# University of Texas Bulletin

No. 2132: June 5, 1921

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BY

Frederick B. Plummer and Raymond C. Moore

Bureau of Economic Geology and Technology
Division of Economic Geology
J. A. Udden, Director of the Bureau and Head of the Division

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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. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

# Stratigraphy of the Pennsylvanian Formations of North-Central Texas*

BY

Frederick B. Plummer and Raymond C. Moore

*The Bureau of Economic Geology and Technology wishes to express its thanks to the liberal management of the Roxana Petroleum Company for having donated this valuable contribution to the knowledge of the Pennsylvanian in north-central Texas. In making the donation the company has performed a service which will be highly appreciated by the entire geological profession in our country.—J. A. U.

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## FOREWORD

The studies on which this report is based were conducted under the direction of Mr. Plummer and were primarily concerned with the possible development of oil and gas in the north Texas Pennsylvanian area. Field work in the region of outcrop of the Bend group and the Strawn group in the Brazos Valley was done by Mr. Moore. Jointly with Mr. Plummer investigations of the stratigraphy and paleontology of the higher divisions of the Pennsylvanian were undertaken. Many of the fossil collections which were made during the course of work in the area were made by other geologists and referred to Mr. Moore for identification and study. There has not been opportunity for the completion of detailed studies of the sort that both writers are keenly anxious to have been able to make and the information which is here presented is to such an extent incomplete. In view, however, of the comprehensive scope of the area covered and the new information which has been gathered, it is believed that the observations here presented will be of value to future work.

In the preparation of the report the writers have conferred frequently concerning the many points in question which have arisen, but the conditions under which the work was done, especially the lack of opportunity, by reason of the geographic separation of the writers, for more effective joint work, have made difficult this task. While most of the stratigraphic nomenclature and classification is the work of Mr. Plummer and much the result of joint consideration, it has been necessary in the final revision of the manuscript which was done by Mr. Moore (Mr. Plummer being absent abroad) to make some changes for which he is responsible.

# STRATIGRAPHY OF THE PENNSYLVANIAN FORMATIONS OF NORTH-CENTRAL TEXAS

By FREDERICK B. PLUMMER and RAYMOND C. MOORE

## INTRODUCTION

### LOCATION AND EXTENT OF AREA

The Pennsylvanian area of north-central Texas may be described with reference to the Mid-Continent field as two great inliers of Carboniferous sediments that protrude through the Cretaceous strata on the east and dip beneath Permian rocks on the west and north. The two areas are separated by a narrow tongue of Cretaceous (Trinity) sand, and the southernmost outcrop abuts Ordovician rocks for a short distance along the Llano uplift, so that the southern portion does not possess the relationships of a true inlier.

The total area covered by the two great inliers is approximately 7000 square miles. It includes the west portion of Montague, the southeast part of Clay, the greater portion of Jack, Young, Stephens, Palo Pinto, Eastland, Brown, the eastern half of Coleman, the northern part of San Saba, and the northeast part of McCulloch counties. The shape and location of these Pennsylvanian areas are shown on the index map, Figure 1.

### PREVIOUS GEOLOGIC WORK

*General Discussion.*—The Pennsylvanian strata of north-central Texas furnish a complete and beautifully exposed section exceedingly variable in lithologic character and very prolific in well-preserved fossils. Yet, because of their isolation from the classic Mississippi Valley section, detailed study of them has been long delayed. The discovery in recent years of great petroleum resources within this area has brought to it many geological workers and has served as a great stimulus to the study of the stratigraphy, the differentiation, and correlation of its formations with those of other parts of the Mid-Continent region. Only recently, therefore, has it been receiving its due amount of attention.

The Pennsylvanian series of Texas was first explored by Roemer, and later by Shumard, Ashburner, and others, but the only publications that deal essentially with the stratigraphy of the north Texas Pennsylvanian area have been written by Tarr,[1] Cummins,[2-3] and Drake[4] in the early volumes of the Geological Survey of Texas.

*Work of Tarr.*—R. S. Tarr was the first to observe the three general groups of sediments in the Carboniferous system of Texas and in his pre-

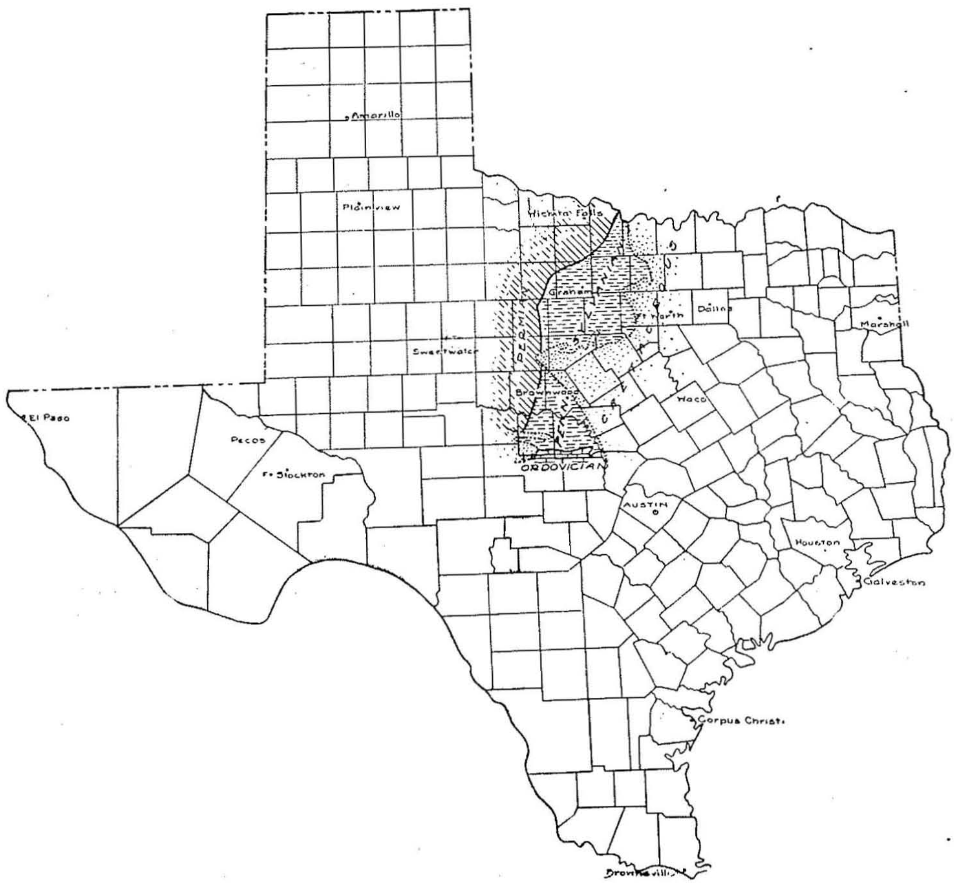


Fig. 1

Index Map of Texas Showing Area Covered by This Report

liminary paper classified them into a lower group of limestones which he believed to be Mississippian in age; a middle group of alternating sandstones, shales, conglomerates, and limestones, which he divided into the

[1]Tarr, R. S., A preliminary report on the coal fields of the Colorado River: Geol. Surv. Texas, 1st Ann. Rept., pp. 201-216, 1889.

[2]Cummins, W. F., The southern border of the central coal fields: Geol. Surv. Texas, 1st Ann. Rept., pp. 145-182, 1889.

[3]Cummins, W. F., Report on the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., pp. 359-394, 1890.

[4]Drake, N. F., Report on the Colorado coal field of Texas: Geol. Surv. Texas 4th Ann. Rept., pp. 357-481, 1892.

Richland, Brownwood, Milburn, and Waldrip formations; and an upper group of limestones which he called the Coleman formation. The following diagram shows the relationship of the six formations with later divisions.

| **Present Report** | **Tarr's Report** |
| --- | --- |
| Albany | Coleman |
| Cisco | Waldrip |
| Canyon | Brownwood and Milburn |
| Strawn | Richland |
| Bend | Basal limestone |

*Work of Cummins.*—Cummins in his report shows clearly that the strata of the north Texas coal fields are of Pennsylvanian age. He measured the section accurately, described the strata, and proposed a very good classification of the sediments. This pioneer worker deserves much credit, for, considering the condition of the frontier country at that time, the task was most excellently done. Later geologists can add details and derive new conclusions, but the observations of Cummins will stand as a tribute to his keenness and will be an inspiration to the present and future workers. In the classification made by Cummins[5] the divisions of the Pennsylvanian are described as follows:

1. Bend: The name Bend[6] was proposed for the black shales and limestones typically exposed at McAnnelly's Bend of the Colorado River in

[5]Cummins, W. F., Report on the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., p. 375, 1890.

[6]See Report of the State Geologist: Geol. Surv. Texas, 1st Ann. Rept., p. lxv, 1889.

San Saba County for the strata which overlie the Ordovician rocks. Although resting unconformably beneath the coal-bearing Carboniferous sandstones, they contain a preponderance of Coal Measures fossils and were therefore thought to belong to the Pennsylvanian. The division was first referred by Tarr[7] to the Mississippian, then as a result of Cummins's[8] work was transferred to the Pennsylvanian system.

2. Millsap: The Millsap formation included[9] all strata in the valley of Brazos River from the top of the black shales of the Bend division to the bottom of coal seam No. 1. Later it was found that coal No. 1 could not be traced in the Colorado River valley, and the Millsap could not be separated as a distinct formation; therefore, the name was dropped by both the United States and the Texas surveys.

3. Strawn: The Strawn formation was made to embrace all the strata of the northern area from the bottom of coal No. 1 to the bottom of the heavy beds of limestone of the overlying Canyon division.

4. Canyon: Unfortunately the Canyon division was not clearly defined by Cummins. He states[10] "This division includes the heavy beds of limestone and is easily recognized by the fact that the limestones of other divisions are much thinner bedded."

5. Cisco: The Cisco formation included[11] all the strata that are made up of interbedded sandstones, limestones, and sandy shales above the heavy limestones of the Canyon division.

6. Albany: The Albany formation, which was at first believed to belong to the Coal Measures series, included those strata practically all of which are composed of thick limestones and shales, above the sandstones of the Cisco formation and below the Red Beds of the Permian. Later Cummins ascertained that the shales and limestones above the Cisco formation were equivalent to the Permian Red Beds of the Wichita district to which the name Wichita formation had been given, and the name Albany was dropped, though the series is still frequently referred to as the Wichita-Albany group.

*Work of Drake.*—The most detailed early work on the Pennsylvanian geology of Texas was done by Drake[12] who mapped the area along Colorado River Valley from the vicinity of Brownwood and Coleman to the Llano Mountains. He adopted the classification proposed by Cummins but defined the divisions more exactly by choosing a certain limestone to mark

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[7]Tarr, R. S., Preliminary report on the coal fields of the Colorado River: Geol. Surv. Texas, 1st Ann. Rept., p. 1889.

[8]Cummins, W. F., Report on the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., p. 372, 1890.

[9]Idem.

[10]Loc. cit., p. 374.

[11]Loc. cit., p. 375.

[12]Drake, N. F., Report on the Colorado coal fields of Texas: Geol. Surv. Texas, 4th Ann. Rept., pp. 357-481, 1812.

the top of each group. Thus Drake's Strawn formation included the strata from the upper black shale of the Bend formation to the base of the "Coral" limestone; his Canyon formation extended from the base of the "Coral" limestone to the top of the "Campophyllum" bed; and his Cisco formation included all strata from the top of the "Campophyllum" bed to the top of the Santa Anna Branch bed. The section as described by Drake along the Colorado River is shown graphically in Figure 2.

*Work of Hill, Gordon, Paige, and Udden.*—Besides Tarr, Cummins, and Drake, who have worked wholly on the Pennsylvanian strata, others have described certain parts of this series of beds in papers on other portions of Texas geology. The most noteworthy of these are R. T. Hill,[13] C. H. Gordon,[14] Sidney Paige,[15] and J. A. Udden.[16]

R. T. Hill in his monumental paper on the Cretaceous formations of the Black and Grand Prairies of Texas mentioned briefly the rocks of the Bend group in the vicinity of Marble Falls and gave them the name Marble Falls limestone.[17]

C. H. Gordon in studying the underground water supply of some of the counties of north-central Texas made a small-scale map showing the three Pennsylvanian formations and described as *Campophyllum*-bearing limestone outcropping east of Jacksboro as the top of the Canyon formation in Jack County.[18]

Sidney Paige in his folio on the geology of the Llano and Burnet quadrangles published an excellent description of the Bend strata. He used Hill's term "Marble Falls limestone" for the limestone member below and named the upper black shales the Smithwick shale.[19] A list of fossils from the Marble Falls limestone as identified by Girty was presented.

J. A. Udden[20] in his review of the geology of Texas describes briefly the several formations of the Pennsylvanian series and makes special comment on the lower Bend shale. Recently Girty[21] and Moore[22] have studied new

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[13]Hill, R. T., Geography and geology of the Black and Grand Prairies of Texas: U. S. Geol. Surv., 21st Ann. Rept., pt. 7, 1901.

[14]Gordon, C. H., Geology and underground waters of northeast Texas: U. S. Geol. Surv., Water Supply Paper 276, 1911.

[15]Paige, Sidney, Geology of the Llano and Burnet quadrangles: U. S. Geol. Surv. Geol. Folio 183, 1912.

[16]Udden, J. A., Baker, C. L., and Böse, Emil, Review of the geology of Texas: Bureau Econ. Geol. Univ. Texas, Bull. 44, 1916.

[17]Hill, R. T., loc. cit., p. 94.

[18]Gordon, C. H., loc. cit.

[19]Paige, Sidney, Geology of the Llano and Burnet quadrangles: U. S. Geol. Surv. Geol. Folio 183, p. 57, 1912.

[20]Udden, J. A., Baker, C. L., and Böse, Emil, Review of the geology of Texas: Bureau Econ. Geol. Univ. Texas, Bull. 44, 1916.

[21]Girty, G. H., and Moore, R. C., Age of the Bend series: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 418-420, 1919.

Girty, G. H., The Bend formation and its correlation: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 71-81, 1919.

[22]Moore, R. C., The Bend series of central Texas: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 217-241, 1919.

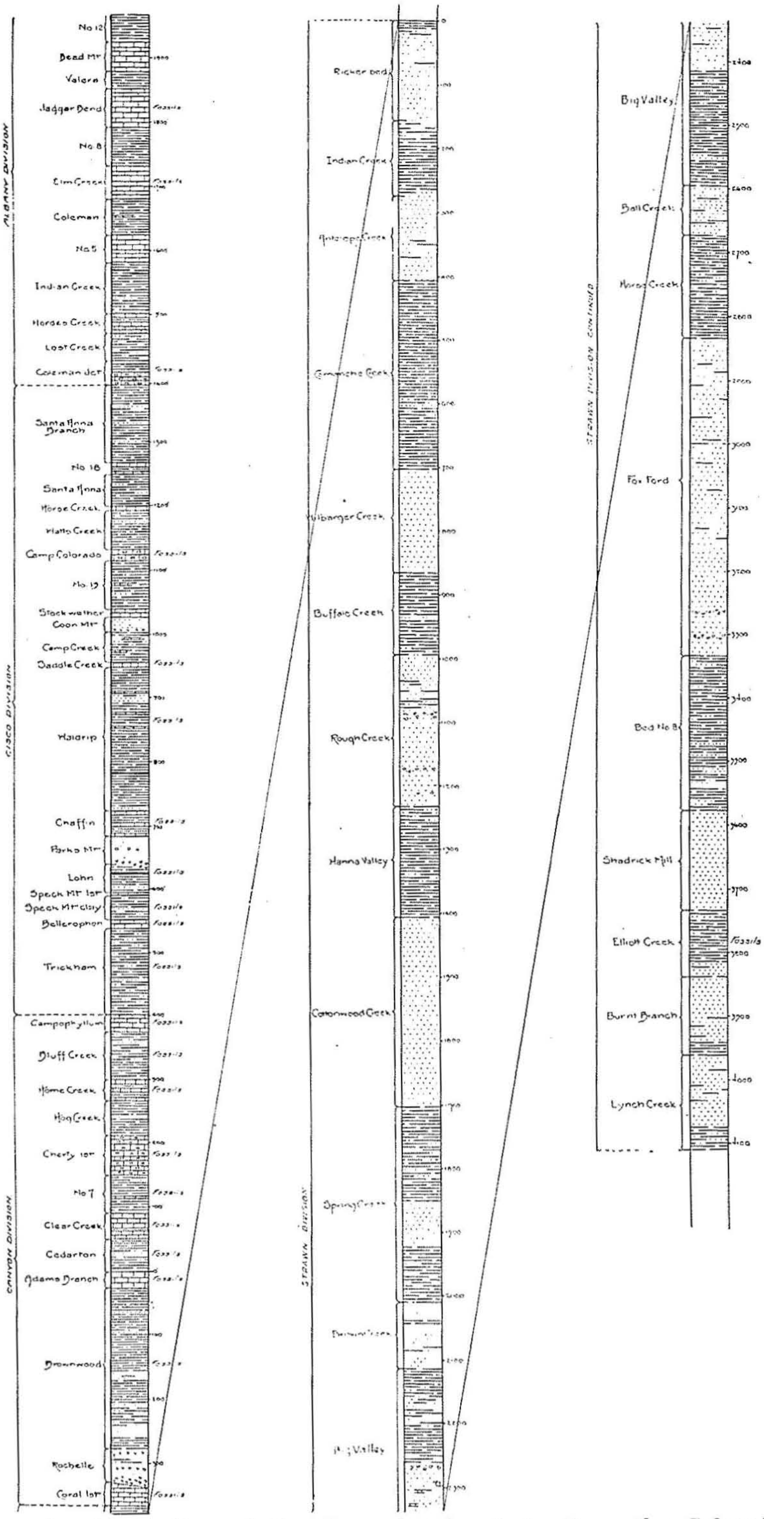


Figure 2. Graphic section of the Pennsylvanian beds along the Colorado River measured by Drake

collections of fossils from the Smithwick, Marble Falls, and lower Bend members and have concluded that the upper portions of the Marble Falls and that of the Smithwick shale are of Pennsylvanian age. Girty concludes that the fossils from the lower Bend shale are probably Mississippian, but Moore is of the opinion that the lower shale should be included in the Pennsylvanian.

## RECENT WORK OF THE GEOLOGISTS OF THE ROXANA PETROLEUM CORPORATION

In December, 1916, the geologists of the Roxana Petroleum Corporation began the systematic mapping of the structure of the northern portion of the Pennsylvanian area. Adequate topographic maps of this area were not available, and the need of a map similar to that of Drake's showing the principal strata was urgently felt. As the work progressed, the maps prepared by the different geologists were fitted together and the data slowly compiled for a new geologic map of north Texas. Preliminary papers on the results of this work were presented by the writers[23-24] at the meeting of the American Association of Petroleum Geologists in March, 1919. At this time the section of the strata in the northern portion of the Pennsylvanian area was briefly described, and a preliminary scheme of classification was proposed.

At the present time almost the entire area of the Pennsylvanian outcrops of north-central Texas has been mapped, and the results of the work are shown on Plate I, in the pocket. In the territory that was located favorably for oil production the outcrops of all the principal limestones have been traced by plane-table and alidade method, and hundreds of sections have been measured accurately and described. The extreme southwestern portion of the area shown on the map (Plate I), that is, the portion south of Colorado River and west of Brady, has not been traversed, and the position of the limestone members has been taken from Drake's report and map. Also the northwestern portion of the area in Shackelford County north and west of Albany has not been worked in detail. The outcrops of the limestone members in this portion were sketched on reconnaissance trips and are necessarily more generalized than the rest of the work.

The study of the strata, the taking of thousands of necessary elevations in the structural work, and the tracing of the outcrops has been the work of all the geologists of Roxana Petroleum Corporation working in Texas. The following, however, deserve special credit:

---

[23]Plummer, F. B., Preliminary paper on the stratigraphy of north-central Texas: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 132-150, 1919.

[24]Moore, R. C., Bend series of central Texas: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 215-241, 1919.

John Burtt and assistants mapped most of Jack and Young, and parts of Palo Pinto, Stephens, and Coleman counties.

Paul Applin, James Armstrong, Sam Wells, Chester Hammill and their assistants mapped Eastland, Callahan, Shackelford, and parts of Palo Pinto and Erath counties.

Chester Hammill, Angus McLeod, Grady Kirby, Paul Applin, and their assistants mapped Brown and the greater portions of San Saba, Mills, McCulloch, and Coleman counties.

E. G. Allen has furnished much valuable information concerning the subsurface character of the Bend group as a result of his studies of samples collected from wells in the oil fields.

Miss Linda Green has furnished the cross-section, Figure 4, as a result of her subsurface studies of well logs and well samples.

Special care has been taken to correlate accurately the strata across areas covered by Trinity (Cretaceous) sand, by careful comparison of the measured sections, comparison of the lithologic characteristics of the strata, and comparisons of the faunal groups where the beds are sufficiently fossiliferous. For example, the Saddle Creek limestone member by its position in the section 60 to 80 feet above the upper coal layers can not be mistaken. The Ranger limestone member because of its uniformly great thickness and chert content has distinguishing stratigraphic and lithologic characteristics. The Graham formation may everywhere be recognized by its prolific and characteristic fauna. The Graford formation contains a thin *Fusulina* bed by which it may readily be distinguished from the other Canyon divisions. In these ways the correlations of the principal limestones were made reasonably sure across the north-central Texas Pennsylvanian area.

The paleontological work has been done by Mr. Moore who spent two months during the summer of 1918 studying the Bend group in San Saba, Lampasas, and McCulloch counties. Sections were measured, and faunal collections as complete as possible were made. Later several collecting trips were made by the writers to various localities in the upper Pennsylvanian formations of the area, and fossils collected by the various geologists of the Roxana Petroleum Corporation were submitted to Mr. Moore for study. All fossil determinations, plates and faunal lists have been made by Mr. Moore, and he has written the paragraphs on the paleontology and correlations and is responsible for the faunal lists and paleontological determinations.

## ACKNOWLEDGMENTS

The president of the Roxana Petroleum Corporation, Mr. Waterschoot van der Gracht, and the head geologist, Mr. R. A. Conkling, have contributed largely by inspiration, advice, and helpful criticism. It is through their permission that the results are here set forth.

W. S. Adkins, of the Bureau of Economic Geology, University of Texas, has assisted greatly in proof-reading the manuscript and diagrams.

Dr. T. W. Stanton of the United States Geological Survey has given much assistance in selecting names for the limestones and formations and for suggestions and criticisms of the preliminary paper.

Wallace Pratt, chief geologist for the Humble Oil and Refining Company, has generously furnished information and contributed many helpful suggestions.

Mrs. F. B. Plummer has drawn the diagrams and maps, helped in the arrangement and copying of the manuscript, and has rendered invaluable assistance.

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## STRATIGRAPHY

### CONDITIONS OF SEDIMENTATION

The Pennsylvanian sediments of north Texas are essentially deposits laid down in shallow water. This period of sedimentation began in the region with conditions favorable for the deposition of petroliferous limestones and carbonaceous shales which make up the Bend group. At the end of this first epoch there was an elevation in the Llano Mountain area, an uplift of the old land masses to the east, and a folding of the rocks which resulted in more or less erosion, especially on top of the larger folds of the sediments previously deposited. Then followed a deposition of thick beds of sand and gravel interbedded with clay, which are now known as the Strawn group. These coarse sediments were succeeded largely by calcareous oozes and marls which make up the series of strata which form the Canyon group. The latter part of the period was marked by a long epoch of oscillating levels of the sea during which beds of clay, sand and limestone were deposited in alternating succession to form the series of strata which are included in the Cisco group.

During most of the Pennsylvanian period the shore-line was constantly oscillating, and the individual strata of the various epochs were laid down under various conditions of sedimentation which changed not only from one epoch to another in the same place, but varied laterally in short distances during the same epoch. In most places the limestones and sandstones are lentils and can be traced laterally only a few miles before grading into shales and sandy strata. However, at certain periodic spaces of time throughout each epoch, conditions in this epicontinental sea were apparently rather uniform over the area. For example, during the Graford stage of deposition in the Canyon epoch the same group of invertebrates lived in all parts of the north Texas sea, and during certain time intervals a remarkably uniform deposit was formed.

## CLASSIFICATION OF FORMATIONS

### CLASSIFICATION BY CUMMINS

In the classification of the Pennsylvanian beds presented by Cummins the beds of dominantly clastic type are distinguished from those of dominantly non-clastic type. His classification is thus based almost wholly on lithologic character. It has proved a convenient grouping and would be without fault if the same conditions of sedimentation producing beds of similar lithologic character had begun and ended at exactly the same time in all parts of the north Texas area. Unfortunately, however, this has not been the situation. For example, the dominant limestone epoch which produced the beds of the Canyon group began later and ended sooner in the northern portion of the area than in the southern, so that the Canyon formation of Cummins in Jack County is not exactly the same as his Canyon formation in Brown County.

### CLASSIFICATION BY DRAKE

Drake in his work in the Colorado coal fields has improved upon the classification of Cummins by choosing definite members to limit the top and bottom of the different formations in his area. Thus Drake defined his Canyon formation as extending from the top of the "Campophyllum" limestone above to the top of the "Coral" limestone below. This method of division, however, is unsatisfactory when applied to the stratigraphic section in the northern portion of this north Texas area. The "Coral" limestone is a lentil made up mainly of the coral *Chaetetes* which is not found outside the Brownwood district and can not be traced more than a few miles. It is undoubtedly somewhat higher in the section than the Palo Pinto limestone which constitutes the bottom of the Canyon division according to Cummins in his section of the strata in Palo Pinto County. Furthermore, the "Campophyllum" limestone when traced northward has been proved equivalent to the Gunsight limestone member of the Graham formation in the Cisco group. At the town of Gunsight in Eastland County this limestone is 240 feet above the base of the Cisco as defined by Cummins[25] in Palo Pinto County. It is also stratigraphically above the "Campophyllum" limestone at Jacksboro, which was chosen by Gordon as the top of the Canyon. Obviously then the Canyon formation as defined by Drake in the Brownwood district is not the same as the Canyon formation of Cummins in Palo Pinto County and is still different from the Canyon of Gordon in Jack County.

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[25]Cummins, W. F., loc. cit., p. 374.

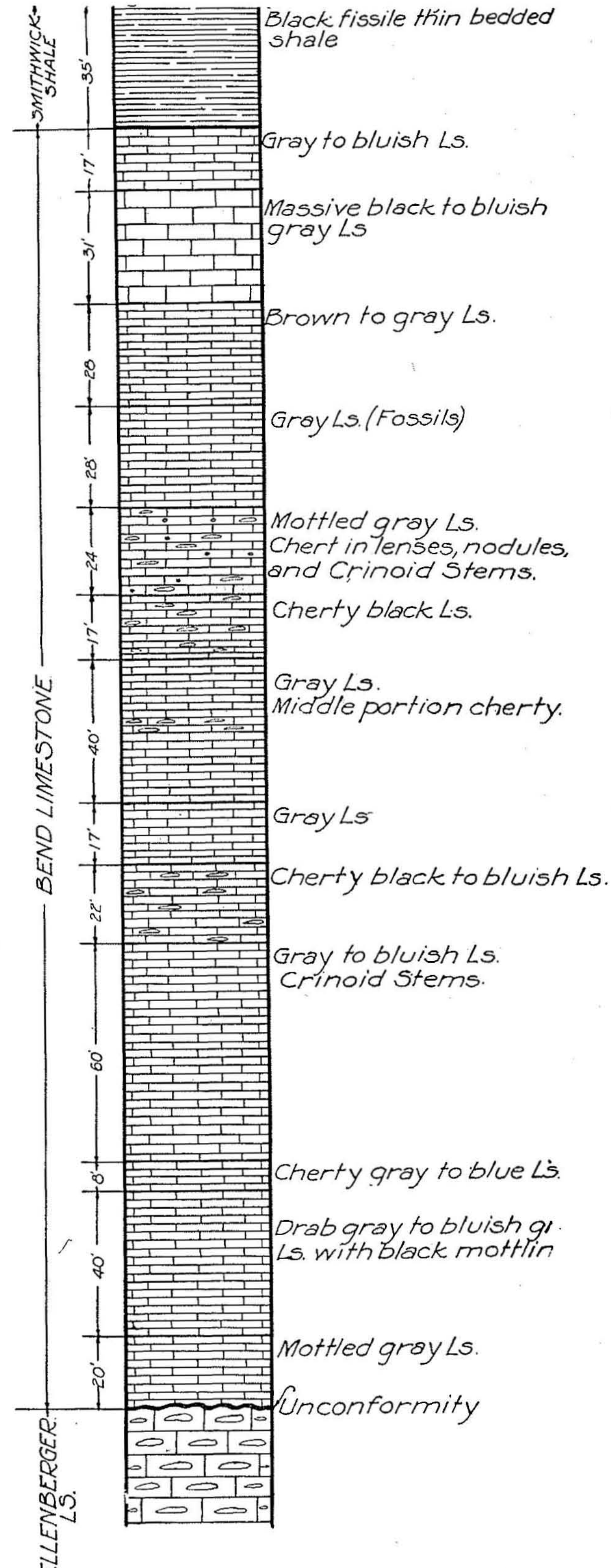


Figure 3. Sections of the Marble Falls formation measured along the Colorado River at Marble Falls

## PRESENT CLASSIFICATION

In making the new geologic map of the Pennsylvanian area an attempt has been made to present a classification that will conform as nearly as possible to the well-known groups of Cummins, and apply equally well to the whole of the area from Jacksboro to Brownwood. Such a classification must be definite and at the same time be based on natural divisions as far as possible, corresponding to natural geologic epochs, sub-epochs, and stages. In this attempt the section measured by Moore at Bend[26] and along Cherokee Creek in San Saba County has been taken as the type section of the lower part of the Texas Pennsylvanian (Section 1, Plate V), and the section measured by Cummins[27] along the Brazos River Valley from Millsap to Fort Belknap and in part of Drake in the Colorado River Valley, has been taken as the type section for the higher part. The rocks in other exposures have been correlated with these type areas.

On the basis of lithologic character and characteristic groups of fossils, the Carboniferous beds beneath the Strawn group in north-central Texas have long been distinguished from the higher stratigraphic divisions, and have been named the Bend group. Although the basal subdivision of the Bend, which is named the Barnett shale in this report, may prove to belong to the upper Mississippian, the term Bend is here retained to designate the strata which have heretofore been commonly included in this division. Probably no geologic division in the north Texas area is so widely known, and it is believed both unnecessary and unwise at this time to attempt to redefine and rename the stratigraphic group. The well established names Marble Falls limestone and Smithwick shale are employed to denote respectively the thick beds of limestone and the upper shale division of the Bend.

It is clear from Cummins' section and from his map[28] that his Canyon division included the strata from the top of the limestone at Finis in Jack County, now known to be equivalent to the Home Creek limestone of Drake, to the base of the limestone on the east branch of East Fork of Keechi Creek, now known as the Palo Pinto limestone (Plate V). Therefore, in the classification here proposed these two limestone members are used to separate the upper Pennsylvanian strata into three major groups: the Strawn below, the Canyon in the middle and including these two limestones, and the Cisco above. These major groups have been further separated into formations bounded stratigraphically by the most persistent and easily recognized limestones. Many of these persistent limestones form the tops of prominent escarpments, so that most formations extend from the top of one escarpment to the top of the next escarpment above. These escarpments may easily be traced for long distances, and the strata of

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[26]Moore, R. C., Bend series of central Texas: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 221-225, 1919.

[27]Cummins, W. F., Report on the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., Pls. XVI and XVIII, 1890.

[28]Cummins, W. F., loc. cit.

## Table 1

## CLASSIFICATION OF THE TEXAS PENNSYLVANIAN

| CUMMINS | DRAKE | | PRESENT CLASSIFICATION: Colorado River Valley | | | Brazos River Valley | | |
|---|---|---|---|---|---|---|---|---|
| CISCO FORMATION<br>Includes all the strata from the top of the massive Canyon limestones to the base of the Permian. | CISCO FORMATION<br>Separated into 19 divisions, from the base of the Trickham sandstones to the top of the Santa Anna Branch bed. | CISCO GROUP | PUTNAM FORMATION | 75-150 | Shale and thin linestone, Coleman Junction bed at top. | PUTNAM FORMATION | 175-200 | Shale and thin limestone, Coleman Junction bed at top. |
| | | | MORAN FORMATION | 200 | Shale and thin limestone, Sedwick limestone at top. | MORAN FORMATION | 175-300 | Shale and thin limestone, Sedwick limestone at top. |
| | | | PUEBLO FORMATION | 125-175 | Shale and thin limestone, Camp Colorado limestone at top. | PUEBLO FORMATION | 100-180 | Shale and thin limestone, Camp Colorado limestone at top. |
| | | | HARPERSVILLE FORMATION | 150-200 | Shale, sandstone, limestone and coal, Saddle Creek bed at top. | HARPERSVILLE FORMATION | 175 | Shale, sandstone, thin limestone and coal. Saddle Creek bed at top. |
| | | | THRIFTY FORMATION | 150-175 | Thin limestones and shale, Breckenridge limestone at top. | THRIFTY FORMATION | 100-150 | Thin limestones and shale, Breckenridge limestone at top. |
| | Campophyllum bed<br>Bluff Creek bed | | GRAHAM FORMATION | 90-125 | Thin coralline limestone and sandy shale. | GRAHAM FORMATION | 350-550 | Thick sandy shale, sandstones, conglomerate and thin limestones. |
| CANYON FORMATION<br>Includes the massive limestones in the middle part of the Pennsylvanian section of Texas. | Home Creek bed<br>Hog Creek bed | CANYON GROUP | CADDO CREEK FORMATION | 30-75 | Sandstone, shale and lenticular conglomerate, Home Creek limestone at top. | CADDO CREEK FORMATION | 100-175 | Sandstones, shale, with persistent Home Creek limestone at top. |
| | Cherty limestone<br>Bed No. 7<br>Clear Creek bed | | BRAD FORMATION | 200-240 | Sandy shale, limestone lentils, persistent, cherty Ranger lime stone at top. | BRAD FORMATION | 175-325 | Shale, sandstone and limestone lentils, with cherty Ranger limestone at top. |
| STRAWN FORMATION<br>Includes strata from base of massive limestones to coal bed No. 1. | Cedarton bed<br>Adams Branch bed<br>Brownswood bed<br>Rochelle conglomerate<br>Coral limestone | | GRAFORD FORMATION | 150-250 | Shale with lenses of sandstone, limestone and conglomerate, Adams Br. limestone at top. | GRAFORD FORMATION | 400 | Massive limestone and thick sandy shale. Adams Branch limestone at top. |
| | | | | | | PALO PINTO LIMESTONE | 50-100 | Massive light to dark limestone, pinches southward. |
| MILLSAP FORMATION<br>Below coal No. 1. | STRAWN FORMATION<br>Separated into 19 divisions consisting of shale, sandstone and sandy shale. | STRAWN GROUP | UNDIFFERENTIATED | 1200-3800 | Shale, massive sandstone conglomerate and few thin limestones. | MINERAL WELLS FORMATION | 600-750 | Massive, coarse sandstone, sandy shale and few very thin impure limestones. |
| | | | | | | MILLSAP FORMATION | 800-3000 | Dark blue to black shale, few limestones and light sandstones, coal at top. |
| BEND FORMATION<br>The black shale and limestone exposed at McAnnelly's Bend of Colorado River. | BEND (Not discussed) | BEND GROUP | SMITHWICK SHALE | 100-400 | Yellow green sandy shale overlying black fissile shale. | SMITHWICK SHALE | 100-600 | Dark fissile and sandy shale. |
| | | | MARBLE FALLS LIMESTONE | 200-600 | Dark gray to black, massive, crystalline limestone. | MARBLE FALLS LIMESTONE | 700-800 | Dark gray and black crystalline limestone and thick beds black shale. |
| | | | BARNETT SHALE | 0-150 | Dark gray and black fissile shale. | BARNETT SHALE | ? | Not known but probably present. |
| ELLENBURGER LIMESTONE | ELLENBURGER LIMESTONE | ORDOVICIAN | ELLENBURGER LIMESTONE | | Light gray and white massive limestone. | ELLENBURGER LIMESTONE | | Light gray and white massive limestone |

## TABLE 2. CORRELATION OF THE TEXAS PENNSYLVANIAN

| | Drake's subdivisions | PRESENT CLASSIFICATION: Colorado River Valley | Formations | Brazos River Valley | |
|---|---|---|---|---|---|
| ALBANY (Permian) | Jagger Bend bed | Limestone and shale | BELLE PLAINS FORMATION | Limestone and shale | WICHITA GROUP (Permian) |
| | Bed No. 8 | | | | |
| | Elm Creek bed | Elm Creek limestone | ADMIRAL FORMATION | Elm Creek limestone | |
| | Coleman bed | Limestone and shale | | Limestone and shale | |
| | Bed No. 5 | | | | |
| | Indian Creek bed | | | | |
| | Hordes Creek bed | Hordes Creek limestone | | | |
| | Lost Creek bed | Lost Creek shale | | | |
| | Coleman Junction bed | Coleman Junction limestone | PUTNAM FORMATION | Coleman Junction limestone | CISCO GROUP |
| CISCO | Santa Anna Branch bed | Santa Anna Branch shale | | Shale and thin limestones | |
| | Bed No. 18 | Sedwick limestone | MORAN FORMATION | Sedwick limestone | |
| | Santa Anna bed | Santa Anna shale | | Sandy shale | |
| | Horse Creek bed | Horse Creek limestone | | Dothan limestone lentil | |
| | Watts Creek bed | Watts Creek shale and sandstone | | Sandy shale | |
| | Camp Colorado bed | Camp Colorado limestone | PUEBLO FORMATION | Camp Colorado limestone | |
| | Bed No. 13 | Shale | | Shale | |
| | Stockwether bed | Stockwether limestone | | Eolian limestone | |
| | *Camp Creek bed | Camp Creek shale | | Shale | |
| | Saddle Creek bed | Saddle Creek limestone | HARPERSVILLE FORMATION | Saddle Creek limestone | |
| | | | | Shale and sandstone | |
| | | | | Belknap limestone | |
| | Waldrip bed | Shale, sandstone and coal | | Shale, sandstone and coal | |
| | | | | Crystal Falls limestone | |
| | | | | Shale | |
| | Chaffin bed | Breckenridge limestone | THRIFTY FORMATION | Breckenridge limestone | |
| | | Shale, sandstone and limestone | | Shale | |
| | Parks Mountain bed | | | Blach Ranch limestone | |
| | Lohn bed | Speck Mountain limestone | | Shale and sandstone | |
| | Speck Mountain limestone | Shale, sandstone and limestone | | Ivan limestone | |
| | Speck Mountain clay | | | Shale and sandstone | |
| | Bellerophon bed | | | Limestone | |
| | | | | Avis sandstone | |
| | Trickham bed | Wayland shale | GRAHAM FORMATION | Wayland shale | |
| CANYON | Campophyllum bed | Gunsight limestone | | Gunsight limestone | |
| | | | | South Bend shale | |
| | | | | Bunger limestone | |
| | Bluff Creek bed | Bluff Creek shale | | Gonzales Creek shale | |
| | | | | Jacksboro limestone | |
| | | | | Finis shale | |
| | Home Creek bed | Home Creek limestone | CADDO CREEK FORMATION | Home Creek limestone | CANYON GROUP |
| | Hog Creek bed | Hog Creek shale | | Hog Creek shale | |
| | Cherty limestone | Ranger limestone | BRAD FORMATION | Ranger limestone | |
| | Bed No. 7 | Placid shale | | Seaman Ranch shale | |
| | Clear Creek bed | Clear Creek limestone | | | |
| | Cedarton bed | Cedarton shale | | | |
| | Adams Branch limestone | Adams Branch limestone | GRAFORD FORMATION | Adams Branch limestone | |
| | Brownwood bed | Brownwood shale | | Brownwood shale | |
| | Coral limestone† | Capps limestone | | | |
| | Rochelle conglomerate† | Rochelle conglomerate | | | |
| | | (Not present) | PALO PINTO LIMESTONE | Undifferentiated | |
| STRAWN | Ricker bed | | | Keechi Creek shale | STRAWN GROUP |
| | Antelope Creek bed | | | | |
| | Indian Creek bed | | | Turkey Creek sandstone | |
| | Comanche Creek bed | | | | |
| | Wilbarger bed | | | Salesville shale | |
| | Buffalo Creek bed | | | | |
| | Rough Creek bed | | | Lake Pinto sandstone | |
| | Hanna Valley bed | | MINERAL WELLS FORMATION | | |
| | Cottonwood Creek bed | | | East Mountain shale | |
| | Spring Creek bed | | | | |
| | Brown Creek bed | Undifferentiated | | Brazos River sandstone | |
| | Big Valley bed | | | | |
| | Bull Creek bed | | | Mingus shale | |
| | Horse Creek bed | | | | |
| | Fox Ford bed | | | | |
| | Bed No. 8 | | | Thurber coal | |
| | Shadrick Mill bed | | MILLSAP FORMATION | | |
| | Elliott Creek bed | | | | |
| | Burnt Branch bed | | | Undifferentiated | |
| | Lynch Creek bed | | | | |
| BEND | | Undifferentiated | SMITHWICK SHALE | Not exposed | BEND GROUP |
| | Undifferentiated | Undifferentiated | MARBLE FALLS LIMESTONE | Not exposed | |
| | | Undifferentiated | BARNETT SHALE | Not exposed | |

*Coon Mountain sandstone is Cretaceous.
†Drake's order reversed.

their slopes in many places have coarse sands and sandy shales at the base, fine shales and thin limestones above, and a thick limestone at the top. The series in each formation exhibits characteristics peculiar to the epoch during which they were deposited or have distinctive faunal families, so that the divisions are natural and easily recognized.

