by the convex profile of the early portion of the shell and the greater apical angle and lesser development of beading and fine striae between the strong lirae.

Type data.—Holotype and numerous paratypes in Stenzel Collection, Austin, Texas.

Type locality.—Stone City (or Moseley's Ferry), bluff on right bank of Brazos River at bridge of State highway No. 21 and bridge of Southern Pacific Railroad, Burleson County, Texas; Bureau of Economic Geology locality No. 26–T–1.

Geologic horizon.—Basal Wheelock member of Crockett formation, Claiborne group, middle Eocene, Texas.

Distribution.—Base of Crockett formation, Brazos and Burleson counties, Texas. The species is abundant in the basal 9 feet of the Crockett formation.

TURRITELLA CHIRENA Stenzel & Turner, n.sp.

Pl. 47, fig. 3

Description.—Apical angle 25°; spire profile slightly concave. Apical whorls with three primary spiral lirae which gradually become obsolete on adult whorls; one obsolete accessory spiral is added between the posterior primary rib and the suture. Whorls obtusely angulated near the anterior suture, making the sutures appear impressed. Whorls straight or slightly concave between the angulation and the posterior suture. Base of body whorl smooth with a slight angulation at the place which the suture occupies. Growth lines sinuous with maximum inflection slightly posterior to the middle of the whorl and sharply inflected at the basal angulation.

This species is distinguished from *T. carinata* Lea by the greater apical angle of the early whorls and straighter spire profile. It differs from some specimens of *T. carinata* by the early obsolescence of the lirae and from other specimens of *T. carinata* by the lack of a sharp carina. *Turritella carinata palmerae* Bowles has stronger and more numerous spiral lines.

Type data.—Holotype in Turner Collection, Agricultural & Mechanical College of Texas, College Station, Texas.

Type locality.—East ditch of road from Chireno to State highway No. 21, north of town, Nacogdoches County, Texas.

Geologic horizon.—Cane River formation, Claiborne group, middle Eocene.

Distribution.—Known only from type locality.

TURRITELLA PLUMMERI Stenzel & Turner, n.sp.

Pl. 47, fig. 1

Turritella kincaidensis in part Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas: Univ. Texas Bull. 3232, p. 815, pl. 10, fig. 3a; not fig. 3, 1933.

Description.—Apical angle 13°, apical whorls lost. Shell medium in size, thin-walled. Whorls with many fine revolving threads very nearly equal except at basal carina where they are slightly coarser; space between carina and anterior suture with 4 or more revolving threads; beading on spiral threads obsolete. Whorls angulated; anterior slope of angulation a little less than one half as long as posterior slope; both slopes straight.

Distinguished from *T. kincaidensis* Plummer by the angulated whorls and from *T. hilli* Gardner by the obsolete beading of the spiral lines, finer lines at the angle, and a straight rather than concave posterior slope above the angle.

Type data.—Monotype, No. 9072, in Plummer Collection, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Right bank of Colorado River one-fourth mile below the mouth of Dry Creek and approximately 1¼ miles below the Bastrop-Travis County line, Bastrop County, Texas.

Geologic horizon.—Kincaid formation, Midway group, Paleocene.

Distribution.—Kincaid formation of central Texas.

TURRITELLA KINCAIDENSIS Plummer

Pl. 47, fig. 2

Turritella kincaidensis Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas: Univ. Texas Bull. 3232, p. 815, pl. 10, fig. 3; not fig. 3a, 1933.

Turritella kincaidensis, Gardner, J. A., The Midway group of Texas: Univ. Texas Bull. 3301, p. 285, 1935.

Turritella kincaidensis, Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, pp. 320, 321, 1939.

Original description.—Apical angle 12.5°; sculpture consisting of 14 finely beaded lirae; shape of whorl convex with greatest diameter anterior.

Observations.—Plummer's original description is a composite description of two different species. The apical angle of the lectotype is 17°; whorls inflated with maximum inflation one-fourth the height of the whorl from the anterior suture and with a pronounced concave constriction at the posterior suture.

Turritella plummeri Stenzel & Turner has a straight slope between the anterior and posterior angulation. *Turritella hilli* Gardner is angulated close to the anterior suture and has a whorl profile concave between the angulation and the posterior suture.

Type data.—Lectotype, No. 5388, in Plummer Collection, Bureau of Economic Geology, The University of Texas, Austin, Texas.

Type locality.—Quarry and creek approximately 1 mile south of Ola, eastern Kaufman County, Texas.

Geologic horizon.—Rocky Cedar Creek limestone lentil of the Kincaid formation, Midway group, Paleocene.

Distribution.—Known only from type locality.

TURRITELLA ARENICOLA DANVILLENSIS Stenzel & Turner, n.subsp.

Pl. 47, figs. 4, 5

Description.—Apical angle 24° juvenile, 14° adult; shell profile slightly convex. First two apical whorls smooth; two median, equal, and closely spaced primary revolving ribs appear on third whorl; as the anterior of these two ribs becomes gradually weaker and disappears on seventh or eighth whorl the other primary forms a prominent carina situated a little anterior to the median of the whorl; anterior primary reappears on ninth or tenth whorl and increases gradually in size until it becomes equal to the other on the adult whorls; 3 to 4 accessory ribs are added between the primaries and the posterior suture; a few fine threads arise between the ribs. Adult whorls convex with the greatest diameter at the level of the 2 primaries; ornamentation consists of 5 or 6 sharply raised spirals, of which the 2 anterior ones are most conspicuous, and a few scattered fine spiral threads; area just behind the suture excavated. Base of body whorl set off by a sharp spiral rib, which is hidden by the suture on the spire whorls. Incrementals most advanced at posterior suture, less so at anterior suture, to which they descend at a steep angle; sinus centers posterior to the primary rib.

This subspecies differs from typical *T. arenicola* Conrad by the usually more sharply raised spiral ribs, the smaller number of ribs and threads, the greater convexity of the adult whorls, and the short bicarinate stage on the apical whorls which precedes the usual unicarinate stage usual in the *T. arenicola* group.

Type data.—Syntypes in Stenzel Collection, Austin, Texas.

Type locality.—Bluff on right bank of Ouachita River at Danville Landing on boundary between Caldwell and Catahoula parishes, Louisiana; Bureau of Economic Geology locality No. La-9.

For exact location, compare Chawner, W. D., Geology of Concordia and Catahoula parishes: Louisiana Geol. Surv., Geol. Bull. 9, 1936.

Geologic horizon.—Danville Landing beds, upper Jackson group, upper Eocene.

Distribution.—Known at present only from type locality.

Genus MESALIA J. E. Gray, 1842

Synopsis of the contents of the British Museum, 44th edition, p. 61.

Genotype.—*Cerithium mesal* Adanson = *Turritella mesal* Deshayes = *Turritella brevialis* Lamarck, living off the north coast of Africa, by original designation.

MESALIA ALABAMIENSIS BOWLESI Stenzel & Turner, n. subsp.

Pl. 47, figs. 9, 10

Mesalia alabamiensis, Harris, G. D., The Midway stage: Bull. Am. Pal., vol. 1, p. 227, pl. 12, fig. 1, 1896.

Mesalia pumila, Bowles, Edgar, Eocene and Paleocene Turritellidae of the Atlantic and Gulf Coastal Plain of North America: Jour. Pal., vol. 13, pp. 325, 326, pl. 34, fig. 7, 1939.

Description.—Spire high, rather abruptly tapering, although not especially so for the genus. Whorls numerous, rounded, sharply constricted at the linear sutures. Sculpture consisting of two rather prominent revolving cords on the earliest whorls, with accessory revolving cords appearing both anterior and posterior to them on the fourth to the seventh whorls; secondary sculpture increasing rapidly in prominence until on adult whorls it is hardly distinguishable in degree of elevation from the two primary cords. Total number of revolving cords on the adult whorls variable, ranging from five to eight in a rather limited suite of specimens. Growth lines simple, gently arcuate, not reflexed. Aperture unknown.

Observations.—This subspecies resembles *M. alabamiensis* (Whitfield) much more closely than it does the figure of the type of *Mesalia pumila* (Gabb) under which name Bowles placed it. *Mesalia alabamiensis* has two faint revolving lirae on the early whorls, has very similar ribs on the adult whorls, and is of the same general character; *M. alabamiensis bowlesi* differs chiefly in having a better marked bilirate stage, more deeply inflected growth lines, more deeply impressed sutures, a tendency to carination of the whorls, and a smaller size.

Type data.—Syntypes in Stenzel Collection, Austin, Texas.

Type locality.—Graveyard Hill, Wilcox County, Alabama, northwest slope of hill occupied by State Graveyard, southeast quarter sec. 32, T. 12 N., R. 10 E.; 3 miles airline distance north of Oakhill; by private road 1.05 mile west of county road and 4.15 miles from

Oakhill crossroads; Bureau of Economic Geology locality No. Ala–19.

Geologic horizon.—Sucarnoochee formation, Midway group, Paleocene.

Distribution.—Sucarnoochee formation of Alabama and undifferentiated Midway group of Georgia and Arkansas.

MESALIA ALABAMIENSIS TETRADEIRAS Stenzel & Turner, n.subsp.

Pl. 47, figs. 6–8

Potamides alabamiensis, De Gregorio, A., Monographie de la faune Éocénique de l'Alabama et surtout de celle de Claiborne de l'étage Parisien: Annales de Géologie et de Paléontologie, livr. 7 and 8, p. 124, pl. 11, fig. 13a (?), 1890.

Description.—Shell medium in size; apical angle 30°–35° on early whorls, 22°–25° on adult whorls; earliest whorls bilirate; adult whorls with usually 4, rarely 5, strong narrow elevated revolving ribs, which are sharp crest-like except for the fourth from the posterior suture. This rib is high and flat-topped. Interspaces with exceedingly fine striae; slightly stronger striae between the anterior suture and the most anterior rib. The space at the sutures appears excavated because it lacks the crest-like ribs. Whorls convex.

Observations.—This species is very similar to *M. alabamiensis* (Whitfield) differing chiefly in having 4 to 5 revolving ribs instead of seven. *Mesalia alabamiensis bowlesi* Stenzel & Turner is a smaller species with a better marked bilirate stage and a tendency to an obscure angulation of the whorls.

The subspecific name is derived from the Greek τέτρα, four, and δειράς, ridge, and refers to the four large revolving ribs.

Type data.—Syntypes in Stenzel Collection, Austin, Texas.

Type locality.—Bells Landing on left bank of Alabama River west of Tinela, Monroe County, Alabama.

Geologic horizon.—Bells Landing marl, Tuscahoma formation, Wilcox group, lower Eocene.

Distribution.—Bells Landing marl, Tuscahoma formation of Alabama.

PLATE 46

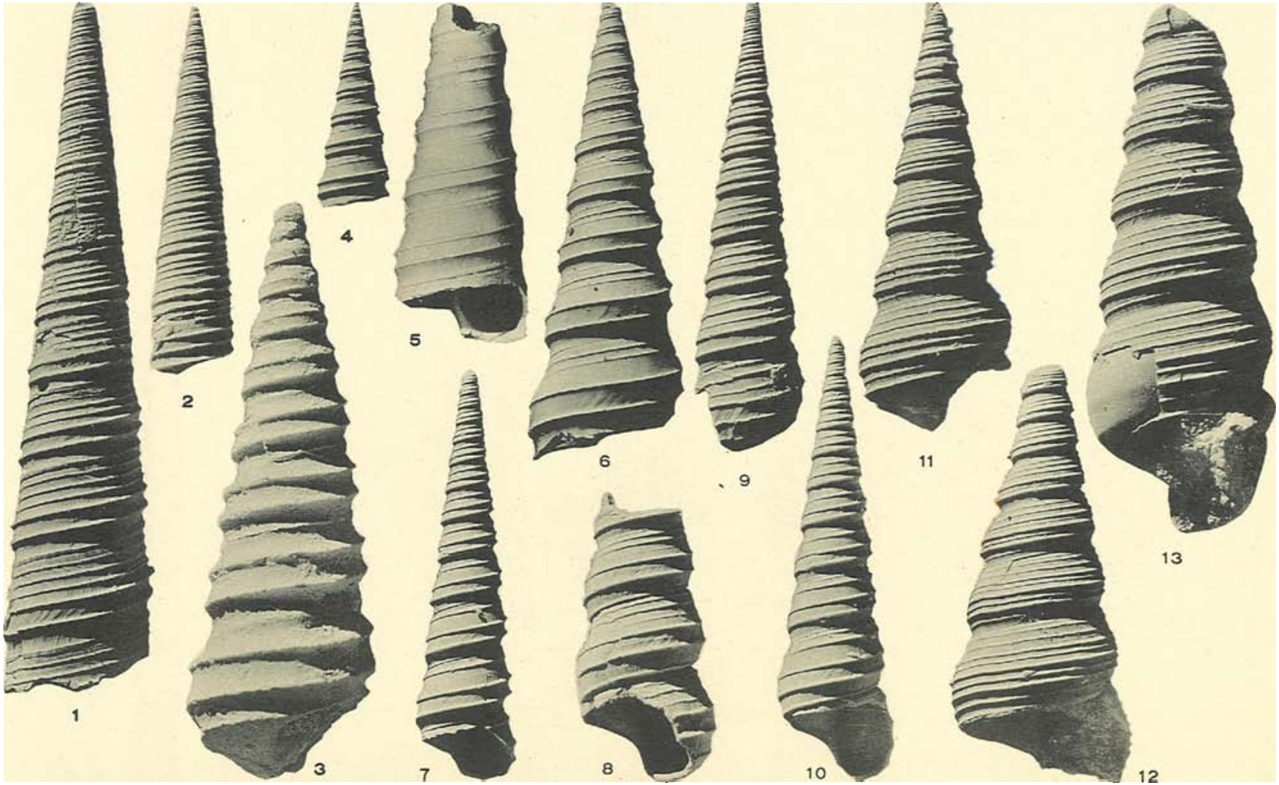
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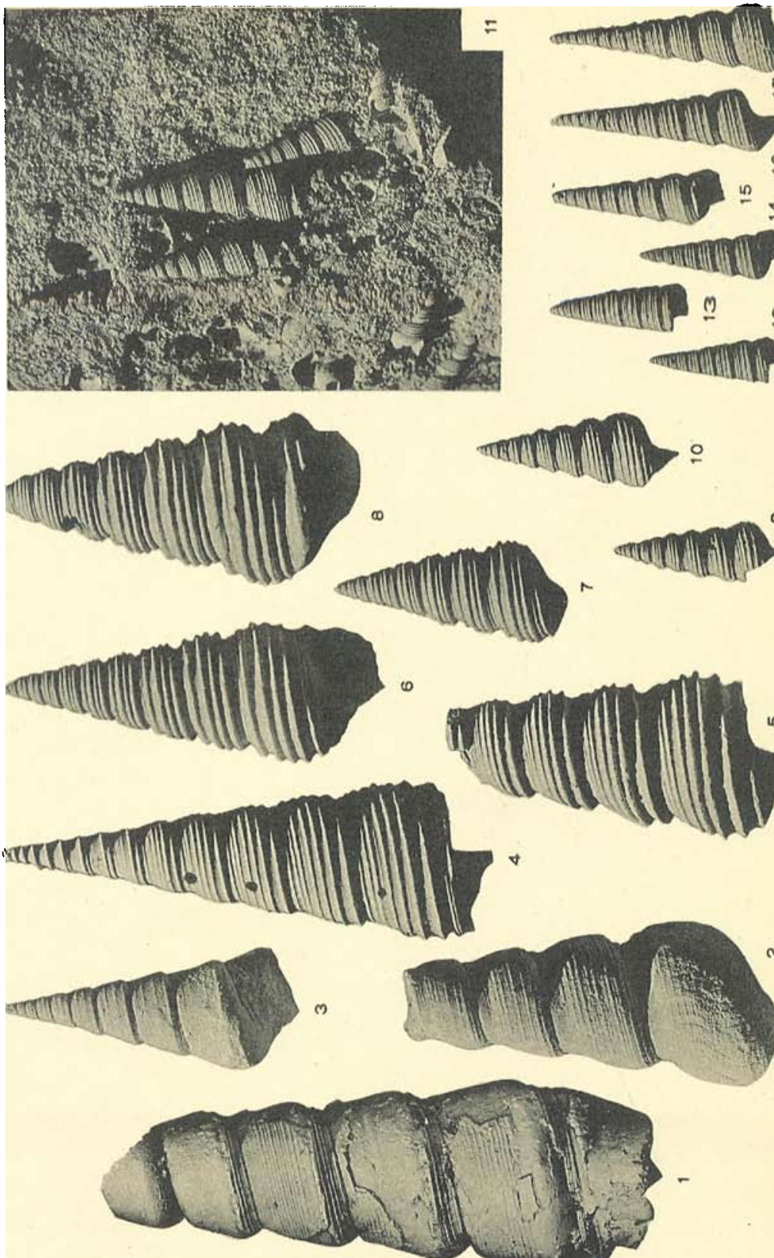
PLATE 47



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THE YEGUA PROBLEM

H. B. Stenzel

ACKNOWLEDGMENTS

The present report contains observations which go back several years and were slow in the making. Recently the work was speeded up for presentation at the convention of the American Association of Petroleum Geologists in New Orleans in March, 1938. Preliminary preprints of this paper were also released at that time. However, the present paper differs considerably from the preprint release. It would hardly have been possible to finish the work were it not for the cordial coöperation and help extended by friends and colleagues.

Paul L. and E. R. Applin, C. L. Baker, B. W. Blanpied and Roy T. Hazzard, Edgar Bowles, M. N. Broughton, Alexander Deussen, A. C. Ellisor, Julia A. Gardner, Marcus A. Hanna, W. B. McCarter, C. L. Moody, M. C. Israelsky, A. R. Mornhinveg, W. S. Pike, Jr., Helen J. Plummer, F. W. Rolshausen, T. W. Vaughan, A. C. Veatch, and E. A. Wendlandt have kindly helped and supplied much needed information. The Committee on Geologic Names, U. S. Geological Survey, has assisted in nomenclatorial questions.

The writer wishes to express his thanks for their generous help.

INTRODUCTION

The beds of the Yegua formation are a fairly well-defined, although not entirely homogeneous, unit. The formation is composed of such sedimentary rock types as lignites, lignitic shales, lignitic silty and sandy shales, and brown or gray lignitic sands. Among these the brown, silty or sandy, poorly bedded or poorly sorted, lignitic clay-shales predominate. All rock types occurring in the formation have the common bond of containing lignitic matter, although the content varies in wide degree from bed to bed. That the unit is a well-defined one may be gathered from the fact that it took the early geological explorers of Texas but two years to outline the formation roughly and largely correctly from one end of Texas to the other. Particularly E. T. Dumble[1] recognized early

[1]Dumble, E. T., The Cenozoic deposits of Texas. Jour. Geol., vol. 2, p. 552, 1894.

Issued June, 1940.

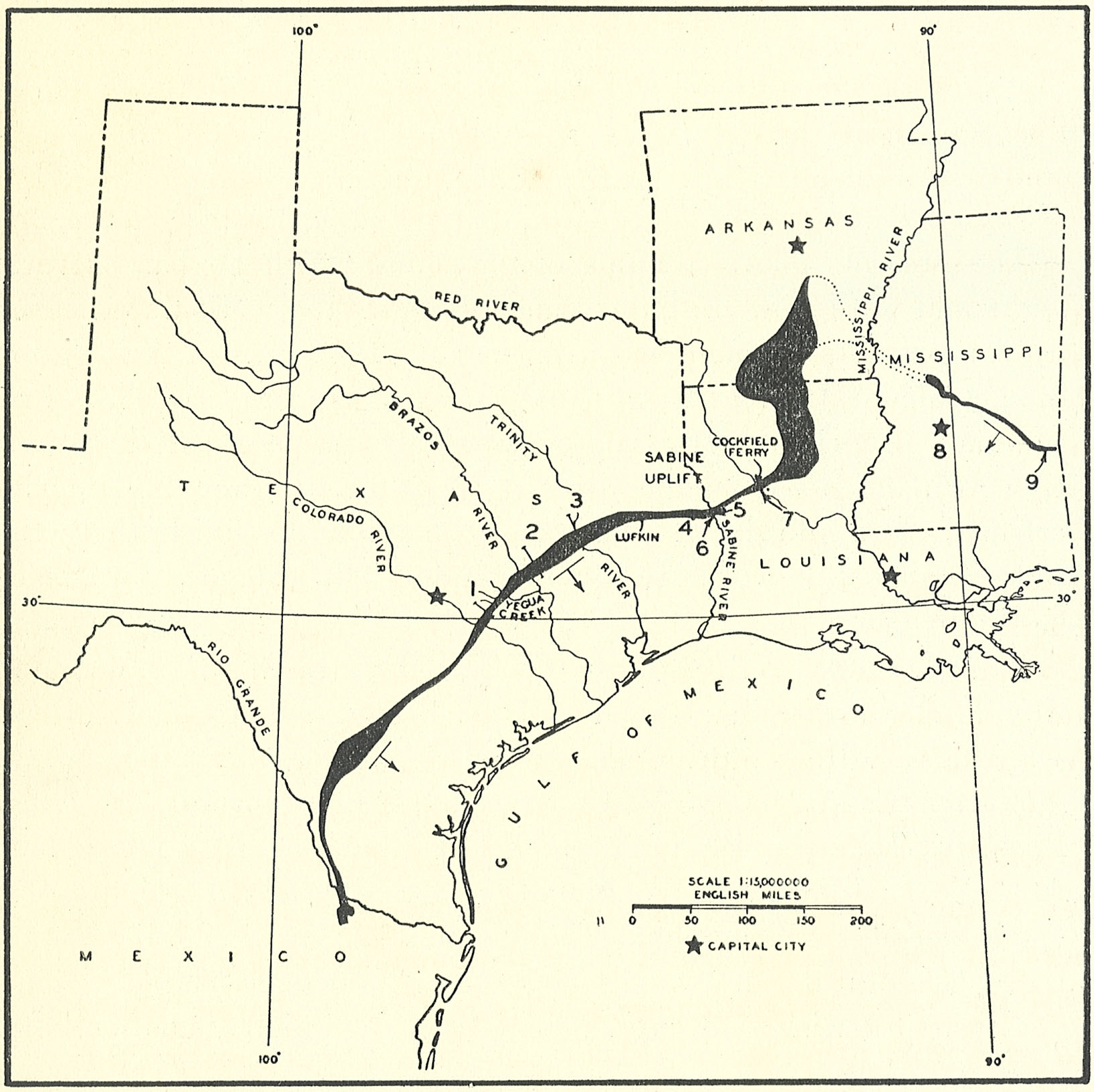

Fig. 129. Map of the Yegua outcrops. Numbers refer to sections or localities discussed in the text. 1, Bastrop County section. 2, Robertson and Brazos County section. 3, Leon, Madison, and Grimes County section. 4, Pineland. 5, Housen Bayou. 6, Robinson's Ferry. 7, Creole Bluff near Montgomery on Red River. 8, Moodys Branch in Jackson. 9, Garland's Creek. Outcrops of the Yegua formation are shown in solid black.

that the sedimentary types of the Yegua belong together. William Kennedy[2] also noticed early the importance of silicified wood as a characteristic component of the Yegua beds. He wrote: "In many places they contain quantities of silicified wood, forming a strong contrast with the beautifully opalized wood of the succeeding deposits."

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[2]Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Surv., 3d Ann. Rept., p. 59, 1892.

THE STRATIGRAPHIC PROBLEM

In spite of the well defined nature of the Yegua beds numerous difficulties have arisen. Two illustrations of the difficulties encountered may be related here. When the new geologic map of the State of Texas was being compiled by the United States Geological Survey it was found that geologists placed the lower boundary of the Yegua formation at different horizons, stratigraphically as much as 250 feet apart. As a result the location of the boundary lines on maps differed as much as 5 miles. Even the final edition of the map has not entirely eliminated these discrepancies. Another result of this uncertainty as to the placing of the base of the Yegua is miscorrelations of beds. An example of these miscorrelations is to be found in F. B. Plummer's account of the Tertiary of Texas.[3] There the correlation of the central Texas with the east Texas Claiborne column is erroneous. The columns were taken from two authors who located the base of the Yegua in a different manner. As a result, the line which connects the base of the Yegua from one column to the other does not connect homotaxial beds. The Yegua-Crockett contact line should instead be nearly level between these two columns. These two examples demonstrate that there is urgent need for revision or redefinition of the boundaries of the Yegua.

If the Yegua formation is a fairly well defined unit, why then do such difficulties arise? They are in a great measure due to the nonmarine nature of the formation. Nonmarine formations always have presented difficulties in correlation. One needs only to mention as classical examples of such correlation problems the Wealdon of southern England and the Laramie problem in this country. The chief cause of the difficulties is that the most characteristic Yegua outcrops have not yielded a marine fauna. We do not know how marine Yegua fossils would look and cannot compare them with those of the over- or underlying marine formations.

Only the lowermost and uppermost beds of the thick Yegua formation carry some fossil shells at a few, rare localities. The uppermost beds carry fossils at only two obscure localities, on Sabine River in Texas and Red River in Louisiana. The lowermost

[3]Plummer, F. B., Cenozoic systems in Texas, *in* The Geology of Texas. Vol. I. Stratigraphy: Univ. Texas Bull. 3232, p. 612, 1932 [1933].

Yegua beds carry fossil shells in Mexico and in the Rio Grande region[4] of Texas only. Oyster beds make their appearance there. But the fauna of these oyster beds is poor in number of species although it is rich in individuals, a condition characteristic of brackish water faunas. The beds contain perhaps only three or four species which are merely brackish water forms and useless for stratigraphic correlation.[5] However, the bulk of the thick Yegua formation is devoid of fossil shells.

The problem is therefore not so much the nature, composition, and origin of the Yegua formation itself as the location and nature of its upper and lower boundaries. In order to understand and define these boundaries it is necessary to study the under- and overlying formations in detail. Hence, the following pages are devoted largely to an account of the under- and overlying formations. In other words, I shall not describe but circumscribe the Yegua formation in the following pages.

Lower Boundary

The location of the lower boundary of the Yegua has been a problem of long standing. The problem requires comparative stratigraphic studies extending over a long distance along the outcrops of the Yegua formation. For this reason it has remained open for so long a time. To attack the problem one will have to consider stratigraphic sections in east and central Texas.

The first section considered here is well exposed in east Texas along U. S. highway No. 75 in Madison and Leon counties[6] on the west side of Trinity River. Briefly the section is as follows: At the bottom are the nonmarine Sparta sands, which are 250 feet thick and composed of slightly lignitic sands and brown or gray, silty shales. The Sparta sands grade upward by interfingering into the Stone City beds,[7] which are about 80 feet thick and composed of

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[4]Trowbridge, A. C., Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U. S. Geol. Surv., Bull. 837, pp. 131–132, 1932.

[5]Kane and Gierhart seem to think that a more richly fossiliferous Yegua facies carries from Mexico into Texas. However, it is impossible to state definitely that these beds are not Crockett. Compare Kane, W. G., and Gierhart, G. B., Areal geology of Eocene in northeastern Mexico. Bull. Amer. Assoc. Petr. Geol., vol. 19, p. 1375, 1935.

[6]Stenzel, H. B., The Geology of Leon County, Texas: Univ. Texas Pub. 3818, 1939.

[7]Stenzel, H. B., A new formation in the Claiborne group: Univ. Texas Bull. 3501, pp. 267–279, 1936.

The Stone City beds have been traced for considerable distances to both sides of the type locality. On Sabine River they are 40 feet thick and crop out on the long west-east reach of the river above Columbus.

glauconitic, sandy layers and some brown shales. The Stone City beds are at least partly marine and have yielded a characteristic fauna. A widespread disconformity cuts off the top of the Stone

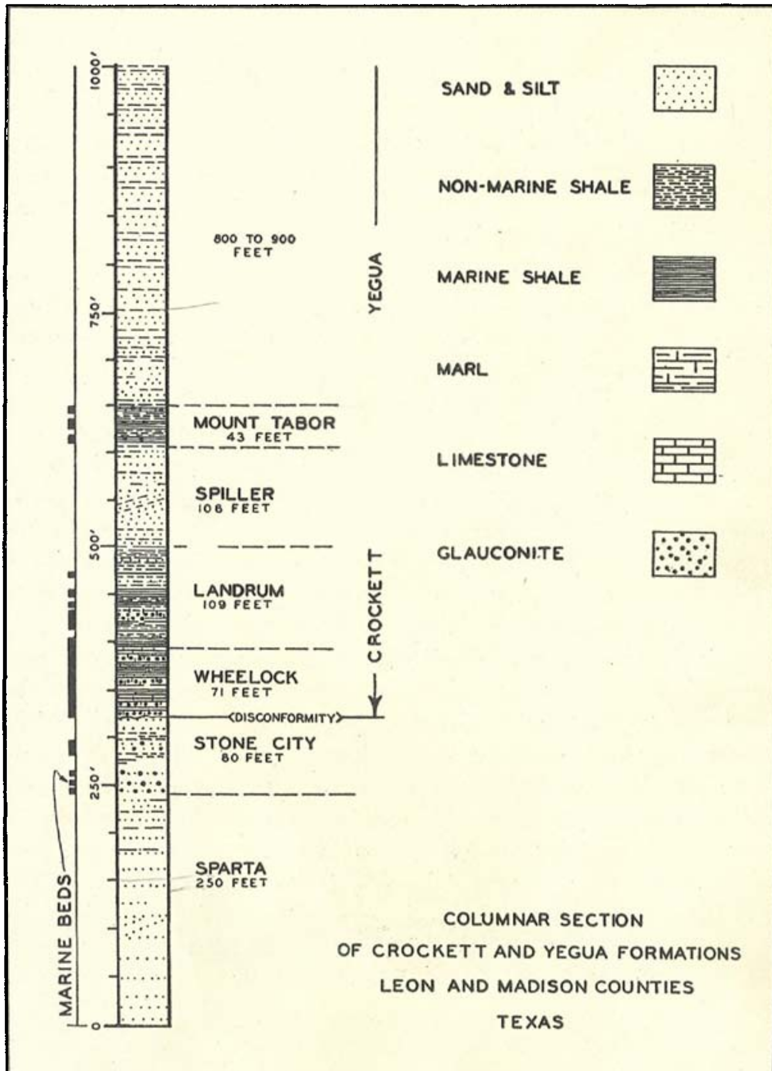

Fig. 130. Columnar section of Crockett and Yegua formations in Leon and Madison counties, Texas.

City beds abruptly. Above this disconformity lies the Crockett[8] formation and higher up the Yegua. However, certain useful subdivisions of these formations may be recognized and mapped easily in this region. The first member above the disconformity is composed chiefly of gray, calcareous, fossiliferous, glauconitic, marine shales and marls. Impure limestones, highly glauconitic beds, and various concretions are common but subordinate. This member is 70 feet thick and is called the Wheelock member (Ewk). The type locality is Wheelock Prairie in Brazos and Robertson counties where 80 years ago the first Crockett fossils were collected. These fossils were described by W. M. Gabb.[9] The Wheelock marls change upward partly by interfingering and partly by imperceptible transition into the Landrum shale member (Eld). The lower part of this member consists of black-brown, unctuous, non-glauconitic shales of brackish water origin with some interbedded lentils of calcareous, glauconitic, marine shales and glauconites. But these lentils are subordinate. Upward the Landrum shales become less unctuous and plastic and more silty. The black-brown, uniformly distributed color gives way to a speckled brown produced by lignitized plant remains. This upper part of the Landrum shale member is nonmarine. The entire Landrum shale member is 110 feet thick. The type locality is in southeastern Leon County on Two-Mile Creek, which flows through J. L. Landrum survey. At the top the Landrum shales become sandy and are interbedded with sand beds of increasing thickness. This transition and interfingering lead over to the next higher member, the Spiller sand (Esp). The Spiller sand consists chiefly of gray or brown, lignitic sands with some brown shale partings. The thickness is 105 feet. The type locality is near Spiller's Store in southeastern Leon County. Above the Spiller sand lies the Mount Tabor shale member (Emt), which consists of brown, partly calcareous shales. The shales contain subordinate beds of glauconitic marl and black, impure limestone, both rich in marine fossils. This member is apparently partly brackish and marine in origin. The thickness is about 45 feet. The type locality is at Mount Tabor School in northern Madison County. The Mount

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[8]Crockett is used here as originally defined; compare Wendlandt, E. A., and Knebel, G. M., Lower Claiborne of east Texas, with special reference to Mount Sylvan dome and salt movements: Bull. Amer. Assoc. Petr. Geol., vol. 13, pp. 1347–1375, 1929. Some writers use Cook Mountain for Crockett. This usage prevails in Louisiana.

[9]Gabb, W. M., Descriptions of new species of American Tertiary and Cretaceous fossils: Jour. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 4, pp. 375–406. 1860.

Tabor contains the stratigraphically highest marine Claiborne fauna of east Texas. The uppermost beds of the Mount Tabor contain in many localities a hard layer of glauconitic sandstone or calcareous clay-ironstone. This bed forms a prominent cuesta in many places. All beds above this member are nonmarine, although they combine to a thickness of 800 to 900 feet. At the base of these nonmarine beds one finds a lenticular sand body, the Bryan sand. This sand thickens and thins and is even absent in some places. It thickens at the expense of the overlying beds. The greatest known thickness of 122 feet was encountered in Rio Bravo Oil Company Lanza No. 2 core test in Brazos County. This basal sand is gray, loose, cross-bedded, and lignitic; it is an important water-bearing horizon. The type locality is along State highway No. 21 from 2.1 to 3.75 miles west of the courthouse in Bryan, Brazos County. The beds above the sand are variable; but gray, brown, or greenish-brown, silty, lignitic shales predominate. Silicified wood makes its first appearance in these beds.

All geologists agree that these silicified wood-bearing beds belong to the Yegua; they also agree that the Wheelock member belongs to the Crockett (or Cook Mountain) formation. But where the members in between belong is not agreed upon.

If one wants to draw a boundary between the Crockett (or Cook Mountain) on one hand and the Yegua formation on the other one has a great number of choices. One could place that boundary anywhere between the top of the Wheelock member and the base of the Bryan sand. However, the boundary one chooses must be not only convenient but also logical. Certain convenient places located at lithologic boundaries suggest themselves immediately.

(1) For instance, a possible place for that boundary would be the base of the Bryan sand. This choice has the advantages of placing all fossiliferous and marine beds in the Crockett and leaving the overlying Yegua well defined as an entirely nonmarine formation, but it has the great disadvantage of including in the Crockett (or Cook Mountain) formation four unlike, marine and nonmarine members. In that case the Yegua would be exclusively a nonmarine formation, but the Crockett a mixed formation containing large thicknesses of nonmarine beds.

(2) Another possible place for the boundary would be the top of the Wheelock member. In that case the Crockett (or Cook Mountain) would be a single unit of gray, calcareous, glauconitic,

marine shales and marls, but the Yegua would have in its lower part three different members, the Landrum, Spiller, and Mount Tabor. Two of these members are marine or partly marine. This choice has evidently its advantages and disadvantages like the first choice.

(3) A third possible place would be the top of the Landrum member. This boundary would have the advantage of placing all sands in the Yegua and restricting the Crockett to a unit composed of shales only. But the disadvantage of this arrangement is that the upper part of the Crockett would contain lignitic nonmarine beds and the lower Yegua would contain marine, calcareous, and shaly layers in the Mount Tabor member.

Any other place would have the disadvantage of leaving the Crockett as well as the Yegua composed of unlike, marine and nonmarine members. All places proposed here and any other place that might be proposed have their advantages as well as their pronounced disadvantages. No matter where the boundary is put, one cannot restrict both the Crockett and the Yegua to lithologically uniform beds. One place is as good as another, and it is impossible to decide in favor of any one place on a reliable or scientific basis so long as one considers the lithologic composition of the beds alone. In order to arrive at a logical conclusion one must use other evidence besides lithologic composition. Such additional evidence is the fauna and flora of the beds and the presence of available breaks in sedimentation. In the following pages the writer will give four reasons for placing the Crockett-Yegua boundary at one particular level. For these same reasons any other level for the Crockett-Yegua boundary is definitely excluded.

The fauna of the fossiliferous members of this section is well known today, because extensive collections of the larger fossils have been made at several localities. The fauna of the Wheelock member, for instance, is well represented at Little Brazos River in Brazos County.[10] It consists there of several hundred well-defined

[10]Description of the location (Bureau of Economic Geology locality No. 21-T-1): On banks and in bed of Little Brazos River, from bridge of State highway No. 21 upstream for about 0.3 mile; 9.43 miles west of courthouse in Bryan by speedometer; in eastern part of W. Mathis survey, Brazos County. Best available topographic map: Brazos River (sheet 1), State Reclamation Department, Austin, Texas, advance sheet. For list of fossils, see Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, pp. 99–105, column 4, 1931. This locality is the same as No. 727 in Palmer, K. Van W., The Claibornian Scaphopoda, Gastropoda, and dibranchiate Cephalopoda of the southern United States: Bull. Amer. Pal., vol. 7, no. 32, p. 10, 1937. The description of locality No. 727 is given incorrectly in that book.

species. The fauna of the lower Landrum is best collected in Two-Mile Creek near Two-Mile Negro Church[11] in Leon County, where numerous exposures afford a good insight into the stratigraphy of the Landrum. This fauna is also very rich and varied in number of species. The fauna of the Mount Tabor is difficult to obtain because the shales of this member leach and disintegrate very rapidly, so that fresh exposures are scarce. However, fair collecting is found in Leon[12] and Burleson[13] counties.

The three members, Wheelock, Landrum, and Mount Tabor, have numerous species of large fossils in common. Most of the abundant and some of the rare Crockett species range through all three members. Examples of the former are *Dentalium minutistriatum* Gabb, *Corbula conradi* Dall, *Ficopsis texana* Harris, and *Latirus moorei* Gabb. Some of the species which occur in only one member are restricted to a small region and do not range far horizontally in the member. Such species are obviously local and cannot be used for stratigraphic correlation.

The striking feature of the three faunas is their similarity. They are so similar that it is at present impossible to tell the three members apart by their fossils. The three faunas are also clearly lower Claiborne faunas and are easily distinguished from such upper Claiborne faunas as the one from the Gosport sand at Claiborne Landing in Alabama. The presence of such a uniform fauna from the base of the Wheelock to the top of the Mount Tabor makes it impossible to place the Crockett-Yegua boundary anywhere else but above the Mount Tabor beds.

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[11]The best locality is Bureau of Economic Geology locality No. 145-T-71: left bank of Two-Mile Creek at first ford above iron bridge and Two Mile Church, between the fence of Emma & E. J. Houston land and fence of Gary D. Woods 300-acre tract but in west corner of Emma & E. J. Houston land (said to belong to Mr. King), T. L. Landrum survey, Leon County, Texas. Compare Stenzel, H. B. The Geology of Leon County, Texas: Univ. Texas Pub. 3818, 1939.

[12]Best locality in Leon County is Bureau of Economic Geology locality No. 145-T-80: Right bank of dry branch in woods about 200 feet below fence and tank in south corner of F. C. Wilson 100 acre tract, Felix A. Richardson survey, Leon County, Texas. (Above-mentioned fence is probably the west line of the survey.) Compare Stenzel, H. B., The Geology of Leon County, Texas: Univ. Texas Pub. 3818, 1939.

[13]The following locality is important. Jonas Tarver 40 acre tract, near southwest corner of A. Kuykendall survey about 5 miles southwest of Stone City, airline distance, eastern Burleson County, Texas. Compare Renick, B. C., and Stenzel, H. B., The lower Claiborne on the Brazos River, Texas: Univ. Texas Bull. 3101, p. 98, 1931. The stratigraphic position of the locality near Edge, Brazos County, Texas, mentioned in that report, is doubtful. It might be Landrum.

Among the foraminifera, *Ceratobulimina eximia* (Rzehak) has been found in the Wheelock and lower Landrum. It is not present in the upper Landrum and the Spiller sand, because both are nonmarine. It has not yet been found in the Mount Tabor member of the Brazos and Trinity river regions. In these regions the Mount Tabor has yielded so far only arenaceous forms, the calcareous forms having been leached by weathering presumably. However, it is expected that *Ceratobulimina eximia* (Rzehak) will be found because it occurs in the Mount Tabor member farther west in the Colorado River region.

Fossil plants are unfortunately very rare, and exploited localities are very few in spite of the diligent work of E. W. Berry and O. M. Ball. Such scanty data cannot give any reliable information for stratigraphic purposes. However, the occurrence of silicified wood is of importance to the problem.

Silicified wood, or rather chalcedonized wood, is common in some nonmarine formations of the Coastal Plain but is absent in others. For instance, the nonmarine Wilcox is rich in silicified wood, but the equally nonmarine Queen City and Sparta are almost free of it. Silicified wood is a sensitive indicator of certain conditions of nonmarine deposition. These conditions prevailed in Wilcox and Yegua times but did not exist during Carrizo, Queen City, and Sparta times.[14]

Silicified wood has not been found in nonmarine beds below the Bryan sand, such as the Spiller or upper Landrum beds, although these beds are nonmarine and have a composition similar to some beds above the Bryan sand. This significant fact emphasizes the unity of the Yegua beds from the Bryan sand up. Therefore, the presence of silicified wood in these beds favors the location of the Crockett-Yegua boundary at the base of the Bryan sand.

Breaks in sedimentation, that is, disconformities and the like, should be of utmost importance in this question. However, continued search for sedimentation breaks has failed to bring them to

[14]The importance of silicified wood as a special facies marker for certain nonmarine formations was pointed out to the writer by Dr. T. L. Bailey whose keen observations have contributed much to the knowledge of the Tertiary.

E. A. Wendlandt stated in a letter of April 18, 1938, that he had found silicified wood locally in a number of places in the Carrizo, Queen City, and Sparta formations within the east Texas basin. However, silicified wood is scarce in the Carrizo and Sparta but relatively more plentiful in the Queen City, according to Wendlandt. Nevertheless, in comparison with the Wilcox and Yegua, those formations are almost free of silicified wood.

light in the Wheelock, Landrum, and Spiller section, although numerous fresh exposures are available in that region. The Mount Tabor and Bryan are not so well exposed, but even in this section no indication of a break was found. It seems to the writer that the entire Crockett-Yegua series of beds is a conformable sequence with interfingerings or gradual transitions between succeeding members.

A. C. Ellisor[15] has indicated that the Yegua overlaps certain underlying beds in Texas west of Angelina County. The place of this overlap in the section under discussion would be between the Mount Tabor shale and the Bryan sand. Should this overlap prove to be present, it would be a third and weighty argument for the placing of the Crockett-Yegua boundary at the top of the Mount Tabor.

A fourth argument for this particular location of the boundary is obtained by mapping these members across country. The writer has been able to do some reconnaissance mapping from Trinity River westward to beyond Colorado River. Fortunately this region includes important lateral changes in the composition and nature of the beds and contains some of the most important type localities of older formation names. The sections to be compared now are the Leon and Madison County, the Robertson and Brazos County, and the Bastrop County sections. The four members, the Wheelock, Landrum, Spiller, and Mount Tabor, behave differently as they are traced westward. The Wheelock remains practically unchanged throughout the region. The Landrum member decreases in thickness rapidly. In Leon County it is 110 feet thick; in Brazos County at a distance of 45 miles from Leon County it has decreased to 50 feet without much change in composition. In Bastrop County, 60 miles to the west of Brazos County, the Landrum is still 50 feet thick. However, its composition has changed slightly to a more uniform, brown, gypsiferous or calcareous shale series containing a few silty shale beds at the base. The Spiller sand shows the most pronounced change westward. In Leon County it is 105 feet thick.

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[15] Ellisor, A. C., Correlation of the Claiborne of east Texas with the Claiborne of Louisiana: Bull. Amer. Assoc. Petr. Geol., vol 13, p. 1339, 1929.

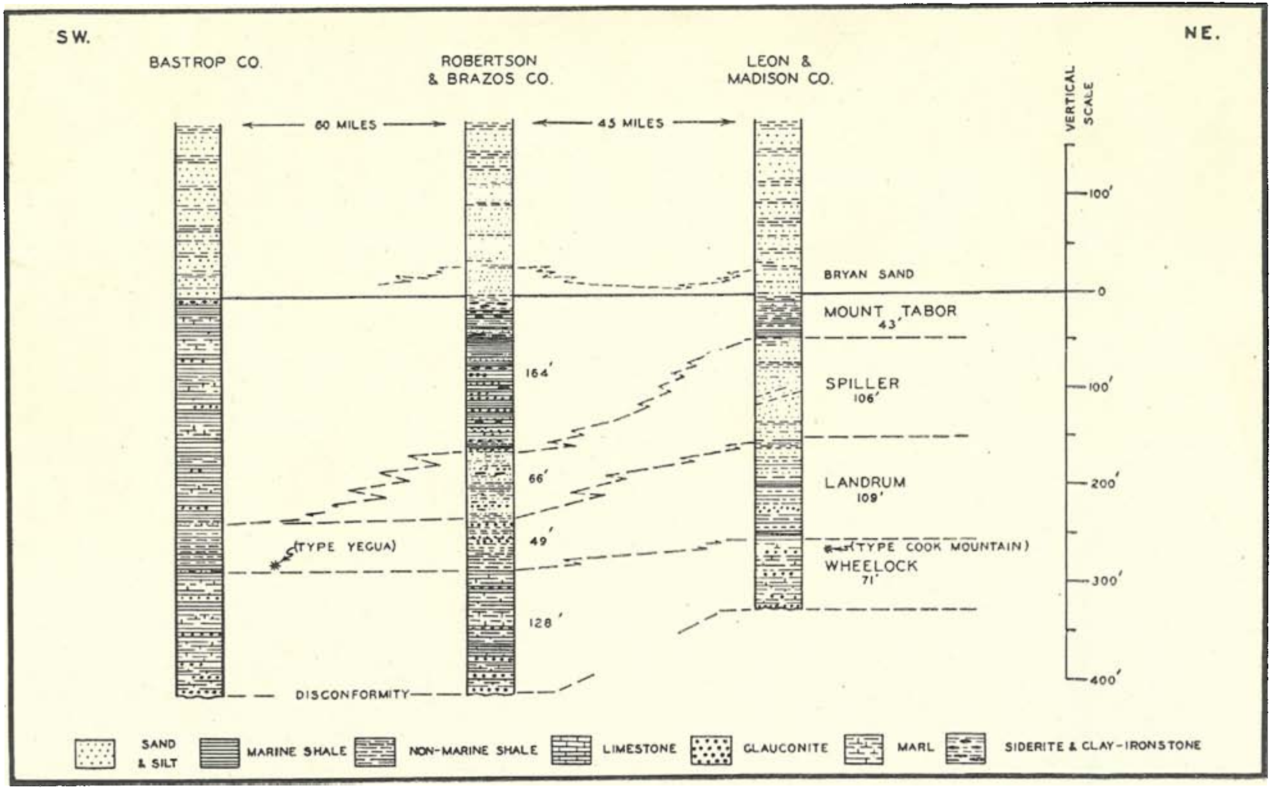

Fig. 131. Columnar sections of Crockett and Yegua formations in Texas.

In Brazos County it is 65 feet thick and has changed into a very clayey sand or sandy clay with few sand beds. This change apparently continues westward, because in Bastrop County the sand has almost disappeared. The only beds which might belong to the Spiller member are two or three sand beds, each of about 1 or 2 feet thickness, which occur at the top of the Landrum shales interbedded with them. These thin sand beds represent presumably the westernmost feather-edge of the Spiller sand body. The Mount Tabor shales are 45 feet thick in Madison County, but in Brazos County they attain a thickness of 165 feet. The beds which Renick and Stenzel called marine Yegua lentils in 1931 are in reality parts of the Mount Tabor member of Brazos and Burleson counties. The Mount Tabor continues as an important member westward and becomes more calcareous and marine. In Bastrop County it is rather similar to the Wheelock member; nevertheless, brown-colored, calcareous shales still predominate in the Mount Tabor. In this region the top of the Mount Tabor member is emphasized by a hard, glauconitic sand lentil, the Serbin sand lentil, which forms a prominent cuesta. This glauconitic layer is particularly prominent at its type locality, about 1¾ miles northwest of Serbin, Lee County.

The Wheelock–Mount Tabor section along and south of Colorado River consists of a unified, homogeneous series of more or less calcareous shales, because the Spiller sand has disappeared and the Wheelock, Landrum, and Mount Tabor have become more similar. On the other hand, the contrast between the unified Wheelock–Mount Tabor section and the overlying Yegua beds has become more pronounced. The unified lower section is calcareous, marly, marine, and devoid of silicified wood; the beds above the Mount Tabor are noncalcareous, lignitic, nonmarine, and rich in silicified wood.

In the region south of Colorado River no geologist has hesitated to place the Crockett-Yegua boundary at the top of the Mount Tabor member. It is the uniformly accepted boundary in that region. Were one to place the Crockett-Yegua boundary below the Mount Tabor, the result would be an impossible boundary. The lithologic differences within the Wheelock–Mount Tabor section are so slight that one could neither map nor use such a boundary. Also, the foraminifer *Ceratobulimina eximia* Rzehak, which is generally considered an important guide fossil of the Crockett, occurs in the

Colorado River region in the Mount Tabor as well as in the members below. For these reasons all geologists have agreed on the location of the Yegua-Crockett boundary south of Colorado River.

One must determine the location of the Crockett-Yegua boundary in east Texas by the same criteria that one uses in the region south of Colorado River. One cannot place the Mount Tabor in the Crockett in one region and in the Yegua in another. South of Colorado River the top of the Mount Tabor is the only possible place for that boundary. The same place must be chosen all along the strike. This is the fourth and perhaps most convincing argument for that particular location of the boundary.

As it happens, the location of the Yegua-Crockett boundary advocated here is exactly the same as that published by Wendlandt and Knebel[16] in 1929. The present study attests to the good judgment and insight of the field geologists who worked out the stratigraphy of that report.

Upper Boundary

In contrast to the lower boundary of the Yegua, the upper boundary has not presented such great difficulties until recently. Originally mistakes were made in the location of the upper limit of the Yegua in that here and there the brown shales of the Caddell formation of the Jackson group were included with the Yegua. These errors in mapping have now been recognized. As a consequence the upper boundary of the Yegua in Texas is well known and well defined. That this boundary is so well known and well defined is due largely to certain geologic conditions which are discussed below.

In Grimes County, the Yegua-Jackson contact is exposed in the road cuts 0.4 mile north of the store and road–T at Keith. The Yegua consists there of poorly bedded to massive, brown, lignitic, silty mudstone or clay which contains some lignitized plant remains. The overlying Jackson is composed of gray, loose, slightly glauconitic sand and red, indurated, richly glauconitic sandstones which are well bedded. They rest on a wavy erosion surface which bevels the Yegua bedding in places. The boundary between the

[16]Wendlandt, E. A., and Knebel, G. M., Lower Claiborne of east Texas, with special reference to Mount Sylvan dome and salt movements: Bull. Amer. Assoc. Petr. Geol., vol. 13, pp. 1347–1375, 1929.

Yegua and Jackson is sharp; a transition does not exist. Glauconite grains occur in the Jackson only, lignitized plant remains in the Yegua only.

In Brazos County, the freshest outcrops are in a deeply incised gorge of a right-hand tributary of Hopes Creek, in the oakwoods on Phillip Hensarling's land in the northern part of James Hope survey, about 5 miles south of College Station. There the uppermost Yegua consists of a massive, brown, silty clay which contains numerous twig-shaped pieces of dark brown clay. (Compare Pl. 48, fig. 2, and Pl. 49, fig. 3.) These may possibly be cavities produced by ancient plant roots and filled in during Yegua times. The upper boundary is uneven, wavy and clearly erosional. The Jackson above consists of soft, gray, marine sand with brown shale partings. The shale partings are well bedded but wavy; they are deposited on the ripple marks of the sands. Although the shale is uniformly brown it does not contain lignite fragments as the Yegua clay. A few feet above the contact, glauconitic sands appear in the Jackson section. Occasionally one finds borings extending from the Jackson into the Yegua for a few inches. Such borings are filled with Jackson materials.

Numerous other exposures in east Texas have similar Yegua-Jackson contacts. These disconformable Yegua-Jackson contacts are much too numerous to be explained as local, unrelated disconformities. They line up to form a widespread, regional disconformity possibly representing a large time interval. This conclusion is very much strengthened by observations in Louisiana and Mississippi which are discussed below. Hitherto, authors have stated generally that the Texas Jackson overlies the Yegua conformably.

Farther east, one of the best outcrops of the Yegua-Jackson contact is the bluff on the east or left bank of Red River, below the ferry and west of the cemetery, about 1 mile southwest of Montgomery, Grant Parish, Louisiana. The bluff is known as Creole Bluff, presumably from Creola, the original name of old Montgomery, which was built on the bluff. The section has been described by several authors.[17] A new, detailed description is given on pages 876–877 and Plate 51.

The Jackson Moodys marl at Creole Bluff is characterized by several large foraminifera, *Camerina moodybranchensis* Gravell and Hanna, *Operculina vaughani* Cushman, *Lepidocyclina mortoni* Cushman, and *Discocylina* sp. A Gravell and Hanna. These large foraminifera were described in detail by Gravell and Hanna.[18] The foraminifera are found in a gray-green, massive to poorly bedded, richly fossiliferous, calcareous and glauconitic marl, 5 feet thick. The marl contains near its base numerous large boulders. Boulders collected by the writer are up to 7 inches long and up to 4 inches thick; they weigh up to 5 pounds. (Compare Pl. 50 and Pl. 49, fig. 1.) Some, but not all, of the boulders are well rounded. The boulders are composed of a gray, dense, sparingly glauconitic limestone, which is probably of Tertiary age. Attached to the surface of the boulders are many sessile organisms, such as oysters, bryozoa, tubicolous annelids, corals, and alcyonarians. These animals require a solid substratum for attachment and growth. In addition the boulders are pock-marked with numerous holes which were made by boring mussels. Complete bivalve shells are preserved in natural position in some of their holes. These boring mussels also indicate that the boulders were hard and exposed to the sea water at Jackson time. This condition obviously excludes any possibility that the boulders are Moodys marl concretions. They are undoubtedly eroded fragments of rocks older than the bed which encloses them. The limestone composing the boulders is not known to the writer as an outcropping bed. It is probable that it does not exist as an outcrop today, because it may have been entirely destroyed by erosion during Moodys marl time. The boulders may not have been moved a very long distance from their source; nevertheless, all were moved sufficiently to acquire some rounding. As the boulders are numerous, large, and heavy

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[17]Vaughan, T. W., A brief contribution to the geology and paleontology of northwestern Louisiana. U. S. Geol Surv., Bull. 142, pl. 1, fig. 8, 1896.

Harris, G. D., and Veatch, A. C. A preliminary report on the geology of Louisiana: Louisiana Geol. Surv., Rept. for 1899, pp. 1—138, 1899.

Fisk, H. N., Geology of Grant and La Salle parishes: Louisiana Dept. Conservation, Geol. Bull. 10, pp. 94–96, 1938.

[18]Gravell, D. W., and Hanna M. A, Larger Foraminifera from the Moody's Branch marl, Jackson Eocene, of Texas, Louisiana, and Mississippi. Jour. Pal., vol. 9 pp. 327–340, 1935.

they must have required heavy wave action for transportation and erosion. Heavy wave action and numerous, large boulders could not have failed to erode deeply the ground over which they were moved. Or, to state the same idea in stratigraphic terms, wherever numerous, large boulders occur in marine Tertiary beds of the Coastal Plain there must be a large disconformity beneath. In this particular case the soft, sandy, lignitic shales of the underlying Yegua could not possibly have withstood the pounding of waves and boulders. A certain amount of the top of the Yegua must have been removed during Moodys marl time. This erosion is also clearly indicated by the slabs of Yegua shale, which are discussed below.

If it is correct to assume that a considerable thickness of Yegua beds was destroyed by the sea before and during the deposition of the Moodys marl, a possible explanation of the origin of these limestone boulders is apparent. The Yegua shale section which was destroyed by the early Moodys marl sea may have contained a limestone layer or perhaps a bed of lime concretions like the concretions found about 23 feet below the present top of the Yegua at Creole Bluff (compare bed (f) of the section on Pl. 51). The soft, shaly beds of the section were destroyed by wave action and the fine, broken-up material shifted out into the deeper parts of the sea, but the harder parts, that is, the lime concretions, were merely broken and rounded without being moved far down the slope. These boulders were perhaps only shifted back and forth while the surrounding shales were destroyed, so that the boulders were gradually let down as erosion continued.

This explanation of the origin of the boulders is confirmed by microscopic examination of the boulders. Under the microscope the boulder material consists of a uniform, very fine-grained, brownish calcite matrix in which are embedded numerous, small, angular quartz and fresh plagioclase fragments, a few small lignite fragments, a few foraminifera filled with iron sulphide, and a little brown mica. The material of the cannon-ball concretions is very similar in general appearance under the microscope. Indurated Moodys marl differs very much from these two. A sample of a Moodys marl lime concretion from Sabine River consists under the microscope of innumerable pieces of fossils, foraminifera as well as other. These pieces are held together by a gray, finely crystalline calcite matrix which contains also green and black glauconite and some angular quartz and fresh plagioclase fragments. The Moodys marl is chiefly a shell agglomerate with many different fossils, but the cannon-ball concretions and the boulders are mainly very fine-grained, silty limestones containing a few foraminifera only.

Large slabs of the underlying brown shale are included in some places within the green Moodys marl below the layer which contains the limestone boulders. These slabs were torn loose from the bottom of the sea in Moodys marl time and included in the marine deposits. In no case have these slabs been moved far. On the cliff face one can see where the slabs fit back into the rough surface of the underlying shale, or rather where they were broken out by the waves. These slabs were not moved more than 1 foot in nearly all cases. The slabs are to be considered part of the basal conglomerate of the Moodys marl. It is a peculiar kind of conglomerate, because the material, that is, the soft, brown Yegua shales, available to the waves in early Moodys marl time was peculiar and did not lend itself to the making of well-rounded, hard conglomerate boulders. That the slabs appear to have been moved only 1 foot is not surprising. Those slabs which were moved a larger distance were apparently broken up by the pounding of the waves and did not survive.

There are also other signs of a disconformity between the Jackson and the Yegua at Creole Bluff. Glauconitic marl is found below the basal, boulder-bearing layer of the Moodys marl. This glauconitic marl fills irregular, branching, pipe-like bodies which break in any direction through the Yegua beds below the boulder-bearing horizon. (Compare Pl. 49, figs. 1 and 2.) Some pipe-like bodies are even vertical. When these pipe-like bodies are dug out they are seen to connect upward with the overlying glauconitic marl beds of the Jackson but end blindly in the underlying beds. They extend as an average 1 foot down into the underlying beds, but rare examples have been found 7 feet down. The pipe-like bodies are filled with Moodys marl and Moodys marl fossils.

These pipe-like bodies are boreholes made by boring animals such as clams or crustaceans. They were made at the bottom of the Jackson sea in very shallow water and filled in during earliest

Jackson time by sediment sifting in from above. These boreholes remind one of the pipes at the base of the Austin chalk which were figured by L. W. Stephenson.

In the well-known outcrop in Moodys Branch at Jackson, Hinds County, Mississippi, the basal glauconitic Moodys marl of the Jackson group rests on a wavy, eroded surface of the Yegua. The bedding in the Yegua is cut by the erosion surface. There is, of course, no transition between Jackson and Yegua at that place; the boundary is sharp. This disconformity has already been suspected by W. H. Monroe[19] and indicated with a question mark by Stephenson, Logan, and Waring.[20]

Another excellent outcrop of the Yegua-Jackson contact in Mississippi is on Garland's Creek. The locality is in the northwest corner of section 28, R. 16 E., T. 1 N., about 3½ miles northeast of Shubuta, Clarke County, eastern Mississippi. Here again similar features may be observed at the base of the Moodys marl and a disconformity is clearly indicated. Irregular fragments of the underlying black shale lie in the 1-foot thick bottom layer of the Moodys marl. (Compare fig. 133.) There are also short boreholes in the underlying black shale bed. These boreholes contain among other foraminifera *Lepidocyclina mortoni* Cushman and *Camerina jacksonensis* Gravell and Hanna.[21]

Additional localities might be mentioned, but these would merely repeat the features which were described before. The three important localities in Louisiana and Mississippi, which were discussed above, may suffice to indicate that the disconformity at the base of the Moodys marl is well developed in the two states.

These Yegua-Jackson contacts are very similar to some of the disconformable contacts which L. W. Stephenson[22] has described from the Cretaceous. Stephenson's article on the unconformities

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[19]Monroe, W. H., The Jackson gas field, Hinds and Rankin counties, Mississippi: U. S. Geol. Surv., Bull. 831, pp. 7–8, 1932.

[20]Stephenson, L. W., Logan, W. N., and Waring, G. A., The ground-water resources of Mississippi: U. S. Geol. Surv., Water-Supply Paper 576, generalized section opposite p. 28, 1928.

[21]Stratigraphy and paleontological notes on the Eocene (Jackson group), Oligocene and lower Miocene of Clarke and Wayne counties, Mississippi, [Guidebook] 11th Annual Field Trip, Shreveport Geological Society, pp. 32–33, 1934.

Monsour, Emil, Micropaleontologic analysis of Jackson Eocene of eastern Mississippi: Bull. Amer. Assoc. Petr. Geol., vol. 21, pp. 80–96, 1937.

[22]Stephenson, L. W., Unconformities in Upper Cretaceous series of Texas: Bull. Amer. Assoc. Petr. Geol., vol. 13, pp. 1323–1334, 1929.

contains, in spite of its regrettable brevity, a wealth of information on the methods employed to detect Coastal Plain disconformities. Stephenson's criteria are particularly important because they are based on a wide experience and numerous observations in the field. The criteria are useful not only in the Cretaceous but also in the Tertiary. The Yegua-Jackson contacts are disconformities in the sense used by Stephenson and compare favorably with the Cretaceous disconformities discussed by that author.

The disconformity which marks the top of the Yegua formation has generally been overlooked. However, its widespread nature makes it a rather important stratigraphic break in the Coastal Plain. The disconformity is traceable from Brazos County, Texas, through Louisiana into eastern Mississippi. Presumably it extends southwestward beyond Brazos County for a considerable distance. In Texas the Caddell formation of the Jackson group rests on the disconformity; in extreme eastern Texas, Louisiana, and Mississippi the Moodys marl rests on it. That the boundary between the Yegua and the overlying Jackson group is so well known and so well defined is due largely to this widespread, regional disconformity.

It seems, offhand, that such a clear-cut disconformity should make it possible to outline the top of the Yegua formation so definitely that difficulties would not appear. Nevertheless, some difficulties have arisen recently. They derive chiefly from one locality on Sabine River in Texas. A clear understanding of that locality is of utmost importance in this problem. The locality is discussed in considerable detail in the following paragraphs.

A. C. Veatch[23] investigated the outcrops along Sabine River with great care at a time when detailed observations of the Tertiary were rare. In his remarkable work the formations were mapped across the river from Louisiana into Texas. All outcrops along the river were described, mentioned, or located by numbers on the map. Of special interest are his localities 29 and 30. Locality 29 is above Robinson's Ferry; the exposure consists of a 6-foot shelf of dark-colored clay which belongs to the unfossiliferous, lignitic shales of the Yegua, for which Veatch used the name Cocksfield Ferry beds

[23]Veatch, A. C., The geography and geology of the Sabine River, *in* A report on the geology of Louisiana: Louisiana Geol. Surv., vol. 6, pp. 101–148, 1902.

Important additional information was given by A. C. Veatch in a letter to H. B. Stenzel dated February 26, 1938.

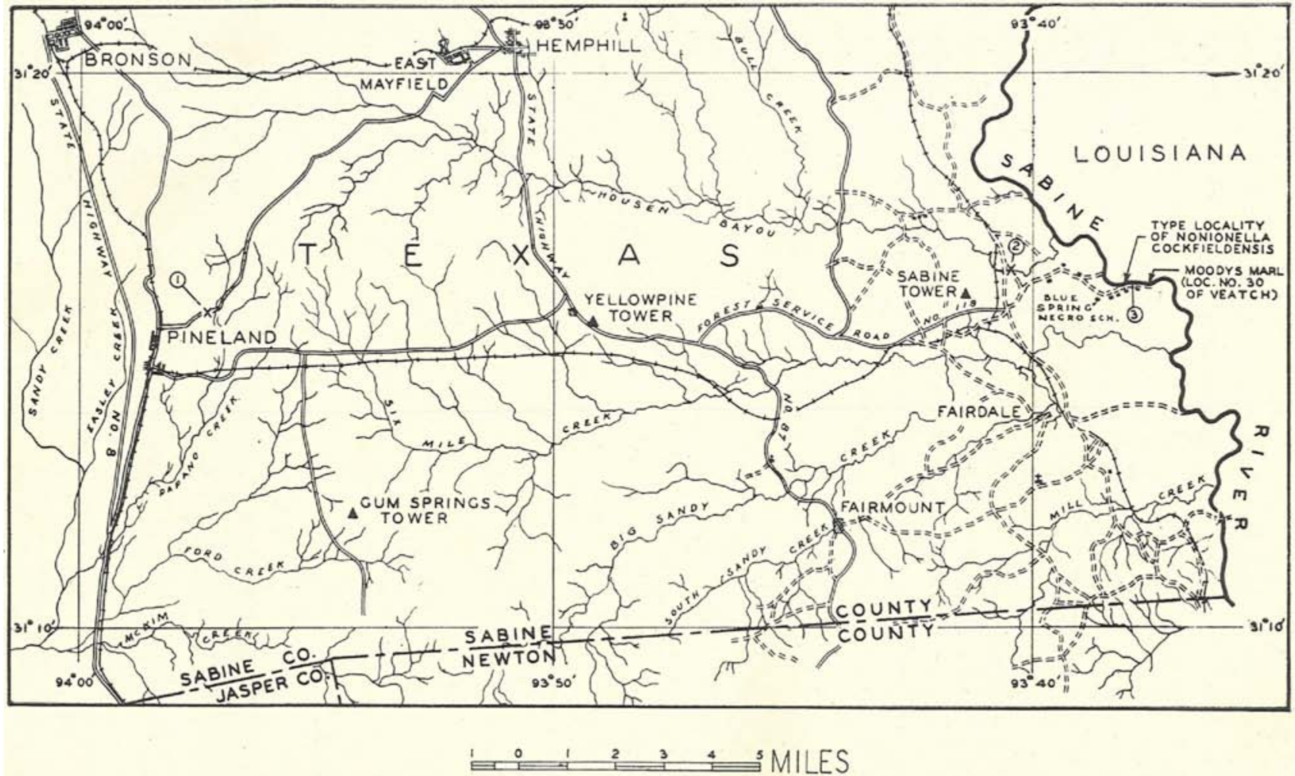

Fig. 132. Map of Sabine River region in Texas. Locations of measured sections: (1) Pineland; (2) Housen Bayou; (3) Robinson's Ferry.

in that report. Locality 30 is in the middle of a long west to east reach 6,000 feet downstream from the Texas landing of Robinson's Ferry as measured along the course of the river on aerial photographic maps. The exposure is shown on Plate XXX of Veatch's report and consists of 5 feet of bright blue-green, tough, very fossiliferous, glauconitic marl with two large concretions of yellow, hard, fossiliferous, glauconitic limestone. One of these concretions is over 9 feet thick. Both concretions are deeply pitted with recent solution holes, particularly on the upstream side. The outcrop yielded a Jackson Moodys marl fauna and has the characteristic composition of the Moodys marl. Veatch had not the least doubt about his mapping of the Yegua-Jackson contact on the banks of Sabine River. He placed the contact between localities 29 and 30.

The next publication to cover the area is by Alexander Deussen.[24] Deussen's admirable report brought among other important data one addition to the outcrops on the Sabine River banks. He discovered a locality which was apparently not visible at the time A. C. Veatch studied the river. This is locality No. 25 of Deussen's report. It is situated between Veatch's localities 29 and 30.

At the time of Veatch's investigation, February 12 to March 2, 1900, Sabine River must have been about at average water stage. The stage of the river is clearly shown on Veatch's published photograph of his locality 30. Sabine River is usually at high-water stage in winter and spring. However, in order to study the important locality discussed below one should visit the river at extreme low water. Extreme low water is usually reached after a dry summer in the last half of October and may continue through November.

According to investigations made by the writer in the fall of 1938, the important locality discovered by Deussen consists of several exposures of an 800-foot long outcrop which are separated by a thin veneer of alluvial cover resting against the low cliff face. The outcrop is on the right or Texas bank of Sabine River. The first exposure is near the beginning of a long west-east reach of the river 3000 feet downstream from the Texas landing of Robinson's

[24]Deussen, Alexander. Geology and underground waters of the southeastern part of the Texas Coastal Plain. U. S. Geol. Surv., Water-Supply Paper 335, 365 pp., 1914.

Ferry as measured along the course of the river. It is 5 feet below a spring issuing on the steep bank, or 33 to 35 feet below the level of the roadway on top of the bank, and opposite a negro house. This is the third dwelling counting from Blue Springs Negro School. The exposure is 2.3 feet high. Other exposures of the same outcrop are farther downstream, but the beds exposed farther downstream are a few feet higher in the section, because the dip is gentle and downstream. The last exposures form a nearly vertical cliff, which continues steeply down into the water. The exposures extend for about 800 feet down the river from the first spring and exposure. The last of these exposures is opposite the fourth negro house. The top edge of the river bank there is excavated in the form of a half-bowl of semicircular plan. This hollow is free of trees except a few 7-year old pine sprouts. The hollow is the result of a landslip which carried the alluvial deposits into the river to be swept away by the current. A sluggish spring issues iron-scum covered water at the lip of the hollow. Beneath this spring the exposures form a very steep cliff of about 8 feet height at low stage of the river. This exposure is at a slight turn of the river course into a more nearly easterly direction. Beyond this exposure the river bank is covered by alluvial sands for 2200 feet. The next outcrop downstream is Moodys marl with two large lime concretions (Veatch's locality 30).

All these exposures are conveniently accessible in dry weather by automobile on the road which runs on top of the river bank alongside the stream. The road can be reached easily from Yellowpine on State highway No. 87 and Forest Service road No. 119.[25] The section shown in these exposures is as follows (compare fig. 133).

Section on Sabine River bank, near Robinson's Ferry, Sabine County, Texas.

		Thickness *Feet*
(A)	Moodys marl with two large limestone concretions; base not visible (locality 30 of Veatch)	9.0
(a)	Estimated interval; covered by alluvial sands	5.0
(b)	Light chocolate-brown shales interbedded with light gray-yellow to light brown silts. Bedding is thin and lenticular. Lenses rich in brown-black, lignitized plant fragments are numerous. Occasionally one finds a well-preserved leaf. Bore-holes are restricted to the upper 2 feet of this layer. They	

[25]The best available map of this region is Sabine National Forest, Texas: Forest Service, U. S. Dept. of Agriculture, 1937; scale 1 inch equals 2 miles.

		Thickness *Feet*
	are nearly level or only gently inclined and apparently contemporaneous. They are filled with slightly glauconitic sand. The color of the beds is light chocolate-brown on the weathered outside but remains fresh bluish gray deeper in. The latter color is the original one. This layer is found only in the exposure below the landslip scar	3.3
(c)	Tough, bluish-gray, fresh, poorly bedded, silty clay, without clearly discernible silt layers or glauconite but containing black streaks of lignitized plant fragments and rare, undamaged leaves. The upper 2 feet appears more massive than the remainder and forms a rounded bulge on the cliff	5.0
(d)	Tough, bluish-gray, fresh, poorly bedded, glauconitic, very sandy clay with fossils and rounded, water-worn fragments of lignite. Total thickness of this layer is not shown because the base is covered by alluvium; the lower 2.3 feet of this layer is visible at the first exposure, 5 feet below the spring. At this place fossil mollusks are common. The collection discussed below came from this place. About	5.0

Alexander Deussen[26] wrote concerning this locality:

When I was doing the field work many years ago for this Water-Supply Paper 335, I was studying the section on Sabine River, and in the course of this study came to Robinson's Ferry.

The fossils that I listed on Plate IV that accompanies this paper, section exposed along Sabine River, were collected at this outcrop. The determinations were by Dr. Vaughan.

At the time I collected, the stage of the water was very low, and this exposure was on the right bank of the river and just above the water level and at the base of the bluff.

I am not aware that other people have made collections from this same locality, but I believe Miss Ellisor has been so much interested in the problem that they have made additional collections, but on this point I cannot be certain.

I do recall, however, that at the time I had very considerable argument with both Dall and Vaughan and they made a careful examination of the collections and decided that the material was Claiborne. It was for this reason that I included this locality in the Yegua and not the Jackson.

If this locality be actually Yegua it would be the only known marine fossil locality in Texas in the upper Yegua. All other marine Yegua localities of Texas occur in the basal Yegua. They are the brackish water beds in the Rio Grande region.

Several years later the locality assumed great importance because J. A. Cushman and A. C. Ellisor[27] described a new species of

[26]Letter to H. B. Stenzel dated January 31, 1938.

[27]Cushman, J. A., and Ellisor, A. C., Two new Texas Foraminifera: Contr. Cushman Lab. Foram. Res., vol. 9, pp. 95–96, pl. 10, 1933.

foraminifer from it. They named the foraminifer *Nonionella cockfieldensis*, thereby indicating that it was supposed to come from marine Cockfield or Yegua. M. C. Israelsky[28] has shown by careful subsurface correlations that the foraminifer is an important subsurface guide fossil in the Coastal Plain. The *Nonionella cockfieldensis* zone is generally called Cockfield in subsurface work, although a fossil zone should not be called by a locality name like a mappable surface formation.

The assumption that the *Nonionella* zone is of Yegua age and represents the gulfward, marine equivalent of the nonmarine Yegua at the surface rests partly on the age determination of the fossil mollusks from Deussen's locality. This condition is brought out clearly in the last paragraph of Deussen's letter.

What are these fossils? Are they beyond a doubt Claiborne in age? A reëxamination of this fauna in the light of present-day knowledge should obviously be crucial. Doctor Julia Gardner and Edgar Bowles had the kindness to examine three collections made by Alexander Deussen, A. C. Ellisor, and H. B. Stenzel respectively. The collection made by A. C. Ellisor contained the type of *Nonionella cockfieldensis.* Miss Ellisor had the kindness to point out to the writer the exact spot from which she obtained her material. The collection made by the writer was made at that same spot and is clearly a duplication of the collection made by Alexander Deussen. All three collections were made at the first exposure of the outcrop, 5 feet below a spring, and opposite the third negro house counting from Blue Springs Negro School (compare p. 869). The material comes from the lower 2.3 feet of bed (d) of the section (compare p. 870). Fossil mollusks are quite common at this locality but are absent or very rare at the other exposures farther downstream.

Doctor Julia Gardner wrote about this fauna (letter of July 21, 1938):

> We have always considered the molluscan fauna from Robinson's Ferry to be Jackson in age, and I see no evidence for a reversal of that opinion. The fauna includes close to a hundred species, the majority of them small. Lloyd

[28]Israelsky, M. C. and others, Coastal Plain stratigraphic nomenclature. Bull. Amer. Assoc. Petr. Geol., vol. 17, pp. 1535-1536, 1933.

Israelsky, M. C., Tentative foraminiferal zonation of subsurface Claiborne of Texas and Louisiana. Bull. Amer. Assoc. Petr. Geol., vol. 19, pp. 689-695, 1935.

G. Henbest was good enough to look at some of the siftings from the matrix in which the Mollusca occur, and he reports *Nonionella cockfieldensis*, so there is little doubt but that we are talking about the same locality. The number of opisthobranchs, pyramidellids, lucinoids, and leptonacids is unusually high, and, for one reason or another, I find these of very little use in an age determination such as this. The species most heavily weighted is a *Turritella* at least subspecifically identical with *arenicola* Conrad from Moodys Branch, Mississippi. It is the most common of the univalves at Robinson's Ferry, and both juveniles and adults are represented by well-preserved individuals. Furthermore, *Turritella arenicola* and its subspecies, among them *branneri* Harris from White Bluff, is in the western Gulf among the most widely distributed of the diagnostic Jackson species. The specimens of young *Calyptraphorus*, too, are affiliated with the Jackson species rather than with that from Claiborne Bluff. The volutes are also juvenile and referable to the *petrosa* group, but they do not agree exactly with any of the described forms with which they have ben compared. There is also a small and fairly common capulid . . . . . The small and abundant *Corbula*, which is probably that referred to *oniscus*, is apparently new. So is the *Periploma*, which is also common and a good facies indicator. The difference in facies is probably a factor in explaining the want of similarity between the Robinson's Ferry fauna and the sand-bottom fauna from Montgomery, Louisiana.

The collection made by H. B. Stenzel contains abundant *Turritella arenicola* Conrad, a few specimens of *Turritella perdita* Conrad, and one specimen of *Turritella carinata* Lea (identifications by H. B. Stenzel and F. E. Turner). Of these Turritellas the first two are widespread in the Moodys marl, but the last is a well known species from the upper Claibornian Gosport sand.

In addition to the fossil mollusks, the microfauna of the same locality has distinct Jackson affinities. H. J. Plummer[29] stated that:

The faunal assemblage of that locality is strongly Jacksonian in the presence of the distinctive species *Siphonina jacksonensis* C. & A., *Nonion inexcavatum* C. & A., *Nonionella hantkeni spissa* C., and *Anomalina dibollensis* C. & A. These four species are abundant in the sample.

A list of the species from the type locality of *Nonionella cockfieldensis* Cushman and Ellisor, Sabine County, Texas (Ellisor collection), identified by H. J. Plummer is given here:

Nonionella cockfieldensis Cushman & Ellisor
Siphonina jacksonensis Cushman & Applin
Nonion inexcavatum (Cushman & Applin)

[29]Note to H. B. Stenzel, February 18, 1938.

Nonionella hantkeni (Cushman & Applin) var. spissa Cushman
Glandulina laevigata (D'Orb.) var. ovata Cushman & Applin
Bulimina jacksonensis? (Cushman & Applin) (1 poor specimen)
Anomalina dibollensis Cushman & Applin
Pseudopolymorphina dumblei (Cushman & Applin)
Textularia dibollensis Cushman & Applin
Loxostoma clabornense? Cushman (1 specimen)
Hemicristellaria, sp.
Eponides jacksonensis? (Cushman & Applin). (1 fairly good specimen that appears to exhibit the very oblique sutures of the Jackson form, but more material is necessary to confirm this tentative identification)
Guttulina, sp.
Globulina, sp.
Quinqueloculina, sp.
Quinqueloculina, sp.
Massalina, sp.

That the microfauna of the *Nonionella*-bearing beds underground in Texas and Louisiana has Jackson affinities had been recognized in 1934 by M. C. Israelsky and is now admitted generally by paleontologists working in the Gulf Coastal Plain. Israelsky[30] clearly stated this affinity in the following sentences:

> This species has been included in the Claiborne only because A. C. Ellisor omitted the zone characterized by it from the Jackson.
>
> This writer believes the zone between the top range of the *Nonionella cockfieldensis* and the top range of *Eponides yeguaensis* is more nearly related to the Jackson.

That the fauna of the zone and the type locality of *Nonionella cockfieldensis* is more nearly related to the Jackson is an astounding result and introduces great difficulties, because it is generally assumed that the Yegua belongs to the Claiborne group and grades laterally by interfingering into the Gosport sand, which is the type of the upper Claiborne. According to this correlation one would expect that the zone and type locality of *Nonionella cockfieldensis* would contain a fauna similar to the Gosport sand fauna. That this is not the case is the crux of the present difficulties. These difficulties make it necessary to reëxamine the relationship of the *Nonionella*-bearing beds to the overlying Moodys marl and the underlying nonmarine, typical Yegua beds.

The type locality of *Nonionella cockfieldensis* near Robinson's Ferry on Sabine River does not lend itself to an easy interpretation

[30] Israelsky, M. C., *op. cit.*, p. 690.

of that nature, because the outcrops are discontinuous and surrounded by alluvium. It is impossible to ascertain the relationship of the *Nonionella*-bearing beds at that outcrop to the Moodys marl downstream or to the lignitic shales of the true, nonmarine Yegua upstream.

However, certain important relationships are clear. These may be summarized here as follows: The stratigraphically highest exposure is Moodys marl at Veatch's locality 30. Only 9 feet of the marl is visible, the base being hidden. The next lower part of the stratigraphic section is hidden. This gap is estimated to be about 5 feet. The next beds below are the *Nonionella*-bearing beds, of which 13.3 feet is visible. The fossils occur in the lowest 2.3 feet of these beds (compare section on pp. 869–870). Parts of bed (c) and bed (b) of the section have a lithology strikingly similar to true nonmarine Yegua beds. These two beds occur above the marine bed (d), which yielded *Nonionella cockfieldensis.*

While it is not possible to obtain a definite interpretation of the relationship between Moodys marl and the underlying beds at this one locality, it is possible to do so in other places nearby. The relationship of the *Nonionella*-bearing beds to the overlying Moodys marl and the underlying nonmarine, typical Yegua beds is shown in four stratigraphic sections, which are discussed in detail below (compare figs. 132 and 133).

The westernmost section is exposed in the road ditches of the old Pineland-Hemphill road, 1.05 miles east-northeast of the railroad crossing at Pineland, on the slope toward a right tributary of Papano Creek, in southwestern Sabine County, Texas. This road forms the present boundary line of Sabine National Forest.

Section 1.05 miles northeast of Pineland, Sabine County, Texas (compare fig. 133).

	Thickness *Feet*
(A) Weathered Moodys marl; weathered marl with secondary lime nodules of 1-inch diameter and large, yellow, fossiliferous, impure, glauconitic limestone concretions; not exposed on road but found on cuesta to the south of the road. Total thickness not exposed	-
regional disconformity (covered)	
(a) Gray-brown, thin-bedded to laminated, alternating layers of gray-brown, waxy, silt-free clay-shale and weathered brown, ferruginous, or fresh, light gray-green, glauconitic sands about 1 inch thick. One sand layer is 2.3 feet thick. Some sand layers are harder and more glauconitic and have a	

		Thickness *Feet*
	few fossil mollusk imprints. There are at least 21 feet of this series well exposed in the ditch. However, the base of this series is 37 feet below the top of the hill; therefore, the estimated total thickness is	40
	~~slight disconformity visible~~~	
(b)	Massive to poorly bedded, very sandy mudstone or clay, very light gray-brown to whitish on the dry surface but light gray-brown below the surface; contains no glauconite or fossils. The sand content is light gray to light brown; the clay is chocolate-colored. The distribution of these two constituents is very uneven; chunks of chocolate clay are surrounded by the sand. Exposed on this hill	19

The next section is exposed on the right bank of Housen (or Housing) Bayou near the old iron bridge of the Fairdale-Sabinetown road, 1 to 1.25 miles above the mouth of Housen Bayou as measured in airline distance, in southeastern Sabine County, Texas. This exposure is the last large Tertiary exposure on Housen Bayou because downstream from this exposure the bayou flows through the deep alluvial fill of Sabine River.

Section on Housen Bayou, Sabine County, Texas (compare fig. 133).

		Thickness *Feet*
(A)	Weathered Moodys marl exposed on cuesta south of Housen Bayou; for instance, near Sabine Tower lookout station	- -
	~~regional disconformity (covered)~~~	
(a)	Interval; covered by terrace deposits	30?
(b)	Interbedded shales and sands; shales are laminated, chocolate-brown to dark green-gray, muscovitic, and contain tiny lignitic plant fragments; sands are bright rust-yellow, medium grained, lenticular bedded, up to 1 inch thick. The entire series is lenticular in detail but even-bedded as a whole. The sand lens at the base is more conspicuous and 3 inches thick	3.0
(c)	Similar to (b) but the sands are very thin and inconspicuous; bedding of the shales is crinkly	1.5
(d)	Light gray, nodular, hard, earthy limestone with glauconite, fossils, and sand grains	0.2
(e)	As (c)	0.1
(f)	Sand as at base of (b)	0.1
(g)	Lenticular to crinkly-bedded, dark green-gray when fresh, chocolate-brown when weathered, interbedded lignitic, muscovitic shales and gray silt partings, grading by increase in sand lentils into the bed below	2.4
(h)	Light greenish-gray when fresh, light gray-brown on outside, medium-grained, lenticular sands interbedded with dark green-gray, muscovitic shales	1.6
(i)	Limestone similar to bed (d) alternating with sands and brown shales similar to bed (h) as follows: limestone, 3 inches; sand and shale, 5 inches; limestone, 2 inches; sand and	

	Thickness *Feet*
shale, 2 inches; limestone, 1 inch; sand, 14 inches; limestone, 1 inch; sand, 4 inches. The lower boundary of this bed is irregular in detail and fragments of the underlying bed are enclosed in its base	2.7
~~slight disconformity~~~	
(j) Poorly- and crinkly-bedded to massive, dark green-gray when fresh, chocolate-brown on outside, sandy, lignitic mudstone, showing weathering by exfoliation. This bed contains a small amount of glauconite	5.3
(k) Poorly-bedded, dark green-gray, lignitic, sandy clay, containing a small amount of glauconite	------

The third section is the section on the banks of Sabine River and has been detailed on pages 869–870.

The fourth section is the section exposed on Creole Bluff, near Montgomery, Grant Parish, Louisiana (compare Pl. 51).

Section of Yegua and Jackson beds at Creole Bluff, near Montgomery, Grant Parish, Louisiana.

	Thickness *Feet*
Jackson group—	
Yazoo clay: Tullos member—	
(J) Blue clay-marl with thin, lenticular sands (noted by H. N. Fisk but not seen by H. B. Stenzel	12.0
(I) Light gray, earthy, marly limestone without glauconite or fossils	0.2
(H) Dark greenish-gray, dark brown weathering, laminated, gummy shale	3.0
(G) Light green-gray, well-bedded, marly shale with casts of fossils	1.8
(F) Light green-gray, hard, earthy, massive, chalky limestone in two beds separated by shale	1.8
(E) Similar to (G); the middle part weathers darker than the rest; dark gray	6.4
(D) Limestone, similar to the limestone of (F)	0.5
(C) Marly shale, as (G)	9.7
(B) Light green-gray, glauconitic, earthy, hard, fossiliferous, chalky limestone	0.8
Moodys marl—	
(A) Bluish-green when wet, light gray-green when dry, massive to poorly bedded, richly glauconitic and fossiliferous Moodys marl. Contains numerous pebbles and boulders near its base. Boreholes extend as an average 1 foot down into the underlying beds. Very few reach 7 feet down. At the base of the Moodys marl there are in some places large slabs of the underlying shale included	4.9
~~regional disconformity~~~	
Claiborne group—	
Yegua formation—	
(a) Dark brown-gray, irregularly-bedded shale with gray-brown, irregular silt lenses and occasional fragments of black lignite in form of rounded slabs. Indistinct marine	

		Thickness *Feet*
	lentils occur 8 feet from the top. These lentils are not boreholes	9.0
(b)	Blue-green, fossiliferous, richly glauconitic sand; top and bottom boundaries are indistinct and transitional	0.8
(c)	Similar to (a)	4.4
(d)	Similar to (a) but contains several light yellow to gray, thin-bedded, conspicuous sand lenses which are up to 0.3 foot thick	1.6
(e)	Similar to (c)	7.3
(f)	Cannon-ball concretions; gray, finely crystalline septarians about 0.7 foot thick. Some reach a horizontal diameter of 1.8 feet	0.7
(g)	Gray-brown-black, massive to poorly-bedded, micaceous, silty, lignitic mudstone with copiapite incrustations at the outside	6.3
(h)	Dark gray to black, massive, clayey sand; shows on weathering a tangled mass of fucoids; contains also glauconite	3.0
(i)	Dark gray to black, cross-bedded, micaceous, clayey, lignitic sand	2.0
(j)	Dark gray to black, micaceous, silty, thin-bedded shale; has numerous large, flat pieces of lignite at base	3.3
(k)	Dark green-gray to black, well-bedded sand; base not visible	15.0

Great importance is attached to the fauna of bed (b), which clearly is older than the Moodys marl. Samples of this layer collected by the writer were investigated by A. R. Mornhinveg who reported the following foraminifers:

Eponides jacksonensis (Cushman & Applin)
Bolivina jacksonensis Cushman & Applin
Siphonina jacksonensis Cushman & Applin
Siphonina advena Cushman
Nonion advenum Cushman
Nonionella cockfieldensis Cushman & Ellisor
Polymorphina, sp.
Cibicides americanus (Cushman)
Discorbis globulo-spinosa Cushman
Globulina gibba D'Orbigny
Nonion scaphum (Fichtel & Moll)
Anomalina danvillensis Howe & Wallace
Guttulina irregularis (D'Orbigny)
Discorbis hemispherica Cushman

In addition the following two species of gastropods were recognized:

Turritella alveata Conrad
Turritella perdita Conrad

Both Turritellas were hitherto known only from the Moodys marl and overlying formations. The discovery of these two gastropods in a layer 9 feet below the Moodys marl extends their stratigraphic range by that distance.

In all four sections the Moodys marl is a readily recognizable reference level. The beds below this reference level are of variable appearance. Some beds are obviously marine. Such beds are the glauconitic and fossiliferous layer (b) of the Creole Bluff section, the glauconitic and fossiliferous layer (d) of the Sabine River section, and the glauconitic limestone layers in bed (i) of the Housen Bayou section. The tangled mass of fucoids in bed (h) of the Creole Bluff section is also obviously marine because such a feature has hitherto been recorded from marine beds only. The cannon-ball concretions are also marine or brackish in origin, because they contain a few foraminifers visible in thin sections.

On the other hand, the large, thin lenses of pure lignite occupying a well-defined horizon at the base of bed (j) at Creole Bluff are nonmarine. However, not all lignite pieces in every bed or section indicate nonmarine deposition. Some of the lignite pieces are rounded as if they were water-worn pebbles. Such lignite pebbles are present in bed (d) of the Sabine River section. They are not indicators of nonmarine deposition; on the contrary, they might possibly be indicators of marine deposition.

The sedimentary environment, marine, brackish, or nonmarine, can be analyzed in some cases, but in most cases it remains obscure. Indicators of marine sedimentation are glauconite, marine fossils, limestone layers, fucoids. A doubtful indicator of marine or brackish deposition is cannon-ball concretions. An indicator of nonmarine deposition is lignite in form of large lenses but not in form of fragments or pebbles.

All in all, the beds below the Moodys marl are a mixed, and interbedded sequence of marine, brackish, and nonmarine layers, but their general appearance is more nonmarine than marine.

It has been shown already that the Moodys marl rests on a widespread disconformity which is traceable from Texas into Mississippi. It is obvious that this disconformity is also present in the four sections discussed above, although that particular part of the stratigraphic column which contains the base of the Moodys marl is not well exposed in three of these four sections. However,

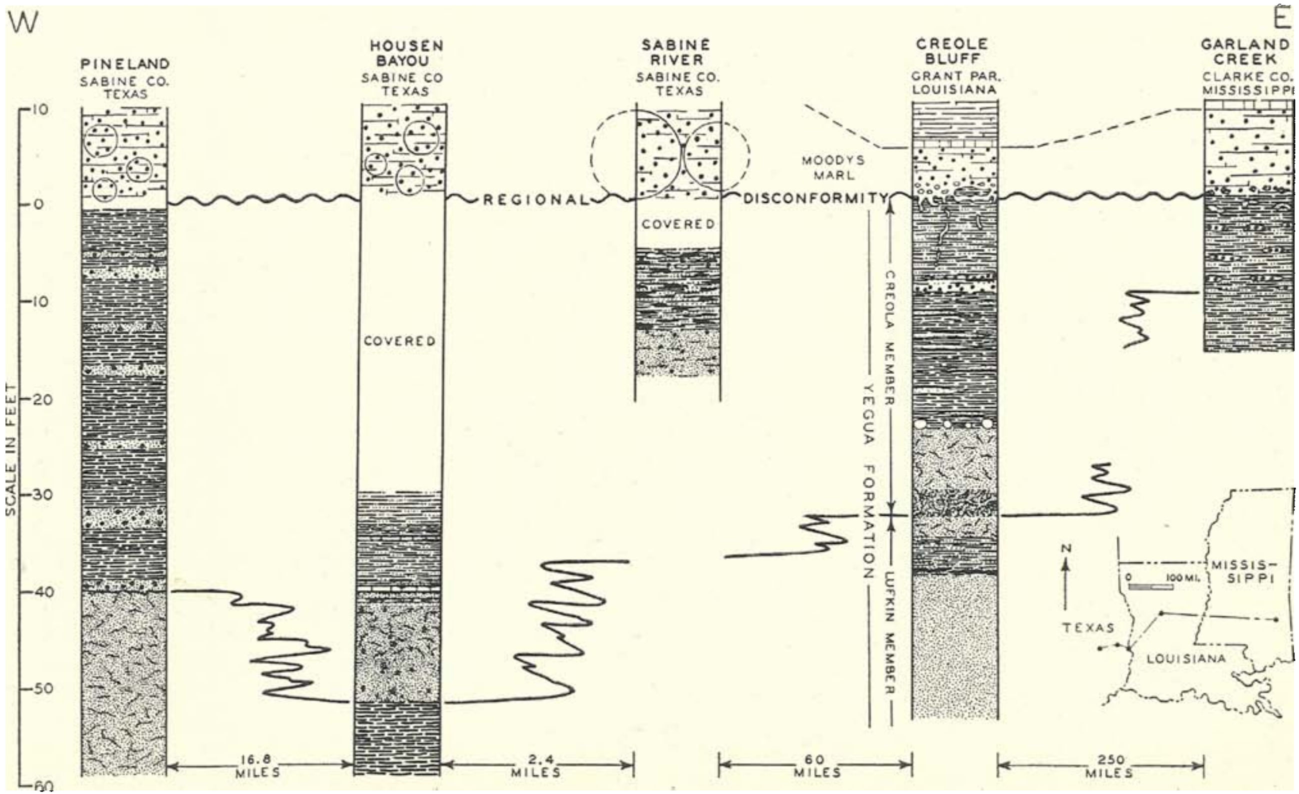

Fig. 133. Correlation of the uppermost Yegua beds in east Texas, Louisiana, and Mississippi.

the Creole Bluff section is particularly clear in this connection. This section is sufficient proof of the presence of the disconformity at the base of the Moodys marl. Therefore, the marine beds which contain the *Nonionella cockfieldensis* fauna lie below this disconformity and belong either to the Yegua or to a new, unnamed formation intervening between the Yegua and the Moodys marl.

These two possibilities must be considered. In some of the sections discussed above there are slight disconformities visible. It might be argued that the true Yegua lies below and a new unnamed formation lies above these disconformities but below the Moodys marl. Such an argument would presuppose that the slight disconformities observed in separate sections line up into one well-defined level. The field observations do not indicate this arrangement. It is highly doubtful that the slight break noted between beds (a) and (b) of the Pineland section occupies the same stratigraphic level as the slight break noted between beds (i) and (j) of the Housen Bayou section. These slight breaks are presumably only local features and of no consequence to regional stratigraphy. Besides, the Creole Bluff section is apparently free of any break in that part of the stratigraphic column. Another argument against the presence of a break defining a new formation is the fact that glauconite occurs below that supposed break in beds (i) and (j) on Housen Bayou and that beds of Yegua lithology occur above the fossiliferous, marine bed (d) on Sabine River. It can hardly be doubted that the partly marine beds which contain the *Nonionella cockfieldensis* fauna are an integral part of the Yegua formation.

Therefore, it must be conceded that the upper part of the Yegua formation of extreme eastern Texas and adjoining Louisiana is an interbedded sequence of beds with marine, brackish, and nonmarine appearance. The nonmarine beds of that sequence have characteristic Yegua composition. *Nonionella cockfieldensis* and an associated fauna of large and microscopic fossils occur in some of the marine beds of this sequence. Usually, the fossils are weathered away and cannot be studied. But two localities contain well-preserved fossils. They are as follows:

(1) The type locality of *Nonionella cockfieldensis* near Robinson's Ferry on Sabine River, Sabine County, Texas.

(2) Creole Bluff, near Montgomery, Grant Parish, Louisiana (bed (b) of section; compare Pl. 51), where *Nonionella cockfieldensis* is also present.

This fauna of the upper part of the Yegua formation has unmistakable Jackson affinities and is therefore probably younger than the Gosport fauna of Claiborne, Alabama.

This upper part of the Yegua which is marine in part has hitherto not received a formational name. Authors have been content to call it the "transition zone" between typical Yegua and typical Jackson. Continued use of the term transition would now only lead to confusion on account of the presence of a widespread disconformity cutting off the top of the Yegua. Besides, other authors have used the term "transition" in an entirely different sense for the topmost Yegua bed which contains the Moodys marl-filled boreholes at Creole Bluff. To avoid further confusion among these beds a name should be used which does not imply any theory of origin. Such a name is best supplied by a formation name derived from a locality. Therefore, the writer is introducing here the name Creola for those beds of the upper Yegua which contain unmistakable marine indicators, such as marine fossils, glauconite, limestone layers, or fucoids.

The Creola beds are bounded at the top by the widespread disconformity on which the lower Jackson rests. This upper boundary is clear-cut and sharp. At the base the Creola beds grade into the typical nonmarine Yegua beds. This lower boundary is indistinct. The Creola beds should be regarded as a member and portion of the Yegua formation. The term is applicable only to a lithologic and mappable unit and not to a fossil zone. The type locality is Creole Bluff on which the old town of Creola was built in 1850.

The thickness of the Creola beds is naturally variable. The following thicknesses have been found:

	Feet
Texas:	
Pineland	40
Housen Bayou	47
Robinson's Ferry	18.3 + (incomplete)
Louisiana:	
Creole Bluff	32.4
Mississippi:	
Garland's Creek	10

West of the Pineland section in Sabine County, Texas, the Creola outcrops become more and more nonmarine and fade into the uppermost Yegua beds.

The Yegua formation has now been limited in the stratigraphic section by defining its base and top. The Yegua formation is a convenient and natural stratigraphic division composed nearly entirely of nonmarine beds. Even where marine beds occur, that is, at the top of the Yegua section in extreme eastern Texas, Louisiana, and Mississippi, they are interbedded with beds of nonmarine appearance and Yegua character. However, even in this part of the Yegua, nonmarine characteristics predominate. In this way the Yegua formation is limited at the top and bottom by marine formations, namely, the Moodys marl and Caddell formation at the top and the Crockett (or Cook Mountain) formation at the bottom. The Yegua epoch was preceded by the extensive, although fluctuating, marine ingression of Crockett time and followed by the widespread advance of the sea during early Moodys marl or Caddell time. The Yegua epoch represents a major, widespread, and long-lasting recession of the sea.[31]

This result introduces the question whether these uppermost beds of the Yegua which contain a fauna with unmistakable Jackson affinities should be placed in the Jackson or the Claiborne group. In connection with this question it is necessary to point out emphatically the fundamental difference between Jackson from the paleontologic point of view and Jackson from the stratigraphic point of view.

If one looks at the question from a purely paleontologic point of view it might be well to consider the uppermost beds of the Yegua as belonging to the Jackson. This point of view has been stated concisely by M. C. Israelsky and is expressed in the statement that these uppermost Yegua beds contain a fauna with Jackson affinities. Then, it is also logical to say that the Yegua formation includes the transition from the Claiborne to the Jackson or, perhaps more correctly, the transition from a Claiborne to a Jackson fauna.

If one looks at the question from a broader. stratigraphic point of view, faunas become merely one of the many stratigraphic characteristics which one must consider. Other characteristics have equal rights or equal importance. For instance, one must consider also the composition of the beds, the nature of their contacts,

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[31]It is interesting to note that similar principles of stratigraphic delimitation are used in modern English and French Eocene stratigraphy. Compare Wrigley, Arthur, and Davis, A. G., The occurrence of *Nummulites planulatus* in England with a revised correlation of the strata containing it: Proc., Geologists Assoc., Vol. XLVIII, pt. 2, pp. 203-228 1937.

the nature of their environment during deposition, and perhaps, above all, the incidence of major advances or regressions of the sea. Were one to follow paleontologic evidence alone one would have to place the boundary between the Claiborne and Jackson groups somewhere within the Yegua formation. One could neither use nor map such a boundary because there is not a single bed in the Yegua formation which can be traced by mapping. Such a boundary is obviously impracticable and not supported by other evidence which ought to be considered also. All other evidence makes the widespread, regional disconformity at the top of the Yegua formation the logical choice of the Claiborne-Jackson group boundary. Even the paleontologic evidence alone does not demand rigorously the other choice, because the marine Yegua fauna is not necessarily a Jackson fauna in every one of its aspects. Rather, the expression "a fauna with Jackson affinities" implies that not all species of that fauna are necessarily Jackson species but that a noticeable number of Jackson species or numerous specimens of an important Jackson species are already present in the fauna.

For these reasons beds which contain faunas with Jackson affinities do not belong necessarily to the Jackson group. Such beds as the "*Scutella*" bed of the Claiborne Bluff section belong in this category. It might be necessary to include this bed in the Claiborne group if there are other valid characteristics which demand this transfer.

Lateral Boundary

By limiting the Yegua in the manner discussed above the formation has been restricted chiefly to nonmarine beds. As stratigraphy is based on marine fossils there are no direct means of obtaining the age of most of the Yegua, because by far the greater part of the Yegua does not carry marine faunas at the outcrops. Only the small, upper, marine portion of the Yegua in extreme eastern Texas and adjoining Louisiana carries a marine fauna and this fauna has unmistakable Jackson affinities. Indirectly, of course, the age of the Yegua has been limited to younger than the Crockett, which is lower Claiborne in age, and older than the Caddell and Moodys marl, which are early Jackson in age. Nevertheless, one would like to have a better stratigraphic determination of the age of the Yegua, if this be feasible at the present state of knowledge.

Such a determination has been attempted long ago. T. W. Vaughan[32] used lateral correlation to determine the age of the Yegua. In 1895 he found that the Yegua, or the Cocksfield Ferry beds as he called this formation then, lies between Jackson and lower Claiborne in Louisiana. Since it was well known that the Gosport sand of Alabama lies between Jackson and lower Claiborne, he assumed that the Yegua represents in a general way the Gosport sand of Alabama.

Cooke stated the basis of this correlation clearly in 1925 in the following words:[33]

> The correlation of the Yegua with the Gosport is based primarily upon the stratigraphic position of both between the Lisbon and the Jackson, for the paleontologic evidence is inadequate.

Cooke supposed that the Yegua interfingers laterally with the marine and richly fossiliferous Gosport sand of western Alabama. This supposition was based on the occurrence of lignitic shale lentils or tongues in the Gosport sand at some outcrops.[34]

Such occurrence of lignitic lentils is in itself not a strict proof that the Gosport and Yegua interfinger, because such lentils occur in many otherwise strictly marine formations and the lentils were not definitely proved to be Yegua or connected with it. Blanpied and Hazzard[35] have supplied the proof by tracing the formations in considerable detail. Their work supports Cooke's conclusions fully.

These two authors also had available a number of important core-drill samples in Alabama. The samples showed the relationship of the Gosport and Yegua. In one core hole, for instance, the basal part of the Gosport sand showed an interbedding of fossiliferous greensand and gray-brown clays. Although the two forma-

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[32]Vaughan, T. W., The stratigraphy of northeastern Louisiana: Amer. Geol., vol. 15, pp. 205–229, 1895.

[33]Cooke, C. W., Correlation of the Eocene formations in Mississippi and Alabama: U. S. Geol. Surv., Prof. Paper 140, p. 136, 1925.

[34]Cooke, C. W., The Cenozoic formations: Geol. Surv. Alabama, Spec. Rept. 14, p. 273, 1926.

————, Correlation of the Eocene formations in Mississippi and Alabama: U. S. Geol. Surv., Prof. Paper 140, p. 136, 1925.

Smith, E. A., Johnson, L. C., and Langdon, D. W., Jr., Report on the geology of the Coastal Plain of Alabama: Geol. Surv. Alabama, p. 126, 1894.

[35]Blanpied, B. W., and Hazzard, R. T., Correlation of Cockfield and Gosport formations, eastern Mississippi and western Alabama: Bull. Amer. Assoc. Petr. Geol., vol. 22, pp. 309–314, 1938. Blanpied and Hazzard generously allowed the writer to read and use their manuscript. The paragraphs treating the Gosport are based on their report.

tions interfinger, the Gosport is found above lignitic shales of the Yegua in all core holes. This means that, as one proceeds eastward, first the uppermost parts of the Yegua are replaced by the Gosport, while the parts below persist unchanged for some distance eastward. However, these lower parts wedge out gradually eastward, so that at the lower Claiborne Landing 17 feet of richly fossiliferous, marine Gosport sand rests on beds equivalent to the Crockett of Texas.

These relations seem to indicate that parts of the Yegua correlate with the Gosport. Therefore, a portion of the Yegua must be of upper Claiborne age.

This conclusion appears to be at variance with the paleontologic age determination of the Creola member of the Yegua near Robinson's Ferry, Sabine County, Texas. This locality carries a fauna of decided Jackson affinities.

This discrepancy may be adjusted perhaps by a restudy of the Gosport-Jackson section in Alabama. The writer has been able to investigate only one locality in Alabama, but this locality is crucial. The locality is the well-known Claiborne Bluff on Alabama River in Monroe County, Alabama. The exposures in the new highway cut at the east end of the new bridge and in the cuts of the old road leading to the old ferry landing above the bridge were investigated in detail.

Section at new highway bridge at Claiborne, Monroe County, Alabama.

	Thickness *Feet*
a. Ocala formation: soft, gray-green, glauconitic marl with very few fossils. Total thickness not exposed	......
—nature of contact unknown—	
b. Hard, white to light gray limestone with very few fossils ... About	10
c. "*Scutella*" bed: hard, white to light gray limestone with numerous flat echinoids, *Periarchus lyelli* (Conrad), grading downward into	2.5
d. White to light gray, glauconitic marl, poor in fossils, grading into	1.3
e. Gosport sand: gray-brown. coarse, glauconitic sand with numerous Gosport fossils. At the base there is a layer, 0.6 feet thick, which contains also numerous flat shale pebbles derived from the underlying bed	0.8
f. Brown-gray to drab, micaceous, interbedded shale and sand. The shale and sand layers are wavy in a small way; the shale contains partly lignitized plant fragments and leaves. There are no marine fossils in this bed. It grades into	12.1

	Thickness *Feet*
g. Yellow, coarse, weathered glauconitic sand with numerous Gosport fossils	3.3
Disconformity	
h. Lisbon formation: bluish or greenish, calcareous marl with *Ostrea sellaeformis* Conrad and *Ceratobulimina eximia* Rzehak	--

The base of the section is formed by the Lisbon formation, a bluish-gray, glauconitic marl, which contains the well-known guide fossils *Ostrea sellaeformis* Conrad (typical) and *Ceratobulimina eximia* Rzehak. The fossils occur up to the top of the Lisbon formation and indicate that that portion of the Lisbon is of Crockett (or Cook Mountain) age.

The marine and richly fossiliferous, coarse-grained Gosport sand lies with a very sharp boundary on the Lisbon formation. This boundary is abrupt and very uneven. Pipe-like bodies filled with Gosport sand extend two to three inches down into the Lisbon formation. The Lisbon-Gosport contact is a disconformity which indicates that an unknown amount of the Claiborne group is missing at that level.

In the new highway cut there are 12.1 feet of brown, lignitic shale interbedded with thin, nonfossiliferous sands (bed f) exposed in the middle of the fossiliferous Gosport sand. The interbedded shales and sands are presumably nonmarine, because they do not carry glauconite or fossil mollusks, but are rich in leaf imprints. A similar lignitic, fossil plant-bearing shale bed of 3 feet thickness occurs in the middle of the marine Gosport sand in the cuts of the old ferry road.

At both localities, Gosport sand with its characteristic fossils lies below as well as above these nonmarine layers. The nonmarine layers are a lentil which splits the Gosport sand into two beds. The top and bottom boundaries of the nonmarine lentil toward the Gosport sand are conformable and transitional. These conditions have not been recognized by some authors. For instance, in the Claiborne Bluff section given by Cooke[36] the portion of the Gosport sand lying above the nonmarine lentil is included erroneously in the Ocala limestone.

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[36]Cooke, C. W., The Cenozoic formations: Geol. Surv. Alabama, Spec. Rept. 14, p. 271, 1926.

The Gosport sand is overlain by the "*Scutella*" bed (bed c). This is an indurated, white to gray, impure limestone ledge containing numerous specimens of *Periarchus lyelli* (Conrad), a flat,

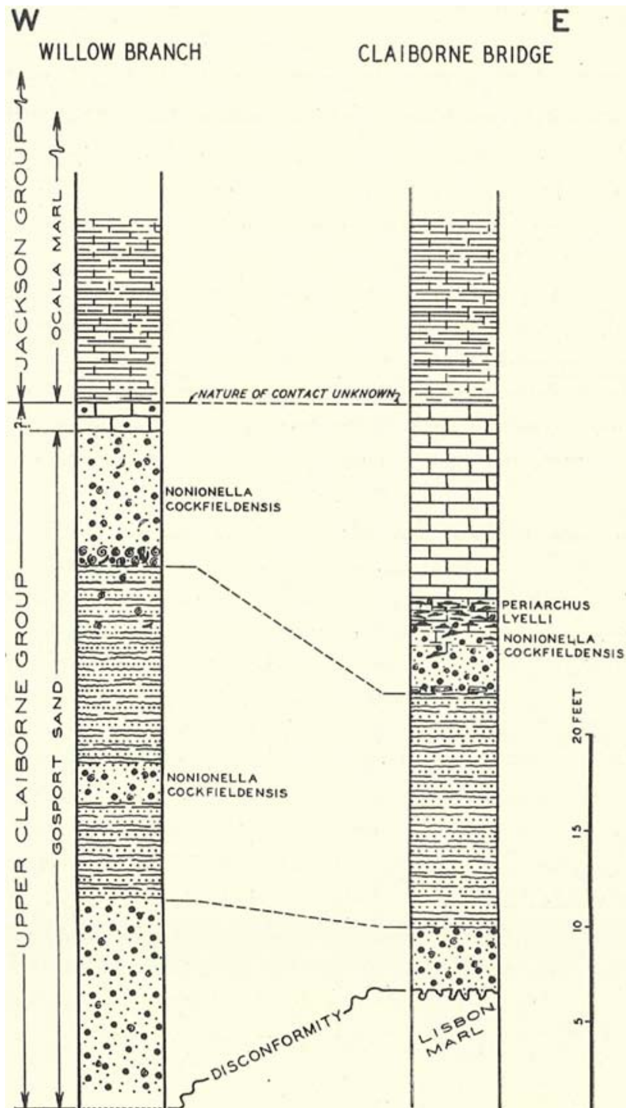

Fig. 134. Gosport sand sections in Alabama.

disk-shaped echinoid. Other large fossils are rather rare in this bed. The writer has investigated with particular care the boundary between the Gosport sand and the "*Scutella*" bed in the new highway cut and along the old ferry road at Claiborne. The boundary is very indistinct, although it is very well exposed. In some places loose, fossiliferous, typical Gosport sand reaches up a little higher in the section than in others. By gradual disappearance of the sand and the Gosport fossils and gradual appearance of calcareous cement, the top of the Gosport sand grades imperceptibly upward and sideward into the "*Scutella*" bed. The transition is so gradual that not a single bedding plane can be chosen as the boundary.

In addition, *Periarchus lyelli*, the characteristic "*Scutella*" bed fossil, occurs also in the uppermost part of the Gosport sand (bed e). This echinoid is not confined to the "*Scutella*" bed. It merely reaches its maximum distribution in that bed. To make this distribution absolutely certain the writer has dug out some of these echinoids from the Gosport sand (upper part of bed e) in places where the echinoid was surrounded on all sides, including top and bottom, by typical and undamaged Gosport mollusks. *Periarchus lyelli* (Conrad) can not be considered an exclusive guide fossil of the "*Scutella*" bed.

Important is also the distribution of the foraminifer *Nonionella cockfieldensis* Cushman and Ellisor. The Gosport sand usually does not contain any recognizable foraminifera. One reason for their absence is that the sediment was originally unfavorable for the deposition of foraminifer shells, because it is a coarse-grained nearshore sand deposit. Also, the sand is somewhat weathered so that the few foraminifera which are present are thickly encrusted with secondary lime deposits and unrecognizable. Therefore, foraminifera can be expected only in a few favorable parts of the section. The important discovery that *Nonionella cockfieldensis* occurs at Claiborne was made by J. B. Garrett.[37] Samples from the upper portion of the Gosport sand and the "*Scutella*" bed, that is, beds e, d, and c of the section on p. 885, were found to contain this

[37]Garrett, J. B., Jr., Occurrence of *Nonionella cockfieldensis* at Claiborne. Alabama. Jour. Pal., vol. 10, pp. 785–786, 1936.

The heading for the fossil list given by Garrett, p. 785, should read: "*Microfauna from Beds 11 and 12 at Claiborne Bluff*" and not Beds 10 and 11, according to a letter received from J. B. Garrett.

foraminifer associated with a fauna of lower Jackson aspect. It should be remembered that the "*Scutella*" bed had always been regarded as Jackson in age.[38]

The list of foraminifera and ostracoda identified by J. B. Garrett is given below. To these should be added the echinoid *Periarchus lyelli* (Conrad) which is very abundant in the so-called "*Scutella*" bed and has given it its name. A list of the large fossils as contained in the writer's collection is also included.

Foraminifera:
- Textularia dibollensis Cushman & Applin
- Textularia mississippiensis Cushman
- Textularia recta Cushman
- Textularia, sp.
- Quinqueloculina longirostra D'Orbigny
- Spiroloculina grateloupi D'Orbigny
- Miliola saxorum Lamarck
- Robulus alato-limbatus (Gümbel)
- Robulus propinquus (Hantken)
- Robulus, sp.
- Planularia truncana (Gümbel)
- Marginulina, sp.
- Dentalina hantkeni Cushman
- Nodosaria fissicostata (Gümbel)
- Nodosaria latejugata Gümbel
- Nodosaria vertebralis (Batsch)
- Lagena sulcata (Walker & Jacob)
- Guttulina irregularis (D'Orbigny)
- Guttulina irregularis, fistulose var.
- Guttulina spicaeformis (Roemer)
- Globulina gibba D'Orbigny
- Globulina gibba, fistulose var.
- Globulina gibba D'Orbigny var. tuberculata D'Orbigny
- Globulina minuta (Roemer)
- Globulina munsteri (Reuss)
- Globulina rotundata (Bornemann)
- Glandulina laevigata D'Orbigny
- Sigmomorphina jacksonensis (Cushman)
- Polymorphina advena Cushman
- Ramulina, sp.
- Nonion advenum (Cushman)

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[38]Cooke, C. W., The age of the Ocala limestone: U. S. Geol. Surv., Prof. Paper 95, pp. 107-117, 1915.

———, The Cenozoic formations, *in* Geology of Alabama: Geol. Surv. Alabama, Spec. Rept 14, p. 271, 1926.

Nonion inexcavatum (Cushman & Applin)
Nonion micrum Cole
Nonion planatum Cushman & Thomas
Nonionella cockfieldensis Cushman & Ellisor
Nonionella jacksonensis Cushman
Nonionella hantkeni (Cushman & Applin)
Nonionella hantkeni var. spissa Cushman
Camerina, sp.
Operculina mariannensis Vaughan
Bolivinella, sp.
Virgulina dibollensis Cushman & Applin
Bolivina jacksonensis Cushman & Applin
Bolivina, sp.
Reussella eocena (Cushman)
Angulogerina ocalana Cushman
Trifarina bradyi Cushman var. advena Cushman
Discorbis assulata Cushman
Discorbis globulo-spinosa Cushman
Discorbis hemisphaerica Cushman
Lamarckina ocalana Cushman
Gyroidina soldanii D'Orbigny var.
Eponides jacksonensis (Cushman & Applin)
Siphonina advena Cushman var. eocenica Cushman & Applin
Siphonina cf. jacksonensis Cushman & Applin
Pulvinulinella exigua (H. B. Brady)
Globigerina, sp.
Anomalina, sp.
Planulina cf. byramensis (Cushman)
Cibicides americanus (Cushman)
Cibicides lobatulus (Walker & Jacob)
Cibicides mississippiensis (Cushman)
Cibicides pseudoungerianus (Cushman)
Cibicides yazooensis Cushman
Gypsina globula (Reuss)

Ostracoda:

Cytherella, sp.
Cytherelloidea montgomeryensis Howe
Bairdia, sp.
Paracypris franquesi Howe & Chambers
Cytheridea caldwellensis Howe & Chambers
Cytheridea grigsbyi Howe & Chambers
Cytheridea montgomeryensis Howe & Chambers
Paracytheridea belhavenensis Howe & Chambers
Cytheropteron montgomeryensis Howe & Chambers
Eocytheropteron spurgeonae Howe & Chambers
Cythereis deusseni Howe & Chambers

Cythereis florienensis Howe & Chambers
Cythereis gibsonensis Howe & Chambers
Cythereis hysonensis Howe & Chambers
Cythereis israelskyi Howe & Pyeatt
Cythereis jacksonensis Howe & Pyeatt
Cythereis montgomeryensis Howe & Chambers
Cythereis yazooensis Howe & Chambers
Cytheretta alexanderi Howe & Chambers
Brachycythere watervalleyensis Howe & Chambers

Crustacea Decapoda:
Callianassa, n.sp.
Calappid, genus indet., dactylus

Echinoidea:
Periarchus lyelli (Conrad)

Bryozoa:
Numerous branches, indet.

An equally important discovery was made by A. C. Ellisor[39] who found *Nonionella cockfieldensis* in the middle and upper portions of the Gosport sand in Willow branch about 4 miles from Silas on the road to Fail, Choctaw County, Alabama. The foraminifer occurs there in beds 3 and 6 of the section described by Cooke.[40] *Nonionella cockfieldensis* and *Periarchus lyelli* range, therefore, from the upper Gosport sand into the "*Scutella*" bed. Whether the *Nonionella* ranges also into the lower part of the Gosport sand is a moot question, because no recognizable formanifera have been found in the lower Gosport sand so far. Nevertheless, it seems rather obvious that the *Nonionella* might be found at a favorable locality in that part of the Gosport sand too.

These observations point to the conclusion that the "*Scutella*" bed and the Gosport sand belong together. Therefore, it is not feasible to place one in the Jackson and the other in the Claiborne group. It is perhaps not even advisable to separate them into different formations. This conclusion is at variance with current ideas and is based on the evidence discussed above, which is herewith summarized:

(1) Perfect transition exists between Gosport sand and "*Scutella*" bed.

(2) *Periarchus lyelli* (Conrad) occurs in both layers.

[39]Letter to H. B. Stenzel dated March 12, 1938.
[40]Cooke, C. W., The age of the Ocala limestone: U. S. Geol. Surv., Prof. Paper 95, p. 115, 1915.

(3) *Nonionella cockfieldensis* Cushman and Ellisor occurs in both layers.

Nonionella cockfieldensis is an important guide fossil and is used extensively in subsurface correlation. The top of the *Nonionella* zone in particular is widely used and considered a reliable stratigraphic marker. If it can be used in subsurface correlation, it is obviously also useful in surface correlations.

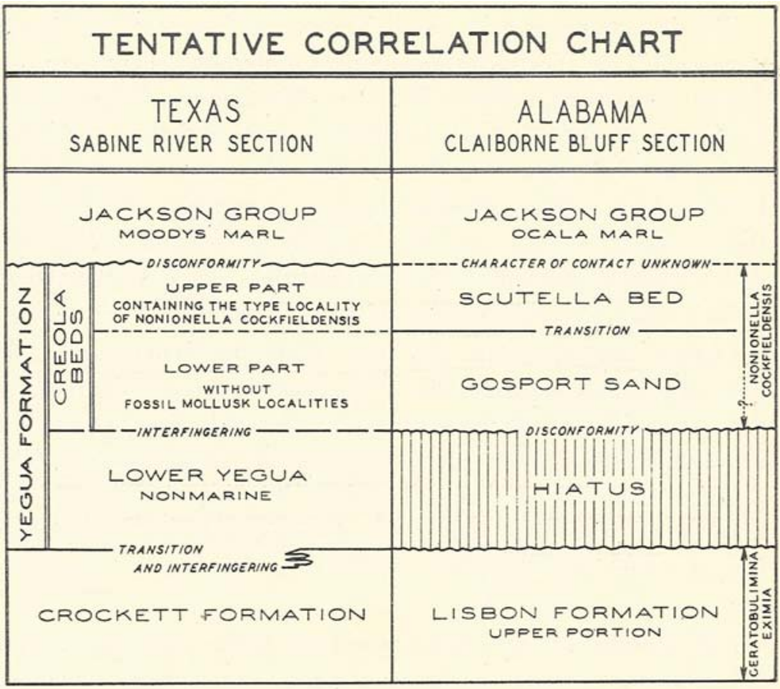
These considerations lead to the following tentative correlation: The "*Scutella*" bed of Claiborne Landing, Alabama, is the approximate equivalent of the fossiliferous Creola bed on Sabine River near Robinson's Ferry, Texas. This correlation is indicated for the following four reasons:

Both beds (1) carry *Nonionella cockfieldensis*
(2) are at or very near the top of the *Nonionella cockfieldensis* zone
(3) have faunas with pronounced Jackson affinities
(4) underlie beds which belong to the Moodys marl of the Jackson group or its stratigraphic equivalent.

According to this correlation it is not expected that the Creola beds along Sabine River in Texas carry a fauna similar to the Upper Claibornian Gosport fauna. The lone fossil locality of this region is too high in the Creola section to carry such a fauna. Perhaps if one could find a fossil locality far enough down in the Creola beds, it would carry such a fauna. Tentatively, one might perhaps assume that the lower part of the Creola beds corresponds to the Gosport sand. There is no strict proof of this assumption, because there are no marine fossil localities known in the lower part of the Creola beds. However, although there is no strict proof of this correlation there is one indication: The Gosport sand interfingers to the west with the upper part of the Yegua formation.

Whether the lower part of the Texas Yegua section is represented by stratigraphically equivalent beds in the bluff at Claiborne, Alabama, is doubtful. It is possible that the equivalent of the lower part of the Yegua is missing, its place being taken by the hiatus which is indicated in the disconformity between the Lisbon and Gosport formations.

All these correlations of the beds in Alabama must be considered as tentative only. Much more work, particularly field work, is necessary to produce a firm basis of correlation. At the present state of knowledge the chief difficulties lie in the Alabama section, and the problem is not so much a Yegua problem as perhaps a Gosport problem.



These correlations differ very much from those recently proposed by Cooke.[41] Cooke claims that the Gosport sand and the Moodys

[41]Cooke, C. W., Equivalence of the Gosport sand to the Moodys marl: Jour. Pal., vol. 13, pp. 337–340, 1939.

Gardner Julia Recent collections of upper Eocene mollusca from Alabama and Mississippi: Jour Pal., vol. 13, pp. 340–343, May, 1939.

In a footnote on a correlation chart dated January, 1937 but not yet published Cooke had already stated: "The Gosport sand may be equivalent to the Moodys marl, and younger than the Yegua." Although H. B. Stenzel did not see this correlation chart until May, 1939 he had been advised of Cooke's correlation by Julia Gardner through a letter sent October 21, 1938.

The mimeographed preprint of "The Yegua Problem" was distributed in March, 1938, and copies of it were sent at that time to C. W. Cooke and Julia Gardner. The distribution of these preprints and the presentation of the paper "The Yegua Problem" at the annual convention of the American Association of Petroleum Geologists in March, 1938, greatly stimulated interest in the Yegua and Gosport problems. Therefore Cooke and Gardner undertook some field work in Alabama in November, 1938. The results of their work were published in the above listed papers.

marl are at least partly contemporaneous and that both are younger than the Yegua. He considers the Gosport sand a part of the Jackson group and places the Yegua formation in the underlying "lower Claiborne." By this procedure he claims to have made the "lower Claiborne" fauna stand out in much sharper contrast to that of the Jackson group.

This is certainly not the case. The marine faunas of the Creola member of the Yegua formation near Robinson's Ferry, Sabine County, Texas, and at Creole Bluff near Montgomery, Grant Parish, Louisiana, do not stand out in sharp contrast to that of the Jacksonian Moodys marl. On the contrary, these two Yegua faunas have decided Jackson affinities and are apparently of an evolutionary stage younger than the Gosport sand fauna. Were the entire Yegua formation of "lower Claiborne" age as Cooke claims it is, it could not carry a fauna of Jackson affinities.

Cooke's contention that the lower Claiborne fauna stands out in much sharper contrast to that of the Jackson group if the Gosport sand is included in the Jackson is also not tenable even if one were to disregard the above mentioned marine Yegua faunas. The Gosport fauna has very many elements which occur also in the lower Claiborne. The percentage of species common to both the Gosport sand and the lower Claibornian Crockett is quite impressive.

Paleontologic evidence does not support Cooke's conclusions; on the contrary, it tends to disprove them. Stratigraphic evidence presented by Cooke is best summarized in his own words:

> The Moodys marl of Mississippi bears a striking resemblance, both in lithologic characteristics and in stratigraphic relations, to the Gosport sand of Alabama. As both merge upward with no discernible interruption into equivalent beds ["*Scutella*" beds], and as both are separated from beds below by a stratigraphic break, the evidence is strong that the Gosport and the Moodys are at least partly contemporaneous.

This stratigraphic evidence is not as conclusive as it would seem. A proof that the stratigraphic break at the base of the Gosport sand and the one at the base of the Moodys marl are the same has not been given by Cooke. On the contrary, there is evidence that these two stratigraphic breaks are not the same. Whether the "*Scutella*" bed at the top of the Gosport sand is the same as the "*Scutella*" bed at the top of the Moodys marl is not known. The two beds would have to be connected by mapping.

Cooke's and Gardner's recent publications should be construed as working hypotheses rather than proved facts. It can not be emphasized too much that much more work, particularly field work, is necessary to produce a firm basis of correlation. At the present state of knowledge the chief difficulties lie in the Alabama section, and the problem is not so much a Yegua problem as perhaps a Gosport problem.

THE NOMENCLATORIAL QUESTION

Hitherto there has been considered only the factual evidence bearing on the Yegua problem. The problem consists not only of a factual or observational part but also of a nomenclatorial part. The nomenclatorial question is discussed in the following pages. The first part of the discussion is left essentially as it was presented in the preprint of this paper. The last part contains the final conclusions in nomenclature.

Lufkin or Angelina County Deposits

The beds which are called Yegua in the preceding part of this report were first given a separate name by Kennedy in May, 1892.[42] He called them the Lufkin or Angelina County deposits. Naturally at that time it was hardly possible to define the beds with much certainty, and some misconceptions crept into his description. One must remember also that the time available to Kennedy was very limited. Houston County, for instance, was mapped within two months. The basal beds of the Lufkin deposits as he gives them are not the same everywhere, and as to his correlation of the basal beds Kennedy entertained considerable doubts which are clearly expressed in the paragraph at the bottom of page 59. Near Alto in Cherokee County the base of the Lufkin beds is given at places

[42]Kennedy, William. A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Surv., 3d Ann. Rept. pp. 41-125. 1892.

which are considered basal Sparta today. In Houston County,[43] the base of Kennedy's boundary rises in the section, according to the present interpretation of the stratigraphy, from basal Sparta to basal Landrum. It is to be expected that the lithologic description of Kennedy's Lufkin deposits reflects this condition. He writes at one place (p. 59) that they consist of gray, white and blue sands, sometimes laminated and cross-bedded, which indicates that possibly he had Sparta beds in mind. On the other hand, he writes that in many places the deposits contain quantities of silicified wood, which indicates Yegua beds as they are now understood. However, this mix-up is for four reasons not so bad at it seems at first glance. First, the choice of Lufkin as the type place clearly indicates that Kennedy had the present-day Yegua in mind; second, the mix-up concerns only the basal part and not the bulk of his formation: third, he had already excluded the Cook's Mountain as a separate formation; fourth, the definition of the Yegua contains exactly the same mix-up. As his Cook's Mountain roughly corresponds to the Crockett, his mapping in Cherokee County is to be considered erroneous. Thus it appears that Kennedy gave the name "Lufkin or Angelina County deposits" to beds which correspond roughly to the bulk of the Yegua formation in the present report, although he may have included in the Lufkin certain upper members of the Crockett as that formation is defined in the present report.

Yegua Division

E. T. Dumble introduced the name Yegua division for the beds at a later date[44] than Kennedy. The letter of transmittal of Kennedy's report is dated May 1, 1892; the letter of Dumble's report November 1, 1892. In addition to this dating by letter of transmission, Dumble himself stated in a later report[45] that his Yegua beds were proposed at a later date than Kennedy's Lufkin.

In the report on the brown coal and lignite of Texas Dumble renamed Kennedy's Lufkin or Angelina County deposits, calling them Yegua division. However, he used Kennedy's text almost word for word for the first two pages of his description of the Yegua.

[43]Kennedy, William Houston County: Texas Geol. Surv., 3d Ann. Rept., pp. 3–40, 1892.

[44]Dumble, E. T., Report on the brown coal and lignite of Texas; character, formation, occurrence, and fuel uses: Texas Geol. Surv., 3d Ann. Rept., pp. 3–40, 1892.

[45]Dumble, E. T., The middle and upper Eocene of Texas: Trans. Texas Acad. Sci., vol. 11, pp. 50–51, 1911.

One will notice readily that Dumble's account of his Yegua on page 149, top, to page 151, line 7, is almost an exact copy of Kennedy's report on pages 58 to 60. Dumble even mentions in one place, page 149, line 10 from bottom, "the upper portion of Lufkin deposits" which he failed to replace by his own term Yegua. In the succeeding pages Dumble gave his own account of the Yegua in the Brazos, Colorado, and Rio Grande sections. Thus Dumble was able to trace these beds nearly through the entire width of Texas. This admirable feat will always remain a monument to Dumble's energy and ability. Aside from this extension of the beds along the strike to the southwest, Dumble also corrected their age. Kennedy had considered the Lufkin deposits and the succeeding Fayette sands and Fleming beds as Miocene. However, on page 61 Kennedy stated that fossils found in the Fayette were referred to the Eocene by W. H. Dall on the strength of the existence of the cast of what appeared to be a *Cardita planicosta.* Dumble evidently drew the necessary conclusion from Dall's determination and placed the Yegua and Fayette in the Eocene. Dumble recognized that his Yegua and Kennedy's Lufkin were exact equivalents. In a later publication[46] he stated:

> In the Third Annual Report of the Geological Survey of Texas. Mr. W. Kennedy, in his paper on this Section from Terrell to Sabine Pass gives the details of the section as he made it from the Angelina River to Corrigan along the line of the H. E. & W. T. Ry. He describes the Lufkin or Angelina County deposits as extending from the Angelina River southward across the Neches River and the Fayette sand as extending from the south side of the Neches, where it overlay the Angelina beds, southward to and beyond Corrigan, where it was overlain by the Flemming clays. Later, when the Yegua beds were differentiated along the Brazos drainage, the Angelina beds were correlated with them, owing to their position above the recognized Marine beds and below the supposed Fayette and the Flemming beds were called Frio.

Naturally Dumble had to make an error of correlation identical with that of Kennedy in Cherokee County, because Dumble used that part of Kennedy's report.

From all this it appears that Dumble's Yegua is a substitute name for Kennedy's Lufkin or Angelina County. Yegua was substituted without any reasons being given for that procedure. Pos-

[46]Dumble, E. T., The Middle and upper Eocene of Texas: Trans. Texas Acad. Sci., vol. II, p. 50. 1911.

sibly Kennedy's name was considered merely a local or temporary name among the members of the Geological Survey of Texas.

There are at present no rules to govern the choice of type localities for a geological formation. Kennedy did not give any type locality for his Lufkin or Angelina County deposits, but from the name he gave it, it is apparent that the type locality should preferably be located near Lufkin. That would place the type locality in about the middle of the Yegua as it is understood today.

Dumble also did not designate a type locality for his Yegua in the report of 1892, which is not surprising because at that time type localities did not receive such strict attention as today. By a peculiar accident he even omitted in 1892 all mention of the localities along Elm Creek, a tributary of Yegua Creek in Lee County, although he designated these localities very definitely as type localities many years later.[47] There is little doubt that these localities were visited by Dumble before the appearance of his report on the brown coal and lignite of Texas, because in a later report[48] he stated that he took a party consisting of Messrs. Cragin, Kennedy, Singley, and Ragsdale through Lee, Washington, and Waller counties, leaving Austin May 16, 1892. This date is about 7 months earlier than the date of transmittal of the brown coal report, the latter being December 12, 1892.

The type localities of Dumble's Yegua are located, as he pointed out in 1920, along the basal boundary of his Yegua. At these localities are found many fossiliferous layers, of which some belong to fossiliferous lentils in the basal part of Dumble's Yegua. These localities were visited and examined critically by Julia Gardner.[49] M. M. Stadnichenko[50] reported on the foraminifera and ostracoda of the localities. The writer has also visited these localities in Lee County and found that what Dumble called Cook's Mountain at that place is the writer's Wheelock member and what Dumble and Julia Gardner understood to be basal Yegua is lower Landrum by correlation. The fossils discussed by Julia Gardner and M. M. Stadnichenko come from the transition of the Wheelock into the

[47]Dumble, E. T., The geology of east Texas: Univ. Texas Bull. 1869 pp. 102–106. 1918 [1920].

[48]Dumble, E. T., (Report of State Geologist for 1892): Texas Geol. Surv., 4th Ann. Rept., p. xxv, 1893.

[49]Gardner, Julia, The correlation of the marine Yegua of the type sections: Jour. Pal. vol. 1, pp. 245–251. 1927.

[50]Stadnichenko, M. M., The Foraminifera and Ostracoda of the marine Yegua of the type sections: Jour. Pal., vol. 1 pp. 221–243, 1927.

Landrum. Dumble's original definition of the Yegua includes, therefore, the Landrum shale, the Spiller sand, the Mount Tabor shale. and the Yegua of the present writer. Had the present writer followed the original definition of the Yegua strictly he would have had to call the Wheelock member Cook's Mountain and to include all beds above the Wheelock member in the Yegua. Factual evidence presented on preceding pages makes such procedure inadvisable.

It is obvious that the fauna from these so-called type localities can not be used to determine the age of the Yegua, because a fauna can be used for stratigraphic correlation only when its exact stratigraphic position is known. The exact stratigraphic position of these so-called type localities was not known previously.

Cocksfield Ferry Beds

The next name applied to the beds was Cocksfield Ferry beds. This name was introduced by T. W. Vaughan in 1895.[52] Vaughan's work was in northwestern Louisiana. At that time Dumble's Yegua had not been traced eastward up to the east boundary of Texas. Therefore. Vaughan could not tie his section in with the Texas section and was fully justified in introducing a name for the unit which he recognized clearly. According to Vaughan the type locality of these beds is Petite Ecore Bluff on the left bank of Red River near a ferry and adjacent to a plantation owned at that time by two Cocksfield brothers. Petite Ecore Bluff is in the center of section 2, T. 8 N., R. 6 W., Grant Parish. Louisiana. It is about halfway between St. Maurice and Montgomery, which would put the type locality in about the middle of the formation as understood today.

Harris[53] and Veatch[54] were able to correlate the Louisiana and east Texas sections as early as 1902. This correlation was apparently the first of its kind. According to these two authors, Cocksfield Ferry and Jackson together correspond to the Yegua of east Texas. That the Jackson was thought to correspond with part of the Yegua is due to the fact that at that time no Jackson was known in east Texas. But these details are of no consequence to the present

[52]Vaughan, T. W.. The stratigraphy of northwestern Louisiana: Amer. Geol.. vol. 15. pp. 205–229. 1895.

[53]Harris, G. D, The geology of the Mississippi embayment with special reference to the State of Louisiana. *in* A report on the geology of Louisiana. Louisiana Geol. Surv., vol. 6. p. 21, 1902.