The Strawn group contains no persistent limestones, and as yet insufficient work has been done to warrant the exact correlation of any of the sandstone members in the Colorado River Valley with those of the Brazos River Valley. Consequently the Strawn beds in the different districts have been described separately. In the Brazos River Valley two main subdivisions have been recognized, each of which contains several members. In the Colorado River Valley Drake's 19 divisions have been retained. The Canyon group has been divided into four divisions, and the Cisco into five. The relationships of all the geologic units and brief stratigraphic divisions are presented in Table 2 and are shown graphically in Plate II. (Pocket)

## BEND GROUP

The lowermost strata of the Pennsylvanian in north-central Texas are exposed on the north and east flanks of the Llano Mountain area. They consist of gray and black limestone and beds of black and greenish shale which are different in lithologic character from the higher portions of the Pennsylvanian and are separated from them by an angular unconformity. These beds have been designated the Bend group from McAnnelly's Bend of the Colorado River in eastern San Saba County[29] and the name has come into such common usage not only among the scores of geologists who have been engaged in the oil fields of north-central Texas but among all those interested in the oil development of this region, that it may well be regarded as one of the most widely known of the geological units of the southwest. Notwithstanding some uncertainty at the present time as to whether all of the beds which have commonly been placed in the Bend are from the standpoint of geological age a unit, the name is used in this report to designate the lowermost group of Carboniferous rocks in the north-central Texas region. No other geological division in the area under consideration has such great economic importance or general interest.

### BEDS OF UNCERTAIN AGE

Under this head is included the lowermost portion of the North Texas Carboniferous, 10 to 50 feet in thickness at the outcrop, which has previously been known as the Lower Bend shale[30] and which is here named the Barnett shale. Many of its contained fossils are closely related to upper Mississippian forms and it is possible that this basal division belongs

[29]Cummins, W. F., loc. cit., p. lxv.

[30]Udden, J. A., Baker, C. L. and Böse, E., Review of the geology of Texas, Bur. Econ. Geol. and Tech., Bull. 44.

to the Mississippian portion of the Carboniferous.[31] On the other hand, as will be indicated in the discussion of the age and correlation of the Barnett shale, it is the opinion of some workers[32] that the beds in question are to be referred to the Pennsylvanian. In any case, it seems best for the present, tentatively to retain this basal shale as a part of the Bend group, to which it has previously been referred and to which it naturally and economically belongs.

### BARNETT SHALE

*Name and Stratigraphic Position.*—At the base of the Pennsylvanian formations and overlying the Ellenburger limestone in certain places around the Llano Mountains is a thin layer of soft shale, 10 to 50 feet in thickness, overlain by thin layers of brownish, concretionary, petroliferous limestone. These beds are here named the Barnett shale, from Barnett Springs, about five miles east of San Saba, near which is a typical exposure of the shale. As here defined the Barnett shale comprises all the shale and limestone strata between the massive beds of the Marble Falls limestone above and the Ellenburger (Ordovician) limestone, as observed in the Llano region and reported in well logs in north-central Texas.

*Extent and Thickness.*—The Barnett shale may be traced as a narrow belt between the Marble Falls limestone and the Ellenburger outcrop. Many of the roads in San Saba County follow the contact between the Marble Falls and Ellenburger limestones, because the weathering of the Barnett shale makes a narrow smooth pathway about the width of a road between the very rough, difficultly passable terranes on either side. In fact, the outcrop is in most places too narrow to show by a separate color on the map and it is represented by the line of contact between the limestones above and below. The maximum thickness of the shale on the outcrop is not over 50 feet, and in most places the beds are less than 30 feet in thickness. At Marble Falls and at the base of the Marble Falls outcrop south of Lampasas the formation is apparently lacking and the Marble Falls rests directly on the Ellenburger limestone (Fig. 4B). The Barnett shale is recorded in nearly all the well logs which have been drilled to the Ellenburger north of Brownwood, its average thickness ranging from 80 to 120 feet in this region. (Plate V)

*Noteworthy Exposures.*—Some of the best exposures of the Barnett shale are on Cherokee Creek southwest of the town of Bend, in the southeastern part of San Saba County. It may also be studied along the San Saba road five miles east of San Saba, and along the Bend-Cherokee road about ten miles west of Bend.

*Lithologic Character.*—Where exposed on the outcrop the Barnett shale weathers in most places to a yellow-gray, soft, clayey material containing

[31]Girty, George H., The Bend formation and its correlation, Bull. Am. Assn. Pet. Geol., vol. 3, pp. 71-81, 1919.

[32]Moore, Raymond C., The Bend series of central Texas, Bull. Am. Assn. Pet. Geol., vol. 3, pp. 217-241, 1919.

a few fossils. In other places it is a black, fissile, and non-fossiliferous shale. Samples from the wells show the original shale to be soft, black, and quite petroliferous, and in many places it will yield an odor of petroleum without heating.

The limestone just above the black shale, which contains nautiloids and Caneyellas of Mississippian aspect, is dark drab to brownish black in color, is shaly and weathers into rounded concretionary forms. The concretions when broken give a distinct odor of petroleum and most of them contain fossils. The following section measured on the San Saba-Chappel road shows the shale at its maximum thickness:

**Section Measured Along the San Saba-Chappel Road Just South of Simpson Creek**

| | Thickness Feet |
|---|---|
| MARBLE FALLS LIMESTONE— | |
| 3. Limestone, dark drab to black, fine-grained, thin-bedded, well-defined conchoidal fracture | 20 |
| BARNETT SHALE— | |
| 2. Shale, drab, gray to yellow-brown, sandy, with thin beds of soft and hard brown sandstone, few fossils | 55 |
| ELLENBURGER LIMESTONE— | |
| 1. Limestone, light blue gray, massive to thin-bedded, medium to rather coarse-grained, crystalline, some beds cherty, non-fossiliferous | 80 |

*Regional Variations.*—In the wells drilled in Mills, San Saba, and Brown counties the thickness of the Barnett shale varies much the same as it does on the outcrop. The wells listed in Table 3, for which trustworthy records were kept and samples saved, show the areas in which the Barnett shale is absent and the Marble Falls limestone lies directly in contact with the Ellenburger limestone.

**TABLE 3.—Wells in which the Marble Falls limestone lies in direct contact with the Ellenburger limestone.**

| Well Name | Company | Location |
|---|---|---|
| Cross No. 1 | Bishop Oil Co. | 9½ mi. N. of Regency, near Brown-Mills county line. |
| Cummins No. 1 | Coline Oil Co. | Near Locker, San Saba County. |
| Cawyer No. 1 | Burford Brimn | 2½ mi. SE. of Mercury, McCulloch County. |
| Matlock No. 1 | Pecan Bayou Oil Co. | 4 mi. E. of Brownwood, Brown County. |

The wells listed in Table 4, from which samples were also collected and studied, show the Barnett formation about the same thickness as in the best sections along the outcrop.

**TABLE 4.—Wells south of Brownwood which showed the thickness of the Barnett shale similar to that along the outcrop.**

| Well and Company | Location | Thickness Feet |
|---|---|---|
| Calloway, Lone Star Co. | | 40 |
| Coyle, Lucky Six Co. | 5 mi. SW. of Brownwood, Brown County | 30 |
| Knox-Andrews, Pippin Co. | 1 mi. S. of Elkins, Brown County | 45 |

In the northern portion of the area, as far north as Graham in Young County, a shale beneath the Marble Falls limestone has been encountered in wells drilled to the Ellenburger limestone. In Table 5 is a list of wells from which samples showed the thickness of this shale to be considerably greater than its average thickness along the outcrop.

**TABLE 5.—Wells north and east of Brownwood which showed thicknesses of the Barnett shale greater than the average thickness along the outcrop.**

| Well | Company | Location | Thickness Feet |
|---|---|---|---|
| Capps No. 1 | Texas Eastern | 2 mi. N. of Brownwood, Brown County.. | 125 |
| Baugh | Bartles-Dumenil | 8 mi. N. of Brownwood, Brown County.. | 120 |
| Weedon | Patridge | 6 mi. E. of Thrifty, Brown County........ | 125 |
| Neff | Sinclair-Gulf | 3½ mi. W. of Burkett, Coleman County | 80 |
| Rudd | Roxana | 3 mi. SW. of Gorman, Comanche County | 85 |
| Shoor | Humble | 6½ mi. S. of Cisco, Eastland County.... | 150 |
| Holcomb | Cosden | 2 mi. E. of Eastland, Eastland County.... | 132 |
| Seaman | Roxana | 6 mi. N. of Brad, Palo Pinto County...... | 140 |
| Arnold No. 2 | Texas | 9 mi. NW. of Graham, Young County.... | 140 |

The cause of the thinning and non-appearance of the Barnett shale in places along the outcrop and in sections of wells drilled south of Brownwood has not been definitely determined. Some geologists have regarded this condition as evidence of an erosional unconformity between the Marble Falls limestone and the Barnett shale and ascribe the absence of the shale to a pre-Marble Falls erosion period. Others have attributed its absence to non-deposition of the shale due to elevation of the Ellenburger floor in certain places, particularly around Llano Mountains, above the Barnett shale sea and to an overlap of the Marble Falls limestone on the Ordovician shore. The latter hypothesis seems better substantiated by observations: (1) In well logs where the Barnett shale is absent the Marble Falls limestone is much thinner due to the thinning or absence of the shale beds in the lower part of the Marble Falls, whereas the top of the Marble Falls and overlying Smithwick shale is of normal character and thickness (Plate V); (2) in places where several wells have been drilled to the Ellenburger, as those in the Sipe Springs-Gorman district, the top of this Ordovician limestone is known to be uneven, and though it is in general an old base-level surface, doubtless a few hills or monadnocks remained; (3) finally, no sand layers, coarse material, or Ellenburger pebbles are known to be present anywhere between the Marble Falls limestone and the Barnett shale either on the outcrop or in any of the hundreds of samples from wells at this horizon. Surely a marked unconformity above the Barnett shale would be shown by some evidence in the section.

*Paleontology.*—The fauna of the Barnett shale, as known at the present time, is not large but it has an important bearing on the problem as to the geologic age of the formation. Not all parts of the Barnett, so far as they have been studied, are by any means equally fossiliferous. The black, fissile, carbonaceous beds appear to contain no recognizable fossils; the yellowish, clay shales contain some fossils but the most fossiliferous portions of the formation appear to be some marly beds consisting of thin alternating beds of shale and shaly limestone such as appear in the vicinity of Barnett Spring on the road from San Saba to Bend. The locations where collections were made are shown on Plate VIII.

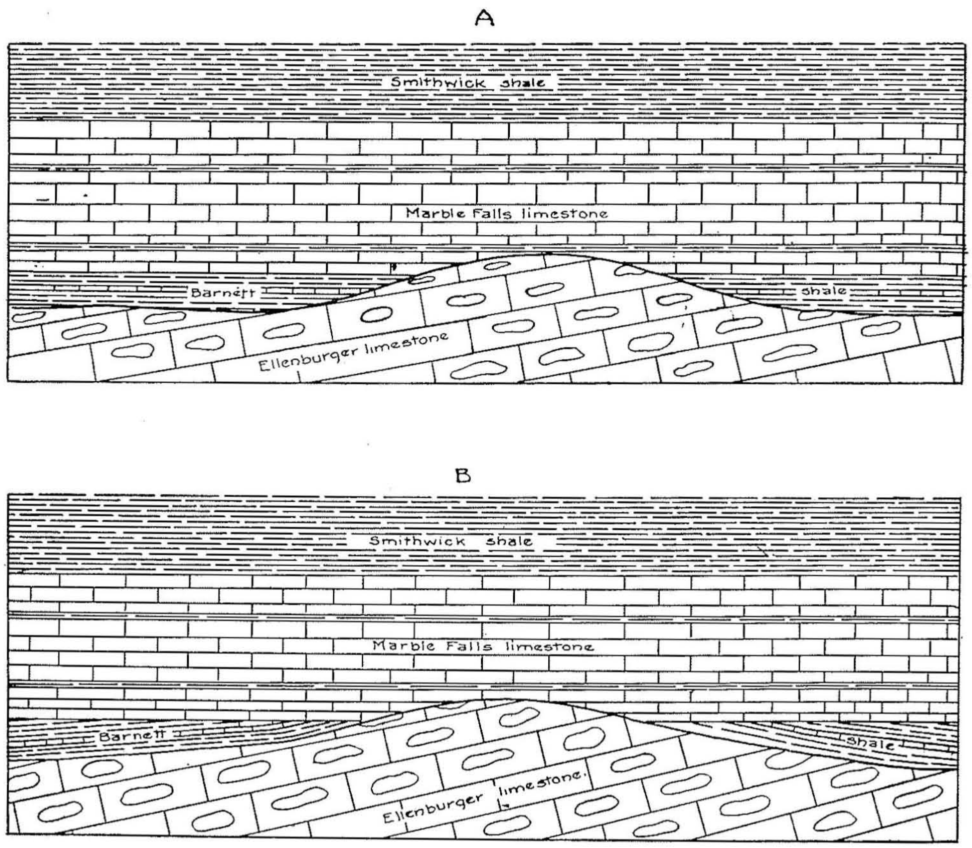


Figure 4. Diagram showing the possible relationships of the Bend group to the underlying Ellenburger limestone at Marble Falls

One collection was made from the shale beneath the Marble Falls limestone on the San Saba-Chappel road two miles southeast of San Saba. The fossils are weathered out of the shale and are well preserved.

**Fauna of the Barnett shale, southeast of San Saba**

*Leiorhynchus carboniferum* (Girty)
*Leda bellistriata* (Stevens)
*Glyphioceras* n. sp.

A second collection was obtained from calcareous nodules in the black shale on Wallace Creek about 9 miles southwest of San Saba. A considerable number of specimens was found here but almost all belong to a single species, *Ambocoelia planoconvexa.*

**Fauna of the Barnett shale, Southwest of San Saba**

Plant fossil (*Cordaites?*)
*Lingula albapinensis* Walcott
*Orbiculoidea* n. sp.
*Ambocoelia planoconvexa* (Shumard)

Girty[33] reports that about 35 to 40 species are contained in his collections from this horizon. They include a considerable number of cephalopods belonging to three or four species of goniatites, one or two species of pelecypods probably referable to the genus *Caneyella,* and brachiopods, the most important and abundant of which is *Leiorhynchus carboniferum.* (Plate VI).

Data are perhaps insufficient for an analysis of the Barnett shale fauna. It appears to be a typical shale fauna in that it contains a larger molluscan element than the limestone fauna above it. The most common and important forms are the brachiopods *Leiorhynchus carboniferum, Ambocoelia planoconvexa,* a series of small high-spired gastropods and the cephalopods belonging to the genus *Glyphioceras.* The last includes the two species which have been reported in some writing as *Goniatites striatus* and *G. crenistria.*[34]

A single specimen which is apparently referable without question to the common Pennsylvanian genus of protozoans, *Fusulina,* is contained in a collection of fossils made by Mr. Plummer from marly beds near Barnett Spring which appear to be transitional between the Barnett shale and the Marble Falls limestone. This shell is typical in form, about 1.0 mm. in diameter and 4 mm. in length. The specimen has not been thin-sectioned and has not been specifically identified. There has not, unfortunately, been opportunity for search for other specimens. On account of the absence of typical Fusulinas in Mississippian sediments and their common presence in rocks of Pennsylvanian age, the occurrence of this form in the basal part of the Bend is significant.

The brachiopods which have been studied from the Barnett include representatives of the genera *Lingula* and *Orbiculoidea* which appear to be associated characteristically with clastic, muddy sediments. They are not very readily or accurately identifiable but one is practically identical with Walcott's figures of *L. albapinensis* from the White Pine shale of Nevada. The most common species is a robust rhynchonelloid shell,

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[33]Girty, G. H., The Bend formation and its correlation, Bull. Am. Assn. Pet. Geol., vol. 3, pp. 72-73, 1919.

[34]The structural characters of the Barnett cephalopods under consideration place them in the genus *Glyphioceras* as now defined. Careful study of the specimens in hand makes very doubtful the equivalence of Hyatt's species *G. cumminsi* and *G. incisum* with *G. striatum* and *G. crenistria* respectively. The latter species are European forms which are questionably identified with American shells. While without doubt there is a general agreement in form and markings, important specific differences appear to exist.

*Leiorhynchus carboniferum,* first described by Girty from the Moorefield shale of northern Arkansas. This species is common also in the Caney shale of southern Oklahoma and is regarded by Girty as important evidence of the relation of the Barnett shale to those formations. *Cliothyridina,* which is represented by fragmentary material, is known both from the Mississippian and the Pennsylvanian but is more common in the former.

Among the pelecypods, *Leda bellistriata* (Plate VII) is very widely distributed and abundant in the Pennsylvanian of the Mississippi Valley and the Cordilleran region. It is reported from Stage B (Marmaton) to Stage G (Shawnee) in the Kansas section. However, this form is so similar to some of the Mississippian shells that with little doubt it has been confused in some of the identifications.

The cephalopods of the Barnett shale are without doubt an important element in the fauna which have a significant bearing on the age and correlation of the formation. Of these, four species are at present recognized: *Glyphioceras cumminsi, G. incisum,* a new species of *Glyphioceras* and *Gastrioceras entogonum.*

The genus *Glyphioceras,* to which it appears that a considerable portion of the old, broadly inclusive genus *Goniatites* should now be referred, is much the most abundantly represented in the Barnett fauna. Individuals of each of the species, especially in some localities, are very common while examples of *G. entogonum* are rather uncommon. *G. cumminsi* and *G. incisum,* while possessing readily distinguishable characters in form, sutures and surface ornamentation, are both medium-sized subglobose shells with low whorls and with the exterior marked by longitudinal and cross striae. The new species (Plate VII), which is very abundant and beautifully preserved, is very small and very unlike the other two.

*G. cumminsi* and *G. incisum* resemble respectively two European species, *G. striatum* and *G. crenistrium* which are characteristic fossils of the upper part of the Lower Carboniferous in Great Britain, Belgium, and Germany. In his monograph on the Carboniferous ammonoids of North America, Smith[35] identified these European species from two localities in the United States (1) the Moorefield shale at Moorefield and near Batesville, Arkansas, and (2) the Bend series near Lampasas and in San Saba County, Texas. Thus he referred Hyatt's species from the Barnett to the two Old World species. Shells apparently identical with Smith's were collected by Girty[36] from the Moorefield shale at Moorefield, Spring Creek, and Howard Wells, Arkansas. He referred them all to a new species *G. (Goniatites) choctawensis* which he recognized as related to *G. striatum* but evidently different from the European form. *G. choctawensis* has been identified in the Caney shale of southern Oklahoma. The species is

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[35]Smith, J. P., Carboniferous ammonoids of North America, U. S. Geol. Surv., Mon. 42, 1903, pp. 69-70, 80-81.

[36]Girty, G. H., Fauna of the Moorefield shale, U. S. Geol. Surv. Bull. 439, p. 98, 100-1.

regarded by Girty as equivalent to Smith's *G. striatum* from northern Arkansas and probably Bend, Texas, but he does not include *G. cumminsi* Hyatt in the synonymy of *G. choctawensis.* Girty suggested Smith's *G. crenistrium* from the Moorefield shale probably belongs at least in part to *G. choctawensis* but on the authority of Smith's identification he retained it in the faunal list of the Moorefield. According to Girty *G. crenistrium* possessing the characters of Hyatt's *G. incisum* from the Bend is not found in the Moorefield shale, nor does typical *G. cumminsi* appear to be present there. In short, careful study of the discussions, descriptions and illustrations of Hyatt, Smith and Girty indicates that the two forms from the Barnett shale described under the names *G. cumminsi* and *G. incisum* are more or less distinct both from the Caney-Moorefield forms described by Girty as *G. choctawensis* (=*G. striatum* and probably in part *G. crenistrium* Smith) and from the European species mentioned. Without doubt the Bend species are related to the others.

*Gastrioceras entogonum* and the new species of *Glyphioceras* are not known outside of the Bend series. It may be noted with reference to the genus *Gastrioceras* that of the 14 species which have been described from North America outside of the Bend, all but two, which come from the Caney and Moorefield shales, are Pennsylvanian. The new species of *Glyphioceras* is very abundant, associated with numerous *Leiorhynchus carboniferum* and other elements of the Barnett fauna in the basal part of the Marble Falls limestone on Cherokee Creek in eastern San Saba County.

*Correlation.*—The determination of the geological age and the correlation of the Barnett shale rests upon its paleontological character and stratigraphic relations to the contiguous formations.

Some of the elements in the fauna, as has been indicated, appear by comparison with the fossil life of other geologic formations to represent late Mississippian time. Suggestive of the Mississippian are the brachiopods *Leiorhynchus carboniferum, L. carboniferum polypleurum,* and the goniatites *Glyphioceras cumminsi* and *G. incisum.* The species of *Leiorhynchus* are found typically and abundantly in the faunas of the Moorefield shale of northern Arkansas and the Caney shale of southern Oklahoma. Goniatites nearly allied to those of the Barnett shale are also found in both of these formations. Representatives of the pelecypod genus *Caneyella,* which are reported by Girty, also suggest affinities with the Moorefield and Caney. Doctor Girty regards the occurrence of these forms in the Barnett as very strong if not conclusive proof of the Mississippian age of the shale.

On the other hand, some of the elements in the fauna of the Barnett shale indicate the possible Pennsylvanian age of the shale. One of these at the top of the Barnett, is *Fusulina,* a world-wide marker of the Pennsylvanian and Permian but which has not been reported from Mississippian strata. *Leda bellistriata* is a very common Pennsylvanian fossil but one which is not particularly diagnostic. The goniatites may be regarded, as it appears to the writers, as lower Pennsylvanian as well as upper Mississippian, for it is not at all certain that they are conspecific with the form from the Moorefield and Caney shales and almost assuredly they are different from the European species. Both *Glyphioceras* and *Gastrioceras* are typically Pennsylvanian rather than Mississippian genera.

From the standpoint of its stratigraphic relations the Barnett shale seems to be inseparable from the beds which overlie it and which with it have previously been referred to the Bend group. In the first place there can be no question of the conformability of the basal part of the limestone, which is here referred to the Marble Falls division, to the shale, for not only is there no evidence of erosional break at the contact of the shale with the limestone but the distinctive faunal elements of the shale, *Leiorhynchus carboniferum*, pelecypods and goniatites, occur very abundantly in the lower part of the massive limestone.[37] Also in some places the upper part of the Barnett shale is composed of thin alternating beds of limestone and shale which appear to grade without sharp line of division into the massive limestone which is called Marble Falls. The absence of the Barnett shale beneath the Marble Falls in some localities and apparently of some of the basal beds of the Marble Falls limestone as well, is probably the result of overlap upon the somewhat irregular surface of the Ordovician limestone.

In the second place studies of very many well logs in north-central Texas which have now been drilled through the Barnett shale indicate that the formation is widely distributed and remarkably uniform in thickness. Should a soft, non-resistant formation such as the Barnett shale have been exposed to subaerial erosion for an appreciable time, it might be anticipated that it would have been deeply and irregularly eroded, in which case the thickness in closely adjacent areas might be notably unlike. Also, in the stratigraphic relations of the shale to the subjacent Ellenburger limestone as shown in well records, there is indication that the strata of the Barnett division are conformable to those of the Marble Falls.

If the Barnett shale is Mississippian it is either (1) entirely conformable with the Pennsylvanian Marble Falls limestone above or (2) there is an unconformity in the lower part of the massive limestone which is here regarded as Marble Falls. In the first case it would appear that in late Mississippian time the sea began to advance over a wide land of Ordovician limestones with very gentle relief. The region was not apparently covered at any other portion of the Mississippian for no other rocks have been observed at the outcrop or in well records between the Barnett and

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[37]Marcus Goldman in a paper presented before the December, 1920, meeting of the Geological Society of America reports the presence of glauconite at the top of the Barnett shale in three series of well cuttings examined. From this it is concluded, notwithstanding the occurrence of this mineral at many other horizons in the Bend, that a marked unconformity exists between the basal black shale and the Marble Falls limestone. However, in field occurrences observed by the writers, the typical basal Bend fauna extends beyond the supposed break into the massive limestone and there is no observed evidence of unconformity.

the Ellenburger. Although in other parts of the Mississippi Valley there was a pronounced break and in places a very prolonged break between the Mississippian and Pennsylvanian there was none here. Apparent conformity suggests stratigraphic relations which are reported in parts of the west. In the second case, an interval of erosion, perhaps not a long one, intervened after the shale and a part of the massive limestone had been deposited. When deposition was resumed the sediments were sufficiently like those which had been previously laid down to conceal the line of unconformity. The only evidence of such a break is then in the apparent change in the fossils which takes place between the lower part of the limestone and the middle and upper parts which contain an undoubted Pennsylvanian fauna.

Girty has suggested that the Marble Falls limestone includes only the beds which are exposed at the type locality which do not contain the typical Barnett shale fossils. The lower part of the limestone in eastern San Saba County which contains fossils like those of the subjacent shale should then be included with the Barnett shale.

If the Barnett shale is Pennsylvanian, as appears probable to the writers, it is to be regarded simply as the initial deposit of the advancing early Pennsylvanian sea in this region. The change to limestone deposition more or less sharp in different localities was not accompanied by a marked change of fauna. Gradually and without observed break in sedimentation a fauna of unquestioned early Pennsylvanian aspect developed, as seen higher in the Marble Falls limestone. Parts of the Llano Uplift were apparently not at first submerged and here the Barnett shale and some of the lower beds of the limestone were not deposited. Where the Marble Falls limestone rests directly on the Ellenburger limestone its lower portion has been described as distinctly conglomeratic, fragments of the lower limestone being included in the younger formation. It is perhaps noteworthy that this conglomeratic phase is at no point observed above the Barnett shale.

The Barnett shale may be correlated with the lower part of the Morrow group of northern Arkansas and northeastern Oklahoma if, as here considered, it constitutes the lower portion of the Bend group, conformable beneath the higher divisions. The correlation of the Marble Falls limestone with the Morrow and other geologic units will be discussed in treating that division. The Barnett is possibly equivalent to the upper part of the Caney shale of southern Oklahoma. The Caney underlies the Wapanucka limestone which is apparently equivalent to the Marble Falls.

## MARBLE FALLS LIMESTONE

*Name and Stratigraphic Position.*—The massive limestone division which comprises the middle portion of the Bend group was named by R. T. Hill[38] in 1889 from exposures in the vicinity of the town of Marble

[38]Hill, R. T., Amer. Geol., May, 1889.

Falls, on the southeast side of the Central Mineral Region. The limestones are excellently exposed in the gorge of the Colorado River and opposite the town have produced a picturesque falls.

Wherever the Marble Falls limestone has been observed in direct contact with the Barnett shale they appear conformable. In a few places, as in the vicinity of Marble Falls, the Marble Falls limestone overlaps the Barnett shale and lies directly on the Ellenburger (Ordovician) limestone with unconformable relationships. In a few places where these two limestones are adjacent the line of contact is marked by a bed of chert and limestone pebbles or by a thin layer of conglomerate; in other places a thin layer of partially cemented limestone breccia is present. In the district near San Saba no gravel marks the contact, but the upper portion of the Ellenburger is altered at the contact to a white, soft, chalky, tufa-like layer 5 to 8 feet thick.

*Extent and Thickness.*—The extent of the outcrop of the Marble Falls limestone is well shown on the map (Plate 1). North of the outcrop it extends beneath the younger formations across the entire north-central Texas area and has been encountered in every well drilled through the Strawn formation as far north as Red River and as far east as Fort Worth. Its western limit beneath the younger formations is not known. However, black limestones similar in lithologic character to the Bend have been recognized in deep tests as far west as San Angelo in Tom Green County, and beds which are very similar and perhaps equivalent to it are reported from wells drilled in west Texas beyond the Pecos.[39]

It is difficult to measure and describe a continuous section across the Marble Falls limestone because folding and faulting have displaced the beds, because continuous exposures are rare, and because of an absence of prominent horizon markers that makes it impossible to trace the limestone beds from one exposure to another. The average thickness of the Marble Falls limestone on the outcrop is about 400-500 feet.

In San Saba, Mills, and McCulloch counties and in Brown County south of Brownwood, the section as studied from well logs closely resembles that described from the San Saba exposures where it is from 200 to 300 feet thick. North of Brownwood the formation thickens to 500 or 600 feet, and more shale is present in the section. In Eastland and Stephens counties the limestone is thinner bedded and contains thicker layers of black shale. In Palo Pinto County the total thickness of the Bend is recorded as about 1200 feet, but it is impossible to determine how much of this thickness belongs to the Marble Falls and how much to the Smithwick. Presumably the lower 700 or 800 feet belong to the limestone division. The Barnett shale has not been reached in wells drilled in eastern Palo Pinto County.

*Noteworthy Exposures.*—Typical exposures are to be seen at the town of San Saba which is built upon the upper ledge of the Marble Falls limestone. The road south of San Saba to Llano crosses the section and offers

[39]Udden, J. A., Bull. Am. Assn. Pet. Geol., vol. 3, 1919.

many good exposures. The bluffs along Rough Creek, Cherokee Creek and the Colorado River in eastern San Saba County contain excellent exposures. Southeast of the Llano uplift are good exposures along the Colorado River at Marble Falls where the massive limestone is in direct contact with the Ellenburger limestone.

*Lithologic Character.*—The Marble Falls limestone is comprised almost wholly of thickly bedded, finely crystalline, dark gray to black limestone. The color, texture, and fossil content of the limestone vary both vertically and horizontally. Some of the layers, especially those near the top and bottom of the section, are distinctly black and noticeably bituminous. Other layers, particularly those in the middle of the section, are very light gray or even white. Shale beds from 10 to 20 feet thick have been found between some of the limestone beds.

In the exposures along the Llano road south of San Saba the dark limestone is characterized by numerous veinlets of calcite along the cleavage lines, abundance of foraminifera, sponge spicules, and fragments of small shells. On the whole the Llano road section resembles the alternating layers of shale, gray limestone, and dark blue or black foraminiferal limestone known from the well cuttings collected in the oil fields more than do the previous sections measured along Rough and Cherokee creeks.

North of the outcrop the Marble Falls limestone has been penetrated in hundreds of tests, so that its subsurface aspect is well known, as samples from a great many wells have been studied and a large number of thin sections made. The best published description of subsurface samples is that by Udden and Waite.[40] The microscopic characteristics of the limestone make it readily distinguishable from the strata of the Strawn above and from the underlying dolomitic and oolitic limestones of the Ellenburger beds. Therefore careful studies of the subsurface stratigraphy give almost as accurate determinations as observations at the outcrop. Microscopically the Marble Falls limestone is a fine-grained, semi-crystalline rock varying from wholly crystalline to granular and sub-crystalline. Commonly the sections show spots of dark granular limestone surrounded by light-colored calcite. The granular areas frequently contain minute organic remains consisting of sponge spicules, fragments of crinoids, brachiopod spines, foraminifera, and other organic fragments. Many sections show small angular-shaped pieces or crystals of quartz and here and there a grain of glauconite. The shale samples of the Marble Falls formation contain more glauconite, many small grains of pyrite, but fewer sponge spicules and organic remains. Small pyritized fossils have been washed from cuttings of the shale from a few wells. Photomicrographs of typical thin sections of the Marble Falls limestone furnished by Udden are shown on Plate IV.

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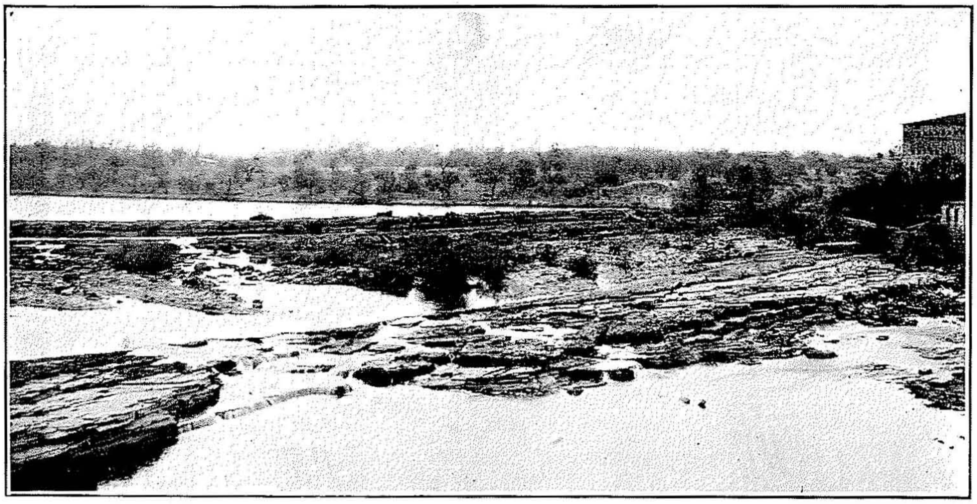
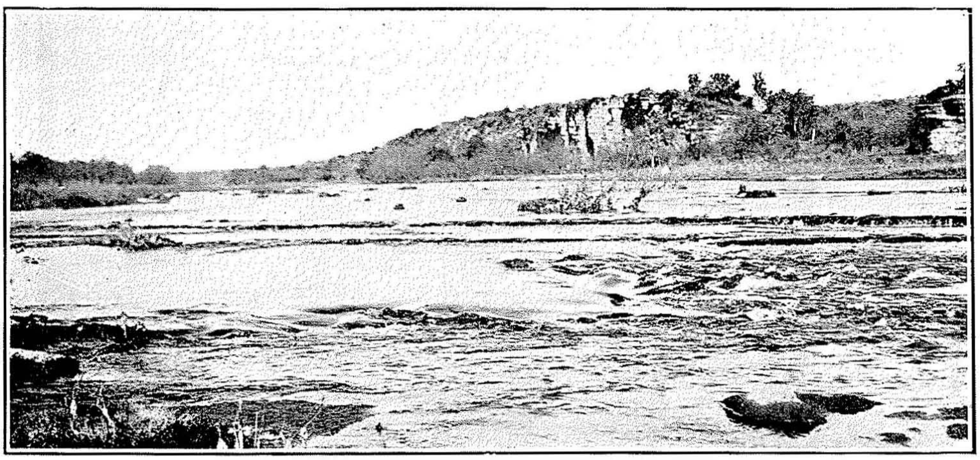
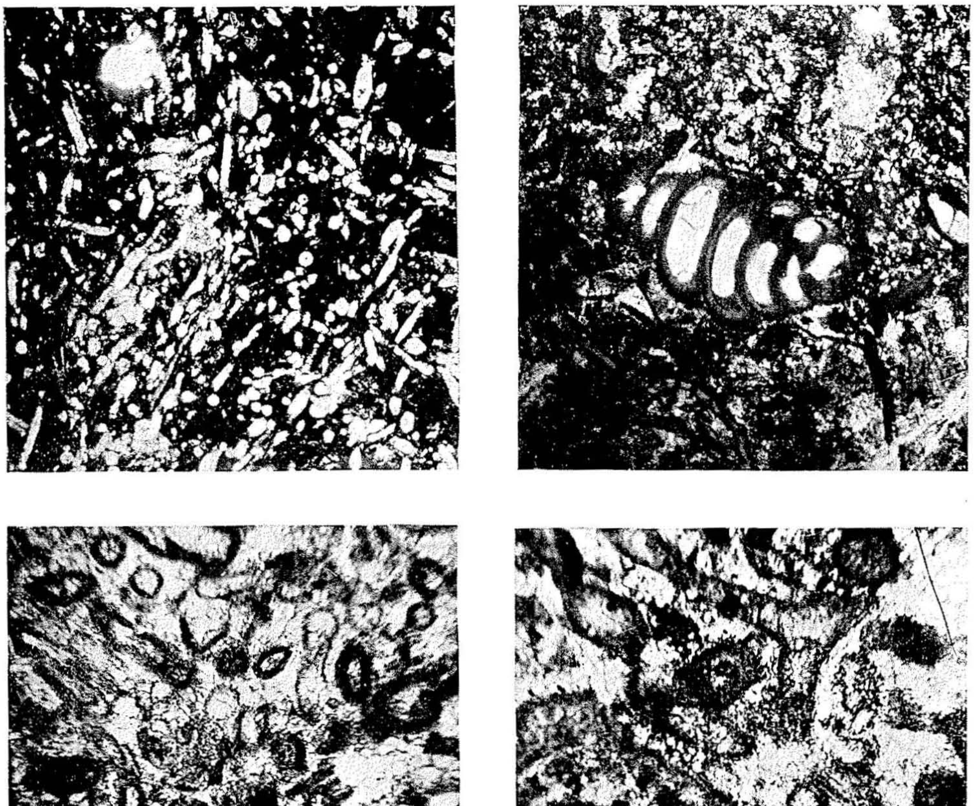
[40]Udden, J. A., and Waite, V. V., Observations on the Bend in Baugh No. 1, in Brown County: Bull. Am. Assn. Pet. Geol., vol. 3, pp. 334-344, 1919; also Bur. Econ. Geol. and Tech., Univ. Texas, Bull., 1919.



A. Outcrop of Marble Falls limestone in Colorado River at Marble Falls.



B. The rapids in the foreground are the basal chert of the Marble Falls limestone, in the San Saba River about 20 miles west of San Saba. The bluffs in the background are a thin-bedded phase of the Marble Falls limestone. Photograph furnished by Bureau of Economic Geology, Austin, Texas.



Photomicrographs of the Marble Falls limestone showing microscopic organic structure
Photographs by Udden and Waite
A, upper left figure; B, upper right figure; C, lower left figure; D, lower right figure.

*Sections of the Marble Falls Limestone at the Outcrop.*—Many typical sections have been measured along the outcrops of the Marble Falls limestone and adjacent formations, and some of these are presented here.

EXPLANATION OF PLATE IV

*A*

A bituminous limestone containing spicules of sponges in great profusion. The matrix containing these spicules consists of mostly granular calcareous material. From an outcrop of the Bend limestone in San Saba County. Magnified about 25 diameters.

*B*

A bituminous organic fragmental limestone. The organic fragments are variable in size. *Climacammina* (?) in oblique section is a conspicuous object. Some of the larger fragments exhibit a cancellated texture suggesting that they may be fragments of crinoid stems. The dark blotches in the photograph are caused by impregnating bituminous material. This sample comes from about 80 feet below the top of the Marble Falls limestone in the Bartles and Dumenil Baugh No. 1 well, Brown County. Magnified about 25 diameters.

*C*

An organic limestone consisting of tubular structures imbedded in a crystalline matrix. This rock is of the same kind as that described as occurring between the depths of 115 feet and 190 feet below the top of the Bend limestone in the Bartles and Dumenil Baugh No. 1 well, Brown County. This section is from the same well, at a depth of 2090 feet. Magnified about 40 diameters.

*D*

An organic limestone consisting of some tubular organic structures imbedded in a crystalline matrix. The tubules are curved and sometimes branched. Structures of this kind have been noted at from 115 feet to 190 feet below the top of the Bend limestone in the Bartles and Dumenil Baugh No. 1 well, Brown County. Magnified about 40 diameters.

**Section measured along Colorado River near Marble Falls**

| | Thickness Feet |
|---|---|
| SMITHWICK SHALE— | |
| 15. Shale, black, fissile, thin-bedded, upper portion partly concealed | 35 |
| MARBLE FALLS LIMESTONE— | |
| 14. Limestone, dark gray to bluish, rather thin-bedded, fine-grained, compact | 17 |
| 13. Limestone, black to very dark bluish gray, massive | 31 |
| 12. Limestone, brown to gray, rather evenly bedded, coarse-grained | 28 |
| 11. Limestone, dark gray, subcrystalline, thin to massively bedded, fossiliferous | 28 |
| 10. Limestone, light and dark gray, some beds mottled, chert in lenses and nodules, crinoid stems | 24 |
| 9. Limestone, black, evenly bedded, cherty | 17 |
| 8. Limestone, gray, rather coarsely crystalline, middle portion cherty | 40 |

| | | |
|---|---|---|
| 7. | Limestone, gray, very uneven, and irregular | 17 |
| 6. | Limestone, black to dark bluish gray, cherty | 22 |
| 5. | Limestone, gray to bluish, medium to massively bedded, crinoids | 60 |
| 4. | Limestone, dark gray to blue, fine-grained, cherty | 8 |
| 3. | Limestone, drab gray to bluish gray, with black mattling, rather thin bedded | 40 |
| 2. | Limestone, grey, mottled, somewhat brecciated and irregular | 20 |
| ELLENBURGER LIMESTONE— | | |
| 1. | Limestone, very light gray, crystalline, very massively bedded, excellently exposed | .... |

The total thickness of the Marble Falls at the type locality here is 352 feet, and a graphic section of the beds is shown in Figure 3.

In eastern San Saba and western Lampasas counties the Marble Falls limestone is exposed over a large area, but it is very difficult to find extended exposures. A very high bluff on Cherokee Creek about nine miles northeast of the town of Cherokee is typical of many small exposures and exhibits very well indeed the lower part of the Marble Falls limestone. The following section was measured at this point.