[54]Veatch, A. C.. The geography and geology of the Sabine River, *in* A report on the geology of Louisiana: Louisiana Geol. Surv.. vol. 6 pp. 130–131. 140–141. 1892.

problem. The important fact is that Harris and Veatch were able to correlate the Cocksfield Ferry and Yegua beds roughly. By the time Alexander Deussen[55] investigated east Texas it was known that the Yegua of east Texas and the Cocksfield Ferry of Louisiana were exact stratigraphic equivalents. Throughout Deussen's report Yegua is used in preference to Cocksfield Ferry. Vaughan, who collaborated and discussed problems with Deussen for that publication, recognized the priority of Yegua over Cocksfield Ferry.

In recent times the term simplified to Cockfield has been revived and is used even today by some writers. However, the term Cockfield has acquired two different, unrelated uses: one, the original use, meaning the nonfossiliferous, sandy, lignitic, nonmarine shales of Claiborne age; another, a new use, meaning the zone of *Nonionella cockfieldensis* Cushman and Ellisor, which occupies, however, only a part of the Yegua formation as understood in the present report. Considerable confusion has been the result of the new use of Cockfield as a formation name for the zone of *Nonionella cockfieldensis.* For instance, in one report dealing with subsurface stratigraphy the two names, Cockfield and Yegua, are used. It is stated that the Cockfield formation overlies the Yegua formation. In another report, also dealing with subsurface sections, the Yegua formation is divided in two members, Cockfield and Upper Saline Bayou. The Cockfield member is said to be the upper of the two. Both publications treat the same stratigraphic interval. One wonders whether it is necessary to use formational names for fossil zones employed in subsurface stratigraphy, particularly for publication in scientific and professional journals. A recent article by M. A. Hanna[56] shows in a clear and exemplary manner how fossil zones and formation names should be handled.

This confusion has made the name Cockfield as a surface formation name undesirable. Therefore, to avoid confusion both usages of the term Cockfield should be dropped.

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[55]Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Surv., Water-Supply Paper 335, 365 pp., 1914.

[56]Hanna, M. A., Wilcox Eocene production at Segno field, Polk County, and Cleveland field, Liberty County, Texas: Bull. Amer. Assoc. Petr. Geol., vol. 22, pp. 1274–1277, 1938.

SUMMARIZED NOMENCLATORIAL DATA

	Pro	Con
Lufkin or Angelina County Deposits Date: May, 1892 Author: W. Kennedy Type locality: Probably near Lufkin, Angelina County, Texas Definition: Same as Yegua	Priority over Yegua and Cocksfield Type locality lies in middle of the section Misuse of name almost entirely absent Description of beds independent; exactly the same as Yegua description	Common usage is nearly nil Redefining of boundaries needed
Yegua Division Date: Nov., 1892 Author: E. T. Dumble Type locality: Yegua Creek, Lee County, Texas	Common usage favors Yegua	Priority none Type locality lies in lower part of Crockett Misuse of name restricted to basal beds Description not independent; chiefly based on Lufkin description Redefining of boundaries needed
Cocksfield Ferry Beds Date: 1895 Author: T. W. Vaughan Type locality: Petite Ecore Bluff near Cocksfield Ferry on Red River, La.	Type locality lies in middle of the section Description clear, precise	Priority none Common usage is small Misuse of name common, for the *Nonionella cockfieldensis* zone Redefining of boundary needed

Conclusion

The three terms Lufkin, Yegua, and Cockfield have been used for the beds in question in the past. Today two of the terms are in more or less wide use. All three terms have their advocates. However, this writer believes few advocates of one term or the other have up to now had sufficient data at hand to judge correctly. Most certainly one should first consider and weigh the factual evidence, that is, the observations in the field. This factual evidence is paramount, and the name which is being used must be adapted to fit the hard and unavoidable facts.

The retention of the name Yegua in this report should not be construed as an approval or commitment of any sort. On the contrary, the writer advocates the use of Lufkin as a name for these beds. The reasons for this preference are detailed in the nomenclatorial discussion in the preceding pages and are summarized below in table form. However, the writer has refrained from introducing Lufkin in a formal manner, because he feels that prior to such a nomenclatorial change the question should be brought to the attention of other workers interested in this problem. Nevertheless, the writer might be permitted to point out that a decision should be made now, because postponement would increase confusion. It might also be pointed out that since a decision must be made, it would be just as feasible to reintroduce the name Lufkin as to retain one of the other terms. The occasion for consideration of a change is now here.

Added Statement

This discussion of the three names, Lufkin, Yegua, and Cockfield, was included in a preprint of this paper, which was sent to numerous geologists working in the Gulf Coastal Plain. Many geologists have been so kind as to give the writer their reaction to the nomenclatorial question. Although some agreed with the writer's arguments and indicated their preference for the name Lufkin, the concensus was decidedly against it and for the retention of the name Yegua.

The time is past when a single investigator could propose a major change in nomenclature in the Gulf Coastal Plain. Such changes are properly settled by majority opinion of the investigators concerned with this region. Therefore, the name Yegua is herewith used definitely and formally in preference to any other name and in disregard of the writer's previous arguments. The name Yegua is a surface formation name and is, of course, to be used only for surface stratigraphy.

As a consequence of this decision, the type localities of the Yegua as given by Dumble and other authors following him are herewith declared invalid and are abandoned. Another, new type locality could very well be found and definitely designated. Such a locality should preferably be located on Yegua Creek, which flows in parts of its course across the entire Yegua formation. However, for the present it is just as well that no definite locality be chosen.

Where the uppermost Yegua contains beds which are clearly marine, for instance, glauconitic sands and clays or fossiliferous beds or fucoid layers, it is advisable to use a definite name for this partly marine section. For this section the writer has introduced the name Creola member. This term should be used in preference to the indefinite and incorrect term "transition." In order to distinguish that part of the Yegua which lies below the Creola member, the writer reintroduces herewith Lufkin in a restricted form. The Yegua formation is therefore divided into an upper, partly marine member, the Creola, and a lower, nonmarine member, the Lufkin.

The members need only be used where a distinction between the two is necessary. Because such distinction is not needed in most cases, the use of these member names should remain small. The two member names are proposed merely for surface work. They should not be used in place of fossil zones.

SUMMARY

1. The Crockett of east and central Texas consists of four members, Wheelock, Landrum, Spiller, Mount Tabor, which are described and defined.
2. The lower boundary of the Yegua lies on top of the Mount Tabor member and at the base of the Bryan sand, which is a local sand lentil of the Yegua.
3. The upper boundary of the Yegua is defined by the disconformity with which sediments of the Jackson group begin.
4. The redefined Yegua is a convenient and natural nonmarine formational unit bounded by a major, regional regression

of the sea at the base and a major, regional transgression of the sea at the top.

5. Where the uppermost beds of the Yegua are marine in part, the Yegua is divided into the upper, partly marine Creola and the lower, nonmarine Lufkin member. The boundary between these two members is indistinct and transitional.
6. The upper layers of the Creola member of the Yegua contain marine faunules with Jackson affinities.
7. The Creola member is tentatively correlated with the Gosport sand and the "*Scutella*" bed of the Alabama section.
8. The "*Scutella*" bed is tentatively referred to the Claiborne group.

PLATE 48

Jackson-Yegua contacts in Brazos County, Texas.

1. Jackson-Yegua contact near Humble pipeline in gully, right tributary to Carters Creek, north of Rock Prairie, in J. M. Higgins 122-acre tract, Thos. Caruthers survey, about 4.25 miles airline distance southeast of the Agricultural and Mechanical College of Texas. Dr. F. E. Turner holds his hand on the contact.
2. Jackson-Yegua contact in deeply incised gorge of right tributary of Hopes Creek, in the oakwoods on Phillip Hensarling's land in northern part of James Hope survey, about 5 miles south of College Station. (Compare Pl. 49, fig. 3.) The contact is indicated by stars.


1


2

PLATE 49

Jackson-Yegua contacts.

1, 2. Moodys marl–Yegua contact on Creole Bluff, near Montgomery, Grant Parish, Louisiana, showing large boulders in basal portion of Moodys marl and bore holes filled with Moodys marl extending into the underlying Yegua beds.

3. Same locality as figure 2, Plate 48, showing well-bedded Caddell formation above and poorly bedded, exfoliating Yegua beds below the contact. The contact is indicated by stars.

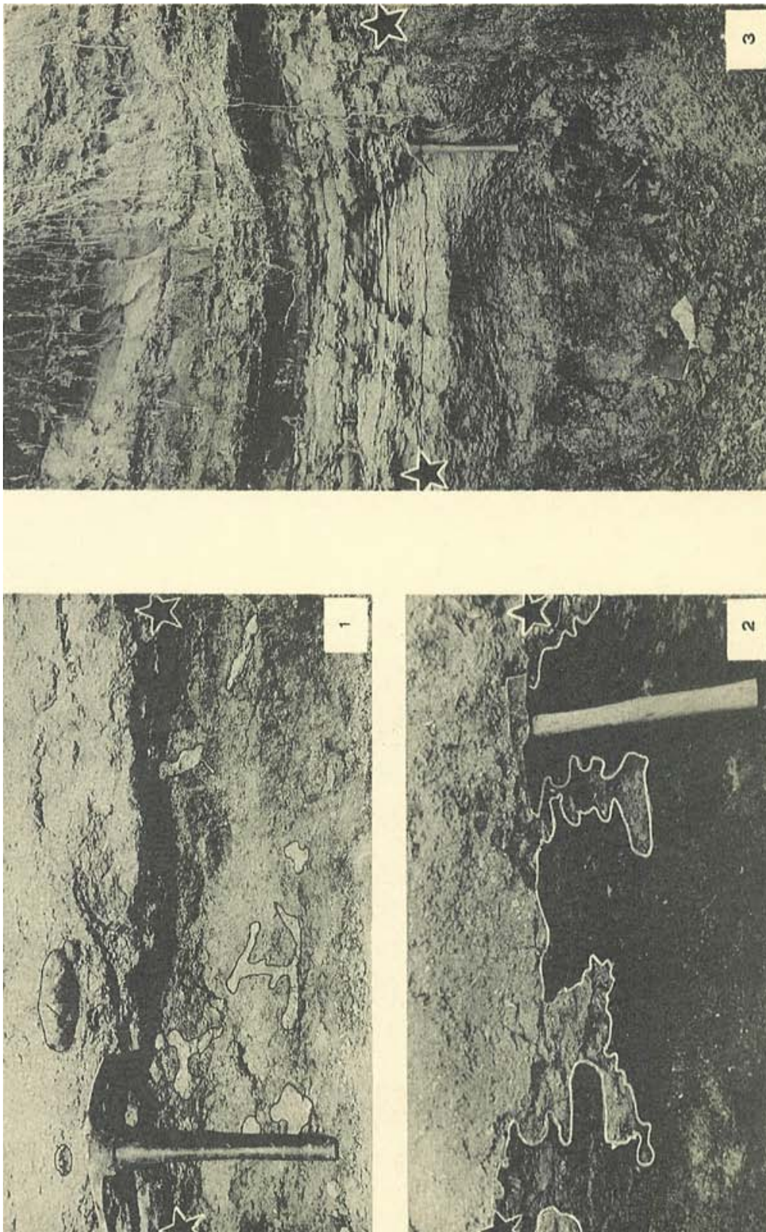
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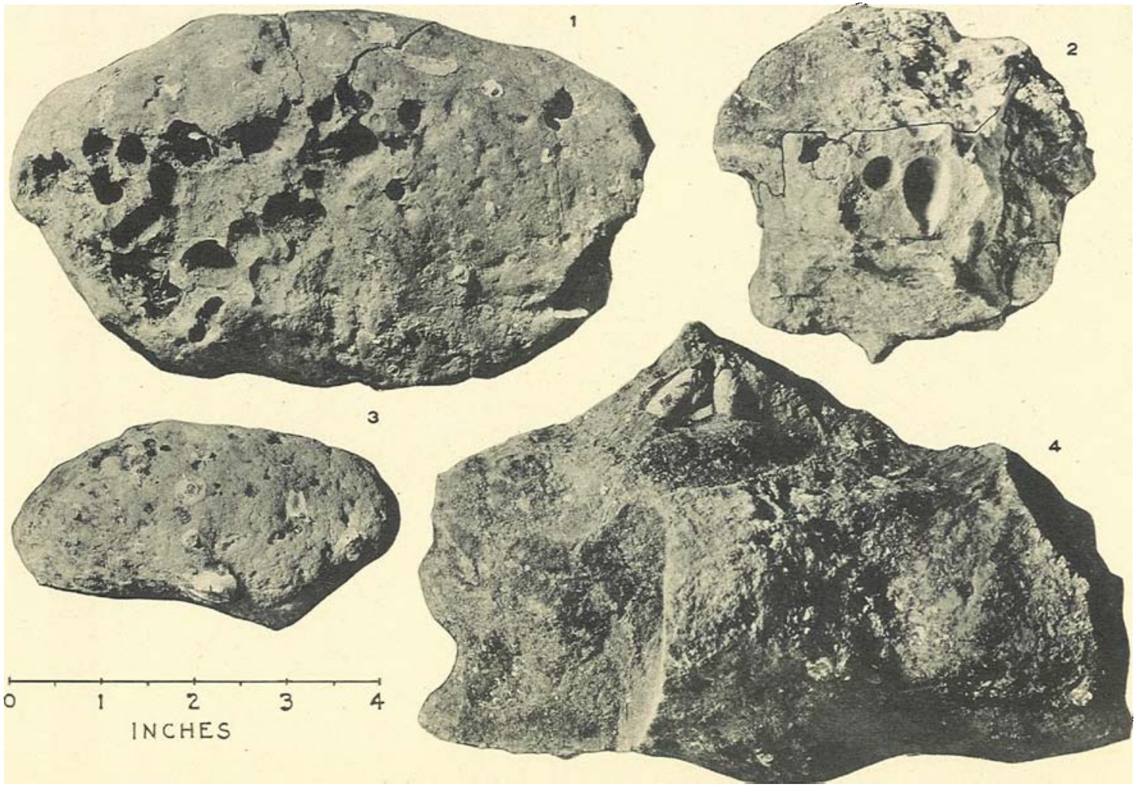
PLATE 50

Boulders from the basal Moodys marl of Creole Bluff near Montgomery, Grant Parish, Louisiana.

1. Boulder with bore holes broken open. One of the cracks on top is overgrown by Bryozoa.
2. Broken boulder in matrix showing two empty bore holes, one in cross section, the other in axial section, and one matrix-filled bore hole. Thin white lines in matrix above the boulder are large foraminifera in cross section.
3. Complete small boulder with bore holes and bases of corals grown onto the boulder.
4. Large boulder, broken, showing on top two bore holes filled with fossil boring clams in their original position.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INCHES

A BISMUTH-MOLYBDENUM PROSPECT (KIAM PROSPECT) OF LLANO COUNTY, TEXAS

PART 1

H. B. Stenzel

Location.—The Kiam prospect is one of the many prospects of the Central Mineral region of Texas. This region occupies the center or core of the Llano uplift, where the pre-Cambrian basement rocks have become exposed due to the doming of the rocks and the subsequent removal of the overlying sediments.

The Kiam prospect is in southeastern Llano County about 12 miles southeast of the town of Llano by air-line distance. Its location is between Riley and Packsaddle mountains on the banks of Honey Creek, which is a right tributary of Llano River.

The nearest easily accessible shipping point is Llano. Although the depot at Kingsland is nearer, it is not easily accessible on account of the lack of a bridge over Llano River at that place.

This prospect was examined by H. B. Stenzel in December, 1938. Samples collected at that time were investigated in the laboratory by V. E. Barnes.

Rock sequence.[1]—The rocks exposed in and around the prospect are all pre-Cambrian in age and crystalline in character. The oldest rocks are schists which belong to the Packsaddle schists. These schists are of variable composition in the vicinity of the prospect. The most common type is a fine- to medium-grained, feldspathic quartz-mica schist of gray color and pronounced schistosity. South of the entrance to the underground workings there is a band of marble of gray to white color and coarse grain. This marble is very poorly exposed at the surface. It has been penetrated by an inclined diamond drill hole south of the prospect. North of the prospect there is an exposure of chlorite-hornblende schist on the left bank of Honey Creek. This schist is blue-black

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[1]Stenzel H. B., Pre-Cambrian of the Llano uplift, Texas (abst.): Pan-Am. Geol., vol. 57, pp. 72–73, 1932; Bull. Geol. Soc. Amer. vol. 43, pp. 143–144, 1932.

———, Pre-Cambrian structural conditions in the Llano region *in* Sellards, E. H. and others, The geology of Texas Vol. II, Structural and economic geology: Univ. Texas Bull. 3401, pp. 74–79, 1935

———, Pre-Cambrian unconformities in the Llano region: Univ. Texas Bull. 3501, pp. 115–116 1935.

Issued June 1940.

in color and thinly schistose. In spite of the variations in composition, the different types of schist comprise a unified series of concordant layers which strike west-northwest and dip about 35 degrees to the south-southwest in the vicinity of the prospect.

The next younger rock is the Valley Spring gneiss which crops out about 1500 feet north of the prospect. This gneiss is a pink, thick-layered, and medium- to fine-grained rock of intrusive origin.

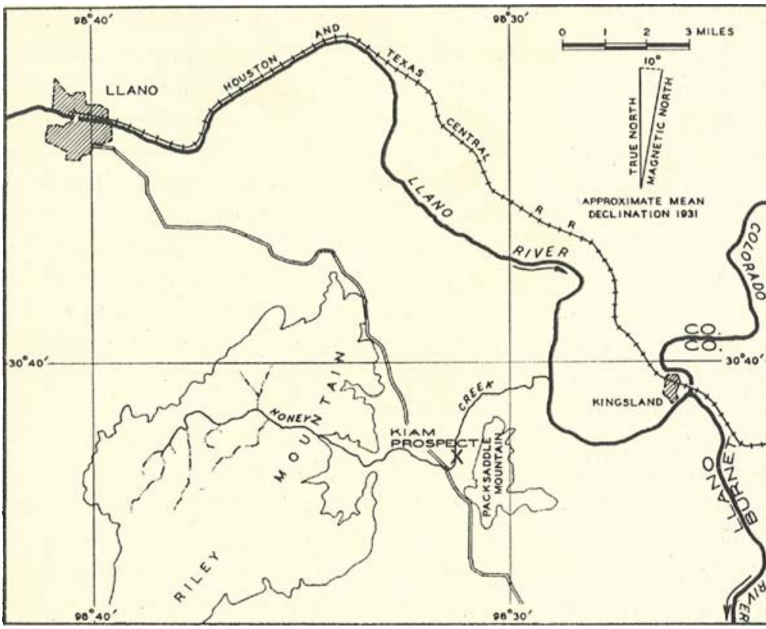


Fig. 135. Map showing location of Kiam prospect in Llano County, Texas.

Its schistosity is parallel with that of the schists. In this region the gneiss dips under the schists into which it is intruded.

The pegmatites are younger than the gneiss and schists and are intrusive into both. There are several pegmatites in the region around the prospect. These pegmatites are granite pegmatites composed chiefly of white, milky quartz, flesh-colored or pink microcline, and minor amounts of silvery muscovite and other minerals. The grain is very coarse but variable. Feldspar is usually more common along the margins, while quartz is more common in the center of the pegmatites. The pegmatites are roughly parallel with the schists into which they are intruded. They strike and dip in the same directions as the schists. The pegmatites vary considerably in thickness from place to place and do not seem to exceed 15 feet.

Younger than the pegmatites are quartz veins. These veins are composed almost entirely of quartz. Pink feldspar is found in small quantities in them, indicating that the quartz veins are closely related to the pegmatites. An interesting example of this relationship is visible near the east end of the underground workings. There a quartz vein extends from the pegmatite upward through the schists. The quartz in the center of the pegmatite gives rise to the quartz vein, and the transition from pegmatite to quartz vein is a gradual one. At this place it is clear that the quartz vein is a late offshoot of the residual pegmatite magma. It is presumed that the other quartz veins are of similar origin. Most of the quartz veins are short lenses roughly concordant with the schists. Usually several such lenticular and parallel quartz veins are found in the schists near the schist-pegmatite boundaries either below or above the pegmatite. Their distance from the pegmatite rarely exceeds 4 feet. The fact that these quartz veins accompany the pegmatite is a further indication of their derivation from the pegmatite magma. These quartz lenses are usually only a few inches thick. Cross-cutting quartz veins are rarer than the roughly concordant lenses. Two of these cross-cutting veins are exposed underground.

Structure.[2]—The structure of the region is essentially simple, although it is complicated by several factors. The Kiam prospect lies on the southwest flank of a pitching anticline. The axis of this anticline, called the Babyhead anticline, trends southeastward and pitches in that direction. The core of the anticline is composed of Valley Spring gneiss while the flanks are composed of Packsaddle schists. Therefore, the gneiss underlies the schists and dips under them. This relationship is recognizable along the course of Honey Creek north of the prospect. There the gneiss is exposed about 1500 feet north of the prospect and dips under the schists, which

[2]Stenzel, H. B., Structural study of a phacolith: Rept. 16th Intern. Geol. Congress, vol. 1, pp. 361–367, 1936.

————. Pre-Cambrian structural conditions in the Llano region, *in* Sellards, E. H., and others, The geology of Texas, Vol. II, Structural and economic geology: Univ. Texas Bull. 3401, pp. 74–79, 1935.

are exposed to the south of the gneiss. The dip is south-southwestward at about 35 degrees. For that reason it is probable that the gneiss underlies the schists at the prospect roughly 1100 feet below the surface.

The schists are intruded by several lenticular bodies of granite pegmatite. These pegmatites are roughly parallel with the schistosity of the schists; in other words, the pegmatites are sills. Nevertheless, cross-cutting relations are clearly shown in several places. At the west end of the underground workings there is a large block of schist enclosed by the pegmatite and one of its branches. The branch is in part cross-cutting. At another place in the west drift the schists are turned up from their normal dip and abut against the pegmatite (fig. 137, section B). Between sections F and G of figure 136 the pegmatic sill widens suddenly. This widening is accomplished by cross-cutting of the schists in an irregular manner. This relationship is well shown underground in the east drift at a place located about halfway between the two sections. Although similar cross-cutting relationships are visible in many places, they are of minor importance and do not change the fact that the granite pegmatite is essentially a sill.

Among the pegmatites one is of particular importance. This is the pegmatite exposed at the prospect on the surface and in the workings. This pegmatite has been followed by the underground workings for about 350 feet along its strike. On the surface it may be traced for a much longer distance to both sides of the prospect. The greatest thickness exposed underground is 9 feet, which is found near the center of the underground workings. Toward the east the thickness decreases, and at the east end it is only 2.8 feet. The thickness decreases similarly to the west, but an exact thickness cannot be given for the farthest end of the underground workings because only one of the sill contacts is visible there.

The granite pegmatite is accompanied by thin quartz lentils. These lentils are also chiefly sill-like in character, although cross-cutting branches are quite numerous. The lentils are in the schists, above and below the pegmatite, and most common within 4 feet from the contacts of the pegmatite with the schists.

This whole series, schists, pegmatite, and quartz lenses, strikes as a whole west-northwest, but at one place in the east drift there is a pronounced flexure, and the strike at that place is rather northwest than west-northwest. The dip of the series fluctuates between 17 and 57 degrees without any apparent regularity.

The arrangement of these rocks is complicated by several faults, the oldest of which is a thrust fault. This fault is well exposed in the middle part of the east drift and the lower part of the incline. Soft clay-like gouge is found along the fault plane. The fault plane dips at a low angle, 31 degrees, and this angle is smaller than the dip of the schists and the pegmatite. The pegmatite is repeated by the fault, and the arrangement is such that it can be explained only by thrusting (fig. 137). The south block has moved up and over the north block. What appears to be the same fault is exposed in the south end of the longer one of the two cross-cuts off the west drift. However, this fault exposure is too small to show a repetition of the pegmatite. From the situation underground it is evident that the thrust fault must abut against the fault breccia of the large normal fault, although the place where this abutting takes place is not opened up in the underground workings.

Two cross faults are exposed underground. The larger of the two is visible at the mouth of the incline and at the fork of the west drift and the longer of the two cross-cuts. This fault is also visible at the surface of the ground above the underground workings. The throw at the entrance is 9 feet. The fault is filled with breccia of angular and crushed schist and pegmatite fragments. This breccia attains a thickness of 2 feet. The dip of the fault plane is steep to the east-southeast, the angle of dip being 71, 67, and 84 degrees at various places, indicated on figure 136. This fault offsets the pegmatite sill. This offsetting is clearly visible at the surface above the mouth of the incline and underground along the longer one of the two cross-cuts. The arrangement indicates that the fault is a normal one. The second cross fault is visible farther west in the west drift. It cuts off abruptly the southwest end of a white quartz vein. The fault plane is well shown on the south wall of the drift, but on the north wall it seems to split into several fractures of negligible throw. The angle of dip of the fault plane is 83 degrees to the west-northwest. The throw of this fault could not be determined. This fault is most probably a normal one.

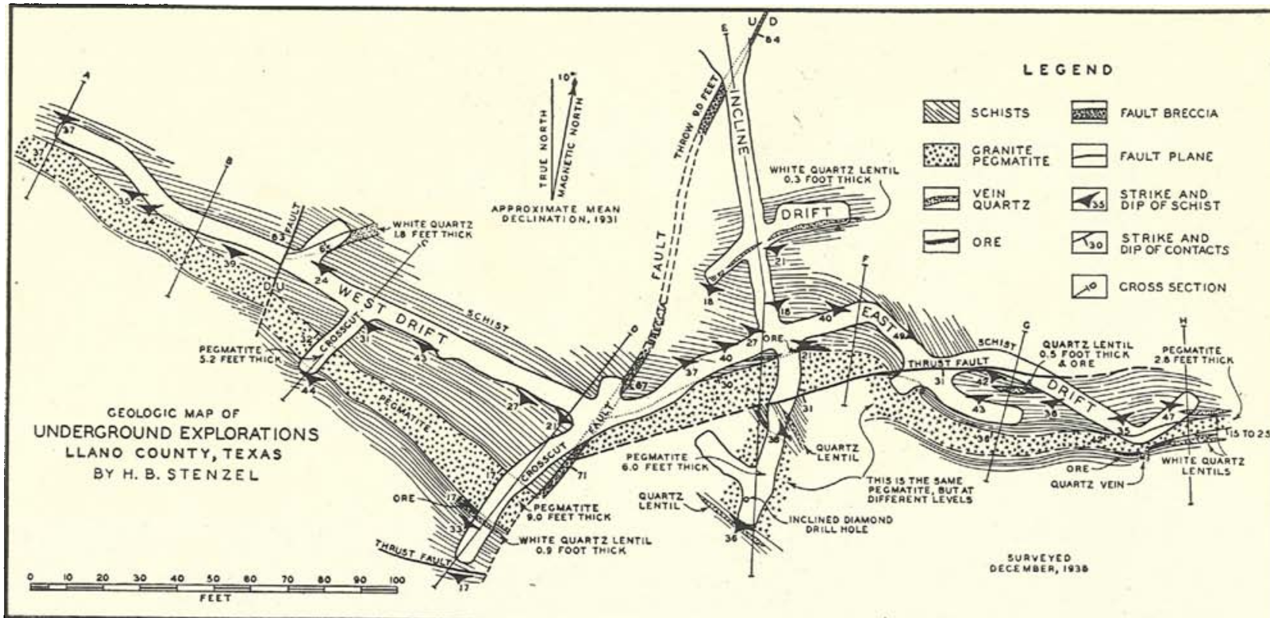


Fig. 136. Geologic plan of the underground workings of the Kiam prospect, Llano County, Texas.

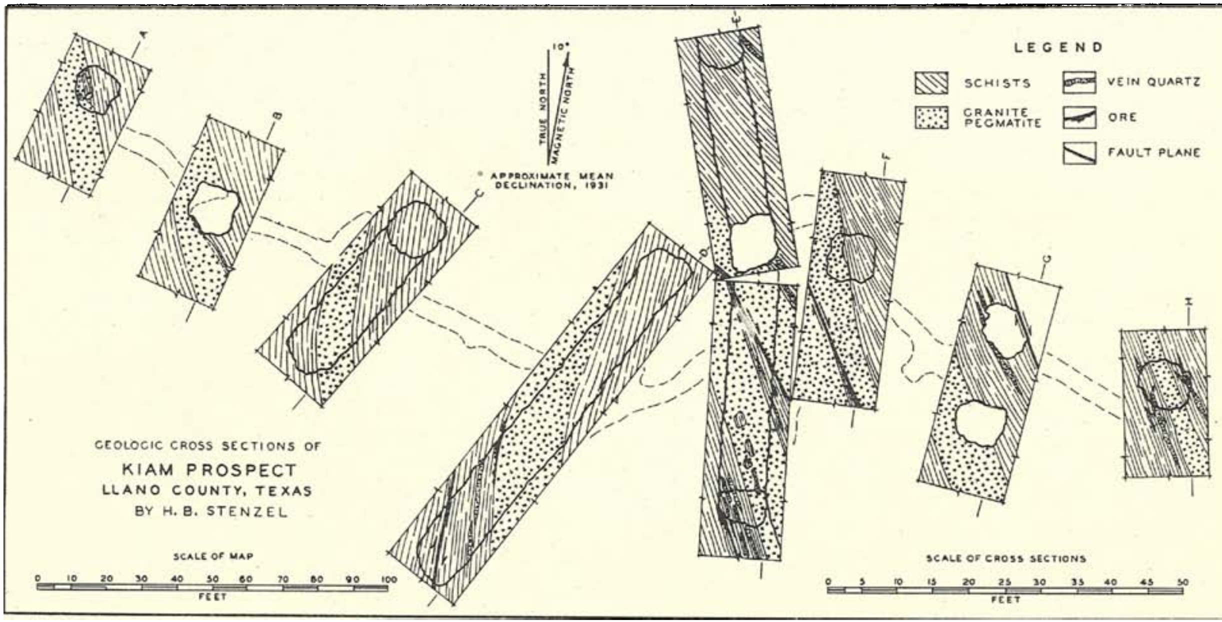


Fig. 137. Geologic cross sections of the underground workings of the Kiam prospect, Llano County. Texas.

Part 2

Virgil E. Barnes

A polished section examination using etching tests supplemented by microchemical tests was made of the ore minerals from the Kiam prospect. Molybdenite is present as clusters of flakes and individual flakes, some of which are curved. Two other metallic minerals, native bismuth and bismuthinite, are present. Some intergrowths of these two minerals were seen which range up to 3 millimeters across. The bismuthinite where observed is always associated with native bismuth. The native bismuth, however, is also widely distributed elsewhere as pin-point sized specks. Tetradymite was not found in the specimens examined. It was especially searched for after mention of it was found in a private report. Tests for copper and lead were also negative.

In addition to these metallic minerals, a small amount of pyrite is present along joint planes in the pegmatite. This pyrite was deposited much later and has no connection with the original mineralization.

A petrographic examination was made of the ore-bearing pegmatite, of the offshoot quartz veins, and of the intruded schist. The ore-bearing pegmatite is of a very light buff or tan color and is different in appearance from most of the pegmatites of the Llano area. When tested with hydrochloric acid much effervescence takes place, indicating the presence of a carbonate. The pegmatite contains some molybdenite near the upper contact, as well as a bluish-black discoloration caused by finely divided bismuth.

In thin section the non-ore-bearing pegmatite is a highly sericitized potash-feldspar in which it is difficult to see the feldspar outlines and twinning. So far as could be seen, carlsbad twinning is common; microcline twinning is absent, or so confused that it was not recognized; and albite twinning in irregular small patches within extinction areas indicates a perthitic structure. In the sections studied, quartz is very scarce and where present is usually associated with the ore minerals. A small amount of muscovite is also present in the harder portions of the pegmatite.

Dark-colored areas of the pegmatite are composed of the same minerals as the light-colored areas, with the addition of bismuth having a broken reticulate pattern. The bismuth has replaced the feldspar along the cleavages, not as continuous sheets, but as elongated blebs, or plates. Plate 52, figure 1, is a photomicrograph illustrating this replacement. Fine black lines in one thin section, when magnified, have much the same appearance as the reticulated bismuth just mentioned. The blebs of bismuth, however, are more densely distributed along the fracture lines and thin out rapidly along the feldspar cleavages at either side, giving a feathery appearance to the bismuth aggregate. Plate 52, figure 2, is a microphotograph illustrating the feathery type of replacement.

The bismuth-bismuthinite intergrowths are massive and in large part are associated with calcite. The calcite and the bismuth minerals have penetrated the pegmatite as veinlets replacing the minerals encountered. The edge of one quartz grain along such a veinlet has a micropegmatitic structure. The intergrown material is bismuth. A highly micaceous portion of the ore-bearing pegmatite was sectioned. Poikiloblastic structures have been developed by replacement. In some minerals the replacement is slight with small patchy areas of replacement, while in others, the replacement has proceeded until only small disconnected areas of the original mineral are left. These original mineral areas are recognized by the synchronous extinction of the remaining fragments. The replacing minerals are calcite, muscovite (sericite), and the ore minerals. The replaced minerals are feldspar and, to a much smaller extent, quartz. The ore minerals occupy positions along muscovite grain boundaries and cleavages, which suggests that they were last in the series to be deposited.

Titanite and molybdenite are associated with a greenish feldspar-quartz-pegmatite vein in one of the samples. A thin section was made including part of the titanite area. The titanite is mostly of the same crystal orientation and is apparently one of the original pegmatite minerals. Several minerals are present within this titanite crystal, including quartz, muscovite, chlorite with an anomolous blue interference color, and bismuth. Small, rounded areas of another mineral not identified are present. Surrounding this mineral, the titanite is radially cracked as if expansion had taken place. This expansion may be a weathering effect since the mineral varies from a colorless anisotropic mineral to one that is brown clouded and practically amorphous.

From this examination, it is concluded that the ore-bearing solutions followed and replaced portions of the pegmatite and caused sericitization of the feldspars at some time following the injection of the pegmatite into the schist.

Quartz stringers as offshoots of the pegmatite have penetrated the schist. Thin sections cut across the quartz-schist boundary show a clearly visible knife-edge alteration zone containing sericite and clouded feldspar. The next quarter of an inch of schist is also altered, but this is not so apparent without careful examination. The structure of this zone of alteration is the same as that of the normal schist. The mineral composition is somewhat different. In the altered zone, biotite, quartz, and oligoclase are predominant. Some albitization has taken place. Very narrow schist stringers extend into the quartz vein along crystal boundaries. These stringers show a progressive change in character. Near the schist, the biotite is darker colored and pleochroic, and farther from the contact, the biotite becomes fainter in color and in pleochroism until at the ends of the stringers, a colorless mica greatly resembling muscovite is present. The feldspar in these stringers is altered and hazy appearing throughout.

The quartz vein is composed of crystalline quartz in grains averaging about 3 to 5 millimeters in size. The grain boundaries are interlocking. The quartz has sheet-like zones containing fine bubbles or inclusions. These sheets are at a steep angle to the schist contact and in places extend across grain boundaries.

The unaltered schist is composed of biotite, microcline, oligoclase, and quartz. In both the altered and unaltered schist, the biotite is nicely aligned.

A fine-grained schist not immediately adjacent to the pegmatite was also examined. It is a biotite-muscovite schist containing, in addition, quartz and potash-feldspar. The feldspar is in part without twinning and in part with poorly developed microcline and carlsbad twinning. The biotite is almost perfectly aligned, but the muscovite is oriented at random. The muscovite plates are much larger in size than the biotite plates, and they are arranged in zones which are parallel to the schistosity. The muscovite has been introduced following the development of the schistosity. A few porphyroblasts of feldspar are present, and one cataclastic fragment about 3 millimeters long is composed of feldspar at one end and a mosaic of quartz at the other. The feldspar porphyroblasts have been reduced by attrition to a bi-wedge shape, and biotite is concentrated along the borders. Some less distinct, more elongated porphyroblasts or cataclastic fragments of quartz are also present.

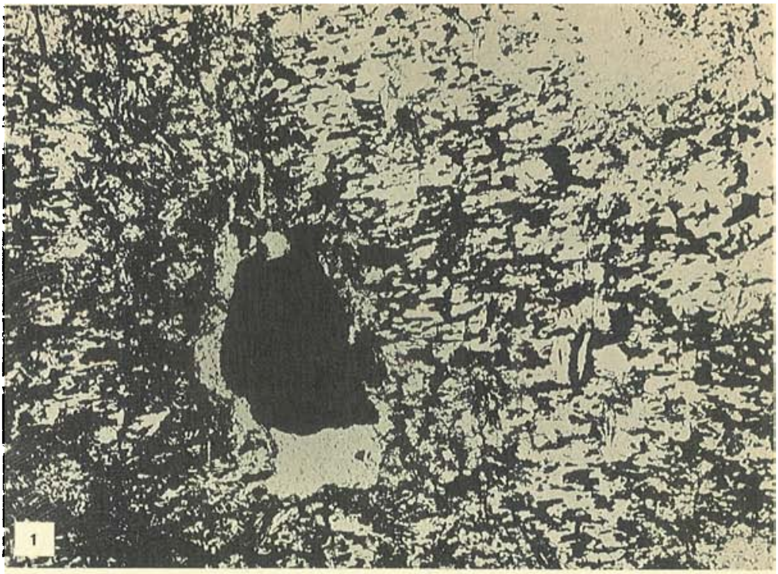
This pegmatite is lighter colored and is somewhat different in appearance from most of the pegmatites of the central pre-Cambrian area. However, other light-colored pegmatites are present to the east of Packsaddle Mountain that might warrant examination for mineral deposits. A study of all these light-colored pegmatites might lead to the identification of the granite from which these pegmatites were derived. The structure of the granite could then be determined and recommendations for further prospecting made.

No assays or analyses were made of this ore-bearing material. From the field examination of this property, it is apparent that insufficient molybdenum and bismuth minerals are present to be commercial. Gold has been reported in assays, but apparently an insufficient amount is present to warrant exploitation.

PLATE 52

Photomicrographs of bismuth replacing feldspar in the pegmatites of the Kiam prospect.

1. Bismuth replacing feldspar along the cleavages producing a broken reticulate pattern.
2. Bismuth replacing feldspar along fractures and to some extent along cleavages outward from the fractures.



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SUBSURFACE DIVISIONS OF THE ELLENBURGER FORMATION IN NORTH-CENTRAL TEXAS

Leo Hendricks

Research on the Ellenburger formation of Texas has been carried on over a period of several years. As set out in this paper, the results of this work show that the Ellenburger formation in north-central Texas can be divided into four units. Basis for the division is the change in character of contained cherts as revealed by study of insoluble residues. Regional correlation shows westward thinning of the formation due to pinching out at the base and erosion at the top. In the region of the Red River uplift the formation is greatly thinned by erosion and perhaps lack of deposition at the top.

The Ellenburger formation was named by Sidney Paige[1] to include a series of limestones and dolomites outcropping in the Central Mineral region of Texas. The formation is Cambro-Ordovician in age, several faunal units having been recognized lately. Dake and Bridge[2] found the faunal equivalents of the following Missouri formations:

Cotter
Jefferson City
Roubidoux
Gasconade
Eminence
Potosi

They also report an estimated thickness of 2000 feet at the outcrop. As revealed by well drillings, the thickness of the formation varies from 495 to 2366 feet in the subsurface of north-central Texas.

The lithology of the Ellenburger formation consists of fine, medium, and coarse dolomites, and dense, gray to white limestones. In general, the upper part of the Ellenburger is fine to micro-crystalline dolomite with some limestone members. The middle

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[1]Paige, Sidney, Description of the Llano and Burnet quadrangles: U. S. Geol. Surv., Geol. Atlas, Llano-Burnet Folio (No. 183).

[2]Dake, C. L., and Bridge, Josiah, Faunal correlation of the Ellenburger limestone of Texas: Bull. Geol. Soc. Amer., vol. 43, pp. 725–741, 1932.

Issued June, 1940.

Ellenburger may be fine or coarse grained, with limestones more abundant in the upper part. The lower Ellenburger is characteristically coarse grained, with limestone members rare. Changes in lithology can not be used for regional correlation, and in local correlation lithologic character is merely an aid and not conclusive evidence. As an example, the Bartles and Dumenil No. 1 Baugh well and the Y. C. No. 1 Jones well in Brown County are only 5 miles apart, yet their limestone members can not be correlated exactly. The texture of the dolomite is similar in the two wells.

In order to understand the stratigraphic relationships from well to well and to get a precise picture of the underlying structure, it is necessary to divide the Ellenburger into recognizable units. Residues obtained from treating samples of the formation with dilute hydrochloric acid have furnished data of such correlative value that a division of the formation can be made.

The use of residues from acid treatment as an aid in stratigraphic correlation has become fairly well established as a geologic method. By common understanding the term "insoluble residue" is used to describe the material left after the acid treatment, even though only one type of acid is used. McQueen[3] has been able to draw many subsurface cross sections in Missouri using residues to identify formations. Another early study using residues of both surface samples and well cuttings was made on Mississippian limestones of Kentucky.[4] More recently the method has been successfully applied to subsurface limestones of central Kansas,[5] and to Ordovician and overlying formations in Tennessee.[6] M. G. Cheney[7] has correlated the Ellenburger from wells to the outcrop by means of residue studies. In every case the procedure has been essentially the same as that followed for this paper, with some workers making a quantitative as well as a qualitative study of the residues.

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[3]McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geol. Mines, 56th Bien. Rept. Appendix I, p. 102, 1931.

[4]Martin, H. G., Insoluble residues of some Mississippian limestones of western Kentucky: Kentucky Geol. Surv., Ser. VI, vol. 41, p. 133, 1931.

[5]Hiestand, T. C., Studies of insoluble residues from "Mississippi Lime" of central Kansas: Bull. Amer. Assoc. Petr. Geol., vol. 22, p. 1588, 1938.

[6]Born, Kendall E., and Burwell, H. B., Geology and petroleum resources of Clay County, Tennessee: Tennessee Division of Geol., Bull. 47, pp. 20–57, 1939.

[7]Cheney, M. G., Geology of north-central Texas: Bull. Amer. Assoc. Petr. Geol., vol. 21, pp. 65–118, 1940.

In preparing residues for this study, the following method was used: A cut of the original sample was placed in a 250-cc. beaker and enough dilute muriatic acid (about 12 per cent) added to dissolve the carbonate content. When dissolution was completed, the residue was carefully washed by adding water and decanting, and then dried on a hot plate. The amount of original sample used in the case of well samples was usually limited by the amount available. An amount up to 30 grams is desirable. As little as 4 to 5 grams has been used successfully. A qualitative study of the residues under a low-power microscope was made the basis for zonation of the formation. A quantitative study was found to be unreliable.

The residues from the Ellenburger formation consist for the most part of chert and quartz in one form or another. Accessory materials are sand grains, shale fragments, pyrite, a soft, chalky, siliceous material, anhydrite, and, in one case, fluorite. The diagnostic feature for correlation purposes is the texture of the characteristic chert of a zone. By "characteristic chert" is meant that type of chert that occurs most consistently from sample to sample, not necessarily the most abundant type in each sample. The diagnostic textures are: *smooth, crystalline, granular.* The difference in these textures when studied microscopically is on the order of the difference between a crystalline dolomite and a dense limestone. The break from one type to another is usually quite distinct, so that where the samples are good the contacts are well marked.

Using the changes in character of insoluble residues as the principal criterion, four units are recognized in the Ellenburger in the area covered by this paper (Pl. 53). For identification the units are assigned numbers, unit 1 being the youngest, unit 4 the oldest. These units and their varying relationships are illustrated on cross sections (Pl. 54), the locations of which are shown on the map (Pl. 53).

The residue from unit 1 is marked by the prevalence of smooth-textured white chert. Rounded and frosted sand is characteristic of the unit but not diagnostic. The sand is more abundant in the lower half of the unit. Translucent chert is occasionally very abundant but has no particular correlative significance. Shale fragments and flakes, soft, unctuous, gray, and light green, are typically present. The argillaceous residues are more typical of the limestone members. Clear quartz may be present but is rare in this unit. The white chert may be slightly dolocastic,[8] occasionally contains sand grains, and is oolitic in part. This unit is best developed in the Western Lampasas Oil Company No. 1 Whittenburg well, Lampasas County. In this well it has a thickness of 960 feet, but it thins to the north and west over the Bend arch. With more material for study this unit probably can be further subdivided, at least for local correlation. But with the material at hand no sound basis for division could be established.

The diagnostic feature of unit 2 is the crystallinity of the characteristic chert. The texture varies from finely crystalline to cryptocrystalline. The color is white for the most part but varies to buff, brown, and gray. The chert may be vitreous to translucent. It is more abundantly dolocastic than unit 1 chert and may be highly dolocastic. Clear, drusy quartz is characteristic of this unit and is the most outstanding feature from a descriptive standpoint, but since it is not unique to this unit it can not be used as a diagnostic marker. Frosted sand grains continue to appear but not as abundantly as in the unit above. Some chalk-textured white chert and very little smooth white chert appear in the residues. Unit 2 averages a little over 500 feet in thickness where it is not wedged out at the bottom or eroded at the top.

Unit 3 has the most easily recognizable residues of the formation. The distinctive feature is the granular appearance of the characteristic chert. The fragments are usually small, uneven, and occasionally branching. The fragments may even become granulated, so that they separate into granules when crushed. The texture varies from microgranular to finely granular. Another feature characteristic but not diagnostic of the unit is very finely dolocastic white chert. All other types of chert found in the formation may appear at one place or another in the unit. In fact, other types may almost obscure the granular chert, but the latter is the only type that persists throughout the unit. It is chiefly white but in some cases is brown. Oolites occur intermittently, as do frosted

[8]Dolocast, cavity left after dissolving out dolomite crystal. See McQueen, H. S., Insoluble residues as a guide in stratigraphic studies: Missouri Bur. Geol. Mines, 56th Bien. Rept., Appendix I, p. 102 1931.

sand grains. The average thickness of the unit is 400 feet where it is fully developed.

Unit 4 does not offer a distinctive type of chert by which it can be identified. Therefore, recognition of this unit depends on the general appearance of the residue as a whole. The upper part of the unit has a rather variegated residue, each sample characteristically containing several types of chert. The most common type is a chalky to chalk-textured, white chert, but there may also be smooth, white, crystalline, vitreous, and translucent chert. The fragments may be dense, rough, smooth, porous, or dolocastic. The residue as a whole is more dolocastic than otherwise. As the unit is penetrated deeper the residues become more drusy and quartzose until the lower part of the unit is marked by an abundance of coarsely drusy, dolocastic quartz. The unit is distinguished from the one directly above it by the absence of granular chert, but in some cases it is very difficult to differentiate between it and unit 2. It is a matter of carefully studying and developing a "feel" for the general appearance of the residues. The Deep Oil Development Company No. 1 Hirschi well in Wichita County, the only well so far known to drill entirely through unit 4, found 1072 feet of that unit. It is assumed, as indicated on the cross sections (Pl. 54), that this unit wedges out entirely toward the west on the east flank of the Bend arch.

The detailed descriptions of the residues from two wells (see end of paper) will help illustrate the basis for setting up the four units. Application of the residue method, in the case of the Ellenburger at least, is made difficult by the appearance of apparently significant variables. By this is meant the presence of such things as frosted sand grains, shale fragments, oolites, translucent chert, and quartz fragments, that appear to define zones in one well but do not appear at the expected intervals in the next well. Even after the textures of characteristic cherts are made the basis for division, the presence of such materials in abundance tends to obscure the significant element. Another variable that affects the character of the residues is the texture and composition of the original rock. Limestones tend to have more argillaceous residues than dolomites. Fine and coarse-grained dolomites give a slightly different appearance to the same type of chert.

It is not assumed that the criteria used for correlation in this report will apply equally well throughout the extent of the Ellenburger. They are described primarily to show the basis for the correlations herein contained.

The cross sections (Pl. 54) show the variable thickness of the Ellenburger to be due to wedging out at the base and erosion, with possibly lack of deposition, at the top. Some structural feature in the region extending north-northwest from San Saba County had a profound influence on the deposition of the Ellenburger. Coming up over the present arch from the east, the lower units successively wedge out on an older Cambrian formation. The upper unit is greatly thinned by erosion and perhaps lack of deposition. Going off the arch to the west, there is a continued slight thinning of the formation, with only parts of units 1 and 2 being present in the Jamison No. 1 Webb well in Taylor County. Dake and Bridge[9] found a similar condition of basal beds becoming successively younger in going from east to west across the Central Mineral region uplift.

Northward in the region of the Red River uplift, the Ellenburger reveals very interesting stratigraphic and structural relationships. South of the uplift, as shown in the Lindsey-Deep Oil Development Company No. 1 Wilson, Archer County, much older Ellenburger was deposited than in the area to the south of that well. The upper units, however, including 1, 2, and part of 3, are now missing, even though the well is structurally low. On the south flank of the Electra structure, still older Ellenburger has been penetrated, and more of the younger units are missing, in the Gulf Oil Corporation No. 43 Burnett, Wichita County. North of the Electra structure the Deep Oil Development Company No. 1 Hirschi, Wichita County, penetrated what approaches a full section of the Ellenburger as it is developed east of the Bend arch. Going completely through the formation, the well drilled 2237 feet of the Ellenburger as compared to 2366 feet drilled in the Seaboard Oil Corporation No. 1 Dawson, Hamilton County. Most of unit 1 is missing in the No. 1 Hirschi, but this well penetrated over 550 feet more of unit 4 than did the Hamilton County well.

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[9]Dake, C. L., and Bridge, Josiah, *op. cit.*

Contours on the uneroded top of a unit give a more nearly accurate structural picture than do contours on the eroded top of the Ellenburger (Pl. 53). Since no one unit extends entirely over the area under consideration, it is necessary to contour on one unit over the Bend arch region and on another in the Red River uplift area. Due to lack of control, the contours on the map and correlation lines on the cross sections are only general guides as to where the Ellenburger will be reached by the drill. In some instances the two are not in good agreement. For instance, a well drilled near Graham in Young County should reach unit 2 somewhere below —4500 feet, according to the structural contours. According to cross section A-A this unit should be reached at about —3800 feet. Closer control probably would reveal that the units continue to dip north for some distance from the Lassiter et al No. 1 Texas Pacific Fee well in Palo Pinto County instead of reversing at that well as indicated on the section. Thus the structural contour is the more reliable guide.

CORRELATION OF SUBSURFACE UNITS WITH FAUNAL ZONES

A number of surface exposures of the Ellenburger formation have been sampled and studied in detail. Samples were taken at an average of 5-foot intervals. It was thought at the time that this type of sampling was adequate for an insoluble residue study of the formation. Now it is realized that in order to pick definite contacts and identify units the sections must be sampled much more closely. Fresh chip samples should be taken every few inches and a composite sample made covering about 5 feet of the section. This procedure would offer greater insurance that each sample included characteristic residues of its unit. However, samples taken at 5-foot intervals furnish enough evidence to make a general correlation of the surface section with the subsurface units.

Dake and Bridge measured a section about 10 miles due southeast from Llano on Honey Creek.[10] From faunal evidence they identified the entire section of 750 feet as Cotter-Jefferson City, with possibly a small amount of Roubidoux at the base. Residues from this section are typical of unit 1. Thus the Cotter and Jeffer-

[10]Dake, C. L., and Bridge, Josiah, *op. cit.*

son City equivalents are definitely correlated with a part at least of unit 1.

Along Llano River about 10 miles southwest of Mason, Dake and Bridge identified approximately 300 feet of Ellenburger as Roubidoux in age. Residues from this section are closely similar to those from unit 1. The Roubidoux, therefore, is at least in part included in unit 1. The section sampled occurs in a bluff about one-half mile upstream from where the White ranch road crosses Llano River.

No section definitely identified as upper Gasconade has been found that is suitable for sampling. A section of Ellenburger along Honey Creek about 6 miles west of Mason has middle Gasconade, marked by *Eccyliomphalus gyroceras*, at the base and Roubidoux, marked by *Roubidouxia*, sp.,[11] at the top. It is assumed that some part of the intervening medium crystalline dolomite member is upper Gasconade in age. The actual thickness of the members represented in this section can not be measured due to numerous small faults. For some distance below the top of the section, samples show residues typical of unit 1. Likewise, for some distance above the base the residues are typical of unit 3. Residues from the intervening zone are characteristic of unit 2. Based on the above assumption of age, the upper Gasconade is tentatively correlated with unit 2 of the subsurface.

As indicated above, the middle Gasconade faunal zone produces residues that correspond in character to those of unit 3. A section north of Camp San Saba along the Brady-Mason highway identified by Dake and Bridge as middle Gasconade yielded residues typical of unit 3. The middle Gasconade zone is therefore correlated with unit 3.

Dake and Bridge measured a zone of lower Gasconade at least 260 feet thick on the west slope of Indian Mountain in the northwest portion of the Burnet quadrangle. Residues from this section are characteristic of unit 4. This indicates that the lower Gasconade belongs somewhere within that unit.

An Eminence-Potosi section in the extreme southeast corner of San Saba County is described by Dake and Bridge. This section is in the slope above what is now the west shore line of Buchanan

[11]Fossils identified in the field by C. L. Dake.

Lake, about three-quarters of a mile north of the mouth of Fall Creek. Samples yielded a residue characteristic of that from unit 4. Hence the Eminence-Potosi faunal zones are placed in unit 4 along with lower Gasconade.

In summary, a comparison of residues from surface samples to residues from subsurface samples suggests the following correlation.

Unit 1	Cotter Jefferson City Roubidoux
Unit 2	Upper Gasconade
Unit 3	Middle Gasconade
Unit 4	Lower Gasconade Eminence Potosi

Much more field work involving intense sampling and fossil collecting must be done before it can be determined whether or not the contacts of the faunal zones correspond to those of the subsurface units.

ACKNOWLEDGMENT

Much credit is due Dr. E. H. Sellards, Director of the Bureau of Economic Geology, for his encouragement and helpful criticism of this work. It was his original suggestion that the Ellenburger formation could be sub-divided in this manner. The writer therefore wishes to express his sincere thanks to Dr. Sellards.

WELL DATA

Samples from the Ellenburger section were studied in numerous wells in north-central Texas. The limits of the units present in sixteen of these wells are given in the following summary. Only those wells drilling a considerable section of Ellenburger are included in the summary.

SUMMARY OF WELLS*

Name and location of well	Elev. *Feet*	Unit 1	Unit 2	Unit 3	Unit 4	Total depth *Feet*
Archer County						
Lindsey-Deep Oil Development Co. No. 1 Wilson, lse. 5-A; Sec. 75, A.T.N.C. Lands; 10 mi. from E, 11 from N county line	981	Abst.	Abst.	5335 to 5638	5638 to 5740	5740
Brown County						
Bartles & Dumenil & Texas Co. No. 1 Baugh; Osborn Dalton surv. 26; 7½ mi. N, 1½ E Brownwood	1395	2278 to 2597	2597 to 3039	Abst.	Abst.	3400
Y.C. Oil Co. et al. No. 1 Jones; H. Kraber surv. 19; 2 mi. NE Brownwood	1367	1794 to 1960	1960 to 2425	2425 to 2545	*	2545
Comanche County						
Gallagher & Lawson No. 1 Terry; N. H. Kuykendall surv.; 1½ mi. SE Desdemona	1334	3403 to 4015	4015 to 4511	4511 to 4633	Abst.	5257
Eastland County						
S. A. Hopkins et al. No. 1 Davis; block 4, sec. 47, H. & T. C. RR. surv.; 7 mi. N, 7 W Cisco	1449	3930 to 4483	4483 to 4839	Abst.	Abst.	5591
Hamilton County						
Seaboard Oil Corp. No. 1 Dawson; sec. 41, B.B. B. & C. surv.; 5½ mi. from SW, 2 from most southerly NW county line	1442	2993 to 3900	3900 to 4420	4420 to 4850	4850 to 5359	5359
Seaboard Oil Corp. No. 1 Fee; A. C. Grimes surv.; 4 mi. W Fairy	1228	4140? to 4483	*	*	*	4483
Lampasas County						
Western Lampasas Oil Co. No. 1 Whittenburg; block 229, sec. 38, John Boyd surv. 612; 3 mi. W Lometa	1450T	962 to 1922	1922 to 2515	2515 to 2645	Abst.	4180
Palo Pinto County						
Lassiter et al. No. 1 Texas Pacific Fee; sec. 5. A. B. & M. surv.; 1½ mi. NE Gordon	948	4029 to 5060	5060 to 5567	5567 to 5630	*	5630
San Saba County						
Norman No. 1 Gibbons; G. Voight surv.; 22½ mi. from S, 6½ from W county line	1640	200 to 715	715 to 1002	*	*	1002

*The depths given in the four unit columns are depth in feet below the surface. An asterisk (*) in the column indicates that unit was not reached.

Name and location of well	Elev. Feet	Unit 1	Unit 2	Unit 3	Unit 4	Total depth Feet
Shackelford County						
Hammond Oil & Gas Co. No. 1 Morrison; sec. 159, B.B.B. & C. surv.; 2 mi. from N, 1½ from W county line	1605	5127 to 5194	5194 to 5222	*	*	5222
Taylor County						
Jamison et al. No. 1 Webb; sec. 46, L.A.L. surv.; 3 mi. from E, 13 from S county line	1905	4770 to 4956	4956 to 5265	Abst.	Abst.	6016
Throckmorton County						
Swenson Oil & Gas Co. No. 1 Swenson; sec. 173, B.B.B. & C. surv.; 8 mi. from W, 7½ from N county line	1506	5500 to 5732	5732 to 5964	*	*	5964
Wichita County						
Deep Oil Development Co. No. 1 Hirschi; D. Cowan surv., A-43; 1 mi. S Red River, 10 mi. from W county line	1069	3510 to 3750	3750 to 4270	4270 to 4675	4675 to 5747	6002
Deep Oil Development Co. No. 1 Munger; block 30, K.W.V.F.L. surv.; 9 mi. from W, 1½ from S county line	1013	Abst.	Abst.	4240 to 4609	4609 to 5430	5430
Gulf Oil Corp. No. 43 Burnett; sec. 4, H. & T. B. surv., A-752; 5 mi. S, 2 E Electra	1126	Abst.	Abst.	Abst.	3715 to 4295	4295

Description of Insoluble Residues from Well Samples

The diagnostic element, where present, is indicated by bold-face type.

Deep Oil Development Company No. 1 Hirschi; D. Cowan survey, A-43; 10 miles from west line of county, 1 mile south of Red River, Wichita County. Elevation 1069 feet.