**Section of upper part of Marble Falls limestone nine miles northeast of Cherokee on Cherokee Creek**

| | | Thickness Feet |
|---|---|---|
| MARBLE FALLS LIMESTONE— | | |
| 8. | Limestone, light gray, fine to medium-grained, massively bedded, making a bold prominent jutting ledge | 8 |
| 7. | Limestone, bluish gray, weathering very massive, with thin beds and lenses of chert | 32 |
| 6. | Limestone. light bluish gray, like overlying beds but lighter color. weathers in thin flakes oblique to bedding, non-cherty, makes bold scarp along bluff | 61½ |
| 5. | Limestone, bluish-drab, dense, fine-grained, conchoidal fracture, massively bedded, lenses and thick bands of chert | 66 |
| 4. | Limestone, blue to light gray, fine-grained, thin-bedded, irregular stratification, thick-bedded in upper portion | 35 |
| 3. | Limestone, light bluish-drab, fine-grained, thin-bedded, hard, very fossiliferous | ½ |
| 2. | Covered interval | 2 |
| BARNETT SHALE— | | |
| 1. | Shale, black, fissile, bituminous, exposed | 5 |

The total thickness of the Marble Falls limestone exposed at this locality is 158 feet. It is noteworthy that the base of the Marble Falls limestone here is in no sense conglomeratic or brecciated, though it is observed that the stratification of the lower divisions is somewhat uneven. The uniform presence of a basal conglomerate mentioned by Udden has not been observed by the writers, and as noted here it is certainly not evident everywhere. From this it may be presumed that where the Marble Falls rests directly on the Ellenburger a conglomeratic phase is present, but where it is underlain by Barnett shale the conglomeratic or brecciated zone is not developed, and the contact appears to be conformable. This should be noted in connection with the discussion of the age of the Barnett shale.

The middle portion of the Marble Falls limestone is excellently exposed on Rough Creek near the crossing of the San Saba-Bend road. The basal part of the section is, as nearly as could be determined, equivalent to the top of the Cherokee Creek section. Certainly Bed No. 2, which is very distinctive lithologically and which is marked by a well-defined fauna, is higher than the uppermost bed of the Cherokee Creek section. The equivalent of Bed No. 2 was identified at other localities in San Saba County, as at the location one and one-half miles south of San Saba on the San Saba-Chappel road, proving that it is a rather widely developed and recognizable horizon. The section is as follows:

**Section of the middle portion of the Marble Falls limestone on Rough Creek, San Saba County**

| | Thickness Feet |
|---|---|
| MARBLE FALLS LIMESTONE— | |
| 12. Limestone, bluish gray, hard, crystalline, partly covered to top of hill | 12 |
| 11. Limestone, gray, crystalline, medium-grained, hard, thin-bedded, caps bluff | 8 |
| 10. Limestone, gray to yellowish or mottled, partly dolomitic, weathers to soft somewhat chalky yellow rock, fossiliferous | 48 |
| 9. Limestone, light gray, fine to medium-grained,subcrystalline, in beds 1 to 2 feet thick | 10 |
| 8. Limestone, black and mottled, gray, dense, fine-grained, very hard, fossiliferous | 3 |
| 7. Limestone, gray, fine-grained, compact, massive, numerous large forms of *Chaetetes milleporaceus* | 12 |
| 6. Limestone, yellowish, soft, shaly | 1 |
| 5. Limestone, yellowish gray, fine-grained, dense, subconchoidal fracture, thin-bedded, fossil fragments | 4 |
| 4. Limestone, gray, massive, medium-grained, subcrystalline, non-cherty | 25 |
| 3. Limestone, gray, massive or weathering to thin even beds, subcrystalline, cherty, the chert occurring in thin lenses and beds | 28 |
| 2. Limestone, mottled gray or drab and yellowish gray, weathers yellow, fine-grained, subconchoidal fracture, beds rather uniform in thickness (average 4 to 12 inches) in marked contrast with adjacent beds | 12 |
| 1. Limestone, bluish gray, medium to fine-grained, very massive, weathers to rounded surfaces | 58 |
| Total thickness of Marble Falls | 221 |

The upper part of the Marble Falls limestone and the contact with the Smithwick shale are best studied in the vicinity of Bend on Colorado River and Cherokee Creek. A section measured from a point about one mile west of the town of Bend from Colorado River south to a high bluff on Cherokee Creek shows the Smithwick shale in its typical development and the upper part of the Marble Falls limestone.

**Section of Smithwick shale and upper Marble Falls limestone from Colorado River to point one mile south on Cherokee Creek**

| | Thickness Feet |
|---|---|
| SMITHWICK SHALE— | |
| 10. Shale, olive to greenish gray, clayey to sandy, thin-bedded, weathers readily | 100 |
| 9. Shale, black, fissile, bituminous, lower part contains thin beds of black limestone | 115 |
| MARBLE FALLS LIMESTONE— | |
| 8. Limestone, black to bluish black, thin-bedded, hard, subconchoidal fracture, fossiliferous | 10 |
| 7. Limestone, dark bluish gray or dove-colored, subcrystalline, hard, beds 6 to 12 inches thick | 2 |
| 6. Limestone, light yellowish gray, dolomitic, fossil fragments and molds | 2 |
| 5. Limestone, dark bluish gray, medium-grained, subcrystalline, very massive, contains chert nodules and fossil fragments | 4 |
| 4. Limestone, light gray, nodular, uneven stratification, weathers into grayish-green thinner beds | 9 |
| 3. Limestone, yellowish gray, thin-bedded to shaly, lower part covered | 14 |
| 2. Limestone, dark bluish drab to mottled, thin-bedded, hard, dense subconchoidal fracture | 38 |
| 1. Limestone, gray, medium-grained, very massive, weathers in flakes oblique to the bedding, gives smooth surfaces | .... |

The section of the Marble Falls limestone accompanying the geologic map (Plate I) is a generalized section made by combining the sections measured on upper Cherokee Creek and lower Cherokee Creek and Rough Creek. This gives as typical a section for the whole formation as it is possible to obtain in eastern San Saba County.

The following section measured along the San Saba-Llano road two miles south of San Saba gives details of the lower part of the section containing gray and black shale layers that were not well developed in the sections previously presented.

**Section of Marble Falls limestone two miles south of San Saba**

| | Thickness Feet |
|---|---|
| (Top of hill) | |
| 5. Limestone, gray, soft, chalky, decomposed | 8 |
| 4. Limestone, dark blue, dense, hard, fine-textured | 1½ |
| 3. Limestone, dark blue gray, hard, thin-bedded | 1 |
| 2. Clay, yellowish gray, soft, contains many small high-spired gastropods | 20 |
| 1. Limestone, dark blue, dense and hard | 5 |

*The Marble Falls Limestone in the Oil Fields.*—The series of stratigraphic sections shown in Plate V, made from well records along a line extending from south to north across the Pennsylvanian area, presents the characteristics of the Bend group as revealed by drilling. All the logs shown in this section have been made from samples collected and carefully studied, and all the data are regarded as trustworthy.

At the outcrop the Marble Falls limestone formation along the outcrop contains no important sandy layers, sandy shales, or coarse clastic sediments of any kind. In many of the wells drilled in the Desdemona, Ranger, and Breckenridge oil fields, however, sands and sandy layers are recorded by drillers, and many petroleum geologists have attempted to correlate and to trace the extent of these so-called sands with various results. A generalized section of the Bend group as recorded by drillers' logs in the Ranger field is shown in Figure 5 and a section made up from a microscopically studied series of samples is as follows:

**Generalized Section of the Bend Group from Samples of Well Cuttings in the Ranger Field**

| | Average thickness Feet |
|---|---|
| SMITHWICK SHALE— | |
| 14. Slate, black, brittle | 180 |
| 13. Limestone, black, alternating with thin layers of calcareous shale and slate (limestone E) | 100 |
| 12. Shale and slate, thin bedded, fissile | 200 |
| MARBLE FALLS LIMESTONE— | |
| 11. Limestone, hard, black, grading downward into | |
| 10. Limestone, soft, gray, in places porous, and containing oil (limestone D) | 30 |
| 9. Limestone, black | 60 |
| 8. Shale, black and gray | 100 |
| 7. Limestone, hard, dense, black, (limestone C) | 20 |
| 6. Limestone, soft, porous, cavernous, often logged as sandy lime or oil sand | 30 |
| 5. Shales, black to gray, thick, contain thin dark colored limestones | 60 |
| 4. Limestone, gray or white, thick-bedded (limestone B) | 80 |
| 3. Shale, dark, black, and brown, contains few dark limestone layers | 110 |
| 2. Limestone, dense, massive, uniformly gray (limestone A) | 60 |
| Total average thickness | 550 |
| BARNETT SHALE— | |
| 1. Shale, black or brown, bituminous | 130 |

Though the individual layers vary in thickness, hardness, and porosity in different wells, the measured intervals between the limestones E and D and between limestones D and C are remarkably constant in trustworthy logs, a valuable feature that is used for purposes of correlation and in determining structural relationships. It is a question whether the top of the Marble Falls formation should be drawn at the top of limestone D or limestone E. However, as the Smithwick shale can be traced continuously in a great many wells south of Ranger across Eastland and Comanche counties in log sections in which the top of the Marble Falls limestone corresponds to the position marked limestone D, and as many wells drilled northeast of Ranger show continuous sections of shale above the top of limestone D, it is thought that the interpretation given in the section, Figure 5, is the more probable.

The section of the Marble Falls formation as known from the well cuttings in the Desdemona field is shown in Figure 6.* Section A is drawn from the log of Rushing No. 1 of the Humble and Lone Star companies and is quite similar to the Ranger section. Section B is drawn from the log of Spalting No. 1 of the Magdalene Oil Company. In this well the Marble Falls formation is thinner and lies directly upon the Ellenburger which evidently protrudes into the Bend group as a pre-Pennsylvanian hill. The uneven surface of the Ordovician in the Desdemona-Gorman district is noteworthy. The porous oil-bearing layers occur nearer the

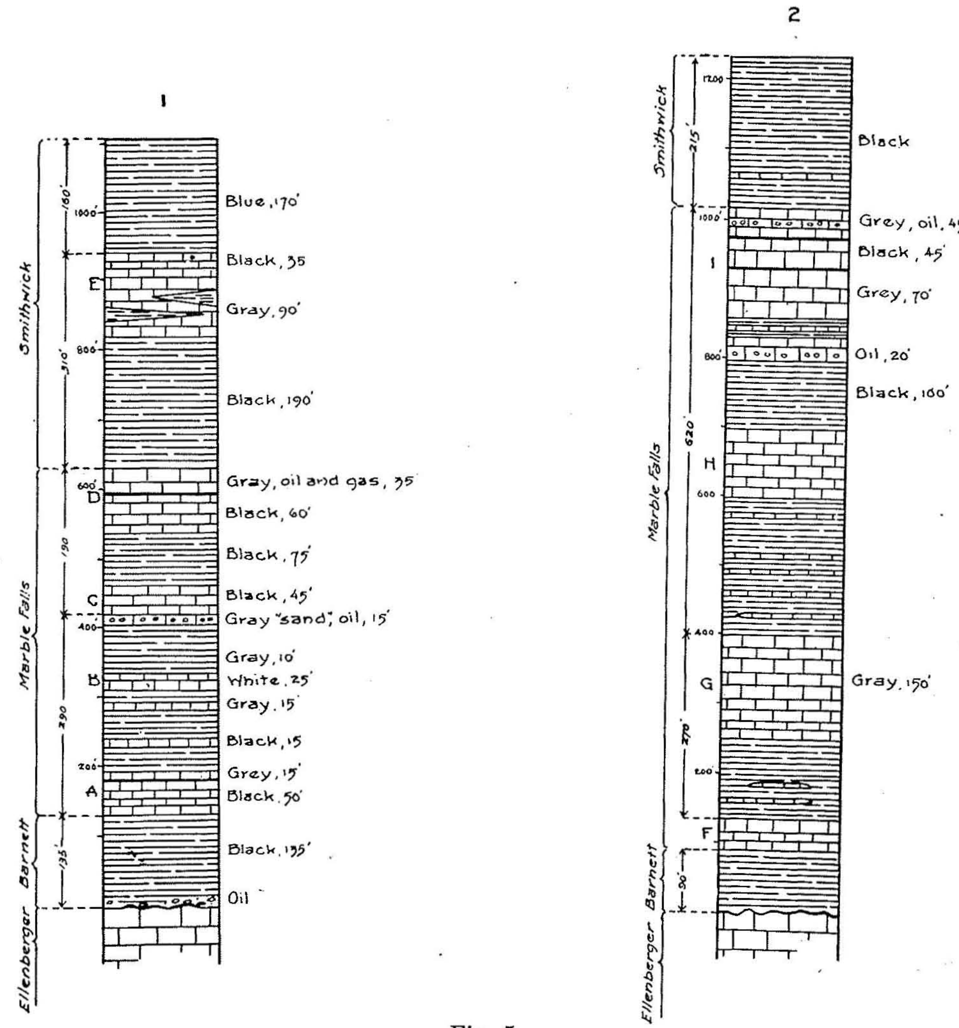



Fig. 5

Generalized Columnar Sections Showing (1) Bend Group in Ranger Oil Field, and (2) Bend Group in Breckenridge Oil Field

top of the Marble Falls formation than at Ranger, although a few porous spots have been found containing oil at various depths, and the oil horizon is not so uniform as at Ranger.

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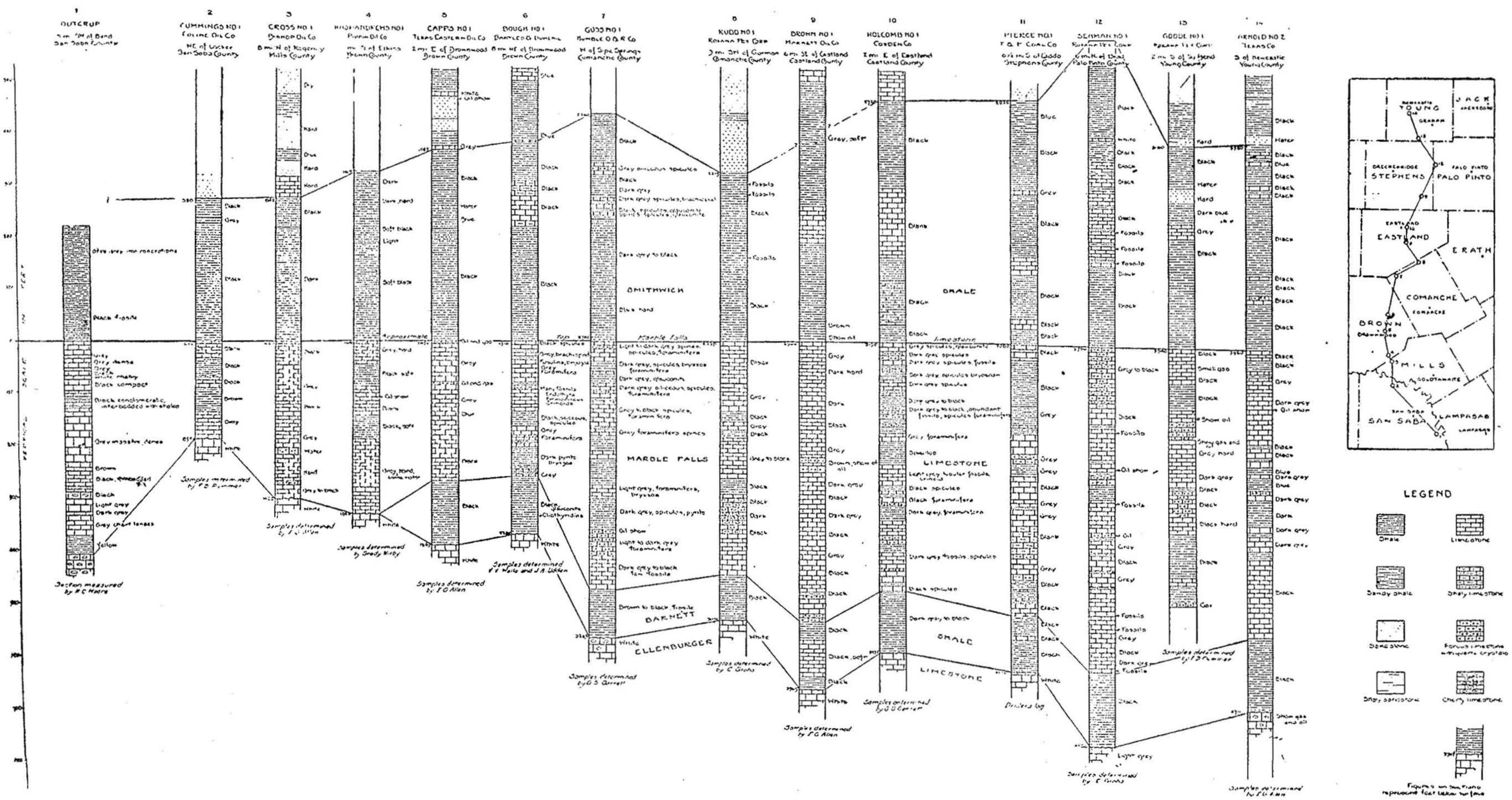
*Missing from MSS.

The subsurface section of the Marble Falls formation in the Breckenridge field and the northern part of Stephens County is very similar to that at Ranger except that the limestone is probably somewhat thicker and the intervening shales thinner. The generalized Section 2 in Figure 5 is typical. The total thickness of the Smithwick, Marble Falls, and the Barnett shales averages 1185 feet at Breckenridge, about 100 feet thicker than at Ranger. Nearly all deep wells show about 200 feet of shale, 40 to 50 feet of porous gray limestone containing oil, then 150 to 200 feet of nearly solid limestone comprising the upper one-fourth of the Marble Falls formation. It should be noted that according to this interpretation the Smithwick shale is much thinner than normal and that the upper half of the Marble Falls contains thicker limestone members. It is a much argued question among north Texas geologists whether the gray and black limestones in the upper part of the Bend group at Breckenridge should be correlated with limestone E of the Ranger section and belong in the Smithwick, or correspond to limestone D at Ranger and represent the top of the Marble Falls formation. It is difficult to trace limestone E of the Ranger section northward across Stephens County. Most of the limestones of the Smithwick formation are lentils, and because of the lack of any paleontologic evidence, the question of this correlation can not be settled. It is probable that the gray limestone I at Breckenridge should be regarded as the top of the Marble Falls, for the following reasons. It can be traced in well logs with a fair degree of certainty from Breckenridge northward to the Young County line, and eastward to Caddo where it is assuredly a part of the Marble Falls. Examination with the microscope of samples collected from the limestone E horizon at Ranger shows it to be a brittle, shaly limestone containing much fewer fossil fragments such as spicules and spines than the typical Marble Falls strata. The gray portion of limestone I at Breckenridge is soft, porous, pure and not in the least shaly. The black portion of limestone I is quite fossiliferous and very typical of the Marble Falls. In Palo Pinto and in most places in Shackelford and Young counties, Bed I is overlain by the Smithwick shale in its normal or more than normal thickness, and is underlain by a still greater thickness of Marble Falls limestone and shales. The Bend group thickens northward and eastward either by the coming in of older strata at the base and a thickening of the Smithwick shale at the top, or by a thickening of the entire Bend group. Possibly in the northern area the basal strata are Mississippian, and the older beds are progressively overlapped by younger strata toward the south and west. Certainly the basal beds in Young and northern Stephens counties are older than the basal beds of the outcrop.

*Oil in the Marble Falls Formation.*—The Marble Falls formation has yielded nearly all the large oil wells of the north Texas fields.

In Ranger, as well as in other fields, the oil evidently originates in the petroliferous black shales in the Marble Falls and Smithwick formations and accumulates wherever in the section these shales come in contact with



Graphic section of the Bend group represented by well logs from south to north, San Saba to Young counties.

porous beds. The most prolific oil-bearing beds in the Ranger field are two especially porous layers in the Marble Falls: (1) a gray limestone at the top of the formation which is more or less porous and yields considerable production after being loosened up by a shot of nitroglycerine; (2) the cavernous portion of the black limestone, known by the drillers as the "Ranger" oil sand 190 to 200 feet below the top, which has yielded the big Ranger gushers. At Breckenridge the oil occurs in the gray limestone at the top of the Marble Falls formation, and the cavernous limestone of the lower horizon of the Ranger field is absent or much less developed. At Desdemona the most prolific porous area lies 60 to 120 feet below the top of the Marble Falls, a little higher in the section than at Ranger.

An examination of a large number of samples of the so-called sand from the lower horizon at Ranger and Desdemona shows it to be an unusual sedimentary deposit. A washed sample examined megascopically has the appearance of a beautifully white, pure, quartz sand. When this material is examined with the miscroscope, each individual grain is seen to have one or more crystal faces, and in an ordinary sample several perfect quartz crystals can be found. The sides of the grain not showing crystal faces are generally rough and appear to have been freshly broken, though some grains show rounded edges. Thin sections of these grains under a high-power petrographic microscope appear perfectly clear and give no evidence of secondary growth around a smaller grain.

From several wells in the Ranger and Desdemona fields large chunks of limestone from two to three inches in diameter have been thrown out by the shot with nitroglycerine. Examination of some of these shows quartz veins, cavities, and vugs a fraction of an inch in diameter lined with perfect quartz crystals, which after being broken out are identical with the "sand" grains washed out of the well cutting. From these observations it seems reasonable to conclude that the quartz "sand" of the Ranger and Desdemona fields is largely secondary quartz formed by the crystallization of the silica dissolved out of the cherty or sponge spicule beds in the Marble Falls formation and crystallized in veins or cavities at certain porous horizons at some time previous to the migration of the oil.

This type of sand has been termed "secondary" sand. Samples of it have been collected not only from the wells in the Ranger and Desdemona fields but from tests on the Gray Ranch in Coleman County, from the Parrick wells 13 miles northeast of Cisco, from wells in Stephens County south of Caddo, and from wells near South Bend in Young County. In most places in a given area this "sand" is generally found at a definite horizon below the top of the Bend series and associated with limestone that is filled with sponge spicules and cherty layers. In the section measured on the Colorado River and on Cherokee Creek in San Saba County continuous cherty layers were found near the middle of the Marble Falls formation. The presence of persistent cherty or silica-bearing beds in the Marble Falls probably explains the apparent continuity of the porous secondary sand layers in the oil field districts.

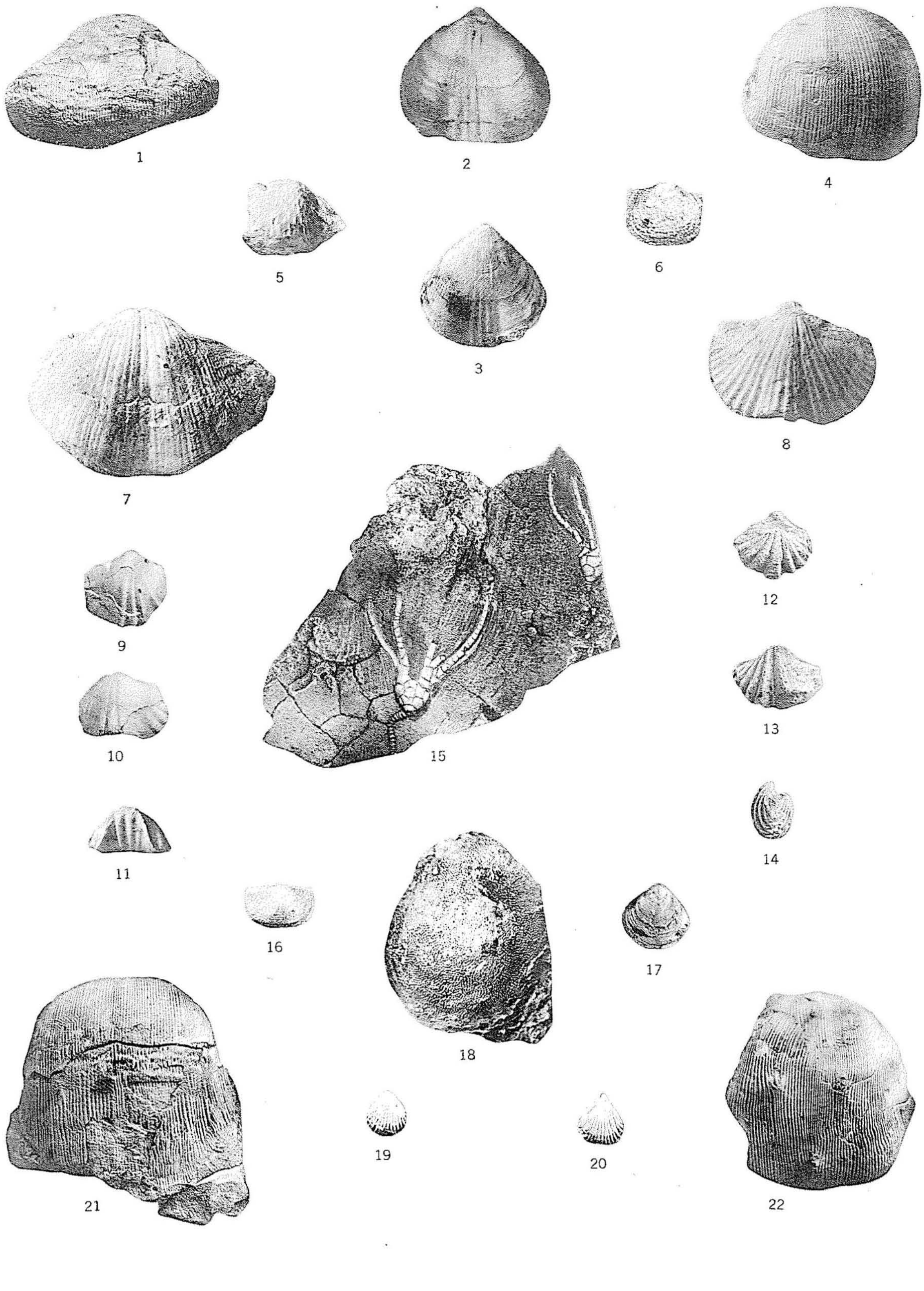
*Paleontology.*—Parts of the Marble Falls limestone are abundantly fossiliferous, but in many exposures very few fossils of any sort appear. Of the localities visited during the course of the work upon which this report is based, the outcrops along the Colorado River near the town of Bend, and on the Bend-Chappel road, representing the upper part of the formation; along Rough Creek near the crossing of the Bend-San Saba road, and on a small tributary of Wallace Creek about 12 miles southwest of San Saba, belonging to the middle part; and on upper Cherokee Creek southwest of Bend, representing the basal part, were most fossiliferous. Large areas in which the Marble Falls limestone appears at the surface are but sparingly fossiliferous. The type locality of the formation at Marble Falls, in Burnet County, on the southeast side of the Llano Uplift, contains, unfortunately, few fossil remains. The small collections made in this area during the course of work by the U. S. Geological Survey gave little basis for satisfactory determination of the true faunal character or the correlation of these beds.

Although the collections which have been made from the Marble Falls limestone in San Saba County contain much material of very interesting character which is as yet undescribed, the results of the studies which have been based upon it will not be presented at this time, since a complete report on the fossils of the Bend is in contemplation. A brief statement without prejudice to other studies of the essential facts which have been observed, will be made here.

On the upper Cherokee Creek (locality 151.6), southwest of Bend, black, fissile, bituminous shale which certainly represents the Barnett division is overlain by a dark bluish-drab, dense, hard, fine-grained limestone which is extraordinarily fossiliferous. Since this limestone is lithologically similar to the continuous section of limestone which extends approximately 160 feet above it in the cliff exposure, it seems to represent with little doubt the base of the Marble Falls limestone. Though the fossils in this basal bed are extraordinarily abundant, the fauna which is represented is not large. Its most interesting feature is the content of species which, as represented by the collections which have been made from the Barnett shale, have been regarded as diagnostic of that basal part of the Bend series. The composition of this lowermost limestone fauna is as follows:

**Fauna of limestone at the base of the Marble Falls limestone on upper Cherokee creek, San Saba County, Texas.**

Crinoid stems
*Lingula albapinensis* Walcott?
*Orbiculoidea caneyana* Girty?
*Chonetes* sp.
*Productus coloradoensis* Girty?
*Productus cora* D'Orbigny
*Leiorhynchus carboniferum* Girty
*Leiorhynchus carboniferum polypleurum* Girty
*Ambocoelia planoconvexa* (Shumard)
*Composita subquadrata* (Hall)?
*Aviculopecten* sp.
*Pleurotomaria* sp.
*Glyphioceras* n. sp.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## BEND FOSSILS

Figure 1. *Productus cora,* ventral view of a deformed, somewhat flattened shell, from middle portion of Marble Falls limestone on Rough Creek, southeast of San Saba (151.1a).

Figures 2, 3. *Leiorhynchus carboniferum,* brachial and ventral views, respectively, of typical examples of this species from the base of the Marble Falls limestone on upper Cherokee Creek (151.6). This is one of the index fossils of the lower part of the Bend group.

Figure 4. *Productus morrowensis,* pedicle valve of an average specimen from Marble Falls limestone west of Wallace Creek (152.2).

Figures 5, 6. *Pustula* sp. Two small spinose productid brachiopods from the upper part of the Marble Falls limestone, Rough Creek (151.1c).

Figure 7. *Spirifer* n. sp. Pedicle valve of a shell which is related to but apparently quite distinct from the common Pennsylvanian species *Spirifer cameratus.* It is very abundant in some parts of the Marble Falls limestone. Rough Creek (151.1b).

Figure 8. *Spirifer rockymontanus,* brachial view. This species is distinguished by its rounded, simple plications and relatively small aveıage size. Rough Creek (151.1a).

Figures 9, 10, 11. *Pugnax* cf. *P. rockymontanus,* brachial and anterior views of two specimens from the Marble Falls limestone west of Wallace Creek (152.2).

Figures 12, 13, 14. *Spiriferina kentuckiensis,* brachial, ventral and side views of typical specimens from the middle part of the Marble Falls limestone, on Rough Creek (151.a).

Figure 15. *Cromyocrinus* n. sp., two small crinoids with arms and stems in place on a slab of Marble Falls limestone from Rough Creek (151.1a). Nearly a dozen specimens of this species were found.

Figure 16. *Chonetes choteauensis,* a small brachiopod most abundant in the upper part of the Marble Falls limestone. Pedicle valve of a specimen from outcrop of Marble Falls limestone on the road from Bend to Chappel (151.2).

Figure 17. *Composita subtilita* ? a small shell, common in parts of the Marble Falls limestone (151.1a).

Figure 18. *Tabulipora heteropora,* a massive bryozoan which is found in the middle part of the Marble Falls limestone (151.1a).

Figures 19, 20. *Hustedia miseri,* pedicle and brachial valves, respectively, from the Marble Falls limestone (151.1a).

Figure 21. *Productus morrowensis,* a typical specimen showing well the characteristic features of the species, from the Marble Falls limestone west of Wallace Creek (152.2).

Figure 22. *Productus cora,* a specimen from the Marble Falls limestone west of Wallace Creek (152.2).

## BEND FOSSILS

Figures 1, 5, 5a, 6, 6a. *Leda bellistriata,* specimens with enlargements, from the Barnett shale southeast of San Saba (151.8).

Figure 2. *Michelinia n. sp.,* a peculiar colonial coral found in the upper part of the Marble Falls limestone. On road between Chappel and Bend (151.2).

Figure 3. *Hadrophyllum aplatum,* the flattened, coin-like coral common in parts of the Smithwick shale. From point where Bend-Chappel road leaves Bend-San Saba road (151.4).

Figure 4. *Squamularia perplexa,* a very abundant brachiopod fossil in some beds of the Millsap formation. From limestone just east of Rayville, southwest Parker County (76.2).

Figure 7. *Naticopsis* n. sp., a large gastropod from the middle portion of the Marble Falls limestone, west of Wallace Creek (152.2).

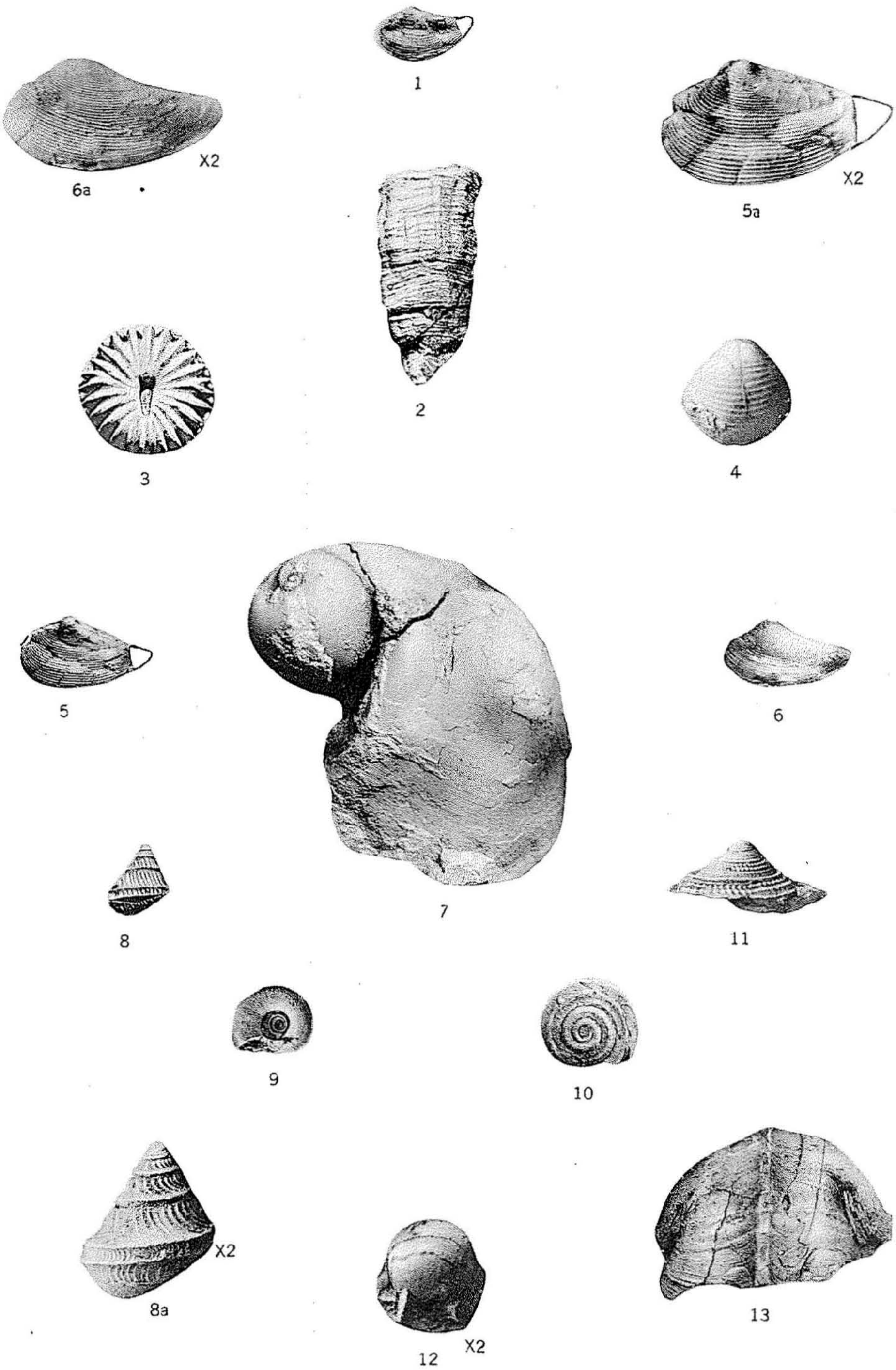
Figures 8, 8a. *Bembexia nodomarginata,* a small pleurotomaroid gastropod from the Smithwick shale, at junction of the Bend-San Saba and Bend-Chappel roads (151.4).

Figures 9, 10. *Euomphalus* n. sp., a common, flat coiled gastropod of the Smithwick shale, at junction of Bend-San Saba and Bend-Chappel roads (151.4).

Figure 11. *Turbo* n. sp., a flattened shell from the Smithwick shale, at junction of Bend-San Saba and Bend-Chappel roads (151.4).

Figure 12. *Glyphioceras* n. sp., a rotund cephalopod which is very abundant in the basal bed of the Marble Falls limestone on upper Cherokee Creek (151.6).

Figure 13. *Bellerophon* n. sp., one of the most common fossils of the Smithwick shale, at junction of Bend-San Saba and Bend-Chappel roads (151.4).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13

The most abundant forms are *Leiorhynchus carboniferum* and a new species of *Glyphioceras*. All are very well preserved. No specimens of *Glyphioceras cumminsi* or *G. incisum* which are very common in some of the collections from the Barnett were found in this limestone, but otherwise the fauna suggests this basal part of the Bend much more strongly than the higher part of the Marble Falls limestone. Since there was no observed indication of a stratigraphic break above the limestone, and since a striking and very sharp lithologic change appears below the limestone, the writer concludes that the bed under discussion should be regarded as an integral part of the Marble Falls formation. If this interpretation is correct, it is evident that there is not a sharp faunal break between the Barnett shale and the Marble Falls limestone.

At another locality, on the Bend-San Saba road five miles east of San Saba, another collection has been made by Mr. Plummer from a marly limestone which represents, he believes, the base of the Marble Falls limestone. The typical Barnett shale immediately underlies it, the exposure being not far from the type locality of the shale. It is possible that these transition beds should rather be included with the Barnett. The fauna contains the following species:

**Fauna of the basal part of the Marble Falls limestone five miles east of San Saba**

*Fusulina* sp.
Crinoid stems
*Lingula albapinensis* (Walcott)
*Leiorhynchus carboniferum* Girty
*Leiorhynchus carboniferum polypleurum* Girty
*Dielasma* sp.
*Ambocoelia planoconvexa* (Shumard)
*Composita* sp.
*Cliothyridina* sp.
*Zaphrentis* sp.
*Liopteria* ? sp.
*Pleurotomaria* aff. *perhumerosa*
*Orthoceras* sp. 1, 2
*Glyphioceras cumminsi* (Hyatt)
*Glyphioceras* n. sp.
*Glyphioceras* sp.

The occurrence of *Fusulina, Leiorhynchus carboniferum* and *Glyphioceras cumminsi* together in this collection is of special interest. While, so far as the data at hand indicate, it is possible that the fossils here reported might properly be referred to the uppermost part of the Barnett shale, the occurrence of an undoubted species of the common Pennsylvanian *Fusulina* at this horizon seems significant.

The middle portion of the Marble Falls limestone contains a large variety of invertebrate fossils which are for the most part beautifully preserved. The largest collections were obtained at the exposures on Rough Creek near the point where the Bend-San Saba road crosses the stream

(Locality 151.1). The collections from this locality, representing the middle portion of the Marble Falls division, include the following species. Many of the same forms were found at the locality on Wallace Creek, southwest of San Saba, which appears to represent approximately the same portion of the Marble Falls formation. The following list shows the species which have been identified.

**Fauna of the middle portion of the Marble Falls limestone, San Saba County, Texas**

Coelenterata
- *Zaphrentis* sp.
- *Amplexus corrugatus* Mather
- *Lophophyllum profundum* (Edwards and Haime)
- *Campophyllum torquium* (Owen)
- *Campophyllum* sp.
- *Axophyllum rude* (White and St. John)
- *Michelinia eugeneae* White?
- *Michelinia* n. sp.
- *Chaetetes milleporaceus* Edwards and Haime

Vermes
- *Tubicola* ? sp.

Echinodermata
- *Cromyocrinus* n. sp.
- *Eupachycrinus* sp. 1, 2
- Crinoid stems
- *Archeocidaris mucronatus* Meek and Worthen
- *Archeocidaris norwoodi* Hall?
- *Archeocidaris* sp. 1, 2

Bryozoa
- *Fistulipora carbonaria* Ulrich
- *Fistulipora* n. sp.
- *Tabulipora heteropora* (Conrad) n. sp. 1, 2
- *Tabulipora* sp.
- *Fenestella compressa* Ulrich
- *Fenestella modesta* Ulrich
- *Fenestella* sp. cf. *multispinosa* Ulrich
- *Fenestella* sp. 1, 2, 3, 4.
- *Polypora* sp. 1, 2
- *Septopora biserialis* (Swallow)
- *Septopora* sp.
- *Pinnatopora* sp.
- *Rhombopora attenuata* Ulrich
- *Rhombopora lepidodendroidea* Meek

Brachiopoda
- *Lingula albapinensis* (Walcott)
- *Orbiculoidea batesvillensis* Weller ?
- *Rhipidomella pecosi* (Marcou)
- *Orthotichia schuchertensis* (Girty)
- *Schellwienella* ? sp.
- *Orthotetes* ? *kaskaskiensis* (McChesney)
- *Chonetes choteauensis* Mather
- *Chonetes mesolobus* N. and P.
- *Chonetes* n. sp. 1
- *Productus coloradoensis* Girty ?
- *Productus cora* D'Orbigny

*Productus inflatus* McChesney
*Productus morrowensis* Mather
*Productus nanus* M. and W. ?
*Productus parvus* M. and W.
*Productus* sp.
*Pustula bullata* Mather
*Pustula globosa* Mather
*Pustula moorefieldana pusilla* (Girty)
*Pustula nebraskensis* (Owen)
*Pustula punctata* (Martin)
*Pustula sublineata* Mather?
*Avonia ? arkansana multilirata* (Girty)
*Marginifera ingrata* Girty ?
*Marginifera splendens* N. and P. ?
*Marginifera* sp.
*Marginifera* ? sp.
*Pugnax osagensis* (Marcou)
*Dielasma bovidens* (Morton)
*Dielasma* sp.
*Spirifer increbescens* Hall ?
*Spirifer marcoui*
*Spirifer rockymontanus* Marcou
*Spirifer* n. sp.
*Spiriferina kentuckiensis* (Shumard)
*Spiriferina spinosa* (N. and P.)?
*Spiriferina transversa* (McChesney)
*Hustedia miseri* Mather
*Squamularia perplexa* (McChesney)
*Athyris* sp.
*Composita subquadrata* (Hall)?
*Composita wasatchensis* (White)
*Composita* sp.
*Cliothyridina hirsuta* (Hall)?

Pelecypoda

*Solenomya* n. sp.
*Sanguinolites* sp.
*Nucula rectangula* McChesney
*Leda bellistriata* (Stevens)
*Leda bellistriata attenuata* (Meek)?
*Leda nasuta* Hall?
*Parallelodon* sp.
*Parallelodon* ? sp.
*Leptodesma spergenense robustum* Girty ?
*Pinna* sp.
*Conocardium* n. sp.
*Leiopteria* n. sp.
*Leiopteria* sp. n. var.
*Schizodus depressus* Worthen
*Acanthopecten* n. sp.
*Streblopteria hertzeri* (Meek)
*Caneyella* n. sp.
*Modiolus* n. sp.
*Conocardium obliquum* M. and W.

Gastropoda

*Bellerophon* sp.

*Pleurotomaria* sp. (1), (2, 3).

*Worthenia* ? sp.

*Murchisonia* sp.

*Sphaerodoma* ? sp.

*Holopella* sp.

Cephalopoda

*Gastrioceras kingi* (Hall and Whitefield)?

*Paralegoceras* n. sp.

Trilobita

*Griffithides scitulus* M. and W.

*Griffithides* ? sp.

*Phillipsia missouriensis* Shumard ?

Pisces

*Helodus* ? sp.

Fish tooth

In addition to the species reported in the foregoing list, the occurrence of a representative of the coral genus *Paleacis* in the middle portion of the Marble Falls limestone is reported by Girty.[41] The appearance of this form is of special interest as it has not previously been known from a horizon younger than the Mississippian.

The upper portion of the Marble Falls limestone is locally fossiliferous but so far as observed by the writers the fossils are not so abundant as in the middle portion of the formation nor are they so well preserved. It was found very difficult at the localities where the collections from the upper horizons were obtained to secure good, satisfactorily identifiable material. The fauna of the upper Marble Falls is without doubt more varied than is indicated by the species which have been identified, but there was not opportunity in the course of field work to make an extended study of these beds. The localities from which the following species were taken are on the Chappel-Bend road, about two miles east of Chappel and along the Colorado River at the bend about three-quarters of a mile west of the bridge at Bend. Both of these exposures belong to the uppermost part of the Marble Falls. On the Colorado River the transition from the limestone to the lower beds of the Smithwick shale may be seen clearly, beds of very dark limestone being interbedded with the lower part of the shale. The Smithwick is without question entirely conformable with the Marble Falls limestone.

**Fauna of the upper portion of the Marble Falls limestone in eastern San Saba County, Texas**

Coelenterata

*Lophophyllum profundum* (Edwards and Haime)

*Campophyllum torquium* (Owen)

*Michelinia* n. sp.

*Chaetetes milleporaceus* Edwards and Haime

[41]Girty, G. H., loc. cit.

Echinodermata
- Crinoid stems
- *Archeocidaris mucronatus* Meek and Worthen

Bryozoa
- *Fenestella* sp. 1, 2, 3
- *Cystodictya* n. sp.

Brachiopoda
- *Orbiculoidea* sp.
- *Rhipidomella pecosi* (Marcou)
- *Chonetes choteauensis* Mather
- *Productus cora* D'Orbigny
- *Productus inflatus* McChesney
- *Productus* sp.
- *Pustula nebraskensis* (Owen)
- *Pustula moorefieldana pusilla* (Girty)?
- *Avonia arkansana* (Girty)
- *Avonia* n. sp.
- *Spirifer rockymontanus* Marcou
- *Spirifer* n. sp.
- *Spiriferina spinosa* (Norwood and Pratten)?
- *Spiriferina transversa* (McChesney)
- *Squamularia perplexa* (McChesney)
- *Squamularia transversa* Mather ?

Pelecypoda
- *Aviculopecten* n. sp.
- *Acanthopecten carboniferus* (Stevens)?
- *Acanthopecten* n. sp.

Gastropoda
- *Bellerophon wewokanus* Girty
- *Bellerophon* n. sp.
- *Euphemus carbonarius* (Cox)
- *Schizostoma catilloides* (Conrad)
- *Meekospira peracuta* (Meek and Worthen)
- *Platyceras parvum* (Swallow)

Cephalopoda
- *Orthoceras* sp. 1, 2, 3
- *Metacoceras walcotti* Hyatt
- *Nautilus* sp. 1, 2
- *Cyrtoceras* sp.
- *Gastrioceras compressum* Hyatt

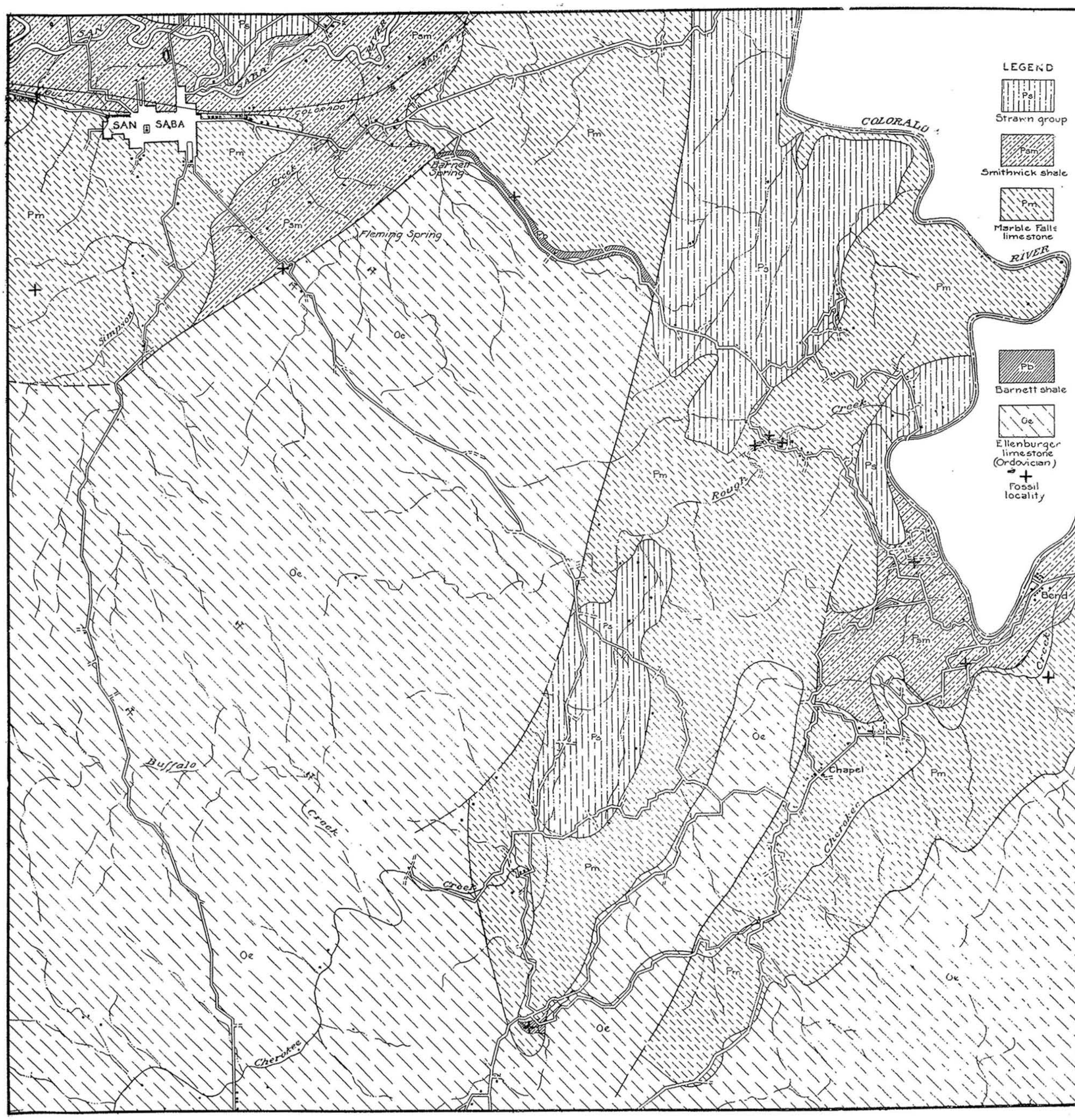
Trilobita
- *Griffithides scitulus major* Meek and Worthen

A critical study of the fauna of the Marble Falls limestone makes evident its transitional position between the typical faunas of the Mississippian and those most characteristic of the Pennsylvanian. The fauna as a whole is different in many respects from the faunas of approximately the same stratigraphic horizon which have previously been described, for there is in the Marble Falls formation a considerable number of undescribed species. The number of forms which are common to other formations of known geologic age is sufficient, however, to permit no question as to the correlation of the Marble Falls limestone. It is noteworthy that some types which have previously been reported only from formations regarded as Mississippian in age are here found in the typical Marble

Falls limestone. Even if the basal part of the formation, as defined in this report, should be referred to the Mississippian, the occurrence of such a form as *Paleacis* high in the formation and of numerous species which, while less certainly identifiable, are yet closely related to typical Mississippian species, is to be observed. In the fauna of the Marble Falls limestone, however, the fossils of Pennsylvanian aspect are much the most important element. Among the representatives of this period are some of the most common and characteristic forms. Since the newer or younger elements in a fauna are much the most significant in the determination of the geologic age of the containing beds, the Pennsylvanian fossils in the Marble Falls indicate clearly that the formation is a deposit of this period. It appears both from the composition of the Pennsylvanian element of the fauna and the presence of the Mississippian types which have been noted that the formation is to be regarded as belonging to a very early part of the Pennsylvanian, certainly within the lower Pottsville. The residual elements of the Marble Falls limestone fauna and the incoming or proemial element of the Pennsylvanian are shown to a greater or less degree in each of the classes of invertebrates. The following lists indicate the relationships of the Marble Falls fauna.

**Comparison of the Mississippian and Pennsylvanian elements in the Marble Falls fauna**

| Residual Mississippian element | Proemial Pennsylvanian element |
|---|---|
| Protozoa | |
| | *Fusulina* sp. |
| Coelenterata | |
| *Acervularia* sp.* | *Zaphrentis gibsoni** |
| *Paleacis* sp.* | *Lophophyllum profundum* |
| | *Campophyllum torquium* |
| | *Chaetetes milleporaceus* |
| Echinodermata | |
| *Cromyocrinus* sp. | *Eupachycrinus* sp. |
| Bryozoa | |
| *Rhombopora attenuata* | *Fistulipora carbonaria* |
| *Rhombopora persimilis* | *Fenestella modesta* |
| *Rhombopora tabulata*? | *Septopora biserialis* |
| *Cystodictya lineata*? | *Rhombopora lepidodendroidea* |
| *Prismopora* n. sp. | |
| *Glyptopora* n. sp. | |
| Brachiopoda | |
| *Orbiculoidea caneyana* | *Rhipidomella pecosi* |
| *Orthotetes ? kaskaskiensis* | *Orthotichia schuchertensis* |
| *Productus inflatus* | *Chonetes mesolobus* |
| *Productus parvus* | *Pustula nebraskensis* |
| *Pustula moorefieldana pusilla* ? | *Pustula punctata* |
| *Spiriferina spinosa* | *Aulosteges* n. sp.* |
| *Spiriferina transversa* | *Dielasma bovidens*? |
| *Composita subquadrata?* | *Spirifer cameratus** |
| *Cliothyridina hirsuta?* | *Spirifer* n. sp. |
| | *Spirifer rockymontanus* |
| | *Squamularia perplexa* |
| | *Ambocoelia planoconvexa* |


LEGEND
Ps
Strawn group
Psm
Smithwick shale
Pm
Marble Falls limestone
Pb
Barnett shale
Oe
Ellenburger limestone (Ordovician)
Fossil locality
SAN SABA
COLORADO RIVER
Barnett Spring
Fleming Spring
Simpson
Buffalo Creek
Cherokee
Rough Creek
Chapel
Bend

Pelecypoda
- *Schizodus depressus*
- *Caneyella* sp.
- *Pseudomonotis* sp.
- *Acanthopecten* n. sp.

Gastropoda
- *Bellerophon wewokanus*
- *Euphemus carbonarius*
- *Bucanopsis meekiana*
- *Schizostoma catilloides*
- *Meekespira peracuta*
- *Platyceras parvum*

Cephalopoda
- *Gastrioceras kingi?*
- *Glyphioceras cumminsi*
- *Metacoceras walcotti*
- *Paralegoceras* n. sp.

Trilobita
- *Griffithides scitulus*

Pisces
- *Edestus minor*

Two small collections of fossils and fossil fragments have been obtained from the cuttings of the Goode No. 1 well, located two miles south of South Bend, Young County. The first collection came from a depth of 3958 feet and the second at 4009 feet (steel line measurements). As the top of the Smithwick occurred at 3335 feet and the top of the Marble Falls at 3649 feet these shells are of much interest in the bearing they might have on the age of the Bend in Young County. The specimens from 3958 feet are pyritized casts of small forms 1 to 2 mm. in length and it was impossible to determine them specifically. The genera represented are as follows:

*Pleurotomaria* sp.
*Bellerophon* sp.
*Worthenia* sp.
*Leda* sp. cf. *L. coslyona*
*Yoldia* sp.

The fossils from 4009 feet are also minute forms out of black shale fragments. Although they are slightly better preserved, the species are either new or indeterminate so that only the genera can be given, which are as follows:

*Chonetes* sp.
*Bellerophon* n. sp.
Crinoid stems
Coral

The specimens are indistinguishable, many of them from very common material collected from the Marble Falls limestone in San Saba County and there can be little doubt that they belong to the Marble Falls fauna of the Pennsylvanian.

*Correlation.*—Even casual study of the fossils of the Marble Falls limestone calls attention to the similarity in composition of the fauna to that of the Morrow group of Arkansas and Oklahoma which has recently been described by Mather.[42] Not only is there a similar intermingling of residual Mississippian and incoming Pennsylvanian forms observed in the latter fauna but very many of the species, including a number which have to the present time been reported only from the Morrow, are common to the two. Some examples of distinctive Morrow species which are found in the Marble Falls limestone, as *Productus morrowensis, Chonetes choteauensis,* are numerous and typical. Some of the characteristic Mississippian genera which were reported from the Morrow fauna such as the blastoid *Pentremites* and the peculiar bryozoan, *Archimedes,* however, have not been found in the Marble Falls. Nevertheless, careful comparison of the two faunas leaves no question concerning the equivalence of the Marble Falls limestone to at least a portion of the Morrow group. The position of the Morrow beds with reference to a fossil flora of known age (early Pottsville), the Pennsylvanian elements in its invertebrate fauna, and the occurrence of an important unconformity beneath it, make clear the early Pennsylvanian age of the group in spite of the fossils of Mississippian appearance which it contains.

Recent study of the Wapanucka limestone of southern Oklahoma has shown the presence in that formation of many characteristic fossils of the Morrow group, and according to Mather[43] the Wapanucka is without question equivalent in age to the Morrow. Many of the species are likewise common to the Marble Falls limestone of Texas, and though the latter is not known to contain *Pentremites* and *Archimedes* which are reported from the Wapanucka, the Marble Falls limestone may also be correlated with the Wapanucka limestone.

Recent collections made by Moore from outcrops of the Glenn formation north of Ardmore, Oklahoma, also contain typical Morrow or Bend species. The lower portion of the Glenn, it appears, is approximately equivalent to the Marble Falls limestone in Texas, to the Wapanucka limestone northeast of the Arbuckles and to the Morrow group in northeastern Oklahoma and northwestern Arkansas.

The Marble Falls limestone is certainly older than any of the Pennsylvanian divisions which have been described in the northern Mid-Continent region, as indicated by a comparison with the faunal horizons described from Kansas in the papers of Beede and Rogers. The fauna of the Cherokee shale, the basal Pennsylvanian formation in the Kansas region, contains none of the residual Mississippian elements which are so prominent a feature both of the Bend limestone and the Morrow.

It is possible that deposits essentially contemporaneous with the Marble Falls limestone may be found in the Rocky Mountain region of New Mexico and Colorado but studies in the latter areas have not been sufficiently detailed to permit satisfactory comparison of the invertebrate faunas. How-

[42]Mather, Kirtley F., The fauna of the Morrow group of Arkansas and Oklahoma, Denison Univ. Sci. Bull., vol. 18, pp. 59-284, 1915.

[43]Mather, Kirtley F., Pottsville formations and faunas of Arkansas and Oklahoma, Am. Jour. Sci., vol. 43, pp. 133-139, 1917.

ever, it may be observed that the lower beds of the northern New Mexico Pennsylvanian and the Hermosa formation in southwestern Colorado contain lower Pennsylvanian fossils some of which also occur in the Bend.

### SMITHWICK SHALE

*Name and Stratigraphic Position.*—The Smithwick shale was named by Sidney Paige[44] from the town of Smithwick located southeast of Marble Falls. It is defined as a layer of black slaty shales from 200 to 400 feet thick below the sandstones of the Strawn group and overlying conformably the Marble Falls limestone.

*Extent.*—As shown on the map it occurs all along the outcrop around Llano Mountains, and recently an outlier was found in a synclinal area nine miles south of the Marble Falls-Smithwick contact due south of Richland Springs. It also occurs above the Marble Falls limestone throughout a very large area, north, east and west of the Llano region, for it is reported in practically every well which has been drilled to the proper horizon. It may be conceived to underlie all of the north-central Texas area.

*Noteworthy Exposures.*—Besides the type exposure at Smithwick excellent outcrops of the shale are to be seen on the south side of the Colorado River at Bend in San Saba County, along a small creek valley one-half mile south of the railroad station at Algerita, and on the sides of a prominent conglomerate-capped hill on the north side of Walnut Springs two miles west of Harkeyville, San Saba County.

*Lithologic Character.*—As exposed the Smithwick shale is typically a hard, dense, black, finely laminated, brittle, fissile shale containing fragile calcareous concretions, ferruginous seams, and small ferruginous concretions. Two phases are recognizable lithologically: a lower black, fissile, carbonaceous, thinly bedded, slaty shale interbedded with dense, black, thin limestone layers, the whole being about 120 to 200 feet thick; and above, a dark-colored to yellow-green or brown, somewhat sandy shale free from calcareous layers, this series being from 100 to 150 feet thick. The upper phase is more like the shales of the Strawn beds, and in well logs it is difficult to differentiate it from the overlying Strawn.

Everywhere well samples from this formation are characterized by dense, black, splintery shale fragments that are usually distinguished from the overlying Strawn shales by their darker color, greater hardness, and their lesser tendency to disintegrate into mud when washed from the bailings in a well or triturated with water in a beaker. Its content of organic remains is less and the number of foraminifera fewer than that of the Strawn shales. Also the percentage of calcium carbonate and sandy material is less in the Smithwick shale than in the other formations.

A typical section of the Smithwick as measured by Moore near the Colorado River west of Bend is as follows:

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[44]Paige, Sidney, Geology of the Llano and Burnet quadrangles: U. S. Geol. Surv. Folio 183, p. 57, 1912.

**Section of Smithwick formation west of Bend**

| | Thickness Feet |
|---|---|
| SMITHWICK SHALE— | |
| 2. Shale, olive to greenish gray, clayey to sandy, thin bedded, weathers easily | 100 |
| 1. Shale, black, fissile, carbonaceous, lower part contains thin beds of limestone | 115 |

The average thickness of the Smithwick shale in well sections is about 450 feet, although owing to the erosion of the upper part of the soft shales on the outcrop it is rare that a complete section showing this thickness is found.

*Regional Variations.*—The recorded thickness of the shale as reported by geologists varies greatly from one field to another, and in some areas the thickness changes markedly in short distances. The variation is due in part to a thinning or thickening of the formation and in part to failure of the geologists always to distinguish the upper lighter phase of the Smithwick from the overlying Strawn or to a mistake in identifying some of the limestone layers at the base of the Smithwick as the top of the Marble Falls limestone. The studies of well sections checked by samples show, however, that the shales have an average thickness of 300 feet in central Brown County, 450 feet in Eastland County, 400 feet in Stephens County, and 500 to 600 feet in Young County, but marked deviations from these averages are common. East of the oil fields in Palo Pinto and Jack counties the thickness of the brittle black shale referred to the Smithwick is much greater. The Edmondson well located nine miles south of Mineral Wells, of which a careful log and samples of cuttings were kept by the geologists of the Empire Oil and Gas Company, shows 700 feet of shale containing sandy layers, above the limestone of the Marble Falls formation. The log of the Dye No. 1 test drilled by Roxana Petroleum Company east of Graford, from which samples also have been collected and checked against the driller's record, shows 600 feet of this black shale.

It is not known whether this greater thickness is due wholly to a thickening of the Smithwick or to a playing out eastward of the upper limestone layers of the Marble Falls formation, so that the shale includes the upper part of the older formation. However, the top of the Marble Falls limestone and the top of the Ellenburger limestone dip eastward from Breckenridge and Caddo across Palo Pinto County, and by projecting the top of the Marble Falls limestone from Caddo it comes at about the depth where limestones are encountered in the holes 700 feet below the top of the black shales (Plate IX). Therefore, it is concluded that the greater thickness of the shales in the deep tests all belongs to the Smithwick shale formation.

In tests drilled in the Caddo and Breckenridge fields the Smithwick shale is undoubtedly abnormally thin (Plate V and section of the Breck-

Oversized
page

enridge field, Plate IX). This thinness is due either to an uplift that gave rise to the Caddo and Breckenridge domes following the Marble Falls epoch, so that the full thickness of the Smithwick was never deposited, or more probably to removal of a portion of the shale on top of the domes in the pre-Strawn epoch, the same as the Smithwick in places on the Llano uplift was removed so that the Strawn lies in direct contact with the Marble Falls limestone. This last conclusion is given added weight by the fact that the Davis No. 1 well drilled by the Gulf Production Company in the Breckenridge field at a location near the top of the subsurface dome (on the west side of the Breckenridge-Cisco road four miles south of Breckenridge, T. E. & L. Survey, No. 3386) had less than 100 feet of shale that can be referred to the Smithwick in its section. Samples of the cuttings from this well were carefully saved and have been studied by E. G. Allen who furnishes the following section:

**Section of lower part of Davis No. 1 well, four miles south of Breckenridge**

| Description | Thickness | Depths |
|---|---|---|
| STRAWN GROUP— | | |
| Blue shale and sand | 18 | 2906-2924 |
| Dark blue shale | 40 | 2924-2964 |
| Blue sandy shale | 10 | 2964-2974 |
| Blue shale | 50 | 2974-3024 |
| BEND GROUP— | | |
| Smithwick shale | | |
| Dark slaty shale | 10 | 3024-3034 |
| Limestone | 6 | 3034-3040 |
| Gray shale and sand, water-bearing | 8 | 3040-3048 |
| Dark grey shale and slate | 86 | 3048-3134 |
| Marble Falls limestone | | |
| Gray, porous limestone | 111 | 3134-3245 |

*Paleontology.*—The uppermost formation of the Bend group is found to contain fossils at certain horizons. The collections of the writers were made chiefly along the excellent exposures near the junction of the Bend-San Saba road and the Bend-Cherokee road, about a mile west of the town of Bend. The lower black, fissile shale is not fossiliferous but in the lower part of the upper olive gray shale numerous fossils are found. This horizon is in the middle portion of the Smithwick division. Although some hundreds of specimens in all were secured, the number of species represented is not large. In the main, they are different from those which were found in the subjacent limestone. It is probable, however, that the differences in composition are the natural result of the marked change in sediments which characterized the latter part of the Bend time. The change was somewhat gradual, as evidenced by the interbedded black limestone and black, bituminous shale at the top of the Marble Falls limestone, and it is clear that there was no break in deposition of sediments before the Smithwick shale.

The fauna of the Smithwick shale, as represented by the collections near Bend, is as follows:

**Fauna of the Smithwick shale, eastern San Saba County**

Coelenterata
- *Hadrophyllum aplatum* Cummins

Echinodermata
- Crinoid stems

Bryozoa
- *Cystodictya lineata* Ulrich?

Brachiopoda
- *Lingula* sp.
- *Orbiculoidea* sp.
- *Chonetes laevis* Keyes
- *Chonetes* sp.
- *Athyris* ? sp.
- *Cliothyridina sublamellosa* (Hall) ?

Pelecypoda
- *Leda bellistriata* (Stevens)
- *Leda bellistriata attenuata* (Meek) ?
- *Conocardium* sp.
- *Myalina subquadrata* Shumard ?

Gastropoda
- *Bellerophon wewokanus* Girty
- *Bellerophon* n. sp.
- *Bucanopsis meekiana* (Swallow)
- *Phanerotrema* n. sp.
- *Bembexia nodomarginata* (McChesney)
- *Euomphalus* n. sp.
- *Turbo* n. sp. 1, 2
- *Sphaerodoma* ? sp.
- *Meekospira peracuta* (Meek and Worthen)
- *Bulimorpha* ? sp.

Cephalopoda
- *Orthoceras* sp. 1, 2
- *Gastrioceras compressum* Hyatt
- *Gastrioceras* sp.
- *Paralegoceras* n. sp.
- *Paralegoceras* sp.

Pisces
- *Edestus minor** Newberry

This fauna is very dominantly molluscan, both in number of different species and the number of individuals. The species *Bellerophon* sp. and *Gastrioceras compressum* are much the most common forms present. Both are apparently restricted to the Bend group, although the latter is found in the upper part of the Marble Falls limestone as well as in the Smithwick shale. Most of the specimens of this cephalopod found in the shale are crushed flat, a condition which indicates a very thin, fragile shell.

*Correlation.*—Of the species composing the fauna of the Smithwick shale a very important element is apparently confined, so far as known at present, to this formation. Most of the common shells are either undescribed forms or types which have previously been described from the Smithwick alone. Such are *Hadrophyllum aplatum*, a very curious coin-shaped coral (see Plate VII) described by Cummins, a highly ornamented

*Conocardium*, new species of *Bellerophon, Phanerotrema, Euomphalus,* and *Turbo, Paralegoceras,* and *Gastrioceras compressum.* The coral commonly weathers to a pure white color which contrasts strikingly with the dark color of the shale. The remaining species in the fauna are numerically not important, but they indicate relationships which, with the generic character of the forms which are restricted to the Smithwick, show clearly the approximate geologic age of the formation. All of the associations of the Smithwick fauna appear to be with the Pennsylvanian, although the occurrence of such a form as *Bembexia nodomarginata*, elsewhere reported from the Moorefield shale, is an interesting remnant of Mississippian aspect.

It is apparent that the Smithwick, like the Marble Falls limestone which it conformably succeeds, is a deposit of the early Pennsylvanian Pottsville division and equivalent in age to a portion of the Morrow group of Oklahoma and Arkansas. It is probably also contemporaneous with some portion of the clastic sediments of the Atoka and succeeding strata which overlie the Wapanucka limestone northeast of the Arbuckle Mountains in southern Oklahoma, and to a portion of the Glenn formation on the south side of the Arbuckles.

## STRAWN GROUP

### GENERAL DISCUSSION

*Definition.*—The Strawn group as here defined includes all the strata from the top of the Smithwick shales to the base of the Palo Pinto limestone as mapped in the Brazos River Valley or its stratigraphic equivalent in the Colorado River Valley. The Palo Pinto limestone is now known to be represented in the Brownwood district by beds 200 feet below the thick Adams Branch limestone. Therefore the upper contact of the Strawn in the southern district is marked in some places by the Rochelle conglomerate and in other places by the top of the first coarse sandstone that lies approximately 200 feet below the Adams Branch limestone at the base of the "Campophyllum" bed of Drake.

The heavy layers of sands and gravels of the Strawn group were the first to be deposited after the great regional uplift and epoch of erosion that followed the deposition of the Smithwick shale. The series stands out in striking contrast to the carbonaceous muds and calcareous oozes of the preceding group. The uplift consisted of an elevation with arching and local folding of the sediments in north-central Texas along a line through Eastland, Stephens, and Young counties accompanied by a depression in the eastern part of Erath, eastern part of Palo Pinto, and Jack counties, and an elevation in the Llano Mountains.

The Strawn sea advanced over a low, mud-covered country probably much like the Texas Gulf Coast of today, except that the land consisted of broad ridges and shallow depressions and sloped northward and eastward. The water first advanced into an embayment formed by the downwarping in eastern Jack and Palo Pinto counties. The bay was fairly deep, and a land mass lay to the northeast in eastern Texas and southeastern Oklahoma. During the first half of the epoch limestone and fine dark-colored clays were laid down in the Mineral Wells embayment. In the latter part of the epoch the sea advanced westward and southward reaching the Colorado River Valley area where the sea was shallow and the sediments were mostly coarse clastics. All the sediments were deposited as if along a broad subaqueous outwash plain with a gentle depositional dip to the west. Subsequent tilting has accentuated the west dip and tilted the northern beds toward the north so that the normal dip of the group is west and northwest, and the best sections are now to be seen along the east exposures.

*Stratigraphic Relationships.*—The relationships of the Strawn to the Smithwick shale are everywhere unconformable. On the north side of the Llano Mountains where the lower contact is exposed, the Strawn sands are deposited on the eroded surface of the Smithwick and Marble Falls formations and overlap in one or two places on the Ellenburger limestone. In the Brazos River, Colorado River, and Trinity River sections the basal beds of the Strawn pinch out westward so that the younger beds progressively overlap the older strata, and wells drilled along an east-west line in the west side of the area reach the Smithwick shales at progressively shorter distances through the Strawn as shown in Plate III. This condition suggests that relative uplift of the land mass continued during the Strawn epoch so that each younger bed was carried out and deposited farther down-dip and farther off shore than the preceding. In the Brazos River section the contact of the Strawn and Bend is known only from well logs. Nearly all records show a light-colored quartz sand near the base of the Strawn. In places the sand lies directly on black Smithwick shale, and in other places it is separated from the black shale by blue clays and thin limestone layers (Plate IX). This sand is known to the drillers in the Desdemona field as the "hurry up" sand and by others as the "pepper and salt" sand. In many sections it contains salt water. Under the microscope samples are found to contain grains of black shale and black chert that resemble very closely the shales and cherts of the Bend group. It is thought that this sand phase in well sections at the base of the Strawn represents the line of unconformity between the Strawn and the Bend, and it has been employed constantly in determining the subsurface stratigraphy of the oil fields.

The Strawn is overlain unconformably on the east side of its outcrop by Cretaceous deposits and conformably on the west side by the beds of the Canyon group. However, in the Colorado River district close to the Llano Mountains some evidence of local unconformity at the base of the Canyon has been found, which will be discussed in the consideration of the stratigraphic relationship of that group.

*Areal Distribution.*—The outcrops of the Strawn group form two large triangular areas located in the Colorado River Valley, and Brazos River Valley, as shown on the sketch map, Figure 7. There are also narrow strips along the tributaries of De Leon River in Comanche County and possibly in the West Fork of the Trinity River in Wise County.

The Colorado River outcrop is a wedge-shaped area with its broad side extending from a point near the San Saba-McCulloch county line west of Hall to a place about four miles northeast of Brownwood, and the point of the wedge extends down the Colorado River Valley as far as Nix postoffice in Lampasas County. The south side of the outcrop is bordered by the alluvial flats of the San Saba River from Algerita to the Colorado River and the north side by the stream-indented escarpment of Cretaceous gravel and limestone extending across the west side of Mills County.

The Brazos River Valley outcrop extends from a west border line drawn from Salesville in Palo Pinto County down the Brazos River Valley as far as Dennis in Parker County, an area covering about 1000 square miles. The outcrop is bordered on the northeast and south by Cretaceous sands and on the west by the massive Palo Pinto limestone of the overlying Canyon group.

Three small outliers in the midst of the Cretaceous belt are located, one in the valley of Sabanna River south of Gorman, another along Copperas Creek in the central part of Comanche County seven miles south of DeLeon, and the third on Hog Creek two miles south of Desdemona (Figure 7).

## STRAWN GROUP IN THE COLORADO RIVER VALLEY

*General Statement.*—As the strata in the Brazos and Trinity river valleys present marked differences in type of sediments and lithology and contain faunas not yet discovered in the Colorado River Valley, and as the areas are separated by so broad a stretch of Cretaceous deposits, it has been impossible to correlate definitely any layers of the Brazos River Valley with any in the Colorado River Valley. Therefore, it seems preferable to discuss the two areas separately, and until definite correlations can be made, to use different names for the subdivisions of the group in the separate districts.

*Drake's Classification.*—In the Colorado River Valley the Strawn has been mapped and described by Drake.[45] The columnar section on Figure 11 shows graphically the character of his subdivisions as plotted from his published descriptions. The group in this area consists of sandstones alternating with clay layers of about equal thickness. Each continuous clay bed and each series of sandstones received separated names as follows:

20. Ricker bed
19. Antelope Creek bed
18. Indian Creek bed
17. Comanche Creek bed
16. Wilbarger bed
15. Buffalo Creek bed

[45]Drake, N. F., Report on the Colorado coal field of Texas: Geol. Surv. Texas, 4th Ann. Rept., p. 374, 1892.

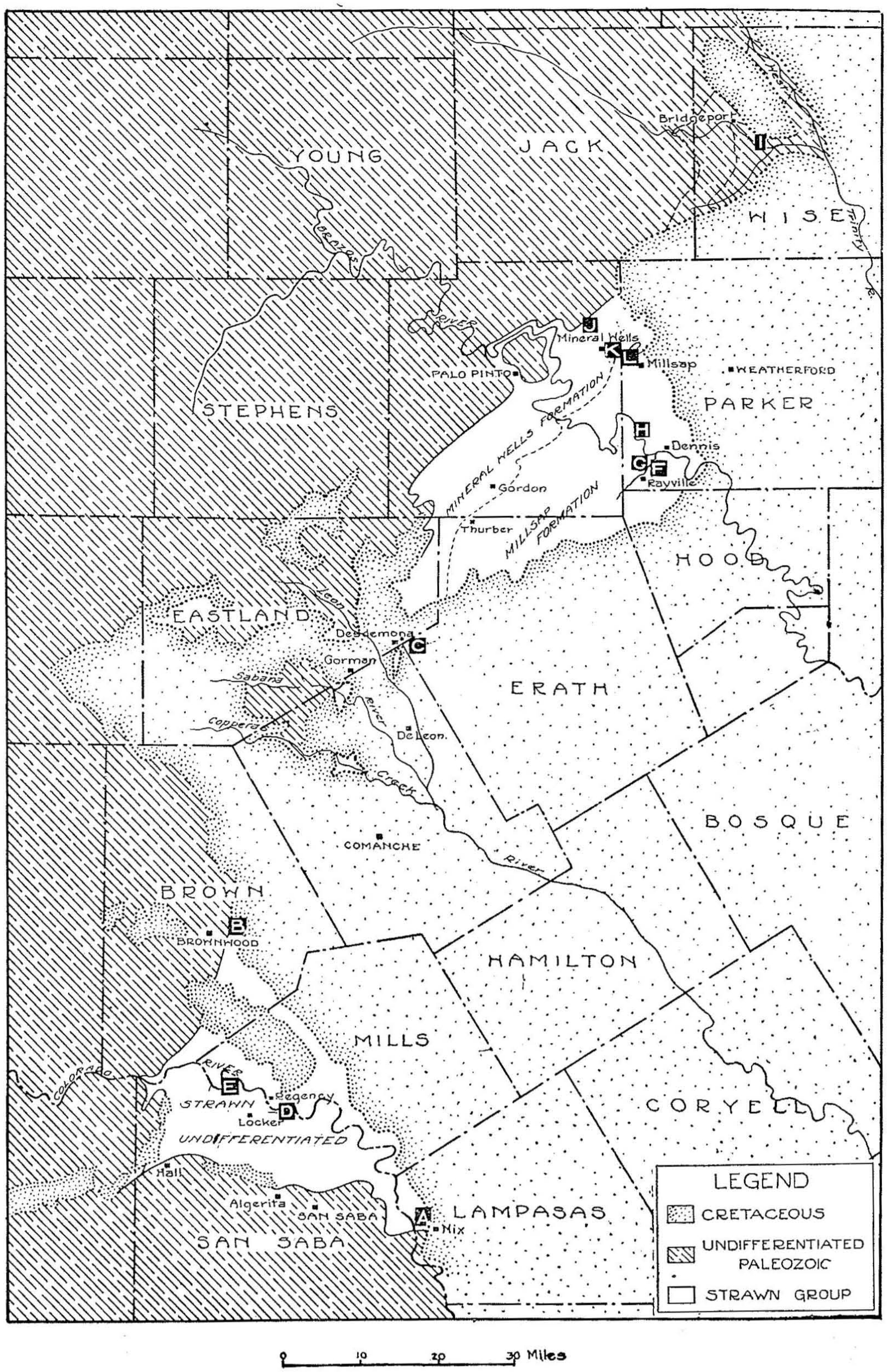



Figure 7. Map showing area of the Strawn outcrop

14. Rough Creek bed
13. Hanna Valley bed
12. Cottonwood Creek bed
11. Spring Creek bed
10. Brown Creek bed
9. Big Valley bed
8. Bull Creek bed
7. Horse Creek bed
6. Foxford bed
5. Bed No. 8
4. Shadrick Mill bed
3. Elliott Creek bed
2. Burnt Branch bed
1. Lynch Creek bed

As each bed has been carefully described by Drake,[46] and as the sandstones and shales of a given bed closely resemble those of any other in the group, it is unnecessary to describe again each layer individually. Therefore, the Strawn group will be discussed briefly as a whole and only such new sections and detailed descriptions given as will supplement the descriptions of Drake.

*Noteworthy Exposures.*—The best exposures of the Strawn in contact with the Smithwick shale are along Lynch Creek west of Nix postoffice in Lampasas County. The lower sandstones and shale beds are best studied on the east side of the Colorado River near Shadrick Mill. The middle beds including the Cottonwood Creek series of sandstones are excellently exposed along a prominent escarpment which extends from a point north of Richland Springs northeastward to Regency on the Colorado River. The upper beds outcrop typically along the Brownwood-Regency road five miles south of Brownwood.

*Thickness.*—The drill shows the greatest thickness of the Strawn south of Brownwood to be not over 1200 feet. Because of the abrupt pinching out of the lower beds by overlap this thickness is very much less than the combined thickness of the individual beds measured along the outcrop. The measurements on the outcrop by Drake, and more recently, in the course of the Roxana work, by Wells and McLeod, give a total thickness for the beds of more than 3800 feet. As the Strawn passes beneath the younger beds of the Pennsylvanian and Permian divisions, it continues to decrease in thickness, both by the playing out of the lowermost beds and by the thinning of the sandstone members which are replaced laterally by thin limestone lentils and shales, a change that indicates a farther off-shore phase. This change in sediments is illustrated in the well log section, Figure 8. Two miles east of Brownwood where the Capps wells were drilled the Strawn is 1100 feet thick; five miles west of Brownwood the Coyle well of the Lucky Six Oil Company located on top of the Brownwood fold shows the Strawn to be 700 feet thick; the Davis well drilled by the Carter Oil Company seven miles south of Bangs shows 800 feet of

[46]Idem, pp. 375-389.

Strawn; and the Morris well drilled by the Magnolia Oil Company nine miles north of Coleman shows only 500 feet of the Strawn group. North and northwestward from Brownwood the group thickens, and the top of the Smithwick is found at progressively greater depths in the wells located northwestward along the strike of the surface strata.

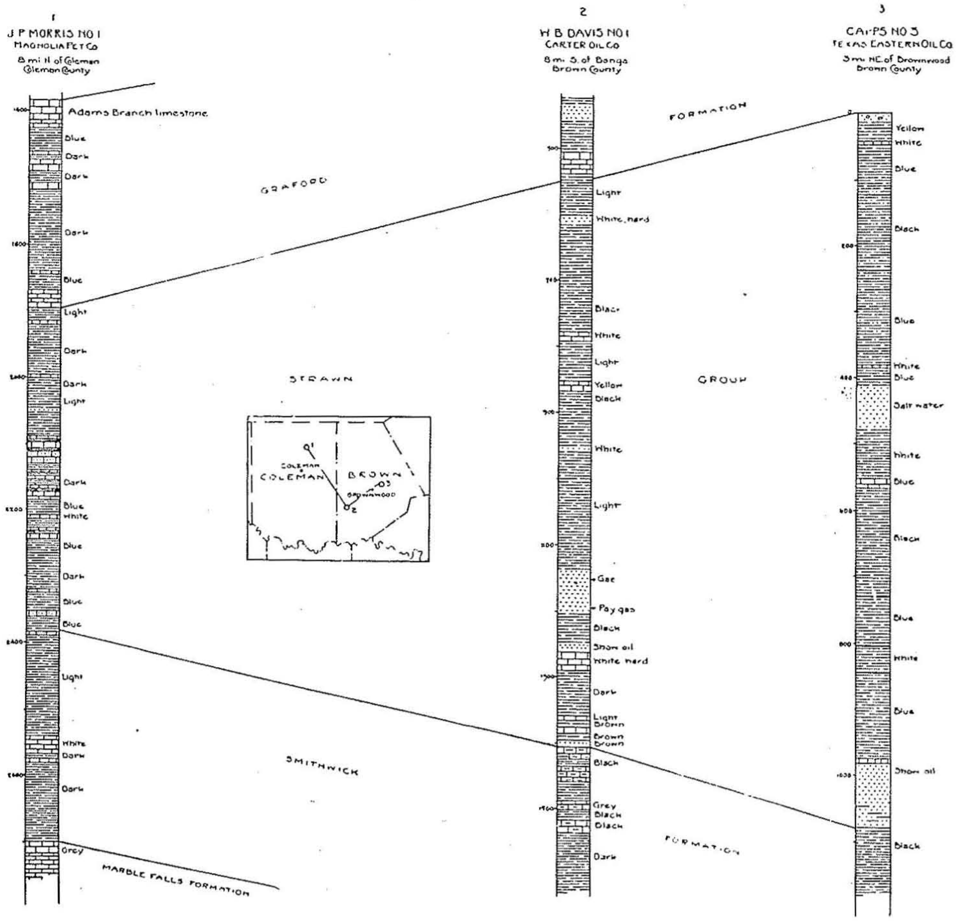



Figure 8. Section across Brown and Coleman counties showing thinning of the Strawn group toward the west

*Lithologic Character.*—In the Colorado River Valley the Strawn series consists of beds of calcareous blue and gray shales, sandy shales, and shales interbedded with thin sandy layers alternating with massive sandstone beds most of which are coarse-grained and reddish-brown and contain thin layers of shale and lentils of conglomerate. In many places the sandstone contains fragments of coal plants, and thinner flaggy layers, which in places show ripple marks along the bedding planes. Most of the individual sandy layers have been deposited irregularly and, though a given series such as the Cottonwood beds may be traced for miles, any individual layer is found to grade laterally into beds of shale and a new lentil of sand may appear just above or just below the first position in the section. The upper 400 or 500 feet of the Strawn contains a greater proportion of shale and less sand than the middle and lower portions.