	Depth Feet
Smooth to cryptocrystalline, white chert; large caving sand, shale, quartz grains	3510–20
Smooth-textured, white to grayish-white chert with few fine dolocasts; large caving sand, shale, chert	3520–30
Smooth-textured, white chert, arenaceous in part; soft, white powdery fragments containing few sand grains; rounded, frosted sand grains	3530–40
Smooth white chert; soft, white fragments containing few sand grains; rounded, frosted sand	3540–50
Smooth white chert; soft, white fragments; sand grains may be in place	3550–60

	Depth *Feet*
Soft white fragments; few rounded, frosted sand grains; **trace smooth white chert**	3560–70
Smooth, white chert; light cream-colored, oolitic chert; soft, gray flakes and fragments; few coarsely frosted sand grains	3570–80
Soft, white to grayish-white fragments; **smooth-textured, uneven white chert;** few frosted sand grains probably in place	3580–90
Small residue; soft, white chalky fragments; **smooth-textured white chert,** one fragment arenaceous; few rounded, frosted sand grains	3590–3600
Smooth, white to slightly translucent chert; finely porous, cryptocrystalline white chert; finely granulated silica in porous fragments; soft white fragments; waxy green shale may be in place; few fine frosted sand grains	3600–10
Smooth white chert; finely porous, white, chalky fragments; very finely granulated silica; fine to medium, rounded, frosted sand grains	3610–20
Same as sample from 3610–20 feet	3620–30
Smooth white chert with trace light buff chert, scattered oolites; finely porous, white, chalky fragments; finely granulated silica, sometimes embedding sand grains; fine, rounded, frosted grains	3630–40
Translucent chert; **smooth white and some buff-colored chert,** showing an occasional fine dolocast; fine, rounded, frosted sand grains	3640–50
Translucent chert; **smooth-textured white chert with scattered fine dolocasts;** finely granulated silica; frosted sand grains	3650–60
No sample	3660–70
Large shale caving; no residue recognizable as being in place	3670–85
Same as sample from 3670–85 feet	3685–90
No sample	3690–3700
Large shale caving; small residue **smooth-textured white chert**	3700–10
No sample	3710–15
Smooth white chert with trace oolites; smooth-textured white chert, in part very finely porous; large shale caving	3715–23
Large shale caving; no residue recognizable as being in place	3723–28
Small residue **smooth and cryptocrystalline white chert,** large shale caving	3728–40
Same as sample from 3728–40 feet	3740–50
Small residue smooth and cryptocrystalline white chert; small fragments **delicately porous microcrystalline chert;** sand and shale cavings; some clear quartz; trace very fine druse	3750–63
No sample	3763–65
Large shale caving; small residue **cryptocrystalline white chert** with trace dolocasts; trace fine druse	3765–70
Same as sample from 3765–70 feet	3770–78

	Depth *Feet*
Microcrystalline, slightly grayish-white chert, dolocastic in part; **cryptocrystalline, vitreous chert;** very finely granular white chert; drusy flakes; large shale caving	3778–85
Microcrystalline, dolocastic white chert; cryptocrystalline white chert; thin, drusy chert flakes; large shale caving	3785–90
Slightly translucent, white to slightly buff chert; microgranular, finely porous and dolocastic chert; trace **microcrystalline, vitreous chert;** large shale caving	3790–96
Microcrystalline, finely porous and dolocastic white chert; smooth white chert; vitreous white chert; very finely drusy, irregular chert flakes; large shale caving; few oolites of white chert	3796–3800
Finely crystalline, white chert with scattered dolocasts; some smooth white and vitreous white chert; clear quartz showing terminated crystals; shale cavings	3800–05
Finely crystalline white chert, in part porous and dolocastic, in part flaky fragments; smooth white to light buff chert, in part semi-translucent; trace clear quartz; shale caving	3805–15
Finely crystalline white chert, in part finely porous and dolocastic; smooth white to buff, slightly translucent chert; trace clear, crystal quartz	3815–25
Finely crystalline to microcrystalline white chert; smooth white chert; sand and shale cavings	3825–35
Same as sample from 3825–35 feet	3835–45
Finely crystalline white chert, dolocastic and drusy in part; smooth white chert; trace clear quartz	3845–60
Rough, dissected, **granular crystalline white chert;** trace smooth white chert; trace fine chert oolites	3860–70
Granular crystalline chert, in part rough and dissected; trace knarly white chert	3870–80
Finely crystalline uneven white chert; smooth to slightly knarly white chert; trace clear crystal quartz	3880–85
Finely crystalline to microcrystalline white chert; smooth white to slightly translucent chert	3885–90
Uneven, slightly knarly white chert; **finely crystalline granular chert;** trace clear quartz	3890–3900
Uneven, very **finely crystalline granular white chert;** smooth white to light buff chert; chert oolites may be cavings	3900–10
Rough, **crystalline granular chert,** white to translucent, with scattered dolocasts; trace smooth white chert; some clear crystal quartz	3910–20
No sample	3920–30
Rough, **crystalline granular, white chert,** in part porous and dolocastic; **cryptocrystalline, vitreous white to slightly brownish chert;** some clear crystal quartz	3930–40

	Depth Feet
No sample	3940–50
Rough, **finely crystalline granular chert; microcrystalline, slightly brownish chert;** trace clear crystal quartz	3950–60
No sample	3960–70
Nature of residue badly obscured by caving; apparently **microcrystalline, vitreous chert; finely crystalline granular chert;** clear crystal quartz	3970–75
Microcrystalline, vitreous chert; rough, dissected, **crystalline granular chert;** very finely granular silica; rounded, frosted sand grains in place; trace clear quartz	3975–80
Finely crystalline granular chert, drusy in part; **microcrystalline, vitreous chert;** finely granulated silica; some rounded, frosted sand grains in place; sand and shale caving	3980–90
Microgranular white chert with few dolocasts; trace white chert; sand may be caving; trace finely granulated silica	3990–95
Cryptocrystalline, white to slightly buff chert; smooth white to translucent chert; some vitreous chert; trace drusy quartz; very fine to medium, rounded, frosted sand	3995–4005
No sample	4005–10
Cryptocrystalline to smooth, **cream-colored to white chert;** some vitreous chert; trace granular, **crystalline, dissected chert;** fine to medium, rounded, frosted sand	4010–15
No sample	4015–25
Sand, shale, and chert cavings; residue apparently rounded, frosted sand and smooth to **cryptocrystalline white chert**	4025–30
Microcrystalline to cryptocrystalline chert; smooth white to light buff chert; trace crystalline granular, dissected chert; rounded, frosted sand	4030–40
No sample	4040–50
Finely crystalline to microcrystalline, vitreous chert with trace fine druse; some smooth white chert; few rounded, frosted sand grains	4050–65
Microcrystalline, vitreous chert; microgranular, highly porous white chert; smooth white chert with few fine dolocasts; rounded, frosted sand grains	4065–75
Fine, rounded, frosted sand; smooth, white chert; some **microcrystalline white chert**	4075–85
Smooth, white to buff chert; **microcrystalline, white to buff chert;** microgranular, uneven, finely porous white chert; fine to medium, rounded, frosted sand	4085–90
No sample	4090–4100
Microcrystalline, white to vitreous chert, in part rough, finely granular; smooth, white to buff chert; fine to medium, rounded, frosted sand	4100–05
No sample	4105–20

	Depth Feet
Small residue; light green, waxy shale; traces smooth white and vitreous chert	4120–30
Fine to very fine, rounded, frosted sand; **cryptocrystalline vitreous to white chert;** smooth white chert	4130–35
Same as sample from 4130–35 feet	4135–40
Cryptocrystalline, white to slightly vitreous chert; smooth white chert; some microgranular, finely porous white chert; fine, frosted sand grains	4140–45
No sample	4145–50
Cryptocrystalline, white to grayish-white and buff chert, with some vitreous chert; very uneven, microgranular, finely porous, white chert; smooth white chert; fine to medium-coarse, rounded, frosted sand	4150–55
Microgranular, very irregular, porous white chert with traces fine dolocasts; **cryptocrystalline white to slightly vitreous chert;** smooth white chert; fine to medium, rounded, frosted sand	4155–60
Same as sample from 4155–60 feet	4160–65
No sample	4165–70
Irregular, microgranular, finely porous white chert; irregular white siliceous flakes showing very fine dolocasts; **cryptocrystalline white to slightly vitreous chert;** few frosted grains	4170–75
Same as sample from 4170–75 feet	4175–80
No sample	4180–89
Cryptocrystalline, white to vitreous chert; some smooth white to slightly translucent chert; fine, frosted sand grains	4189–91
No sample	4191–4230
Smooth, white to translucent chert, with some buff colored; **some cryptocrystalline,** cream-colored chert; few fine sand grains	4230–40
Microcrystalline, cream-colored to white chert; smooth, white to slightly translucent chert; trace clear quartz; few fine sand grains	4240–45
Same as sample from 4240–45 feet	4245–50
Cryptocrystalline, white to brownish gray chert; some smooth white chert; trace quartz; few fine sand grains	4250–60
Cryptocrystalline, white, some cream-colored chert; some smooth white chert; fine, frosted sand grains	4260–70
Cryptocrystalline, white to cream-colored chert; **finely granular, light brown chert;** smooth white to translucent chert; light green, slightly waxy shale	4270–80
No sample	4280–90
White, extremely fine chert dolocasts; cryptocrystalline, white to cream-colored chert; **trace finely granular, light brown chert;** very light green, soft, slightly waxy shale	4290–4300

	Depth Feet
Smooth to cryptocrystalline white chert; **some brownish colored, finely granular chert;** some translucent chert with trace oolites; light green, slightly waxy shale	4300–10
Smooth white, some buff-colored chert; some cryptocrystalline white chert; very fine white chert dolocasts; light green, slightly waxy shale, with trace dolocasts	4310–20
Smooth, white to slightly translucent chert; **finely granular light brown chert;** very fine white chert dolocasts; light green, finely pyritic shale	4320–30
Smooth white to slightly translucent chert; **finely granular, light brown chert;** trace green shale	4330–40
Same as sample from 4330–40 feet	4340–50
Smooth white to translucent chert; **finely granular, light brown chert;** clear quartz; trace green shale	4350–60
Smooth, white to buff-colored chert; translucent chert; **finely crystalline granular, light brown, some white chert;** clear quartz; trace green shale	4360–70
Cavings shale, sand, chert; residue apparently smooth white to slightly translucent chert with uneven, porous and dolocastic streaks; trace chalk-textured white chert	4370–80
Large caving sand and shale; smooth white to light buff chert	4380–92
Cryptocrystalline, highly dolocastic white chert; trace microcrystalline, vitreous chert	4388–98
Cryptocrystalline, white to slightly vitreous, finely dolocastic chert, in part finely drusy; **rough, granular crystalline chert, granular crystalline chert grains;** few brittle white dolocasts	4398–4408
Very rough, uneven, porous, granular crystalline, brownish chert; smooth white chert; trace vitreous chert dolocasts	4408–18
Vitreous, granular crystalline, porous, dolocastic chert; trace smooth white chert	4418–25
Extremely fine porous, soft, grayish-white material; smooth white chert	4425–35
Slightly uneven, chalk-textured white to slightly translucent chert; trace clear, dolocastic chert	4435–45
Cryptocrystalline white chert, finely dolocastic in part, chalk-textured white chert with inclusion of finely crystalline, vitreous chert	4445–55
Small residue smooth white, dolocastic chert; **trace microgranular, slightly brownish chert**	4455–65
Microgranular and finely porous white chert; trace smooth white chert and fine white dolocasts	4465–75
Very finely granular, porous, brownish chert, finely oolitic in part	4475–85
Sand and shale caving obscure nature of residue	4485–95

	Depth *Feet*
Trace microgranular, brownish and white chert	4495–4505
Small residue rough, finely crystalline, vitreous chert	4505–15
Few fragments smooth white chert	4515–25
Finely granulated silica; few frosted sand grains (in place); trace rough, knarly, vitreous chert	4525–35
Fine, granular grains white chert showing many fine siliceous rhombs	4535–45
Finely granulated chert with some very fine siliceous rhombs	4545–55
Very finely granular chert grains; finely granulated silica	4555–65
Uneven, knarly, creamy white chert, with suggestion of oolitic structure; rough, finely crystalline, vitreous chert fragments	4565–75
No sample	4575–78
Irregular, brittle, white fragments, finely dolocastic; smooth white chert; **trace very finely granular brownish chert**	4578–85
Trace smooth white chert	4585–95
Small fragments very rough, slightly knarly white chert; trace white dolocasts	4595–4605
Very finely granulated silica in porous fragments; soft, grayish-white dolocasts; white, chalk-textured chert	4605–15
Uneven, grayish white, chalk-textured chert with inclusions clear quartz; **trace finely granulated silica**	4615–25
Very finely porous, soft, grayish-white material; soft white dolocasts	4625–35
Very finely granulated silica in rough flakes and fragments; very finely porous and dolocastic, brittle white fragments	4635–45
Cryptocrystalline, brownish chert; **very finely granulated silica**	4645–55
Few fragments finely porous, chalky material; trace white chert	4655–65
Very finely porous, brittle, white fragments; **trace very finely granulated silica**	4660–70
Brittle, white dolocasts; dolocastic, smooth white chert; smooth, white to slightly brownish chert	4669–80
Variegated residue: creamy white, chalk-textured chert; cryptocrystalline, tan to white, in part finely dolocastic chert, and with traces oolitic structure; finely dolocastic brittle white fragments	4680–90
Extremely fine dolocastic white chert with some quartz druse; few waxy, light green dolocasts	4690–4700
No sample	4700–05
Variegated residue: extremely fine dolocastic white chert; very finely porous soft white fragments; trace delicately porous, clear crystalline chert	4705–15
Variegated residue: extremely fine dolocastic and porous white chert and chalky white material; chalk-textured and milk-white chert	4715–25
Waxy, greenish-white dolocasts; fragment very finely porous, chalk-textured, grayish-white chert	4725–35

	Depth Feet
Very small residue chalky white chert grains and trace soft dolocasts	4735–45
Finely dolocastic fragments and flakes slightly greenish-gray, waxy material	4745–55
Fine white chert oolites: trace white, waxy material	4755–65
Very fine, gray dolocasts and waxy flakes	4765–75
No sample	4775–80
Fragment uneven, chalky white chert; greenish waxy flakes	4780–90
No sample	4790–4800
Variegated residue: delicately porous, microgranular white chert; trace cryptocrystalline white chert; few white dolocasts	4800–10
Fragment microcrystalline, brown, dolocastic chert; light green to gray, waxy dolocasts	4810–20
Variegated residue: delicately porous, microgranular white chert; gray, waxy, finely dolocastic fragments; microporous gray flakes	4820–30
Soft, gray and greenish-gray porous and dolocastic fragments, trace white chert dolocasts	4830–40
Very small residue white, chalky material. one fragment microcrystalline, porous, vitreous chert	4840–50
Smooth white to buff chert; chalk-textured white chert; green, unctuous shale	4850–60
Variegated residue: white to grayish-white, chalk-textured chert; trace smooth, light gray, oolitic chert; brittle, greenish-white, slightly dolocastic material	4860–70
Few fine grains white chert	4870–80
Few fine, lightly frosted sand grains; few greenish waxy dolocasts	4880–90
Mottled, light green and brownish waxy flakes	4890–4900
Very small residue fine white to grayish white dolocasts	4900–10
Fine, light green, some white dolocasts; trace finely divided silica	4910–20
Very rough, porous. microgranular white chert; traces of fine, light green dolocasts	4920–30
Soft, skeletal white fragments; white dolocasts; some fine granular silica	4930–40
Fine white dolocasts; finely granulated silica	4940–50
Finely granulated silica; trace cryptocrystalline white chert	4950–60
Variegated residue: smooth white chert; brittle white dolocasts; fragment white, chalk-textured, dolocastic chert	4960–69
No sample	4969–70
Smooth white chert: white chert dolocasts	4970–89
Few very fine sand grains; fragment microcrystalline white chert; chert with orange-colored inclusions	4989–99
Very fine sand grains; white, finely dolocastic flakes	4999–5010
Variegated residue: very rough, very porous, finely crystalline granular, brownish chert; rough, yellowish-buff, finely arenaceous chert; very fine sand	5010–20

	Depth *Feet*
Residue obscured by cavings	5020–30
Variegated residue: soft, white, dolocastic fragments; smooth white and chalk-textured chert; fragment mottled white and clear chert	5030–40
Chalk-textured white chert; microcrystalline white to grayish-white chert	5040–50
Uneven, finely crystalline, gray vitreous chert; chalk-textured white chert, some very irregular fragments	5050–60
Brittle white dolocastic fragments; chalk-textured to smooth white chert	5060–70
Chalk-textured to smooth white chert	5070–80
Variegated residue: very finely crystalline, vitreous white to slightly brownish chert in very uneven fragments; chalk-textured white chert; flake of druse; few white dolocasts	5080–90
Variegated residue: very rough, craggy fragments chalky white chert; brittle white, dolocastic fragments; microcrystalline, mottled brownish and white chert, may be cavings	5090–5100
Finely crystalline to microcrystalline, brown and white, oolitic chert, very porous in part; irregular white fragments	5100–10
Microcrystalline, vitreous to white chert with trace oolitic structure; trace soft, white dolocasts	5110–20
No sample	5120–30
Sand caving; trace white chert dolocasts and chalk-white chert	5130–40
Dolocastic in part, chalk-white chert; much sand caving	5140–50
Chalk-white chert, uneven fragments, porous in part	5150–60
Dense white to vitreous, drusy, highly dolocastic chert	5160–70
Variegated residue: cryptocrystalline, white chert with traces of druse, dolocastic in part; microgranular, white, dolocastic chert; some chalk-white chert	5170–80
Cryptocrystalline, white chert, traces dolocasts; white chert dolocasts	5180–90
Variegated residue: microcrystalline, vitreous, dolocastic chert; finely crystalline, brown, dolocastic chert; white chert dolocasts; brittle white dolocasts	5190–5200
Brittle white dolocasts; finely crystalline, vitreous chert dolocasts	5200–10
Variegated residue, chalk-white chert; finely crystalline, brownish chert, porous and dolocastic; trace clear quartz	5210–20
Variegated residue: brittle white dolocasts and porous fragments; finely crystalline, vitreous, dolocastic chert; trace clear quartz	5220–30
Chalk-white to buff, dense chert; trace finely crystalline, vitreous chert	5230–40
Microgranular, porous white chert, slightly dolocastic; white chert dolocasts	5240–50
Chalk-white chert, uneven, porous, dolocastic in part; microcrystalline, vitreous chert dolocasts	5250–60

	Depth *Feet*
Cryptocrystalline white chert; microcrystalline, highly dolocastic chert, drusy in part	5260–70
Microcrystalline, vitreous, highly dolocastic chert, with trace of druse; brittle white, dolocastic fragment	5270–79
Microcrystalline, white, dolocastic chert, drusy in part; drusy, dolocastic quartz; fine sand grains	5276–90
Variegated residue: chalk-white, uneven chert; microcrystalline, vitreous, dolocastic chert; brittle, white dolocastic fragments	5290–5300
Variegated residue: cryptocrystalline, white chert, dolocastic in part; porous and dolocastic, chalk-textured white chert; semi-clear, quartzose dolocasts; finely granulated silica	5300–10
Microcrystalline, white to vitreous chert, dolocastic in part; highly porous and dolocastic, chalk-white chert	5310–20
Variegated residue: fine, slightly frosted sand; chalk-textured, grayish-white chert; trace microcrystalline, vitreous, dolocastic chert	5320–30
Variegated residue: cryptocrystalline white chert, dolocastic in part; trace microcrystalline, vitreous chert; soft grayish-white dolocasts	5330–40
Fine, lightly frosted sand grains; trace white chert dolocasts and cryptocrystalline white chert	5339–50
White, quartzose chert dolocasts; chalk-white, dolocastic chert	5350–60
Microcrystalline, dolocastic white chert with quartzose streaks; **drusy dolocastic quartz**	5360–70
Variegated residue: finely crystalline, dolocastic white chert, drusy in part; **drusy, dolocastic quartz;** white chert dolocasts; chalk-white chert fragments; few frosted sand grains	5370–80
White, highly dolocastic, **drusy chert;** few frosted sand grains; some chalky chert	5380–90
Same as sample from 5380–90 feet	5390–5400
Smooth white chert, in part finely dolocastic; **drusy and in part dolocastic quartz;** fine to medium, frosted sand grains	5400–10
Finely crystalline, white, **highly dolocastic and drusy chert**	5410–20
Same as sample from 5410–20 feet	5420–30
White to vitreous, quartzose, highly dolocastic chert with scattered pink streaks; **terminated quartz crystals;** light green, slightly waxy shale fragments	5430–40
Same as sample from 5430–40 feet	5440–47
Microcrystalline, highly dolocastic, white chert with some **drusy quartz**	5447–56
Microcrystalline, white to light buff, highly dolocastic chert with some quartzose inclusions; **coarsely drusy quartz**	5456–65
Microcrystalline, white, highly dolocastic chert with quartzose streaks	5465–70

	Depth *Feet*
Microcrystalline, white to grayish-white and vitreous, dolocastic chert with quartzose inclusions; **drusy, slightly clouded quartz**	5470–77
Microcrystalline, highly dolocastic, white chert, **drusy and quartzose** in part	5478–83
Same as sample from 5478–83 feet	5483–92
Microcrystalline, brown to brownish-gray, porous, dolocastic chert with suggestion of oolitic structure; **trace drusy quartz**	5492–97
Same as sample from 5492–97 feet	5497–5500
Microcrystalline, grayish-white, dolocastic chert, finely drusy in part; trace banded, vitreous chert	5500–10
No sample	5510–14
Microcrystalline, white to grayish-white. dolocastic chert; **drusy, dolocastic quartz**	5514–19
Cryptocrystalline, grayish-white, highly dolocastic and drusy chert; **drusy, dolocastic quartz; terminated quartz crystals**	5520–30
Drusy, dolocastic quartz; grayish-white to brown, dolocastic chert with trace pink staining	5530–40
Cryptocrystalline, brown and white, dolocastic chert with quartz inclusions, trace pink staining in quartz; **drusy, dolocastic quartz**	5540–47
Cryptocrystalline, white, dolocastic chert, drusy in part; **trace dolocastic, drusy quartz**	5547–57
White to grayish-white, finely dolocastic chert; **coarsely drusy quartz**	5557–67
Chalk-white, dolocastic and porous chert; cryptocrystalline, brown to gray chert, dolocastic in part; **coarsely drusy quartz**	5567–77
No sample	5577–87
Dolocastic, drusy, slightly clouded quartz; brown white and gray, finely dolocastic chert	5587–97
Clouded, drusy, dolocastic quartz, coarse, terminated crystals; white, dolocastic chert	5597–5607
Drusy, dolocastic quartz, coarse, terminated crystals; white chert dolocasts	5607–17
Same as sample from 5607–17 feet	5617–27
Cryptocrystalline to smooth, white, highly dolocastic chert, drusy in part; **coarsely drusy quartz**	5627–37
Dolocastic, drusy quartz; microcrystalline, white to tan, dolocastic chert	5637–47
Same as sample from 5637–47 feet	5647–57
Clouded to clear, drusy dolocastic quartz; cryptocrystalline brown and white, dolocastic chert	5657–67
Finely crystalline to microcrystalline, brown chert, porous and dolocastic in part; **drusy, quartzose, dolocastic chert**	5667–77

	Depth *Feet*
Drusy, dolocastic quartz; cryptocrystalline brown chert, with some druse and dolocastic in part; white to gray, highly dolocastic chert	5677–87
Dolocastic, drusy quartz; cryptocrystalline, grayish-white and brown, dolocastic chert	5687–97
Same as sample from 5687–97 feet	5697–5707
Dolocastic quartz druse; cryptocrystalline, slightly vitreous, slightly dolocastic chert	5707–17
Drusy, dolocastic quartz; smooth white chert, dolocastic in part; trace vitreous, finely crystalline chert	5717–27
Cryptocrystalline, dolocastic white chert, drusy in part; **dolocastic quartz**	5727–37
Microcrystalline, white, highly dolocastic chert; **dolocastic drusy quartz**	5737–47
Extremely fine dolocastic and porous soft fragments, light greenish gray and purplish brown in color; dolocastic, grayish chert; trace glauconite	5747–57
Extremely fine porous and dolocastic material, greenish and purplish in color; gray shale flakes; vitreous and dolocastic chert probably cavings	5757–67
Same as sample from 5757–67 feet	5767–77
Light, slightly greenish-gray, extremely fine, porous shale flakes; light green, waxy flakes and fragments	5777–87
Total depth	6002

SUMMARY

Unit 1	3510–3750
Unit 2	3750–4270
Unit 3	4270–4675
Unit 4	4675–5747

Seaboard Oil Corporation No. 1 Dawson; B.B.B. and C. RR. Company survey; 1000 feet from south and west lines of sec. 41; Hamilton County. Elevation 1442 feet.

Pyrite; frosted grains; gray flakes and porous fragments—top core		2993–3003
Pyrite; gray porous fragments; few frosted quartz grains and small crystals	mid. core	2993–3003
Finely granular, porous gray fragments; frosted sand grains	top core	3003–09
Crinkled gray flakes; frosted sand grains	mid. core	3003–09
Gray, porous fragments; frosted sand grains; siliceous spines		3005–10
Finely granular, greenish-gray flakes and porous fragments; frosted quartz grains	bot. core	3003–09
Porous gray fragments and flakes; frosted grains; pyrite; small quartz crystals		3010–15
Granular gray flakes; quartz flakes	top core	3009–29

		Depth *Feet*
Porous gray fragments; gray chert showing traces of organic structure; fine frosted grains; dolocastic fragments		3015–20
Granular brown flakes: gray flakes; frosted grains	mid. core	3009–29
Gray and brown granular flakes and fragments; gray chert showing traces of organic structure; fine, irregular chert grains		3020–25
Finely granulated chert in small irregular fragments	bot. core	3009–29
Granular brown fragments; white chert fragments with finely fibrous appearance; few frosted grains; finely dolocastic fragment		3025–30
Very finely granular, porous gray fragments	top core	3029–34
Finely porous gray chert; few frosted grains; few fragments of siliceous spines		3030–35
Gray shaly flakes; greenish-gray, unctuous flakes; finely dolocastic, grayish-white fragments	mid. core	3029–34
Fine, coarsely frosted, angular quartz grains; granular brown fragments	bot. core	3029–34
Coarse to very fine, angular, elongated, frosted quartz grains; small, finely granular chert fragments	top core	3034–37
Gray and finely porous chert (cavings?); fine, coarsely frosted grains; finely dolocastic brown fragment; elongate quartz fragments		3034–37
Angular, crystalline, clouded quartz fragments and grains; finely granular, irregular chert fragments; microcrystalline brown chert porous in part; finely dolocastic gray fragments; green flakes; frosted grains	mid. core	3034–37
Porous gray flakes; irregular fragments of finely granulated chert	bot. core	3034–37
Gray chert; small irregular fragments of finely granulated chert; frosted sand grains		3037–42
Few fine frosted grains	top core	3037–42
Coarsely frosted quartz grains and crystals grading into finely granulated chert	mid. core	3037–42
Fine, frosted quartz grains	bot. core	3037–42
Cavings of finely porous chert; very finely granulated chert fragments; fine, coarsely frosted sand grains and crystals		3042–47
Medium to fine, angular, coarsely frosted sand; quartz crystals; very finely granulated grains	top core	3042–49
Fine, angular, coarsely frosted sand	mid. core	3042–49
Few angular chert grains	bot. core	3042–49
Cavings of finely porous chert (silicified ostracod); porous granulated chert fragments; few frosted grains		3047–52
Very finely granular, very finely porous gray fragments	top core	3049–59
Fine, angular, frosted sand; granulated chert fragments; pyrite and porous gray chert cavings		3052–57
Gray, argillaceous, dolocastic flakes and fragments	mid. core	3049–59

	Depth Feet
Finely divided and irregular fragments of pyrite bot. core	3049–59
Very fine, loosely cemented quartz grains; cavings of gray chert	3057–62
No chert residue top core	3059–70
Gray, porous, dolocastic fragments; extremely fine. frosted quartz grains mid. core	3059–70
Minute quartz crystals and very fine, angular, frosted grains bot. core	3059–70
Few clear quartz fragments top core	3070–80
Cavings? of gray chert with many fine siliceous spines; very fine, angular quartz grains	3070–75
Few pyrite fragments mid. core	3070–80
Porous, gray fragments; few fine, angular grains	3075–80
Few pyrite grains bot. core	3070–80
Very fine, angular quartz grains; granular chert fragments	3080–85
Very fine, angular chert grains	3085–90
Few finely granular, irregular chert fragments	3090–95
Very finely granular, irregular chert fragments	3095–3100
Very finely granular, irregular chert fragments	3100–05
Extremely granular, irregular chert fragments	3105–10
Extremely fine granular, irregular chert fragments	3110–15
Light greenish-gray, argillaceous flakes; fine, frosted sand grains	3115–20
Thin flakes; fine, frosted quartz grains; very finely granular chert fragment	3120–25
Fine to very fine, frosted quartz grains; thin flakes; microgranular, finely porous, brown chert	3125–30
Very fine, frosted quartz grains; thin flakes; microcrystalline porous brown chert	3130–35
Thin, crinkled, light gray flakes top core	3133–43
Thin, crinkled, light gray flakes mid. core	3133–43
Thin, crinkled, light gray flakes	3135–43
Thin, crinkled flakes; very finely granular, irregular chert fragments bot. core	3133–43
Finely granulated chert to fine, frosted quartz grains; unctuous gray flakes top core	3143–53
Fragment of finely crystalline chert mid. core	3143–53
Thin, crinkled flakes; few fine, frosted grains and minute crystals	3143–48
Thin, greenish-gray flakes bot. core	3143–53
Thin flakes; small crystals and very fine, frosted grains of quartz	3148–53
Gray, porous chert; small, very finely granular chert fragments; thin flakes; fine quartz grains	3153–58
Thin, crinkled flakes; small very finely granular, porous chert fragments	3158–63
Thin, crinkled flakes; small very finely granular, porous chert fragments; minute crystals	3163–68

	Depth *Feet*
Gray, finely granular flakes; minute crystals and quartz grains; very fine chert dolocasts	3168–73
Gray flakes and porous fragments; finely crystalline chert fragment; finely granular chert fragment	3173–78
Gray flakes; fine, frosted quartz grains; minute crystals	3178–83
Gray flakes; frosted grains	3183–88
Gray flakes; frosted grains	3188–93
Gray flakes; small, irregular, very finely granular chert fragments	3193–98
Thin, gray flakes; few minute crystals	3198–3203
Very finely granular, irregular chert; gray and brown, finely oolitic chert; gray flakes; frosted grains	3203–08
Frosted sand grains; thin, gray flakes	3208–13
Frosted sand grains; porous gray flakes and fragments	3213–18
Porous flakes and fragments; frosted grains; minute, prismatic crystals; crystalline quartz fragment	3218–23
Fine, white dolocasts; minute, prismatic crystals; gray flakes	3223–28
Porous brown chert; gray flakes; very finely granular, irregular fragments; minute crystals	3228–33
Porous gray chert; gray flakes; fine fragmentary, white dolocasts	3233–38
Fine, frosted sand grains; gray flakes; minutes crystals	3238–43
Gray flakes; very fine frosted grains; very fine chert dolocasts; gray porous chert	3245–50
Small, gray flakes core	3245–50
Gray flakes; very minute crystals and grains top core	3250–60
Gray flakes; very minute crystals, quartz grains	3250–55
Gray flakes; very minute crystals and grains mid. core	3250–60
Microgranular vitreous chert in skeletal and branching fragments; gray flakes; few fine, frosted grains and minute crystals	3255–60
Soft, brown, very finely porous fragments; small gray flakes bot. core	3250–60
Thin, light green and gray flakes; minute crystals and grains	3260–65
Greenish-gray flakes; frosted sand grains	3265–70
Greenish-gray flakes; frosted sand grains; fine, white, fragments dolocasts	3270–75
Frosted grains, free and joined by fine, white dolocasts; thin, greenish-gray flakes	3275–80
No sample	3280–85
Thin, gray flakes; irregular, finely granular chert fragment	3285–90
Thin, gray, crinkled flakes; frosted grain	3290–95
Thin, gray flakes, soft, porous, brown fragments; frosted grains	3295–3300
Thin, gray flakes; very fine quartz grains	3300–05
Thin, gray flakes; very fine quartz grains	3305–10
Greenish-gray flakes and fragments; fine quartz grains and crystals	3310–15
Gray flakes and porous fragments; very fine, white dolocasts; very fine quartz grains and minute crystals	3315–20

	Depth Feet
Small, gray flakes; very minute quartz grains and crystals	3320–25
Brown and gray flakes; small, rough, irregular, white chert fragments	3325–30
Crinkled gray flakes; few minute crystals and grains	3330–35
Brownish-gray flakes; small, white chert grains; minutes quartz crystals	3335–40
Crinkled gray flakes; few fine quartz grains	3340–45
Crinkled gray flakes; few fine quartz grains	3345–50
Crinkled gray, brown, and green flakes; few very fine quartz grains	3350–55
Crinkled gray and greenish-gray flakes; few very fine, angular quartz grains	3355–60
Crinkled gray and greenish-gray flakes; few very fine quartz grains; soft fragments with very finely divided pyrite	3360–65
Greenish-gray flakes; small fragments finely granular chert; very fine dolocasts	3365–70
Greenish-gray flakes; finely granulated chert; minute quartz grains and crystals; fine dolocasts	3370–75
Greenish-gray flakes; very small fragments finely granular chert; minute quartz grains and crystals; fine dolocasts	3375–80
Light green flakes; very finely granulated chert fragments; fine dolocasts	3380–85
Very fine dolocasts; light green flakes	3385–90
Light green flakes and porous fragments; small, very finely granular chert fragments; minute grains and crystals	3390–95
Light green flakes; small, very finely granular chert fragments; minute grains and crystals	3395–3400
Light greenish-gray flakes	3400–05
Light green flakes; fine to very fine, frosted grains	3405–10
Greenish-gray flakes; minute grains and crystals	3410–15
Fine, frosted grains; greenish-gray flakes; brown chert	3415–20
Rounded, frosted sand; thin, green flakes	3420–25
Rounded, frosted sand; thin, green flakes; minute grains and crystals	3425–30
Rounded, frosted sand; thin, green flakes; minute grains and crystals	3430–35
Thin, light green flakes; few frosted sand grains; minute quartz grains	3435–40
Smooth, white chert; brown chert, oolitic in part; fine, frosted sand; green flakes; soft, chalky fragments	3440–45
No sample	3445–50
Smooth, white, and tan chert; porous buff chert, oolitic in part; fine, frosted sand; green flakes	3450–55
Medium, rounded to very fine frosted sand; brown, finely oolitic chert; fine, white dolocasts	3455–60

	Depth *Feet*
Smooth, white chert; brown, porous, oolitic chert; fine frosted sand; thin flakes; light brown, fine dolocasts	3460–65
Fine, frosted sand; very fine, white to brown chert dolocasts	3465–70
Thin, gray flakes; frosted grains; minute quartz grains and crystals	3470–75
Thin, greenish-gray flakes; fine, frosted sand; minute grains and crystals; **smooth-textured white chert in rough fragments** and containing sand grains	3475–80
Thin, greenish-gray flakes; fine, frosted sand; minute grains and crystals; **rough white, sandy chert**	3480–85
Thin, greenish-gray and brown flakes; fine, frosted sand, white, finely porous chert fragments	3485–90
Thin, greenish-gray and brown flakes; very fine, frosted sand	3490–95
Thin, greenish-gray and brown flakes; very fine, frosted sand; **smooth, white chert fragment**	3495–3500
Thin, greenish-gray and brown flakes; soft, white fragments	3500–05
Thin, greenish-gray and brown flakes; frosted grains: minute grains and crystals	3505–10
Thin, greenish-gray and brown flakes; frosted grains; minute grains and crystals	3510–15
Thin, greenish-gray and brown flakes; frosted grains; minute grains and crystals	3515–20
Medium to fine, frosted sand; greenish-gray flakes; minute grains and crystals; **smooth, white chert fragment**	3520–25
Medium to fine, frosted sand; light green flakes; minute crystals; chert oolites	3525–30
Medium to fine, frosted sand; light green flakes; minute crystals; brown chert fragment; chert oolites	3530–35
Light green flakes; medium to fine, frosted sand grains; minute quartz grains	3535–40
Light green flakes; few frosted grains; minute grains and crystals; fragment of fine, white to clear, crystalline chert	3540–45
Fine, frosted sand; one coarse, well-rounded grain; very porous fragments; **cream-colored, porous and oolitic chert; white, slightly translucent chert**	3545–50
Thin greenish-gray flakes; very fine quartz grains	3550–55
Light green flakes and porous fragments; fine, frosted sand	3555–60
Fine, frosted sand; gray flakes; **smooth, white chert, arenaceous** in part	3560–65
Light gray flakes; minute crystals: very fine grains	3565–70
Fine, frosted sand; thin, light gray flakes; **chalk-textured, white chert**	3570–75
Medium to fine, frosted sand; **smooth, grayish-white chert;** gray flakes	3575–80
Smooth-textured, white to gray chert; thin, gray and light green flakes; fine, frosted sand	3580–85

	Depth *Feet*
No sample	3585–90
Few light green flakes and fragmentary dolocasts	3590–95
Fine, lightly frosted sand; **few fragments of smooth, white chert;** few flakes	3595–3600
Fine, frosted sand, free, lightly cemented, and in quartzitic fragments; **fragment of white, chalk-textured chert;** green flakes	3600–05
Few very fine grains and minute crystals	3605–10
Finely crystalline, arenaceous chert fragments; very fine grains; very fine, light green dolocasts	3610–15
Finely granular, porous and dolocastic, very irregular, vitreous chert fragments; frosted grains; gray dolocasts	3615–20
Microgranular, porous and dolocastic, very irregular chert fragments; soft, fine, gray dolocasts; frosted grains; rough, dolocastic, vitreous chert	3620–25
Fine, lightly frosted sand; light green flakes	3625–30
Drusy, dolocastic chert; light green, fragmentary dolocasts; fine, frosted grains; crinkled gray flakes	3630–35
Light green dolocasts; fine, frosted sand; thin flakes	3635–40
Very fine dolocasts; light green dolocasts; clear, dolocastic chert fragments; frosted grains	3640–45
Fine grayish dolocasts; drusy, finely dolocastic chert	3645–50
Irregular, greenish-gray flakes; very fine quartz grains; rough, vitreous chert flake	3650–55
Clear, granular and very finely dolocastic chert; green flakes and dolocasts; frosted grains	3655–60
Very rough, porous and dolocastic, finely granular, vitreous chert; medium to angular, very fine quartz grains; few green flakes	3660–65
Clear, finely dolocastic chert; very fine quartz grains; gray flakes	3665–70
Skeletal fragments very fine, clear chert dolocasts; frosted grains; very fine quartz grains	3670–75
Fine, frosted to very fine, angular sand grains; finely dolocastic greenish fragments	3675–80
Coarse, rounded to fine, angular, frosted sand; drusy translucent chert fragments	3680–85
Medium, rounded to very fine, angular, frosted sand	3685–90
Coarse, rounded to fine, angular frosted sand; fine, white dolocasts; angular quartz fragments	3690–95
Coarse, subrounded to fine, angular frosted sand	3695–3700
Coarse, subrounded to fine, angular, frosted sand; very fine, white to gray dolocasts	3700–05
Coarse, subrounded to fine, angular, frosted sand; white to gray dolocasts	3705–10
Coarse, rounded to fine, frosted sand	3710–15

	Depth *Feet*
Coarse, rounded to fine, frosted sand; fine, white to light green dolocasts; small, granular, dolocastic chert fragments	3715–20
Coarse, rounded to fine, frosted sand grains; fine, greenish-white dolocasts; cryptocrystalline, porous, white chert fragment	3720–25
Fine, white dolocasts; few frosted grains; clear, dolocastic chert	3725–30
Coarse, rounded to fine, coarsely frosted sand; few white dolocasts	3730–35
Fine, greenish-white dolocasts; frosted sand grains; clear, dolocastic chert	3735–40
Very fine, frosted quartz grains; few white dolocasts; gray flakes	3740–45
Medium, frosted sand grains to very fine quartz grains; fine, white dolocasts	3745–50
Angular, coarsely frosted quartz grains	3750–55
Fine, coarsely frosted quartz grains	3755–60
Fine, coarsely frosted quartz grains	3760–65
Frosted grains; fine, white dolocasts	3765–70
Medium to fine, coarsely frosted sand grains; pyrite; gray flakes	3770–75
Coarse to medium, coarsely frosted sand grains	3775–80
Medium to fine, coarsely frosted sand grains; fragmentary white dolocasts	3780–85
Medium to fine, coarsely frosted sand grains; fragmentary, white dolocasts	3785–90
Medium to fine, coarsely frosted sand grains; fragmentary, white dolocasts	3790–95
Medium, coarsely frosted sand grains; fine to very fine, angular quartz grains; soft, porous and dolocastic greenish fragments	3795–3800
Medium to fine, lightly frosted, subrounded sand	3800–05
Soft, greenish-gray flakes and dolocasts; porous fragments, dolocastic in part; medium, angular, frosted sand grain	3805–10
Soft, light, gray and green flakes and fragments; dolocastic in part; **smooth white chert;** few frosted grains	3810–15
Soft, white and light green, dolocastic fragments; fine, angular, frosted sand grains; **smooth, white chert fragment**	3815–20
Soft, white and light green, dolocastic fragments; fine, angular, frosted sand grains; smooth, variegated chert fragment, translucent to gray	3820–25
Medium to fine, subrounded, frosted sand; soft, irregular, light green flakes; smooth, **white to light brown chert**	3825–30
Coarse to fine, frosted sand; rough, porous, microgranular chert, white to vitreous; small, soft, white and green fragments	3830–35
Medium to fine, frosted sand; microgranular, rough, porous, arenaceous chert; small, soft, white and light green fragments; microcrystalline, white to translucent chert	3835–40

	Depth *Feet*
Medium to fine, frosted sand; microgranular, rough, porous chert; small, soft, white and light green fragments; finely crystalline white chert	3840–45
Soft, light green to white, dolocastic fragments; fine, frosted sand grains	3845–50
Soft, light green to white, dolocastic fragments; fine, frosted sand grains	3850–55
Soft, light green to white, dolocastic fragments; fine, frosted sand grains; irregular, microgranular chert fragment; cryptocrystalline, grayish-white chert	3855–60
Very irregular, microgranular chert; soft, light green to white, dolocastic fragments; frosted sand grains; translucent, vitreous chert fragment	3860–65
Fine, frosted grains; few soft grains and flakes; smooth, brownish-gray chert fragment	3865–70
Fine, frosted grains; few soft grains and flakes	3870–75
Green dolocasts and flakes; finely crystalline, vitreous chert fragments; few fine, angular quartz grains	3875–80
Fine, frosted grains; light green dolocasts	3880–85
Irregular, microgranular, white chert with trace druse; few green flakes and quartz grains	3885–90
Very irregular, finely granular, white chert; few frosted grains; microcrystalline, slightly dolocastic white chert	3890–95
Rough, cryptogranular chert fragments; clear fragment; soft, light green fragments; small quartz grains; microcrystalline, vitreous chert fragment	3895–3900
Very finely crystalline white chert; finely granulated chert; few dolocasts in chert	3900–05
Compact white chert; fine, fragmentary, white dolocasts; **microcrystalline white chert with clear chert streaks**	3905–10
Microcrystalline white chert with few dolocasts; grayish-white, fragmentary dolocasts; medium to fine, subrounded to angular, frosted sand	3910–15
White, microcrystalline chert; very finely granular, porous chert; gray and white, smooth chert; fine, frosted sand grains	3915–20
Drusy, dolocastic quartz; **microcrystalline white chert fragments;** fine, frosted sand grains	3920–25
Drusy, granular, dolocastic quartz; **white cryptocrystalline chert;** frosted grains	3925–30
Drusy, granular, slightly dolocastic **quartz; white, microcrystalline chert;** frosted grains	3930–35
Microgranular, rough, porous, vitreous chert; **buff to white, microcrystalline chert;** small fragments of drusy quartz	3935–40
Rough, granular, white to buff chert; **microcrystalline white chert;** clear, drusy, dolocastic quartz; frosted grains	3940–45

	Depth Feet
Clear, drusy, dolocastic chert; rough, very finely granular chert; **cryptocrystalline, slightly dolocastic, white chert**	3945–50
White to buff, microcrystalline chert; rough, very finely granular chert; frosted grains	3950–55
White to buff, microcrystalline chert, dolocastic in part; rough, very finely granular chert; frosted grains in small aggregates; drusy quartz	3955–60
White and buff, smooth to **crystalline chert,** dolocastic in part; rough, very granular chert; frosted grains; soft, light green flakes	3965–70
White, smooth chert; rough, very finely granular chert; frosted grains; clear chert dolocasts; **cryptocrystalline, white and buff, porous chert**	3970–75
Rough, granular chert; **gray, cryptocrystalline chert**	3975–80
Buff, microcrystalline chert; frosted sand; rough, finely granular chert	3980–85
Buff, microcrystalline chert, dolocastic in part	3985–90
Buff to white cryptocrystalline chert, oolitic in part; rough granular chert fragments; frosted grains	3990–95
White and buff crystalline chert, oolitic and dolocastic in part; drusy quartz	3995–4000
White, dolocastic and rough, microgranular chert; **buff to cryptocrystalline chert,** dolocastic and oolitic in part	4000–05
Microgranular, white chert; **cream-colored, crystalline chert,** oolitic and dolocastic; white, smooth chert, frosted grains	4005–10
Rough, very finely granular chert; **white, microcrystalline chert;** dolocastic in part; frosted grains; drusy quartz	4010–15
White to buff, cryptocrystalline, dolocastic chert; vitreous chert; frosted grains; trace quartz druse	4015–20
Drusy, dolocastic quartz; **cryptocrystalline, white dolocastic chert**	4020–25
White and buff, microcrystalline, dolocastic chert; drusy, dolocastic quartz; granulated and granular fragments of chert; frosted grains	4025–30
Cryptocrystalline, white to vitreous, dolocastic chert; white dolocasts; drusy, dolocastic quartz	4030–35
Light buff, cryptocrystalline chert, dolocastic in part; frosted grains; very finely granular chert	4035–40
White cryptocrystalline chert, dolocastic in part; frosted grains; **light buff chert, finely crystalline;** drusy, dolocastic quartz	4040–45
Drusy, dolocastic quartz; frosted grains; **cryptocrystalline, white to light buff chert,** rough and porous	4045–50
Microcrystalline, drusy, dolocastic, white to light gray chert; irregular, finely granular fragments; drusy quartz	4050–55

	Depth *Feet*
Microcrystalline, drusy, dolocastic, white to light gray chert; irregular finely granular fragments; drusy quartz	4055–60
Microcrystalline, drusy, dolocastic, white chert; irregular, finely granular fragments; few frosted grains; drusy quartz	4060–65
Microcrystalline, drusy, dolocastic, white chert; few frosted grains; **finely crystalline drusy brown chert;** dolocastic, drusy quartz	4065–70
Microcrystalline, white to vitreous, dolocastic chert; few frosted grains	4070–75
Microcrystalline, drusy, dolocastic, white to vitreous chert; few frosted grains	4075–80
Microcrystalline, drusy, dolocastic, white to vitreous chert; drusy, dolocastic chert	4080–85
Cryptocrystalline, white and brown, dolocastic and oolitic chert; drusy quartz	4085–90
Very rough, **cryptocrystalline to drusy, dolocastic, white chert; cryptocrystalline, cream-colored chert**	4090–95
Cryptocrystalline to drusy, dolocastic, white chert; frosted grains; smooth white, dolocastic chert	4095–4100
Microcrystalline to drusy, dolocastic, white and brown chert, oolitic in part; frosted grains; drusy, dolocastic chert	4100–05
Microcrystalline to drusy, dolocastic, white chert; cryptocrystalline brown chert; frosted grains	4105–10
Cryptocrystalline to drusy dolocastic white chert; cryptocrystalline brown, oolitic chert	4110–15
Cryptocrystalline to drusy dolocastic white chert; cryptocrystalline brown, oolitic chert; frosted grains; drusy quartz	4115–20
Cryptocrystalline, white, dolocastic chert; cryptocrystalline, brown, oolitic chert; frosted grains; clouded quartz	4120–25
Microcrystalline, white dolocastic chert; cryptocrystalline chert; frosted grains; trace drusy quartz	4125–30
Microcrystalline, white dolocastic chert; white chert dolocasts; clouded dolocastic quartz	4130–35
Cryptocrystalline to drusy, dolocastic white chert; white chert dolocasts; finely drusy quartz	4135–40
Cryptocrystalline to drusy, dolocastic white chert; white dolocasts; brown, oolitic chert	4140–45
Microcrystalline, white to vitreous, dolocastic chert; brown, oolitic chert	4145–50
Chert oolites; fragments of rough, finely granular chert; porous fragments **cryptocrystalline, vitreous chert**	4150–55
Cryptocrystalline, white dolocastic chert; drusy, dolocastic quartz	4155–60
Cryptocrystalline, white dolocastic chert; quartz fragments	4160–65
Cryptocrystalline to drusy, dolocastic chert; drusy and dolocastic quartz	4165–70

	Depth *Feet*
Cryptocrystalline, drusy, dolocastic, white chert; white chert dolocasts; drusy, dolocastic quartz	4170–75
No sample	4175–80
Cryptocrystalline to drusy, dolocastic white chert; white chert dolocasts; drusy quartz	4180–85
Cryptocrystalline, white dolocastic chert; coarsely frosted quartz grains; clouded quartz	4185–90
Cryptocrystalline, white dolocastic chert; white chert dolocasts; drusy, dolocastic quartz	4190–95
Cryptocrystalline to drusy, dolocastic chert; cryptocrystalline, brown, dolocastic chert; white chert dolocasts; clouded, dolocastic quartz	4195–4200
Microcrystalline, vitreous, dolocastic chert; frosted grains; crystalline vitreous chert with quartz inclusions	4200–05
Cryptocrystalline white chert, dolocastic in part; microcrystalline, vitreous chert, trace banding	4205–10
Microcrystalline, vitreous chert, dolocastic in part; white chert dolocasts; **cryptocrystalline, white, dolocastic chert;** drusy quartz	4210–15
Cryptocrystalline white chert, dolocastic in part; white chert dolocasts; **microcrystalline, vitreous chert,** quartz inclusions; drusy quartz	4215–20
Cryptocrystalline white chert, dolocastic in part; white chert dolocasts; **microcrystalline, vitreous chert,** quartz inclusions	4220–25
Microcrystalline, vitreous chert; white chert dolocasts; clouded drusy quartz	4225–30
Cryptocrystalline vitreous chert, dolocastic in part; white chert dolocasts; drusy, dolocastic quartz	4230–35
White, cryptocrystalline, dolocastic chert; white chert dolocasts; drusy, dolocastic quartz	4235–40
Cryptocrystalline, white dolocastic chert; white chert dolocasts; clouded, drusy, dolocastic quartz	4240–45
Cryptocrystalline, white to vitreous dolocastic chert; white chert dolocasts; dolocastic quartz; banded, vitreous fragment	4245–50
Cryptocrystalline, dolocastic white chert; dolocastic, drusy quartz; white chert dolocasts	4250–55
Drusy, dolocastic quartz; **white, granular crystalline chert**	4255–60
White and drusy chert dolocasts; **granular crystalline chert;** vitreous, quartzose chert	4260–65
White and gray, cryptocrystalline chert, dolocastic in part; vitreous chert; **brown, microcrystalline chert;** chalk-textured white chert	4265–70
White and brown, cryptocrystalline chert, dolocastic in part; **crystalline vitreous chert;** drusy, dolocastic quartz; smooth white chert	4270–75

	Depth *Feet*
White and brown, cryptocrystalline, porous, dolocastic chert; white and clear chert dolocasts; frosted grains; smooth white, dolocastic chert; drusy quartz	4275–80
Vitreous and white, cryptocrystalline, dolocastic and porous chert; gray chert with brown chert and quartz inclusions	4280–85
Cryptocrystalline, white and brown, partially dolocastic chert; fine, white dolocasts; clouded, drusy quartz; smooth white chert	4285–90
Cryptocrystalline, grayish-white and brown, partially dolocastic chert; rough, granular chert; fine white dolocasts; **crystalline, vitreous chert**	4290–95
Cryptocrystalline, grayish-white, dolocastic chert; frosted grains; drusy, dolocastic quartz	4295–4300
Cryptocrystalline, white dolocastic chert; drusy quartz; **crystalline, vitreous, dolocastic chert**	4300–05
White and brown, cryptocrystalline chert, dolocastic in part; white and clear chert dolocasts; white, smooth chert; drusy quartz; chalk-textured white chert	4305–10
Brown and white, cryptocrystalline chert; granular chert; white chert dolocasts; **crystalline vitreous chert**	4310–15
Crystalline, vitreous dolocastic chert; rough, granular chert; very fine, **granular crystalline, white chert**	4315–20
Clear, drusy, dolocastic quartz; pyrite; **fragment cryptocrystalline, dolocastic white chert**	4320–25
Clear, drusy, dolocastic quartz; **cryptocrystalline white chert dolocasts;** pyrite	4325–30
Drusy dolocastic quartz; fine, white chert dolocasts; granular, **crystalline chert;** frosted grains	4330–35
Drusy, dolocastic quartz; **cryptocrystalline, grayish-white, dolocastic chert**	4335–40
Clear and white chert dolocasts; **crystalline granular chert**	4340–45
Clear and white chert dolocasts; granular fragments; **cryptocrystalline, porous white chert**	4345–50
White chert dolocasts; **granular crystalline fragments;** drusy quartz	4350–55
White chert dolocasts; **granular crystalline fragments; microcrystalline, vitreous chert fragment**	4355–60
White, cryptocrystalline dolocastic chert; white and clear chert dolocasts; granular fragments; siliceous rhombohedrons, drusy quartz	4360–65
White cryptocrystalline, dolocastic chert; white chert dolocasts; drusy, dolocastic quartz; granular chert	4365–70
White to clear chert dolocasts; drusy, dolocastic quartz; **cryptocrystalline, white dolocastic chert**	4370–75
White to clear chert dolocasts; granular chert; drusy quartz; **cryptocrystalline, vitreous, dolocastic chert**	4375–80

	Depth *Feet*
White to clear chert dolocasts; granular chert; **cryptocrystalline, white to vitreous, dolocastic chert**	4380–85
Drusy quartz; frosted grains; **cryptocrystalline, white to vitreous, dolocastic chert**	4385–90
Drusy quartz; white chert dolocasts; very fine, translucent dolocasts; **cryptocrystalline, white to buff, dolocastic chert**	4390–95
Drusy, dolocastic quartz; white chert dolocasts; granular chert fragments; **cryptocrystalline, brown chert fragment**	4395–4400
White, smooth and **cryptocrystalline chert dolocasts;** granular chert; very light green flakes; **cryptocrystalline, vitreous white chert**	4400–05
Very finely dolocastic white chert; granular chert fragments; light green dolocasts; **cryptocrystalline, vitreous white chert**	4405–10
Crystalline granular chert dolocasts; granular chert fragments; gray, **cryptocrystalline chert**	4410–15
Very finely dolocastic, white chert; **crystalline granular chert dolocasts;** granular chert fragments; **grayish, cryptocrystalline chert**	4415–20
Very finely dolocastic, white chert; **rough, granular chert fragments**	4420–25
Very finely dolocastic, white chert; **rough, granular chert fragments**	4425–30
Very finely dolocastic, white chert; **rough, granular chert fragments**	4430–35
Very finely dolocastic, white chert; **rough, granular chert fragments;** drusy, dolocastic quartz	4435–40
Very finely dolocastic, white chert; **rough granular chert fragments**	4440–45
Roughly granulated chert; clouded quartz fragment	4445–50
Roughly granular and granulated chert; clouded crystalline, dolocastic chert; very finely dolocastic, white chert	4450–55
Roughly granular and granulated chert	4455–60
Clear, drusy, dolocastic quartz; white, dolocastic chert; **roughly granular chert;** cryptocrystalline, vitreous, dolocastic chert	4460–65
Very finely dolocastic, white chert; dolocastic, cryptocrystalline, vitreous chert; smooth chert; **roughly granular chert**	4465–70
Rough, granular chert; drusy, dolocastic quartz	4470–75
Rough, granular chert; drusy, clouded quartz; cryptocrystalline buff and vitreous chert	4475–80
Brittle, white dolocasts; translucent chert dolocasts; **rough granular chert;** drusy, dolocastic quartz; frosted grains; trace cryptocrystalline, vitreous, dolocastic chert	4480–85
Very rough, granular chert; frosted grains; white chert dolocasts	4485–90

	Depth *Feet*
Vitreous, white, smooth-textured chert; **rough, granular and granulated chert;** white chert dolocasts; brittle, white dolocasts; light green flakes; trace cryptocrystalline, vitreous chert	4490–95
White to translucent chert dolocasts; **granular and granulated chert;** very light green, fragmentary dolocasts; finely drusy quartz	4495–4500
Rough, cryptocrystalline, white chert; very finely dolocastic white chert; drusy, dolocastic quartz; **rough, granular chert;** frosted grains; green flakes	4500–05
Rough, granular chert; rough, smooth-textured chert; fragmentary white dolocasts	4505–10
Rough, granular chert; rough, crystalline, vitreous and brown chert; green dolocasts	4510–15
Rough, granular chert; cryptocrystalline, vitreous chert dolocasts; green dolocasts	4515–20
Rough, granular chert; rough, crystalline chert; smooth, white chert; green dolocasts; cluster of frosted grains	4520–25
Rough, granular chert; white chert dolocasts; smooth, white chert; green dolocasts	4525–30
Rough, granular chert; green dolocasts	4530–35
Rough, granular chert; translucent, crystalline chert; green dolocasts	4535–40
Rough, granular chert; translucent, crystalline chert; translucent chert dolocasts; green dolocasts	4540–45
Rough, granular chert; green flakes and dolocasts	4545–50
Rough, granular chert; green flakes and dolocasts	4550–55
Rough, granular chert; green flakes and dolocasts	4555–60
Rough, granular chert; green flakes and dolocasts	4560–65
Rough, granular chert; crystalline chert dolocasts; green flakes and dolocasts	4565–70
Rough, granular chert; crystalline chert dolocasts; green flakes and dolocasts	4570–75
Rough, granular chert; green flakes and dolocasts; very finely dolocastic, translucent chert	4575–80
Granular chert fragments and flakes; green dolocasts and flakes	4580–85
Granular chert fragments and flakes; green dolocasts and flakes	4585–90
Granular chert fragments and flakes; green dolocasts and flakes	4590–95
Granular chert fragments and flakes; clear, dolocastic chert; green dolocasts and flakes	4595–4600
Granular chert fragments and flakes; clear, dolocastic chert; green flakes and dolocasts	4600–05
Light green dolocasts and flakes; **rough, granular chert fragments and flakes**	4605–10

	Depth *Feet*
Rough, granular chert, delicately porous in part; green flakes and dolocasts	4610–15
Rough, granular chert, delicately porous in part; green flakes and dolocasts	4615–20
Rough, granular chert, delicately porous in part; green flakes and dolocasts; clear dolocasts	4620–25
Rough, granular chert; white, cryptocrystalline, dolocastic chert; green flakes and dolocasts; drusy, dolocastic quartz	4625–30
Rough, granular chert; clear crystalline, dolocastic quartz; green flakes and dolocasts	4630–35
Rough, granular chert; white, crystalline, drusy dolocastic chert; green flakes and dolocasts	4635–40
Rough, granular chert; white cryptocrystalline chert; green flakes and dolocasts	4640–45
Rough, granular chert; white cryptocrystalline chert; green flakes and dolocasts; frosted grains	4645–50
Rough, granular chert; green flakes and dolocasts; frosted grains	4650–55
Rough, granular chert; green flakes and dolocasts; frosted grains	4655–60
Rough, granular chert; green flakes and dolocasts	4660–65
Rough, granular chert; green flakes and dolocasts	4665–70
Rough, granular chert; green flakes and dolocasts	4670–75
Rough, granular chert; green flakes and dolocasts	4675–80
Rough, granular chert; white, finely dolocastic chert; green flakes and dolocasts: white, very finely granular fragments	4680–85
Rough, granular chert; green dolocasts and flakes	4685–90
Rough, granular chert; green dolocasts and flakes	4690–95
Rough, granular chert; translucent, cryptocrystalline chert; grayish-green flakes and dolocasts	4695–4700
Rough, granular chert; translucent, cryptocrystalline chert; white, dolocastic, finely drusy chert; grayish-green flakes and dolocasts	4700–05
Rough, granular chert; translucent. crystalline chert; white. dolocastic, finely drusy chert; grayish-green flakes and dolocasts	4705–10
Rough, granular chert; rough, porous, vitreous chert; grayish-green dolocasts and flakes	4710–15
Rough, granular chert; rough, porous, vitreous chert; grayish-green dolocasts and flakes; frosted grains	4715–20
Very rough, irregular, vitreous chert fragments; **rough, granular chert;** grayish-green dolocasts and flakes	4720–25
Very rough. granular vitreous chert fragments; **rough, granular chert;** grayish-green dolocasts and flakes	4725–30
Very rough, irregular, vitreous chert fragments; **rough, granular chert;** grayish-green flakes and dolocasts	4730–35

	Depth *Feet*
Rough, granular chert; clear chert dolocasts; green and gray dolocasts and flakes	4735–40
Rough, very irregular fragments of vitreous chert; **rough, granular chert;** gray and green flakes and dolocasts	4740–45
Rough, very irregular fragments of vitreous chert; **rough, granular chert;** gray and green flakes and dolocasts	4745–50
Rough, vitreous chert; dolocastic white chert; grayish-green dolocasts; rough, **granular chert fragments**	4750–55
Grayish-green dolocasts and flakes; rough vitreous chert; **granular chert fragments;** cryptocrystalline white chert	4755–60
Very finely dolocastic white chert; dolocastic, clear quartz; grayish-green dolocasts and flakes; **granular chert fragments; granlar, dolocastic, white chert;** cryptocrystalline, finely dolocastic, cream chert	4760–65
Rough vitreous chert; **granular chert;** green dolocasts and flakes; frosted grains	4765–70
Finely granular, white, dolocastic chert; granular chert; green flakes and dolocasts; cryptocrystalline, vitreous white chert	4770–75
Rough, finely granular white chert; granular chert fragments; green dolocasts and flakes; frosted grains; cryptocrystalline, vitreous chert	4775–80
Finely granular, rough, dolocastic chert; granular chert fragments; green flakes and dolocasts; frosted grains	4780–85
Rough, granular chert; drusy, dolocastic quartz; green flakes and dolocasts; frosted grains	4785–90
Very finely dolocastic, white chert; **granular chert fragments;** white, cryptocrystalline chert; green flakes and dolocasts	4790–95
White, cryptocrystalline chert; **rough, granular chert;** green flakes and dolocasts	4795–4800
Rough, granular chert; green flakes and dolocasts	4800–05
Cryptocrystalline, white chert; **rough, granular chert;** green flakes and dolocasts; frosted grains	4805–10
Irregular, rough, granular fragments; green dolocasts and flakes	4810–15
Rough, white to chalk-textured chert; **granular chert;** green flakes and dolocasts; trace banded vitreous chert	4815–20
Rough, vitreous, white chert; clear, dolocastic quartz; **granular chert;** green flakes and dolocasts	4820–25
Rough, granular chert; vitreous crystalline chert; fragmentary white dolocasts; green flakes	4825–30
Crystalline, dolocastic chert; **granular chert;** green dolocasts and flakes	4830–35
Rough, dolocastic chert; crystalline, dolocastic chert; frosted grains; green flakes	4835–40

	Depth Feet
Rough, granular chert; white chert with quartz grains included; frosted grains	4840–45
Rough, granular chert; frosted grains; green flakes	4845–50
Rough, granular chert; vitreous crystalline chert; frosted grains	4850–55
Variegated residue: white to translucent chert dolocasts; granular fragments; very finely dolocastic, white chert; frosted grains; cryptocrystalline, white to variegated white and brown chert, porous in part; trace druse	4855–60
Variegated residue: uneven, porous, cryptocrystalline, grayish-white chert; very fine granular textured, dolocastic white chert; white finely drusy chert dolocasts; finely oolitic, cryptocrystalline, buff-gray chert	4860–65
Variegated fragments of intermixed very finely granular white chert, clear quartz, and crystalline vitreous chert; very finely crystalline vitreous chert; very finely dolocastic white chert; vitreous to clear chert dolocasts, finely drusy in part	4865–70
Variegated residue: cryptocrystalline, grayish-white chert; intermixed cryptocrystalline white chert; crystalline vitreous chert and clear quartz; white chert dolocasts; fine frosted sand grains	4870–72
Variegated residue: very fine-textured highly porous and dolocastic white chert; cryptocrystalline, grayish white chert with trace of druse; vitreous chert dolocasts; trace drusy dolocastic quartz; fine frosted sand grains	4872–75
Variegated residue: cryptocrystalline, buff-gray chert; cryptocrystalline, white, dolocastic chert; uneven, very fine-textured white chert; vitreous to drusy chert dolocasts	4875–80
Variegated residue: rough, porous, fine-grained white chert; drusy, dolocastic quartz; cryptocrystalline, white to light gray chert; slightly frosted quartz grains	4880–85
Variegated residue: cryptocrystalline light gray chert; rough, granular appearing, vitreous chert with trace fine druse; crystalline, porous, vitreous chert; white chert dolocasts	4885–90
Variegated residue: intermixed fine-textured white and vitreous chert in finely oolitic, porous fragments; cryptocrystalline light gray chert; microcrystalline, dolocastic chert; small fragments rough, fine-grained white chert	4890–95
Variegated residue: porous, white chalky fragments siliceous material; cryptocrystalline light gray chert; very fine-textured, porous white chert; drusy, highly dolocastic quartz	4895–4900
Variegated residue: microgranular, porous, oolitic and oolicastic[12] white chert; porous, white, chalky, siliceous fragments; cryptocrystalline, vitreous white chert; drusy, dolocastic quartz	4900–05
Microgranular, highly oolicastic, slightly oolitic, vitreous white chert; trace cryptocrystalline, vitreous chert	4905–10

[12]Oolicast—cavity left after dissolving out oolite.

	Depth Feet
Variegated residue: very fine-textured, grayish-white chert; microgranular, oolicastic and dolocastic, vitreous white chert; cryptocrystalline, grayish-white chert; drusy, dolocastic quartz	4910–15
Variegated residue: cryptocrystalline, vitreous gray chert with some intermixed vitreous chert; soft, white, chalky material; microgranular, porous and oolicastic chert; few frosted sand grains	4915–20
Variegated residue: porous, white chalky material; very fine-textured white chert with some intermixed vitreous chert; cryptocrystalline, vitreous gray chert, finely oolitic in part	4920–25
Variegated residue: cryptocrystalline, vitreous gray chert; microgranular, oolitic gray chert; soft, porous, chalky fragments; finely crystalline, rough, porous, vitreous chert; trace clear quartz	4925–30
Variegated residue: porous, white, chalky fragments; microcrystalline, porous vitreous chert; very fine-textured, white, porous chert with some included quartz; cryptocrystalline gray chert; fine frosted sand grains	4930–35
Variegated residue: white, porous, chalky fragments; cryptocrystalline white chert, porous and oolitic in part; finely crystalline gray chert	4935–40
Variegated residue: porous, white, chalky fragments; fine, white chert oolites, free and in a finely crystalline matrix; porous, crystalline, vitreous chert; trace quartz dolocasts	4940–45
Variegated residue: cryptocrystalline, gray chert; very fine-grained, rough, porous, oolitic, white chert; white chalky fragments; free chert oolites	4945–50
Porous, white, chalky fragments; cryptocrystalline gray chert, oolitic in part	4950–55
Variegated residue: cryptocrystalline, vitreous gray chert; cryptocrystalline white chert, oolitic in part; soft, white, porous fragments	4955–60
Cryptocrystalline, white to gray chert, oolitic in part; soft, white fragments	4960–65
Variegated residue: cryptocrystalline gray chert, oolitic in part; soft, white, porous fragments; very fine-grained, porous fragments; very fine-grained, porous, vitreous chert containing quartz grains; drusy, clouded quartz; smooth white chert	4965–70
Cryptocrystalline, grayish-white chert with some intermixed, fine-textured white chert; trace soft white material	4970–75
Variegated residue: porous, white, chalky fragments; cryptocrystalline, vitreous chert; smooth white chert; dolocastic, drusy quartz	4975–80

	Depth *Feet*
Variegated residue: porous, white chalky fragments; cryptocrystalline, vitreous gray chert; oolitic in part; very fine-grained, oolitic white chert; fine-textured translucent chert; trace quartz	4980–85
Variegated residue: cryptocrystalline, gray to white chert; very fine-grained, porous and dolocastic, vitreous chert; soft, white porous fragments; smooth white chert	4985–90
Variegated residue: cryptocrystalline, gray chert; cryptocrystalline, white, dolocastic chert; very fine-grained, porous white chert; chalk-textured white chert, oolicastic and dolocastic in part; trace drusy quartz dolocasts	4990–95
Variegated residue: cryptocrystalline, grayish-white chert with some dolocasts and trace of druse; smooth white chert with streaks of druse; chalk-textured white chert; drusy, dolocastic quartz; skeletal fragments finely granular vitreous chert; frosted sand grains	4995–5000
Variegated residue: cryptocrystalline, grayish-white chert; cryptocrystalline, vitreous chert; chalk-textured white chert; extremely fine-grained white chert in granular, dolocastic fragments; drusy, dolocastic quartz	5000–05
Variegated residue: very fine-textured, porous, dolocastic white chert; cryptocrystalline, white to light gray chert with trace druse and fine oolites; soft, grayish-white material; granular, dolocastic fragments extremely fine-grained, grayish-white chert; drusy, dolocastic quartz	5005–10
Variegated residue: cryptocrystalline, white, dolocastic chert; extremely fine-grained, porous, dolocastic, vitreous chert; vitreous, gray, finely-oolitic chert; drusy, dolocastic quartz	5010–15
Variegated residue: cryptocrystalline, gray to white chert, porous and dolocastic in part; cryptocrystalline, gray to vitreous chert with very fine pebbled appearance; smooth white chert; drusy, dolocastic quartz	5015–20
Variegated residue: cryptocrystalline, gray to white, partially porous and dolocastic chert, some with pebbled appearance; very fine-textured, grayish-white to buff, porous, oolitic chert; small, skeletal, porous and dolocastic fragments vitreous chert; drusy, dolocastic quartz	5020–25
Variegated residue: cryptocrystalline, grayish to white, porous chert, in part oolitic and pebbled; very fine-grained, highly porous, vitreous chert; vitreous, fine-grained, chert dolocasts; drusy, dolocastic quartz	5025–30
Variegated residue: cryptocrystalline, grayish to white chert, in part finely oolitic and porous; microgranular, highly porous fragments; vitreous chert dolocasts; dolocastic, drusy quartz	5030–35
Variegated residue: cryptocrystalline, vitreous gray to white chert, in part porous and dolocastic; rough, finely granular,	

	Depth Feet
highly porous chert; vitreous chert dolocasts; drusy, dolocastic quartz	5035–40
Rough, highly porous and dolocastic, finely crystalline, vitreous gray chert; cryptocrystalline white to gray chert; trace drusy, dolocastic quartz	5040–45
Variegated residue: cryptocrystalline, light buff-gray chert, slightly porous; cryptocrystalline, dolocastic white chert; porous finely granular, vitreous chert; vitreous, drusy dolocasts; trace white chalky material	5045–50
Cryptocrystalline, white dolocastic chert, drusy in part; rough, porous, very finely granular, vitreous chert	5050–55
Variegated residue: cryptocrystalline, grayish-white, dolocastic chert; uneven, very fine-grained, porous and dolocastic white chert; vitreous to clear crystalline fragments; brown, highly oolitic chert; drusy, dolocastic quartz; frosted sand grains	5055–60
Variegated residue: cryptocrystalline, grayish-white, dolocastic chert; uneven, very fine-grained, porous and dolocastic white chert; vitreous to clear crystalline fragments; brown, highly oolitic chert; drusy, dolocastic quartz	5060–65
Very rough, fine-grained, porous and dolocastic, vitreous white chert; cryptocrystalline, white and light buff-gray, dolocastic chert; trace oolitic brown chert	5065–70
Variegated residue: uneven, very fine-grained, white and buff, dolocastic and porous chert; uneven, cryptocrystalline white chert; dolocastic in part; fragment smooth, dark brown chert	5070–75
Variegated residue: uneven, very fine-grained, porous and dolocastic, grayish-white chert; microcrystalline, uneven, porous and dolocastic white chert; microcrystalline, light brown, oolitic chert; finely drusy, dolocastic quartz	5075–80
Variegated residue: cryptocrystalline, grayish-white chert, porous and oolitic in part; smooth-textured white chert with scattered inclusions of quartz; rough, finely granular, dolocastic chert; few light green shale flakes	5080–85
Variegated residue: very rough, fine-grained, porous and dolocastic, grayish-white chert; cryptocrystalline, light buff chert with intermixed quartz; vitreous white, dolocastic chert with included quartz grains; smooth-textured, gray, semi-translucent chert; few frosted sand grains	5085–90
Variegated residue: cryptocrystalline, white to grayish-white, highly dolocastic chert; finely intermixed, brown and light gray chert; drusy quartz, dolocastic in part; cryptocrystalline, grayish-white chert	5090–95

	Depth *Feet*
Variegated residue: cryptocrystalline, white to light buff, dolocastic chert, finely drusy in part; smooth-textured, light buff-gray chert, very finely drusy; crystalline, vitreous white chert, porous, finely drusy in part; trace chalky material	5095–5100
Variegated residue: cryptocrystalline, grayish-white, dolocastic chert; finely drusy in part; smooth-textured white chert; finely oolitic buff chert; microcrystalline, vitreous fragment	5100–05
Coarsely drusy, dolocastic quartz: cryptocrystalline, white and brown, dolocastic quartz	5105–10
Fine to coarsely drusy, dolocastic quartz; cryptocrystalline, oolitic and dolocastic, white to buff-gray chert	5110–15
Coarsely drusy, dolocastic quartz: cryptocrystalline, grayish-white to vitreous, dolocastic chert	5115–20
Coarsely drusy, dolocastic quartz: cryptocrystalline, grayish-white to vitreous, dolocastic chert; white chert dolocasts	5120–25
Coarsely drusy, dolocastic quartz: cryptocrystalline, white, dolocastic chert; cryptocrystalline, light brown, dolocastic chert	5125–30
Coarsely drusy, dolocastic quartz: smooth-textured and cryptocrystalline, dolocastic chert	5130–35
Coarsely drusy, dolocastic quartz: cryptocrystalline, white to grayish-white, dolocastic chert; white chert dolocasts	5135–40
Drusy, dolocastic quartz: grayish-white, cryptocrystalline, dolocastic chert; trace brown, dolocastic chert	5140–45
Drusy, dolocastic quartz: cryptocrystalline, brownish-gray to gray chert; very rough finely granular, white to grayish, dolocastic chert	5145–50
Coarsely drusy, dolocastic quartz: fragment very fine-grained, oolicastic, porous chert; fragment smooth, gray, dolocastic chert	5150–55
Coarsely drusy, dolocastic quartz: intermixed smooth-textured and cryptocrystalline, grayish-white chert; porous white chalky fragments	5155–60
Coarsely drusy, dolocastic quartz: uneven fragments smooth textured white chert; cryptocrystalline, dolocastic white chert	5160–65
Drusy, dolocastic quartz: dolocastic, white to grayish-white, cryptocrystalline chert; crystalline, vitreous, dolocastic chert; chalk-textured white chert	5165–70
Drusy, dolocastic quartz: cryptocrystalline, white, dolocastic chert; chalk-textured white chert, part in uneven fragments; intermixed, brown and white, very fine-grained chert; finely oolitic brown chert	5170–75
Drusy, dolocastic quartz; cryptocrystalline, white, and light gray to vitreous, dolocastic chert; cryptocrystalline, brown, in part dolocastic chert	5175–80

	Depth *Feet*
Coarsely drusy, dolocastic quartz: white to light gray, cryptocrystalline, dolocastic chert; light gray to brown, finely oolitic chert	5180–85
Drusy, dolocastic quartz: cryptocrystalline, white dolocastic chert, drusy in part; cryptocrystalline brown chert, oolitic in part	5185–90
Drusy quartz: cryptocrystalline, white to light gray, dolocastic chert, drusy in part	5190–95
Cryptocrystalline, brown chert, oolitic and dolocastic in part; uneven, grayish-white, cryptocrystalline chert, dolocastic in part; trace **dolocastic quartz**	5195–5200
Uneven, porous, white, cryptocrystalline chert, dolocastic in part; cryptocrystalline, brown, oolitic chert; fragments smooth white, oolitic chert	5200–05
Drusy, clouded quartz: cryptocrystalline, grayish white, highly dolocastic chert	5205–10
Drusy, clouded quartz: cryptocrystalline, white, highly dolocastic chert, finely drusy in part; trace chalk-textured chert	5210–15
Drusy, dolocastic quartz: cryptocrystalline, white to grayish-white, dolocastic chert, drusy in part; trace brown oolitic chert; trace chalky white chert	5215–20
Drusy, dolocastic quartz: cryptocrystalline, white to light gray, dolocastic chert; trace cryptocrystalline brown chert	5220–25
Drusy, dolocastic quartz: cryptocrystalline, white to light brownish-gray, dolocastic chert, drusy in part; trace chalky white chert	5225–30
Drusy, dolocastic quartz and quartz dolocasts; cryptocrystalline, grayish-white chert	5230–35
Finely drusy quartz dolocasts; cryptocrystalline, grayish-white, highly dolocastic chert; fragment smooth-textured, white, oolicastic chert	5235–40
Drusy, dolocastic quartz; cryptocrystalline, grayish-white, dolocastic chert, drusy in part	5240–45
Drusy, vitreous, dolocastic chert; trace drusy quartz; cryptocrystalline white to buff chert with trace quartz veining; very fine-textured, white porous and dolocastic chert	5245–50
Coarsely drusy, dolocastic quartz; cryptocrystalline, grayish-white chert, dolocastic in part; very uneven, highly porous, chalk-textured white chert	5250–55
Coarsely drusy quartz, dolocastic in part; cryptocrystalline, grayish-white, highly dolocastic chert, drusy in part	5255–60
Coarsely drusy, slightly clouded, dolocastic quartz; cryptocrystalline, grayish-white to vitreous, highly dolocastic chert; some smooth-textured, grayish-white, dolocastic chert	5260–65

	Depth *Feet*
Coarsely drusy quartz; cryptocrystalline, grayish-white to light gray, highly dolocastic chert, with trace of druse; uneven, smooth-textured white chert with trace druse	5265–70
Trace drusy, dolocastic quartz; cryptocrystalline, grayish-white to vitreous, highly dolocastic chert, drusy in part	5270–75
Drusy, dolocastic quartz; cryptocrystalline, grayish-white, highly dolocastic chert with traces druse	5275–80
Drusy, dolocastic quartz; cryptocrystalline, white to grayish-white, highly dolocastic chert, with traces fine druse; cryptocrystalline, light buff chert; trace translucent chert	5280–85
Coarsely drusy, dolocastic quartz; cryptocrystalline, grayish-white, highly dolocastic chert; smooth-textured white chert with fine traces quartz; trace banded, quartzose chert	5285–90
Coarsely drusy, dolocastic quartz; cryptocrystalline, grayish-white to white, dolocastic chert, drusy in part; smooth white chert	5290–95
Drusy, dolocastic quartz; cryptocrystalline, grayish-white, dolocastic chert, drusy in part; brown, porous chert, dolocastic in part	5295–5300
Coarse to finely drusy, dolocastic quartz; cryptocrystalline, white to grayish-white chert with traces very fine druse; cryptocrystalline brown chert	5300–05
Drusy, slightly clouded quartz; cryptocrystalline, white, dolocastic chert; smooth-textured white chert, drusy in part	5305–10
Drusy, slightly clouded quartz; cryptocrystalline, white to grayish-white, dolocastic chert with traces fine druse	5310–15
Drusy, dolocastic chert; cryptocrystalline, white, dolocastic chert with traces fine druse; cryptocrystalline, brown porous dolocastic chert	5315–20
Drusy, dolocastic quartz; cryptocrystalline, dolocastic white chert, drusy in part; smooth-textured white chert with quartz vein	5320–25
Coarsely drusy, dolocastic quartz; cryptocrystalline, white, dolocastic chert; cryptocrystalline brown chert; frosted grains	5325–30
Drusy, dolocastic quartz; cryptocrystalline, white, dolocastic chert; cryptocrystalline, porous, brown chert	5330–35
Thin, laminated, light green and grayish-brown shale flakes top of core	5334–44
Drusy, dolocastic quartz; cryptocrystalline, white to vitreous, dolocastic chert, drusy in part; grayish-white, cryptocrystalline, dolocastic chert	5335–40
Small fragments rough, finely nodular white chert mid. core	5334–44
Trace drusy, dolocastic quartz; cryptocrystalline, white to vitreous drusy and dolocastic chert; very fine-grained, uneven, grayish-white chert	5340–45

	Depth *Feet*
Very rough, uneven, nodular white chert .... bot. core	5334–44
Dolocastic, slightly clouded quartz; cryptocrystalline, finely drusy, dolocastic, white chert	5345–50
Drusy, dolocastic quartz; cryptocrystalline, white to grayish-white, porous and dolocastic chert; very fine, white dolocasts; trace rough, nodular, white chert; fine frosted sand grains	5350–55
Drusy, dolocastic quartz; cryptocrystalline white chert, drusy and dolocastic in part; smooth-textured white chert with trace druse; fragment silicified, hollow spine	5355–59

SUMMARY

Unit 1	2993–3900
Unit 2	3900–4420
Unit 3	4420–4855
Unit 4	4855–5359

The smooth white chert typical of unit 1 is very poorly developed in this well. The unit is identified by abundance of rounded, frosted sand grains, and by its stratigraphic position.