*Detailed Sections.*—The columnar section from Drake's descriptions shown in Figure 2, the columnar Section No. 1 on Plate II and the described sections by L. E. Wells and Angus McLeod, given on page 67 are accurate representations of the stratigraphy of the Strawn series as a whole. The lowermost beds of the Strawn near the contact with the Smithwick shale are well illustrated by the following section measured along Lynch Creek two and one-half miles northwest of Nix postoffice at A, Figure 7.

**Section of Lynch Creek two and one-half miles northwest of Nix**

| | Thickness Feet |
|---|---|
| STRAWN GROUP— | |
| Lynch Creek Bed | |
| 5. Sandstone, brown, ferruginous | 20 |
| 4. Sandstone, reddish-gray, interbedded with shale layers | 30 |
| 3. Shale, bluish, sandy | 10 |
| 2. Shale, bluish, sandy | 10 |
| 2. Shale bluish | 40 |
| 1. Shale, black and bluish green | 20 |

The basal shales closely resemble the layers of the Smithwick formation and probably represent redeposited material from the Bend group. An apparent upward gradation from the black Smithwick shales into bluish shales followed by thick layers of sandstone is typical of the sections exhibited by many well logs. For example, a study of the cuttings from the Capps well two miles east of Brownwood, at B in Figure 7, gives the following section:

**Section of portion of the Capps well two miles east of Brownwood**

| | Thickness | Depth |
|---|---|---|
| STRAWN GROUP— | | |
| 6. Sand, gray and white | 60 | 990-1050 |
| 5. Shale, sandy, grayish-blue | 35 | 1050-1085 |
| 4. Limestone, gray, sandy | 5 | 1085-1090 |
| BEND GROUP— | | |
| Smithwick Shale | | |
| 3. Shale, dark bluish-black | 110 | 1090-1200 |
| 2. Shale, blue, sandy at top | 40 | 1200-1230 |
| 1. Shale, black, brittle | 210 | 1230-1450 |

About 30 miles northeast of the Capps well in the Desdemona field the basal formation is well known from a large number of samples collected from the cuttings and studied in the laboratory. The following section taken from the Herrington No. 1 well of the Plains Oil and Gas Company, located at C in Figure 7, as interpreted from samples collected by Ray Austin, is as follows:

**Section of basal Strawn beds in the Desdemona field**

**(C in fig. 7)**

| | Thickness Feet | Depth Feet |
|---|---|---|
| STRAWN GROUP— | | |
| 5. Sandstone, gray, hard, water-bearing, contains bit of black shale and black chert derived possibly from the Marble Falls limestone | 100 | 1900-2000 |
| 4. Shale, blue-gray, soft | 140 | 2000-2140 |
| 3. Shale, grey, calcareous | 30 | 2140-2170 |
| BEND GROUP— | | |
| Smithwick shale | | |
| 2. Shale, black, soft | 250 | 2170-2420 |
| 1. Shale, black, brittle, caving | 230 | 2420-2650 |

In some other sections, as in the Rudd well three miles southwest of Gorman, the sandstone lies in direct contact with the Smithwick shales (columnar Section 8, Plate V).

The middle portion of the Strawn contains more sandstone and conglomerate layers, and the shale content is less. The shales are mostly blue in color, in fresh cuts, weathering to gray or yellow where exposed for a long time. Most of the shale layers are more or less discontinuous and grade laterally into sandstones. The sandstones are gray, changing to red or brown when weathered; everywhere they are soft and disintegrate readily into loose sand obscuring the outcrop in those places where erosion is not sufficiently vigorous to remove the debris. At various horizons in the sandstone beds there are thin layers of conglomerate which consist largely of angular fragments of small siliceous pebbles less than one-half inch in diameter. The gravel grades from coarse to fine in short distances. The following section of the Cottonwood beds as measured by L. E. Wells is typical of the middle portion of the Strawn.

**Section of upper part of Cottonwood Creek beds from mouth of Cottonwood Creek west to San Saba-Brownwood road**

**(D in fig. 7)**

| | Thickness Feet |
|---|---|
| STRAWN GROUP— | |
| Cottonwood Creek Bed | |
| 8. Sandstone, gray, friable, massive at top, thin-bedded and shaly at bottom, weathers brown, breaks into large blocks | 5 |
| 7. Sandstone, blue, weathers gray, sandy toward bottom | 10 |
| 6. Sandstone, gray, friable, massive | 55 |
| 5. Shale, sandy shale, and sandstone | 13 |
| 4. Sandstone. gray, thin-bedded, with thin bed of coarse conglomerate made up of siliceous pebbles ½ inch in diameter and smaller | 1 |
| 3. Shale, blue gray | 4 |
| 2. Sandstone, gray, friable, massive | 33 |
| 1. Sandstone, thin-bedded, changes laterally into massive sandstone | 29 |
| Total thickness measured | 141 |

The upper third of the Strawn section contains shales and sandstones in about equal proportions, and its characteristics are best illustrated by the following section:

**Section of Strawn group, along north side of Colorado River, Mills County, Texas. By Angus McLeod. (E. in fig. 7)**

| | Feet |
|---|---|
| STRAWN GROUP— | |
| Antelope Creek Sandstone? | |
| Shale | 6 |
| Sandstone | 4 |
| Shale | 8 |
| Sandstone | 12 |
| Shale | 6 |
| Sandstone, forming prominent escarpment | 16 |
| Comanche Creek Shale? | |
| Shale | 86 |
| Sandstone | 2 |
| Shale | 42 |
| Sandstone | 6 |
| Shale | 34 |
| Sandstone | 2 |
| Shale | 30 |
| Sandstone | 6 |
| Shale | 92 |
| Wilbarger Sandstone? | |
| Sandstone, gray, massive, weathers to large blocks | 4 |
| Shale, yellow | 8 |
| Sandstone, dark gray, gritty in places, conglomeratic | 8 |
| Shale, yellow, sandy | 8 |
| Sandstone, gray-brown, medium-grained | 10 |
| Shale, yellow, sandy | 16 |
| Sandstone, gray to red or brown, massive-bedded, medium to coarse-grained, contains fragments of coal plants | 6 |
| Shale, gray | 10 |

| | |
|---|---|
| Sandstone, gray, weathering buff and reddish-brown | 6 |
| Shale, gray | 12 |
| Sandstone, gray, to red or brown, massively bedded, medium to coarse-grained, some beds contain coal plants | 22 |
| Shale, yellow | 6 |
| Sandstone, gray, massive to flaggy | 28 |
| Shale, gray | 16 |
| Buffalo Creek—Hanna Valley Beds? | |
| Shale, yellowish-gray to white, containing layers of ferruginous and calcareous concretions | 92 |
| Sandstone, gray to yellowish-gray, medium-grained | 24 |
| Shale, gray, sandy, containing thin layers of sandstone | 28 |
| Sandstone, dark gray, massive, hard, fine-grained | 26 |
| Shale, gray-blue | 18 |
| Cottonwood Sandstone? | |
| Sandstone, gray, weathering reddish-brown | 6 |
| Shale, bluish-gray | 10 |
| Sandstone, grayish-brown | 12 |
| Shale, bluish-gray, sandy | 8 |
| Sandstone, gray or reddish-brown, massive, conglomeratic in places | 28 |
| Shale, blue-gray | 12 |
| Sandstone, yellow-gray, ferruginous | 16 |
| Shale, blue, weathering to yellow | 16 |
| Sandstone, ferruginous, coarse in places, conglomeratic | 2 |
| Shale, blue, weathering to yellow | 10 |
| Sandstone, gray, with coarse conglomerate at top | 6 |
| Spring Creek Shale? | |
| Shale, blue | 54 |
| Sandstone, gray | 2 |
| Shale, blue-gray | 12 |
| Sandstone, gray | 6 |
| Shale | 11 |
| Sandstone | 8 |
| Shale | 8 |
| Sandstone, gray, massively-bedded, few layers more resistant than others form benches, base concealed by loose sand | 36 |
| Shale | 18 |
| Sandstone | 6 |
| Shale | 18 |
| Sandstone | 2 |
| Shale | 12 |
| Sandstone | 8 |
| Shale | 6 |
| Sandstone | 6 |
| Shale | 30 |
| Sandstone | 2 |
| Shale | 12 |
| Sandstone, gray to brown, in places shaly, medium hard | 5 |
| Shale | 13 |
| Sandstone | 4 |
| Shale | 20 |
| Sandstone, gray, red and brown, calcareous | 6 |
| Shale | 42 |
| Sandstone | 10 |
| Shale | 10 |

## STRAWN GROUP IN THE BRAZOS RIVER VALLEY

*General Statement.*—The series of Strawn beds in the Brazos River Valley has not been systematically studied as a whole, and it is regretted that a map showing the prominent sandstone members can not be presented. However, detailed work has been done on the lower beds in the vicinity of Dennis and Kickapoo Falls, and on the upper beds in the vicinity of Mineral Wells and Gordon, and therefore the Strawn section as a whole in this area is quite well known.

The Strawn group in the Brazos River Valley has been divided into two formations:

2. Mineral Wells
1. Millsap

The best exposures of the lower beds are to be seen in the southwest corner of Parker County, especially at Dennis on the Brazos River, 11 miles south of Weatherford, and at Kickapoo Falls and Rayville, two miles south of Dennis (Plate X). The middle portion of the Strawn group is excellently exposed in the vicinity of Millsap where the clays may be seen at a beautiful section near the Acme Brick Company plant along the Texas and Pacific Railroad tracks two miles west of the town. The sandstones and conglomerates can be seen along the escarpment crossed by the Mineral Wells-Waco road three miles northwest of Millsap. Another vantage point from which to observe the massive Strawn sandstones is along the 300-foot cliff overlooking the great curve in the Brazos River at Inspiration Point eight miles due south of Mineral Wells. The upper strata of the group may be seen in typical section on the sides of East Mountain in Mineral Wells and along the Mineral Wells-Palo Pinto road.

## MILLSAP FORMATION

*Definition and Stratigraphic Relationships.*—The name Millsap, given to the basal beds in the Brazos Valley by Cummins in 1890 and later abandoned by the State Survey, has been retained here for the same series of strata; namely, all the beds in the Brazos River Valley below Coal Seam No. 1 and above the black shales of the Smithwick formation. The basal beds of the Millsap formation are now very well known from the drill records, as a great many holes have been put down in the vicinity of Millsap, Mineral Wells, Gordon, and Thurber. The fauna is very different from that of the overlying Mineral Wells formation, and the lithology is sufficiently distinctive to make this formation easily recognizable as a separate unit of the Strawn group.

*Extent.*—The outcrop of the Millsap beds is confined to small areas in stream valleys where the overlying Cretaceous beds have been removed. The largest outcrop is located in the Brazos River Valley and includes the southwest corner of Parker County and the north edge of Erath County. Two other areas have recently been discovered in the midst of the Cretaceous sands of Comanche County: one in the valley of Hog Creek two miles south of Desdemona, and the other in the valley of Copperas Creek six miles south of DeLeon. The location of these outcrops is shown in Figure 7 and on the geologic map, Plate I.

*Lithologic Character.*—The Millsap formation consists mostly of dark blue and black clays with a series of limestones and several thin, light-colored, friable sandstones. At the outcrop of the oldest exposed strata of the formation at Kickapoo Falls and Rayville in Parker County, 10 miles south of Weatherford, are some massive, dark-colored blue limestones, fine-grained light sandstones, and dark blue shales. The limestones are lenticular, unevenly bedded and can not be traced continuously on the outcrop or by drill records.

*Detailed Section.*—A section of the basal portion of the outcrop measured on the Weatherford-Stephenville road near Rayville is as follows:

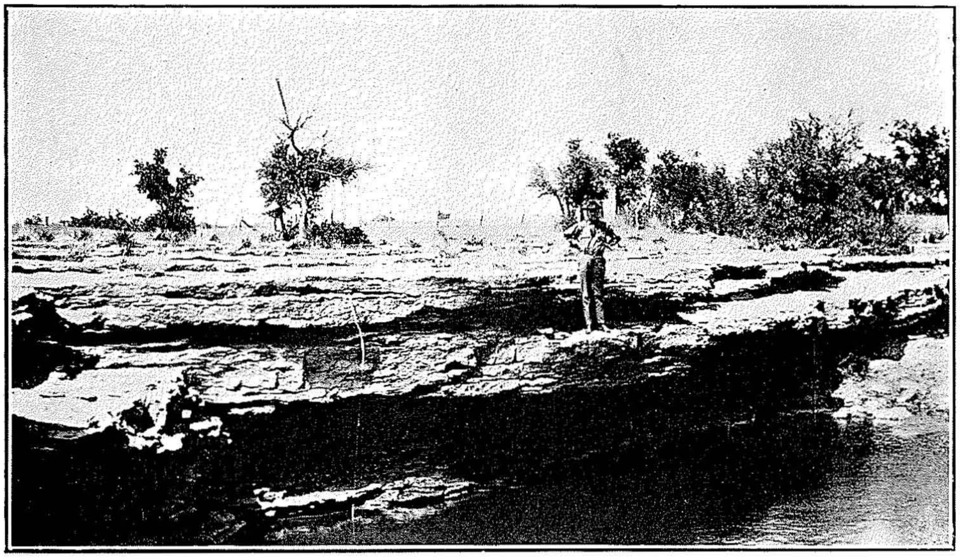
**Section of Millsap Station beds one-half mile northeast of Rayville (F in fig. 7)**

STRAWN GROUP—

| Millsap Formation | | Thickness Ft. | In. |
|---|---|---|---|
| 23. | Sandstone, conglomeratic, contains predominance of limy fragments | 3 | |
| 22. | Sandstone, white, soft, laminated | 3 | |
| 21. | Covered | 14 | |
| 20. | Shale, yellow, sandy | 2 | |
| 19. | Limestone, gray, weathers yellow, hard, fossiliferous | — | 4 |
| 18. | Shale, yellow, sandy | 2 | |
| 17. | Limestone, brown, dolomitic | 2 | 8 |
| 16. | Sandstone, white, soft, thin-bedded | 2 | |
| 15. | Shale, yellow, sandy, fragments of chert at base | 2 | |
| 14. | Limestone, brown, dolomitic, hard | 1 | 6 |
| 13. | Limestone, yellow-brown, thin-bedded | 1 | 6 |
| 12. | Shale, yellow, sandy | 1 | |
| 11. | Limestone, brown, dolomitic, hard, massive | 2 | 6 |
| 10. | Shale, yellow, sandy | 1 | |
| 9. | Limestone, brown, dolomitic, hard, massive | 2 | 6 |
| 8. | Sandstone, white, massive, rather hard when fresh, weathers to soft, shaly below | 22 | |
| 7. | Limestone, brown, dolomitic, massive | 1 | |
| 6. | Shale and limestone, yellowish, thin-bedded | 5 | |
| 5. | Limestone, bluish gray, hard | 1 | |
| 4. | Shale, yellowish, sandy | 4 | |
| 3. | Limestone, brown, dolomitic | 2 | |
| 2. | Shale (partly covered) | 15 | |
| 1. | Sandstone, reddish to brown, shaly | 6 | |

(Thickness in lower part estimated)

Along the southeastward-flowing stream at Rayville is the easternmost exposure of the peculiar dense blue limestone that is so typically and well exposed at Kickapoo Falls. The blue limestone is not so thick here as at the falls but shows all the essential characteristics. The section is as follows:



A. Kickapoo Falls limestone of the Millsap formation at Kickapoo Falls, 13 miles south of Weatherford, Parker County.

B. Limestone in the Millsap formation at Dennis on the Brazos River, 10 miles south of Weatherford, Parker County.

**Section of Millsap beds along stream east of Rayville, Parker County**

STRAWN GROUP
Millsap Formation

| | | Thickness Feet |
|---|---|---|
| 5. | Limestone, blue to drab, dense, hard, subcrystalline, rather massively bedded | 6 |
| 4. | Limestone, brown, hard, dolomitic | 3 |
| 3. | Shale, yellow, sandy | 2 |
| 2. | Limestone, brown | 1 |
| 1. | Sandstone, light yellow | — |

At Kickapoo Falls the limestone is thicker, harder, and darker blue in color and resembles so closely the Marble Falls limestone that when this exposure was first discovered it was thought it might belong to that formation. The limestone at this location has been called the Kickapoo Falls limestone. A section including exposures a short distance down stream east of the falls is as follows:

**Section along stream east of Kickapoo Falls**
**(G in fig. 7)**

STRAWN GROUP—
Millsap Formation
Kickapoo Falls Limestone

| | | Thickness Feet |
|---|---|---|
| 3. | Limestone, blue to drab, dense, very hard, subcrystalline, rather massively bedded, some fossils | 3 |
| 2. | Limestone, light blue or bluish-gray, thinner bedded than the above, more evenly bedded, fossiliferous | 7 |
| 1. | Limestone, brown, dolomitic, with thin intercalated beds of yellow sandy shale | 15 |

At Powell's Ferry on the Brazos River, located southeast of Millsap, Cummins[47] measured the following section:

**Section of Millsap Station beds at Powell's Ferry**
**(H in fig. 7)**

STRAWN GROUP—
Millsap Formation

| | | Thickness Feet |
|---|---|---|
| 5. | Limestone, fossiliferous | 4 |
| 4. | Clay, blue | 20 |
| 3. | Limestone, yellow | 1½ |
| 2. | Sandstone | 3 |
| 1. | Limestone, thin bedded, fossiliferous | 4 |

*Subsurface Aspect of Millsap Formation.*—Holes that have been drilled to the Smithwick shale in the vicinity of Millsap, Mineral Wells, and the

[47]Cummins, W. F., Report of the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., p. 381, 1890.

Brazos show the Millsap formation to have a thickness ranging from 1800 to 3000 feet. The upper portion of the division has about the same characteristics to the west beneath the surface as exhibited along the outcrop. The basal portion contains 400 to 500 feet of dark blue or black petroliferous shales and lentils of dark blue impure and calcareous sand in contact with petroliferous shales; in many places the formation contains gas or light oil in small quantities. In the Strawn field the oil sand lies about 500 feet below the top of the Millsap formation, the gas at Mineral Wells about 900 feet down in the formation, and the light oil at Millsap 1800 feet below its upper limit. The character of the Millsap beds beneath the surface is shown in the section drawn from well logs, Plate IX. West of the Palo Pinto County line the formation thins abruptly; at Brad in Palo Pinto County it is 2200 feet thick; at Caddo 1600 feet; and at Breckenridge 800 feet.

*Paleontology.*—The paleontologic character of the Millsap formation, so far as determined by the work of the writers, is indicated by collections made chiefly from the limestone beds in the lower part of that portion of the formation which appears at the surface. As previously indicated these outcrops are located in southeastern Parker County and the horizon belongs in the upper part of the Millsap formation as a whole, the lower parts being nowhere exposed. The fossil collections were obtained from three limestones at different but stratigraphically distantly separated horizons.

The lowermost appears on the south side of the Brazos River at Dennis, southwest of Weatherford. The limestone is thick and weathers in very massive blocks, but it is rather thin and very irregularly bedded. It is specially characterized by an abundance of *Fusulina.* Other fossils are not very numerous, nor are they very well preserved. The collection from this exposure includes the species which are listed in the following table from locality 76.1. This is evidently the locality and the horizon visited by Cummins and reported by him[48] in his paper on the Geology of Northwestern Texas.

The second horizon is represented by exposures of thin beds of hard, dark colored limestone interbedded with shale and sandstone which appear on a small tributary of Kickapoo Creek a short distance east of Rayville, a point on the Weatherford-Stephenville road not far southwest of Dennis. This outcrop is a short but undetermined distance above the limestone at Dennis. The limestone is very different in lithologic character and thickness and the absence of *Fusulina* is at once observed. Fossils, except *Squamularia perplexa,* are not common but there are numerous well preserved specimens of this form. The fauna collected from this horizon at two points (localities 76.2 and 76.3) near Rayville is shown in the faunal table of the Millsap formation below.

The upper limestone of the three horizons mentioned is found at the falls of Kickapoo Creek where the Weatherford-Stephenville road crosses

[48]Cummins, W. F., loc. cit., p. 381, 1891.

the stream. This exposure is a large one and shows the massive, hard, blue limestone beds which form the falls for some distance along the creek in the vicinity of the falls. The fossils collected from two localities (76.4 and 76.5) are shown in the table below.

**Fauna of the Millsap formation in southeast Parker County, Texas**

| LOCALITIES | 76.1 | 76.2 | 76.3 | 76.4 | 76.5 |
|---|---|---|---|---|---|
| Fusulina sp. | x | | | | |
| Zaphrentis gibsoni | x | | | x | x |
| Zaphrentis sp. | | x | | | |
| Campophyllum torquium | | | | x | |
| Crinoid stem | x | x | | x | x |
| Tabulipora sp. | x | | | | |
| Fenestella sp. | x | x | | | |
| Productus coloradoensis ? | x | x | | | |
| Productus cora | | | x | | |
| Productus morrowensis | | | | x | x |
| Marginifera haydensis ? | | | | x | x |
| Marginifera muricata | | x | | | |
| Dielasma bovidens ? | | | | x | |
| Spirifer cameratus | x | x | x | x | x |
| Spiriferina kentuckiensis | | x | | | |
| Squamularia perplexa | x | x | x | x | x |
| Composita subtilita | x | x | x | x | x |
| Solenomya sp. | x | | | | |
| Edmondia sp. | | | | | x |
| Aviculopecten sp. | | x | | | |
| Allorisma sp. | x | | | | |
| Pleurotomaria sp. | x | | | x | |
| Porcellia sp. | x | | | | |
| Murchisonia sp. | x | x | | | |
| Schizostoma catilloides | | x | | | |
| Strophostylus sp. | | | | x | |
| Naticopsis altonensis giganteus | | | | | x |
| Naticopsis sp. | x | | | x | |
| Meekospira sp. | x | | | | |
| Sphaerodoma sp. | | x | | | |
| Griffithides scitulus ? | x | | | | |
| Fish tooth | x | | | | |

*Correlation.*—Most of the species which are found in the Millsap beds are long ranging Pennsylvanian types which have relatively little significance as precise markers of a definite horizon within the Pennsylvanian. However, the collections are not large and it is probable that more detailed study of the Millsap formation than was possible during the course of the writers' work would show the presence of fossils which would permit independent determination of the relationships of these beds from a paleontological standpoint. It is of course evident that the Millsap is older than the Mineral Wells formation which appears conformably to succeed it and the fossils which have been found in the lower beds do not include many of the common types of the upper Strawn. It was thought in advance of the field study of the limestones in southwest Parker County that these possibly represented some portion of the Bend group, perhaps equivalent to the Marble Falls limestone, for in the southern area of the Strawn outcrop the first limestones beneath the very clastic Strawn are in the Bend. However, the limestones of Parker County in no way resemble the Marble Falls either in lithologic character or fauna and it is clear that the former are considerably higher in stratigraphic position. As shown by borings in the vicinity of Millsap, Mineral Wells, and elsewhere in the Brazos Valley the Bend lies at least 1500 to 2500 feet beneath these limestones in the Millsap formation. While some of the fossils which are reported in the foregoing table, as *Productus morrowensis,* are most suggestive of the Marble Falls fauna, this element in the Millsap fauna is small. The presence of abundant *Fusulina,* which while not reported definitely in the Marble Falls limestone is found in a collection made by Plummer from the Barnett shale, is indicative of the higher rather than the lower portions of the Pennsylvanian. It is noted in the Kansas Pennsylvanian section[49] that *Fusulina* is exceedingly rare in the rocks of the Des Moines group, that is below the horizon of the Iola limestone. However, the rocks of the Millsap formation are believed to be older than any of the Pennsylvanian in the Kansas section.

If the more abundantly fossiliferous Mineral Wells formation is correlated with some portion of the Pennsylvanian series between the Hartshorne sandstone and the Wewoka formation of southern Oklahoma, as suggested in the discussion of that formation, it is probable that the Millsap includes time equivalents of the lower part of the Oklahoma rock series which succeeds the Wapanucka limestone, that is the Atoka or a portion of it. Although the Strawn is unconformable upon the Bend in the Llano region, it is not necessarily true that there was a break in sedimentation in the Brazos River Valley. As indicated by some considerations, however, it is probable that there was at least a temporary withdrawal of the sea in this region and in southern Oklahoma evidence has recently[50] been advanced to show that there was an erosion break near the top of the Wapanucka horizon.

## MINERAL WELLS FORMATION

*Definition and Stratigraphic Position.*—The Mineral Wells formation is named for the town of Mineral Wells in Palo Pinto County where its middle portion is typically exposed in the escarpment at the edge of town. It was at this locality that Cummins described a section and collected

[49]Beede, J. W., and Rogers, A. F., Coal Measures Faunal Studies, Univ. Geol. Surv. Kan., vol. 9, p. 334, 1908.

[50]Wallis, B. F., Geology and economic value of the Wapanucka limestone of Oklahoma, Okla. Geol. Surv., Bull. 23, 1915.

fossils which established beyond all doubt the Pennsylvanian age of the Strawn sandstones. The Mineral Wells formation includes all the strata from the base of Coal Seam No. 1, as exposed along Rock Creek five miles southeast of Mineral Wells, to the base of the Palo Pinto limestone which outcrops at Palo Pinto. The coal can be traced southwest to Thurber and northeast to the Cretaceous overlap and makes a very definite line for the base of the formation. Thus defined the Mineral Wells formation lies conformably upon the Millsap beds and is overlain with apparent conformity by the basal massive limestone of the Canyon group.

*Extent.*—The Mineral Wells formation outcrops in a belt 10 to 15 miles wide from Salesville in Palo Pinto County to the Cretaceous area four miles south of Thurber in Erath County. Excellent exposures are to be seen at Mineral Wells and at almost any point along Brazos River southwest of the town.

*Lithologic Character.*—In its type locality this formation consists of three thick beds of coarse sandstones separated by beds of clay, sandy clay, and marl, and two or three thin layers of limestones. The formation is of marine origin and the shales in many places contain an abundance of fossils. The sandstones are dark reddish brown, coarse-grained, markedly cross-bedded in places, lenticular, and unevenly bedded. These coarse sandstone layers commonly grade downward into fine-textured calcareous sands and upward into conglomerate. The conglomerate consists of light-colored, sharply angular pebbles averaging from one-quarter to one-half an inch in diameter. Most of the pebbles are of resistant material such as chert and quartz, and are well assorted but appear to have been rapidly deposited by streams into shallow quiet waters for they show little effect of wave action. The shales are a dark blue gray in color and are calcareous, grading locally into sandy shales or sands. In most exposures the shales are fossiliferous. The limestones are very hard and brittle and break with a conchoidal fracture. They are persistent and can be traced for long distances and show considerable uniformity. As the three sandstone layers are very thick and resist weathering better than the other portions of this formation, they produce escarpments and give rise to rugged topography and form the scenic features of the Mineral Wells district. The total thickness of the Mineral Wells formation as measured in the central part of Palo Pinto County is 750 feet, at Strawn it is somewhat thinner, and where penetrated by wells in the Strawn field it is 650 feet thick.

*Subdivisions.*—The subdivisions, or members, of the Mineral Wells formation which have been recognized ,are as follows:

**Subdivisions of the Mineral Wells formation**

8. Keechi Creek sandstone and shale
7. Turkey Creek sandstone
6. Salesville shale
5. Lake Pinto sandstone
4. East Mountain shale
3. Brazos River sandstone and conglomerate
2. Mingus shale
1. Thurber coal

*Thurber Coal.*—The coal bed, designated by Cummins as Coal Bed No. 1, which is mined at Thurber and Strawn, apparently marks a change from the more typically marine sediments of the Millsap formation to the dominantly clastic, very shallow water, littoral deposits of the Mineral Wells formation. Since it is a stratigraphic horizon which is readily traced in the north Texas area, it may be employed in the same manner as suggested in Cummins' early work, as the line of division between the two major portions of the Strawn group in the Brazos River region.

*Mingus Shale.*—The Thurber coal is overlain by 250 to 300 feet of gray, sandy shale which is here named the Mingus shale, from the small mining town south of Mineral Wells. The shale is nowhere well exposed in complete section but is observed in the coal mine shafts and in well borings.

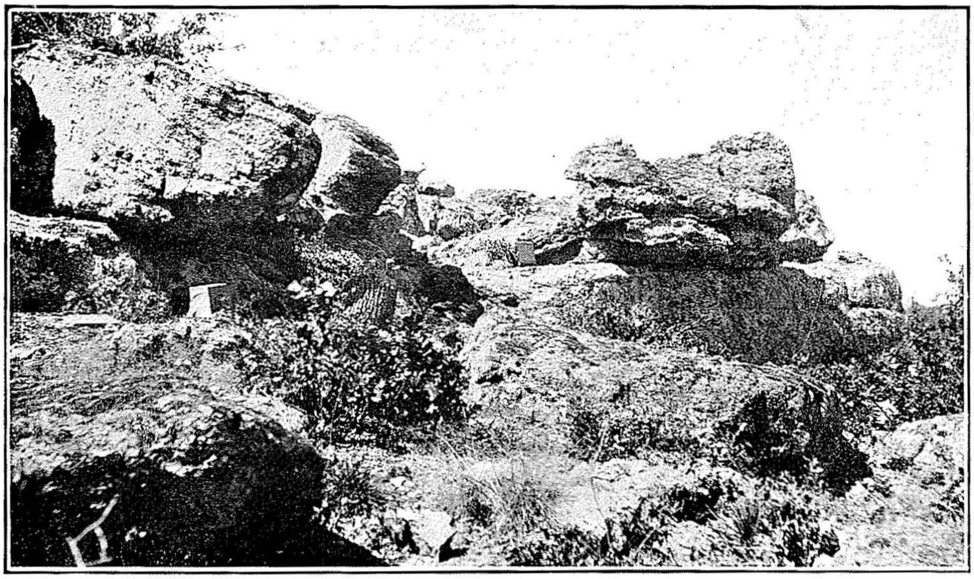
*Brazos River Sandstone and Conglomerate.*—The lowest of the thick sandstones, which are much the most prominent feature of the Mineral Wells formation, occurs about 300 feet above the base of the formation. It is a very prominent ledge of thick, massive sandstone and produces a striking escarpment. From widely distributed exposures along the Brazos River, but especially the high cliff at Inspiration Point, eight miles due south of Mineral Wells, the sandstone is designated the Brazos River member. Typical outcrops are observed near the town of Garner, eight miles east of Mineral Wells along the Mineral Wells-Fort Worth road, and on the big hill seven miles southeast of Mineral Wells on the road to Millsap (Plate XI). Its prominent escarpment may be seen for miles north of the Texas and Pacific Railway between Gordon and Santo. It forms the cap rock of imposing mesa-like hills near Gordon.

The thickness of the Brazos River sandstone member is 25 to 50 feet. It is very massive, coarse-grained, and in places contains lenticular masses of conglomerate. A typical section of the lower portion of the Mineral Wells formation showing the Brazos River member is exposed two and one-half miles northwest of Millsap.

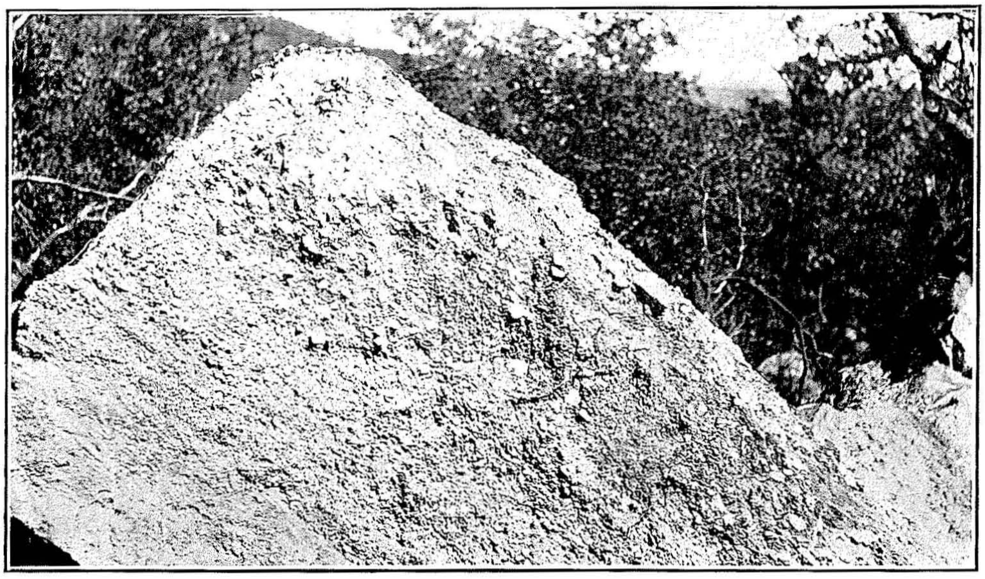
**Section of the lower portion of the Mineral Wells formation on road 2½ miles northwest of Millsap**

**(L in fig. 7)**

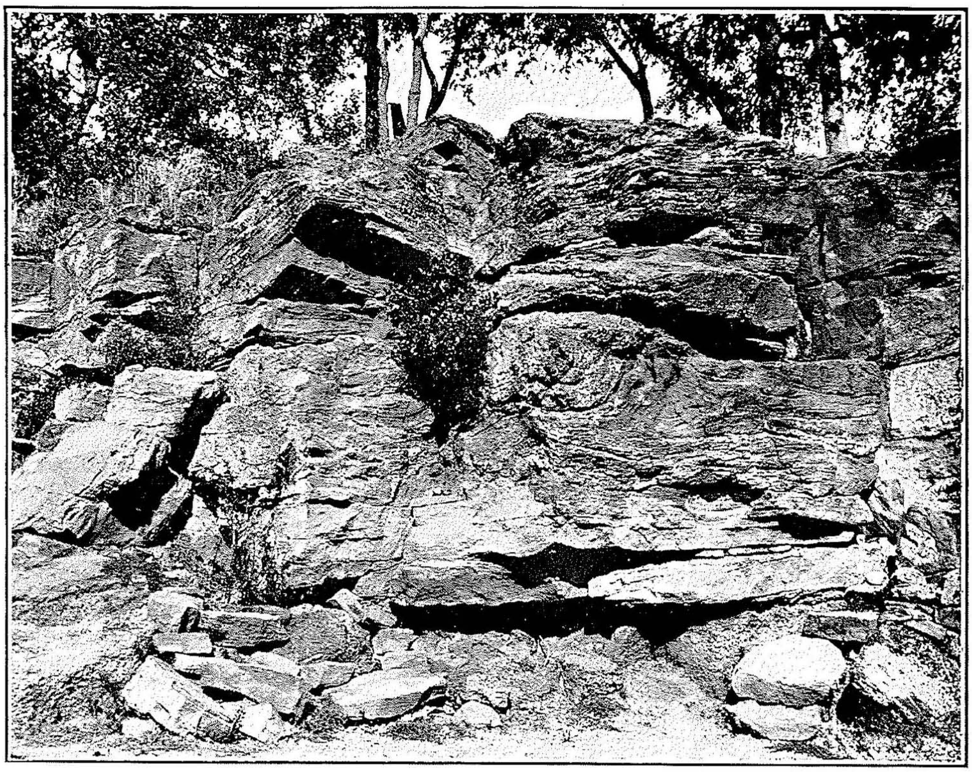
| | Thickness Feet |
|---|---|
| STRAWN GROUP— | |
| Mineral Wells Formation | |
| Brazos River Sandstone | |
| 6. Conglomerate, gray to brown, massive sandstone and conglomerate composed of medium-sized, angular pebbles, ½ to 1 inch in diameter, in matrix of coarse sandstone | 35 |
| Mingus Shale | |
| 5. Shale, gray, sandy | 10 |
| 4. Sandstone, purplish-gray, coarse | 4 |
| 3. Shale, gray, sandy | 50 |
| 2. Sandstone, brownish-gray, medium-grained, grading into shale | 15 |
| 1. Shale, forming base of slope | 100± |
| Total thickness | 214 |



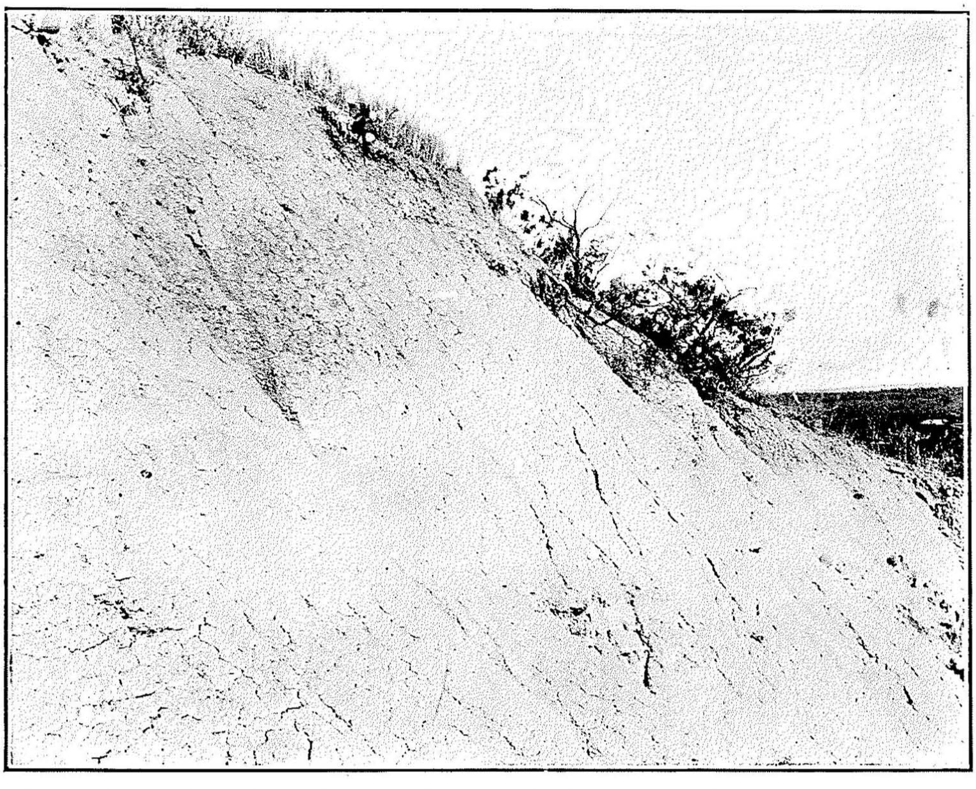
A. Massive Brazos River sandstone in the Mineral Wells formation three miles west of Millsap.



B. Conglomerate lense in the Brazos River sandstone three miles west of Millsap.



A. Typical exposure of Lake Pinto sandstone of Mineral Wells formation on East Mountain at Mineral Wells.



B. East Mountain clay bed one-half mile east of Mineral Wells.

Since the horizon of the Thurber coal is everywhere covered by debris from the weathering of the overlying sandstone and shale, the boundary of the Mineral Wells formation was determined in the field by reference to the position of the Brazos River sandstone.

*East Mountain Shale.*—Succeeding the lower massive sandstone of the Mineral Wells formation just described is an interval consisting chiefly of dark bluish gray shale which is named from exposures in the high escarpment east of the town of Mineral Wells, the East Mountain shale. The total thickness of this shale member is about 300 feet. It contains near its top a lentil of fossiliferous limestone and near its base a bed of massive sandstone. The shale contains a prolific fauna which is very similar to that of the Wewoka fauna of southern Oklahoma and apparently quite dissimilar to that found in the Millsap beds below. Most of the fossil collections made in the vicinity of Mineral Wells are from this member.