CEPHALOPODS FROM THE CRETACEOUS TRINITY GROUP OF THE SOUTH-CENTRAL UNITED STATES

Gayle Scott

INTRODUCTION

For several years the writer has been assembling cephalopod material from the Trinity group of the Southwest. This paper describes all the species known from these strata in the area. Enough stratigraphic data are presented to give an idea of the paleontologic horizons from which they came.

Like many of the other fossils collected from the Trinity formations, the cephalopods are often poorly preserved. Patient preparation has been necessary to make most of the specimens determinable. Intense folding has left many contorted and broken. In some cases the matrix is coarsely crystalline and the shell structure is not preserved, or if the shell is preserved the filling is usually of black shale. As a consequence, good specimens are not easily extracted from the rock. The suture patterns are traced with particular difficulty; especially on specimens preserved in the coarsely crystalline or arenaceous limestone, weathering has often destroyed the details of the suture line until only the general characters may be traced.

The area of outcrop of the Trinity strata in the Southwest is vast, and thicknesses and facies are variable. Over most of the region, cephalopod finds are rare. There are, however, a few localities in which these fossils are relatively numerous.

Since it has, of course, been impossible to search with meticulous care the entire region of outcrop, it is probable that future collectors will be able to add substantially to the number of species. Enough material, however, has been prepared and determined to give a much better idea of the Trinity cephalopod fauna than has heretofore been available.

Certain specimens from the Torcer (Trinity) formation in the Malone Mountain area of Trans-Pecos Texas are not considered here since they have recently been discussed by C. C. Albritton.[1]

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[1]Albritton, C. C., The Upper Jurassic and Lower Cretaceous ammonites of the Malone Mountains, Trans-Pecos Texas: Bull. Mus. Com. Zool., vol. 80, no. 10, pp. 391–412, pls. 1–9, 1937.

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A number of organizations and individuals have aided the writer in this research. Most of the effective collecting was made possible by a grant from the American Academy of Arts and Sciences. The summers of 1933 and 1934 were spent in the field, and several shorter excursions were made. In addition to the cephalopods, a vast amount of paleontologic, stratigraphic, and other data have been assembled.

Professor C. L. Baker, of the A. & M. College of Texas, who has intimate first-hand knowledge of the Trans-Pecos area, aided in directing the writer to little known localities in that region. Professor F. L. Whitney, of The University of Texas, has collected for many years from the Trinity strata in central Texas and has made available for this work all the cephalopods in his collection. Doctor T. W. Stanton, of the U. S. Geological Survey, has made it possible to include data on certain types in the U. S. National Museum and has made available for study specimens collected by him in Arkansas. Doctor E. H. Sellards, of the Texas Bureau of Economic Geology, has granted free access to a number of interesting specimens in the collections there. Roy T. Hazzard, of Shreveport, and Merle C. Israelsky, of Houston, have given specimens representing unusual ammonite recoveries from Trinity strata pierced by deep wells in Louisiana and have given the writer valuable stratigraphic information. The specimens from the Little Hatchet Mountains of southwestern New Mexico were collected by Mr. S. G. Lasky, of the U. S. Geological Survey, and were sent to the writer for study by Mr. Lasky and Doctor John B. Reeside. Finally, Doctor Reeside and Doctor T. W. Stanton, of the U. S. National Museum, and W. S. Adkins, of Houston, have read large parts of the manuscript and have offered valuable suggestions and criticisms.

PREVIOUS WORK

Only three species of cephalopods have previously been described from the Trinity strata in the Southwest. In 1888 Hill (21,[2] p. 128, Pl. I, figs. 1, 1a, 1b) described *Ammonites walcotti* (not *A. walcotii* Sowerby) from Trinity strata near Murfreesboro, Arkansas. The species, now *Pseudosaynella walcotti,* was represented by a single

[2]Numbers in the text in parentheses, as (21), refer to entries under corresponding numbers in the bibliography.

individual, and no additional material has been found. In 1893 Hill (22, p. 37, Pl. VIII, figs. 1–3) again considered this species and referred it to the genus *Neumayria.* In the same paper he described *Acanthoceras* (?) *justinae* (p. 38, Pl. VII, figs. 1, 2, 3), now *Dufrenoya justinae,* from the Travis Peak formation in western Travis County. Meanwhile, Cragin was describing a *Hoplites roemeri* (14, p. 234, Pl. XLIV, figs. 4, 5) from the same general locality. It results that the specimens described by Hill and Cragin are conspecific, and Hill's name has priority. A specimen of the same species from the nearby Coombs Hollow locality, and the same stratigraphic level, was later referred by Lasswitz to *Hoplites furcatus* (36, p. 4, text fig. 1) following Kilian's (30) determination. Burckhardt (9, p. 20, Pl. IX, figs. 2, 3) later studied casts of Lasswitz's specimen and made it the type of his new species *Dufrenoya texana.* This term likewise, in so far as it concerns the Texas specimen, falls into synonomy with *Dufrenoya justinae* (Hill). The Mexican specimens described by Burckhardt under *D. texana* appear to be different from anything yet found in Texas but probably are about Travis Peak in age. The name *Dufrenoya burckhardti* may be assigned to those specimens, and the individual figured by him on Plate IX, figures 7–9, is hereby designated as the type.

"*Acanthoceras*" *hoplitoides* Lasswitz (36, p 19, Pl. III, figs. 3a, 3b), referred by Burckhardt (9, p. 18) to *Dufrenoya,* is not a Trinity ammonite and cannot be a species of *Dufrenoya.*

In his studies of the paleontology of the Texas Cretaceous, Cragin also described *Sphenodiscus roemeri,* now *Knemiceras roemeri,* from the Glen Rose at Iredell, Bosque County.

These species represent all the described cephalopod species that have been assigned a Trinity age in the Southwest. Hill (23, p. 159) mentions the extreme scarcity of ammonites in rocks of Trinity age, but Adkins records ammonites in Trinity strata in the Trans-Pecos area of Texas and notes that the genera *Douvilleiceras* and *Parahoplites* are probably represented by several species (2, pp. 291–295, 305).

STRATIGRAPHIC RELATIONSHIPS OF THE TRINITY AMMONITE FAUNA

It is not intended to describe the stratigraphy of the Trinity group in detail in this paper. Adkins (2) has summarized what is known of the group in Texas and has incorporated pertinent information on areas in Mexico and Louisiana. Miser and Purdue (37, pp. 79–86) have described the occurrence of Trinity formations in southwestern Arkansas. Roy T. Hazzard has given to the writer valuable stratigraphic indications from numerous wells drilled into the Trinity underlying northwestern Louisiana. The enormously thick and interesting section in the Little Hatchet Mountains of southwestern New Mexico has been studied by S. G. Lasky (35), and the cephalopods which he collected are described in this paper. The accompanying table is compiled from all these sources and summarizes the principal stratigraphic units now recognized in Texas, Arkansas, Louisiana, and New Mexico.

CEPHALOPOD ZONES OF THE TRINITY GROUP

Five ammonite zones are demonstrated in the Trinity group as follows:

V. Zone of *Knemiceras nodosum,* Paluxy formation.
IV. Zone of *Knemiceras roemeri,* Glen Rose formation.
III. Zone of *Douvilleiceras mammillatum,* Cuchillo formation.
II. Zone of *Sonneratia trinitensis,* Cuchillo formation.
I. Zone of *Dufrenoya justinae,* Travis Peak formation.

The lowest clearly indicated ammonite zone is that of *Dufrenoya justinae* of the Cow Creek member of the Travis Peak formation. This zone has been known since Hill's early work in Texas. It is well developed in the valleys of Colorado River and its tributaries in Travis, Burnet, Blanco, and Hays counties. Specimens are numerous at several localities, and the species appears to have a limited vertical range. A poor specimen collected in the lowest portion of the Cuchillo formation in the Quitman Mountains is referred to the species. *Dufrenoya robusta* is also known from this level in Texas.

Dufrenoya aff. *D. dufrenoyi* (d'Orbigny) described by Burckhardt (9) from Mexico and specimens recovered from the Gay Long Bell No. 1 and Haynes Production Company Murff No. 1 deep wells in the lower red beds and so-called lowest lower Glen Rose sections of Louisiana are believed to occupy about the same stratigraphic level. Unfortunately, the specimen from the Gay Long Bell well, which was examined by the writer a number of years ago, has been lost. The genus *Dufrenoya* represented by these and

Principal stratigraphic units of the Trinity group in Texas, Arkansas, Louisiana, and New Mexico

Central Texas	Sierra Blanca-Quitman Mt. Area	Marathon Basin	Shafter	Solitario	Little Hatchet Mts., New Mexico	Louisiana	Arkansas	Oklahoma and Northeast Texas
Paluxy	Cox	Maxon			Trinity	Upper red beds Upper Glen Rose limestone	Dequeen limestone	
Glen Rose	Glen Rose	Glen Rose	Glen Rose	Glen Rose		Anhydrite	Ultima-Thule gravel	Antlers
	Cuchillo	Basement sands	Presidio	Cuchillo	Broken Jug	Lower Glen Rose	Dierks limestone	Sands
Travis Peak	Las Vigas			Absent	Trinity	Lower red beds	Pike gravel	
Absent		Absent	Absent			Lower marine		

several similar species, such as *D. furcata,* is widespread and characterizes the upper Aptian or Gargasian of Europe, Africa, and other regions.

In 1925 Burckhardt (9) described an upper Aptian fauna from the state of Durango, Mexico. The writer has recently examined the types in the Instituto de Geologico in Mexico, D. F. The fauna contains species of *Dufrenoya* similar to *D. justinae* of Texas and probably from about the same stratigraphic level. His species of "*Douvilleiceras*" all belong to *Cheloniceras* and probably indicate a slightly lower level, although *Cheloniceras* may range into upper Aptian. Similar indications of age are suggested by several species of *Parahoplites, Uhligella,* and *Puzosia,* although these may be of different age. His species of *Neocomites* and *Ammonitoceras* should be a great deal older than the zone of *Dufrenoya justinae.* None of the material described by Burckhardt in this paper appears to correspond very closely to the younger Trinity zones in Texas.

The second zone, or zone of *Sonneratia,* is well developed and is important on account of its significance in intercontinental correlation. For specific purposes the zone is here designated the zone of *S. trinitensis.* The stratigraphic range of the genus in the Quitman area is considerable, and it is possible that the species may later be assigned to distinct zones. Several specimens of the genus have been found in the Quitman Mountain area in the limestones of the lower and middle Cuchillo formation. In central Texas *Sonneratia whitneyi* occurs low in the Glen Rose. *Sonneratia* is represented by many species in various parts of the world. It always occupies a stratigraphic position low in the Albian. Spath (56, pp. 4, 89) places it in his zone Ia of the Gault at Folkstone, either in the top of his zone of *Leymeriella regularis* or in the base of his zone of *Douvilleiceras mammillatum,* but he is unable to separate satisfactorily the zones in England. Spath mentions that in the Mangyschlak Peninsula *Sonneratia* occurs well above the zone of *Leymeriella,* but *Douvilleiceras* is not found in that area. In the thick section of the southern Quitman Mountains *Sonneratia* occurs several hundred feet below the zone of *Douvilleiceras mammillatum.* In a recent note the writer (49) described a species of the genus from beds of Albian age in Colombia, South America. Several species of *Sonneratia* are known from the Pacific Coast Cretaceous (4).

Zone III, or the zone of *Douvilleiceras mammillatum,* is the most prolific ammonite zone yet found in strata of Trinity age in the

Southwest. Most of the species described in this paper, many of them abundantly represented, are from this level. Future study may establish sub-zones in the main zone, but in the Quitman Mountains where the section is very thick this has not yet been possible. The zone is also widespread in Texas. Numerous specimens have been collected from several localities in the southern Quitman Mountains, in the Solitario basin of Presidio and Brewster counties, and in central Texas. The specimens of *Hypacanthoplites* recovered from well cores in the Glen Rose below the anhydrite in Louisiana are also probably from this zone. The new species *Beudanticeras hatchetense, Trinitoceras reesidei,* and *Douvilleiceras,* n.sp. ind., from the Broken Jug formation of the Little Hatchet Mountains of New Mexico are undoubtedly from this zone or very near it. Species of *Douvilleiceras* group of *D. mammillatum* are among the most widely distributed middle Albian ammonites. *D. mammillatum* is placed at the base of the middle Albian in Spath's Folkstone zonation (56, p. 4). The species of *Douvilleiceras* described by White (59, p. 219, Pl. XXIII, figs. 3, 4) suggests that this zone may be present in Brazil, and the writer has examined a number of specimens of the group from the Horsetown formation of California recently described by Anderson (4) and now in the collections of the University of California and the California Academy of Sciences. The most interesting comparisons of the cephalopod fauna of this zone have been made with faunas from England described by Spath (56), from France described by Jacob (28, 29) and Seunes (50), and from the Caucasus described by Anthula (5) and Sinzow (51). It is interesting to observe that *D. mammillatum* usually occurs a little below species of the group of *D. inaequinodum.* This species has not been recorded from North America, but the writer (49) has described a specimen from the Albian of Colombia.

Zones IV and V do not appear at present to have any particular stratigraphic significance. Zone IV, or the zone of *Knemiceras roemeri,* is sparsely represented by individuals. Known specimens have been found at several localities, and other reported finds are possibly of this species, but its stratigraphic range is entirely unknown. The specimens from localities near the town of Glen Rose are from the middle of the formation as it is represented in that area.

Zone V, or the zone of *Knemiceras nodosum,* has been found only in the limestone lentil of Glen Rose character which lenses out into the Paluxy sand formation in the vicinity of Azle, Tarrant County. Three closely similar species occur in moderate abundance in the zone in this area.

The occurrence of the genus *Knemiceras* in Texas is of considerable biologic and stratigraphic interest, and its species probably herald the remarkable development of the engonoceratids in the Fredericksburg and Washita groups of Texas. Many species of *Knemiceras* have been described from the Albian of Peru by Sommermeier (52), and the resemblance of some of these forms to the Texas species is striking. Several species have been described from the Albian of Arabia by Douvillé (18), and a comparison of his figures with the Texas specimens shows remarkable similarity of the species. *Knemiceras uhligi* (Choffat) (13) from Portugal, described by Douvillé (19, Pl. I, figs. 2a, 2b), appears to be of uncertain age although regarded as Vraconnian by Douvillé.

Two possible stratigraphic levels, different from those included in the above five zones, may be represented by *Pseudosaynella walcotti* (Hill) and *Procheloniceras,* sp.

Ammonites of the genus *Pseudosaynella,* such as *P. bicurvata* (Michelin), appear to occur a little lower stratigraphically than *Dufrenoya* of the group of *D. furcata,* to which *Dufrenoya justinae* belongs; that is, *Pseudosaynella walcotti* would appear to suggest an early late Aptian age for the Dierks limestone. Species of the genus *Procheloniceras* are occasionally found in beds of late Aptian, or even Albian, age but they characteristically occur in the top beds of the lower Aptian. Stratigraphic indications are that the specimen described in this paper is from beds of Aptian age, but this age determination is not at all certain.

CORRELATION OF THE TRINITY STRATA ON THE BASIS OF THE CEPHALOPOD FAUNA

Intra-continental correlation.—From the foregoing summary of the Trinity cephalopod zones it is evident that much of the fauna occupies what has hitherto been a considerable gap in the Cretaceous cephalopod fauna of the Western Hemisphere. It is also apparent that the complex stratigraphic terminology applied to the Trinity in the different areas of outcrop is not indicative of a corresponding number of clearly defined stratigraphic units. Thus, it appears that all of the faunal zones of the Cuchillo formation of Trans-Pecos Texas and of northern Mexico, except the zone of *Dufrenoya justinae*, are found in the lower part of the Glen Rose of central Texas, and the zone of *D. justinae* is in the underlying Travis Peak. The Las Vigas formation, which underlies the Cuchillo, is therefore older than any Trinity sediments outcropping anywhere else in Texas except in the Torcer formation of the Malone Mountain area. Since the Torcer fauna is thought to be very early Cretaceous, a faunal gap of considerable magnitude probably exists between the Torcer fauna and the zone of *Dufrenoya justinae* of the Travis Peak and lowest Cuchillo.

The species from the Dierks limestone of Arkansas suggest an age somewhat older than the zone of *D. justinae*, but this is not at all certain.

The subsurface Trinity section of Louisiana has long been known to be very thick, and the drill has not yet reached its base. Fortunately, ammonites and other data from a great many wells make it possible to postulate certain stratigraphic relationships. After a careful study of these data and much helpful correspondence with Roy T. Hazzard and others, the writer suggests that this underground section is similar to the Quitman Mountain section but thinner and with more stratigraphic breaks. For example, there may be an unconformity in the lower 200–400 feet of the so-called lower Glen Rose in Louisiana marking the Aptian-Albian contact. Both middle Albian ammonites (*Hypacanthoplites, Rhytidhoplites,* and others) and upper Aptian ammonites *(Dufrenoya, Procheloniceras)* have been recovered from this lower Glen Rose section, but there is nothing to suggest that the lower Albian, which in the Quitmans consists of thick beds of limestone, shell beds, and sandstones (lower Cuchillo) with numerous specimens of *Sonneratia,* exists under Louisiana.

The accompanying table is offered as a tentative correlation of the Louisiana and Quitman Mountain sections.

Tentative correlation of the Louisiana and Quitman Mountain sections of the Trinity group.

Louisiana	Quitman Mountain Area
Paluxy	
Upper Glen Rose	GLEN ROSE
Anhydrite	
Lower Glen Rose, upper part Zone *Parahoplites* and *Rhytidhoplites*	BLUE MARLS OF CUCHILLO FORMATION
Disconformity?	Limestones and other beds of lower Cuchillo Zone of *Sonneratia*
Lower Glen Rose, lower part Zone of *Dufrenoya* Zone of *Procheloniceras?*	Travis Peak formation Zone of *Dufrenoya*
Lower Trinity red beds Disconformity?	
Lower marine beds	Las Vigas formation

The writer believes that the very thick Trinity section in the Quitman area may upon further study prove to be of great importance in unraveling the complex Trinity stratigraphy of Mexico and the southwestern United States. This section (see Pl. 55) as measured by the writer is over 12,000 feet thick. The fossil zones are clearly defined and the succession appears everywhere to be normal, except for small rhyolitic bodies which occur in the area but are not shown in the diagrammatic section. Many believe that the section cannot really be so thick and that faulting and overturning have repeated the beds. The writer has sought diligently, however, for repetitions of strata in the section and has found none of consequence. The thickness must, therefore, be taken as measured until repetition is proved. Actually, thick Trinity deposition seems to extend over considerable areas. Accounts by Burrows (11) of the mountains near Ojinaga, Chihuahua; by Burckhardt (9) for various localities in northern Mexico; and by Böse and Cavins (8) for several localities in the Burro Mountains, seem to suggest thick Trinity sections, and Stoyanow (58), with whom the writer has had considerable correspondence, appears to have found a somewhat similar situation near Bisbee, Arizona.

The Trinity section in the Little Hatchet Mountains, as reported by Lasky (35), is astonishingly thick. The exposed and definitely assignable Trinity strata total some 17,000 to 21,000 feet in thickness. Of this section 15,000 feet is in unbroken sequence, and the base is not exposed. The highest definitely assignable strata, according to Lasky, are reef-like limestones with *Orbitolina* and *Toucasia.* Between this Trinity section and Tertiary volcanics may be some thousands of feet more that are still assignable to the Cretaceous (Trinity?), but no fossils have been found that definitely determine the age of these strata.

The ammonite beds occur about 3000 feet to 5000 feet above the base of the exposed, unbroken sequence. *Beudanticeras hatchetense, Trinitoceras reesidei,* and *Douvilleiceras,* n.sp. ind., have been collected at this level. Closely associated with the ammonites are *Exogyra quitmanensis* Cragin and a large species of *Pecten.* These fossils also accompany the *Douvilleiceras*-bearing beds in the Quitman area.

In the California Horsetown (Cretaceous) strata, good specimens of *Douvilleiceras* aff. *mammillatum* and *Sonneratia* have been described by Anderson (4) in whose collections the writer has recently examined them.

Inter-continental correlation.—It is believed that certain of the ammonite zones established in the previous pages make it possible to correlate with a remarkable degree of accuracy certain levels of the Trinity of Texas and neighboring areas with corresponding faunal zones in western Europe and other parts of the world. The accompanying table of inter-continental correlations, using Spath's zonation of the deposits at Folkstone, England (56, p. 4), is suggested. These correlations also indicate that the Glen Rose and equivalent strata are considerably higher than the writer (46, 47) had previously suspected. In 1925 he placed all the Fredericksburg in the Albian and all the Trinity, with the possible exception of the uppermost beds of the Glen Rose and the Paluxy, in the Aptian. In 1928 the Albian zones of *Dipoloceras cristatum* and *D. cornutum* were demonstrated in the Texas Fredericksburg (48). Meanwhile, Adkins (1, p. 9; 2, p. 271) has suggested that a large part of the Glen Rose equivalents should be included in the Albian. The ammonite fauna described here substantiates his contention and indicates that the entire Glen Rose and its equivalents, with the possible exception of the lowest beds which in central Texas may carry species of *Dufrenoya,* should fall into the Albian. The rich ammonite faunas occurring in some places between the zones of *Douvilleiceras mammillatum* and *Dipoloceras cornutum* have not been found in the area under discussion, but their levels are probably represented in the thick upper Glen Rose section, in the Paluxy, and in the lower Fredericksburg strata where the only ammonites yet found are *Knemiceras, Engonoceras,* and *Oxytropidoceras.*

Inter-continental correlation of the Fredericksburg and Trinity groups.

Texas, Arkansas, Louisiana, and New Mexico		Europe	
Formation or group	Zone	Stage	Zone (Spath)
Fredericksburg (Goodland)	Dipoloceras cristatum	Albian	VIII. Dipoloceras cristatum
	Dipoloceras cornutum Oxytropidoceras acutocarinatum		VII. VI. Dipoloceras cornutum V.
Trinity	Knemiceras nodosum Knemiceras roemeri		IV. Dipoloceras delaurei
			III. II. Anahoplites intermedius
			I. Hoplites dentatus
			Hoplites bennetianus
			Douv. inaequinodum
	Douv. mammillatum		Ia. Douv. mammillatum
	Sonneratia trinitensis		
			Leymeriella regularis
	Dufrenoya justinae	Aptian	Dufrenoya furcata
	Pseudosaynella walcotti		
	Procheloniceras?		

The lower Albian zones are apparently not well represented at Folkstone, and Spath (56, p. 4) has listed in these zones some ammonites such as *Hypacanthoplites milletianus, Acanthohoplites jacobi,* and *A. nolani,* the corresponding species of which appear somewhat higher in the section in Texas. Many of the details of these lower zonations are evidently yet to be worked out.

DESCRIPTIONS OF LOCALITIES AND STRATIGRAPHIC SECTIONS

The localities listed here are those from which cephalopods described in this paper have been collected. Many of the localities are difficult of access, and an effort is made to describe them so that they may be determined exactly. At some of them the strata are very thick or the stratigraphy is complex, and in order that the fossils may be properly zoned, stratigraphic sections accompany the descriptions. Localities are given numbers corresponding to the collections from them as they are filed in the type collections of the Bureau of Economic Geology at Austin, Texas, and each specimen has the locality number and the type number written on it. The accompanying chart, figure 138, summarizes the species described in this paper, the localities and stratigraphic levels from which they were collected, and the general area of their occurrence. Unless otherwise stated, all types and figured specimens are deposited in the type collections of the Bureau of Economic Geology at Austin. Plastotypes are in the Department of Geology, Texas Christian University. The localities are as follows:

M1 (map, fig. 139; section, Pl. 55). Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas. Mayfield Canyon is a strike stream that has cut deeply through the mountains and enters the Rio Grande at a point where the latter makes an almost right angle bend 1.6 miles below Indian Hot Springs. Near the mouth of the canyon the ammonite-bearing dark shales and limestones are found on the east wall of the canyon from near the water level up the canyon wall for about 300 feet. The same strata outcrop down the east bank of the Rio Grande to a point where the river again makes a sharp turn and enters the second gorge of its canyon. Mayfield Canyon extends northward from the Rio Grande in the strike for more than 5 miles beyond where the Sierra Blanca–Indian Hot Springs road crosses the southern Quitman Mountains. There is good collecting for at least 4 miles of this distance. The measured section (Pl. 55) crosses Mayfield Canyon near its mouth. The area has been briefly visited by Adkins, Baker, and Arick.

M2 (fig. 139). The dark shales and limestones of the ammonite-bearing beds of the Cuchillo formation in the zone of *Douvilleiceras* are exposed at this locality. The strata are thus the same as beds exposed at locality M1. The Sierra Blanca-Indian Hot Springs road passes directly through the locality

Area of Occurrence	New Mexico			West Texas				Central Texas											North Texas			Arkansas			Louisiana and East Texas *Subsurface*							
Formation	Broken Jug			Cuchillo				Travis Peak	Glen Rose										Glen Rose			Dierks			Trinity *Undivided*							
Locality Number	M 62	M 63	M 64	M 1	M 2	M 5	M 6	M 18	M 45	M 22	M 17	M 19	M 21	M 50	M 57	M 66	M 67	M 68	M 52	M 54	M 55	M 13	M 14	M 15	M 16	M 20	M 56	M 58	M 59	M 60	M 61	M 65
Pseudosaynella hilli																						●										
Uhligella ? *sp. ind.*																							●									
Beudanticeras hatchetense			●																													
Procheloniceras *sp.*																									●							
Cheloniceras adkinsi				●																												
Douvilleiceras mammillatum				●	●	●					●																					
Douvilleiceras cuchillense				●	●																											
Douvilleiceras offarcinatum ?				●																												
Douvilleiceras spathi				●																												
Douvilleiceras quitmanense				●																												
Douvilleiceras *n. sp. ind.*	●																															
Trinitoceras rex				●																												
Trinitoceras reesidei		●	●																													
Dufrenoya justinae							●		●																							
Dufrenoya robusta								●																								
Dufrenoya comalensis												●																				
Dufrenoya *aff.* D. dufrenoyi																												●	●			
Parahoplites umbilicostatus				●																												
Parahoplites wintoni				●																												
Parahoplites thomasi				●																												
Parahoplites ? *sp. ind.*							●																									

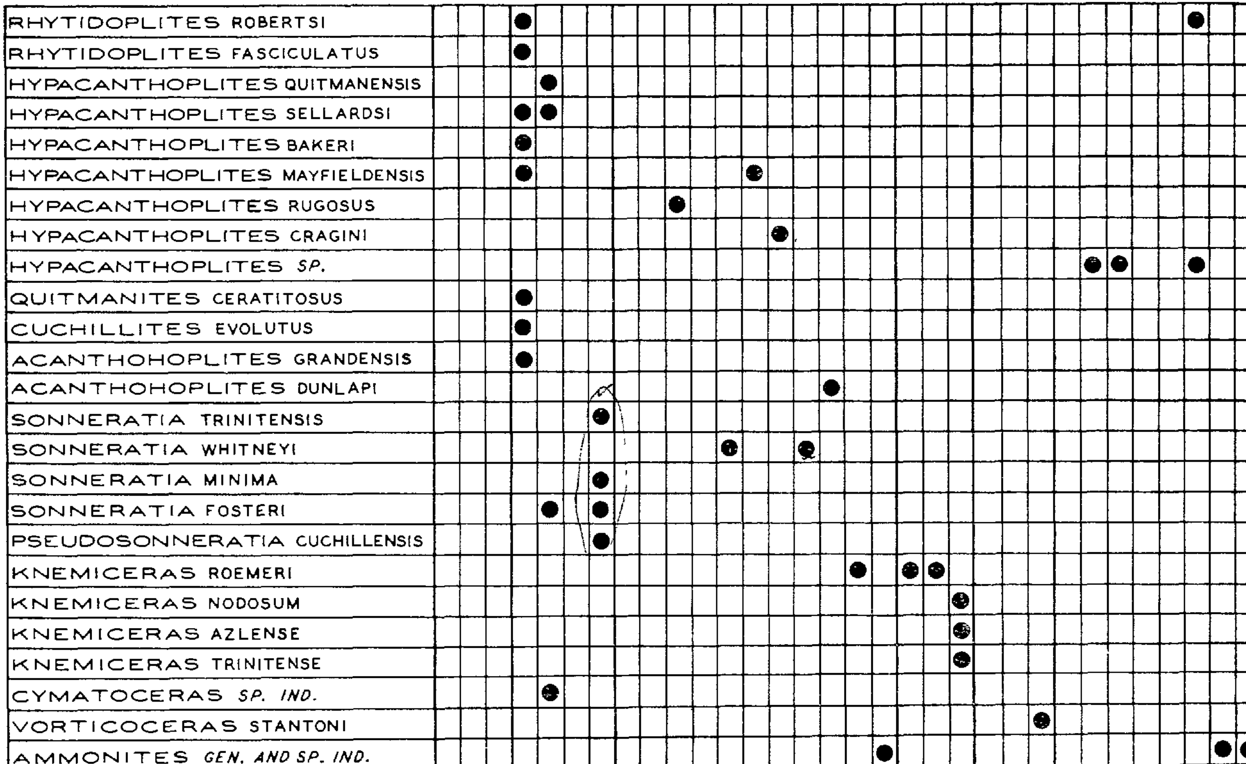

Fig. 138. Chart showing distribution of Trinity cephalopod species in Texas, New Mexico, Louisiana, and Arkansas.

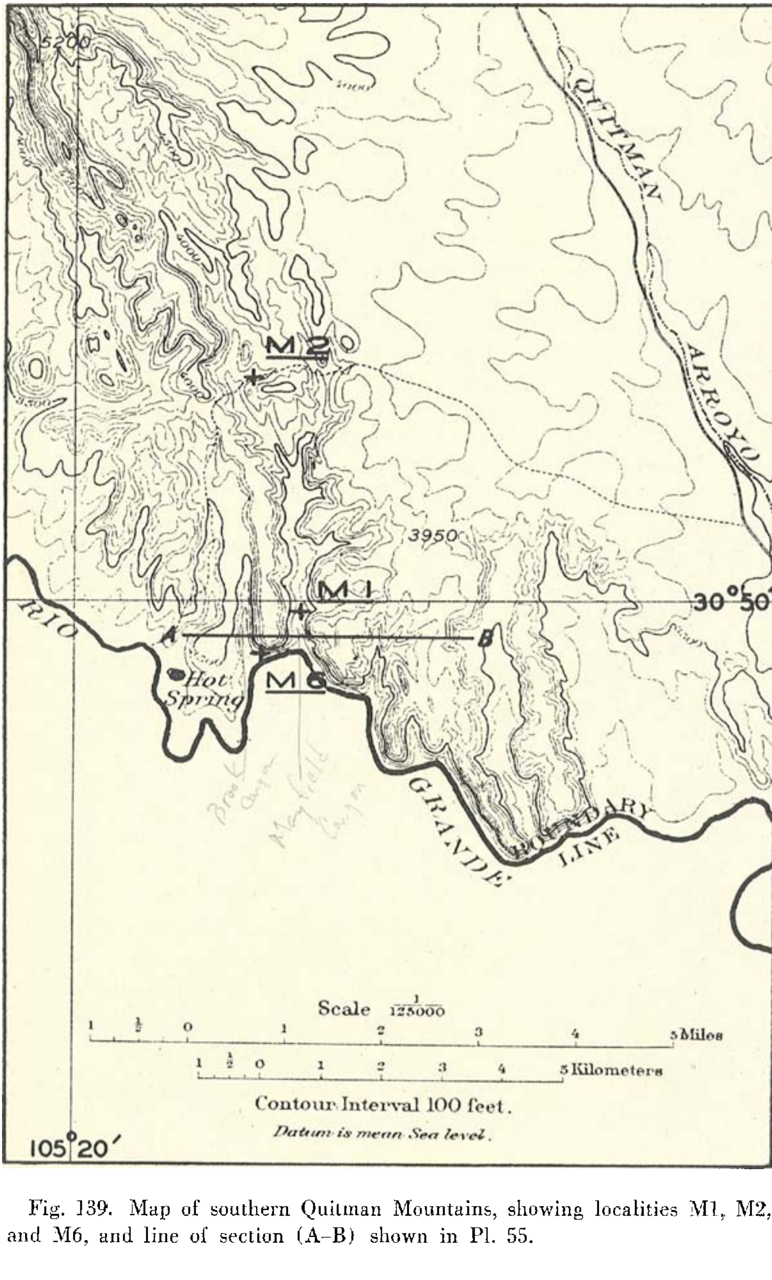

Fig. 139. Map of southern Quitman Mountains, showing localities M1, M2, and M6, and line of section (A–B) shown in Pl. 55.

at a point about 4 miles northeast of Indian Hot Springs, 100 yards east of Quitman Summit in the pass, and just east of an old cattle guard. Ammonites, *Exogyra quitmanensis*, and other fossils are abundant.

This or a nearby locality was evidently visited by Doctor T. W. Stanton (15, Pl. I) about 1897, but no ammonites were reported. Adkins, Arick, and Baker have also briefly visited the locality.

M5 (map, fig. 140; section, fig. 141). This number is assigned to the Trinity strata outcropping around the inner rim of the Solitario Dome basin, where the beds dip steeply away from the central part of the dome. On the southwest side of the dome the writer measured a Trinity section nearly 3000 feet in thickness to the top of Fresno Peak. Beds dip steeply (28–30 degrees) to the southwest along the line of the section.

M6 (map, fig. 139; section, Pl. 55). First gorge of the Canyon of the Rio Grande which begins about 1 mile below Indian Hot Springs. The gorge is deep and narrow, and there is good collecting from the limestone, sandy limestone, and shell beds on both the Texas and Mexican sides of the stream. *Dufrenoya* was found in the lower part of the section while throughout most of the thickness of the strata represented in the canyon, numerous specimens

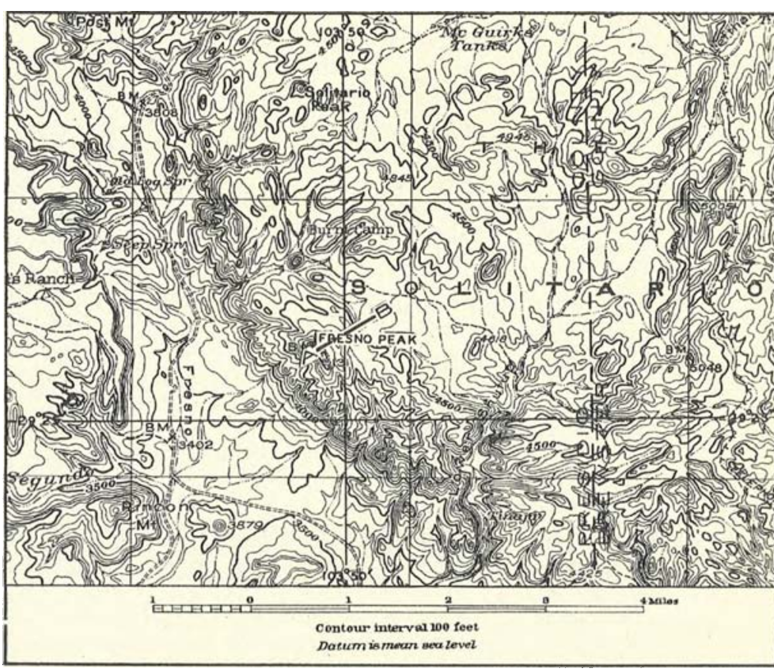

Fig. 140. Sketch map of a part of the Solitario on the line of Brewster and Presidio counties showing position of locality M5 and line of section shown in fig. 141.

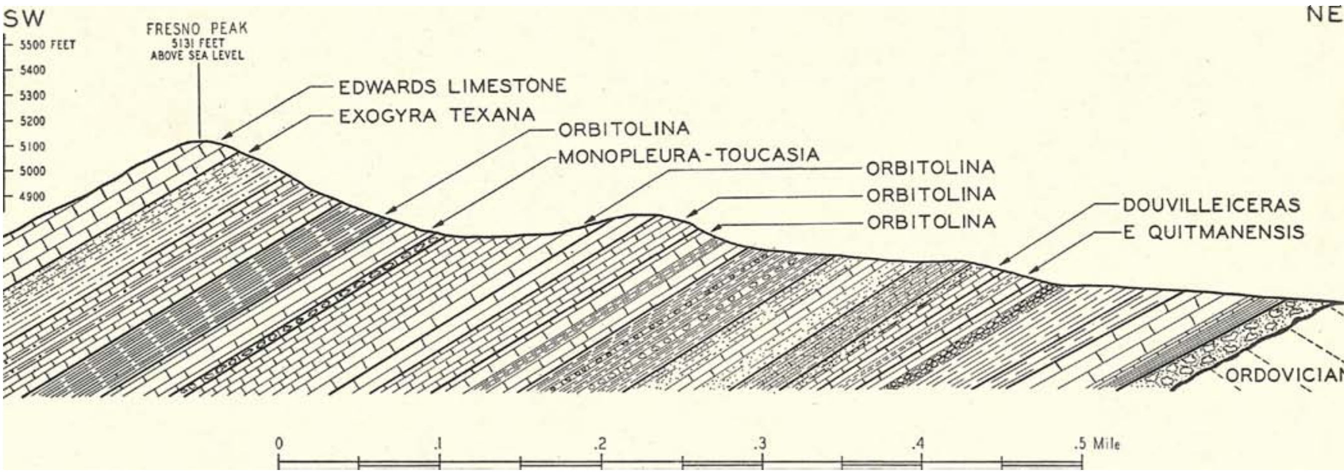

Fig. 141. Section of Trinity strata on the southwest side of Solitario Dome from the inner rim to the top of Fresno Peak.

of *Sonneratia* were collected. The *Sonneratia*-bearing beds underlie the strata outcropping at locality M1. The line of the measured section passes along the canyon at this locality.

M13 (fig. 142). Locality near Murfreesboro, Arkansas, from which Doctor R. T. Hill collected a single ammonite *(Pseudosaynella walcotti)* more than forty years ago. Hill described the species in two separate publications (21, 22) stating in one that it came from "mouth of Caney Creek, branch of Prairie Creek, near Murfreesboro," and in the other that the locality is "banks of Town Creek, one mile southeast of Murfreesboro." These points are very near to each other, and in either case the stratigraphic level of Dierks limestone is clearly indicated.

M14 (fig. 142). U. S. Geological Survey locality 13211, 3 miles east of Murfreesboro on the road to Delight, Arkansas. Doctor T. W. Stanton visited the locality in 1925 and collected a poor specimen of *Uhligella*. The locality is in the Dierks limestone.

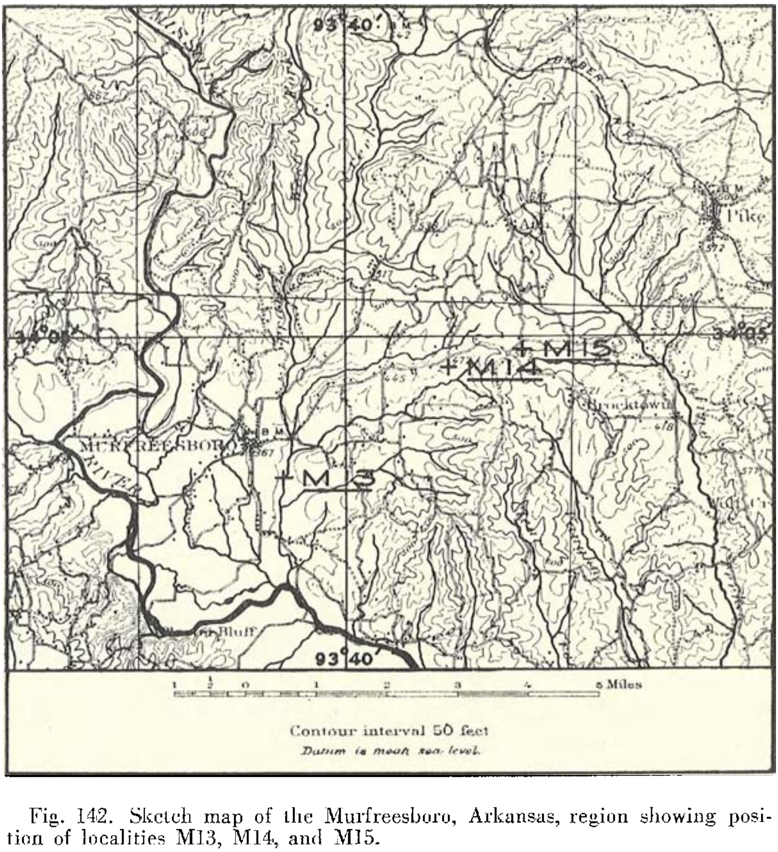

Fig. 142. Sketch map of the Murfreesboro, Arkansas, region showing position of localities M13, M14, and M15.

M15 (fig. 142). U. S. Geological Survey locality 13212, about 4½ miles east of Murfreesboro on the Delight road and less than 1 mile north of Brocktown, Arkansas. Doctor Stanton collected a nautiloid here in 1925. The locality is in the Dierks limestone.

M16. This number is assigned to the deep well, Dillon No. 43, in the Caddo oil field (sec. 13, T. 21 N., R. 15 W.), Sabine Parish, Louisiana. So far as the writer knows only one ammonite specimen was recovered from the well. Casing was set to a depth of 3185 feet, and the well was then shot with a charge of nitroglycerine. The specimen was blown from somewhere below the casing. The total depth of the well was 3625 feet.

M17 (fig. 143). At this locality Professor F. L. Whitney has collected two specimens of *Douvilleiceras.* He labeled the specimens as coming from the "key rock" (of the Glen Rose) at a point one-half mile from the Hays-Blanco County line in Hays County, on the Kyle-Blanco road. The writer has measured a section of the Trinity strata exposed in this general area but has not found any cephalopods and has not been able to fix the "key rock" in his section. The locality, however, is unquestionably low in the Glen Rose formation.

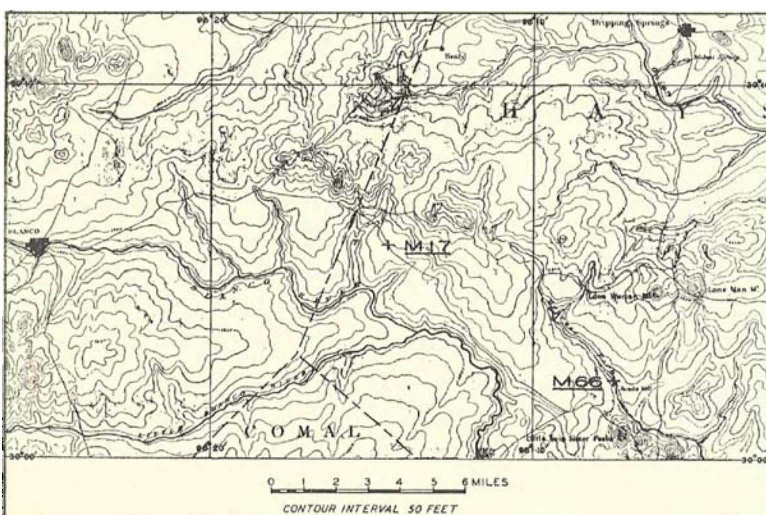

Fig. 143. Sketch map along the Hays-Blanco County line showing position of locality M17.

M18 (fig. 144). Locality from which Professor Whitney collected the specimen here described as *Dufrenoya robusta.* The label with the specimen describes the strata as Travis Peak on Pedernales River along the road to Turner's farm (ranch) in northwest Travis County.

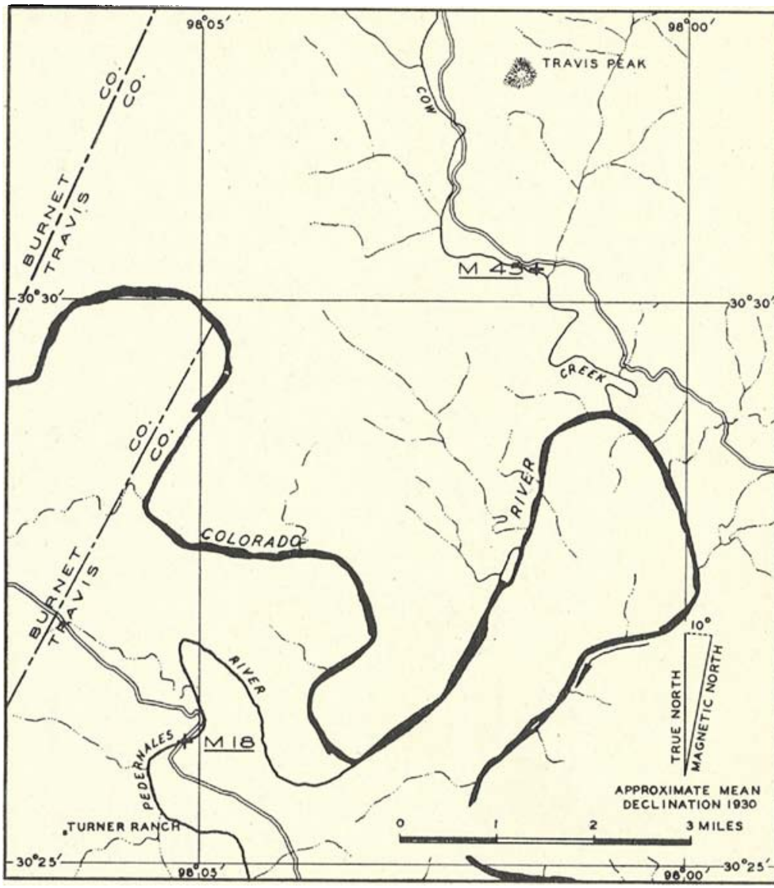

Fig. 144. Sketch map showing the position of locality M18 and locality M45.

M19 (fig. 145). Travis Peak formation or the lower Glen Rose formation, probably the latter, exposed in road cut one-half mile from Fischer's Store on the Fischer's Store–Crane's Mill road. The Trinity strata outcrop widely in Comal County, but beds exposed around Fischer's Store are probably lower Glen Rose or Travis Peak in age. The fossils collected here are from the collections of Professor Whitney. The writer has not visited the locality.

M20. This locality number is assigned to a specimen recovered from a well core at a depth of 4825–34 feet in the United Gas P. S. No. 1 Meadows well, Claiborne Parish, Louisiana (S. 18, T. 21, R. 5 W.).

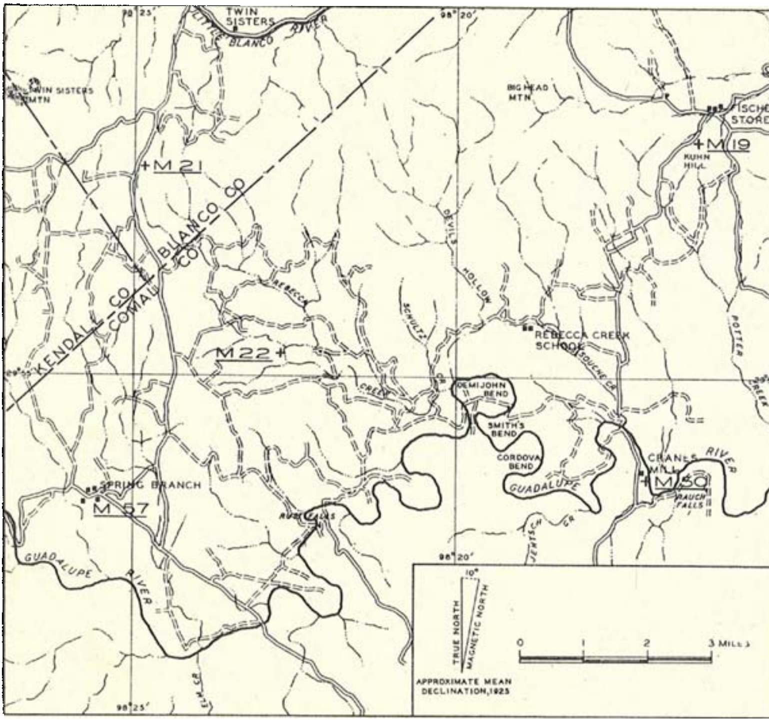

Fig. 145. Sketch map showing localities M19, M21, M22, M50, and M57.

M21 (fig. 145). The exact position of this locality is not known but is designated as "Blanco–New Braunfels road" about 10 miles from Blanco. In this area a Mr. Beckby collected a specimen of *Hypacanthoplites mayfieldensis.* The specimen came to the writer from the collection of Professor Whitney. The locality is evidently in southern Blanco County where the road climbs the escarpment south of Little Blanco River.

M22 (fig. 145). Rebecca Creek, Comal County, where Professor Whitney has collected the holotype of *Hypacanthoplites rugosus.* This locality is about 4 miles northeast of the town of Spring Branch. In the extensive bluffs along the creek the Cow Creek beds outcrop, followed above by about 40 feet of Hensell sands which in turn are overlain by the lowest limestone strata of the Glen Rose (16), out of which the specimen was collected.

M45 (fig. 144). The broad, flat ledges of arenaceous, *Dufrenoya*-bearing beds of the Travis Peak formation are exposed in the bed and banks of Cow Creek in northwest Travis County. The fall of the stream is a little greater than the dip of the beds, and there are low waterfalls. The old Austin–Burnet road follows the bank of this creek for about one-fourth mile and the strata are clearly visible from the road.

The *Dufrenoya* beds are well exposed at numerous places in this general vicinity, as for example at Coombs Hollow near the mouth of Cow Creek and across Colorado River near Driftwood.

M50 (fig. 145). Crane's Mill, on Guadalupe River in Comal County. The holotype of *Hypacanthoplites cragini* was collected by Professor Whitney in the limestones of the lower Glen Rose which outcrop in the stream banks above strata of Travis Peak age.

M52 (fig. 146). Glen Rose beds at the town of Glen Rose in Somervell County. Good exposures are seen in the southwest part of the town of Glen Rose, and specimens of *Knemiceras* have been found here by the writer's students.

M54 (fig. 146). Strata of Glen Rose age are exposed in the banks of Paluxy Creek and its tributaries 4½ miles above Glen Rose. Fossils are numerous, and Professor F. L. Whitney has collected several fragments of *Knemiceras*.

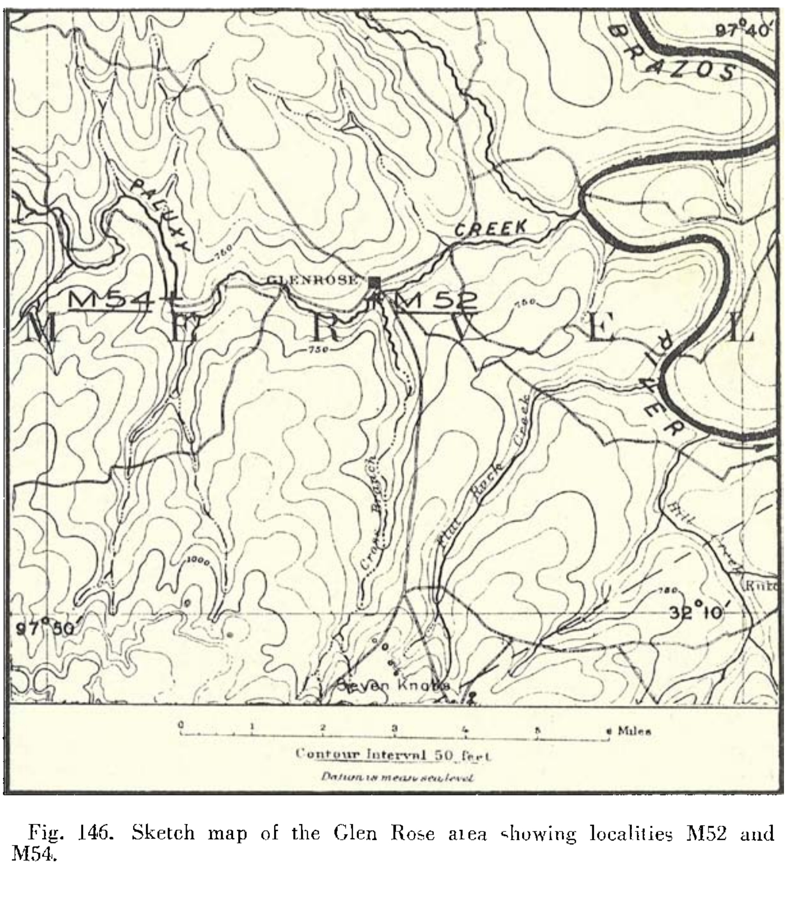

Fig. 146. Sketch map of the Glen Rose area showing localities M52 and M54.

M55 (fig. 147). In the bed of Ash Creek under the concrete bridge of the Jacksboro highway one-fourth mile southeast of Azle, Tarrant County, there is a prominent outcrop of a limestone lentil that lenses out into the Paluxy in the area. The ledge outcrops low in the stream banks for a distance of 100 yards or more both above and below the bridge. Fossils are numerous in the ledge, and specimens of *Knemiceras* belonging to three species have been collected from it.

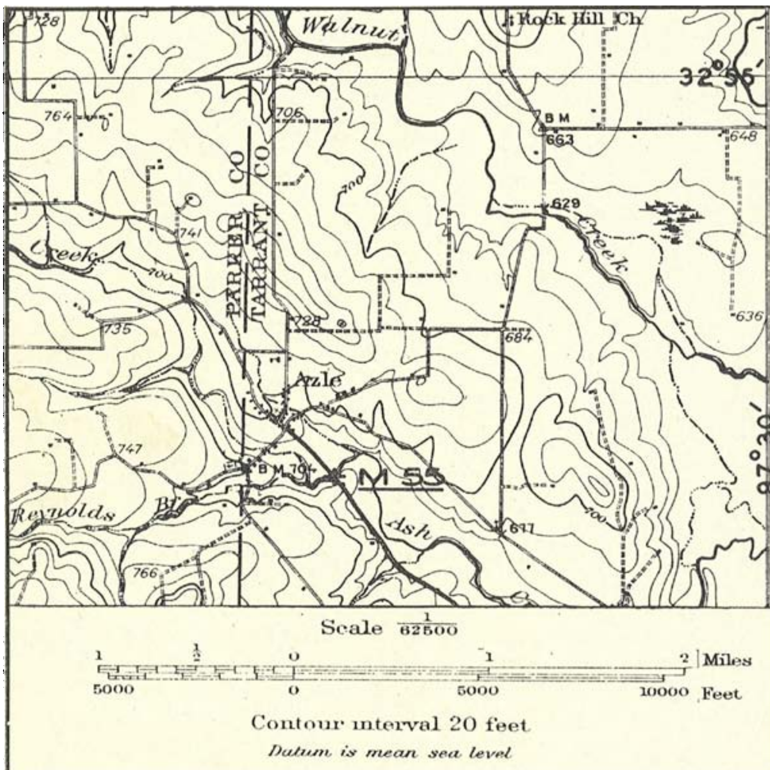

Fig. 147. Sketch map of the Azle area showing locality M55.

M56. Roy T. Hazzard has given to the writer sections of cores from the Shreveport Oil Corporation Muslow D–1 well, sec. 5, T. 20 N., R. 15 W., Caddo Parish, Louisiana. The cores are from the depth 4260–4265, or about 680 feet below the Glen Rose anhydrite, and contain several impressions of ammonites in black shales. The specimens are referred to *Hypacanthoplites.*

M57 (fig. 145). Spring Branch, near Guadalupe River in western Comal County. From this locality low in the Glen Rose, Professor Whitney collected *Sonneratia whitneyi.* The lowest beds outcropping here are the sands of upper Travis Peak, and these are overlain by the lowest beds of the Glen Rose, out of which the holotype of the species was collected.

M58. This number designates the Standard Oil Company Fudicker No. 1 well, sec. 2, T. 17 N., R. 9 W., Webster Parish, Louisiana. Specimens of *Dufrenoya* aff. *dufrenoyi* (D'Orb.) Burckhardt were recovered from this well at a depth of 6202–06 feet and forwarded to the writer by Roy T. Hazzard. The specimens were broken from cores and are believed to be from the lower part of the so-called lower Glen Rose section of that area, or a little over 800 feet below the anhydrite beds.

M59. Haynes Production Company Murff No. 1 well, Sligo oil field, sec. 36, T. 17 N., R. 12 W., Bossier Parish, Louisiana. Cores from this well taken at a depth of 5082–5102 feet contain ammonite fragments believed referable to *Dufrenoya.* The specimens were given to the writer by Roy T. Hazzard.

M60. Prairie River Syndicate Hutchinson No. 1 well, sec. 15, T. 15 N., R. 12 W., Caddo Parish, Louisiana. Cores from this well at a depth of 5366–86 feet yielded ammonite fragments which were sent to the writer by Roy T. Hazzard. *Rhytidhoplites robertsi* and fragments of *Hypacanthoplites* were recognized. One poor fragment may be a desmoceratid.

M61. Lide and Green Smelly No. 1 well, sec. 13, T. 16 N., R. 5 W., Bienville Parish, Louisiana. Cores from a depth of 6658–64 feet were sent by Roy T. Hazzard. Several ammonite impressions are observable in the cores, but none are determinable.

M62. U. S. Geological Survey locality 16962 (Lasky 192–34) in sec. 36, T. 29 S., R. 16 W., at edge of arroyo just north of the Eighth of March shaft, Little Hatchet Mountains, southwestern New Mexico. The locality is in the Broken Jug formation. Mr. S. G. Lasky collected *Douvilleiceras,* n.sp. ind., from the locality.

M63. U. S. Geological Survey locality 17364 (Lasky 46B–35) in N. W. ¼ sec. 36, T. 27 S., R. 16 W., just west of shaft of King-400 Claim, Little Hatchet Mountains, southwestern New Mexico. The locality is in the Broken Jug formation, and a specimen of *Trinitoceras reesidei* of intermediate size was collected by S. G. Lasky. Small fragmentary specimens of ammonites believed referable to *Trinitoceras reesidei* were also collected here.

M64. U. S. Geological Survey locality 17439 (Lasky 7–37), center east line sec. 12, T. 28 S., R. 16 W., Little Hatchet Mountains, southwestern New Mexico. The locality is at a point where the road forks on an outcrop of the Broken Jug formation. From this locality S. G. Lasky collected specimens of *Beudanticeras hatchetense* and *Trinitoceras reesidei.*

M65. The Danciger Oil Company Tatum No. 1 deep well is in the eastern part of Panola County, Texas, near the Louisiana line. In a core taken from the well at a depth of 5844 feet, there is the impression of an ammonite fragment. The specimen is not determinable, but probably is referable to either *Hypacanthoplites* or *Dufrenoya.*

M66 (fig. 143). This locality is at Jacob's Well on Cypress Fork of Blanco River in western Hays County, a short distance from Little Twin Sisters Peaks. The writer has not visited the locality, but Mr. A. H. Dunlap collected the holotype of *Acanthohoplites dunlapi* at the locality. The stratigraphic level is low in the Glen Rose.

M67. This locality is in Burnet County in a roadside cut 3 miles east of Burnet on the Bertram highway. A poor specimen of *Knemiceras* bearing the Bureau of Economic Geology accession No. 17193 is in the Bureau. According to the label the specimen was collected along with large specimens of *Arctica*, below *Exogyra texana* and is Glen Rose in age. The preservation of the specimen does not permit of accurate determination, but it is here tentatively referred to *Knemiceras roemeri* (Cragin).

M68. Locality on San Gabriel River, 3 miles south of Bertram on Hopewell road at base of hills on south edge of the valley; Bureau of Economic Geology accession No. 17253. A large, poorly preserved ammonite apparently belonging to *Knemiceras* bears this label in the Bureau of Economic Geology, but the specimen is not determinable.

SYSTEMATIC DESCRIPTIONS

Order AMMONOIDEA

Family ACONECERATIDAE Spath (56, p. 35)

Genus PSEUDOSAYNELLA Spath

1923. *Pseudosaynella* Spath, Ammonoidea of the Gault, p. 66.

1938. *Pseudosaynella* Roman, Ammonites Jurassiques et Crétacées, p. 363.

This genus was created by Spath to include upper Aptian ammonites of the group of *Ammonites bicurvatus* Michelin. As Spath points out, these ammonites have been incorrectly included in a number of genera by various authors. Kilian (32, p. 15; 33, p. 260) included them in his genus *Saynella*, which, interpreted after Spath, is a purely Hauterivian genus.

Pseudosaynella includes thinly discoid, almost smooth involute ammonites; flanks are flat and converge ventrally to form a sharpened venter; feebly developed costae are widely spaced and falciform. The suture is characterized by a short ventral lobe and broad, long, and asymmetrical first lateral lobe.

Spath believes that *Pseudosaynella* is not in line of descent of the series listed by Kilian but is more probably an end development of some branch of the desmoceratid stock which disappeared without progeny.

Genotype.—*Pseudosaynella bicurvata* Michelin.

PSEUDOSAYNELLA WALCOTTI (Hill)

Pl. 56, figs. 1, 2

1888. *Ammonites walcotti* Hill, Ann. Rept. Geol. Surv. Arkansas, vol. 2, p. 128, Pl. I, figs. 1, 1a, 1b.
1893. *Neumayria walcotti* Hill, Proc. Biol. Soc. Washington, vol. 8, p. 37, Pl. 8, figs. 1–3.
1925. *Saynella hilli* (Stanton MS.) Scott, Études sur les terrains crétacés du Texas, p. 39.
1932. *Pseudosaynella hilli* Adkins, Univ. Texas Bull. 3232, p. 295.
Not *Ammonites walcotii* Sowerby, Mineral Conchology, vol. 2, p. 7, Pl. 106, 1818.

In 1925, while attempting to establish some correlations between the Texas Cretaceous and rocks of the same age in western Europe, the writer became interested in this species, the holotype of which is now in the United States National Museum. Doctor T. W. Stanton kindly sent a copy of the manuscript which he had prepared on the species and has now authorized its use here. The description of the species was done so thoroughly that it needs no revision today, except that the species now falls into the new genus *Pseudosaynella*, established since Doctor Stanton's manuscript was written. In his manuscript Doctor Stanton suggested that the specific name *walcotti* should be rejected as a homonym of *Ammonites walcotii* Sowerby. However, the spelling of the two is different, and the ammonites belong to different genera. The writer is, therefore, retaining Hill's original name. The dimensions of the holotype, in millimeters, are indicated by the following measurements:

Diameter	92
Greater radius	53
Lesser radius	39
Height of last whorl	47
Width of last whorl	26
Width of umbilicus	15
Suture taken at diameter of	63

Doctor Stanton's description follows:

Shell of medium size, compressed discoid, composed of four or five rather closely involute whorls with very gently convex sides; abdomen very narrow but distinctly rounded and without a distinct keel; umbilicus abruptly excavated, rather narrow and relatively deep, showing all the whorls; surface as preserved on a small part of the type almost smooth with a few narrow, inconspicuous, curved ribs and still fewer shallow furrows.

The species is known only by the type specimen which is septate throughout, badly broken and with one side entirely weathered away, though the other side shows the sutures and the surface features of the cast fairly well. With the outline restored it measures about 91 mm. in greatest diameter; height of aperture, 48 mm.; greatest breadth of aperture about 24 mm.; umbilicus 14 mm.

In the second paper cited Mr. Hill quotes a note by Professor Hyatt stating that the species is probably a *Neumayria*, but at that time the details of the suture were not visible excepting as to the auxiliary lobes and saddles near the umbilicus. Some years later the type specimen was again examined by Hyatt, who then stated in a personal letter that it is not *Neumayria* and that he was unable to refer it to a described genus. The suture [fig. 148] has since been carefully prepared so that all the details are shown except the dorsal part of the suture. The ventral lobe is very broad and almost as long as the first lateral, with two large branches on each side. The first lateral lobe is deeply dissected, asymmetrically divided, the marginals on the outer side being larger than those on the inner. The second lateral lobe is much shorter and relatively stouter than the first. The auxiliary lobes, of which there are four on the flank and three visible in the umbilicus, are progressively shorter and more simple, have trifid terminations, and all except the outer one are slightly more narrow than the adjacent saddles. The first lateral saddle is deeply dissected and almost symmetrically divided by a long lobule. The second lateral saddle is also nearly symmetrically divided but not so deeply dissected. The first auxiliary saddle is more slender than any of the others and has a trifid termination. The other saddles become progressively more simple toward the umbilicus, and their broad terminations are broken by two or three irregular denticulations. The saddle on the umbilical shoulder is considerably broader than those adjacent to it on either side.

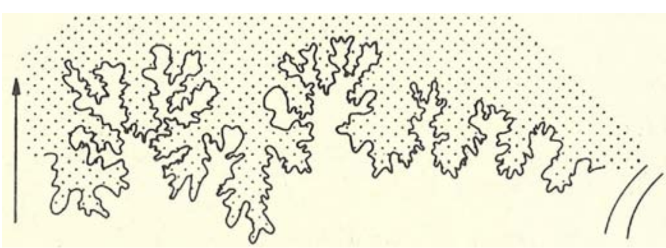

Fig. 148. Suture line of *Pseudosaynella walcotti* (Hill). x2.

A comparison of the suture of this species with the suture of *Ammonites bicurvatus* (Michelin) and with the sutures of related species of the same group as figured by Sarasin (44) shows close similarity both in general character and in details. The chief differences as compared with the suture of *Ammonites bicurvatus* are in the form of the third lateral saddle and in the presence of one additional lobe and saddle on the flank.

The general form and sculpture of the ammonite are also sufficiently similar to those of *Amm. bicurvatus* to justify its reference to the same group.

The generic reference of the group of *Amm. bicurvatus* has been changed many times. Zittel (61, p. 452) regarded it as an early representative of *Placenticeras*. Sarasin referred it first (44, p. 161) to *Sonneratia* and later (45, p. 787) to *Desmoceras*. In 1910 Kilian (32) proposed the name *Saynella* for a series of very peculiar forms extending from the Hauterivian to the Albian and connectin the subgenus *Leopoldia,* and especially *L. castellanensis* (d'Orbigny) with the group of *Amm. bicurvatus* (Michelin). This assemblage of forms constitutes a generic type well characterized by the trenchant form of its siphonal region, by its falciform ribs and by its suture line with short siphonal lobe, first lateral lobe very broad and symmetrical: saddles little branched. Kilian also states that this series shows characters attributed to Desmoceratidae to such an extent that most of the species in question have been referred by different authors to the genus *Desmoceras*. He lists the following representatives of the genus:

In the Hauterivian: *S. clypeiformis* (d'Orbigny), *S. sueuri* (Pictet and Campiche).

In the Barremian: *S. grossouvrei* (Nickles), *S. fabrei* (Torcapel), *S. davydovi* (Karakasch), *S. gouxi* (Sayn), *S. nicklesi* (Karakasch). *S. nicklesi* (Karakasch) var. *deeckei* Kilian.

In the Aptian: *S. bicurvata* (Michelin), *S. heimi* (Sarasin). *S. raresulcata* (Leymerie), *S. undulata* (Sarasin).

Saynella hilli is more closely related to the Aptian species (now included in *Pseudosaynella*), listed by Kilian than to any of the older forms. . . .

Locality and position. Near Murfreesboro, Pike County, Arkansas, in rocks now known to be equivalent of the Glen Rose formation. Hill's first description of the locality said "mouth of Caney Creek, branch of Prairie Creek, near Murfreesboro," and in the second paper it was given as "banks of Town Creek, one mile southeast of Murfreesboro."

The locality is M13.

Type.—The holotype belongs to the Johns Hopkins University, Baltimore, Maryland; plaster cast (No. 1110) in Bureau of Economic Geology, Austin, Texas.

Family DESMOCERATIDAE Zittel (61)

Genus UHLIGELLA Jacob

1907. *Uhligella* Jacob, Mém. Soc. Géol. France, t. XV, Fasc. 3 et 4, p. 26.
1908. *Uhligella* Jacob, Trav. Lab. de Geol., Univ. de Grenoble, tome 8, p. 350.
1920. *Uhligella* Chaput, Mém. Explic. Carte Géol. Det. France, p. 182.
1923. *Uhligella* Spath, Ammonoidea of the Gault, p. 31.
1938. *Uhligella* Roman, Ammonites Jurassiques et Crétacées, p. 404.

Uhligella was created as a subgenus by Jacob to include desmoceratids with moderately flat and embracing whorls. The suture line has a short ventral lobe and a long, sharp symmetrically trifid first lateral lobe. Certain species are moderately costate. According to Chaput, *Uhligella* and related genera probably originated from *Spitidiscus,* but Spath does not accept this point of view. Indeed Spath completely dismembers the genus *Uhligella* as interpreted by Jacob and Chaput, placing Jacob's genotype *Uhligella wallerenti* in the genus *Beudanticeras.*

The doubtful material at hand does not afford an opportunity to discuss these different points of view. For convenience Jacob's original grouping is followed here.

Genotype.—*Uhligella wallerenti* Jacob.

UHLIGELLA?, sp. ind.

Pl. 57, fig. 1

A single fragmentary specimen from the Dierks limestone of southwestern Arkansas is doubtfully referred to *Uhligella.* The specimen is preserved in a fragment of badly eroded shell limestone so that only one flank and the umbilicus are shown.

Description.—Cast moderately globose and evolute with whorls that increase slowly in both height and thickness; umbilicus broad and moderately deep, bounded by an almost vertical wall, the margin of which is broadly rounded. Venter of specimen not shown but appears to be broadly rounded. The following measurements, in millimeters, indicate the dimensions of the specimen:

Diameter	103
Greater radius	67
Lesser radius	36
Height of last whorl	42
Width of umbilicus	27

Sculpture poorly preserved; inner whorls exhibit low, broadly rounded costae which spring from the umbilical wall. Near the middle of the flanks these break into numerous fine costae. Ventral areas of the small whorls not shown. On later whorls are suggestions of low, broad costae.

The suture line (fig. 149) could be only partially outlined, as the ventral lobe is broken away. First lateral lobe moderately long and almost symmetrically trifid; first lateral saddle divided by a long and narrow secondary lobe.

The specimen is unquestionably a desmoceratid, but its state of preservation does not permit satisfactory comparison with known species.

Occurrence.—Dierks limestone of the Trinity group, locality M14 (U. S. Geological Survey locality 13211), 3 miles east of Murfreesboro on the road to Delight, Arkansas. The specimen was collected by Doctor T. W. Stanton in 1925.

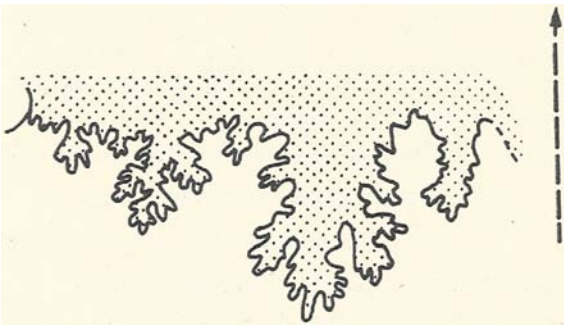

Fig. 149. Suture line of *Uhligella?*, sp. ind. x2.

Repository.—Specimen in United States Geological Survey. Washington, D. C.; plaster cast (No. 1111) in Bureau of Economic Geology, Austin, Texas.

Genus BEUDANTICERAS Hitzel

1902. *Beudanticeras* Hitzel, Bull. Soc. Geól. France, ser. 4, t. 2, p. 875.
1920. *Beudanticeras* Chaput, Les Desmocératidés du Paléocrétacé: Ceph. crétacé du Sud-Est de le France, p. 172.
1923. *Beudanticeras* Spath, Ammonoidea of the Gault, pp. 31–38, p. 49.
1938. *Beudanticeras* Roman, Ammonites Jurassiques et Crétacées, p. 402.

After studies of the family Desmoceratidae by Kilian (33) and Jacob (28), Chaput revised the family and traced the origin of *Beudanticeras* to *Leopoldia.* Spath, who has recently considered *Beudanticeras* and the family to which it belongs, does not accept this view but attaches *Beudanticeras* and others of the polyphyletic desmoceratids to the hoplitids.

Members of the genus have involute, discoid shells that are smooth, or sculptured by periodic constrictions or ridges, and some species have distinct costae, for example, *B. dupinianum* (d'Orbigny) and *B. parandieri* (d'Orbigny). The suture line is characterized by a first lateral lobe considerably longer than the ventral lobe. The first lateral lobe in some species is almost symmetrically trifid, but usually all elements are deeply asymmetrically divided and deeply dissected.

Beudanticeras is similar to other members of the family such as *Desmoceras, Uhligella,* and *Puzosia,* but is much more discoid in form than any of these genera. Its suture line is more dissected than that of *Puzosia* and not as slender, and its umbilicus is smaller. In *Desmoceras* the ventral lobe of the suture line is longer than the first lateral whereas the opposite is the case in *Beudanticeras. Uhligella,* according to Spath (56, p. 38), is restricted to sculptured upper Aptian species of the family.

Genotype.—*Beudanticeras beudanti* (Brongniart).

BEUDANTICERAS HATCHETENSE Scott, n.sp.

Pl. 56, figs. 3, 4, 5

This species is represented by a single fragmentary, completely septate shell of a large specimen. Parts of the thin shell are broken away to show the internal mold of dark limestone. Details of sculpture are shown on parts of the shell.

Description.—Shell involute, discoidal with whorls that increase rapidly in height, slowly in width; flanks flat or gently convex; venter narrowly rounded; umbilicus narrow, relatively deep with steep wall that meets the flank at a distinct umbilical margin. The inner whorls of the holotype, separated from a large fragmentary outer whorl, have the following measurements in millimeters:

Diameter	111
Greater radius	65
Lesser radius	46
Height of last whorl	59
Thickness of last whorl	31.5
Width of umbilicus	18

A fragment of an outer whorl of the same specimen has the following measurements in millimeters:

Height of last whorl	96
Thickness of last whorl	56
Height of umbilical wall	12

A few shell fragments show the strongly sigmoidal striae of growth. Deep, falciform constrictions cross the whorls up to a diameter of at least 110 mm. These are not, however, definitely shown on the large whorl fragment. Ten per whorl occur on the specimen and there may be more that are not shown. They are irregularly spaced and some are more pronounced than others. Some of the constrictions are stronger than others on the venter and may be doubled by the presence in them of low rib-like ridges. No other ribs or sculptured features are shown.

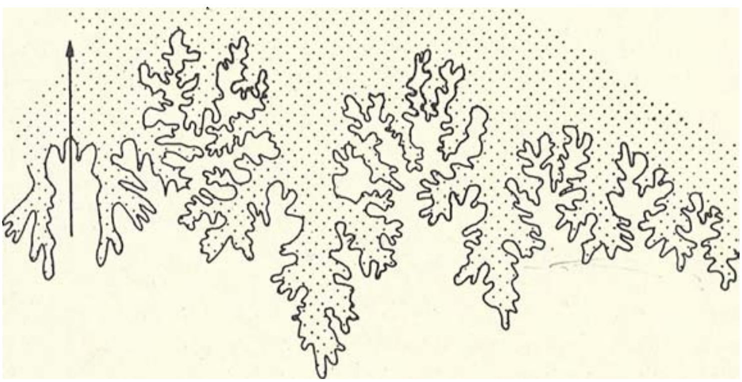

Fig. 150. Suture line of *Beudanticeras hatchetense* Scott, n. sp. x1.

The suture line (fig. 150) is typical of most species of *Beudanticeras*. The ventral lobe is broad, deeply divided and much shorter than the first lateral. The first lateral lobe is asymmetrically trifid, the middle branch being long and slender and widely separated from the ventral branch. All sutural elements are deeply dissected.

Comparison with other species.—All species of *Beudanticeras* are remarkably similar, and extreme precision in comparison of the characters of the shell are required in separating them. As Spath (56, pp. 31–38) has pointed out, it has been customary to refer a great variety of species of the genus, and even species of related genera, to *B. beudanti* (Brongniart), the genotype. *B. hatchetense* is similar to other species but is nearest to *B. ligatum* (Newton and Jukes-Brown) Spath (56, p. 58, Pl. III, figs. 3a–e). In shape and sculpture these two species appear almost identical to the writer. There are approximately the same number of constrictions per whorl, but these are not quite as pronounced in the New Mexico specimen as in *B. ligatum*. The species are readily separated on the basis of their suture lines. In comparison with *B. ligatum*, the New Mexico species has longer, slenderer and more complexly divided sutural elements, and the asymmetry of its first lateral lobe is less marked. It is interesting to observe that in Europe *B. ligatum* occurs in the zone of *Douvilleiceras mammillatum*.

Occurrence.—Locality M64 (U. S. Geological Survey locality 17439) (Lasky 7–37), center of east line of Sec. 12, T. 29 S., R. 16 W., where fork of road lies on outcrop of Broken Jug formation, Little Hatchet Mountains, southwestern New Mexico. The stratigraphic level is probably in the zone of *Douvilleiceras*. The single specimen was collected by S. G. Lasky.

Repository.—Holotype in United States National Museum, Washington, D. C.; plaster cast (No. 1163) in the Bureau of Economic Geology, Austin, Texas.

Family CHELONICERATIDAE Spath (56, p. 64)

Genus PROCHELONICERAS Spath

1923. *Procheloniceras* Spath, Ammonoidea of the Gault, p. 64.
1938. *Procheloniceras* Roman, Ammonites Jurassiques et Crétacées, p. 425.

Spath erected this genus for ammonites of the group of *A. stobieckii* d'Orbigny (39, p. 113; 34, p. 58) species which were previously referred to *Douvilleiceras* de Grossouvre or *Cheloniceras* Hyatt. Unfortunately, this group has not been seriously studied and some of the species are not adequately illustrated.

Jacob (28, p. 371) and Pervinquiere (41, p 195) called attention to the group and included in it ammonites making their appearance in the upper part of the lower Aptian (Bedoulian, zone of *Parahoplites deshayesi*) and including such species as *A. cornuelianus* d'Orbigny, *A. stobieckii* d'Orbigny, *A. albrechti-austriae* Uhlig, and *A. tchernytchewi* Sinzow. Spath in introducing the genus did not describe or limit it but simply suggested that ammonites of the group of *A. stobieckii* are still very close to *Parahoplites* from which they were probably derived.

The genus appears to be well represented in the Bedoulian (lower Aptian) of regions where the cephalopod facies of the stage is found. Roch (42) has described several species of "*Douvilleiceras*" from the type locality of the Bedoulian at La Bedoule which probably fall into the group, but it is impossible at the present time to compile anything like a complete list of species that belong to the genus.

Procheloniceras, as here interpreted, includes the so-called "*Douvilleiceras*" of the lower and middle Aptian. The form of the shell is thick and massive; whorl section rounded with greatest width occurring near the middle of the flanks; whorls slightly embracing with wide and deep umbilici; sculpture consisting of numerous primary and secondary costae which cross the venter without interruption. There are often prominent tubercles in one or two rows on the dorsal part of the flanks from which costae may arise, and two or more additional rows of tubercles on the ventro-lateral areas. The suture, as pointed out by Jacob, is similar to that of *Parahoplites*, but saddles are larger, longer and less dissected. The broad and long first lateral saddle and the deeply divided first lateral lobe may already be prophetic of the typical suture line of *Douvilleiceras*.

Procheloniceras is in need of thorough study, but in collections at hand there is only one fragment of a species belonging to the genus. Roman believes it should not be considered more than a subgenus.

Genotype. *Procheloniceras stobieckii* (d'Orbigny). Roman considers this species a variety of *P. albrechti-austriae* (Uhlig).

PROCHELONICERAS, sp.ind.

Pl. 56, figs. 6, 7

1932. *Douvilleiceras*, n.sp., Adkins, Univ. Texas Bull. 3232, p. 318.

This description is based on a fragment of the living chamber of an ammonite that was blown from the Dillon No. 43 deep well in the Caddo oil field of Louisiana by a nitroglycerine shot in 1924. The specimen is crushed and broken at the last suture, but its diagnostic characters are well shown and it is unquestionably a new species. Since, however, there is no possibility of collecting additional material from its locality, or of determining its exact stratigraphic level, it is simply recorded here and not made the type of a species.

Description.—Shell globose, whorls much broader than high, and only slightly embracing; umbilicus broad and deep. The specimen has the following principal dimensions in millimeters:

Length of fragment	53
Height of last whorl	30
Width of last whorl	43

Sculpture consists of primary and secondary costae and tubercles; costae do not occur according to any fixed relationship to each other, but all cross the venter without interruption; whorl bears eight rows of tubercles, four rows on either side. The row nearest the umbilicus consists of small tubercles slightly elongated radially; next row high on flanks and consisting of large, bullate tubercles, irregular in size and irregularly spaced, and from which spring two or three costae; other four rows of tubercles are faint and lie on the ventro-lateral areas. Suture line cannot be traced, but the general plan of the suture can be made out where the posterior end of the fragment was broken at the last septum. First lateral saddle broad and long, but not appreciably longer than the second lateral; first lateral lobe extremely broad and asymmetrically divided by long secondary saddle. Suture line, therefore, resembles that of *Douvilleiceras*, s.s., in certain respects, but the characters which mark the true douvilleiceran suture line are not yet highly developed.

Comparison with other species.—The large nodose tubercles occurring high on the flanks of the whorls are strikingly like those seen on *Ammonites cornuelianus* d'Orbigny (38, p. 364, Pl. 112, figs. 1, 2) and the general distribution of the other tubercles is similar in the two species. *A. cornuelianus*, however, has much higher whorls, ventro-lateral areas that are more angular and costae that are considerably coarser. The Louisiana specimen is similar in general aspect to the several other species of the genus, but is easily distinguished from any of them.

Occurrence.—Locality M16, interval between 390 and 830 feet below the base of the Glen Rose anhydrite; therefore from the lower Glen Rose.[3] It was blown from the Dillon No. 43 well in the Caddo oil field of Louisiana. Casing was set to a depth of

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[3]Hazzard, R. T., personal communication.

3185 feet, and the specimen must have come from below that depth, probably from the "Dillon" oolitic limestone at the very bottom of the well. The total depth of the well was 3625 feet.

Genus CHELONICERAS Hyatt

1903. *Cheloniceras* Hyatt, U. S. Geol. Surv., Mon. 44, p. 101 (footnote).
1923. *Cheloniceras* Spath, Ammonoidea of the Gault, p. 64.
1938. *Cheloniceras* Roman, Ammonites Jurassiques et Crétacées, p. 426.

This genus was named by Hyatt without adequate description. The name is now in general use to include ammonites previously referred to the group of "*Douvilleiceras*" *martini*. It is evident, however, that Hyatt had selected another species of this same group (*Ammonites royerianus* d'Orbigny) as the genotype.

Ammonites of the genus have generally been interpreted as ancestral to the Douvilleiceratidae and that interpretation is followed here. Spath believes that *Douvilleiceras* also shows affinities with the desmoceratid stock, while he connects *Cheloniceras* to *Parahoplites* through *Procheloniceras*.

Genotype.—*Cheloniceras royerianum* (d'Orbigny).

CHELONICERAS ADKINSI Scott, n. sp.

Pl. 56, figs. 8, 9

The single individual upon which this species is based is poorly preserved and was prepared for description with difficulty. The cast is so weathered that the denticulations of the sutural lobes are greatly obscured.

Description.—Shell inflated with broad, depressed whorls that increase rapidly in size, their width being greater than their height; umbilicus relatively broad and deep, and the umbilical margin narrowly rounded. The principal dimensions of the cast, in millimeters, are as follows:

Diameter	44
Greater radius	25
Lesser radius	19
Height of last whorl	20
Thickness of last whorl	23.5
Width of umbilicus	15
Height of umbilical wall	5
Suture taken at diameter of	30

Surface of cast marked by straight, prominent, distantly spaced costae of equal importance on the ventral region but alternating in importance on the flanks near the umbilicus. On the venter all costae are narrowly interrupted or become indistinct giving a furrowed effect to the ventral region which is greatly accentuated by the presence on all costae of equally prominent, radially compressed ventro-lateral tubercles. On the middle of the flanks alternate costae are marked by large, rounded to conically shaped tubercles; secondary costae end at this same point by small, radially compressed tubercles. On the umbilical margin, primary costae end in low, indistinct, radially elongated tubercles.

On the largest part of the last whorl the costae are poorly preserved, but there is some indication that the ventral tubercles are beginning to break up. There is a broad, shallow notch in the last tubercle shown.

The suture (fig. 151) is poorly preserved and badly weathered, but the long first lateral saddle and deeply divided first lateral lobe establish its douvilleiceran character. A short second lateral lobe lies on the umbilical margin.

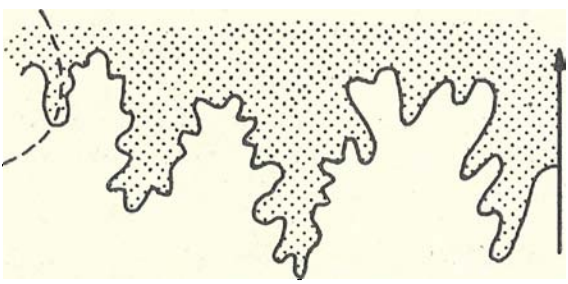

Fig. 151. Suture line of *Cheloniceras adkinsi* Scott, n.sp. x2.

Comparison with other species.—The specimen is very similar in general appearance to many small specimens of *Douvilleiceras* collected by the writer in the Albian of France. In those specimens, however, there are usually two or more primary costae between the secondaries, whereas primaries and secondaries alternate in *C. adkinsi;* and the large undivided tubercles persist to a much larger size in *C. adkinsi* than in any young specimen of *Douvilleiceras* known to the writer. This feature of its sculpture has caused it to be assigned to *Cheloniceras* rather than to *Douvilleiceras.*

Of all the ammonite species known to the writer, *C. adkinsi* is most like *C. clansayense* Jacob (27, p. 413) and may even be a variety of that species. The sutures of the two are remarkably similar and the sculpture is of the same type. The ventro-lateral tubercles, however, are more compressed radially than in *C. clansayense* and the European species lacks the low umbilical tubercles found in *C. adkinsi*. Anderson (4) has recently described several species from California, but all appear to be somewhat older stratigraphically than the Texas species and are not very similar to it.

Occurrence.—A nodular limestone ledge in the blue marls of the Cuchillo formation. The ledge is about 12 feet thick and outcrops 20 to 60 feet above the base of the southeast wall of Mayfield Canyon where the canyon enters the Rio Grande, locality M1.

Family DOUVILLEICERATIDAE Spath (56, p. 64)

Genus DOUVILLEICERAS de Grossouvre emend. auth.

1893. *Douvilleiceras* de Grossouvre, Mém. Carte Géol. de France, p. 26.
1923. *Douvilleiceras* Spath, Ammonoidea of the Gault, p. 68 (synonomy).
1938. *Douvilleiceras* Roman, Ammonites Jurassiques et Crétacées, p. 423.

This genus as originally defined by de Grossouvre is characterized by the long and broad first lateral saddle, and by the peculiar form of the first lateral lobe of its suture. The shape and sculpture of the shell are also diagnostic. The shell is evolute and inflated. The whorls are rounded or depressed with prominent, multi-tuberculate costae.

De Grossouvre included ammonites of the group of *Ammonites martini* d'Orbigny in the genus, but this group falls properly into *Cheloniceras* Hyatt as now interpreted by Spath. An adequate synonomy and thorough discussion of the genus are given by Spath.

Genotype.—*Douvilleiceras mammillatum* (Schlotheim).

DOUVILLEICERAS MAMMILLATUM (Schlotheim) emend. Spath

Pl. 56, fig. 10; Pl. 57, figs. 3, 4

1923. *Douvilleiceras mammillatum* Spath, Ammonoidea of the Gault, p. 68, Pl. IV, figs. 3a, b; Pl. V, figs. 1–4 (comprehensive synonomy).
1938. *Douvilleiceras* aff. *mammillatum* Anderson, Geol. Soc. Amer., Special Paper 16, p. 174, Pl. 36, fig. 3.

Several representatives of this species have been collected from Trinity strata in the Quitman Mountains and the Solitario of Trans-Pecos Texas and from the lower Glen Rose of central Texas. Most of them are fragmentary casts of the septate portions of large whorls. One fragment has a whorl thickness of 89 mm.

Description.—Shell moderately globose with inflated whorls that increase rapidly in width, but slowly in height; whorls but slightly embracing; flanks and venter broadly rounded without pronounced ventro-lateral angles; umbilicus broad and deep with steepsided walls; umbilical margin distinct. The following measurements, in millimeters, are taken from the best specimen:

Diameter	81
Greater radius	50
Lesser radius	31
Height of last whorl	33.5
Thickness of last whorl	38
Width of umbilicus	27

Sculpture consists of equal, rectilinear, multi-tuberculate costae. All begin at a tubercle on the umbilical margin and become increasingly broad and high ventrally; are interrupted or strongly attenuated at the mid-ventral line giving a narrowly furrowed effect to the broadly rounded venter; costae each bear eight or nine pairs of pronounced tubercles, characteristically grouped so that three rows lie just lateral to the venter. These are separated by a wide interspace from four or five rows (depending on the size of the shell) which lie low on the flanks. These are followed by a broad interspace which in turn is followed by a row of tubercles on the umbilical margin. In the broad interspace between the umbilical and lateral tubercles there is a suggestion of low tuberculation. The umbilical tubercles are conical in shape. All the others are spirally elongated. On a very large fragment the sculpture is approaching the costate stage characteristic of large whorls of the species where tubercles are erased or become indistinct.

Several specimens show parts of the suture line, but a complete pattern could not be traced. The parts that are shown have the general characters of the genus and species.

Comparison with other species.—There are no appreciable differences between the several specimens from Texas and examples of *D. mammillatum* collected by the writer some years ago in the

Albian of southeastern France. On large individuals the tubercles in the ventral row of the lateral group are divided making nine rows instead of eight on each side of the venter. The interspace between the umbilical and the lateral tubercles is also a little wider in the Texas representatives than in the European forms. *D. quitmanense* is very similar to this species, but its whorls are much thicker, its tubercles are less pronounced and the ventral furrow is not nearly as well developed. The writer has examined a number of specimens of *Douvilleiceras* from thé upper Horsetown beds of California, which have recently been described by Anderson (4). They do not appear to differ appreciably from *D. mammillatum*, s.s., and are referred to that species by Anderson. In general, however, the other species of *Douvilleiceras* from California tend to be more finely costate than corresponding species in Texas. Lately, Spath (54, pp. 60–66) has discussed a rich douvilleiceran fauna from the Samana Range in India.

Occurrence.—Upper Cuchillo of the Quitman Mountain area and lower Glen Rose of the Solitario and central Texas. Several specimens collected from gray marls of the Cuchillo formation at localities M1 and M2. Other specimens are from the Solitario basin (locality M5) a short distance above the basal conglomerate. Two fragments collected by Professor F. L. Whitney from the "key rock," locality M17. *D. mammillatum* characterizes the middle Albian of many parts of the world.

DOUVILLEICERAS CUCHILLENSE Scott, n.sp.

Pl. 59, figs. 3, 4

Several specimens of this species were collected in the southern Quitman Mountains. All have parts of the original shell poorly preserved and strongly impregnated with carbonaceous material. The shells are filled with indurated black shale, and most of the specimens are badly crushed and inclosed in hard clay stone concretions. A few individuals have been prepared by alternately heating and cooling a great many times in order to cause the concretions to cleave from the fossils, and the best one is used as the holotype.

Description.—Shell inflated; whorls a little wider than high, increasing slowly in height, but rapidly in width; whorls evolute, earlier whorls impressing themselves only slightly into the dorsum of succeeding ones; umbilicus broad with subperpendicular wall, the margin of which is poorly defined. The following measurements, in millimeters, are taken from the holotype:

Diameter	82
Greater radius	47?
Lesser radius	35?
Height of last whorl	33
Thickness of last whorl	36
Width of umbilicus	39
Suture taken at diameter of	60

The whorls bear uniformly spaced multi-tuberculate costae, the three-fourths whorl showing 21 of these. A complete whorl would probably have about 35. Costae nearly equal, but some slightly more prominent than others near the umbilicus, and occasional ones end at the umbilical margin in low, rounded tubercles. Costae

Fig. 152. Suture line of *Douvilleiceras cuchillense*, n.sp. x2.

greatly attenuated across venter but not interrupted, so that the venter of the whorl has a flat or broadly furrowed appearance.

On the costae are seven rows of spirally arranged tubercles, but only four of these rows are prominent. In two of the rows the tubercles are detected only by the sense of touch. The row on the umbilical margin consists only of the occasional tubercles by which some of the costae end. The three rows of tubercles to either side of the venter are the most pronounced. In very young specimens there is a single ventro-lateral tubercle on either side of the venter, but on older whorls this splits into three.

Suture (fig. 152) characteristically douvilleiceratid but characterized by an extremely broad first lateral saddle in contrast with the small second lateral which has become attenuated almost to the point of becoming a secondary element. The curious asymmetry of the first lateral lobe is also a distinguishing feature. Only a part of the living chamber is preserved.

Comparison with other species.—The characters of the suture already mentioned, the relatively high, evolute whorls, the sparse tuberculation and wide umbilicus serve to distinguish *D. cuchillense* from other species of the group of *D. mammillatum* to which it belongs.

The species appears to resemble *D. spiniferum* Whiteaves (60, p. 273, Pl. XXXV, figs. 2, 3; text fig. 14), which Anderson described in his 1902 paper (3, p. 108) as *Douvilleiceras mammillare,* more than any of the others. The writer recently had the opportunity to study a number of Pacific Coast specimens and has convinced himself of the close similarity of the two species. *D. spiniferum,* however, has narrower whorls, and more spine-like ventro-lateral tubercles than *D. cuchillense.*

Occurrence.—Abundant in middle of the blue marls of the Cuchillo formation, localities M1 and M2. The holotype is from the lower reaches of Mayfield Canyon not far above its confluence with the Rio Grande (locality M1).

DOUVILLEICERAS OFFARCINATUM (White)?

Pl. 58, figs. 4, 5

1887. *Ammonites offarcinatus* White, Contrib. Pal. Brazil, Arch. Mus. Nacion. Rio de Janeiro, Vol. VII, p. 219, Pl. XXIII, figs. 3, 4.
1923. *Douvilleiceras offarcinatum* Spath, Ammonoidea of the Gault, p. 70.

In the writer's collection are four poorly preserved fragments of an ammonite which agree in every particular with White's Brazilian species. All the specimens are casts of coarse calcareous material. No trace of a suture could be brought out on any of them, and many of the characters are obscured by the nature of the material in which they are preserved. The specimens are doubtfully referred to White's species.

Description.—Whorls a little broader than high increasing rapidly in size; one specimen shows that the species is evolute, succeeding whorls being impressed but slightly by younger ones. Umbilicus broad with high, rounded walls. One of the specimens has the following principal dimensions in millimeters:

Length of fragment (one-half whorl)	57
Height of last whorl	19
Width of last whorl	21
Width of umbilicus	19
Height of umbilical wall	5.5

Whorls sculptured by numerous evenly spaced, uniformly prominent, multi-tuberculate costae. These are sharply attenuated across a narrow region on the venter giving a furrowed effect to the area. This furrow is much narrower than on any other species of *Douvilleiceras* collected in Texas, but corresponds closely to the furrow shown on White's figure. Costae marked by four rows of tubercles, only the first two rows on either side of the venter being prominent. The costae fade away at the umbilicus and no umbilical tubercles are visible on any of the specimens.

Comparison with other species.—The specimens are referred to White's species mainly on the basis of the narrowly furrowed ventral area, the number and character of the tubercles and the spacing of the ribs. There are also certain resemblances to *Douvilleiceras paucicostatum* Parona and Bonarelli (40, p. 85, Pl. XIII, fig. 4), but that species has more numerous and more prominent tubercles than any of the Texas material.

Occurrence.—Nodular to massive limestone ledge in the lower middle part of the blue marls of the Cuchillo formation. The ledge is about 15–20 feet thick and outcrops about 60 feet above the floor of lower Mayfield Canyon (locality M1).

DOUVILLEICERAS SPATHI Scott, n.sp.

Pl. 58, fig. 3; Pl. 60, fig. 6

The single large, entirely septate specimen upon which this species is based is a fragment of the original shell material highly impregnated with carbonaceous material. It is crushed from the side and is filled with indurated, black shale. The venter, umbilical area and left side are well preserved, but the right side is gone.

Description.—Whorls broadly arched, but much higher and more compressed laterally than in any other known species of the Douvilleiceratidae; whorls increase slowly both in height and thickness; umbilicus exceptionally broad with a high vertical wall which meets the flank along a definite margin marked by prominent bulla-like tubercles. Flanks unusually flat for a species of *Douvilleiceras,* but this may result in part from the fact that the shell has been crushed from the side. The holotype has the following dimensions in millimeters:

Diameter	190
Greater radius	112?
Lesser radius	78?
Height of last whorl	90?
Thickness of last whorl	54?
Width of umbilicus	65
Height of umbilical wall	18

The half whorl of the specimen bears twenty-one closely set, multi-tuberculate costae. These are greatly attenuated for a wide area across the venter, but are not completely interrupted. Costae are an irregular assortment of primaries and secondaries and in passing from umbilicus to venter, bend slightly, but abruptly, posteriorly at the second row of prominent tubercles from the umbilical wall. A primary and one, two or three secondary costae may branch from a single large umbilical tubercle or the secondaries may spring from near the middle of the flank. The primaries, throughout their extent, are more prominent than the secondaries and their tubercles are better developed. Tubercles are arranged in eight distinct spiral rows, but individual tubercles vary greatly in importance. Those on the umbilical margin are large and bulla-like; second row ventral to these of similar character, but more elongated radially and larger on primary costae than on secondaries. Ventral to the second row are five rows which increase rapidly in importance ventrad. The first of these five is indistinct, the last of the five prominent with individual tubercles compressed spirally. Ventrad of the seventh row of prominent tubercles, and just on either side of the venter is a row of low, spirally compressed tubercles. In order to prepare a complete suture, it would have been necessary to destroy many of the features of the shell and it was not attempted, but enough of the pattern is shown to establish its douvilleiceran character.

Comparison with other species.—*D. spathi* is clearly a species of the group of *D. mammillatum* and it is nearer to that species than to any other known to the writer. It is, however, easily distinguished by its varied and flexed costae, its wide umbilicus and high, more compressed whorls.

Occurrence.—*D. spathi* is the highest, stratigraphically, of any of the specimens of *Douvilleiceras* collected in the blue marls of the Cuchillo formation and came from near the top of these marls a short distance below where they grade upward into iron-stained yellow beds, at locality M1 a short distance above the spring where Mayfield Canyon makes a sharp angle turn.

DOUVILLEICERAS QUITMANENSE Scott, n.sp.

Pl. 61, figs. 9, 10

This species is based on one good specimen, collected by Mr. W. S. Adkins. In the writer's collection are two large fragments that may be referable to it.

Description.—Shell globose, fast growing; whorls heavy bodied, increasing in thickness more rapidly than in height; umbilicus deep and relatively narrow. The following measurements, in millimeters, are taken from the holotype:

Diameter	81	
Greater radius	47	
Lesser radius	34	
Height of last whorl	34	
Thickness of last whorl	47	(possibly a
Width of umbilicus	31	little crushed)
Height of umbilical wall	16	

About twenty-five closely spaced, multi-tuberculate costae per whorl; all strongly attenuated on crossing the venter but not interrupted; most of the costae of equal prominence ending on umbilical wall in low rounded tubercles. Occasional ones end just short of the umbilical wall and do not exhibit the terminal tubercles. There are six or seven spiral rows of tubercles but some of the rows are very indistinct. Two ventral rows on each side, the umbilical rows and two rows on the middle of the flanks are prominent. No suture is shown on the specimen.

Comparison with other species.—*D. quitmanense* is extremely close to *D. mammillatum* and has about the same number and disposition of costae, but these stand higher on *D. quitmanense* than on *D. mammillatum*, and the small tubercles break off from the large tubercles of youth at a much later stage of growth. *D. quitmanense* has heavier whorls, is more globose in appearance and has a narrower umbilicus than *D. mammillatum* or any other species of the genus known to the writer.

Occurrence.—Holotype collected by W. S. Adkins from the blue marls of the Cuchillo formation at locality M1.

DOUVILLEICERAS, n.sp. ind.

Pl. 57, fig. 2

In the material from the Little Hatchet Mountains of southwestern New Mexico collected by S. G. Lasky is a limestone slab bearing the flattened impression of a large specimen of *Douvilleiceras*. Mr. Lasky has made a plaster cast of the specimen from the mold. From the mold and cast it is possible to tell something of the shape and sculpture of the shell, but the species is not determinable.

Description.—Whorls increase rapidly in size, shell moderately evolute, umbilicus large and umbilical margin well defined. The following measurements, in millimeters, of the flattened specimen are probably inaccurate, but give an idea of the size of the specimen:

Diameter	210
Height of last whorl	93
Greater radius	130
Lesser radius	80
Width of umbilicus	65

Sculpture consists of numerous costae and tubercles. Costae moderately fine for a specimen of this size. Twenty-two were counted on the specimen of approximately one-half whorl in length. Primary costae more numerous than secondaries which are only occasionally intercolated between primaries. Costae bear numerous prominent, rounded, pointed or elongated tubercles. Eight to nine tubercles are on each primary rib on the flanks. The ventral area is not shown. Tubercles on the ventral part of the flank are spirally elongated, bluntly pointed or rounded. Those near the umbilicus are radially elongated.

The suture line is not shown.

Comparison with other species.—This specimen is unquestionably a species of *Douvilleiceras* of the group of *D. mammillatum*, but it is different from any known to the writer. Several fragments of *Douvilleiceras* of equal or larger size from the Quitman Mountains have coarser and more widely spaced costae and more rounded tubercles. The characteristic feature of the specimen is that it carries to an advanced age the youthful sculpture of young or medium-aged specimens of *Douvilleiceras* of the group of *D. mammillatum*. It is unfortunate that the specimen does not permit more accurate description so that a new species name might be assigned to it.

Occurrence.—Locality M62 (U. S. Geological Survey locality 16962) (Lasky 192–34), sec. 36, T. 29 S., R. 16 W., edge of arroyo just north of Eighth of March shaft, Broken Jug formation, Little Hatchet Mountains, southwestern New Mexico.

Repository.—United States National Museum, Washington, D. C.; plaster cast (No. 1164) in the Bureau of Economic Geology, Austin, Texas.

TRINITOCERAS Scott, n.gen.

A very large ammonite from the southern Quitman Mountains is clearly a douvilleiceratid, but it differs by so many characters from the species of the group of *D. mammillatum*, to which the name *Douvilleiceras* is now restricted, that a new genus is here created for it. A similar species from the Little Hatchet Mountains of New Mexico is also referred to the genus. The relationship of the genus to true douvilleiceratids is revealed in the suture at all stages of growth but the characters by which the douvilleiceran suture is recognized are more pronounced than in *Douvilleiceras.*

The douvilleiceratid sculpture is evident up to or beyond a diameter of 200 mm. Costae are multi-tuberculate as in *Douveillei-ceras*, but the umbilical tubercles are greatly exaggerated in size, forming large bullae on the umbilical margin at the ends of alternate costae. On later whorls costae lose all trace of tuberculation but retain, irregularly, their alternate primary and secondary arrangement. On the latest whorls shown, the ribs are nearly all equal, except that an occasional secondary (marked only by the fact that it does not reach the umbilicus) is intercalated between the primaries. The whorl section, degree of evolution, and umbilical area do not differ greatly from like features of well known species of *Douvilleiceras.*

From this description it appears reasonable to conclude that *Trinitoceras* is a direct descendant of *Douvilleiceras*. Two new species, one from west Texas and one from New Mexico, are here referred to this new genus. It appears probable to the writer that *Douvilleiceras aurarium* Anderson (4, p. 175, Pl. 53, fig. 1) may be a representative of the genus.

The genotype is a very large specimen measuring 420 mm. in diameter and is entirely septate.

Genotype.—*Trinitoceras rex* Scott, n.sp.

TRINITOCERAS REX Scott, n.sp.

Pl. 60, figs. 1, 2, 3

This large species occurs in considerable abundance in the Cuchillo formation of the southern Quitman Mountains, but it is difficult to find anything but fragments. Since materials from the area must be carried out by hand or pack animal 2 to 6 miles, only the specimen here described was collected.

Description.—Shell globose, heavy bodied, and evolute with deep umbilicus; whorls thicker than high and broadly rounded, thickest portion being about one-third of the distance from umbilicus to venter; whorl dimensions increase rapidly with age. The following measurements, in millimeters, give an idea of the size of the species:

Diameter	420
Greater radius	240
Lesser radius	180
Height of last whorl	180
Height of penultimate whorl	80
Thickness of last whorl	220
Width of umbilicus	140
Suture taken at diameter of	300

Young whorls, up to or beyond a diameter of 200 mm., marked by coarse, broadly rounded, evenly spaced, multi-tuberculate costae which alternate regularly as primaries and secondaries; secondaries almost as prominent as primaries across the venter and on the ventral region of the flanks, but fade in significance toward the umbilicus. On young whorls costae carry four or five rows of tubercles on either side of the venter, but only three rows are prominent; tubercles all of the large and rounded type, but are slightly elongated radially. Tubercles by which the primary costae end at the umbilical margin are great bulla-like swellings which greatly increase the whorl width; tubercles at which secondary costae end much less pronounced. On large whorls all traces of tuberculation are obliterated, but the broad rounded costae are still well developed. Up to a diameter of 380 mm. there is alternation of primary and secondary costae, but the alternation becomes somewhat irregular beyond this diameter.

Parts of the ventral lobe of the suture are eroded and broken away, but essential features are shown. In its broad outline, the suture is typically douvilleiceran, as shown in figure 153.

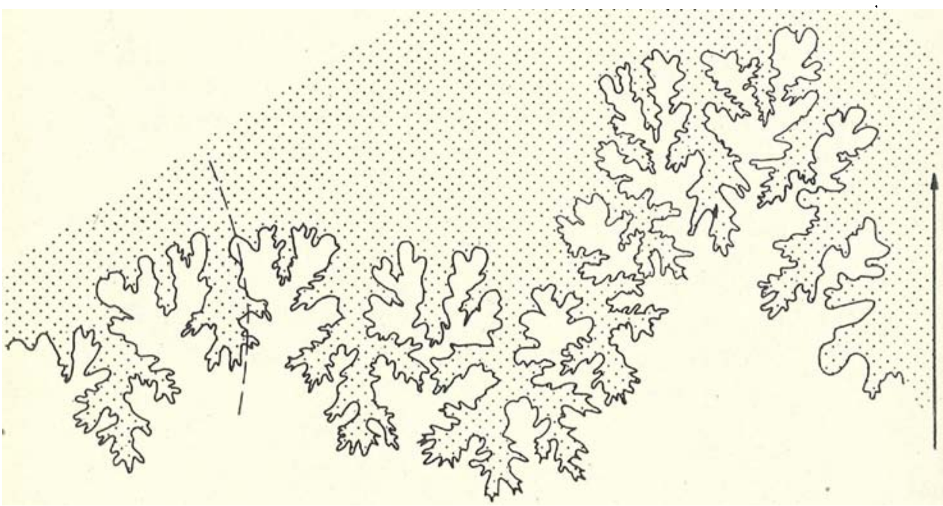

Fig. 153. Suture line of *Trinitoceras rex* Scott, n.sp. x½.

Comparison with other species.—The only other species with which *Trinitoceras rex* may readily be compared is *T. hatchetense* from the Little Hatchet Mountains of southwestern New Mexico. The tuberculation on the young whorls of *T. rex* is much coarser, the bulla-like tubercles on the umbilical margin are more prominent and the costae on the young whorls are stronger and more widely spaced than in *T. hatchetense.* Both species carry to extreme the tendency often shown by douvilleiceratids to lose the tuberculation on larger whorls.

Occurrence.—Upper half of the blue marls of the Cuchillo formation, at locality M1.

TRINITOCERAS REESIDEI Scott, n.sp.

Pl. 57, figs. 5, 6; Pl. 58, figs. 1, 2, 6, 7; Pl. 59, fig. 5

In the material collected from the Little Hatchet Mountains of southwestern New Mexico by S. G. Lasky are two large specimens and three fragments of smaller whorls which appear to be referable to *Trinitoceras,* but are different specifically from *T. rex* of the Quitman area in Texas. All specimens are fragmentary, but the largest shows an impression of the inner whorls and a plaster mold has been made which permits a reasonably satisfactory study of the young whorls.

Description.—Shell globose, heavy bodied, and evolute with deep umbilicus; whorls thicker than high and broadly rounded on older portions of shell, whorl section slightly quadrangular on shells of intermediate size; thickest portion of whorls about one-third of distance from umbilicus to venter; whorl dimensions increase rapidly with age. The accompanying measurements, in millimeters, are taken from the specimens.

	No. 1	No. 2	No. 3	No. 4
Diameter		240	95	80
Greater radius	260	120	56	50
Height of last whorl	200	96	53	31
Thickness of last whorl	185	108	?	37
Width of last whorl	150	67	45	35

No. 1. Large specimen collected at locality M64.

No. 2. Specimen of intermediate size collected at locality M63 just west of shaft on King-400 Claim.

No. 3. Measurements from plaster mold of internal whorls of large specimen (No. 1).

No. 4. Small specimen believed referable to the species, locality M63.

As shown on small mold, the sculpture up to a diameter of at least 100 mm. is pronounced and douvilleiceran in character. The costation and tuberculation, however, are more irregular, markedly coarser, tubercles more bulla-like and less numerous than in species of *Douvilleiceras* of the group of *D. mammillatum.* Unfortunately, the preservation of the specimen does not permit a count of the costae or tubercles, but on a small specimen believed referable to the species there are five to six tubercles on each rib. The sculpture is finer than in the genotype. The specimen of intermediate size, approximately 200 mm. in diameter, has reverted to the sculpture of the hoplitids showing only faint tuberculation on the flanks and venter. The large bulla-like tubercles of the umbilical margin, however, are still prominent at the ends of the primary costae. One to three secondary costae intervene between successive primaries. Sculpture of the large specimen is completely hoplitan in character; all suggestion of tuberculation has disappeared; prominent, smooth, primary costae encircle the whorls without interruption and are separated by only occasional secondaries indistinguishable from the primaries except in length.

The suture line (fig. 154), characterized by its long first lateral saddle and broad asymmetrical first lateral lobe, is of the douvilleiceran type. The ventral lobe is unusually broad and is shorter

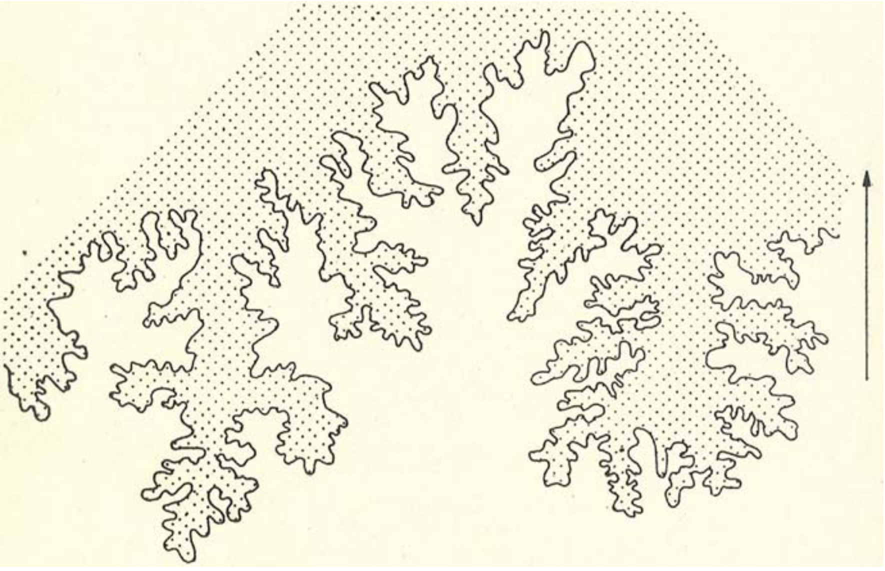

Fig. 154. Suture line of *Trinitoceras reesidei* Scott, n.sp. x1.

than the first lateral. The main branch of the first lateral lobe is long, and deeply and widely separated from the other branches. A second short and narrow lateral lobe lies on the umbilical margin.

Comparison with other species.—In shape and sculpture adult whorls of this species are indistinguishable from *Trinitoceras rex,* but the suture line and sculpture of the young whorls show important differences. In the young of *T. reesidei* the sculpture is much finer than in *T. rex.* In sculpture the young whorls of this species very closely approach *Douvilleiceras* of the group of *D. mammillatum* and to some it may appear preferable to consider the species a *Douvilleiceras* in which the adult whorls have reverted to the hoplitid sculpture. Even in young whorls, however, the costation and tuberculation are coarser than in species of *Douvilleiceras*, and thus accurate generic determinations can be made. The suture line is similar to that of *T. rex*, but the ventral lobe is shorter in comparison to the first lateral and is considerably broader than in *T. rex*. The main branch of the first lateral lobe is more widely and deeply separated from the other branches of the lobe than in *T. rex* or any species of *Douvilleiceras* known to the writer.

Occurrence.—Large adult specimen from locality M64 (U. S. Geological Survey locality 17439), center east line sec. 12, T. 28 S., R. 16 W., where fork of road lies on outcrop of Broken Jug formation. Three fragments of young whorls, one of which shows the sculpture and suture well, are also from this locality and are probably referable to the species. Specimen of intermediate size from locality M63 (U. S. Geological Survey locality 17364), N. W. 1/4 sec. 36, T. 27 S., R. 16 W., outcrop of Broken Jug formation just west of shaft of King-400 Claim.

Repository.—Cotypes in United States National Museum, Washington, D. C.; plaster casts (Nos. 1165, 1166, 1167, 1168) in Bureau of Economic Geology, Austin, Texas.

Family PARAHOPLITIDAE Spath (53, p. 112)

Genus DUFRENOYA Burckhardt (Kilian ms.)

1915. *Dufrenoyia* Kilian, Mém. Expl. Carte Géol. France, pp. 34, 35, 37; spelled *Dufrenoya*, pp. 178, 196, 198, 199, 203, 205, 207. (Name supposedly quoted from Burckhardt MS.)
1922. *Stenhoplites* Spath, Ammonoidea from Angola, p. 110.
1923. *Dufrenoyia* Spath. On the ammonite beds of the Gault and contiguous deposits, Mem. of Geol. Surv. p. 147.
1925. *Dufrenoya* Burckhardt, Inst. Geol. Mexico, Bol. 45, p. 15.
1930. *Dufrenoyia* Spath, On some Ammonoidea of the Lower Greensand, Ann. and Mag. Nat. Hist.. Ser. 10, Vol. V, p. 417.
1938. *Stenhoplites* Roman, Ammonites Jurassiques et Crétacées, p. 347.

Ammonites of this genus were assigned to a number of genera by a number of authors until 1907 when Jacob (28, pp. 354, 357) definitely placed them with *Parahoplites*. Jacob, however, noted that the group represented by *D. furcata* (Sowerby), *D. dufrenoyi* (d'Orbigny) and *D. luensis* (Kilian) was a little aberrant and did not fit well into the genus. Burckhardt traced the history of the study of the group and created the new generic name *Dufrenoya* for them. Before Burckhardt's work was in print Kilian published the name giving Burckhardt credit for it. Unfortunately, Kilian spelled the name two ways, but the spelling as it appears in Burckhardt's work has been generally accepted. After Kilian's paper appeared but before Burckhardt's work was published Spath suggested the name *Stenhoplites* but later abandoned it.

Species are characterized by quadrangular whorl sections, flat or nearly flat venters, and sharp, often faintly tuberculated ventrolateral margins. On early whorls costae are flexuous, rather far apart, branched or unbranched, and cross the venter with little or no attenuation. Whorls increase rapidly in height, slowly in width; umbilicus open and with low indistinct wall; suture-line parahoplitid in character.

Burckhardt gives a list of the known species.

Genotype.—*Dufrenoya dufrenoyi* (d'Orbigny).

DUFRENOYA JUSTINAE (Hill)

Pl. 60, figs. 7, 8; Pl. 62, fig. 9

1893. (June 3). *Acanthoceras justinae* Hill, Proc. Biol. Soc. Washington, Vol. VIII, p. 38, Pl. VII, figs. 1, 2. 3.

1893. (June 11). *Hoplites roemeri* Cragin, Geol. Surv. Texas, 4th Ann. Rept., p. 234, Pl. XLIV, figs. 4, 5.

1901. *Ammonites justinae* Hill, U. S. Geol. Surv., 21st Ann. Rept., Pt. 7, Pl. XXI, fig. 6.

1902. *Hoplites furcatus* Kilian, Bull. Soc. Géol. France, 4 ser., Vol. II, 1902.

1904. *Hoplites furcatus* Lasswitz, Kreide Ammoniten von Texas, p. 4, text fig. 1.

1925. *Dufrenoya justinae* Burckhardt, Inst. Geol. Mexico, Bol. 45, p. 17.

1925. *Dufrenoya texana* Burckhardt, Inst. Geol. Mexico, Bol. 45, p. 20 (in part), figs. 2, 3.

1926. *Parahoplites furcatus* var. *justinae* Scott, Études sur les terrains Crèt. du Texas, p. 119.

Ammonites here referred to this species have been figured by Hill, Cragin, and Lasswitz under three separate names. None of the descriptions makes reference to any of the others, although Lasswitz lists Hill's and Cragin's papers in his bibliography. All specimens studied by these authors are from the same locality, a locality from which the writer collected a great deal of material, and in his opinion it all belongs to the same species.[4] In addition to his own collection, the writer had before him material collected by Prof. F. L. Whitney, W. S. Adkins, and others, and a cast of Hill's type specimen. The specimen described by Cragin appears to be lost.

Burckhardt has described and figured casts of the Lasswitz specimen and has followed Lasswitz in considering it a separate species, but it is doubtful if Burckhardt realized that the original of the casts came from the same general locality as Hill's and Cragin's specimens,[5] and the few characters by which the supposed species are said to differ do not appear to be significant. The specimens are all internal molds and poorly preserved, but the essential characters are well shown on much of the available material. The cast of Hill's holotype and a specimen from the writer's collection have the following measurements in millimeters:

	Cast of Holotype	Specimen
Diameter	110	76.5
Greater radius	67	50
Lesser radius	43	26.5
Height of last whorl	44	35
Height of penultimate whorl	23	?
Thickness of last whorl	20	20
Thickness of penultimate whorl	10	?
Width of umbilicus	35	25
Suture taken at diameter of	?	65

Description.—Species thinly discoid with nearly flat flanks and flattened venter that becomes slightly rounded on older whorls; umbilicus medium-sized, with low, sloping wall, whorls grow slowly in width, rapidly in height. Sculpture consists of more or less regularly alternating primary and secondary costae, and faint

[4] In a personal letter Dr. T. W. Stanton made the following statement: "The two names, *Acanthoceras justinae* Hill and *Hoplites roemeri* Cragin, were in my opinion, both applied to the same species, and the types come from the same locality. I have here Hill's type and a few fragmentary specimens from the type locality which show the essential characters in a better state of preservation. I have no doubt that these belong to the same species as Lasswitz's fragment which Professor Kilian identified as *Parahoplites furcatus*."

[5] Burckhardt (9, p. 18) refers *Acanthoceras hoplitoides* Lasswitz (p. 19 Pl. III, fig. 3a, 3b) to *Dufrenoya*. The specimen, however, according to Lasswitz, came from Shoal Creek near Austin, in which case it could not possibly be from the Trinity strata or a member of the genus *Dufrenoya*. The strata exposed along Shoal Creek are of Washita age and later. It appears probable that the specimen is an Eagle Ford species. In any case the flanks of the specimen bulge far too much for a species of *Dufrenoya*. Adkins (2 pp. 399-400) refers the species to *Mantelliceras*.

ventro-lateral tubercles. All costae cross the venter with equal prominence, but secondaries fade away near the middle of the flanks; primaries continue to the line of involution in the umbilicus. The ventro-lateral tubercles are a little elongated spirally. Suture (fig. 155) well shown on a number of specimens, and is characterized by its short ventral lobe and large, tripartite first lateral lobe.

Comparison with other species.—*Dufrenoya justinae* has long been known to be very similar to *D. dufrenoyi* (Sowerby) and *D. furcata* (d'Orbigny) from the upper Aptian of western Europe, and it is on the basis of these fossils that an Aptian age has been assigned to the Travis Peak beds of the Colorado River valley. In the basalmost, hard, crystalline ledge of the Cuchillo formation a single representative of the species was recovered. It is preserved in coarsely crystalline limestone, but all characters, including the suture line, were easily recognizable before the specimen was

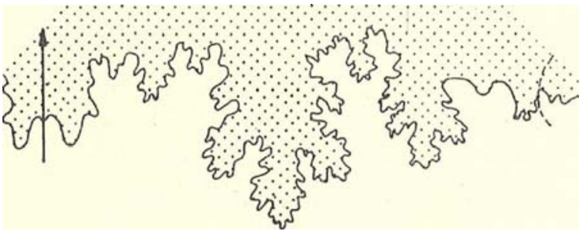

Fig. 155. Suture line of *Dufrenoya justinae* (Hill). x1.

removed, but in removal the rock crumbled badly. The essential features, however, are still evident. This is the only representative of the genus reported from the Trans-Pecos area of Texas, and it suggests a Travis Peak age for the lowest Cuchillo.

Occurrence.—Cow Creek beds of the Travis Peak formation and lowest stratum of Cuchillo formation, at localities M6, M45, and neighboring localities. Hill's type specimen is said to have been collected in front of old Travis Peak post office. The question has been raised as to whether the specimen could have been collected there in place since the post office is somewhat above the beds outcropping in the bed of Cow Creek. It has been suggested that Hill's holotype might have been transported there.

The specimen from the Quitman Mountains was collected at a point where the Rio Grande enters the upper Quitman gorge. This level is 930 feet below the zone of *Sonneratia* and 2300 feet below the zone of *Douvilleiceras.*

Repository.—Topotypes (Nos. 1122, 1123, and plaster cast of holotype 1125) and specimen from Quitman Mountains (No. 1126) in the Bureau of Economic Geology, Austin, Texas. Holotype in the Johns Hopkins University, Baltimore, Maryland; specimen described by Cragin could not be found; individual referred to *D. furcata* by Lasswitz at Breslau, Germany.

DUFRENOYA ROBUSTA Scott, n.sp.

Pl. 63, figs. 8. 9

In the collection of cephalopods made by Professor Whitney, there is an interesting fragment from the Travis Peak beds on Pedernales River. The specimen is poor but is so different from any other ammonite known to the writer and its characters are so distinctive that it is given a new name.

Description.—Internal mold thickly discoid with low, wide whorls, quadrangular in cross section; flanks and venter flat or only slightly bulged; whorls only slightly embracing with wide, shallow umbilicus, the wall of which is low and gently rounded on the margin. Whorls increase in width as rapidly as in height. The holotype has the following dimensions in millimeters:

Diameter	30
Height of last whorl	12
Thickness of last whorl	13
Width of umbilicus	10.5

Sculpture consists of primary and secondary costae of a striking character. Primaries and secondaries usually alternate, but various irregularities in this arrangement are shown; primaries traverse the circumference of the whorl, from whorl suture to whorl suture. Even on the broad, flat venter, they are more prominent than the secondaries which arise at various levels on the flanks or split off from the primaries. All costae are peculiar in their unusual height, their vertical sides and flat tops, and these characters are especially marked on the ventral region where the costae and their interspaces are about equal in width. Only the broad outlines of the suture line can be seen where the specimen is broken. There is a long ventral lobe, a trifid first lateral lobe as long as the ventral lobe, and a short, narrow second lateral near the umbilicus. First lateral saddle broad and long, and asymmetrically divided by a pronounced secondary lobe; secondary lateral saddle, narrow and relatively shallow.

Comparison with other species.—By all of its characters this species is unquestionably referred to the genus *Dufrenoya* but it is easily distinguished from any other known species of the genus by its unusually broad whorls in proportion to their height, and its high, narrow, straight-sided costae.

Occurrence.—Travis Peak formation, locality M18.

DUFRENOYA COMALENSIS Scott, n.sp.

Pl. 60, figs. 4, 5

Only one specimen of this species has been collected by Professor F. L. Whitney. It is fragmentary and preserved as a chalky limestone internal mold somewhat eroded.

Description.—Internal mold thinly discoid and only moderately evolute; whorls high, narrow, and subrectangular in cross section; flanks almost flat, venter narrow and flattened; whorls increase rapidly in height, but slowly in thickness; umbilicus moderately broad with a gently rounded wall. The specimen has the following dimensions in millimeters:

Diameter	35.5
Greater radius	22
Lesser radius	13.5
Height of last whorl	15.5
Width of umbilicus	12

Sculpture consists of irregularly arranged, almost straight, primary and secondary costae, with usually one or two secondaries between the primaries. On the venter all costae are about equal in prominence and in profile stand out like the cogs on a wheel. On the flanks secondary costae fade away at various levels or anastomose with primaries. Primary costae lose some of their prominence on the middle of the flanks, but regain it toward the umbilicus and end abruptly at the umbilical margin. All costae are considerably narrower than the interspaces between them. The suture line is not shown.

Comparison with other species.—In shape and general characters *D. comalensis* is very similar to *D. justinae* and related species, but its whorl section is much thinner. Costae are much straighter than in any other species of the genus yet described, and their unusual prominence across the narrow venter is a striking character.

Occurrence.—Locality M19. It is impossible at present to say whether the specimen came from the lower Glen Rose or from the uppermost Travis Peak, but it is probably from the lower Glen Rose.

DUFRENOYA aff. D. DUFRENOYI (d'Orb.) Burckhardt

Pl. 61, figs. 7, 8; Pl. 62, figs. 3, 4

1925. *Dufrenoya* aff. *dufrenoyi* Burckhardt, Inst. Geol. Mexico, Bol. 45, p. 18, Lam. X, figs. 1-4, 7-9.

Two specimens referred to this species were recovered from a deep well in Webster Parish, Louisiana. They were broken from a black shale core by Roy T. Hazzard and forwarded to the writer for study. Both specimens are jet black shale casts of living chambers with only a little of the septate portions preserved.

Description.—Species thinly discoid with nearly flat flanks; venter flat and narrow; umbilicus medium-sized with low vertical wall; umbilical margin rounded; whorls grow slowly in width, rapidly in height.

The following measurements, in millimeters, give an idea of the size and proportions of the specimens:

Diameter	36	65
Greater radius	20	38.7
Lesser radius	15.5	26.3
Height of last whorl	15	27.6
Thickness of last whorl	10.3	18.7
Width of umbilicus	11.3	21.5

Sculpture consists of flexuous, more or less regularly alternating primary and secondary costae which have small tubercles on the ventro-lateral margins. All costae are greatly attenuated, or even interrupted, in crossing the venter. Primary costae terminate at the umbilical margin, but the secondaries fade away or anastomose with primaries just dorsal to the middle of the flanks. On the larger specimen two primary costae may occur between successive secondaries, and there are intervening fine striae of growth shown on the larger specimen. The ventro-lateral tubercles are small, pointed, and a little elongated spirally. Only a part of the suture is shown on the small specimen where the shell is broken off at the last septum. It is too indefinite to be outlined.

Comparison with other species.—The specimens here described do not differ in any appreciable way from d'Orbigny's type, and are very close to specimens from Mexico referred to the species by Burckhardt. They differ slightly from the Mexican material in the greater attenuation of the costae across the venter, the finer and more regular costation, in the more pronounced ventro-lateral tubercles, and in the somewhat wider umbilicus. The costae on the venter of numerous specimens of *D. justinae* (Hill) are much more prominent than in these specimens, and *D. furcata* (Sowerby) has a much more robust sculpture.

The Louisiana specimens may be a new species, but they are very close to *D. dufrenoyi* and since there is no possibility of getting additional material from the same locality they are not given a new name.

Occurrence.—Two specimens are from the Standard Oil Fudicker No. 1 well designated as locality M58, in Webster Parish, Louisiana. They were broken from a core taken at a depth of 6202–06 feet. The stratigraphic level is referred to as the lower part of the lower Glen Rose. Indeterminate specimens of *Dufrenoya,* probably belonging to the same species, were taken from cores at a similar level in the Haynes Production Company Murff No. 1 well (locality M59) Bossier Parish, at a depth of 5082–5102 feet.

Genus PARAHOPLITES Anthula, emend. Jacob, emend. Spath

1900. *Parahoplites* Anthula, Ueber die Kreidefossilien des Kaukasus, Beitr. Pal. Geol. Oest.—Ung. und des Orients, Vol. XII, p. 55.
1905. *Parahoplites* Jacob, Bull. Soc. Géol. France, 4me ser., vol. 5, p. 406.
1907. *Parahoplites* Jacob, Mém. Soc. Géol. France, tome 5, fasc. 3 et 4, p. 48.
1908. *Parahoplites* Jacob, Études partie moyenne des terrains Crétacé, p. 368.
1907. *Parahoplites* Pervinquière, Carte Géol. de la Tunisie, p. 188.
1913. *Parahoplites* Kilian, Lethaea Geognostica, Unterenkreide, p. 344.
1915. *Parahoplites* Kilian and Reboul (emend.), Mem. Expl. Carte Géol. France, p. 36.
1925. *Parahoplites* Spath, Ammonoidea of the Gault, p. 75 and following.
1938. *Parahoplites* Roman, Ammonites Jurassiques et Crétacées, p. 346.

This genus was proposed by Anthula for a heterogeneous group of ammonites now included in several genera. Jacob believed that one of these groups was closely related to *Douvilleiceras* and he referred them to that genus. This group now falls in the genus *Acanthohoplites* Sinzow and, according to Spath (56, p. 64), is probably not very closely related to *Douvilleiceras.*

More recently Burckhardt (9, p. 15) and Spath (53, p. 110) have separated, under the name of *Dufrenoya,* another group characterized by flat venters and flexuous, irregularly alternating costae. Meanwhile, Burckhardt referred some indeterminate species to *Parahoplites.*

Kilian and Reboul (34, p. 36) emended Anthula's genus and restricted it to include three groups of ammonites represented respectively by: (a) *Parahoplites melchioris* Anthula, characteristic of the lower Gault; (b) *Parahoplites campichei* Pictet; and (c) *Parahoplites hitzeli* Jacob, *P. steinmanni* Jacob, *P. borowae* Uhlig. The group of *P. campichei* now falls into the genus *Hypacanthoplites* Spath (56, p. 64), while those of the third group are variously partitioned according to different authors. The genus *Parahoplites* is thus restricted to the first group of Kilian and Reboul; that is, the group of *Parahoplites melchioris,* and most of the species indicate an early or middle Albian age.

As now interpreted *Parahoplites* includes relatively thin, discoid ammonites with a medium-sized umbilicus. The costae may be straight or flexuous, and regularly or irregularly bifurcate. All costae cross the venter without interruption. The most distinctive feature of the suture is the pointed, trifid first lateral lobe which is usually a little longer than the ventral lobe.

In the restricted sense, it appears that relatively few species of ammonites fall into the genus *Parahoplites,* although Anderson (4, pp. 169–170, pls. 33, 34, 35, 36, 73) has recently described a beautiful suite of species which he refers to the genus. The California species are all stratigraphically older than Texas species considered here.