*Lake Pinto Sandstone.*—The next continuous sandstone above the Brazos River bed is the massive sandstone which caps the escarpments about the town of Mineral Wells. It is named the Lake Pinto sandstone from the lake one-half mile west of Mineral Wells, which lies in a valley almost surrounded by an outcrop of this bed. The exposures in the hills east and west of the town contain lenses of fine to moderately coarse conglomerate locally (Plate XII). A section of the Lake Pinto bed measured on the escarpment east of Mineral Wells is as follows:

**Section of Lake Pinto sandstone and East Mountain shale east of Mineral Wells**

| | |
|---|---|
| STRAWN GROUP— | |
| Mineral Wells Formation | |
| Lake Pinto Sandstone | |
| 7. Sandstone and conglomerate, loosely cemented, contains angular pebbles ¼ to ½ inch in diameter | 12 |
| 6. Sandstone, brown, coarse-grained, cross-bedded | 10 |
| East Mountain shale | |
| 5. Clay, blue, calcareous, weathers yellow, dark colored at base | 10 |
| 4. Limestone, yellow, fossiliferous | 1½ |
| 3. Sandstone, fossiliferous, in places solidly cemented with lime carbonate | 3 |
| 2. Shale, dark, sandy | 20 |
| 1. Clay, dark blue, fossiliferous | 80 |
| Total thickness measured | 136½ |

*Salesville Shale.*—A shale member, named from the small town of Salesville, north of Mineral Wells, overlies the Lake Pinto sandstone. It is about 150 feet thick and consists of sandy clays with a few lentils of sandstone and near the base a thin layer of limestone. It is well exposed in a number of the smaller streams north and west of Mineral Wells.

*Turkey Creek Sandstone.*—The thick, very massive sandstone which forms the first prominent escarpment east of the outcrop of the Palo Pinto limestone has been named the Turkey Creek sandstone, from the creek of that name northwest of Mineral Wells. It is 10 to 15 feet in thickness and forms a prominent topographic feature. The following section, measured on Turkey Creek at the type locality, shows in detail the character of this member and of the associated beds above and below.

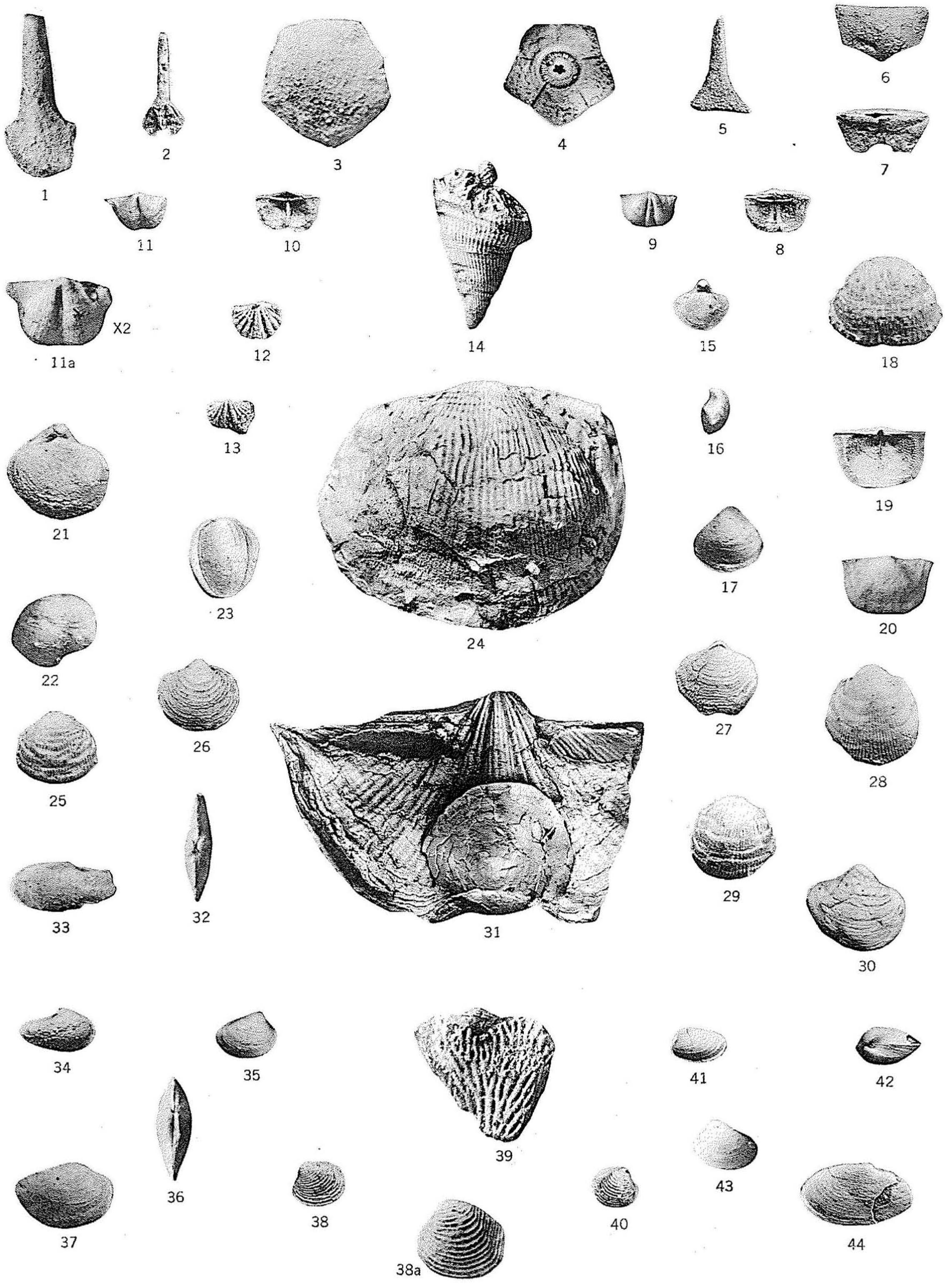
**Section of upper part of Mineral Wells formation from a point on Turkey Creek road 2¼ miles northwest of Mineral Wells, northwest to the Palo Pinto limestone**

**Measured by J. G. Burtt. (J in fig. 7)**

| | Thickness Feet |
|---|---|
| STRAWN GROUP—Palo Pinto Limestone | |
| Mineral Wells Formation | |
| Keechi Creek Sandstone and Shale | |
| 12. Shale, gray, sandy | 15- 40 |
| 11. Sandstone, brownish red, coarse-grained, lenticular, in places cross-bedded, contains lenses of conglomerate | 75-100 |
| Turkey Creek Sandstone | |
| 10. Conglomerate, dark reddish brown, massive, consists of small angular pebbles of quartz and quartzite in a matrix of coarse sand | 10 |
| Salesville Shale | |
| 9. Shale, gray, calcareous | 18 |
| 8. Sandstone, reddish brown, coarse | 8 |
| 7. Shale, gray, soft, sandy | 22 |
| 6. Sandstone, brown, coarse-grained | 6 |
| 5. Shale, gray, sandy | 13 |
| 4. Sandstone, purplish gray, lower part buff, ripple-marked | 5 |
| 3. Shale, gray,soft, partly covered | 54 |
| 2. Limestone, light gray, weathers to buff, hard, fossiliferous | 4 |
| 1. Shale, calcareous | 20 |
| Lake Pinto Sandstone | |
| Total thickness | 275 |

*Keechi Creek Sandstone and Shale.*—In the escarpment below the massive Palo Pinto limestone is a series of light gray, cross-bedded, calcareous sandstones and light gray sandy shales which are here called the Keechi Creek beds. They are typically exposed along Keechi Creek west of Mineral Wells and the Brazos River below the bridge on the Palo Pinto-Graford road. They may be seen at almost any point along the escarpment of the Palo Pinto limestone where not covered by talus. As indicated in the preceding section they have a total thickness of about 100 to 150 feet.

*Regional Variations.*—Taken as a whole the Mineral Wells formation presents about the same aspects all along its outcrop, but individual layers are quite variable. The section as measured near Strawn is shown in columnar section 5, Plate II. The upper sandstones of the Turkey Creek beds have thinned and more shales and marly clays are seen in the section than in the vicinity of Mineral Wells. The Lake Pinto and Brazos River sandstones, though present, are thinner and contain less conglomerate; the thickness of the section is also less. To the northeast in the vicinity of Bridgeport the Mineral Wells beds are poorly exposed because of the overlap of the Cretaceous formations and have not been studied by the writers.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38a

## MINERAL WELLS FOSSILS

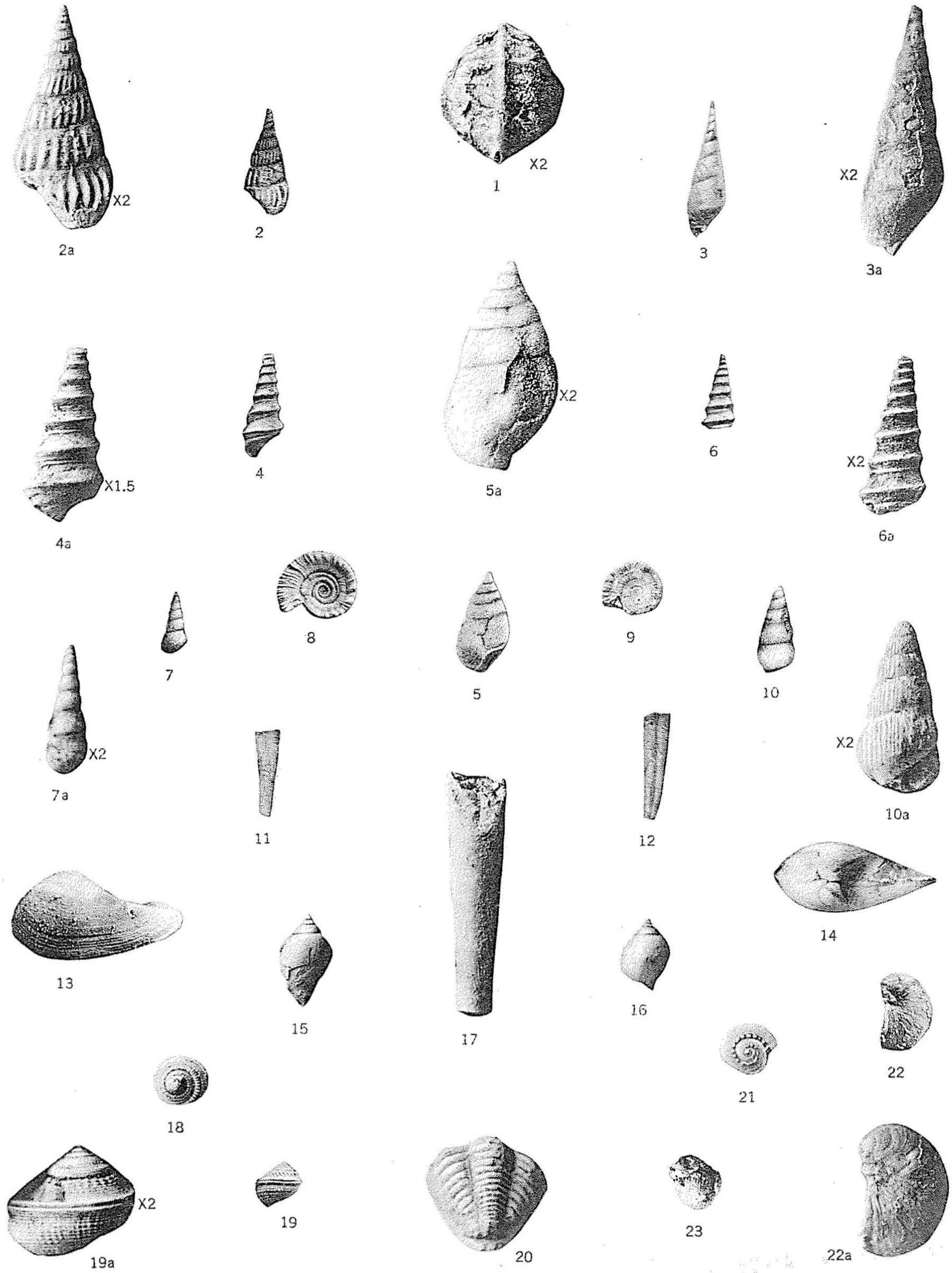
Fossils from the East Mountain shale, Mineral Wells formation, one-half mile east of Mineral Wells, Locality 68.1, Collectors Frederick B. Plummer, Raymond C. Moore.

Figure 1. *Hydreionocrinus* sp., a spine-bearing crinoid plate.
Figures 2, 5. *Hydreionocrinus mucrospinus*, spine-bearing crinoid plates.
Figure 3. *Ulocrinus occidentalis*, an unusually large crinoid plate.
Figure 4. *Hydreionocrinus* sp., circlet of basal plates of the calyx showing impression of the top segment of the stem.
Figures 6, 7. *Delocrinus hemisphericus* ?, side and top view of two radial plates.
Figures 8, 9. *Chonetes mesolobus euampygus*, a small concavo-convex brachiopod with a sharply defined double furrow extending downward from the beak. Figure 8 shows the concave brachial or dorsal valve and cardinal area; Figure 9 is a view of the pedicle or ventral valve.
Figures 10, 11, 11a. *Chonetes verneuilianus*, another small concavo-convex brachiopod which has a single deeply marked furrow extending from the beak. Figure 10 shows the brachial or dorsal valve; Figure 11 is a view of the pedicle or ventral valve of another specimen, of which Figure 11a is an enlargement.
Figure 12, 13. *Spiriferina kentuckiensis*, a small, coarsely plicated brachiopod shell with very fine concentric cross markings. Figure 12 shows a brachial valve, Figure 13 a pedicle valve.
Figure 14. *Lophophyllum profundum*, one of the commonest Pennsylvanian fossil corals, side view showing broken septa and projecting central axis or columella.
Figures 15, 16, 17. *Ambocoelia planoconvexa*, a small brachiopod with prominent beak which is extremely abundant in the East Mountain shale; brachial, side and pedicle views, respectively.
Figure 18. *Pustula nebraskensis*, a small, rather non-typical shell which is referred to this species.
Figures 19, 20. *Chonetes granulifer*, small shells suggestive of *C. flemingi* rather than the large typical *C. granulifer* which occurs at higher horizons. Interior and exterior, respectively, of a pedicle valve.
Figures 21, 30. *Squamularia perplexa*, brachial view of a typical specimen, and pedicle valve of an imperfect specimen.
Figure 22. *Marginifera splendens*, a small, nearly smooth productid, pedicle valve.
Figure 23. *Lingula* sp.,
Figure 24. *Productus inflatus coloradoensis*, pedicle valve.
Figures 25, 28, 29. *Productus pertenuis*, pedicle valves.
Figures 26, 27. *Cliothyridina orbicularis*, pedicle and brachial views, respectively, of a typical specimen showing broken edges of spinose concentric lamellae.
Figure 31. *Spirifer cameratus*, with a large, typical shell of *Roemerella patula* attached.
Figures 32, 33, 44. *Yoldia glabra*, cardinal view and left valve, also left valve of another specimen showing fine concentric striations.
Figure 34. *Leda bellistriata*, a small but characteristic specimen.
Figures 35, 43. *Nucula anodontoides* ?, left and right valves, respectively.
Figures 36, 37. *Anthraconeilo taffiana*, cardinal view and left valve of two specimens.
Figures 38, 38a, 40. *Astartella concentrica*, right and left valves of two very small shells which belong apparently to this species.
Figure 39. *Polypora* sp.
Figures 41, 42. *Nuculopsis ventricosa*, left valve and cardinal view of two small but typical specimens.

## MINERAL WELLS FOSSILS

Fossils from the East Mountain shale, Mineral Wells formation, one-half mile east of Mineral Wells, Locality 68.1, Collectors Frederick B. Plummer, Raymond C. Moore.

Figure 1. *Pharkidonotus percarinatus*, a rather small, non-typical shell.
Figures 2, 2a. *Zygopleura rugosa*, a small, ornamented, high-spired gastropod.
Figures 3, 3a. *Meekospira peracuta choctawensis*.
Figures 4, 4a, 6, 6a. *Murchisonia* sp., two specimens.
Figures 5, 5a. *Bulimorpha inornata* ?, a partly crushed example.
Figures 7, 7a. *Loxonema* ? sp.
Figures 8, 9. *Schizostoma catilloides*, upper sides of two small but characteristic specimens of this species as seen at this horizon.
Figures 10, 10a. *Zygopleura multicostata*, a finely ornamented, high-spired shell.
Figures 11, 12. *Plagioglypta meekiana*, side view of two specimens referred to this species.
Figures 13, 14. *Leda bellistriata*, left valve and cardinal view of two robust, characteristic examples of this species.
Figures 15, 16. *Sphaerodoma primigenia*, two small shells which are referred to this species.
Figure 17. *Pseudorthoceras knoxense*.
Figures 18, 19, 19a. *Phanerotrema grayvillense*, top and side views of two specimens.
Figure 20. *Griffithides* sp.
Figure 21. *Trepospira depressa*, top view of a small specimen.
Figures 22, 22a. *Platyceras parvum*, side view of characteristic specimen.
Figure 23. *Euphemus carbonarius*.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*Paleontology.*—Some portions of the Mineral Wells formation contain numerous well preserved fossils, and the fauna as a whole is a large and varied one. The most prolific fossil horizon which has been observed is a portion of the East Mountain shale member not far beneath the prominent Lake Pinto sandstone which forms the escarpment about the town of Mineral Wells. The fossiliferous portion of the shale is about 25 feet thick and occurs approximately 60 feet below the sandstone. Exposures in the vicinity of Mineral Wells are good and wherever the shale horizon outcrops, some of the fossils may be found. The localities from which the collections of the writers chiefly were obtained is shown in Figure 9. The largest collections were obtained at Locality 68.1, a shale pit on the

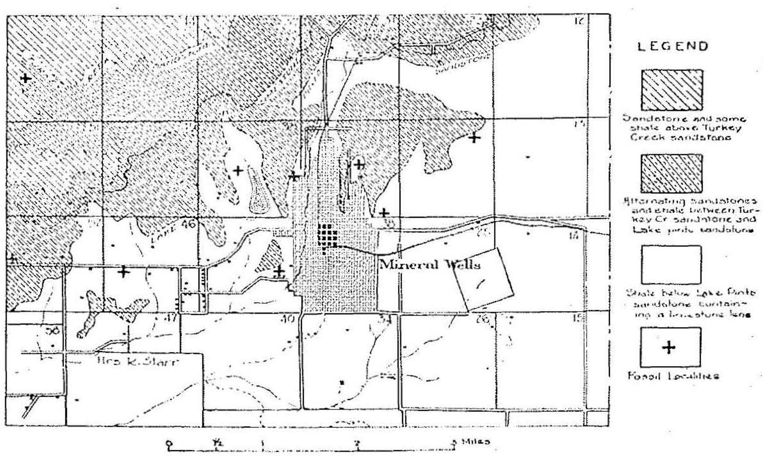


Figure 9. Map showing fossil localities in the vicinity of Mineral Wells

north side of the Mineral Wells-Fort Worth road at the east edge of town. The fossils here are very well preserved and may be collected very easily where they have weatherd out of the shale. At some other points, as west of Mineral Wells, the shells are found to be covered with a coating of lime carbonate which conceals all the surface markings and smaller structural features.

The fauna of the shale is shown in the following list with which is given for comparison mention of identical or closely related species from the Wewoka formation of southern Oklahoma. The Wewoka fauna, as described and figured by Girty[51] shows many striking resemblances to the Mineral Wells fauna.

[51] Girty, G. H., Fauna of the Wewoka formation of Oklahoma, U. S. Geol. Surv., Bull. 544, 1915.

**Fauna of the East Mountain shale member, Mineral Wells formation, near Mineral Wells, Texas, with related species from the Wewoka formation of Oklahoma**

| Mineral Wells formation | Wewoka formation |
|---|---|
| Coelenterata | |
| *Lophophyllum profundum* | *Lophophyllum profundum* |
| *Lophophyllum profundum radicosum* | *Lophophyllum profundum radicosum* |
| *Michelinia* sp. | *Michelinia eugeneae* |
| Echinodermata | |
| *Delocrinus hemisphericus ?* | *Delocrinus hemisphericus ?* |
| *Hydreionocrinus mucrospinus* | *Hydreionocrinus patulus* |
| *Hydreionocrinus* sp. | |
| *Ulocrinus occidentalis* | |
| Bryozoa | |
| *Fistulipora* sp. | *Fistulipora carbonaria* |
| *Rhombopora lepidodendroidea ?* | *Rhombopora lepidodendroidea ?* |
| *Polypora* sp. | |
| Brachiopoda | |
| *Lingula* sp. | *Lingula carbonaria ?* |
| *Roemerella patula* | *Roemerella patula* |
| *Roemerella ?* sp. | |
| *Derbya crassa* | *Derbya crassa* |
| *Chonetes granulifer* | *Chonetes granulifer* |
| *Chonetes mesolobus decipiens* | *Chonetes mesolobus decipiens* |
| *Chonetes mesolobus euampygus* | *Chonetes mesolobus euampygus* |
| *Chonetes verneuilianus* | |
| *Productus coloradoensis* | *Productus coloradoensis* |
| *Productus cora* | *Productus cora* |
| *Productus pertenuis* | *Productus pertenuis* |
| *Pustula nebraskensis* | *Pustula nebraskensis* |
| *Marginifera splendens* | *Marginifera splendens* |
| *Marginifera lasallensis* | *Marginifera lasallensis* |
| *Spiriferina kentuckiensis* | *Spiriferina kentuckiensis* |
| *Spirifer cameratus* | *Spirifer cameratus* |
| *Squamularia perplexa* | *Squamularia perplexa* |
| *Ambocoelia planoconvexa* | *Ambocoelia planoconvexa* |
| *Composita subtilita* | *Composita subtilita* |
| *Cliothyridina orbicularis* | *Cliothyridina orbicularis* |
| *Hustedia mormoni* | *Hustedia mormoni* |
| Pelecypoda | |
| *Nucula anodontoides ?* | *Nucula anodontoides ?* |
| *Anthraconeilo taffiana* | *Anthraconeilo taffiana* |
| *Nuculopsis ventricosa* | *Nuculopsis ventricosa* |
| *Leda bellistriata* | *Leda bellistriata* |
| *Leda bellistriata attenuata* | *Leda bellistriata attenuata* |
| *Yoldia glabra* | *Yoldia glabra* |
| *Schizodus affinis ?* | *Schizodus affinis ?* |
| *Schizodus* n. sp. | *Schizodus alpinus* |
| *Myalina recurvirostris ?* | |
| *Myalina swallovi* | |
| *Myalina* sp. | |
| *Astartella concentrica* | *Astartella concentrica* |

Gastropoda

| | |
|---|---|
| *Plagioglypta meekiana* | *Plagioglypta meekiana* |
| *Phanerotrema grayvillense* | *Phanerotrema grayvillense* |
| *Trepospira depressa* | *Trepospira depressa* |
| *Bellerophon crassus wewokanus* | *Bellerophon crassus wewokanus* |
| *Pharkidonotus percarinatus* | *Pharkidonotus percarinatus* |
| *Bucanopsis meekiana* | *Bucanopsis meekiana* |
| *Patellostium montfortianum* | *Patellostium montfortianum* |
| *Euphemus carbonarius* | *Euphemus carbonarius* |
| *Schizostoma catilloides* | *Schizostoma catilloides* |
| | *Zygopleura rugosa* |
| *Zygopleura multicostata* | *Zygopleura multicostata ?* |
| *Zygopleura plebia* ? | *Zygoplerua plebeia ?* |
| *Zygopleura* n. sp. | |
| *Hemizyga* n. sp. | |
| *Sphaerodoma brevis* | *Sphaerodoma brevis* |
| *Sphaerodoma gracilis* | *Sphaerodoma gracilis* |
| *Sphaerodoma paludiniformis* | *Sphaerodoma paludiniformis* |
| *Sphaerodoma primigenia* | *Sphaerodoma primigenia* |
| *Meekospira peracuta choctawensis* | *Meekospira peracuta choctawensis* |
| *Goniospira lasallensis* | |
| *Muchisonia* sp. | |
| *Loxonema* ? sp. | |
| *Bulimorpha inornata* ? | *Bulimorpha inornata ?* |
| *Conularia crustula* | *Conularia crustula* |
| *Orthoceras* sp. | *Orthoceras* sp. |
| *Pseudorthoceras knoxense* | *Pseudorthoceras knoxense* |
| *Protocycloceras* ? *rushense* ? | *Protocycloceras ? rushense ?* |
| *Dimorphoceras texanum* | *Dimorphoceras lenticular* |
| *Gonioloboceras welleri* | *Gonioloboceras welleri gracile* |
| *Metacoceras perelegans* | *Metacoceras perelegans* |
| *Metacoceras* sp. | *Metacoceras cornutum* |
| *Griffithides scitulus* ? | *Griffithides parvulus* |
| *Griffithides* sp. | |

A sandy limestone or limy sandstone which occurs just above the fossiliferous horizon in the East Mountain shale is locally very fossiliferous. Its most striking fossils are numerous well preserved, large gastropods which probably belong to the species *Pleurotomaria broadheadi,* a form described from the Pennsylvanian of Missouri. This shell has not been observed in other formations of the Texas Pennsylvanian. The sandstone is distinguished also from the subjacent shale by an abundance of crinoidal remains which includes a great variety of plates, spines and stems belonging tc a number of undetermined species. The ubiquitous brachiopod *Composita subtilita* is also very common.

From a locality about one mile northeast of Mineral Wells on the south side of the sandstone escarpment which extends eastward from the town, an interesting collection of very robust corals belonging to the genus *Campophyllum* was made. Numerous very well preserved specimens were obtained, and it seems clear that they belong to a species distinct from the very common and widespread *C. torquium.* The horizon from which these corals were collected is slightly higher than the two fossiliferous zones which have been described.

The only fossils obtained from beds of Mineral Wells age in the Strawn of the Colorado River Valley which have come under the observation of the writers in the course of the recent field work is a collection made by Angus McLeod in the vicinity of Mercury, McCulloch County, from a shale about 200 feet below the Adams Branch limestone. This contains the following species:

**Fauna from shale in upper Strawn, about 200 feet below Adams Branch limestone, McCulloch County**

*Somphospongia* sp. abundant
*Productus coloradoensis* Girty
*Pustula nebraskensis* (Owen)
*Pustula punctata* (Martin)
*Rhipidomella pecosi* (Marcou)
*Composita subtilita* (Hall)
*Allorisma subcuneatum* ?
*Myalina swallovi*
*Nuculopsis* ? sp.
*Bucanopsis meekiana* (Swallow)
*Naticopsis* sp.

The fauna as represented in this collection is not as large as that obtained in the East Mountain shale of the Mineral Wells formation in the Brazos River Valley and it does not have so obviously the typical character of the Wewoka fauna. However, most of the species occur in this fauna and it is possible that careful study of fossil bearing horizons in the Colorado River region would show a larger number of the species observed in the north.

Drake reports fossils from only one division in his Colorado River section of the Strawn group, the Elliott Creek bed, which lies several hundred feet below the top of the group. The fauna recorded by him, with identifications revised so far as possible, is shown in the faunal table for the Colorado River region after Drake (Plate XXVII).

*Correlation.*—Of the 55 species which have been identified with some certainty in the collections from the Mineral Wells formation in the vicinity of Mineral Wells, it may be observed that all but three or four are represented by species identical or closely related in the fauna of the Wewoka formation of Oklahoma. Including new species and forms which are identified with question the similarity is even more striking, for, with the exception of a very few forms such as *Chonetes verneuilianus, Gonioloboceras welleri* and *Dimorphoceras texanum*, there is hardly a shell known in the Mineral Wells formation which does not have a closely related or identical equivalent in the Wewoka. However, it may be noted that not all the Oklahoma species are observed in the Mineral Wells formation in Texas. It has appeared from the paleontological study of the Texas Carboniferous beds that some of the species described in the Wewoka and common to the Mineral Wells do not occur at a higher horizon. Examples are *Chonetes mesolobus*, which is very widely distributed in the early Pennsylvanian rocks of the Mid-Continent and West, and species of

*Zygopleura.* On the other hand a number of the common fossils of the Wewoka which appear at horizons in Texas considerably higher than the Mineral Wells formation, are not found in the latter. From this it would appear that perhaps some of the species of the Wewoka and higher Texas horizons may be found by more careful search in the Mineral Wells beds, or as seems probable, that there is present in the upper Strawn a fauna which, while containing a large proportion of typical Wewoka species, yet represents only one phase of this rather distinctive assemblage of invertebrates which lived in the Texas seas from mid-Strawn to early Cisco time and which was widespread in southern Oklahoma in Wewoka time.

The absence from the Mineral Wells fauna of some of the Wewoka fossils which appear higher in the Texas section suggests rather strongly that the Mineral Wells formation is somewhat older than the Wewoka. The absence from the fauna of some of the common early Pennsylvanian types which appeared abundantly in the Bend and Millsap divisions, such as *Spirifer rockymontanus, Productus morrowensis* and *Chonetes choteauensis,* suggests also that the Mineral Wells formation contains a distinctly younger fauna than the earliest Pennsylvanian. It appears that the invertebrate assemblage which from its typical development, excellent preservation and detailed description in the Wewoka area may well be designated as the Wewoka fauna, was introduced first into the waters of north-central Texas in middle Strawn time, advancing eastward and northward from the southwest. The aspect of the fauna which is seen in the Mineral Wells formation shows a typical near shore development of the fauna during the early part of its occupancy of the Texas region. The fauna spread northward into the shallow waters which at that time covered the Arbuckle and adjoining region in southern Oklahoma, and is found in the McAlester shale,[52] Savanna sandstone and in very typical development in the Wewoka formation. In north-central Texas the waters became clear and open in Canyon time and the fauna here became somewhat modified, mainly by the disappearance temporarily of the abundant molluscan elements which characterize the fossils of both the Mineral Wells and the Wewoka formations. With the recurrence of shallow water muddy and sandy conditions in the Graham formation, there is a widespread development of the typical Wewoka fauna in the Texas area. It is conceived therefore that this fauna was introduced into Texas somewhat earlier than the time of deposition of the Wewoka formation in Oklahoma. The Wewoka formation may be correlated approximately with the Canyon group.

So far as comparison may be made with the distant section in the upper Mississippi Valley the Mineral Wells formation may be regarded as approximately equivalent to the clastic beds at the very base of the Pennsylvanian in northeastern Oklahoma and southeastern Kansas. The We-

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[52]Girty, Geo. H., Preliminary report on Paleozoic Invertebrate Fossils from the region of the McAlester Coal Field, I. T., 19th Ann. Rept., U. S. Geol. Surv., Pt. 3, p. 539ff., 1898.

woka has tentatively been correlated with the Fort Scott limestone in the Kansas section,[53] which is the lowermost member of the Marmaton formation and directly overlies the Cherokee shale. Recent studies by Ohern[54] and others in Oklahoma in which the Fort Scott horizon has been traced southward from the Kansas line indicate that the Fort Scott is equivalent in position to the Calvin sandstone which is about 100 feet below the Wewoka. The Wewoka formation agrees in stratigraphic and general faunal character with the Marmaton formation of Kansas and may, it appears to the writers, be correlated approximately with this unit. It is of course not possible to affirm that the limits of the Marmaton are precisely equivalent to any of the stratigraphic units which have been differentiated in southern Oklahoma.

## UNDIFFERENTIATED LOWER PENNSYLVANIAN

Lower Pennsylvanian strata exposed in the valley of the West Fork of the Trinity River southeast of Bridgeport, Wise County, have been described recently by Emil Böse.[55] The section reported here is shown graphically in Figure 7, and the following detailed description shows the character of the beds:

**Section of Lower Pennsylvanian near Martins Lake south of West Fork of Trinity River, Wise County**

**(I in fig. 7)**

| | | Thickness Feet |
|---|---|---|
| 19. | Bridgeport coal (coal No. 1) | 1½ |
| 18. | Clay, gray, plastic, interstratified with sand in lower part | 20 |
| 17. | Sand, yellowish brown, dark brown, and reddish, intercalated with clay in upper part | 100 |
| 16. | Limestone, yellow and gray | 1 |
| 15. | Sandstone, brown and reddish, coarse-grained, grading upward into thin-bedded brown sandstone and gray shale | 80 |
| 14. | Limestone, yellow, marly | 15 |
| 13. | Limestone, gray, marly | 2 |
| 12. | Sandstone, brown | 11 |
| 11. | Limestone, gray, rough | 1 |
| 10. | Sandstone, light, soft | 15 |
| 9. | Shale, gray, marly, contains layers of rusty and reddish-brown concretions, very fossiliferous | 65 |
| 8. | Limestone, gray, and yellowish brown | 6 |
| 7. | Sandstone, thin, brown, non-fossiliferous, contains gray marly shale | 10 |
| 6. | Limestone, yellowish-gray, contains large crinoids | 4 |

[53]Girty, Geo. H., Fauna of the Wewoka formation, Oklahoma, U. S. Geol. Surv., Bull. 544, p. 14, 1915.

[54]Ohern, D. W., Contributions to the stratigraphy of northeastern Oklahoma, Bull. Okla. Univ., 4, 1910.

[55]Böse, Emil, Geological conditions near Bridgeport and Chico, Wise County: Bur. Econ. Geol. Univ. Texas, Bull. 1758, p. 8, 1917.

| | | |
|---|---|---|
| 5. | Limestone, gray, marly, non-fossiliferous | 15 |
| 4. | Limestone, yellowish brown, fossiliferous | 3 |
| 3. | Marls, gray, intercalated with yellowish-brown sandstones | 20 |
| 2. | Sandstone, brown, calcareous, contains sandy limestone | 2 |
| 1. | Sandstone, light colored, thinly laminated | .... |
| | Total thickness measured | 371½ |

It is an unsettled question as to whether the coal seam at Bridgeport is the same as the coal seam at Thurber, as was thought by Cummins, or whether it belongs higher in the section and is to be correlated with beds in the Canyon group. Unfortunately the Bridgeport area has not been mapped as yet, but judging from the strike of the limestones in eastern Jack County, unless there is a pronounced uplift in Wise County, the Bridgeport coal should belong to the Canyon group. A study of the fossils collected in Wise County by Dr. Böse shows that the fauna in the shales above the coal is similar to collections from the Graford formation and also appears to indicate that the strata are younger than those of the Mineral Wells formation.

## CANYON GROUP

### GENERAL DISCUSSION

The Canyon group of beds represents an epoch following the deposition of sandstones, conglomerates, and coal beds of the Strawn group during which time the bordering land to the east had been worn down and furnished mainly fine calcareous sediments, so that the conditions were favorable for the formation of a series of thick limestones and fine calcareous clays, with only a few lenses of sandstone.

*Definition.*—The name Canyon was given to this group of strata by Cummins[56] for the town of Canyon on the Texas and Pacific Railway four miles west of Strawn. It is an appropriate name as the division forms the most rugged and picturesque topography in north Texas. Along the outcrop are high, steep escarpments and cedar-covered slopes into which streams have cut many deep canyons. The Canyon group has been made to include the same strata originally assigned to it by Cummins in his section made from the Brazos River near Millsap to Fort Belknap in Young County. In this section he included all the strata from the base of the massive limestone outcropping on East Fork of Keechi Creek northeast of Salesville, now named the Palo Pinto limestone, to the top of the massive limestone outcropping near Finis on the Jack-Young county line, which has been found to be equivalent to the Home Creek limestone of Drake and now called the Home Creek limestone in this northern area.

[56]Cummins, W. F., Report on the Geology of Northwestern Texas, Geol. Surv. Texas, 2nd Ann. Rept., p. 374, 1890.

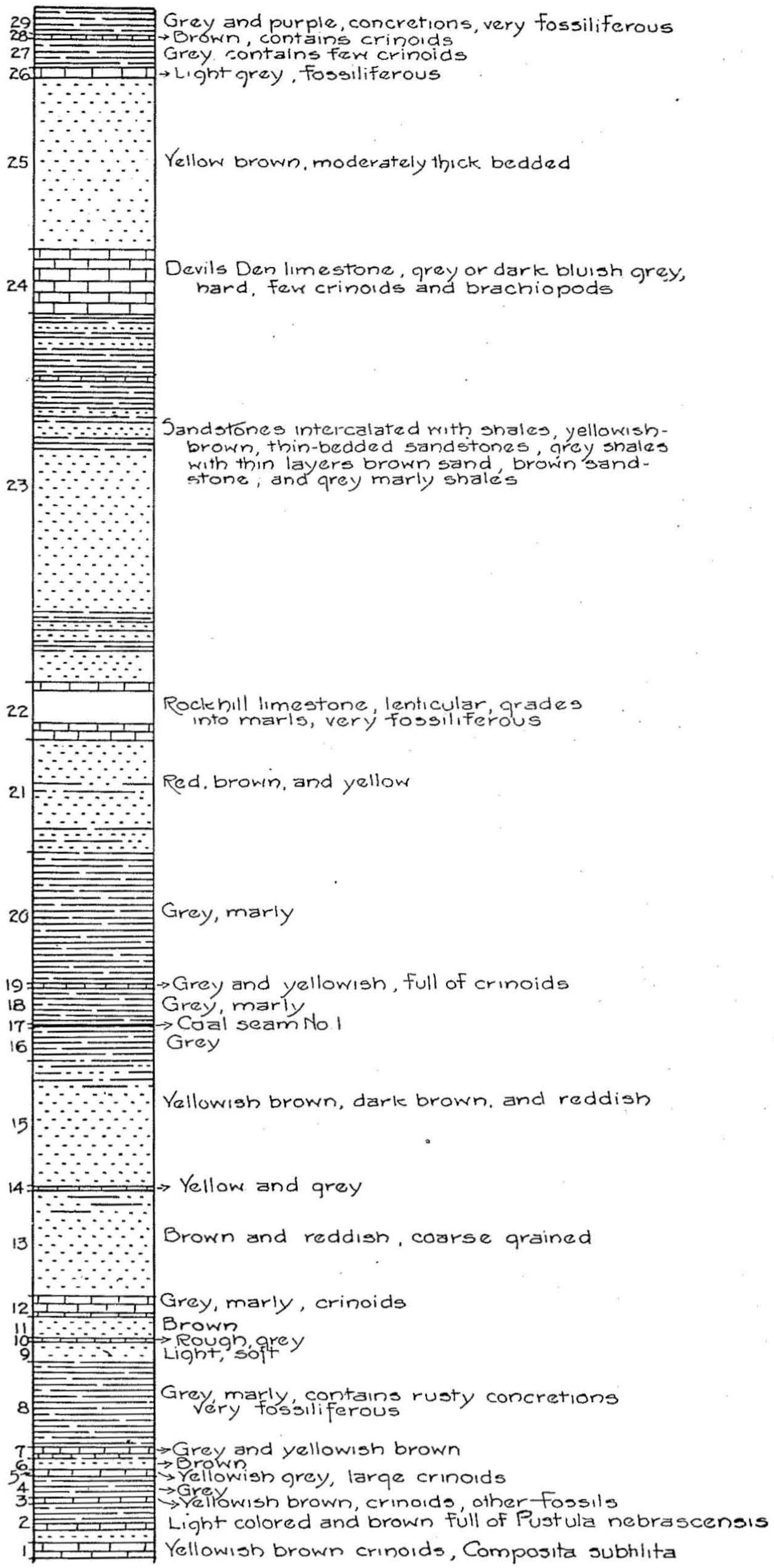



Figure 10. Section of the Pennsylvanian measured along West Fork of the Trinity River, by Böse

The original sketch map showing the divisions as made by Cummins is reproduced in Figure 11. The Home Creek limestone has been mapped continuously, except where covered by Cretaceous sands, across the Brazos River Valley and Colorado River Valley, making a definite upper limit for the Canyon group as defined by Cummins. The Palo Pinto limestone at the base is continuous across the Brazos River area but thins out and changes to sandy shales 10 miles south of Strawn and does not appear in the southern area. Therefore, the base of the Canyon group in the

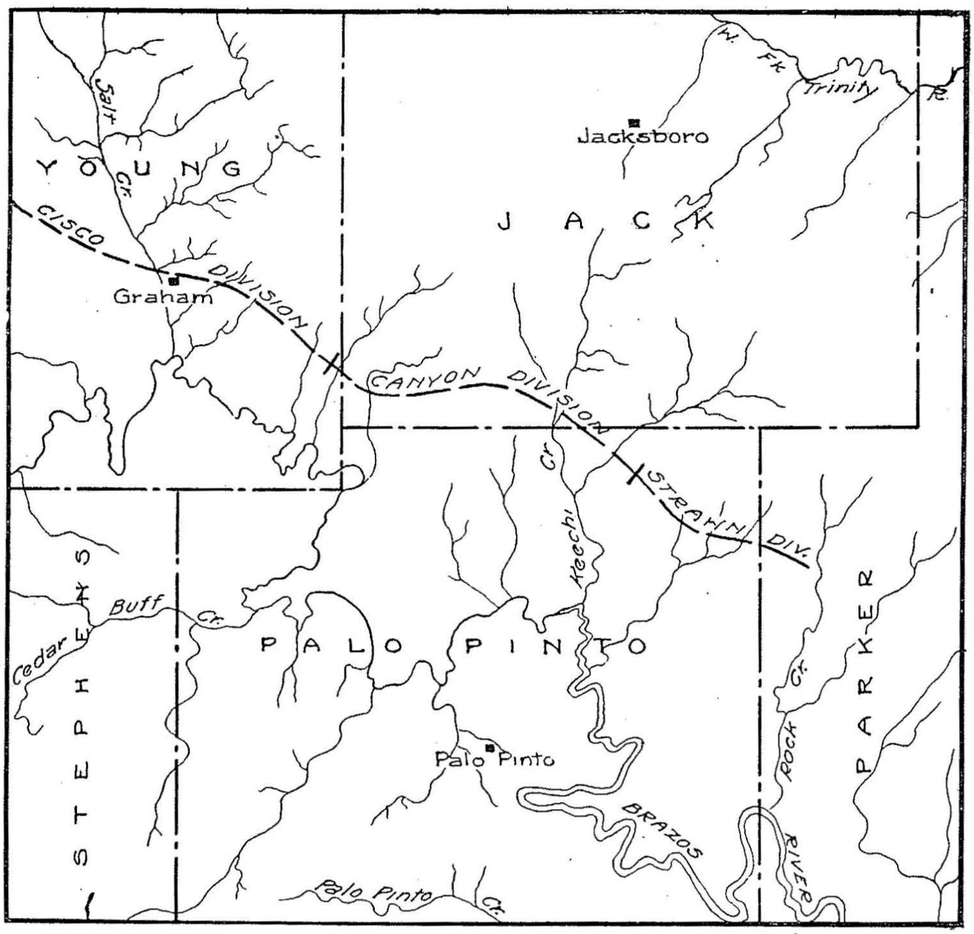



Figure 11. Map showing divisions of the Pennsylvanian according to Cummins

Colorado River Valley is placed at the top of the Ricker bed, the uppermost bed in the Strawn group in this region. In places a "coral" limestone bed and in other places a coarse conglomerate, occupy a position in the section similar to that of the Palo Pinto limestone at the base of the Canyon group. These irregular beds show that there were shallow water and near shore conditions in this area of the Colorado River Valley at the beginning of the Canyon epoch. This was possibly due to a slight uplift of the Llano area at the end of the Strawn epoch which prevented the deposition of the Palo Pinto limestone in this area.