Genotype.—Parahoplites melchioris Anthula.

PARAHOPLITES UMBILICOSTATUS Scott, n.sp.

Pl. 62, fig. 8; Pl. 63, fig. 10

This species is abundant in the southern Quitman Mountains but all specimens are so badly crushed and broken that it is impossible to take accurate measurements of them. The mineralized shell material is filled with soft shale which does not preserve the septa or suture patterns.

Description.—Whorls high and thin with flattened venters, giving a thinly discoid outline to the shell; umbilicus moderately broad and bordered by low perpendicular walls: umbilical margin narrowly rounded. Sculpture consists of numerous, low, rounded to subflattened primary and secondary costae, all of which cross the venter without interruption. Primary costae arise at the umbilical suture and completely encircle the whorls, especially prominent on umbilical walls and about the umbilical border, fade in prominence near the middle of the flanks to become important again on ventral area of the shell. Primary costae separated on ventral area by one to three secondaries which fade out or anastomose with primaries high along the flanks. Near the middle of the flanks all costae are gently flexed posteriorly; all are a little steeper on their anterior than on their posterior sides. The suture is not shown on any of the specimens.

Comparison with other species.—By the prominence of the costae on the umbilical wall *P. umbilicostatus* is easily distinguished from any species known to the writer. The several indeterminate specimens from rocks of Trinity age in Mexico described by Burckhardt (9) do not appear to include examples similar to it.

Occurrence.—Blue marls of Cuchillo formation, locality M1.

PARAHOPLITES WINTONI Scott, n.sp.

Pl. 64, fig. 2; Pl. 67, fig. 8

The holotype of this species is very badly crushed and only approximate measurements could be taken. A number of other poorly preserved fragments in the collection possibly belong to the same species. All specimens are internal molds and are septate throughout.

Description.—Holotype thickly discoid in outline with subquadrangular whorl section; venter broadly rounded or sub-flattened; umbilicus broad, with low, gently inclined wall which gradually rounds into the flank; whorls grow rapidly in height, slowly in thickness. The holotype has the following dimensions in millimeters:

Diameter	140
Greater radius	80
Lesser radius	60
Height of last whorl	75
Thickness of last whorl	37
Width of umbilicus	50
Suture taken at diameter of	140

Sculpture consists of numerous, low rounded costae which arise on the umbilical wall at the whorl suture. Near the middle of the flanks these bifurcate and the branches traverse the venter without attenuation. This feature, although occurring at varying heights on the flank, otherwise appears to be absolutely regular and is the most distinctive character of the species. Details of the suture on the ventral area of the shell have been destroyed, but the general

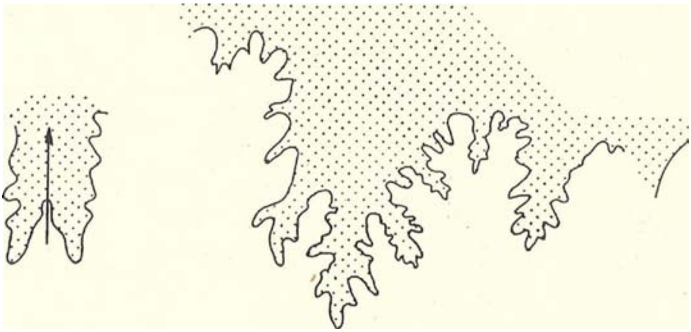

Fig. 156. Suture line of *Parahoplites wintoni* Scott, n.sp. x1.

outline can be traced. The first lateral lobe is characteristically tripartite and somewhat longer than the ventral lobe. A second lateral lobe lies near the umbilicus (fig. 156).

Comparison with other species.—*Parahoplites wintoni* is easily distinguished from other known species by its regularly bifurcate costae, instead of alternate primary and secondary costae as found in most species of the genus.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

PARAHOPLITES THOMASI Scott, n.sp.

Pl. 64, fig. 1

This new species is represented in the collection from the Quitman Mountains by a single poor specimen, but the specific characters are so well shown that its description seems justified. It is assigned to *Parahoplites* since it is closer to that genus than to any other, but it is possible that a new genus may be created for it when better material is available for study. The name is given in honor of N. L. Thomas, who has helped the writer collect in the Quitman area.

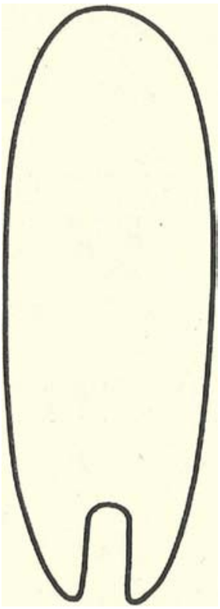

Fig. 157. Sketch showing whorl section of *Parahoplites thomasi* Scott, n.sp. x1.

Description.—The fragment is from a thinly discoid ammonite with a high, thin, sub-quadrangular whorl section (fig. 157). Flanks bulge slightly, venter broadly rounded; whorl section thinnest near the umbilicus; umbilical wall low and indistinct. Only the following measurements, in millimeters, could be taken:

Length of fragment	140
Height of last whorl	78

Whorl sculptured by numerous fine, low, rounded primary and secondary costae, equal in importance except in numbers and in length; primaries pass without interruption or attenuation from line of involution to line of involution, and are much more numerous than the secondaries, often as many as three of them being adjacent; secondaries arise at various levels on the flanks and traverse the venter. There are no tubercles. The suture (fig. 158) is the most distinctive feature of the species. The number and dis-

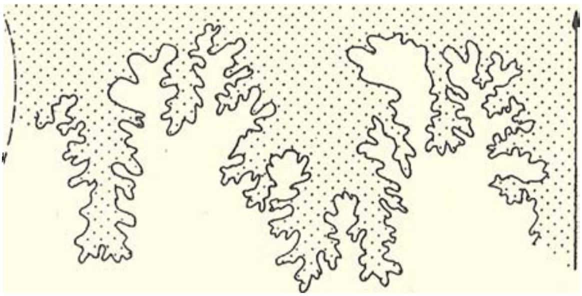

Fig. 158. Suture line of *Parahoplites thomasi* Scott, n.sp. x1.

position of the lobes and saddles is as in *Parahoplites*, but the shape of these elements is markedly different from any known species of the genus. Only a part of the ventral lobe is shown; first lateral lobe long and trifid, but the dorsal branch of this element is unusually long, while the ventral branch is correspondingly short, giving a rectangular outline to the lobe; second lateral lobe almost as long as the first, but is thin and denticulate, and not strongly divided.

Comparison with other species.—If this form is correctly referred to *Parahoplites* it must be regarded as a somewhat aberrant species. It is similar in shape and general appearance to *P. wintoni*, but is easily distinguished from that and all other species by the irregularity of its costation, and by its unusual suture.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

PARAHOPLITES?, sp. ind.

Pl. 61, figs. 5, 6

A single poor specimen found low in the Cuchillo formation is referred with some doubt to *Parahoplites*. It is figured and described here because it is so obviously different from any other ammonite yet found in these strata.

Description.—The fragment is from a thinly discoid ammonite with flattened flanks and gently rounded venter; whorls grow rapidly in height, slowly in thickness, the thickest part being near the umbilicus. The following measurements, in millimeters, give an idea of the size of the fragment:

Length of fragment	55
Height of last whorl	36
Thickness of last whorl	16

Sculpture consists of coarse, widely spaced primary and secondary costae which cross the venter with equal prominence and without attenuation; primaries are prominent to the umbilical wall, but the alternate secondaries fade away near the middle of the flanks. The fragment appears to be a part of the living chamber; at least no suture pattern is shown.

Comparison with other species.—With only a poor fragment at hand it is impossible to say that this form is a new species. It is referred to *Parahoplites*, but its coarse ribbing suggests that it may be a *Dufrenoya.*

Occurrence.—Cuchillo formation in the zone of *Sonneratia*, locality M6, midway down the first gorge of the canyon on the Texas side of the Rio Grande.

Genus RHYTIDOPLITES Scott, n.gen.[6]

The species which fall into this new genus are unquestionably parahoplitids as shown from the shape and coiling of the shells, and the suture lines. The sculpture, however, is distinctive and different from other species referred to genera of the family as these genera are now interpreted.

By way of definition, the genus may be said to include those parahoplitids characterized by costae occurring in bundles. In

[6]Rhytidodes, meaning wrinkled, particularly wrinkled belly

specimens at hand, primary costae arise prominently on the umbilical margin, gradually decrease in importance ventrally on the flanks and split distinctly into secondaries, or have bundles of secondaries arising between them on the flanks. All costae traverse the venter without attenuation. The costation of *Rhytidoplites* resembles somewhat that found on species of the genus *Cleoniceras,* but the shape of the shell is entirely different. In *Cleoniceras* the whorls are less quadrangular and grow more rapidly in height than in *Rhytidoplites.* In *Cleoniceras* the venter tends to be sharpened, whereas in *Rhytidoplites* it is broadly rounded or subflattened.

It appears probable that *Hoplites nolani* Seunes (50, p. 564, Pl. XIII, fig. 4a–b) should fall into this genus. According to Spath's zonation (56, p. 4), however, it would appear that this species is considerably lower in the section than either of the species described here.

Genotype.—*Rhytidoplites robertsi* Scott, n.sp.

RHYTIDOPLITES ROBERTSI Scott, n.sp.

Pl. 61, fig. 11; Pl. 63, fig. 7

A single specimen of this species was collected in the writer's presence by Mr. Morgan Roberts. It is an internal mold to which only small bits of the shell adhere, is slightly crushed, and much of the venter has been eroded away.

Description.—Shell discoid with sub-rectangular whorls that grow rapidly in height, slowly in thickness; whorls thickest near the umbilical border, flanks flat converging slightly toward the almost flat venter; umbilicus relatively broad and shallow, with an almost perpendicular wall, the margin of which is rounded. The holotype has the following dimensions in millimeters:

Diameter	63
Greater radius	39
Lesser radius	24
Height of last whorl	30
Height of penultimate whorl	13
Thickness of last whorl	17
Thickness of penultimate whorl	9
Width of umbilicus	17
Suture taken at diameter of	51

Sculpture consists of numerous low, narrow, rounded primary and secondary costae, three or four secondary costae intercalated between successive primaries; primaries arise on umbilical wall, and on umbilical margin and dorsal area of flanks assume the prominence of greatly elongated tubercles, decrease in prominence ventrally. Near the middle of the flanks they flex gently posteriorly and cross the venter without interruption. Secondaries arise ventrad of the middle area of the flanks, assume prominence quickly, and on the venter are indistinguishable from the primaries. The ventral lobe of the suture line could not be delineated, but the other elements are well shown (fig. 159). First lateral lobe

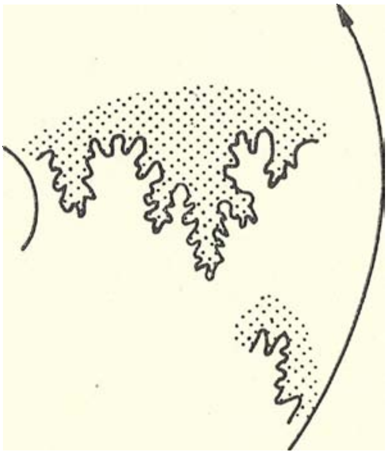

Fig. 159. Suture line of *Rhytidoplites robertsi* Scott, n. sp. x2.

characteristically pointed and almost symmetrically trifid; second lateral lobe low and narrow. A part of the living chamber is preserved.

Comparison with other species.—By its sculpture and shape, *R. robertsi* is easily distinguished from any of the species of the family to which it belongs. Superficially its sculpture closely resembles that of species of *Cleoniceras*, but by its shape it is easily distinguished from species of that genus.

Occurrence.—Blue marls of the Cuchillo formation, locality M1; top of small rounded knoll at the confluence of Mayfield Canyon and the Rio Grande. A poor specimen has also been recovered from a deep well in Louisiana (locality M60).

RHYTIDOPLITES FASCICULATUS Scott, n.sp.

Pl. 61, figs. 3, 4

This species is represented by one good specimen and several fragments.

Description.—Shell thinly discoid with sub-rectangular whorl section; widest part of whorl near umbilical margin from where the flanks, slightly bulged, gently converge ventrally; venter broadly rounded; umbilicus relatively broad and deep, and bounded by a perpendicular wall. The principal measurements of the holotype, in millimeters, are as follows:

Length of whorl fragment	55
Height of whorl	23
Thickness of whorl	15
Width of umbilicus	18

Sculpture consists of bundles of fine, low, rounded costae which arise on the umbilical margin from prominent, radially elongated tubercles or prominent ribs. Each tubercle quickly gives rise to three to five of the fine costae which diverge toward the ventral area of the shell and cross the venter without interruption. The ventral lobe of the suture line (fig. 160) is shorter than the first lateral and is narrow with sub-parallel sides; first lateral lobe strikingly long and narrow, a little asymmetrically trifid and pointed; second lateral lobe short and narrow; first and second lateral saddles broad.

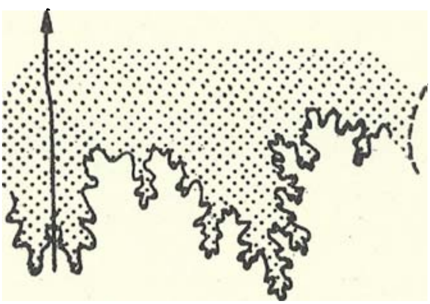

Fig. 160. Suture line of *Rhytidoplites fasciculatus* Scott, n.sp. x2.

Comparison with other species.—*Rhytidoplites fasciculatus* most closely resembles *R. robertsi*, but is easily distinguished by its more bulging flanks, the more definite grouping of its costae, and the long, slender, pointed first lateral lobe of its suture line. It is also similar in general aspect to *Hoplites nolani* Seunes (50, p. 564, Pl. XIII, figs. 4a–b), but the umbilical tubercles are more widely spaced and are more prominent than in that species.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

Genus HYPACANTHOPLITES Spath

1928. *Hypacanthoplites* Spath, Ammonoidea of the Gault, p. 64.

This genus was created by Spath for ammonites of the group of *Ammonites milletianus* d'Orbigny, and includes a group of lower and middle Albian species characterized by moderately evolute, subquadrangular whorl sections, flat venters and relatively flat flanks. They carry numerous primary and secondary costae. The primaries differ from the secondaries chiefly in that the secondaries do not reach the umbilicus. All costae cross the center without interruption.

Genotype.—*Hypacanthoplites milletianus* (d'Orbigny).

HYPACANTHOPLITES SELLARDSI Scott, n.sp.

Pl. 62, figs. 1, 2

This species occurs in considerable abundance in the outcrop of the blue marls and limestones of the Cuchillo formation at Quitman Summit in Hudspeth County. Most of the specimens collected are poorly preserved, but a few indicate the characters of the species. All are internal molds preserved in coarsely crystalline calcite.

Description.—Species thickly discoid with sub-flattened venter and perpendicular, almost flat flanks; shell moderately evolute with wide, shallow umbilicus; umbilical wall low with slightly rounded margin; whorls sub-quadrangular in cross section, increasing rapidly in height, but slowly in thickness. The measurements of the holotype, in millimeters, are as follows:

Diameter	58
Greater radius	34
Lesser radius	24
Height of last whorl	25

Height of penultimate whorl	14
Thickness of last whorl	17
Thickness of penultimate whorl	10
Width of umbilicus	17
Suture taken at diameter of	50

Whorls provided with low, sharp-topped costae about half as wide as the interspaces between them. Costae incline slightly forward in approaching the venter and cross the venter without interruption or attenuation. On the ventro-lateral margins the costae bear indistinct tubercles. Costae are almost equal in importance on the lower half of the whorl, but the secondaries which alternate irregularly with the primaries disappear before reaching the umbilical margin. Primaries end at umbilical margin in relatively prominent, radially elongated tubercles. Suture line (fig. 161) has a short ventral lobe, a long broad first lateral saddle and a

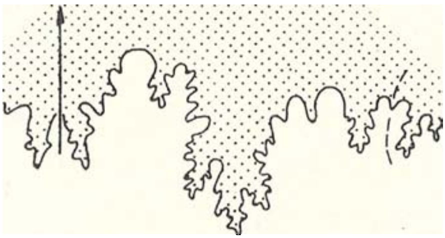

Fig. 161. Suture line of *Hypacanthoplites sellardsi* Scott, n.sp. x2.

long, asymmetrically trifid first lateral lobe; second lateral lobe lies near the umbilical margin and a third is on the umbilical wall. Second lateral saddle broad and almost as long as the first lateral.

Comparison with other species.—Small specimens in the collection are very similar to specimens of *H. milletianus* d'Orbigny collected by the writer from the famous locality at La Balme de Rencurel in southeastern France, but the venter is broad and the whorls are higher and somewhat less inflated. On the other hand, the species is more inflated, less coarsely ribbed and more evolute than species of the family belonging to the genera *Parahoplites* and *Deshayesites,* and the suture does not have the short lateral saddle characteristic of these genera.

Occurrence.—All specimens from a horizon low in the blue marls and limestones of the Cuchillo formation. The best and most numerous examples are from locality M2, others from M1.

HYPACANTHOPLITES QUITMANENSIS Scott, n.sp.

Pl. 62, fig. 7; Pl. 65, fig. 6

This description is based upon a large ammonite which conforms well to characters outlined for the genus *Hypacanthoplites*. The fossil is a badly corroded internal mold and all features are poorly shown. Parts of the suture line were traced, but careful preparation failed to produce a complete pattern in the coarsely crystalline material. In the collection are three other fragments, two of which fit together and were collected only a few feet from the large specimen. It is possible that they are part of it, although they do not fit into any of the broken ends.

Description.—Species thickly discoid with flattened venter and broad, flat flanks, ventro-lateral angles are sharply rounded; umbilicus broad and deep with perpendicular wall, the margin of which is broadly rounded; whorls sub-quadrate, increasing slowly in thickness, rapidly in height. Measurements of the holotype, in millimeters, are:

Diameter	340
Greater radius	200
Lesser radius	140
Height of last whorl	145
Thickness of last whorl	95
Thickness of penultimate whorl	41
Width of umbilicus	98
Suture taken at diameter of	170

Whorls bear primary and secondary costae which usually alternate, but two or more secondary ribs may be intercalated between primaries; all costae equal in prominence except that the secondaries fade out or unite with primaries before reaching the umbilicus; primary costae end at umbilical margin by slightly raised, unequally prominent tubercles which are greatly elongated radially; all costae cross the broad, almost flat venter without interruption or attenuation. Most of the elements of the suture line (fig. 162) can be deciphered, but no one pattern could be outlined. First lateral lobe a little shorter than the ventral, broad and asymmetrically trifid; third lobe poorly shown but much shorter than first lateral; first lateral saddle broad and considerably longer than second lateral. All sutural elements are extremely denticulate, but deep corrosion of the shell has retracted or eliminated many of the small secondary elements. The suture line shown is from a fragment. The large specimen is septate throughout.

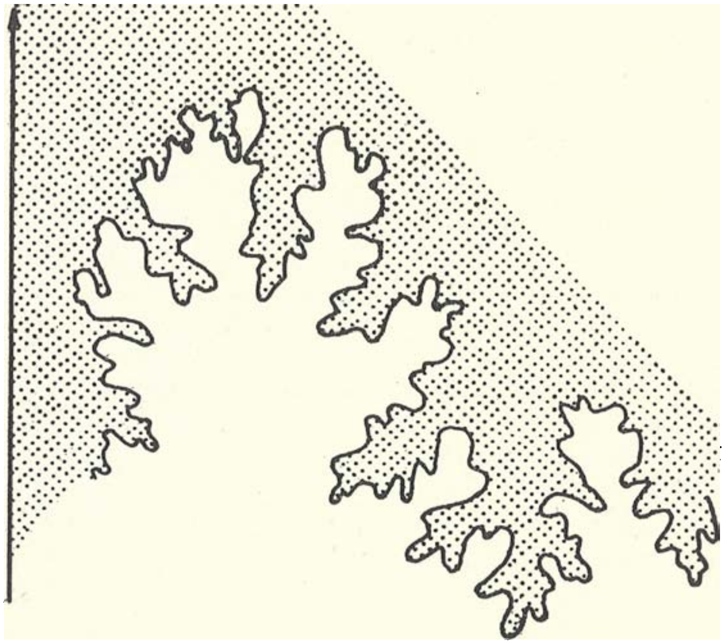

Fig. 162. Suture line of *Hypacanthoplites quitmanensis* Scott, n.sp. x1.

Comparison with other species.—No other species of *Hypacanthoplites* approaches *H. quitmanensis* in size and comparisons are therefore difficult. The markedly flat venter and flanks, the subquadrate whorl section and large size of the species serve to distinguish it easily from any other species of the genus yet described.

Occurrence.—Limestone ledge low in the blue marls and limestones of the Cuchillo formation, locality M2. The clear impression of the large specimen may be seen in a vertical limestone ledge about 100 feet south of the road.

HYPACANTHOPLITES BAKERI Scott, n.sp.

Pl. 65, figs. 3, 4

A number of fragments representing this species were collected by the writer but the holotype is a beautiful specimen collected by Messrs. Adkins, Baker, and Arick. The specimen retains most of the shell material thoroughly impregnated with carbonaceous material. The specimen is slightly crushed and part of the shell was removed to prepare the suture.

Description.—Shell thickly discoid with flattened venter and broad, nearly flat flanks; ventro-lateral angles broadly rounded and show no tubercles; umbilicus broad and relatively shallow; the umbilical wall sub-perpendicular with a broadly rounded margin. The sub-quadrate whorls increase slowly in thickness but rapidly in height. The holotype has the following measurements in millimeters:

Diameter	73
Greater radius	49
Lesser radius	24
Height of last whorl	33
Height of penultimate whorl	20
Thickness of last whorl	20
Thickness of penultimate whorl	18
Width of umbilicus	18
Suture taken at diameter of	70

Whorls bear about forty-two primary and secondary narrow and rounded costae which are equal in prominence but differ in length; all lean forward and cross the venter without interruption or attenuation; primary costae originate on the umbilical wall, while secondaries originate separately or split off from primaries near the middle of the flanks. No tubercles are shown. The suture line (fig. 163) is the most distinctive feature of the species. It is characterized by its unusually broad and short elements. First lateral lobe broadly trifid and longer than the ventral lobe, second lateral lobe lies near the dorsal area of the flank and a third is on the umbilical wall. Both are short and separated by broad short saddles.

Comparison with other species.—This species is very similar to *H. sellardsi*, but its venter is more rounded and its costae are broader and more rounded. The principal distinction, however, is in the suture. In *H. sellardsi* the elements are long and correspondingly narrow, while in *H. bakeri* they are short and broad.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

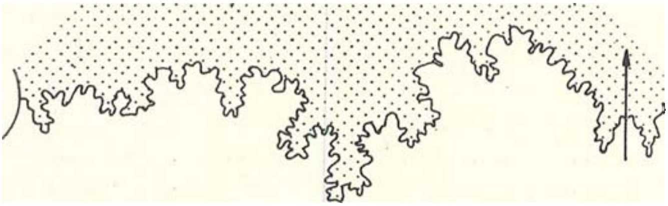

Fig. 163. Suture line of *Hypacanthoplites bakeri* Scott, n.sp. x2.

HYPACANTHOPLITES MAYFIELDENSIS Scott, n.sp.

Pl. 63, figs. 3, 4, 5, 6

This description is based on one fair specimen collected by Messrs. Adkins, Arick, and Baker, but there are a number of fragments in the collection. All specimens are internal molds and badly crushed and corroded.

Description.—Species discoid with high, thin whorls, which, however, do not increase in height very rapidly; venter broadly rounded, almost flat; umbilicus unusually broad, for a species of the genus; umbilical wall low, at an angle to the plane of coiling, and with broadly rounded margin. The holotype has the following dimensions in millimeters:

Diameter	126
Greater radius	73
Lesser radius	53
Height of last whorl	59
Thickness of last whorl	27
Width of umbilicus	48
Suture taken at diameter of	98

Sculpture consists of numerous prominent, rounded costae separated by interspaces a little wider than the costae. All costae are almost straight and cross the venter without attenuation; primary costae arise on umbilical wall and completely encircle the whorl.

Occasionally primaries are adjacent, but usually are separated by one or more secondaries which fade out or anastomose with the primaries at various levels on the flanks; all are of equal importance on the ventral region of the shell. Holotype entirely septate, but erosion has so destroyed the details of the suture lines that only major features are preserved (fig. 164). Ventral lobe long; first lateral lobe shorter than the ventral, asymmetrically trifid and leans dorsally; short second and third lateral lobes lie

Fig. 164. Suture line of *Hypacanthoplites mayfieldensis* Scott, n. sp., taken from the Quitman Mountains holotype. x2.

near the umbilical margin and on the umbilical wall; first lateral saddle long and broad; second lateral saddle likewise broad, but shorter than the first lateral.

Comparison with other species.—In the irregularity of its costation the species is like *Parahoplites* and its venter is more rounded than in typical species of *Hypacanthoplites.* In the general shape of the whorls, and in its suture, however, it is like *Hypacanthoplites.* It is easily distinguished from any other species of the genus by its more rounded venter; its slow growing whorls, and its broad, shallow umbilicus.

Occurrence.—Blue marls of the Cuchillo formation, and the Glen Rose formation. Holotype, locality M1; one specimen collected from the "key rock" of the lower Glen Rose at locality M21 by Professor F. L. Whitney.

HYPACANTHOPLITES RUGOSUS Scott, n.sp.

Pl. 63, figs. 1, 2

The single specimen of this species is a fragmentary mold preserved in soft, chalky limestone, and was collected by Professor F. L. Whitney.

Description.—The species, like *H. mayfieldensis*, is discoid with high, thin, evolute whorls, venter broadly rounded; umbilicus broad and bordered by gently sloping umbilical wall. The measurements of the holotype, in millimeters, are as follows:

Diameter	120
Greater radius	69
Lesser radius	57
Height of last whorl	45
Thickness of last whorl	26
Width of umbilicus	43

Sculpture consists of broad heavy, widely spaced primary and secondary costae; primaries begin at the line of involution and increase in prominence ventrad where they cross the broadly rounded venter. Usually two primary costae are followed by one secondary; secondaries arise near the middle of the flanks and become as prominent as the primaries on the venter. The suture line is nowhere shown on the soft chalky material of the cast.

Comparison with other species.—In general outline and dimensions this species is very similar to *H. mayfieldensis*. The chief difference is found in the costation. In *H. rugosus* the costae are much broader and higher and are more widely spaced than in *H. mayfieldensis*.

Occurrence.—Lower Glen Rose, locality M22.

HYPACANTHOPLITES CRAGINI Scott, n.sp.

Pl. 62, figs. 5, 6

The holotype and only specimen was collected by Professor F. L. Whitney and is a mold preserved in fine-grained, chalky limestone. A large part of the living chamber, about three-quarters of a whorl in length, is preserved.

Description.—Cast discoid with high, moderately thick whorls, thickest part of the whorl being near the venter; flanks flat, and converging ventrally; venter broadly rounded; umbilicus moderately broad and deep; umbilical wall perpendicular with broadly rounded margin. The specimen has the following measurements in millimeters:

Diameter	36.2
Greater radius	21.3
Lesser radius	14.9
Height of last whorl	15.3
Thickness of last whorl	13.8
Width of umbilicus	10.5
Suture taken at diameter of	20.0

Sculpture consists of umbilical tubercles and prominent primary and secondary costae, one or two secondaries being intercalated between primaries; all costae relatively straight on the flanks, but bend forward to cross the venter without attenuation; all are equally prominent on the venter, but secondaries fade away low on the flanks. Primary costae become increasingly bold near the umbilicus and end abruptly at the umbilical margin forming low, radially elongated tubercles. The suture line (fig. 165) does not

Fig. 165. Suture line of *Hypacanthoplites cragini* Scott, n.sp. x4.

differ materially from suture lines of other species of the genus. Ventral lobe moderately short and broad; first lateral lobe broad, long, and symmetrically trifid. A short, narrow second lateral lobe lies near the umbilical margin. First lateral saddle broad, long, and much divided.

Comparison with other species.—Of the several species of the genus found in the Trinity sediments of Texas, *H. cragini* is more like the genotype, *H. milletianus* d'Orbigny, than any of the others, but the costation is a little coarser, the umbilical tubercles bolder and the whorls are higher in proportion to their thickness. The species is also similar to both *H. bakeri* and small specimens of *H. sellardsi,* but the umbilical tubercles are more prominent than in either of those species, the umbilicus is smaller and the whorls are lower.

Occurrence.—Lower Glen Rose formation, from a limestone ledge outcropping on Guadalupe River at Crane's Mill, locality M50. The ledge outcrops above what is known as the "27-foot bed" of the Glen Rose, but the exact level represented in the Glen Rose of this area is not known.

HYPACANTHOPLITES, sp.ind.

Pl. 65, fig. 5

The specimen here described, and its impression, are shown in the broken faces of a shale core taken from a deep well in Louisiana. The costation, height of the whorls and width of the umbilicus are the only features shown. The specimen was sent to the writer through the kindness of Merle C. Israelsky. More recently a number of specimens from the same stratigraphic level and apparently of the same species have been taken from well cores by Roy T. Hazzard and sent to the writer.

Description.—Nothing can be seen of the venter, or of the thickness of the whorls. Flanks broad and flat, whorls increase rapidly in height and are only moderately embracing; umbilicus broad with low, gently rounded wall. Measurements, in millimeters, are as follows:

Diameter	52
Greater radius	34
Lesser radius	18
Height of last whorl	24
Width of umbilicus	17

Sculpture consists of regularly alternating primary and secondary costae; costae and interspaces of about the same width; primary costae arise on umbilical wall and pass entirely across the whorls, are strongly flexuous; secondary costae arise in the interspaces between primaries about the middle of the flanks, but do not appear to split away from the primary costae, and ventrally assume the prominence of the primaries. There are no tubercles and the suture is not shown.

Comparison with other species.—Accurate determination of such specimens is impossible, but careful comparisons may give clues as to relationship. The impressions show striking resemblance to *Dufrenoya* aff. *D. dufrenoyi* as figured by Burckhardt (9, Pl. X, figs. 1–4, 7–9), but the umbilicus is a little wider and there is no suggestion of ventro-lateral tubercles which should show on the impressions. In its rounded and flexuous costation, umbilicus and rapid increase in the height of its whorls it closely resembles *H. bakeri*. Stratigraphically it is believed to occupy a similar level.

Occurrence.—From the upper part of the so-called lower Glen Rose member, which occurs stratigraphically above the "lower red bed formation" in Louisiana. The core from which the specimen was taken came from the United Gas P. S. No. 1 Meadows well, Claiborne Parish, Louisiana (S. 18, T. 21, R. 5 W.) at a depth of 4825–34 feet (locality M20). Other specimens believed referable to *Hypacanthoplites*, and communicated by Roy T. Hazzard, are from the Muslow D–1 well (locality M56) at a depth of 4260–4265 feet and from the Prairie River Syndicate Hutchinson No. 1 well (locality M60) at a similar level.

Genus QUITMANITES Scott, n.gen.

This genus is established for an ammonite with parahoplitid sculpture, but with a whorl section nearly circular and consequently very different in whorl plan from other genera of the Parahoplitidae, to which family the new genus is provisionally referred. The suture line is also of a very unusual and striking type and totally different from any species of ammonite known to the writer. It is characterized by a first lateral lobe which is crescent-shaped in general outline, and which bears a large number of finger-like, serrate lobules. Indeed, the suture line resembles in certain respects the "*pseudoceratitic*" type of pattern found in many genera (that is, *Engonoceras, Placenticeras, Sphenodiscus,* and *Tissotia*) of upper Middle and Upper Cretaceous age.

Genotype.—*Quitmanites ceratitosus* Scott, n.sp.

QUITMANITES CERATITOSUS Scott, n.sp.

Pl. 64, figs. 5, 6

In the blue marls of the Cuchillo formation of the southern Quitman Mountains some fragments of large ammonites were collected, which, on account of their wide umbilicus, sub-circular whorl section and unusual suture pattern, are placed in this new genus and species. All preserve the original shell structure, strongly impregnated with carbonaceous material and filled with dark shales. On account of their evolute form, the soft materials of their preservation, and the intense folding and fracturing to which the enclosing rocks have been subjected, the fossils break up readily and no complete specimens have been found.

Description.—Shell strongly evolute, venter of young whorls impressing preceding whorls but slightly; whorls tumid, almost circular in cross section with broadly rounded venter, flanks, and umbilical margin; increasing slowly in both height and thickness. Measurements of the holotype, in millimeters, are:

Length of fragment	154
Height of last whorl	69
Thickness of last whorl	61
Height of umbilical wall	11

Sculpture consists of numerous primary and secondary, closely set, flexuous costae, that are broadly rounded and separated by interspaces narrower than the ribs; usually about two secondary ribs occur between primaries, cross the venter without interruption or attenuation, and are all equally prominent on the venter and ventral parts of the flanks. At various levels along the flanks secondary costae fade out or anastomose with primaries; primaries become more prominent toward the umbilical margin, at which point they bend sharply forward and traverse the entire depth of the umbilical wall, fading out at the edge of the impressed area. On the ventral region of the shell all costae bend gently backward to cross the venter.

Holotype is septate; ventral lobe of suture line (fig. 166) is considerably corroded, but shows the general outline of the elements; it is broad and nearly as high as the first lateral. First lateral lobe unusual in all of its characters, being broad and crescent-shaped in outline, and bearing eight or nine serrate, elongate, finger-like secondary lobes, which give a ceratitic appearance to the element; second lateral lobe short, narrow and serrate, but undivided, and leaning perceptibly toward the first lateral. There are two short, narrow lobes on the sloping umbilical wall. Saddles broad and divided by short, narrow, serrate secondary lobes. There are no tubercles.

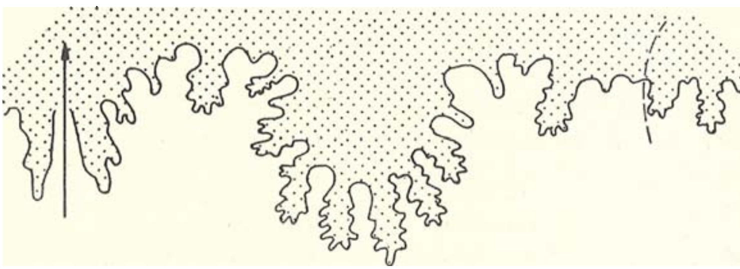

Fig. 166. Suture line of *Quitmanites ceratitosus* Scott, n.sp. x1.

Comparison with other species.—This species and the genus it represents are easily distinguished by the characters of the whorls and suture lines. In whorl section it resembles somewhat species referred to the genus *Ammonitoceras* by Burckhardt (9, p. 39) and Kilian (31, p. 192), but the sculpture and suture are entirely different.

Occurrence.—Occasional specimens occur in the lower part of the blue marls of the Cuchillo formation, locality M1.

Genus CUCHILLITES Scott, n.gen.

This new genus is introduced for an exceedingly evolute species, characterized by a broad umbilicus, almost circular whorl section and parahoplitid sculpture. The suture, although bearing certain diagnostic features, is in general accord with the parahoplitid type, with a broad ventral lobe that is nearly as long as the first lateral; first lateral lobe broad and asymmetrically trifid; first lateral saddle broad and lobate. In many respects the genotype closely resembles two ammonites described from the upper Aptian of Mexico and referred to the genus *Ammonitoceras (A. cornutum, A. fissicostatum)* by Burckhardt (9, pp. 41, 42, Pl. VIII; Pl. IX, fig. 1). Burckhardt's species, however, are described as tuberculate, although tubercles are not clearly shown on the figures. The ammonite discussed here has no tubercles and the costation is different. The genotype of *Ammonitoceras* Dumas, emend. Kilian (31, p. 192), is *A. ucetiae* Dumas. Burckhardt recognized three groups of species which he referred to the genus and, following Kilian and Jacob, saw in them the origin of *Douvilleiceras* (including forms now referred to *Cheloniceras* and *Procheloniceras* by Spath (56, p. 64)). Spath believes that *Douvilleiceras* probably is not in the line of descent from *Cheloniceras (C. martini)* and it appears to the writer improbable that *Cheloniceras* is directly related to *Ammonitoceras*. In any case Burckhardt's Mexican species probably cannot be referred to *Ammonitoceras*, but may fall into this new genus.

Genotype.—*Cuchillites evolutus* Scott, n.sp.

CUCHILLITES EVOLUTUS Scott, n.sp.

Pl. 64, figs. 3, 4

The single specimen of this new genus and species is preserved in dark-colored, indurated shale to which fragments of the shell adhere. The shell material was chipped off and a portion of the internal mold polished to bring out the suture. The specimen was found in a hard claystone concretion with only the edges protruding. The concretion could not be chipped away and was removed by alternately heating and cooling many times. The inner whorls are so badly crushed and broken that they are useless.

Description.—Shell exceedingly evolute with wide, shallow umbilicus; whorls small and subcircular in cross section, increasing slowly with age; dorsum only slightly impressed. Umbilical wall low with broadly rounded and indistinct margin. Measurements of the holotype, in millimeters, are as follows:

Diameter	162
Height of last whorl	52
Thickness of last whorl	38
Width of umbilicus	64
Suture taken at diameter of	90

Sculpture consists of numerous primary and secondary costae which usually alternate, but occasionally two secondary costae are inserted between primaries; costae rounded, thin and separated by interspaces equal to width of costae; all cross the venter without interruption or attenuation; all costae are equal in prominence on the venter, but the secondaries fade out at various levels on the flanks, or anastomose with neighboring primaries; primary costae are increasingly prominent toward the umbilicus, and cross the entire width of the umbilical wall, fading out at the whorl suture. Costae gently flexuous, bending forward at the umbilical margin and backward near the middle of the flanks. There are no tubercles.

Suture line (fig. 167), though not markedly different from other parahoplitid patterns, is characterized by a deep dorsal cleft in the broad trifid first lateral lobe; ventral lobe a little shorter than the first lateral; third and fourth lateral lobes on the flanks short and narrow; saddles broad and primarily and secondarily divided.

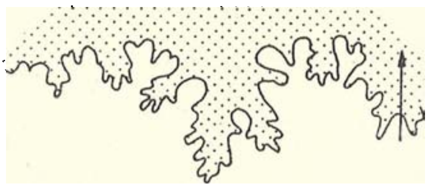

Fig. 167. Suture line of *Cuchillites evolutus* Scott, n.sp. x1.

Comparison with other species.—In sculpture and whorl section *Cuchillites evolutus* resembles *Quitmanites ceratitosus*, but its whorls are much more slender, the umbilicus much wider, the costation is different, and the sutures are not of the same type. The species is most like *Ammonitoceras cornutum* Burckhardt and *A. fissicostatum* Burckhardt, and, as noted in the generic description, these species may be referable to the genus *Cuchillites*. Specifically, at least, the Texas species is easily distinguished from the Mexican forms by its more regularly alternate costation, its non-tuberculate whorls and its suture. *A. cornutum* and *A. fissicostatum* both have sutures characterized by long, narrow, pointed first lateral lobes.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

Genus ACANTHOHOPLITES[7] Sinzow emend. Kilian

1907. *Acanthohoplites* Sinzow, Verhand. Russ. Kais. Min. Gess.
1913. *Acanthoplites* Kilian, Lethaea Geognostica, Unterenkreide, p. 346.
1915. *Acanthoplites* Kilian, Mém. Expl. Carte Géol. France, p. 43.

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[7]Sinzow's original spelling of the name is followed here, although Kilian and Spath have used the contracted spelling *Acanthoplites*.

1923. *Acanthoplites* Spath, Ammonoidea of the Gault, p. 64.

1938. *Acanthoplites* Anderson, Lower Cretaceous deposits in California and Oregon, p. 171.

Young individuals of this genus, as noted by Sinzow, Kilian, and Spath, have a sculpture suggestive of a relationship to *Douvilleiceras.* Later whorls, however, lose this feature and show their correct relationship with the parahoplitids.

Members of the genus are thickly discoid or globose, with whorls that grow rapidly in both height and width. The umbilicus is relatively large. Sculpture of the young consists of narrow costae separated by equally narrow interspaces. Costae of the young are irregularly divided into radially elongate tubercles, but on later whorls costae become entire and the tubercles disappear. The suture is characterized by a first lateral lobe symmetrically trifid or nearly so.

Sinzow (51) and Anthula (5) have described a number of species from the Caucasus, Seunes (50) has described others from western Europe, and Anderson (4) has recently described several species from the Cretaceous of California.

Genotype.—Acanthohoplites aschiltaensis (Anthula).

ACANTHOHOPLITES GRANDENSIS Scott, n.sp.

Pl. 59, figs. 1, 2

Numerous fragments of this large species are found along the east wall of Mayfield Canyon. All specimens are badly broken and fragments of a large example were glued together to represent the holotype. Parts of the shell adhere to the cast and are one-fourth inch or more in thickness.

Description.—Species moderately evolute with broad, thick, heavy-bodied, rounded whorls that increase rapidly in size; umbilicus deep with steep-sided walls; umbilical margin sharply rounded. The following measurements, in millimeters, give an idea of the proportions of the shell:

Diameter	440
Greater radius	260
Lesser radius	180
Height of last whorl	185
Height of penultimate whorl	75

Width of last whorl	160
Width of penultimate whorl	95
Width of umbilicus	132
Suture taken at diameter of	280

On later whorls sculpture consists of straight, broad, low, rounded costae separated by interspaces about equal to their width; on earlier whorls costae near the umbilicus are broken into irregular, radially elongated and indistinct tubercles characteristic of the genus. Costae cross the venter without interruption or attenuation.

No single suture line could be traced in its entirety, but enough of the parts are shown to make out the general features (fig. 168).

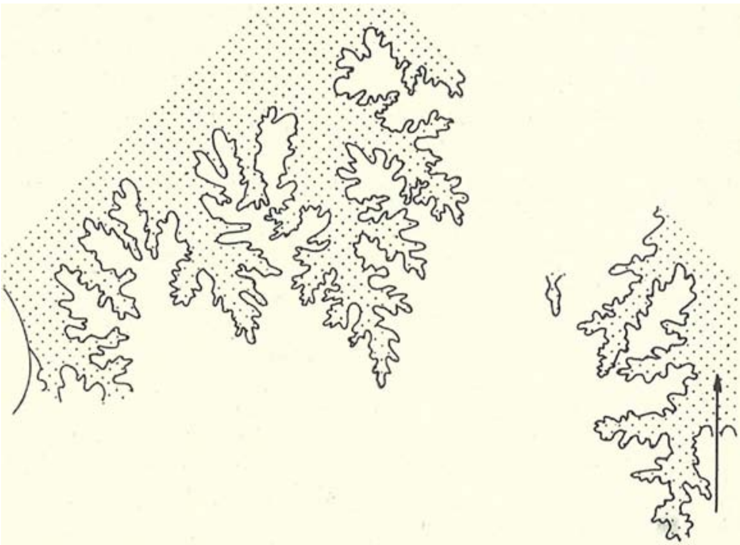

Fig. 168. Suture line of *Acanthohoplites grandensis* Scott, n.sp. x½.

Suture characterized by long, slender elements, and particularly by the long first lateral saddle suggestive of a relationship to the Douvilleiceratidae; ventral lobe longer than first lateral and much dissected; first lateral saddle long, broad, and divided by a long secondary lobe; first lateral lobe long and pointed, more divided ventrally than dorsally and separated from the second lateral lobe by a second lateral saddle shorter and narrower than the first lateral; second lateral lobe pointed and more divided ventrally than dorsally. A third lateral lobe on the umbilical wall could not be delineated. The living chamber is preserved almost intact and is about one-fourth whorl in length.

Comparison with other species.—The large size of specimens of this species makes comparison with other species of the genus difficult. The sculpture of the inner whorls is similar to that of *Acanthohoplites bigoureti* (Seunes) (50, p. 566, Pl. XIV, figs. 3, 4a–b), but the Texas species is more robust and the shells reach a much greater size. The suture of *A. bigoureti* is unknown. The species is very similar to *Acanthohoplites aschiltaensis* described by Anthula (5, p. 117, Pl. X, figs. 3, 5; Pl. XI, fig. 1) from the Albian of the Caucasus. The similarities in the suture are especially striking and the Caucasian species is likewise very large.

Spath (56, p. 64) has noted the douvilleiceran character of the suture and ornamentation in *Acanthohoplites*, but believed that it indicated parallel development rather than relationship.

Occurrence.—Blue marls of the Cuchillo formation, locality M1.

ACANTHOHOPLITES DUNLAPI Scott, n.sp.

Pl. 61, figs. 1, 2

A large whorl fragment composed of parts of the living chamber and the septate portion of a specimen was loaned to the writer by Mr. A. H. Dunlap, of Austin, and serves as the holotype of this new species.

Description.—The fragment is from an internal mold, moderately evolute with broad, thick, heavy-bodied, rounded whorls that increase rapidly in size. Umbilicus moderately deep with steep-sided walls; umbilical margin rounded. The following measurements, in millimeters, are taken from the specimen:

Length of fragment	175
Height of last whorl	77
Width of last whorl	70
Width of umbilicus	71

Sculpture consists of primary and secondary costae which are indistinguishable except in length. These are straight, or only slightly curved forward near the umbilicus. broad, low and rounded, and separated by interspaces about equal to their width. Primary costae arise on umbilical wall and pass entirely around the whorl; secondary costae alternate with primaries and fade out near the middle of the flanks.

Suture line (fig. 169) characterized by long slender elements and a long broad and complex first lateral saddle; ventral lobe equal in length to first lateral; first lateral lobe long, pointed asymmetrically trifid and more deeply divided ventrally than dorsally; second lateral lobe narrower and shorter than first lateral and lying near umbilical border.

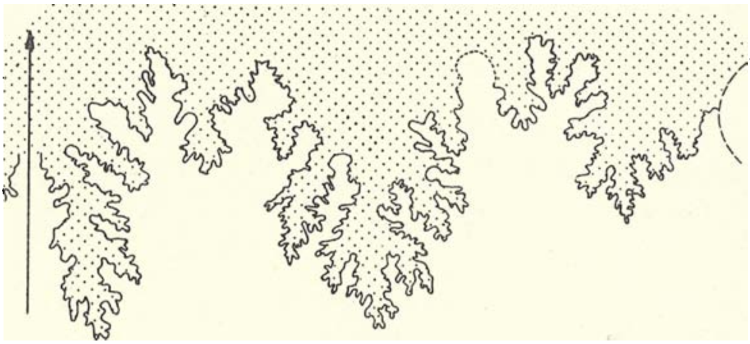

Fig. 169. Suture line of *Acanthohoplites dunlapi* Scott, n.sp. x1.

Comparison with other species.—The fragmentary condition of the specimen makes comparison with other species difficult. The inner whorls not being present, the characteristically tuberculate condition of the young of *Acanthohoplites* is not shown. The species is referred to the genus, however, without doubt on the basis of its rounded whorl section and its suture. *A. dunlapi* is similar to *A. grandensis* from the Quitman Mountains, but is smaller, its sculpture is somewhat finer, the first lateral saddle of its suture is shorter, and other sutural elements are less slender. The fragment closely resembles the outer whorls of *A. multispinatus* (Anthula) var. *tenuicostata* Sinzow as figured and described by Sinzow (51, p. 492, Pl. VII, figs. 1–4).

Occurrence.—The holotype and only specimen was collected at Jacobs Well, Hays County, locality M66. Strata in this vicinity are lower Glen Rose in age.

Family HOPLITIDAE Hyatt (26, p. 668) emend. Spath (56, p. 75)

Genus SONNERATIA Bayle

1878. *Sonneratia* Bayle, Expl. Carte Géol. France, Pl. XL, fig. 6.
1879. *Sonneratia* H. Douvillé, Bull Soc. Géol. France, 3d ser., tome 7, p. 91.
1893. *Sonneratia* Sarasin, Bull. Soc. Géol. France, 3rd ser., tome 21, p. 149. (Part.)
1897. *Sonneratia* Sarasin. Bull. Soc. Géol. France, 3d ser., tome 25, p. 789. (Part.)
1907. *Sonneratia* Jacob, Mém. Soc. Géol. France, tome 15, fasc. 3 et 4, Mém. 38, p. 55.
1913. *Sonneratia* Kilian, Lethaea Geognostica, Unterenkreide, p. 345.
1925. *Sonneratia* Spath, Ammonoidea of the Gault, pp. 76, 88, 90.
1938. *Sonneratia* Anderson, Lower Cretaceous deposits in California and Oregon, p. 193.
1938. *Sonneratia* Roman, Ammonites Jurassiques et Crétacées, p. 362.

The genus *Sonneratia* and the closely related genus *Cleoniceras* Parona and Bonarelli are discussed in some detail by Spath. Most of the species ordinarily referred to these genera fall readily into one or the other, but a few intermediate species are assigned with some difficulty. Such is the case with some of the forms found in Texas. *Sonneratia trinitensis*, n.sp., exhibits many of the characters of both genera. The suture and costation suggest *Cleoniceras,* but the venter is broadly rounded as in *Sonneratia,* rather than sharpened as in *Cleoniceras*. Since this character has been used as the principal basis for separation of the two genera, the Texas specimens are referred to *Sonneratia.* The several species described by Anderson from the California Cretaceous lack the typical whorl height shown by the Texas species.

Sonneratia is placed in the family Hoplitidae, following Spath who uses this grouping "merely for reasons of convenience."

Genotype.—Sonneratia dutempleana (d'Orbigny).

SONNERATIA TRINITENSIS Scott, n.sp.

Pl. 65, figs. 1, 2

This species is based on an almost complete internal mold bearing a part of the living chamber, but the flanks are somewhat corroded so that the costation is imperfectly shown. In addition to the holotype there are a number of fragments in the collection from the Quitman Mountains.

Description.—Shell thickly discoid and involute with relatively narrow umbilicus; whorls high with relatively flat flanks and broadly rounded venter; whorls increase rapidly in height and slowly in thickness; umbilical wall low and perpendicular with sharply rounded margin. Dimensions of the holotype, in millimeters, are as follows:

Diameter	162
Greater radius	94
Lesser radius	68
Height of last whorl	82
Height of penultimate whorl	34
Thickness of last whorl	53
Thickness of penultimate whorl	23.5
Width of umbilicus	37
Suture taken at diameter of	75

Surface of mold marked by numerous (about 75 per whorl), moderately distinct to indistinct, flexuous primary and secondary costae, which are nearly equal in prominence on the ventral part of the shell, but on the flanks secondaries fade out or anastomose with primaries. There are two, three and four secondaries intercalated between primaries, giving the effect of bundles of ribs anastomosing to form a single prominent primary rib which then traverses the flank to end at the umbilical margin in a low, radially elongated tubercle. All costae bend sharply forward to cross the venter without interruption or attenuation.

The first lateral lobe of the suture line (fig. 170) is a little longer than the ventral lobe and is characterized, as in all species

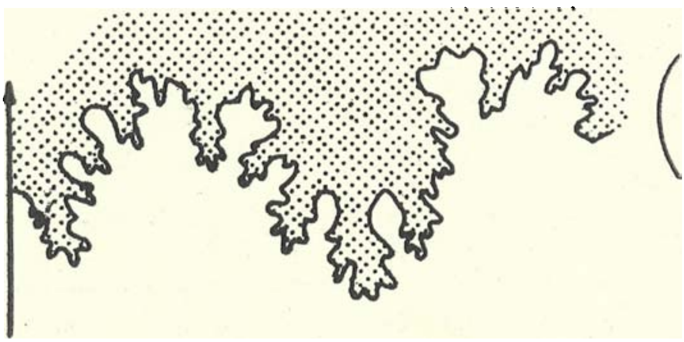

Fig. 170. Suture line of *Sonneratia trinitensis* Scott, n.sp. x2.

of *Sonneratia* and *Cleoniceras*, by its marked asymmetry. The second lateral saddle is a little longer than the first lateral.

Comparison with other species.—*Sonneratia trinitensis* bears a close resemblance to a number of Albian species, notably *S. kitchini* Spath (56, p. 88, Pl. V, figs. 7a, b; Pl. VI, figs. 14a, b), *S. baylei* Jacob, *S. parenti* Jacob (29, p. 59). *S. parenti* and *S. trinitensis* are so similar that it is difficult to find characters by which they may be separated. The sculpture is almost identical on the two, but the first lateral lobe of the suture is shorter and less symmetrical in *S. trinitensis* than in *S. parenti.*

Occurrence.—Massive limestones of the Cuchillo formation through which the Rio Grande has cut the first gorge of its canyon through the Quitmans. The limestones lie about 700 feet below the base of the blue marls section, locality M6 (see section, Pl. 55).

SONNERATIA WHITNEYI Scott, n.sp.

Pl. 66, fig. 9; Pl. 67, fig. 4

This new species is based upon a large whorl fragment which is largely septate but retains a part of the living chamber.

Description.—Shape discoid with involute, high whorls, as in other species of the genus; flanks relatively flat, venter broadly rounded; whorls increase rapidly in height but slowly in thickness; umbilicus narrow and bordered by a low, perpendicular wall, with sharply rounded margin. The fragment has the following dimensions in millimeters:

Length of whorl fragment	140
Height of last whorl	74

Surface of whorls marked by numerous, fine, flexuous costae, which do not appear to be separated into primaries and secondaries, are distinct on the ventral area of the shell where they bend sharply forward in crossing the venter, but on the upper part of the flanks they become obsolescent, a character which tends to become more pronounced with age. It is possible that earlier whorls would show a distinction between primary and secondary costae.

Suture line (fig. 171) badly eroded but shows the essential features of the pattern, which is characterized by extremely broad, short elements; first lateral lobe broad, and nearly as short as the ventral lobe, and deeply trifid asymmetrically; second lateral lobe short and much narrower than the others; first and second lateral saddles short, broad and asymmetrically divided.

Comparison with other species.—*S. whitneyi* is not very similar to the other species of the genus that have been described from the Western Hemisphere. In general outline it is like *S. trinitensis* from west Texas, but its costae are much less distinct and are finer than in that species. The suture line is entirely different and individuals seem to reach a considerably greater size. In its

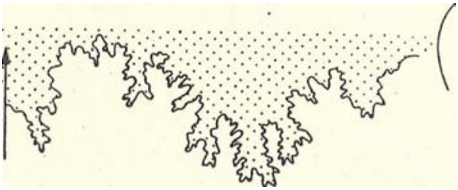

Fig. 171. Suture line of *Sonneratia whitneyi* Scott, n.sp. x1.

sculpture and its suture, it is more similar to *S. baylei* Jacob than to any other species, but it is considerably larger than that species, is less discoid and the first lateral lobe of its suture is more symmetrically trifid.

Occurrence.—Basal Glen Rose formation, locality M57. A second large fragment of a living chamber appears to belong to the same species and was collected near locality M19.

SONNERATIA MINIMA Scott, n.sp.

Pl. 66, fig. 2; Pl. 67, fig. 7

This species is based on two good specimens and several fragments. All are preserved as internal molds and are more or less crushed. All are relatively small and most of the examples exhibit parts of the living chamber.

Description.—Shell flattened, involute, with thick, broadly rounded venter and flat, almost parallel flanks; whorls increase rapidly in height, slowly in thickness; umbilicus relatively narrow, shallow, with a vertical wall the margin of which is sharply rounded. Dimensions of the holotype, in milimeters, are:

Diameter	62
Height of last whorl	32
Width of umbilicus	15

Whorls sculptured by numerous costae which begin on umbilical wall and are inclined gently forward toward the venter; from umbilicus to midway down the flanks primary costae are prominent, but they decrease in prominence toward the venter; secondary costae alternate regularly with primaries on the ventral part of the whorl, but fade out or anastomose with primaries near the middle of the flanks. On one specimen on which the living chamber is preserved, costae tend to become obsolescent.

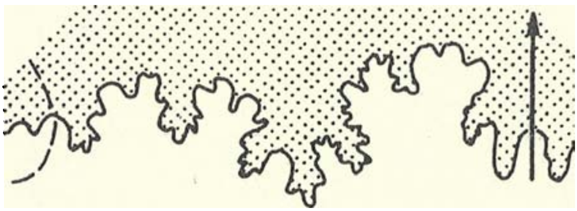

Fig. 172. Suture line of *Sonneratia minima* Scott, n.sp. x2.

Suture (fig. 172) characterized by its short ventral lobe and broad first lateral saddle; first lateral lobe trifid and nearly symmetrical, in this respect differing markedly from most species of *Sonneratia*, in which the first lateral lobe is usually asymmetrical.

Comparison with other species.—This species is easily distinguished from *S. trinitensis* Scott by its coarser, rarer costae and by flatter flanks and thinner cross section. In size, shape, and sculpture it is strikingly similar to *S. baylei* Jacob (29, p. 59, Pl. VII, figs. 25a, b), but the venter of the Texas species is a little narrower in proportion to the whorl thickness than in *S. baylei* and the sculpture is not quite as fine and appears to become obsolescent at a smaller size.

Occurrence.—Massive limestone of the lower Cuchillo formation, locality M6. The limestone lies about 700 feet below the base of the blue marls section.

SONNERATIA FOSTERI, n.sp.

Pl. 67, figs. 1, 2

In the upper limestones of the first gorge of Quitman Canyon and in beds of the same age on the hills near Quitman Summit, the writer and his students have collected specimens of a species of *Sonneratia* which is clearly different from other species described in this paper and which occur below it. It is named in honor of the owner of the hotel and property surrounding Indian Hot Springs.

Description.—Whorl section moderately thin and high with sharply rounded venter; umbilicus moderately narrow with low perpendicular wall. Whorls increase rapidly in height, more slowly in width. The best specimen has the following dimensions in millimeters:

Diameter	82
Greater radius	54
Lesser radius	28
Height of last whorl	40
Thickness of last whorl	34
Width of umbilicus	27

Costae are fine and numerous. These begin prominently on the wall of the umbilicus and break into two or more just ventral to the umbilical margin. They are only moderately prominent on the flanks and venter, but are nowhere interrupted.

The suture line is poorly shown and the matrix of the cast does not permit a preparation of this feature. General characters are outlined on a badly worn part of one side of the best specimen and indicate that the suture is typical of *Sonneratia.* Ventral and first lateral lobes are short and broad; first lateral saddle short and broad and only moderately serrate.

Comparison with other species.—*Sonneratia fosteri* has the shape and suture of the other species of the genus described in this paper, but is easily distinguished from them by its fine and numerous costae. It appears to be a species considerably smaller than *S. whitneyi,* its costae are more prominent than in that species, and the whorl section is higher and thinner in proportion to size.

Occurrence.—Limestones of the Cuchillo formation about 400 to 600 feet below the blue marls, localities M2 and M6. The holotype is from locality M2. *S. fosteri* occurs somewhat higher in the stratigraphic section than any other species of the genus yet found in the area.

Genus PSEUDOSONNERATIA Spath

1925. *Pseudosonneratia* Spath, Ammonoidea of the Gault, p. 76.

This genus was introduced by Spath to include *Pseudosonneratia typica* Spath (type) and *P. iserensis* Spath, previously referred to *Hoplites (Parahoplites) steinmanni* by Jacob (29). The principal difference by which the genus is distinguished from the hoplitids, such as *Arcthoplites, Hoplites* and *Hypacanthoplites,* is in its more rounded venter, thinner whorl section and more flexuous costae. Its relationship to the hoplitids is shown by the suture with its symmetrically trifid first lateral lobe; a character which also serves to separate it from the otherwise very similar *Sonneratia.*

Genotype.—*Pseudosonneratia typica* Spath.

PSEUDOSONNERATIA CUCHILLENSIS Scott, n.sp.

Pl. 66, figs. 3, 4

Collections at hand include a single good specimen, and some poor fragments referable to this new species. The holotype is slightly crushed and preserved in coarsely crystalline limestone. Erosion has obliterated the costae over a large part of the shell. Most of the living chamber, which is about one-half whorl in length, is intact.

Description.—Shell thinly discoid, with whorls that increase rapidly in height but slowly in thickness; venter narrowly rounded; umbilicus relatively broad and bordered by a low perpendicular wall, the margin of which is sharply rounded. The following measurements, in millimeters, are taken from the holotype.

Diameter	67
Greater radius	41
Lesser radius	26
Height of last whorl	31
Height of penultimate whorl	16
Thickness of last whorl	18
Width of umbilicus	13

Sculpture consists of narrow, rounded, closely spaced costae without tubercles; costae bend sharply forward as they leave the umbilicus and continue to flex forward to the mid-ventral line, where they cross without interruption or attenuation. Primary and secondary costae equally prominent on ventral part of the whorls and usually alternate, but secondaries fade out near the middle of the flanks or anastomose with primaries; primary costae end prominently on umbilical margin.

Suture pattern (fig. 173) badly corroded, but characteristic trifid arrangement of first lateral lobe, and broad ventral lobe evident; all elements relatively short.

Fig. 173. Suture line of *Pseudosonneratia cuchillensis* Scott, n.sp. x4.

Comparison with other species.—The species is remarkably similar to *Ps. iserensis* Spath, as can be seen by a comparison with Jacob's Plate VIII, figures 5a, b. It is, therefore, a species transitional from *Pseudosonneratia* to *Hoplites.*

Occurrence.—Limestones of the Cuchillo formation about 600 feet below the blue marls. The stratum from which it came is closely associated with a series of thick oyster beds, locality M6.

Family ENGONOCERATIDAE Hyatt (26, p. 585; 25, p. 153) emend. Spath (56, p. 339)

Genus KNEMICERAS Böhm

1898. *Knemiceras* J. Böhm, Ueber *Ammonites pedernalis* V. Buch, Zeitschr. d. Deutsch. Geol. Ges., Bd. 50, pp. 198–200.
1900. *Knemiceras* Hyatt, in Zittel, Textbook of Paleontology, Eastman translation, 1st ed., p. 671.
1903. *Knemiceras* Hyatt, U. S. Geol. Surv., Mon. 44, p. 145.
1910. *Knemiceras* Sommermeier, Nues Jahrb. f. Min. Geol. u. Pal., Bd. 30, pp. 319, 336.
1911. *Knemiceras* Douvillé, Bull. Soc. Géol. France, tome 11, p. 316.
1916. *Knemiceras* Douvillé, Massif du Moghara, Mém. Acad. Sci., Institute France, pp. 120–129.
1929. *Knemiceras* Spath, Ammonoidea of the Gault, p. 339.

1937. *Knemiceras* Basse, Les Cephalopodes Crétacés des Massifs Cotiers Syriens, p. 167.
1938. *Knemiceras* Roman, Ammonites Jurassiques et Crétacées, p. 497.

The genus *Knemiceras* includes strongly involute, thinly discoid "Pseudoceratites." Whorls are high with sub-flattened or broadly furrowed venter, and sculptured by widely spaced, broad, flexuous or straight costae of varying prominence, and three spiral rows of tubercles. Two rows occur on the flanks and the individual tubercles are conical or slightly elongated radially and widely spaced. The third row consists of numerous spirally elongated tubercles on the ventro-lateral margin, those on opposite sides alternating. As in other "Pseudoceratites" there is a tendency toward simplification of the sutural elements and a multiplication of their number. Representatives of the genus have suture lines similar to species of *Engonoceras*, but the saddles are divided and denticulate, whereas in *Engonoceras* these elements are rounded. Some authors, particularly Douvillé, Basse, and Sommermeier, have attempted to base generic distinction in this family on the number and origin of adventive lobes in the suture line, Douvillé noting that *Knemiceras* has two such lobes. Sommermeier considered that *Knemiceras* has one adventive lobe between the ventral and first lateral lobes, whereas *Placenticeras* has two, and he made a point of separating the two genera on this basis. This character is probably of great phylogenetic value, but in the opinion of the writer is one very difficult to interpret with certainty. The best criteria for identification of the genus seem to be the form of the suture line, the complexity of the saddles, and the form of the ventral lobe. These characters are diagnostic and are clearly shown in the suture lines figured by Douvillé, Sommermeier, Basse, and Spath. Douvillé has noted that the young of *Knemiceras* have rounded saddles, as in *Engonoceras*, and are, therefore, difficult to determine with certainty, but with many specimens of both these genera from the Trinity and Fredericksburg strata of Texas before him, the writer has noted another sutural character which serves readily to distinguish even very young specimens. In *Engonoceras* the ventral lobe is short and its branches are directed in a sense almost opposite to each other. In *Knemiceras* this lobe is long, its branches are sub-parallel or only slightly spread apart, and it shows denticulations near its base at a very early age. The first lateral saddle, likewise, shows early signs of divisions and serrations. In *Engonoceras* the suture line forms a broad backward curve on the flanks, while in *Knemiceras* this line is nearly straight from venter to umbilicus. Finally, the number of elements in the suture line of *Engonoceras* is much greater than in *Knemiceras*.

After creating the family Engonoceratidae, Hyatt proposed the family Knemiceratidae for the genus *Knemiceras*. Spath thinks the name may be retained as a sub-family. This conservative view is favored by the writer, at least until more is known of the phylogenetic relationships of this puzzling group of ammonites.

Douvillé derives *Engonoceras* and its allies from the Pulchellidae and this view is accepted by the writer. That author has also suggested that the characters of the suture line and of the thin, relatively smooth shell were probably developed as a result of the method of locomotion by swimming which he believed the animal might have adopted. The nectonic or extremely shallow habitat of ammonites of this type is also emphasized by Douvillé. While these suggestions are interesting there is little factual support for them. It is interesting to observe that thin-bodied, little ornamented ammonites, such as *Knemiceras, Engonoceras, Oxytropidoceras,* are found in great profusion in rocks of Albian age in Texas and appear to have had their greatest development in the broad, shallow, clear seas of Texas and similar areas in tropical and subtropical regions. Douvillé has also noted that certain species, such as *Knemiceras priscum*, are represented by large and small specimens which he considers respectively females and males. The writer has not been able to make similar observations on the Texas specimens.

Most of the species of *Knemiceras* that have been described are Albian in age although some are possibly from the Aptian. In Texas the genus occurs in the middle and upper Glen Rose strata of north and central Texas. None of the Texas species is closely similar to the several species described from South America by Sommermeier (52), or most of those described from western Asia by Douvillé. All the Texas species are thinner and have less robust sculpture than the South American species. *K. gracile* Douvillé (18, p. 128, Pl. XVI, fig. 9) is similar in shape and sculpture to the Texas species.

Genotype.—Knemiceras syriacum J. Böhm.

KNEMICERAS ROEMERI (Cragin)

Pl. 66, figs. 1, 8; Pl. 67, fig. 5; Pl. 68, fig. 1

1893. *Sphenodiscus roemeri* Cragin, Geol. Surv. Texas, 4th Ann. Rept., p. 235, Pl. XLVI, fig. 1.
1903. *Engonoceras roemeri* Hyatt, U. S. Geol. Surv., Mon. 44, p. 177.
1928. *Engonoceras roemeri* Adkins, Univ. Texas Bull. 2838, p. 261.

The single specimen upon which this species is based was collected by J. A. Taff from the "alternating beds" (Glen Rose) 50 or 60 feet below their upper limit on Bosque River at Iredell, Bosque County. Cragin's single side-view figure is inadequate for identification of the species and the holotype could not be found, having been lost, apparently, soon after Cragin's types were unpacked.[8]

A specimen in the Texas Bureau of Economic Geology is labeled ?*Sphenodiscus roemeri* Cragin and the label is signed by Annie Pritchett, but no locality is indicated. The specimen is a true *Engonoceras* and does not agree at all with Cragin's description and figure. It appears, in fact, to be a species abundant in the Walnut formation (Fredericksburg), and its matrix indicates a Walnut source. The specimen is large, very thin, and the saddles are not strongly divided as in *Knemiceras roemeri*.

Several specimens of the true *K. roemeri* are at hand, and all were collected from the Glen Rose in the vicinity of the town of Glen Rose.