*Stratigraphic Relations.*—The Canyon limestones and shales lie conformably upon the Strawn beds in most places. South of Brownwood in the vicinity of the Llano Mountains the Strawn strata dip northwest at slightly steeper angles than those of the Canyon group, and these two series of beds are here separated by a deposit of gravel and limestone conglomerate that suggests a local unconformity in the mountain district. Also there are fragmentary evidences of crustal movements in the Strawn not observable in the upper groups; for example, anticlines mapped near Locker and Regency in the Colorado River Valley and south of Strawn in the Brazos River Valley, all located within the Strawn outcrop, are much more steeply folded and faulted than the gently plunging folds mapped on the Canyon outcrops a few miles farther west. On the whole the change between the Strawn and the Canyon seems to have been gradual rather than abrupt, and only in the area immediately adjacent to the mountains and in a few neighboring places were the movements sufficiently great to cause a slight discordance between the two groups of strata.

*Areal Distribution.*—The outcrop of the Canyon group occupies a belt of territory 30 miles wide in the northern counties but only 10 miles wide or less in the area south of Brownwood. This belt extends northeast-southwest from central Wise County across the center of Palo Pinto and Eastland counties to the border of the Cretaceous overlap; and reappearing at Brownwood it extends southward across the central part of Brown County and east side of McCulloch County to the Llano Mountains. The extent of the outcrop in the Brazos and Colorado valleys is shown on the map, Figure 12. It is also interesting to note that a small inlier of this formation has been discovered in the central part of Menard County on the Mason-Menard road 10 miles east of Menard.

*Divisions.*—The Canyon group consists of four division beds of massive, hard, thick, blue limestone 10 to 100 feet thick separated by layers of gray and blue marls 250 to 300 feet thick which contain thin limestone layers and in places lentils of sandstone and conglomerate. Below the thick limestone layers are more or less continuous beds of sandstone. The group is characterized chiefly by the greater thickness and predominance of its limestone strata. The following formations are recognized in the Canyon group:

4. Caddo Creek formation
3. Brad formation
2. Graford formation
1. Palo Pinto limestone

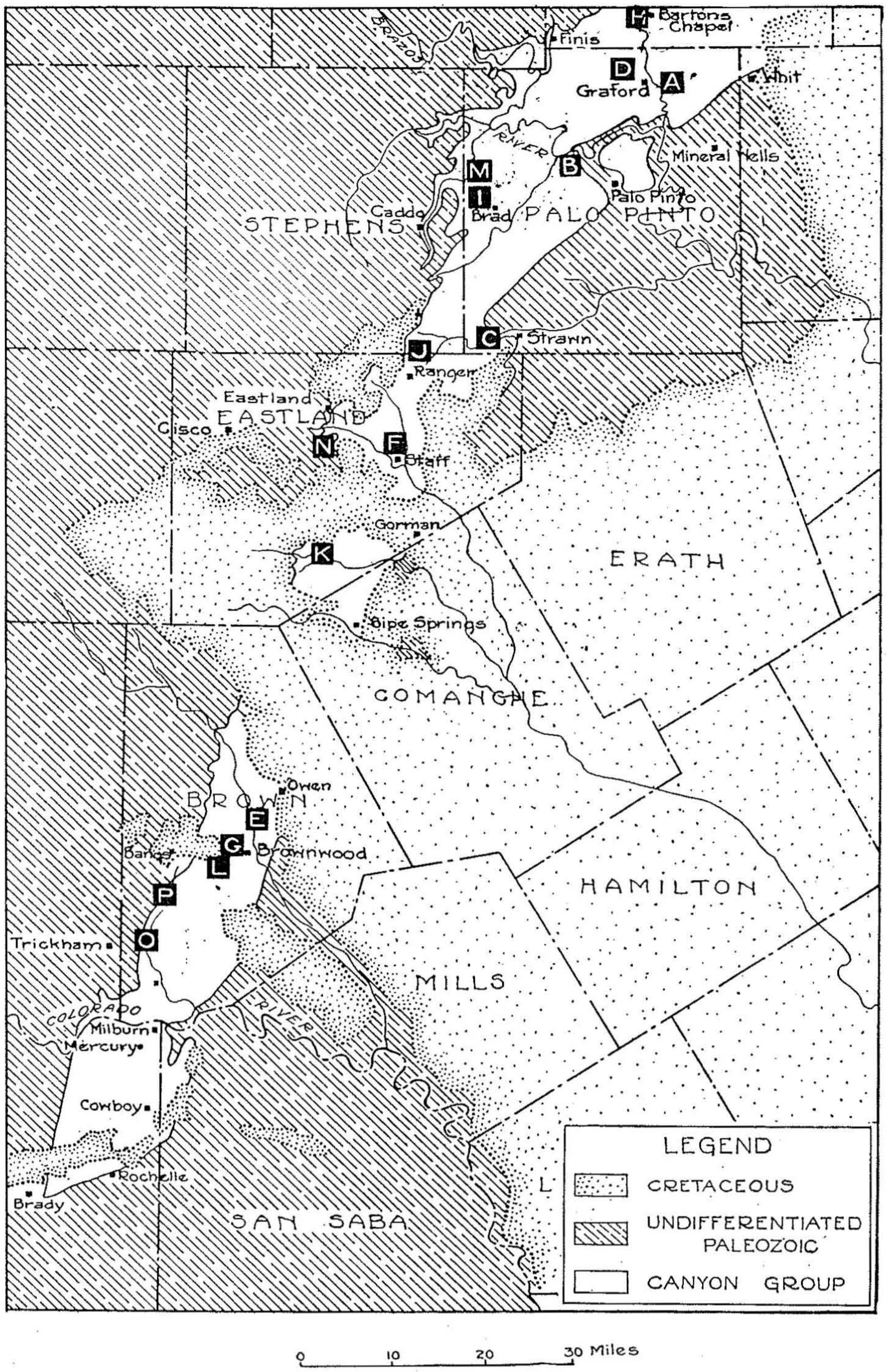



Figure 12. Map showing the area of outcrop of the Canyon group

## PALO PINTO LIMESTONE

*Name and Stratigraphic Position.*—At the base of the Canyon group in the Brazos River Valley and lying with apparent conformity upon the shales and sandstones of the Strawn is a bed of massive limestone which varies in thickness from 50 to 100 feet. This is named the Palo Pinto limestone from the town of Palo Pinto located on its outcrop. It may be recognized easily elsewhere in well logs and in the field because it is the lowermost thick limestone in the section above the Strawn sands.

*Extent.*—The outcrop of the Palo Pinto limestone extends from the town of Whit in Parker County to the Strawn oil field in Palo Pinto County, and thence across Allen Ranch to the Cretaceous sand area.

In most places this limestone bed forms steep cliffs and has good exposures almost anywhere along its outcrop. It has been studied along Keechi Creek two miles southwest of Graford, along the Brazos River at the Graford-Palo Pinto bridge six miles northeast of Palo Pinto, on the Mineral Wells-Palo Pinto road 10 miles west of Palo Pinto, and along the Strawn-Ranger road three miles west of Strawn.

*Lithologic Character.*—The Palo Pinto limestone is a thick, crystalline, dark-gray limestone weathering white or grayish yellow. In many places the lower portion is made up of many thin beds from two to six inches thick, separated by partings of gray marl so that in weathering the rock shelves off into great piles of slabs, chips, and chunks. The upper layers are thicker, dark gray, fine-grained, even-textured, more fossiliferous, and purer than the lower beds. Upon weathering these beds break into large blocks and irregular chunks.

*Detailed Sections.*—The following section measured on Keechi Creek two miles southeast of Graford (A in Figure 12) shows the characteristics of the northern outcrop of this limestone. (See also Plates XV and XVI.)

**Section of Palo Pinto Limestone on Keechi Creek, 2 miles east of Graford, Palo Pinto County**

**(A in fig. 12)**

| | Thickness Feet |
|---|---|
| CANYON GROUP— | |
| Graford Formation | |
| Limestone, blue-gray, hard, fossiliferous | 4 |
| Shale, yellow, soft, calcareous | 20 |
| Palo Pinto Limestone | |
| Limestone, gray, massive, irregularly bedded | 25 |
| Shale, light gray-blue, calcareous | 20 |
| Limestone, massive, fine-textured | 8 |
| Shale, blue-gray | 25 |
| Limestone, blue, base of exposure | 4 |
| Total | 82 |

The sections measured at Wolf Mountain and at Strawn are typical for the strata across Palo Pinto County.

**Section of Palo Pinto limestone at north end of Wolf Mountain**
**Measured by John Burtt. (B, fig. 12)**

| Palo Pinto Limestone | Thickness Feet |
|---|---|
| 5. Limestone, gray, coarse, crystalline | 4 |
| 4. Marl, light gray | 6 |
| 3. Limestone, dark gray, iron stained, weathers into irregular blocks | 7 |
| 2. Shale, limy, covered in part | 21 |
| 1. Limestone, massive, poorly bedded | 20 |
| Total thickness | 58 |

**Section of Palo Pinto limestone in Strawn oil field**
**Measured by H. H. Robinson.[75] (C in fig. 12)**

| Palo Pinto Limestone | Thickness Feet |
|---|---|
| 2. Limestone, very arenaceous. This member forms the top of the main ridge of the field. Light gray weathering darker, fine grained, fairly well cemented, weathered surface smooth and hard. This member contains a resistant ledge just above the fossil horizon that is used as the key rock for the structure map (Pl. 3, U. S. Geol. Survey Bull. 629) | 10 |
| 1. Limestone, light gray, beds rather thin averaging one or two inchts; highly fossiliferous, abundance of crinoid stems, *Productus (?)*, and bryozoa; breaks with irregular fracture | 12 |

The section measured by S. W. Wells on the Allen Ranch shows the Palo Pinto near the southern end of its outcrop, and the beds associated with it above and below.

**Section of strata at Allen Ranch, 10 miles south of Strawn in northeastern part of Eastland County**

**Measured by S. W. Wells**

| | Thickness Feet |
|---|---|
| CANYON GROUP— | |
| Graford Formation (Lower Portion) | |
| 10. Limestone, light gray, weathering buff | 2 |
| 9. Shale, grayish blue, sandy | 28 |
| 8. Sandstone, reddish brown, coarse-grained, irregularly bedded, calcareous | 36 |
| 7. Shale, gray | 9 |
| 6. Limestone, gray, sandy, changes to calcareous sandstone | 1 |
| 5. Shale, gray, calcareous | 14 |
| Palo Pinto Limestone | |
| 4. Limestone, gray, irregularly bedded, shaly, 15 to 20 feet thick in north end of ranch, breaks up toward middle of area into thin platy, sandy beds and is replaced by sandy shales at south end | 0-20 |

[57]Shaw, E. W., Gas in the area north and west of Fort Worth: U. S. Geol. Surv., Bull. 629, p. 44, 1916.

STRAWN GROUP—
Mineral Wells Formation

| | | |
|---|---|---|
| 3. | Shale, gray, sandy | 12 |
| 2. | Sandstone, buff and reddish brown | 20 |
| 1. | Shale, blue gray, sandy | 123 |

*Equivalent Beds in the Colorado River Valley.*—In the area of the present Colorado River Valley the sea was apparently absent at the beginning of the Canyon epoch or at least was too shallow and disturbed to be favorable for deposition of the Palo Pinto limestone. No equivalent of this limestone of the northern area is to be found south of Gorman in Comanche County, and the lowest formation of the Canyon group contains argillaceous wave-worked sands, brecciated limestones containing pebbles of black limestone, chert, reef corals, and conglomerates, deposits which indicate nearness to an old shoreline. (See B, Plate XV.)

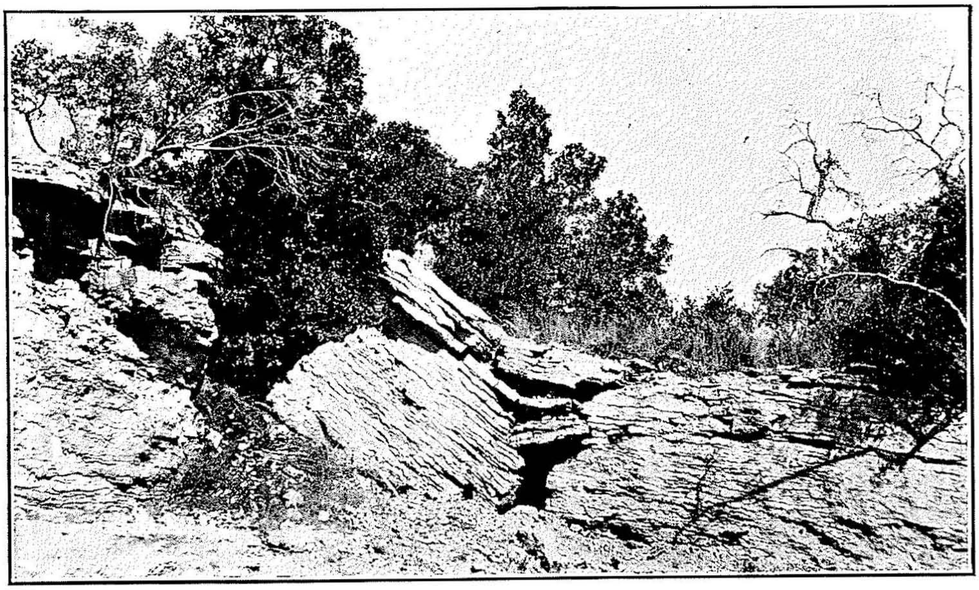
*Paleontology.*—The faunal character of the Palo Pinto limestone has not been indicated satisfactorily in the course of the field work on the Texas Pennsylvanian. The collections are rather meager and for the most part contain only the more common, long-ranging Pennsylvanian types. The limestone is not on the whole very fossiliferous and there has not been opportunity for special paleontological investigation of this horizon. So far as observed the fossils are contained chiefly in the upper portion of the limestone above the parting of yellow shale which divides the formation into two main ledges.

Perhaps the chief characteristic of the Palo Pinto fossils is their robust appearance. Species which at other stratigraphic horizons have only moderate size, appear here as very large individuals which in some cases are almost twice the normal size. Most of the specimens, also, are very perfectly formed and well preserved. Although the composition of the fauna, at least the portion of it which has been determined, is not, apparently, diagnostic of a definite horizon in the Pennsylvanian, the unusual development of size is a distinguishing feature which assists in recognizing this portion of the Canyon limestones. Of course the lithologic character and stratigraphic position have been the most important characters in the mapping of the limestone.

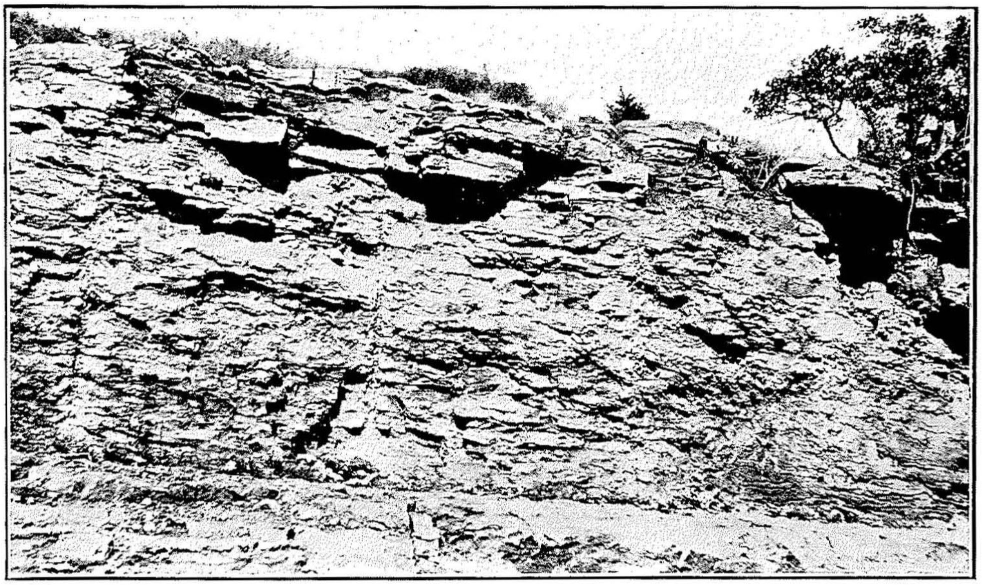
A collection of fossils from the Palo Pinto limestone about four miles west of the town of Palo Pinto, one mile north of the point where the Gordon road branches from the road to Caddo, contains very robust specimens belonging to the following species:

**Fauna of the Palo Pinto limestone four miles west of Palo Pinto**

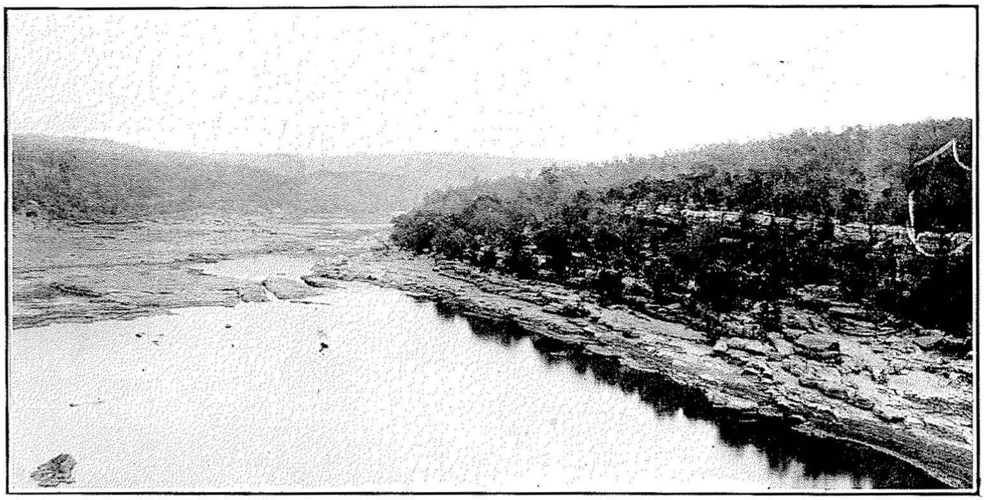
*Productus cora*
*Productus insinuatus* ?
*Productus semireticulatus hermosanus* ?
*Productus* sp.
*Pustula nebraskensis*
*Pustula punctata*
*Spirifer cameratus*
*Composita subtilita*
*Edmondia* sp.



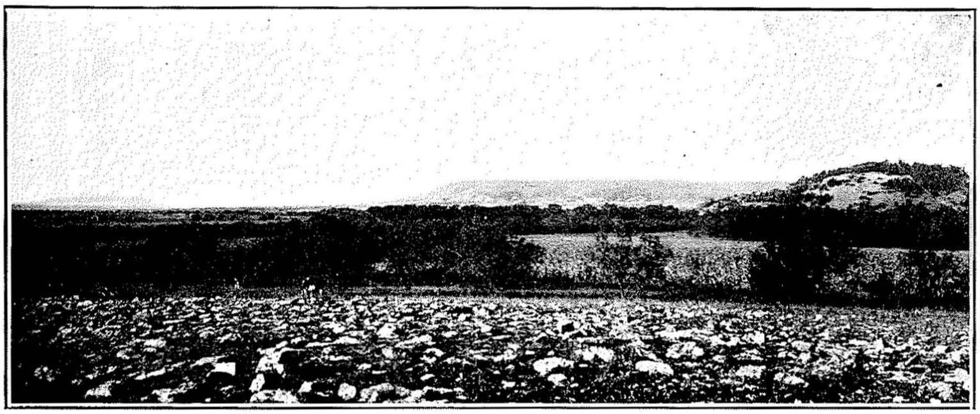
A. Palo Pinto limestone 10 miles west of Mineral Wells.



B. Palo Pinto limestone showing characteristic weathering 10 miles west of Mineral Wells.



A. Outcrop of Palo Pinto limestone in Brazos River at bridge southeast of Palo Pinto. A typical view of the Canyon group.



B. Rochelle conglomerate at base of Canyon group east of Rochelle, McCulloch County.

As is true of most of the limestone faunas in the Texas Pennsylvanian, the preponderance of the molluscoid element in this fauna may be observed.

## GRAFORD FORMATION

*Name and Definition.*—The Graford formation is named from the town of Graford in Palo Pinto County where it is typically developed and where the upper members form a very prominent escarpment just west and north of the town. This is one of the most persistent, uniform, and easily recognized formations of north Texas. It may be recognized readily by the fact that it forms the highest and most continuous escarpment in the Pennsylvanian section and by a thin but very persistent limestone, containing myriads of small emaciated *Fusulina,* which occurs everywhere about 60 feet below the top of the escarpment.

In the Brazos River Valley the formation consists of all the strata from the top of the Palo Pinto limestone to the top of the Adams Branch limestone. In the Colorado River Valley where the Palo Pinto is absent the formation extends from the top of the uppermost heavy sandstone of the Strawn, known as the Ricker bed, to the top of the Adams Branch limestone. The Ricker bed occurs just below the "Coral" limestone bed and is found at Brownwood at a depth of about 240 feet below the top of the Adams Branch limestone.

*Stratigraphic Position.*—In the Brazos River Valley the Graford formation overlies the Palo Pinto limestone conformably. In the southern district across the Colorado River Valley where the Palo Pinto limestone is absent the relationship of the Strawn and Graford formations is probably unconformable. This last statement, however, is made with reservation since it is based more on inference than on observation, for continuous exposures of the contact are wanting. The only evidences of this unconformity are (1) conglomeratic limestones at the base of the Graford formation in the Brownwood district, (2) conglomerates in the Cowboy and Rochelle areas made up of coarse, polished, wave-worn pebbles which are rather strikingly different from the conglomerate lenses common in other formations, and (3) the abrupt change in the character of the sediments from the predominantly cross-bedded and non-marine beds of the upper Strawn group to the very fossiliferous marine Graford beds. These relations possibly indicate a slight uplift in the Llano Mountain area and a slight depression in the Brownwood area at the end of the Strawn epoch.

*Extent.*—The area of outcrop of the Graford formation is shown on the geologic map (Plate I). In the northern area the average width of the outcrop is 10 miles, but in the southern area it narrows to five miles or less. The belt of the outcrop may be traced from near the town of Joplin in Jack County, southwest to Graford, across the Brazos River at Fortune Bend, south of Metcalf Gap, and thence to a point southeast of Staff where it disappears beneath the Cretaceous. West of Gorman it reappears, and the upper beds may be traced to Sipe Springs where the formation again dips beneath the Cretaceous sands. South of this Cretaceous overlap it is found at Owen in Brown County and may be readily followed southward through Brownwood and east of Mercury to the Llano Mountains.

The thickness of the formation varies from 400 feet at Graford to 250 feet and less south of Brownwood.

*Subdivisions.*—The Graford formation has been subdivided into the following members:

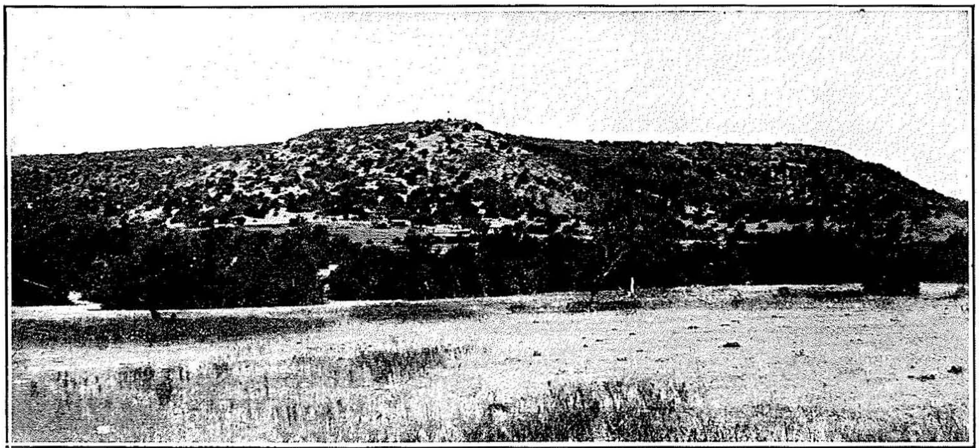
| **Colorado River Valley** | **Brazos River Valley** |
|---|---|
| 3. Adams Branch limestone | 2. Adams Branch limestone |
| 2. Brownwood shale | 1. Brownwood shale |
| Capps limestone lentil | Oran sandstone lentil |
| 1. Rochelle conglomerate | |

The Adams Branch limestone member has been identified and mapped throughout both the northern and the southern area of Pennsylvanian outcrop in north Texas. It forms a prominent escarpment 100 to 150 feet high and may easily be recognized. The clay shale beds below the Adams Branch are known in both the Colorado River and the Brazos River valleys as the Brownwood clay member. In the south it contains locally near its base a lentil of limestone named the Capps bed; in the north it contains a locally prominent sandstone which is known as the Oran sandstone lentil. At the base of the Graford formation near the town of Rochelle is a bed of conglomerate which is here distinguished as the Rochelle conglomerate member. These more resistant beds in the lower part of the Graford produce low hills and faint escarpments toward the eastern edge of the formation outcrop in Brown County and in Palo Pinto County.

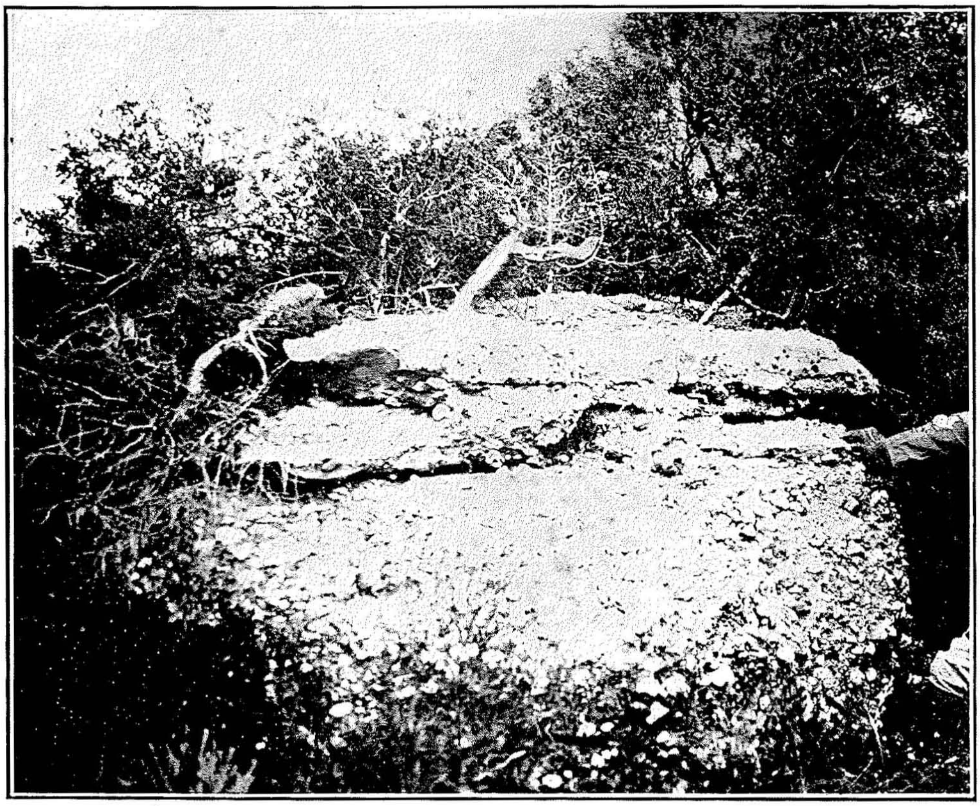
*Rochelle Conglomerate.*—The name Rochelle conglomerate was given by Tarr[58] to a bed of coarse conglomerate found east of the town of Rochelle (See Plate XVI). This conglomerate found at the base of the Graford formation, just above the Ricker bed of the Strawn group, and is distributed in the area adjacent to the Llano Mountains southeast of Mercury. The best exposure of the Rochelle conglomerate is on the San Saba-Brady road, four miles east of Rochelle. A conglomerate very closely resembling the Rochelle bed and of about the same stratigraphic position is well exposed at a gravel pit near Pecan Bayou one-half mile north of Brownwood on the road to Blanket, and near the Capps well four miles northeast of Brownwood.

The Rochelle conglomerate is composed of well rounded, wave-worn pebbles of chert, flint and quartzite, with some scattered greenstone pebbles unlike any which have been observed in the other Pennsylvanian conglomerates farther north. This material was probably derived from old rocks which then outcropped south or east of the present Llano Mountains. The pebbles are highly polished and of many colors. The matrix is a white quartz sand cemented with silica, and in places is of the same hardness as the included pebbles. In the sand are fragments of black shale and small

[58]Tarr, R. S., Preliminary report on the coal fields of the Colorado River Valley: Geol. Surv. Texas, 1st Ann. Rept., p. 205, 1889.



A. Escarpment formed by Adams Branch limestone halfway between Strawn and Caddo.



B. Escarpment formed by Adams Branch limestone west of Graford, Palo Pinto County. Typical topography of the Pennsylvanian area.

pebbles of black chert which closely resembles material from the Marble Falls formation. In the exposure near Brownwood there are several well preserved specimens of the coral *Campophyllum torquium* which are apparently not redeposited. The conglomerate reaches its maximum observed thickness, about 25 feet, in the exposures farthest south. Northward it becomes thinner. The bed at Brownwood is from 6 to 10 feet thick.

The Rochelle conglomerate was correlated by Drake[59] with a deposit of gravel near Milburn, which he states occurs in the Brownwood beds above the "Coral" (Capps) limestone. Careful instrumental measurements show, however, that the conglomerate east of Rochelle lies 60 feet stratigraphically farther below the top of the Adams Branch limestone than does the "Coral" limestone at Brownwood (columnar sections 1 and 2, Plate II), and 80 feet farther below the Adams Branch limestone than the Milburn gravel. The gravel at Milburn is an isolated deposit very close to the Colorado River on the south side and it can be traced only along the river terrace. The pebbles are not so well polished or so varied in lithologic character as those of the Rochelle conglomerate, and the formation is less indurated. It is believed that the Milburn gravel is the remnant of an old terrace of Pleistocene age and not a part of the Rochelle conglomerate. The true Rochelle conglomerate was deposited only near the mountains, probably slightly before but almost contemporaneously with the Capps bed of the Brownwood area.

*Brownwood Shale.*—The name Brownwood shale was applied by Drake[60] to the shaly strata below the Adams Branch limestone and above the Rochelle conglomerate. This shaly portion of the Graford is observed in the north, in the Brazos River Valley, as well as in the south, and has been traced from Joplin, in Jack County, to Rochelle, in McCulloch County. North of the Cretaceous sand area, the Brownwood bed is defined as including all the strata between the base of the Adams Branch and the top of the Palo Pinto limestone.

The Brownwood shale consists of dark gray and blue clay shale, weathering to light gray and yellow. It contains some lenses of sandstone, and a number of thin beds of limestone. The Capps limestone lentil is distinguished in the lower part of the Brownwood shale near Brownwood, and a fairly continuous sandstone lentil in Palo Pinto County is designated the Oran sandstone. At Brownwood the shale is about 180 feet thick, but northward it becomes thicker until at Graford, in Palo Pinto County, it is at least 400 feet thick. In many places the clays are very fossiliferous.

The *Capps limestone lentil,* named from the Capps farm, three miles east of Brownwood where it is well developed, occurs near the base of the Brownwood shale and is apparently the same as the "Coral" limestone of Drake, so named on account of its very abundant and characteristic

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[59]Drake, N. F., Report on the Colorado coal field, Geol. Surv. Texas, 4th Ann. Rept., p. 388, 1892.

[60]Drake, N. F., loc. cit.

corals, chiefly *Chaetetes*. This limestone is not widely distributed and can be traced for only short distances in the areas on either side of Pecan Bayou. Northeast of Brownwood it extends from a point near the Capps well northward to a point beyond the Frisco railroad, a total distance of about three miles. Southeast of Brownwood a good exposure of the bed can be followed from a point near the Santa Fe tracks to the Cretaceous overlap east of Cedarton. The Capps limestone has not been recognized in any of the drilling in the Brownwood oil field, west of the area of its outcrop. A typical exposure of the Capps lentil, showing dense, dark gray-blue limestone filled with numerous *Chaetetes*, which on the weathered surfaces give a knotted, gnarly appearance to the bed, is found west of the schoolhouse two and one-half miles southeast of Brownwood and two miles west of Pecan Bayou. A section measured here by Grady Kirby is as follows:

**Section lower part of Brownwood shale containing Capps limestone lentil, 2½ miles southeast of Brownwood**

| | Thickness Feet |
|---|---|
| Brownwood Shale | |
| 4. Limestone, blue, consists almost entirely of the coral *Chaetetes* (Capps limestone lentil) | 4 |
| 3. Clay, yellow, sandy | 15 |
| 2. Sandstone, brown | 4 |
| 1. Shale, brown | 20 |
| Total thickness | 43 |

The Capps limestone is very irregular in lithologic character. In places it is made up of almost nothing but corals and in other places it is composed of rounded limestone and chert pebbles cemented together by calcium carbonate to form a solid limestone layer. The conglomerate phase is well exposed along the road to Blanket at a point four miles east of Brownwood where it appears to have been broken up by wave action, mixed with pebbles and beach gravel, and then recemented. Four miles east of Brownwood on the road to Zephyr is a striking exposure of a coral reef. The coral colonies are standing perpendicularly in a yellow clay, and are from one to three feet in length, from six to twelve inches in diameter tapering slightly upward.

The following section of the Brownwood shale and associated parts of the Graford formation at the type locality of the member west of Brownwood is as follows:

**Section of Graford formation west of Brownwood**

**(G in fig. 12)**

| | Thickness Feet |
|---|---|
| GRAFORD FORMATION— | |
| Adams Branch Limestone | |
| 11. Limestone, impure, yellow | 16 |
| 10. Limestone, blue, massive, contains calcite veins | 2 |
| Brownwood Shale | |
| 9. Shale, yellow, sandy | 10 |
| 8. Sandstone, yellow | 10 |
| 7. Shale | 25 |
| 6. Limestone containing *Fusulina* | 1 |
| 5. Clay, yellow, fossiliferous | 40 |
| 4. Sandstone, even-textured | 10 |
| 3. Shale, blue | 20 |
| 2. Clay, yellow | 30 |
| Rochelle Conglomerate (?). | |
| 1. Conglomerate, coarse, quartzitic | 4 |
| Total thickness measured | 168 |

Other stratigraphic sections which show the character of the members of the Graford formation at various points along the outcrop are given below.

**Section of Graford formation northwest of Graford**

**(D. in fig. 12)**

| | Thickness Feet |
|---|---|
| GRAFORD FORMATION— | |
| Adams Branch Limestone | |
| 10. Limestone, gray, unevenly bedded, weathers to small pieces | 5 |
| 9. Shale, light gray, calcareous | 15 |
| 8. Limestone, gray, massive, weathers to large blocks with rough pitted surfaces | 10 |
| 7. Shale, yellowish-gray | 7 |
| 6. Limestone, yellow, thin, very fossiliferous, characterized by small *Fusulina* and bryozoa | 2 |
| Brownwood Shale | |
| 5. Shale, dark, fossiliferous | 33 |
| 4. Sandstone, massive, cross-bedded, contains coal plants | 25 |
| 3. Shale, light, contains lenses of sand | 230 |
| 2. Limestone, dark blue, fossiliferous, at Graford changes to sand northward and southward forming the Oran lentil | 10 |
| 1. Shale, sandy, forms broad cultivated fields | 70 |
| Palo Pinto Limestone— | |
| Total thickness measured | 395 |

**Section of Graford formation in escarpment due west of Strawn oil field**
**Measured by H. H. Robinson.[61] (C in fig. 12)**

| | Thickness Feet |
|---|---|
| GRAFORD FORMATION— | |
| Adams Branch Limestone | |
| 15. Limestone, weathers gray, fresh surfaces are blue, shows numerous calcite veinlets, contains bed of conglomerate 1 foot thick, makes top of Lloyd Mountain | 45 |
| 14. Shale, gray | 10 |
| 13. Limestone, sandy, contains numerous crinoid stems and other fossils, especially *Fusulina* | 5 |
| Brownwood Shale | |
| 12. Clay, bluish-gray, numerous white streaks, and blotches | 5 |
| 11. Shale, sandy | 5 |
| 10. Sandstone, buff, loosely cemented, irregularly bedded, cross-bedding common | 15 |
| 9. Shale and clay, bluish gray | 15 |
| 8. Sandstone and sandy shale, sandstone is buff and on the whole is irregularly bedded, cross-bedding common | 55 |
| 7. Interval for most part grassed, presumably made up mostly of shale, some sandy shale, and one or two limestones each about 1 foot thick | 110 |
| 6. Limestone, resistant, exposures poor, estimated thickness | 2 |
| 5. Shale and shaly sandstone, exposures poor | 20 |
| 4. Sandstone, light brown, massive, thick-bedded, grains medium-size, fairly well rounded, weathers to dark rusty brown, massive irregular blocks, in most places loosely cemented (Oran sandstone lentil) | 3 |
| 3. Sandstone, brown, massive, loosely cemented in some portions, other portions very friable, slightly closer grained than overlying member, grains mostly quartz; pore space comparatively large in parts of the member; in places minute cross-beds less than an inch thick are evident; olive-colored specks as large as a pea and imperfect cross-bedding are common in lower part, cross-beds average 1 foot in thickness. (Oran sandstone) | 50 |
| 2. Sandstone, very similar to that above but contains much more iron. Apparently because of the irregularity in distribution of cementing material, the sandstone weathers into very irregular shapes. In lower portion of member are some light brown specks and streaks that are probably $FeCO_3$ | 10 |
| 1. Interval of grassy slope more gentle than the concealed interval, probably friable sandstone | 12 |
| Total thickness measured | 362 |

[61]Shaw, E. W., Gas in the area north and west of Fort Worth: U. S. Geol. Surv. Bull. 629, p. 44, 1916.

**Section of Graford formation, 1¼ miles northwest of Staff (F. in fig. 12)**

| | Thickness Feet |
|---|---|
| GRAFORD FORMATION— | |
| Adams Branch Limestone | |
| Limestone, brownish-buff at base, white at top; massive, in places cherty | 17 |
| Brownwood Shale | |
| Sandstone, reddish-brown, iron-stained, cross-bedded | 22 |
| Shale, blue, sandy | 13 |
| Sandstone, gray, thin-bedded, calcareous | 2 |
| Shale, blue-gray | 3 |
| Limestone, brown, iron-stained | 3 |
| Shale, blue, soft, calcareous | 22 |
| Sandstone, brown, cross-bedded, calcareous | 5 |
| Limestone, brown, mottled, filled with *Fusulina* | 5 |
| Shale, blue, soft, evenly bedded | 20 |
| | 112 |

**Section of Brownwood shale along Salt Creek north of Brownwood, near Cisco-Brownwood road.[62] (E. in fig. 12)**

| | Thickness Feet |
|---|---|
| GRAFORD FORMATION | |
| Adams Branch Limestone | |
| Brownwood Shale | |
| 11. Shale, blue, argillaceous | 20 |
| 10. Sandstone, massive, forming escarpment | 15-25 |
| 9. Shale, sandy | 25 |
| 8. Sandstone, in places calcareous | 4- 5 |
| 7. Shale, fossiliferous (*Fusulina* bed at top) | 40 |
| 6. Sandstone, massive, cross-bedded, locally shaly | 4- 6 |
| 5. Shale, argillaceous, fossiliferous at top | 15 |
| 4. Sandstone, calcareous in places | 4- 5 |
| 3. Shale, blue, argillaceous | 25 |
| 2. Sandstone, calcareous in places | 5- 6 |
| 1. Shale, blue, clayey, top part fossiliferous | 50 |
| Total average thickness | 282 |

*Adams Branch Limestone.*—The Adams Branch limestone was named by Drake from the creek of that name in Brown County west of Brownwood. In the preliminary paper on the Pennsylvanian formations in Texas by Plummer[63] this limestone in the northern area was called Graford limestone. Since it has been found that this limestone is identical with the Adams Branch limestone in the Brownwood district, and since it is undesirable to designate a subdivision of the Graford formation by the same name, Drake's name is here applied.