Description.—Shell thinly discoid, involute with high, thin whorls; flanks flat or slightly convex; venter narrow, truncate or slightly furrowed with sharp ventro-lateral angles, except on older part of living chamber where the venter becomes sub-rounded. The following measurements, in millimeters, are taken from the best fragment:

Length of fragment	69
Height of last whorl	39
Thickness of last whorl	12
Width of umbilicus	7

[8]Hyatt's and Cragin's cephalopod types were unpacked in 1905 and a list of them, including *Sphenodiscus roemeri*, was published by Annie H. Pritchett, Fossil Cephalopoda, described by Hyatt and Cragin in the Museum of The University of Texas Biol. Bull., vol. 8, p. 365. This appears to be the last authentic record of Cragin's specimen.

Sculpture consists of indistinct costae and tubercles. Near the umbilicus is a spiral row of distantly spaced, indistinct tubercles. Near the middle of the flanks is a second similar row of very indistinct tubercles, often detected only by the sense of touch, but these disappear on very old shells. No costae are visible on young whorls, but on older parts of the molds there are low, broadly rounded, flexuous costae which make alternate tubercles on the ventro-lateral angles.

External suture line (fig. 174) consists of a ventral lobe, ten lateral lobes and an umbilical lobe, and corresponding saddles. Lobes all moderately long and the second, third and fourth lateral lobes many times serrate; first lateral saddle short, broad and quadrilobate; other lateral saddles bilobate, trilobate and quadrilobate.

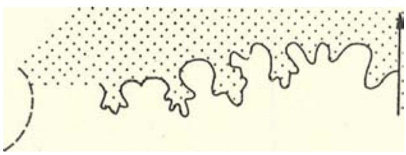

Fig. 174. Suture line of *Knemiceras roemeri* Cragin. x2.

Comparison with other species.—*Knemiceras roemeri* is easily distinguished from all species of *Engonoceras* by the much divided saddles of its suture line. It has a suture line very similar to *K. nodosum* and *K. azlense,* but the shell is much thinner and less highly sculptured than in either of those species.

K. roemeri is not a typical *Knemiceras* in that its shape is like *Engonoceras.* It may on this account be considered as intermediate between the two genera. It is here referred to *Knemiceras* because of its suture line which is typically knemiceratid and totally unlike any known species of *Engonoceras.*

Occurrence.—Upper and middle parts of the Glen Rose formation, localities M54, M52, M67, and locality of Cragin's type specimen.

Repository.—The holotype was deposited in the department of geology of The University of Texas, and unfortunately has been lost. Neosyntypes (Nos. 1155, 1156) in the Bureau of Economic Geology, Austin, Texas.

KNEMICERAS NODOSUM, n.sp.

Pl. 67, fig. 6; Pl. 68, fig. 6

The specimen upon which the species is based is a completely septate internal mold with a few shell fragments on it. The holotype is the only specimen in the writer's collection, but other specimens have been collected at the type locality.

Description.—Shell thickly discoid with a broadly truncated venter; ventro-lateral tubercles give a furrowed effect to the venter. Whorl section reaches greatest thickness a short distance from the umbilicus, from which point flanks converge toward the venter; umbilical wall low, umbilical margin indistinct, so that the whorl section thickens rapidly from the base of the umbilical wall to the point of greatest thickness of the whorl. As in all engonoceratids this species is strongly involute. The holotype has the following dimensions in millimeters:

Diameter	47
Greater radius	26.5
Lesser radius	20
Height of last whorl	23.5
Thickness of last whorl	21.3
Width of umbilicus	4
Suture taken at diameter of	47

Costae low, broad, but indistinct and widely spaced; occasional costae more prominent than the others and marked near the umbilicus by prominent conical tubercles; costae become indistinct across the flanks but rise to prominence near ventro-lateral margin where they end in prominent spirally elongated, compressed tubercles. Tubercles on the two sides of the venter are nearly, but not quite, opposite. Suture line with much divided saddles characteristic of *Knemiceras;* base of pattern almost straight; lobes tripartite to simple, saddles bilobate, trilobate or quadrilobate (fig. 175).

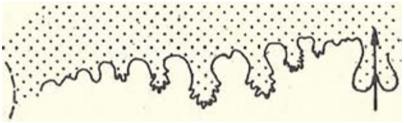

Fig. 175. Suture line of *Knemiceras nodosum* Scott, n.sp. x2.

Comparison with other species.—*K. nodosum* may be easily distinguished from the other species of the genus by its prominent and widely spaced umbilical and ventral tubercles, and by its thick whorl section and wide venter.

Occurrence.—From limestone ledge at the top of the Glen Rose that lenses out into the Paluxy sand in the vicinity of Azle, locality M55.

KNEMICERAS AZLENSE Scott, n.sp.

Pl. 66, figs. 5, 6, 10; Pl. 68, fig. 2

Two specimens representing this species were collected by Mrs. J. H. Renfro, of Fort Worth. They are internal molds in a fair state of preservation.

Description.—Shell thinly discoid, strongly involute, and typically engonoceratid in shape; whorl section thickest near the umbilicus, from which point the flanks gradually converge toward the narrowly truncated venter; umbilicus narrow with a vertical wall, the margin of which is distinct. The following measurements, in millimeters, are taken from the two specimens:

Diameter	45
Greater radius	27
Lesser radius	18
Height of last whorl	25
Height of penultimate whorl	10
Thickness of last whorl	16
Width of umbilicus	6
Suture taken at diameter of	45

Low, broadly rounded, indistinct, flexuous costae radiate from the umbilical area and end at the ventro-lateral margins in prominent, spirally elongated tubercles, giving to the venter a depressed effect. Most of the costae begin at some distance from the umbilical wall, but every third or fourth one begins on the umbilical margin in a prominent radially elongated tubercle. Near the middle of the flanks is a second row of indistinct, widely spaced tubercles. The costae bend sharply forward in approaching the ventro-lateral tubercles which alternate on opposite sides of the venter.

Suture line (fig. 176) is more complex than in other species of the genus; saddles bilobate, trilobate, or quadrilobate, and the lobules in turn much serrated; bases of saddles form a nearly straight line from the venter to umbilicus; third lateral saddle distinctly bilobate; two lobes on either side of this saddle much higher than the others, tending to be tripartite.

Comparison with other species.—*K. azlense* is very similar to *K. nodosum*, but its whorl section is much thinner, venter narrower, and the ventro-lateral nodes are more numerous and alternate more regularly than in that species; suture is also much more complex. *K. azlense* is the only species of the genus known to the writer that bears umbilical tubercles immediately on the umbilical margin.

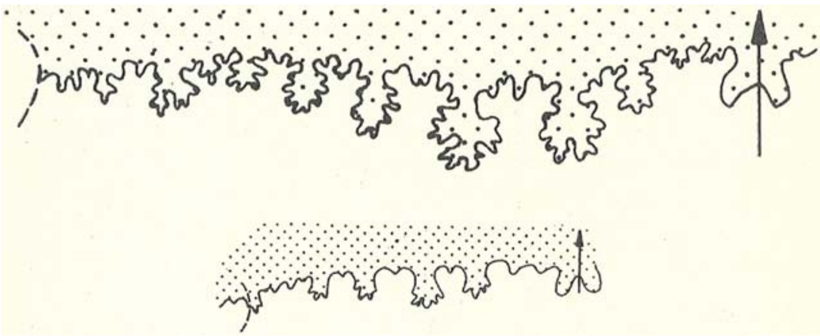

Fig. 176. Suture line of *Knemiceras azlense* Scott, n.sp.; large syntype, x1 (upper suture); small syntype, x2 (lower suture).

Occurrence.—Limestone ledge at the top of the Glen Rose formation that lenses out into the Paluxy sand in the vicinity of Azle, locality M55.

KNEMICERAS TRINITENSE Scott, n.sp.

Pl. 66, fig. 7; Pl. 68, fig. 3

The large specimen serving as the holotype of this species was donated by Mrs. J. H. Renfro, of Fort Worth. It is a completely septate and fragmentary internal mold, but is well preserved.

Description.—Specimen typically engonoceratid in shape with high, thin whorls and truncate venter; flanks broadly arched, almost flat; umbilicus larger than in most species of the genus; size increasing rapidly with age; umbilical wall vertical, but with broadly rounded margin (fig. 177). The following measurements are taken from the holotype:

Diameter	184
Greater radius	110
Lesser radius	74
Height of last whorl	96
Height of penultimate whorl	56
Thickness of last whorl	53
Thickness of penultimate whorl	30
Width of umbilicus	31
Suture taken at diameter of	150

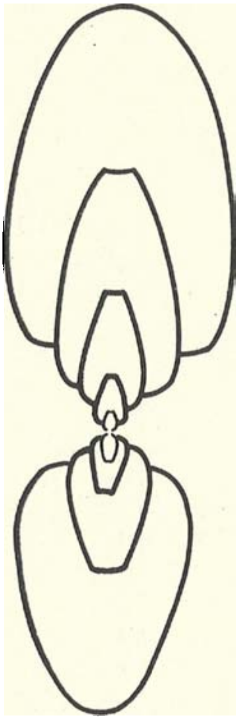

Fig. 177. Sketch showing cross section of *Knemiceras trinitense* Scott, n.sp. x½.

Broad, often indistinct, widely spaced, low, rounded and almost straight costae, mark the flanks; costae terminate at ventro-lateral margins in spirally elongated tubercles. These are almost opposite on the two flanks and are never prominent, even on the young part of the specimen. At about one-eighth of the distance from the umbilical wall to the venter are occasional prominent, conically shaped tubercles which do not appear to become obsolescent on the older part of the shell.

The suture (fig. 178) is the most characteristic feature of the species and it differs markedly from other species of the genus. Base of saddles form a broad and relatively high arch across the middle of the flanks; lobes relatively high, narrow anteriorly, broad posteriorly and tend to be tripartite and denticulate; corresponding saddles broad anteriorly, narrow posteriorly, trilobate, quadrilobate or further divided.

Comparison with other species.—The basic trifid pattern of the lobes and the constricted form of both lobes and saddles distinguish *K. trinitense* from the other known species of *Knemiceras.* The broadly arched line formed by the base of the saddles is a characteristic feature.

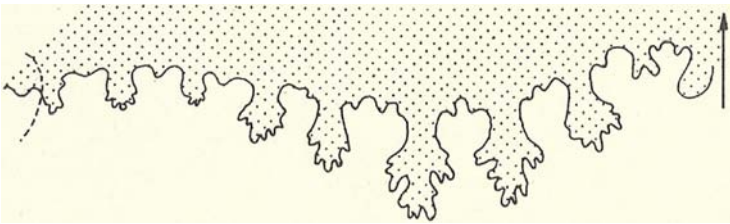

Fig. 178. Suture line of *Knemiceras trinitense* Scott, n.sp. x1.

Occurrence.—Limestone ledge at the top of the Glen Rose formation that lenses out into the Paluxy sand in the vicinity of Azle, locality M55.

Order NAUTILOIDEA

Genus CYMATOCERAS Hyatt

1875. *Cymatoceras* Hyatt, Fossil cephalopods of the Museum of Comparative Zoology, p. 301.

1894. *Cymatoceras* Hyatt, Genera of fossil cephalopods, p. 553.

1928. *Cymatoceras* Adkins, Univ. Texas Bull. 2838, p. 155.

This genus, introduced by Hyatt, includes costate, globose nautiloids in which the costae pass entirely across the venter. Sutures have slight ventral lobes or saddles with deep lateral and dorsal lobes. The genus is widespread in rocks of Cretaceous age.

Genotype.—*Cymatoceras pseudoelegans* (d'Orbigny).

CYMATOCERAS, sp.ind.

Pl. 67, fig. 3

In the collection of Cephalopoda from the Trinity group in the Quitman Mountains, there is one poor specimen not specifically determinable. The specimen is a fragment of the living chamber and is badly corroded, but the sculpture is partially preserved.

Description.—Fragment from large, involute and extremely globose individual; outer whorls appear to envelope completely the inner ones. Sculpture consists of numerous moderately fine, and strongly flexuous costae, which commence near the umbilicus, form a broad saddle across the flanks and bend strongly backward in approaching the venter where they form long, broadly rounded ventral lobes. No suture lines are shown.

Comparison with other species.—The specimen has many characters in common with *Nautilus burckhardti* Castillo and Aguilera, but that species is less involute and it does not show the sculpture of the Quitman Mountains species. In sculpture and general appearance it resembles *C. texanum* (Shumard) and *C. hilli* (Shattuck), but is larger and much more globose than either of these.

Occurrence.—Blue marls of the Cuchillo formation, locality M2.

Genus VORTICOCERAS Scott, n.gen.

This new genus is introduced here to include two known species of rare and unusual Cretaceous nautiloids, characterized by their involute and extremely discoid shape. Whorls high and narrow with narrow flattened or depressed, bicarinate venters; they increase rapidly in height, but slowly in thickness, greatest thickness being about one-fourth the distance from umbilicus to venter; flanks flat, converging gently toward the venter, and sculptured by broad, widely spaced, indistinct costae which curve backward toward the venter. Suture line (fig. 179) broadly curved, forming a narrow, short ventral lobe to either side of which is a short, narrow and almost pointed saddle with apex on the ventro-lateral angle. On the ventral area of the flank the suture line describes a broad, short lobe, followed by a narrow and more sharply rounded saddle. A broad short lobe lies at the umbilical suture.

So far as the writer knows, the species here described and *Nautilus lallieri* d'Orbigny, as described and figured by Douvillé (18,

p. 125, Pl. XVII, figs. 2–6), are the only nautiloids of this general type from anywhere in the Cretaceous or later rocks, although Douvillé suggests that *N. rata* from the Upper Cretaceous of India may belong to the same general group as *N. lallieri.* In describing his numerous specimens of *N. lallieri* from the Aptian of the region east of Suez, Douvillé calls attention to the peculiarities of the species and interprets its disk-like form as indicating a nectonic habitat. He remarks that the discoid form may have been characteristic of cephalopods that were swimmers, and believes that the occurrence of such types is more often sporadic than not. He does not, therefore, consider the peculiar form of *N. lallieri* of generic importance.

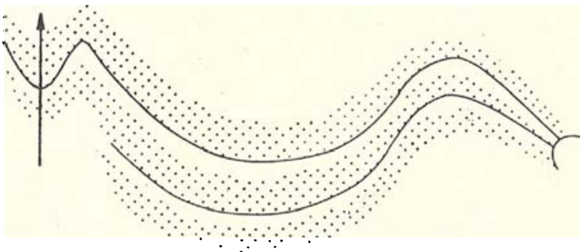

Fig. 179. Suture line of *Vorticoceras stantoni* Scott, n.sp. x1.

There can be little doubt in the writer's opinion that the peculiar form of these nautiloids is a reflection of their habitat, but he believes that the adaptation results from the usual process of natural selection and that these characters are certainly of generic importance.

Nautilus lallieri appears to be a tropical form, but representatives have been found in the Anglo-Parisian basin and elsewhere in France and Switzerland. The finding of a closely related species in Arkansas is of interest since it demonstrates the wide occurrence of nautiloids of this group.

Genotype.—Vorticoceras stantoni Scott, n.sp.

VORTICOCERAS STANTONI Scott, n.sp.

Pl. 68, figs. 4, 5

This new species is represented by a specimen collected by Dr. T. W. Stanton from the Dierks limestone near Murfreesboro, Arkansas, in 1925. It is a fragmentary internal mold, badly eroded and does not retain the living chamber, but most of the essential characters are well preserved.

Description.—Cast thinly discoid with high, thin whorls that increase rapidly in height but slowly in thickness; umbilicus open but narrow and without pronounced wall; flanks moderately flat, but slightly bulged at about one-fourth the distance from umbilicus to venter; venter broadly depressed and strongly bicarinate. The specimen has the following measurements in millimeters:

Diameter	114
Greater radius	72
Lesser radius	30
Height of last whorl	69
Thickness of last whorl	40
Width of umbilicus	5

Sculpture on the cast consists of broad, low, broadly rounded and broadly spaced costae reaching their greatest prominence on the middle of the flanks. They are strongly flexuous and bend sharply backward to approach the venter. The shell structure is not present and no details of its sculpture are shown. Suture line (fig. 179) well shown. On the venter is a short, narrow lobe occupying the narrow ventral depression. On the lateral keels are short, narrowly rounded saddles followed on the flanks by a broad first lateral lobe. This lobe is in turn followed by a narrower, but deep saddle. A second lateral lobe reaches its apex at the line of involution. No preparation to show the siphuncle was attempted on the single specimen.

Comparison with other species.—As indicated in the generic description, *Vorticoceras stantoni* is remarkably similar to *Vorticoceras lallieri* (d'Orbigny) as described by Douvillé from the Massif of Moghara, east of Suez. The two are separable, however, on the basis of the sculpture and the suture line. In *V. lallieri* the costae begin at the umbilicus and fade out before reaching the venter. In *V. stantoni* the costae are not observed far above the middle of the flanks and may be followed to the ventro-lateral angles. In *V. stantoni* the suture lines are very flexuous, resulting in lobes and saddles that are somewhat more pronounced than in *V. lallieri.*

Occurrence.—Dierks limestone of the Trinity group, locality M15.

Repository.—Holotype in the United States National Museum, Washington, D.C., plaster cast (No. 1162) in the Bureau of Economic Geology, Austin, Texas.

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PLATE 56

(The specimen numbers in this and succeeding plates refer to collections in the Bureau of Economic Geology, The University of Texas, unless otherwise stated.)


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PLATE 57

PAGE

Uhligella?, sp.ind., x1 998

1. Lateral view; original in U. S. National Museum; plaster mold in Bureau of Economic Geology (No. 1111). Three miles east of Murfreesboro on the road to Delight, Arkansas; U. S. Geological Survey locality 13211 (Loc. M14).

Douvilleiceras, n.sp.ind., x½ 1015

2. Lateral view of limestone slab containing the natural mold of a large specimen; original in U. S. National Museum; plaster cast in Bureau of Economic Geology (No. 1164). In section 36, T. 29 S., R. 16 W., at edge of arroyo just north of the Eighth of March shaft, Little Hatchet Mountains, southwestern New Mexico; U. S. Geological Survey locality 16962 (Lasky 192–34) (Loc. M62).

Douvilleiceras mammillatum (Schlotheim), x1 1007

3, 4. Lateral and ventral views of crushed specimen, plesiotype, No. 1115. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Trinitoceras reesidei Scott, n.gen., n.sp., x1 1019

5. Plaster mold (No. 1165) of inner whorls of large cotype in Plate 58, figure 6. Center east line section 12, T. 28 S., R. 16 W., Little Hatchet Mountains, southwestern New Mexico; U. S. Geological Survey locality 17439 (Lasky 7–37) (Loc. M64).

6. Ventral view of small specimen; lateral view in Plate 59, figure 5; original in U. S. National Museum; plaster mold in Bureau of Economic Geology (No. 1166). In N.W. ¼ section 36, T. 27 S., R. 16 W., just west of shaft of King–400 Claim, Little Hatchet Mountains, southwestern New Mexico; U. S. Geological Survey locality 17364 (Lasky 46B–35) (Loc. M63).

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PLATE 58

PAGE

Trinitoceras reesidei Scott, n.gen., n.sp., x½ 1019

1, 2. Ventral and lateral views of cotype of intermediate size; suture line in figure 154, page 1020; original in U. S. National Museum; plaster mold in Bureau of Economic Geology (No. 1167). In N. W. ¼ section 36, T. 27 S., R. 16 W., just west of shaft of King–400 Claim, Little Hatchet Mountains, southwestern New Mexico; U. S. Geological Survey locality 17364 (Lasky 46B–35) (Loc. M63).

6, 7. Lateral and ventral views of large cotype, x¼; mold of inner whorls in Plate 57, figure 5; original in U. S. National Museum; plaster mold in Bureau of Economic Geology (No. 1168). Center east line section 12, T. 28 S., R. 16 W., Little Hatchet Mountains, southwestern New Mexico; U. S. Geological Survey locality 17439 (Lasky 7–37) (Loc. M64).

Douvilleiceras spathi Scott, n.sp., x½ 1012

3. Ventral view of holotype, No. 1120; lateral view in Plate 60, figure 6. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Douvilleiceras offarcinatum (White) ?, x1 1011

4, 5. Lateral and ventral views of plesiotype, No. 1118. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).


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PLATE 59

1, 2. Lateral and apertural views of holotype, No. 1148. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Spath (55, p. 419; 57) believes that greatly reduced figures of large ammonites are useless, but if such figures show the characters of the species it appears to the writer they may be useful.

3, 4. Lateral and ventral views of holotype, No. 1117. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

5. Lateral view of small specimen; ventral view in Plate 57, figure 6; original in U. S. National Museum; plaster mold in Bureau of Economic Geology (No. 1166). In N.W. ¼ section 36, T. 27 S., R. 16 W., just west of shaft of King-400 Claim, Little Hatchet Mountains, southwestern New Mexico: U. S. Geological Survey locality 17364 (Lasky 46B-35) (Loc. M63).


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PLATE 60

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Trinitoceras rex Scott, n.gen., n.sp., about 1/4 1017

1–3. Three views of holotype (No. 1122) greatly reduced. Figure 3 is of inner whorl to show sculpture. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Dufrenoya comalensis Scott, n.sp., x1 1026

4, 5. Ventral and lateral views of holotype, No. 1128. Road cut one-half mile from Fischer's Store on the Fischer's Store–Crane's Mill road, Comal County, Texas (Loc. M19).

Douvilleiceras spathi Scott, n.sp., x1/2 1012

6. Lateral view of holotype, No. 1120; ventral view in Plate 58, figure 3. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Dufrenoya justinae (Hill), x1 1022

7, 8. Ventral and lateral views of characteristic specimen, topotype, No. 1122. Cow Creek, northwest Travis County, Texas (Loc. M45).

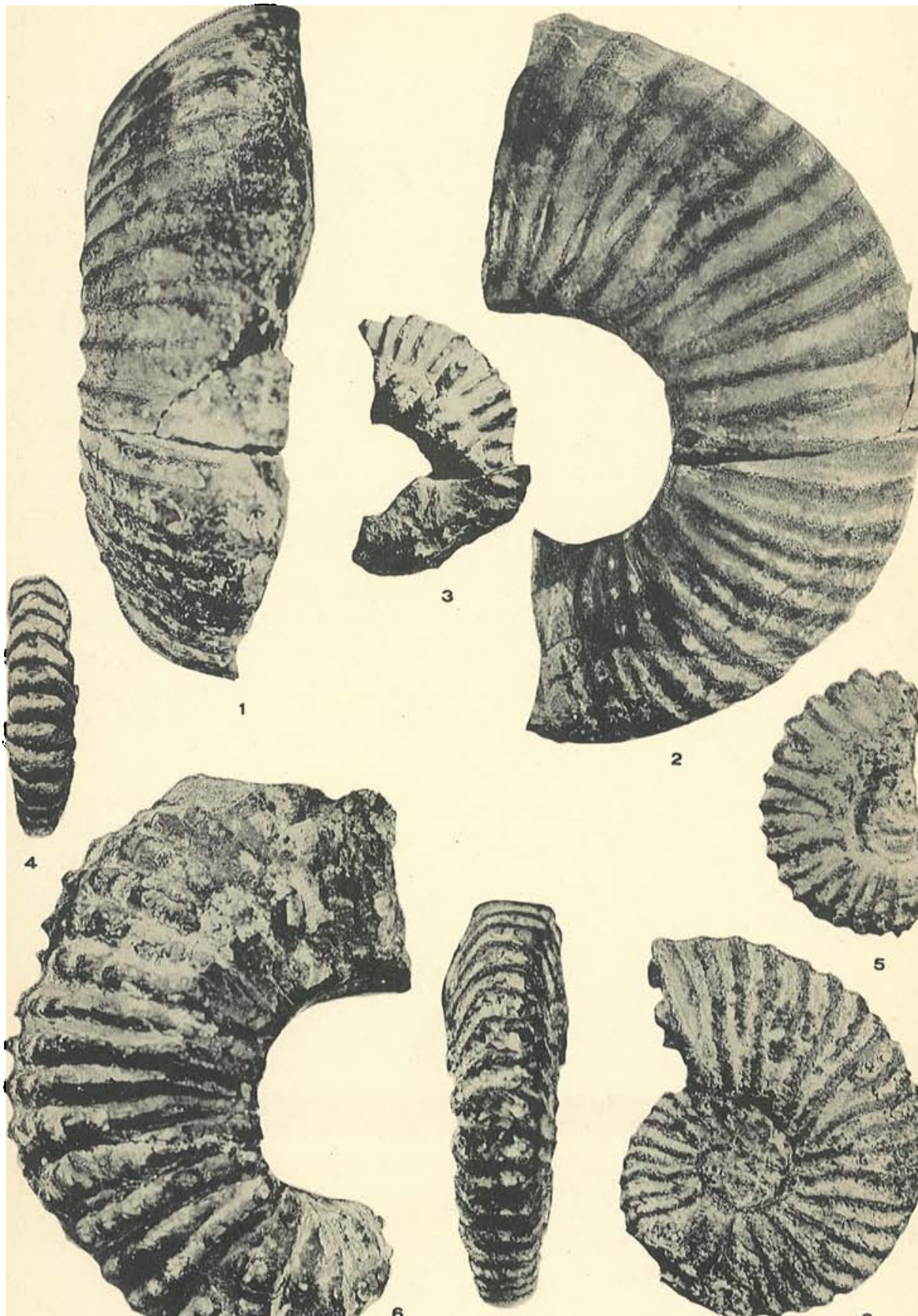
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PLATE 61

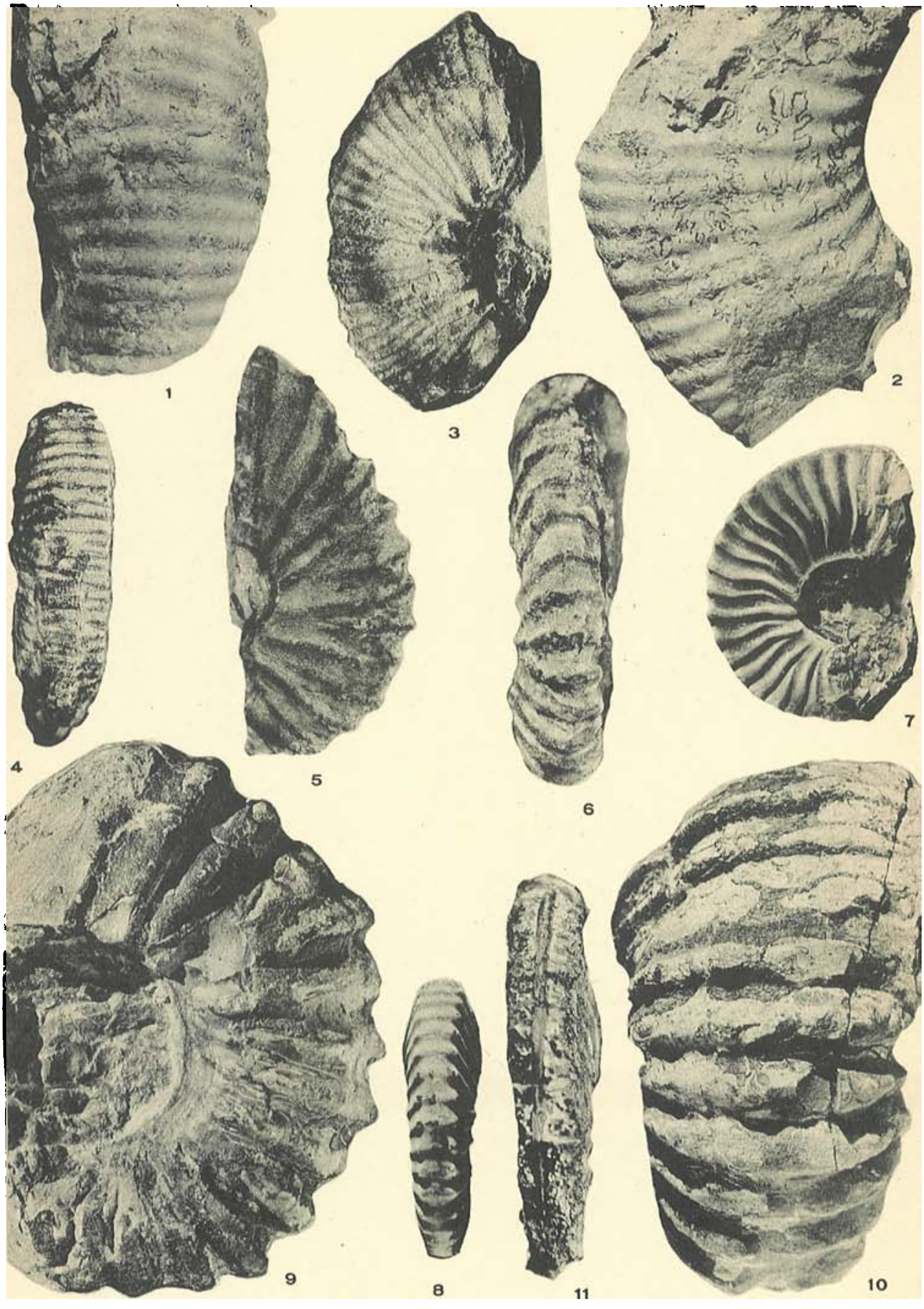
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PLATE 62

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Hypacanthoplites sellardsi Scott, n.sp., x1 1038

1, 2. Lateral and ventral views of holotype, No. 1136. Blue marls of the Cuchillo formation along the Sierra Blanca–Indian Hot Springs road 100 yards east of Quitman Summit and about 4 miles from Indian Hot Springs, Hudspeth County, Texas (Loc. M2).

Dufrenoya aff. *D. dufrenoyi* (D'Orbigny) Burckhardt, x1 1027

3, 4. Lateral and ventral views of large specimen (No. 1170) taken from Standard Oil Company No. 1 Fudicker well, Webster Parish, Louisiana (Loc. M58).

Hypacanthoplites cragini Scott, n.sp., x1 1045

5, 6. Lateral and ventral views of holotype, No. 1141. Crane's Mill, on Guadalupe River in Comal County, Texas (Loc. M50).

Hypacanthoplites quitmanensis Scott, n.sp., about x¼ 1040

7. Lateral view of large cotype (No. 1137) greatly reduced; ventral view of other cotype in Plate 65, figure 6. Blue marls of the Cuchillo formation along the Sierra Blanca–Indian Hot Springs road 100 yards east of Quitman Summit and about 4 miles from Indian Hot Springs, Hudspeth County, Texas (Loc. M2).

Parahoplites umbilicostatus Scott, n.sp., x1 1029

8. Ventral view of holotype, No. 1129; lateral view in Plate 63, figure 10. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Dufrenoya justinae (Hill), x1 1022

9. Lateral view of large specimen, topotype (No. 1123), to show decreasing prominence of costae on older whorls. Cow Creek in northwest Travis County, Texas (Loc. M45).

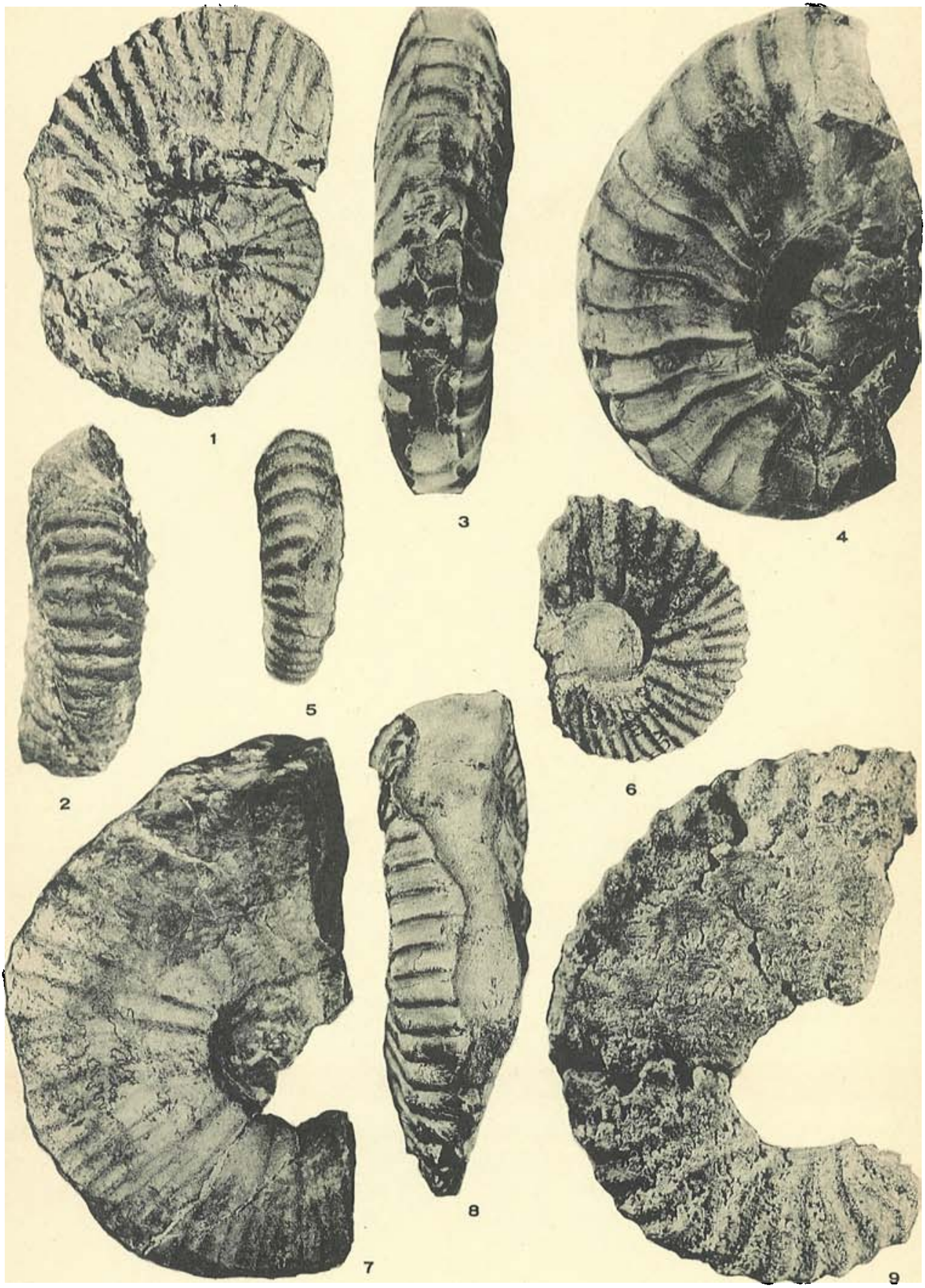
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PLATE 63

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Hypacanthoplites rugosus Scott, n.sp., x½ 1045

1, 2. Lateral and ventral views of holotype, No. 1140. Rebecca Creek, Comal County, Texas, about 4 miles northeast of the town of Spring Branch (Loc. M22).

Hypacanthoplites mayfieldensis Scott, n.sp., x½ 1043

3, 4. Ventral and lateral views of specimen No. 1145 from escarpment south of Little Blanco River, Blanco County, Texas (Loc. M21).

5, 6. Ventral and lateral views of holotype, No. 1144. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Rhytidhoplites robertsi Scott, n.gen., n.sp., x1 1035

7. Lateral view of holotype, No. 1133; ventral view in Plate 61, figure 11. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Dufrenoya robusta Scott, n.sp., x1 1025

8, 9. Lateral and ventral views of holotyps, No. 1135. From road cut exposure one-half mile from Fischer's Store on the Crane's Mill road, Comal County, Texas (Loc. M19).

Parahoplites umbilicostatus Scott, n.sp., x1 1029

10. Lateral view of holotype, No. 1129; ventral view in Plate 62, figure 8. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

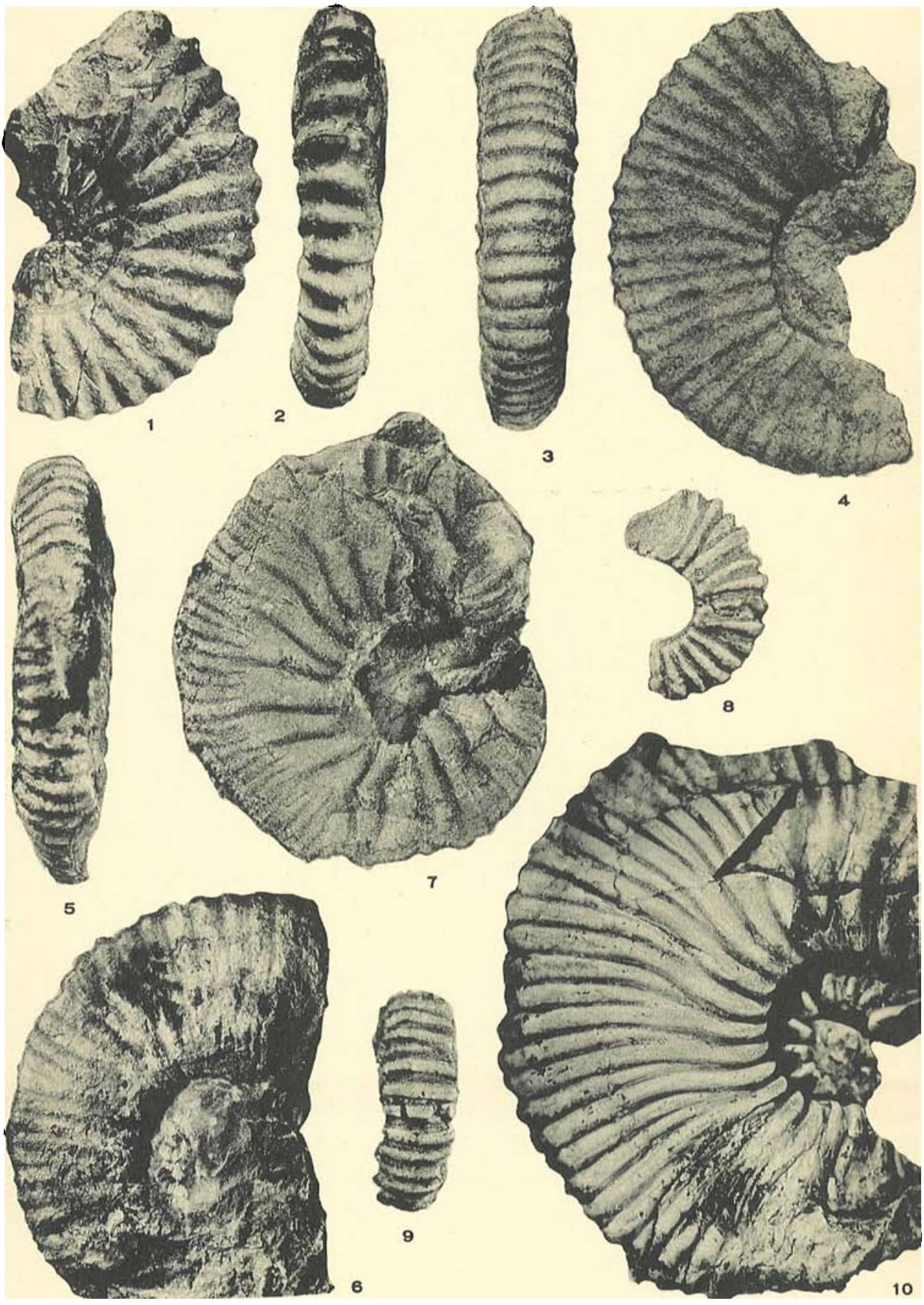
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PLATE 64

All from Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

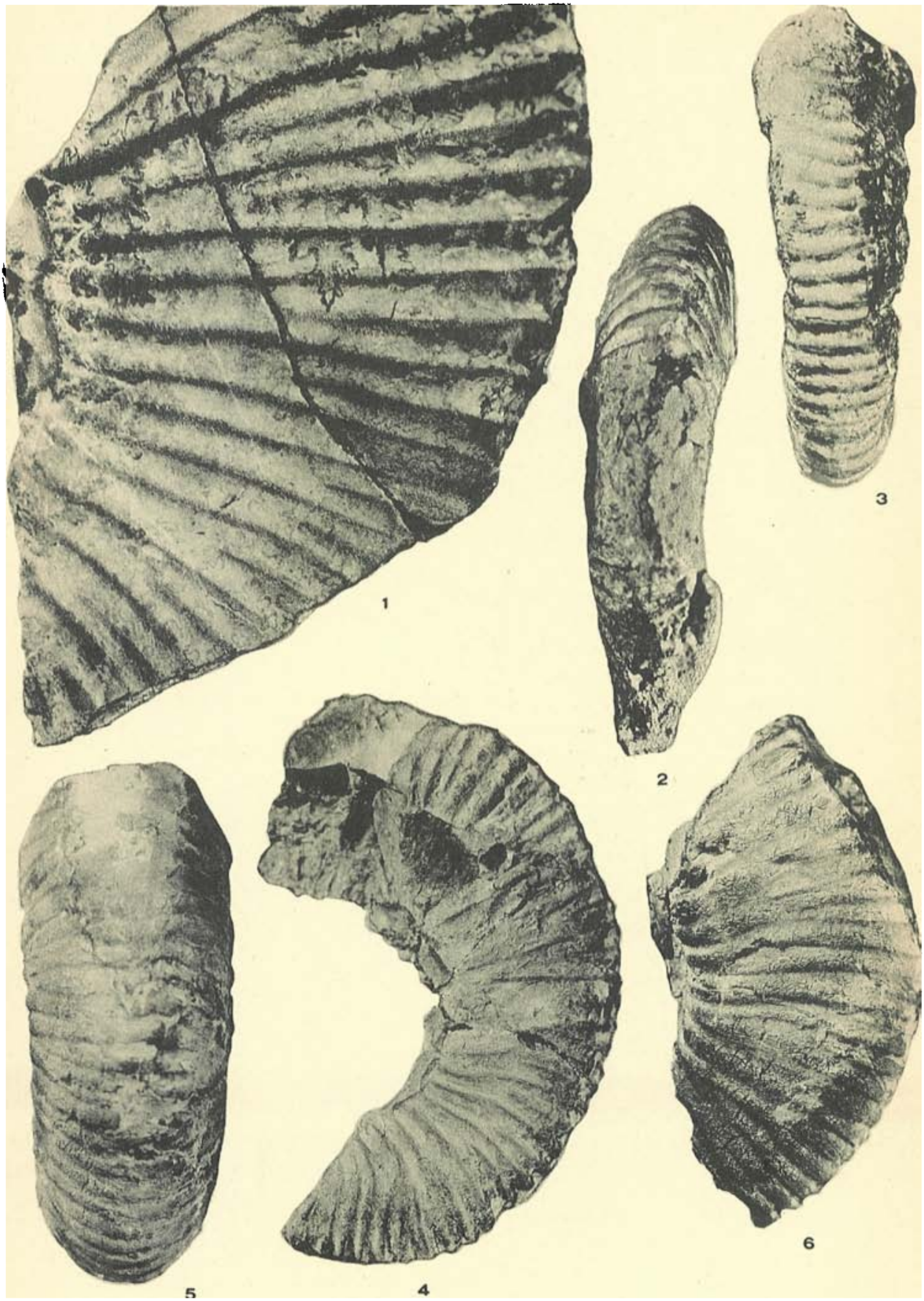

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PLATE 65

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Sonneratia trinitensis Scott, n.sp., x½ 1057

1, 2. Lateral and apertural views of holotype, No. 1149. First gorge of the canyon of the Rio Grande which begins about 1 mile below Indian Hot Springs, Hudspeth County, Texas (Loc. M6).

Hypacanthoplites bakeri Scott, n.sp., x1 1042

3, 4. Ventral and lateral views of holotype, No. 1138; parts of shell removed to reveal suture. Mayfield Canyon in the southern Quitman Mountains, Hudspeth County, Texas (Loc. M1).

Hypacanthoplites, sp.ind., x1 1047

5. View of specimen (No. 1142) as taken from well core of United Gas P. S. No. 1 Meadows well, Claiborne Parish, Louisiana (Loc. M20).

Hypacanthoplites quitmanensis Scott, n.sp., x½ 1040

6. Ventral view of one of cotypes, No. 1137; possibly part of specimen figured in Plate 62, figure 7. Blue marls of the Cuchillo formation along the Sierra Blanca-Indian Hot Springs road 100 yards east of Quitman Summit and about 4 miles from Indian Hot Springs, Hudspeth County, Texas (Loc. M2).


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PLATE 66

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Knemiceras roemeri (Cragin), x1 1067

1. Lateral view of plesiotype, No. 1155; ventral view in Plate 67, figure 5. Banks of Paluxy Creek and its tributaries 4½ miles above Glen Rose, Somervell County, Texas (Loc. M54).

8. Ventral view of specimen (No. 1156) showing living chamber; lateral view in Plate 68, figure 1. Glen Rose beds at the town of Glen Rose in Somervell County, Texas (Loc. M52).

Sonneratia minima Scott, n.sp., x1 1060

2. Ventral view of holotype, No. 1151; lateral view in Plate 67, figure 7. First gorge of the canyon of the Rio Grande which begins about 1 mile below Indian Hot Springs, Hudspeth County, Texas (Loc. M6).

Pseudosonneratia cuchillensis Scott, n.sp., x1 1063

3, 4. Lateral and apertural views of holotype, No. 1153. First gorge of the canyon of the Rio Grande which begins about 1 mile below Indian Hot Springs, Hudspeth County, Texas (Loc. M6).

Knemiceras azlense Scott, n.sp., x1 1070

5, 6. Ventral and lateral views of one of cotypes, No. 1159.

10. Apertural view of one of cotypes, No. 1158; lateral view in Plate 68, figure 2.

In the bed of Ash Creek under the concrete bridge of the Jacksboro highway one-fourth mile southeast of Azle, Tarrant County, Texas (Loc. M55).

Knemiceras trinitense Scott, n.sp., x½ 1071

7. Ventral view of holotype, No. 1160; lateral view in Plate 68, figure 3. In the bed of Ash Creek under the concrete bridge of the Jacksboro highway one-fourth mile southeast of Azle, Tarrant County, Texas (Loc. M55).

Sonneratia whitneyi Scott, n.sp., x½ 1059

9. Ventral view of holotype, No. 1150; lateral view in Plate 67, figure 4. Spring Branch, near Guadalupe River, western Comal County, Texas (Loc. M57).

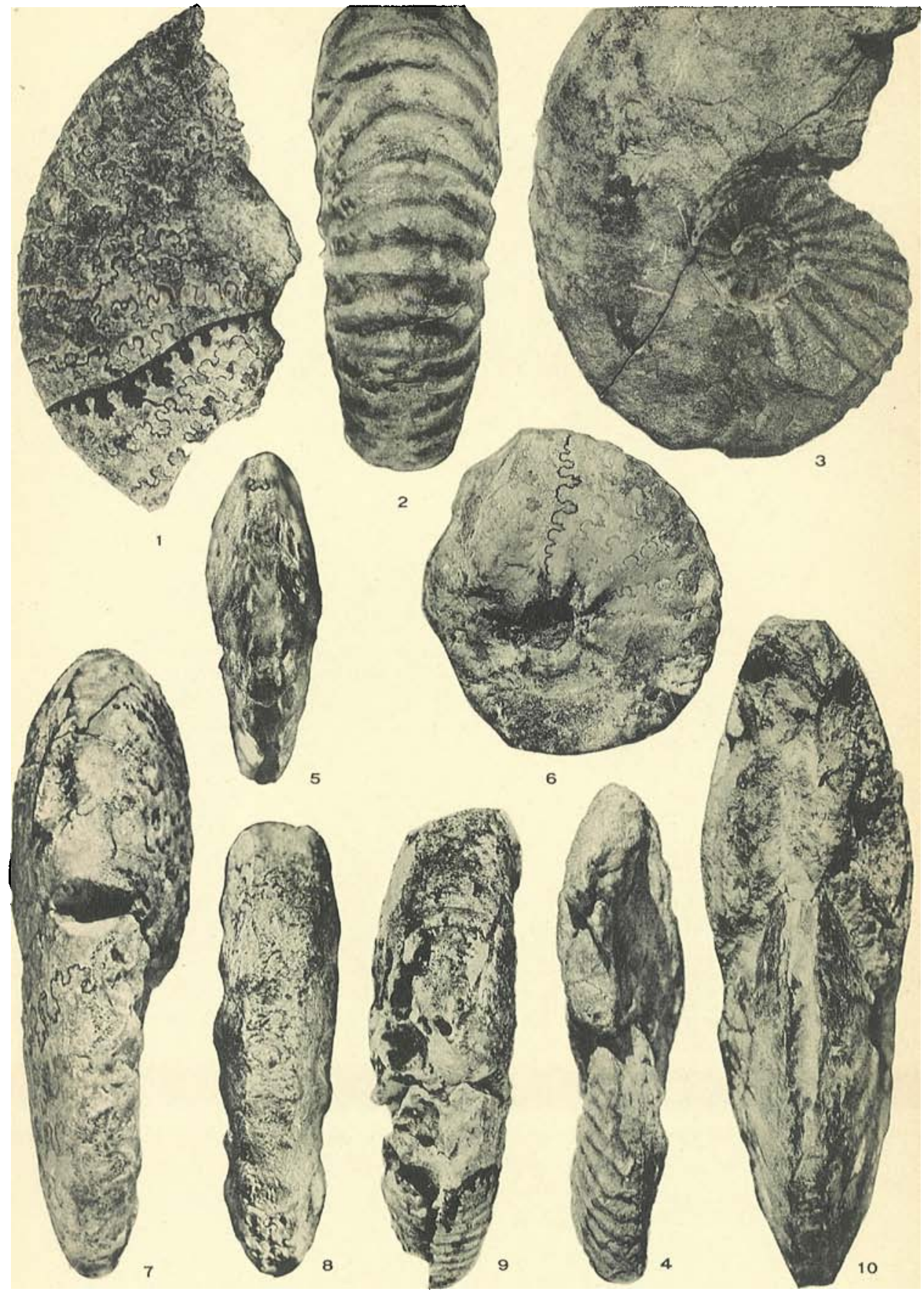
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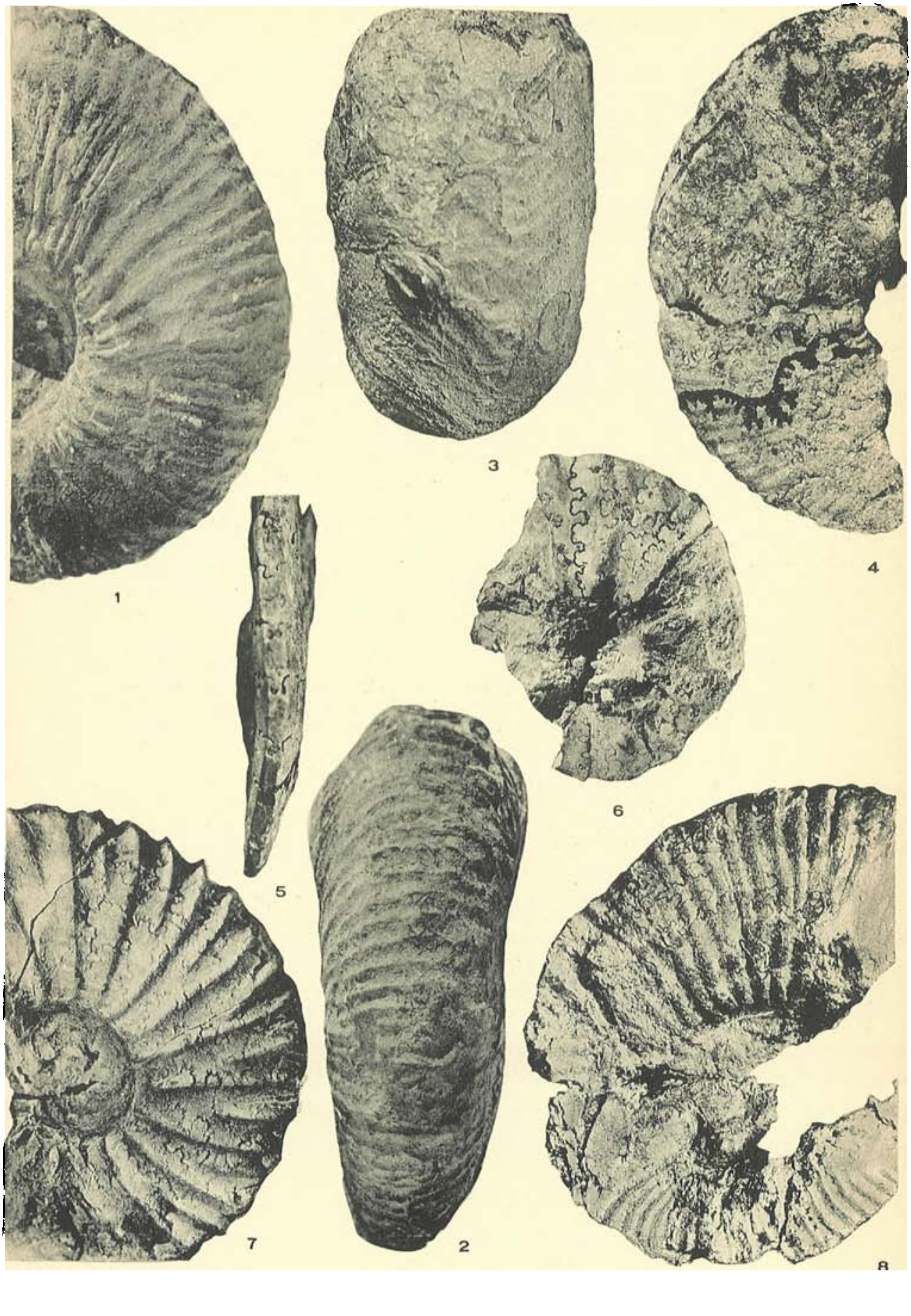
PLATE 67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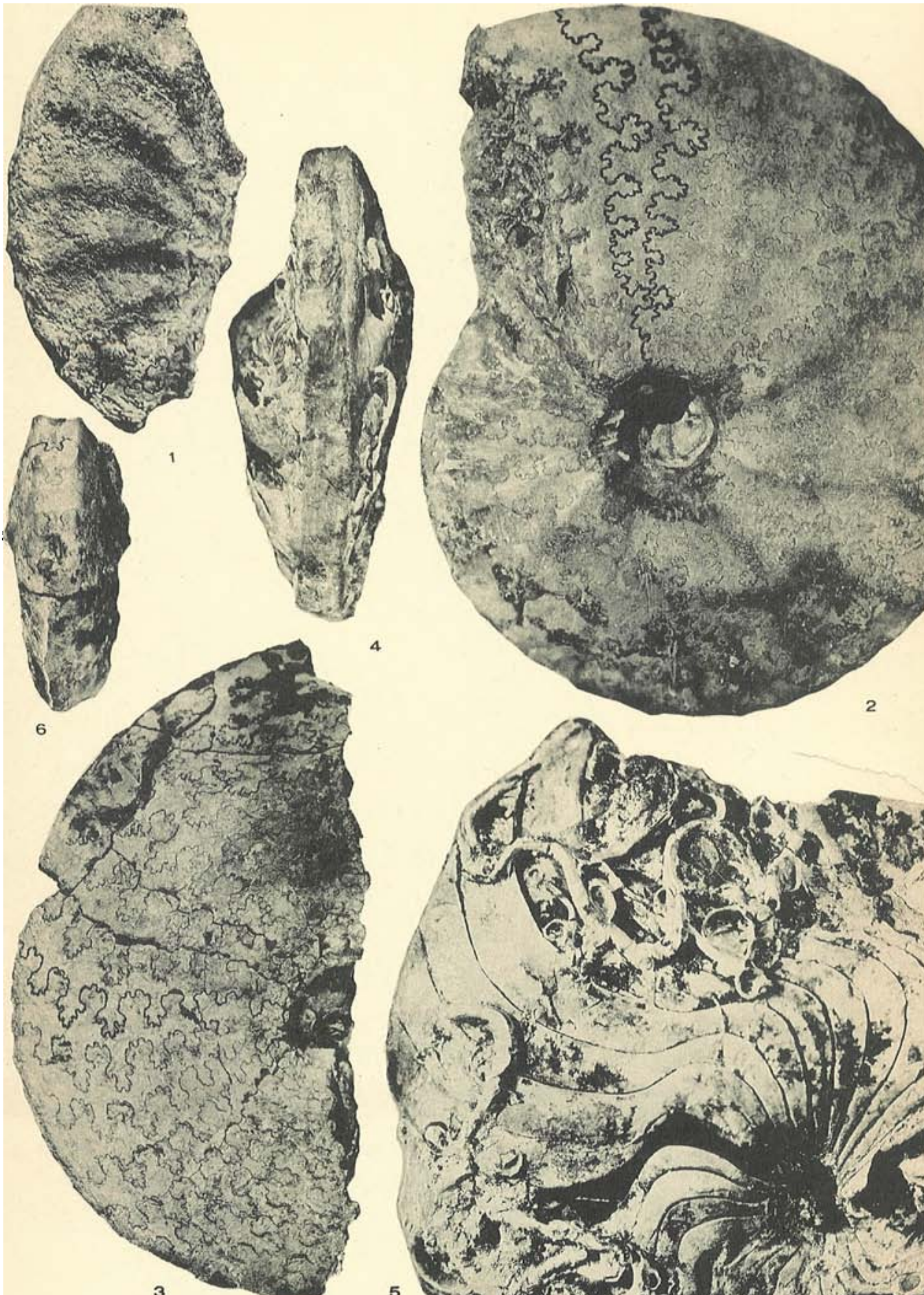
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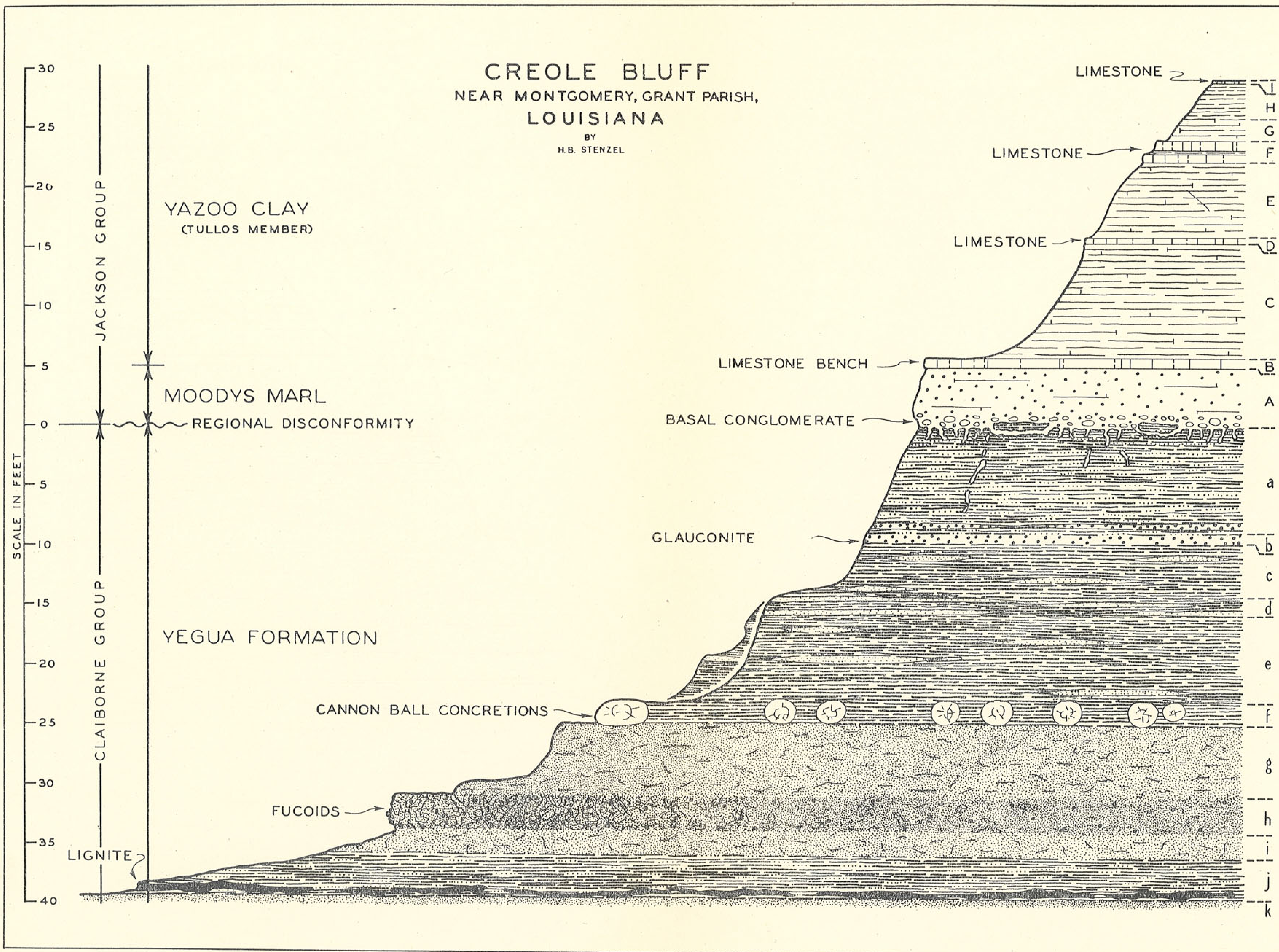
CREOLE BLUFF
NEAR MONTGOMERY, GRANT PARISH,
LOUISIANA
BY
H.B. STENZEL
SCALE IN FEET
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35
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JACKSON GROUP
CLAIBORNE GROUP
YAZOO CLAY
(TULLOS MEMBER)
MOODYS MARL
REGIONAL DISCONFORMITY
YEGUA FORMATION
LIMESTONE
LIMESTONE
LIMESTONE
LIMESTONE BENCH
BASAL CONGLOMERATE
GLAUCONITE
CANNON BALL CONCRETIONS
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SUBSURFACE STRUCTURE ON ELLENBURGER UNITS IN NORTH-CENTRAL TEXAS

ELLENBURGER OUTCROPS (FROM U.S.G.S. MAP OF TEXAS)

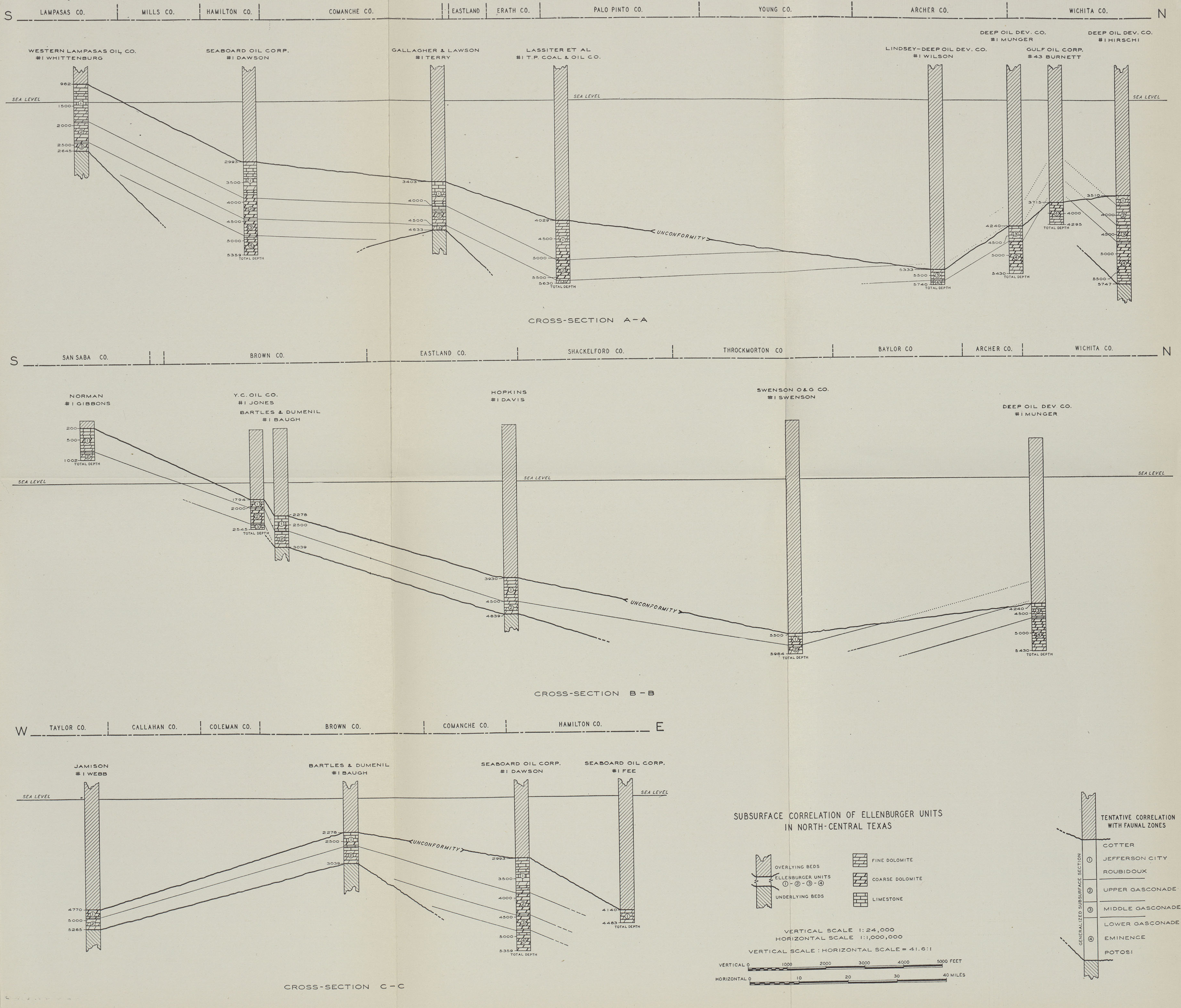
SCALE 1:1,000,000

0 10 20 30 40 MILES

CONTOUR INTERVAL 500 FEET

CONTOURED ON TOP OF UNIT 2

CONTOURED ON TOP OF UNIT 4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LAMPASAS CO.
MILLS CO.
HAMILTON CO.
COMANCHE CO.
EASTLAND
ERATH CO.
PALO PINTO CO.
YOUNG CO.
ARCHER CO.
WICHITA CO.
N
WESTERN LAMPASAS OIL CO. #1 WHITTENBURG
SEABOARD OIL CORP. #1 DAWSON
GALLAGHER & LAWSON #1 TERRY
LASSITER ET AL #1 T.P. COAL & OIL CO.
LINDSEY-DEEP OIL DEV. CO. #1 WILSON
DEEP OIL DEV. CO. #1 MUNGER
GULF OIL CORP. #43 BURNETT
DEEP OIL DEV. CO. #1 HIRSCHI
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UNCONFORMITY
TOTAL DEPTH
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SAN SABA CO.
BROWN CO.
EASTLAND CO.
SHACKELFORD CO.
THROCKMORTON CO
BAYLOR CO
ARCHER CO.
WICHITA CO.
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NORMAN #1 GIBBONS
Y.C. OIL CO. #1 JONES
BARTLES & DUMENIL #1 BAUGH
HOPKINS #1 DAVIS
SWENSON O&G CO. #1 SWENSON
DEEP OIL DEV CO. #1 MUNGER
SEA LEVEL
UNCONFORMITY
TOTAL DEPTH
CROSS-SECTION B-B
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TAYLOR CO.
CALLAHAN CO.
COLEMAN CO.
BROWN CO.
COMANCHE CO.
HAMILTON CO.
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JAMISON #1 WEBB
BARTLES & DUMENIL #1 BAUGH
SEABOARD OIL CORP. #1 DAWSON
SEABOARD OIL CORP. #1 FEE
SEA LEVEL
UNCONFORMITY
TOTAL DEPTH
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SUBSURFACE CORRELATION OF ELLENBURGER UNITS IN NORTH-CENTRAL TEXAS
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COARSE DOLOMITE
LIMESTONE
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HORIZONTAL SCALE 1:1,000,000
VERTICAL SCALE : HORIZONTAL SCALE = 41.6:1
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UPPER GASCONADE
MIDDLE GASCONADE
LOWER GASCONADE
EMINENCE
POTOSI

W CROSS SECTION OF THE SOUTHERN QUITMAN MOUNTAINS IN TEXAS E

GAYLE SCOTT