[62]Drake, N. F., loc. cit., p. 390.

[63]Plummer, F. B., Preliminary paper on the stratigraphy of north-central Texas, Bull. Am. Assn. Pet. Geol., vol. 3, pp. 132-150, 1919.

Everywhere, except where covered by the Cretaceous deposits and recent debris, the Adams Branch limestone caps a prominent escarpment that is easily traceable from the Llano Mountains in McCulloch County to northern Jack County (Plate XVII). In Palo Pinto County the limestone is in most places made up of two layers separated by 10 or 15 feet of yellow clay. The upper layer is from four to five feet thick and the lower layer from 15 to 60 feet and in places 100 feet thick. In Brown County the thickness of the whole member is only 10 to 30 feet. The increased thickness in certain places is due to the changing of the calcareous shales and sands, just below the lower limestone layer, to limestone. The variations across Palo Pinto County are well shown in the diagram, Plate XVIII made by J. G. Burtt.

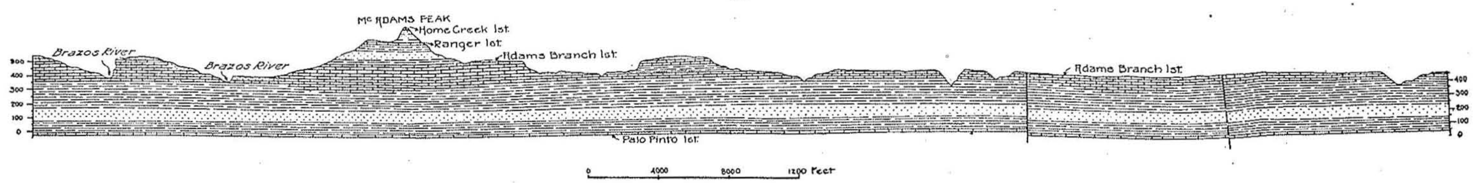
The limestone is light gray, in places iron-stained and quite fossiliferous. The shells are fragmentary and do not weather out in relief but give the limestone the appearance of being fretted with dark, thin, curved lines. The limestones show streaks and blotches of ferruginous matter, very commonly veins of calcite, and rarely small nodules of chert. The rock is massively bedded. The bedding and joint planes are so uneven that weathering produces large irregularly shaped blocks and slabs six or more feet in thickness. The limestone is remarkably uniform throughout its long outcrop. In Brown County west of Brownwood it is composed of the same two members at about the same distance above the *Fusulina* bed of the Brownwood shales as in Palo Pinto County; and it has the same uneven texture and weathers into the same large rough blocks.

*Paleontology.*—Both in the Brazos River Valley and in the Colorado River region the Graford formation contains fossils which are an important aid to stratigraphic and structural work in the field. They comprise a fauna somewhat different as a whole from that of the more typical Wewoka group which is found in the upper Strawn or in the beds of the lower Cisco above. They differentiate somewhat broadly, therefore, this portion of the Canyon group from other Pennsylvanian divisions in Texas.

The formation is not equally fossiliferous in all exposures nor at all horizons. In some places the fossils, though fairly numerous, represent only a few species. The collections which were made by the writers and associated workers represent (1) horizons in the Adams Branch limestone and (2) portions of the Brownwood shale. The chief fossiliferous horizons in the latter are found about 60, 170 and 250 feet, respectively, below the top of the Adams Branch member. The collections from the limestone while containing in some cases a considerable number of specimens, do not represent a large variety of species. Those from the subjacent shale were found chiefly in calcareous or marly beds near the top of the member and at distances of about 60, 170 and 250 feet, respectively, in different places, beneath the top of the Adams Branch limestone.

The limestone fauna, as represented in the collections from localities 67.1, 67.2, 67.10, 78.2, and 79.3 in the faunal table below, is mainly characterized by common brachiopods and in some places with echinoderm

A




B

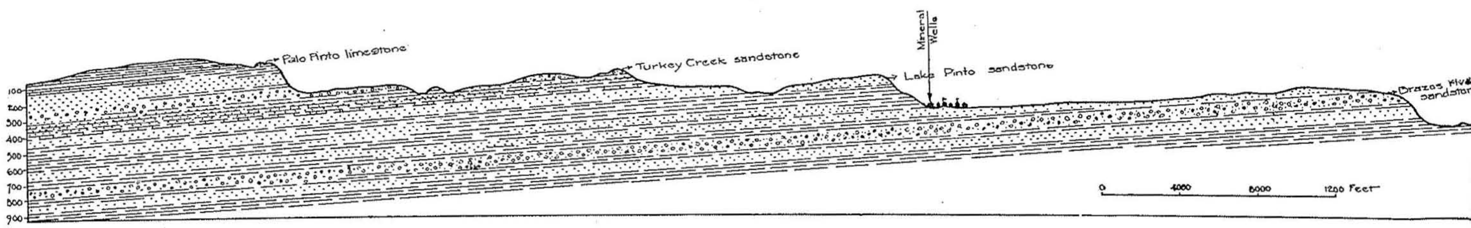



Plate XVIII. A. Geological section in a north south direction in Palo Pinto county, showing the character of the Canyon group. B. East-west geological section in the vicinity of Mineral Wells, showing the Mineral Wells formation.

remains. Corals, bryozoans and mollusks are very few. At some places the wide ranging brachiopod *Composita subtilita* is surprisingly abundant and it constitutes almost the only fossil which is found. As indicated in the columnar sections which are correlated in Plate II there is a horizon in the upper part of the Graford, referred to the Adams Branch limestone, which is characterized both in the Brazos and Colorado river valleys by an abundance of a distinctive long, emaciated type of *Fusulina*. This form has not been sectioned or otherwise subjected to the keen scrutiny which now appears to be necessary in the identification of different species, but it is distinguishable very readily on the basis of its external shape from others of the Texas *Fusulinas*. This bed has been recognized at very many places from Jack County into Brown County and since this species of *Fusulina* is apparently restricted to a very narrow zone, it is an excellent horizon marker.

The Brownwood shale fossils include a variety of corals, echinoderms, bryozoans, brachiopods and mollusks and the collections contain many more species than do those of the limestone. In the northern area a number of collections has been made from exposures between Palo Pinto and Graford, as in the prominent escarpment along the Brazos River. Zaphrentid corals, mollusks of the typical Wewoka aspect, and in one or two localities an unusual number of trilobite fragments seem to characterize this part of the Graford. In the southern area collections were made a few miles west of Brownwood on the Thrifty road at a horizon approximately 200 feet below the top of the formation, and farther south along the escarpment in the vicinity of Brooksmith. The collections west of Brownwood are characterized chiefly by abundant *Rhombopora lepidodendroidea* and other small ramose bryozoans with some of the common Pennsylvanian species. The locality near Brooksmith has afforded an abundance of well preserved fossils which weather out of the calcareous shale and may be collected readily. The fauna contains a larger proportion of the mollusks than observed in most of the collections and in many respects presents characters similar to the Wewoka. However, it lacks very many of the typical Wewoka species and contains some types which do not occur in the Oklahoma formation. An abundance of unusually large, flat-coiled gastropods of the *Euomphalus* type which apparently are distinct from any described species, is an especially noteworthy feature.

The fossils which have been collected from the Graford formation by the writers are shown in the following table:

**Fauna of the Graford formation, Texas**

| LOCALITIES | ADAMS BRANCH | | | | | BROWNWOOD SHALE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 67.1 | 67.2 | 67.10 | 78.2 | 79.3 | 67.4 | 67.5 | 67.6 | 67.9 | 79.2 | 129.1 | 129.2 |
| Fusulina sp. | | | | x | | | | | | | | |
| Somphospongia sp. | | | x | | | | | | | | | |
| Zaphrentis gibsoni | | | | | | | x | x | | | | |
| Zaphrentis sp. | | | | | | x | | | x | | | |
| Lophophyllum profundum | | | x | | | | | x | x | | | |
| Lophophyllum sp. | | | | | | | x | | | | | |
| Campophyllum torquium | | x | | | | | | x | | | | |
| *Michelinia eugeneae | | | | | | | | | | | | |
| Chaetetes milleporaceus | | | | | | x | | | | | | |
| Zeacrinus sp. | | | x | | | | | | | | | |
| Agassizocrinus carbonarius | | | | | | | | x | | | | |
| Hydreionocrinus sp. | | | | | | | | x | | | | |
| *Hydreionocrinus acanthophorus | | | | | | | | | | | | |
| Eupachycrinus magister ? | | | | | | | | | | | x | |
| Eupachycrinus sp. | | | | | | | x | | | | | |
| Delocrinus sp. | | | x | | | x | | | x | | x | |
| Crinoid stems and plates | x | x | x | | | x | x | x | x | | x | x |
| Archeocidaris sp. | | | | | | | | | | | x | |
| Fistulipora carbonaria | | | | | | x | | | x | | | xx |
| Fistulipora nodulifera | | | | | | x | | ? | | | | |
| Fistulipora sp. | | | x | | | | | | | | x | |
| Batostomella sp. | | | | | | | | | | | x | |
| Tabulipora sp. | | | | | | x | x | | | | | |
| Fenestella sp. | | | | | | x | | | x | x | | |
| Polypora sp. | | | | | | x | | x | | x | x | x |
| Septopora biserialis nervata | | | | | | | | x | | | | |
| Septopora sp. | | | | | | | | | x | | x | x |
| Rhombopora lepidodendroidea | | | | | | x | | | | x | x | x |
| Rhombopora sp. | | | | | | | | | | | x | |
| Lingula sp. | | | | | | | | x | | | | |
| *Orbiculoidea convexa | | | | | | | | | | | | |
| Orbiculoidea sp. | | | | | | x | | | | | | |
| Crania modesta | | | | | | x | | | | | | |
| Derbya bennetti | | ? | | | | | | | | | | |
| Derbya crassa | | x | | | | | | | | x | x | x |
| Chonetes granulifer | | | | | | | | | | | x | |
| Chonetes verneuilianus | | | | | | | | | x | | | |
| Productus coloradoensis | | | | | | x | x | | | | | |
| *Productus semireticulatus | | | | | | | | | | | | |
| Productus cora | | | | | | x | x | | | x | | x |
| *Productus costatus | | | | | | | | | | | | |
| Productus insinuatus | | | | | | | | | | x | | |
| Productus sp. | | | x | | | | | | | | | |
| Marginifera splendens | | x | | | | x | | | x | | | x |
| Pustula nebraskensis | | x | x | | | | | x | | x | x | |
| Pustula punctata | | x | | | x | | | | | | | |
| Pugnax rockymontanus | | | | | | | | | x | | | |

**Reported by Drake.*

| LOCALITIES | ADAMS BRANCH | | | | | BROWNWOOD SHALE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 67.1 | 67.2 | 67.10 | 78.2 | 79.3 | 67.4 | 67.5 | 67.6 | 67.9 | 79.2 | 129.1 | 129.2 |
| Dielasma bovidens | | x | | | | | | | | | | |
| Spirifer cameratus | | x | x | | | | x | x | | | x | x |
| Spirifer texanus | | | | | | x | | x | | | | |
| Squamularia perplexa | | x | | | | | | | | | | |
| *Ambocoelia planoconvexa | | | | | | | | | | | | |
| Spiriferina kentuckiensis | | x | x | | | | | | | | x | |
| *Hustedia mormoni | | | | | | | | | | | | |
| Composita subtilita | x | x | x | x | x | x | x | x | | | | |
| Edmondia gibbosa | | | | | | | | | | | | ? |
| Edmondia aspenwallensis | | | | | | | | | | x | | |
| Nucula anodontoides ? | | | | | | | | | | | x | x |
| Nuculopsis ventricosa | | | | | | x | | | x | | | x |
| Anthraconeilo taffiana | | | | | | | | x | | x | | x |
| Leda bellistriata | | | | | | x | x | | | | | x |
| Leda bellistriata attenuata | | | | | | | | | | x | | |
| Yoldia glabra | | | | | | | | | | | x | x |
| Parallelodon obsoletus | | | | | | | | | | | x | |
| Pinna peracuta | | | | | | x | | | | | | |
| Conocardium sp. | | | | | | | | x | | | | |
| Pteria sulcata | | | | | | | | | | | | x |
| Myalina recurvirostris | | | | | | | | | | x | x | x |
| Myalina subquadrata | | | | | | | x | | | | x | x |
| Myalina swallovi | | | | | | | | | | | | x |
| Schizodus alpina ? | | | | | | | | x | | | x | |
| Schizodus wheeleri | | | | | | | | | | | x | |
| Aviculopecten sp. | | | | | | | | | | x | | |
| *Allorisma subcuneata | | | | | | | | | | | | |
| Astartella concentrica | | | | | | x | | | | | x | x |
| Bellerophon crassus | | | | | | | x | x | | | | x |
| Bellerophon crassus wewokanus | | x | | | | | | | | | x | x |
| Bellerophon sp. | | | | | | | | | | x | | |
| Euphemus carbonarius | | | | | | x | | | x | | x | x |
| *Euphemus nodocarinatus | | | | | | | | | | | | |
| Bucanopsis meekiana | | | | | | | | | | x | x | |
| Pharkidonotus percarinatus | | | ? | | | | | | | | | |
| *Pleurotomaria sphaerulata | | | | | | | | | | | | |
| Worthenia tabulata | | | | | | x | | x | | | | |
| Phanerotrema grayvillense | | | | | | x | x | x | x | x | x | x |
| Orestes brazoensis | | | x | | | | | | | | | |
| Murchisonia sp. | | | | | | | | | | | x | x |
| Trepospira depressa | | | | | | x | x | x | x | | | x |
| Euomphalus n. sp. | | | | | | | | | | | | x |
| *Schizostoma catilloides | | | | | | | | | | | | |
| Schizostoma subquadrata | | | | | | | | ? | | | | |
| Zygopleura n. sp. | | | | | | | | | | | | x |
| Trachydomia wheeleri | | | | | | | | | | | | x |
| *Sphaerodoma medialis | | | | | | | | | | | | |
| Sphaerodoma sp. | | | | | | | | | | | | x |
| *Sphaerodoma texana | | | | | | | | | | | | |

**Reported by Drake.*

| LOCALITIES | ADAMS BRANCH | | | | | BROWNWOOD SHALE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 67.1 | 67.2 | 67.10 | 78.2 | 79.3 | 67.4 | 67.5 | 67.6 | 67.9 | 79.2 | 129.1 | 129.2 |
| Sphaerodoma intercalaris | | | | | | | | | | | ? | |
| Bulimorpha ? sp. cf. B. chrysalis | | | | | | | | | | | x | |
| Orthonema carbonaria | | | | | | | | | | | | x |
| Goniospira lasallensis | | | | | | | | | | | | x |
| Aclisina stevensana ? | | | | | | | | | | | x | x |
| *Conularia crustula | | | | | | | | | | | | |
| Pseudorthoceras knoxense | | | | | | x | | x | | | | x |
| Orthoceras sp. | | | | | | | | | | | x | |
| *Nautilus sp. | | | | | | | | | | | | |
| Goniloboceras welleri | | | | | | | | x | | | | |
| Pronorites n. sp. | | | | | | | | x | | | | |
| Gastrioceras hyattanum | | | | | | | | x | | | | |
| Metacoceras cornutum carinatum | | | | | | | x | | | | | |
| Griffithides scitulus | | | | | | | | x | | | | |
| Phillipsia ? sp. | | | | | | | | x | | | x | x |
| *Petalodus destructor | | | | | | | | | | | | |

## BRAD FORMATION

*Name and Stratigraphic Position.*—The Brad formation is named from the small town of Brad in Palo Pinto County, 30 miles west of Mineral Wells. This formation lies conformably upon the Adams Branch limestone and includes all the strata from the top of the Adams Branch limestone to the top of the Ranger limestone, a massive, cherty member easily recognized because it is the only uniformly cherty limestone in the Canyon or Cisco groups and because it forms everywhere a conspicuous sharp-edged escarpment.

*Extent and Thickness.*—The northeasternmost exposure of the Brad formation is near Stewarton in Jack County. From this locality the belt of outcrop runs southeastward into Palo Pinto County across the Brazos River. South of the river it has been deeply excavated by the tributaries of the Brazos and gives rise to the wild and beautiful topography of western Palo Pinto County. From Brad the formation extends southward through the Ranger field and disappears beneath the Cretaceous sand area. South of the town of Carbon it outcrops in a small isolated area in the midst of the Cretaceous and forms a broad belt as far as Copperas Creek where it is again overlapped by the Cretaceous sand. In the Colorado River Valley it extends in a belt four miles wide from a line seven miles south of May in Brown County to Brady in McCulloch County.

In the northern area it has an average thickness of 225 feet; in the Colorado River Valley its average thickness is 200 feet.

Although the total thickness and general character of the Brad formation is approximately the same in the two main areas of Pennsylvanian

**Reported by Drake.*

## GRAFORD FOSSILS

Figure 1. *Myalina subquadrata*, interior view of fragmentary left valve. Brownwood shale, south of Brooksmith (129.2).

Figure 2. *Chonetes granulifer* ?, slightly crushed pedicle valve, Brownwood shale west of Brownwood (129.1).

Figures 3, 5. *Zaphrentis gibsoni* ?, calyx and side views, respectively, of a common fossil coral in the Brownwood shale south of Graford, near Kyle Mountain (67.6).

Figure 4. *Batostomella* sp., a small branching bryozoan, Brownwood shale south of Brooksmith (129.2).

Figure 6. *Pugnax rockymontanus*, pedicle valve, Brownwood shale south of Graford on the Brazos River (67.9).

Figure 7. *Composita subtilita*, an extremely common brachiopod in parts of the Adams Branch limestone. Adams Branch limestone northwest of Graford (67.2).

Figure 8. *Myalina swallovi*, a small, very oblique species, right valve. Brownwood shale west of Brownwood (129.1).

Figure 9. *Leda bellistriata attenuata*, Brownwood shale south of Brooksmith (129.2).

Figures 10, 11, 22. *Nucula anodontoides* ?, left valve, cardinal view and right valve of characteristic specimens from the Brownwood shale south of Brooksmith (129.2).

Figures 12, 13, 14, 15. *Euomphalus* n. sp., a very well preserved, robust gastropod abundant in the Brownwood shale south of Brooksmith. Figures 12 and 14 show respectively, the top and side views of a typical large specimen; Figures 13 and 15 the side and bottom views of another specimen (129.2).

Figures 16, 17, 18. *Yoldia glabra*, two well preserved left valves and a right valve, respectively, from the Brownwood shale south of Brooksmith (129.2).

Figures 19, 20. *Griffithides scitulus*, a small coiled trilobite, Brownwood shale, south of Graford near Kyle Mountain (67.6).

Figure 21. *Anthraconeilo taffiana*, a somewhat exfoliated left valve, Brownwood shale, south of Brooksmith (129.2).

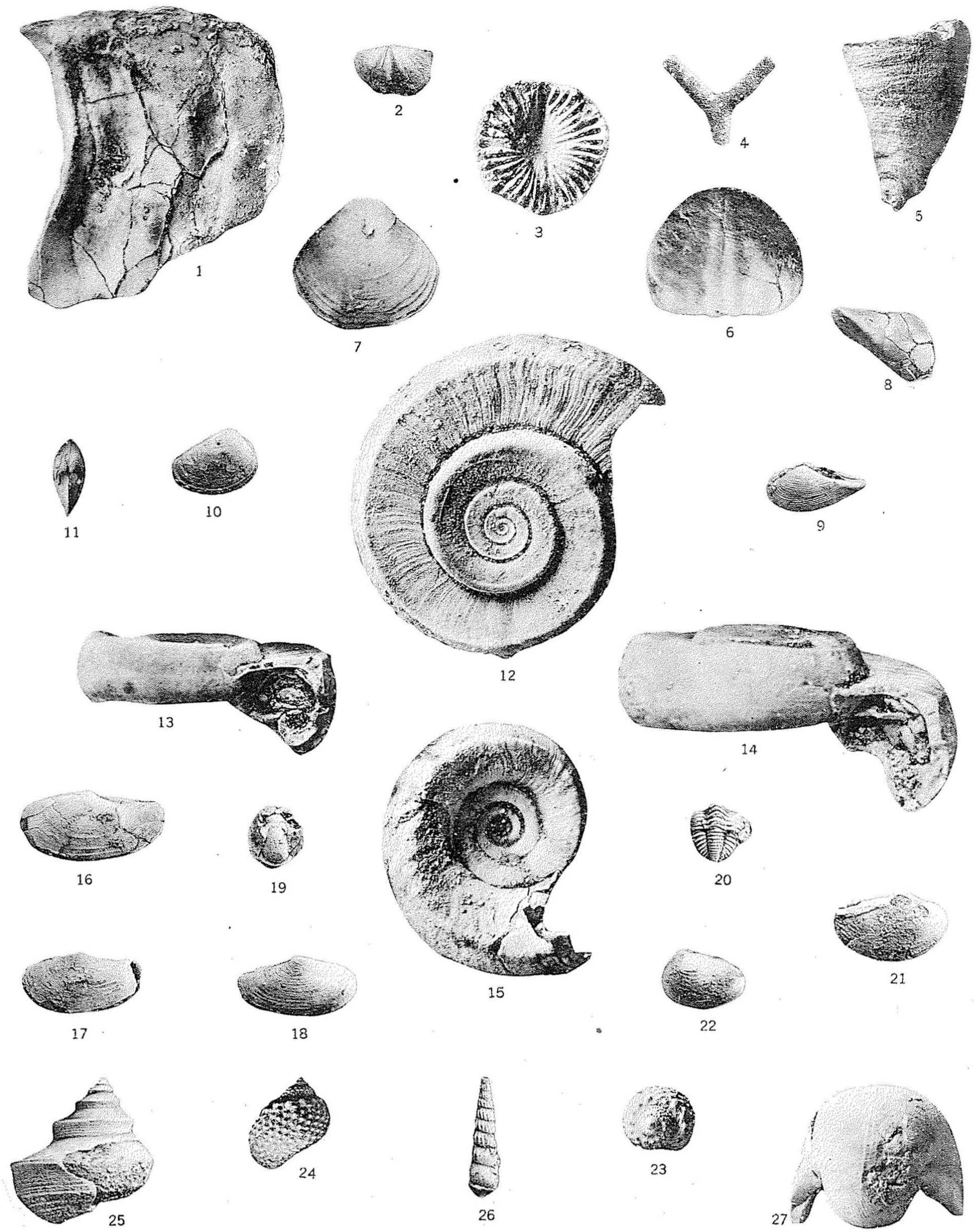
Figures 23, 24. *Trachydomia wheeleri*, top and side views of two perfect specimens from the Brownwood shale south of Brooksmith (129.2).

Figure 25. *Worthenia tabulata*, a partly weathered but characteristic specimen, Brownwood shale, Kyle Mountain (67.4).

Figure 26. *Hemizyga* n. sp., Brownwood shale, south of Brooksmith (129.2).

Figure 27. *Bellerophon crassus*, Brownwood shale, south of Brooksmith (129.2).

The correlation of the Graford formation is discussed with other divisions of the Canyon at the end of the description of the group.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rocks which are separated by the projecting tongue of Cretaceous sand, the sections are sufficiently different to make desirable a consideration of each of the areas separately. The subdivisions which have been recognized are as follows:

| Colorado River Valley | Brazos River Valley |
|---|---|
| 4. Ranger limestone | 2. Ranger limestone |
| 3. Placid shale | 1. Seaman Ranch beds |
| 2. Clear Creek limestone | |
| 1. Cedarton shale | |

### Subdivisions in the Colorado River Valley

In the Colorado River Valley, where Drake's studies were undertaken, the strata which are here included in the Brad formation consist of two more or less prominent and easily traceable limestones and two divisions of shale and sandstone. Of these the uppermost bed, the cherty Ranger limestone, is recognized in the Brazos River Valley, the remaining subdivisions being represented in the north by the Seaman Ranch beds.

*Cedarton Shale.*—The lower part of the Brad formation in the Colorado River Valley consists of 20 to 100 feet of sandy shale with lentils of sandstone and a few thin beds of conglomerate. These beds were named the Cedarton shale by Drake[64] from the small village of Cedarton in Brown County, southwest of Brownwood. The sandstone layers in the Cedarton member are found in most places near the top of the bed and are coarsest near the north end of the outcrop. The shales are blue, in places weathering to red and purple, and are locally fossiliferous. Toward the southern end of the outcrop southwest of Milburn the shales are thinner and more calcareous.

*Clear Creek Limestone.*—Above the Cedarton beds is a layer of limestone named by Drake[65] the Clear Creek bed, which has an average thickness of 10 to 25 feet. According to Drake it has a total thickness locally of as much as 90 feet, consisting of two massive layers separated by clay shale. It may be traced in continuous outcrop from a point four miles east of Brady northward to the Cretaceous sand four miles east of Clio postoffice, northwest of Brownwood. In the Gorman-Sipe Springs district the Clear Creek has been correlated with a limestone between the Ranger and Adams Branch limestones and has been mapped from a point one and one-half miles southwest of Gorman northward to the Cretaceous sand east of Carbon. West of Brownwood and along its outcrop across Brown County it is a yellow-brown limestone made up of several more or less discontinuous layers which in places combine to form a solid ledge, but in others are separated by thin beds of shale. The weathered surfaces are very rough, and it contains more iron than the Ranger limestone above or the Adams Branch limestone below. In places it can be distinguished

[64]Loc. cit.
[65]Ibid, p. 393.

by its dark yellow-brown color. In other places, however, it is light gray and massively bedded, quite like the Adams Branch limestone. West of Sipe Springs in Comanche County are two limestone ledges separated by about 60 feet of clay which represent without much doubt the Clear Creek bed. The lower of these plays out at a point about six miles north of Sipe Springs. The upper layer, 5 to 10 feet thick, seems to be continuous. It is dirty yellow in color, thin-bedded, rough-surfaced, and breaks up on weathered surfaces into small chips and thin slabs full of poorly preserved fossil fragments. Just below the lower limestone is a thin-bedded, fine-grained, light-colored, sandy clay similar to the Cedarton bed in Brown County.

*Placid Shale.*—Overlying the Clear Creek limestone, and below the Ranger limestone, is a shale division containing in places lentils of sandstone. This bed, which was designated by Drake[66] as "Bed No. 7," is here named the Placid shale, from the town of Placid in McCulloch County which is situated on its outcrop. This member makes up the lower portion of the escarpment which is capped by the Ranger limestone and in many places excellent exposures are found. Drake describes the bed as follows:

"West of Lookout Mountain the bed consists of from 40 to 50 feet of clay parted near the middle by two or three feet of dark colored limestone, which in some places is overlain by a thin stratum of sandstone. . . . The bed increases in thickness to the north for ten or fifteen miles. Southwest of Brownwood it is from 30 to 50 feet thick, and the clay is sandy, reddish to purple in color, and capped by from five to six feet of conglomeratic sandstone."

*Ranger Limestone.*—The limestone bed above the Placid shale was named the "cherty limestone bed" by Drake[67] because of its characteristic chert content. It has now been correlated definitely with a continuous limestone bed in the Brazos River Valley which is named the Ranger limestone from the town of Ranger in Eastland County. The new name has been retained in order to substitute an appropriate place name for the undesirable stratigraphic term, "cherty." In the Colorado River Valley the limestone forms a continuous escarpment from Brady Mountains northward to Hog Creek on the Cisco-Brownwood road. The bed is made up of massive, rough, gray and yellowish gray limestone containing chert nodules which are for the most part evenly distributed throughout the bed, but in places are confined to layers near the middle portion. The lithologic characteristics and lithology of the limestone is more fully treated in the description of the beds in the Brazos River Valley.

### Subdivisions in the Brazos River Valley

In the northern area the Ranger limestone is everywhere a persistent ledge at the top of the formation. Below the Ranger the section consists of beds of clay and shale, lentils of limestone, and more or less thick lenses

[66]Ibid.
[67]Ibid.

of sandstone. The Clear Creek limestone has not been identified with certainty in this area and probably does not extend farther north than Carbon in Eastland County. Therefore it is not feasible to apply the subdivisions of Drake to the formation in the Brazos River Valley. The lower part of the Brad formation in this area, including the strata between the base of the Ranger limestone and top of the Graford formation is designated the Seaman Ranch member.

*Seaman Ranch Beds.*—In the Brazos River Valley the shales below the Ranger limestone, which are equivalent to the Placid shale, the Clear Creek limestone, and Cedarton beds of the Colorado River Valley, have been named the Seaman Ranch beds for a ranch in western Palo Pinto County where they are typically exposed along Caddo Creek. They have an average thickness of 150 to 200 feet and consist of a basal bed of shale 60 to 100 feet thick overlain by 50 to 110 feet of dark gray, soft, sandy shale containing one or two lentils of reddish-brown sandstone and a thin layer or two of dark brown limestone. In most places the shales are non-fossiliferous although one or two localities offer very fossiliferous beds.

*Ranger Limestone.*—The Ranger limestone member forms the prominent escarpment west of the town of Ranger in which the larger part of the Ranger oil field is situated and forms a persistent ledge which has been mapped from Stewarton in Jack County to Brady in McCulloch County. Excellent exposures may be seen near Bartons Chapel in southern Jack County, near Brad on the Breckenridge-Mineral Wells road, at Ranger in Eastland County, three miles south of Carbon on the Eastland-Sipe Springs road, and on the Brownwood-Trickham road five miles west of Brownwood.

Like the Adams Branch limestone, the Ranger is made up in most places of two layers, an upper thin limestone separated by 5 to 10 feet of yellow shale from a lower thick and massive limestone. The upper thin layer is in most places more fossiliferous than the Adams Branch limestone, and the lower member is more massive and weathers into large square blocks which give a wall-like appearance to its escarpment; whereas the Adams Branch limestone weathers into more rounded boulders, and its cliff is not so abrupt at the top as is the Ranger cliff. The heavy bed of the Ranger member in many places contains layers and nodules of white chert, a characteristic not common to other members of the Pennsylvanian beds in northern Texas. Many of the chert nodules contain *Fusulina* and other fossils. The chert is found in nodules throughout the limestone, but most commonly forms a layer of chert nodules near the top of the lower bed. In most places the member is light gray, massively bedded, very evenly jointed, and it weathers to smooth surfaces. In the vicinity of Ranger the limestone occurs at the top of a high, abrupt escarpment, and below the heavy ledge are about 60 feet of soft shale. Many streams have cut deep canyons back into the scarp and have left the ledge protruding in narrow, jutting points a quarter of a mile or more in length, and only a few hundred feet wide. The limestone commonly breaks off into blocks which slide down the steep slope and form a fringe of talus around the base. In a few places a great table of limestone several hundred feet long and 200 to 300 feet wide has separated from the ledge along a joint plane, slipped over the soft shale, and has slid down the slope 60 or 70 feet below, nearly intact. One of these slips is located near the famous McClusky discovery well in the Ranger field. The edge of the block, having broken along a joint plane, is remarkably straight, and the whole mass of the limestone appears to be in place except for the fact that the blocks along the joint are turned up on edge. The slip has been interpreted by many geologists as a fault and was regarded at one time as an explanation for the large accumulation of oil on the McClusky tract. Later detailed work has shown that no large faults are present in this part of the field, and the landslide interpretation has been generally accepted. Other excellent examples of large blocks which have slipped down the slope may be seen along the Ranger escarpment two miles east of Olden in section 1, H. T. & R. R.R. Co. Survey, Eastland County.

*Detailed Sections.*—The plotted sections of the Brad formation on Plate II give a good idea of the general stratigraphic character of the strata in the different districts. Additional details regarding the characteristics of the individual layers are included in the descriptions of the following sections measured in widely separated areas along the outcrop.

**Section of the upper part of the Brad formation at Barton's Chapel, Jack County (H in fig. 12)**

| | Thickness Feet |
|---|---|
| CADDO CREEK FORMATION— | |
| Conglomerate and cross-bedded sandstone | 0-60 |
| BRAD FORMATION— | |
| Ranger Limestone | |
| Limestone, massive, gray and brown, weathers to hard, angular blocks | 6 |
| Shale, buff, sandy, containing lentil of light gray, fine-grained, calcareous sandstone | 14 |
| Limestone, gray-brown, hard, sandy | 2 |
| Shale | 4 |
| Limestone, yellow, hard, fossiliferous, cherty, irregularly bedded | 3 |
| Seaman Ranch Shale | |
| Shale, blue, weathering yellow | 40 |
| Sandstone, brown, weathering yellow | 5 |
| Shale | 30 |
| Limestone, changing to calcareous sandstone, quite resistant, weathers red and brown | 3 |
| Shale,sandy, calcareous | 12 |
| Total | 119 |

**Section of Brad formation at type locality south of Brad, Palo Pinto County**

**(I in fig. 12)**

| | Thickness Feet |
|---|---|
| BRAD FORMATION— | |
| Ranger Limestone | |
| 9. Limestone, yellow, brown, thin, hard | 2 |
| 8. Shale, light gray | 9 |
| 7. Limestone, massive, gray | 15 |
| 6. Limestone, massive, yellowish gray, contains chert in places, varies in thickness | 15-25 |
| Seaman Ranch beds— | |
| 5. Shale | 10 |
| 4. Sandstone, brown, calcareous | 4 |
| 3. Shale and cross-bedded sandstone | 36 |
| 2. Limestone, brown, thin-bedded, fossiliferous | 2 |
| 1. Shale and sandstone, shale predominant | 96 |
| Average total thickness | 194 |

**Section of Brad formation at Ranger, Eastland County**

**Measured by S. W. Wells. (J in fig. 12)**

| | Thickness Feet |
|---|---|
| BRAD FORMATION— | |
| Ranger Limestone | |
| Limestone, white, thin-bedded, cherty in two places | 15 |
| Seaman Ranch Beds | |
| Shales, gray | 10 |
| Sandstone, white to dark gray, thin-bedded, calcareous | 7 |
| Shale, blue and gray | 58 |
| Sandstone, dark reddish-brown, iron-stained, coarse-grained | 10 |
| Shale, blue and gray | 20 |
| Sandstone, reddish-brown, calcareous, cross-bedded, lenticular | 15 |
| Shale, blue-gray, in places sandy | 40 |
| GRAFORD FORMATION— | |
| Adams Branch Limestone | |
| Limestone, white, thin-bedded | 15 |
| Total | 190 |

**Section of Brad formation on Eastland- Sipe Springs road three miles south of Carbon, Eastland County**

**(K in fig. 12)**

| | Thickness Feet |
|---|---|
| BRAD FORMATION— | |
| Ranger Limestone | |
| 15. Limestone, light-colored, thin, contains few fossil fragments | 3 |
| 14. Shale, yellow, marly | 10 |

| | | |
|---|---|---|
| 13. | Limestone, massive, grayish white, irregularly bedded, chert-bearing; weathers to smooth gray surfaces; contains much chert in form of nodules 1 to 4 inches in diameter, of rounded and elongated forms; most of the chert is fossiliferous, iron-stained, and weathers to a reddish color | 12 |
| Placid Shale | | |
| 12. | Shale, yellow, calcareous | 5 |
| 11. | Limestone, impure, hard, brown | 1 |
| 10. | Shale, mottled red and yellow, non-fossiliferous | 20 |
| 9. | Sandstone, reddish-brown | 10 |
| 8. | Shale, sandy, contains some sandstone layers | 110 |
| | (Partly grass-covered, not exposed) | |
| Clear Creek limestone (?) | | |
| 7. | Limestone, rough surfaces, unevenly bedded, yellowish-brown | 8 |
| 6. | Shale, not exposed | 10 |
| 5. | Sandstone and sandy shale | 10 |
| 4. | Shale | 30 |
| 3. | Limestone, yellow-brown, thin-bedded, weathers into chips and thin slabs, fossiliferous | 5 |
| Cedarton Shale | | |
| 2. | Shale, thin-bedded, fine-grained, light-colored, sandy | 10 |
| 1. | Shale, not exposed | 85 |
| Top of Adams Branch Limestone | | |
| | Total thickness | 329 |

**Section of Brad formation on Brownwood-Trickham road five miles west of Brownwood, Brown County**

**(L in fig. 12)**

| | | Thickness Feet |
|---|---|---|
| BRAD FORMATION— | | |
| Ranger Limestone | | |
| 10. | Limestone, cherty, yellow, impure | 5 |
| 9. | Limestone, blue | 5 |
| Placid Shale | | |
| 8. | Shale, yellow | 12 |
| 7. | Limestone, cherty | 6 |
| 6. | Shale and yellow clay containing conglomerate and sandstone lenses | 80 |
| Clear Creek Limestone | | |
| 5. | Limestone, blue, abundant calcite veinlets | 12 |
| 4. | Shale, yellow, contains lenticular limestones | 33 |
| 3. | Limestone, yellow, massive | 6 |
| Cedarton Bed | | |
| 2. | Shale, fossiliferous | 2 |
| 1. | Sandstone conglomerate containing chert pebbles | 80 |
| | Total thickness | 241 |

*Paleontology.*—The beds included in the Brad formation are not strikingly fossiliferous, although in some places an abundance of poorly preserved invertebrate shells and fragments may be seen in the limestone members. Most of the fossils which were collected during the course of the recent field work were obtained from the Ranger limestone and the shale immediately underlying it, and the localities are distributed mostly in the Brazos River Valley. Drake reports a number of fossils in the Colorado River Valley from the Clear Creek and "Cherty" limestones but does not give locations in detail. In the following faunal list the species reported by Drake but not represented in the Roxana collections are marked with an asterisk.

The fauna includes representatives of all the important invertebrate groups and is very similar to other divisions of the Canyon. It may be identified as a phase of the well-characterized Wewoka fauna, although many of the common species of the southern Oklahoma formation are lacking here.

**Fauna of the Brad formation**

| FAUNA | LOCALITIES | | | | |
|---|---|---|---|---|---|
| | 53.5 | 66.3 | 67.3 | 67.7 | 79.4 |
| *Fusulina cylindrica | | | | | |
| Amblysiphonella sp. | | x | | | |
| *Zaphrentis sp. | | | | | |
| Lophophyllum profundum | x | x | x | | |
| Lophophyllum profundum radicosum | x | | | | |
| Campophyllum torquium | | | | | x |
| *Chaetetes sp. | | | | | |
| Hydreionocrinus patulus | | | x | | |
| Hydreionocrinus sp. | | | x | | |
| Delocrinus sp. | | | x | | |
| Crinoid stems and plates | x | x | x | x | x |
| *Archeocidaris sp. | | | | | |
| Fistulipora carbonaria | | ? | x | | |
| Fenestella sp. | | x | x | | x |
| Polypora bassleri ? | | | x | | |
| Polypora sp. | | x | x | | |
| *Orbiculoidea convexa | | | | | |
| *Orbiculoidea missouriensis ? | | | | | |
| Rhipidomella pecosi | | x | | | |
| *Derbya crassa | | | | | |
| *Meekella striatocostata | | | | | |
| *Chonetes granulifer | | | | | |
| *Chonetes verneuilianus | | | | | |
| Productus cora | | | x | | x |
| *Productus pertenuis | | | | | |
| *Productus costatus | | | | | |
| *Productus semireticulatus | | | | | |
| Productus sp. | | | x | | |
| Pustula nebraskensis | | | x | | |
| *Pustula symmetrica | | | | | |
| Pustula punctata | | x | x | | |
| Pustula sp. | | x | | | |
| Marginifera lasallensis | x | | | | |
| Marginifera splendens | | x | | | |

*Reported by Drake.

| FAUNA | LOCALITIES | | | | |
|---|---|---|---|---|---|
| | 53.5 | 66.3 | 67.3 | 67.7 | 79.4 |
| *Pugnax uta | | | | | |
| *Dielasma bovidens | | | | | |
| Spirifer cameratus | x | x | x | | x |
| *Spirifer texanus | | | | | |
| *Squamularia perplexa | | | | | |
| Ambocoelia planoconvexa | | | x | | |
| Spiriferina kentuckiensis | | x | | | x |
| Hustedia mormoni | | x | x | | |
| Cliothyridina orbicularis | | x | | | |
| Composita subtilita | x | x | x | | |
| Nuculopsis ventricosa | x | | | | |
| Leda bellistriata | x | | | | |
| Parallelodon sangamonensis | | x | | | |
| *Conocardium obliquium | | | | | |
| Pseudomonotis hawni | | | x | | |
| Myalina subquadrata | x | | x | | |
| *Aviculopecten occidentalis | | | | | |
| *Aviculopecten sp. | | | | | |
| Allorisma subcuneatum ? | | | | | x |
| Astartella varica | | x | | | |
| *Euphemus carbonarius | | | | | |
| *Euphemus nodocarinatus | | | | | |
| Pharkidonotus percarinatus | x | | | | |
| *Pleurotomaria sphaerulata | | | | | |
| Phanerotrema grayvillense | x | | | | |
| Worthenia tabulata | x | | | | |
| *Orestes brazoensis | | | | | |
| Trepospira depressa | x | | | | |
| Euomphalus sp. | | x | | | |
| Schizostoma catilloides | | | x | | |
| Naticopsis sp. | | x | | | |
| Sphaerodoma brevis | x | | | | |
| *Sphaerodoma medialis | | | | | |
| *Sphaerodoma primigenia | | | | | |
| *Sphaerodoma texana | | | | | |
| Sphaerodoma ventricosa | | | x | | |
| Meekospira peracuta choctawensis | | | x | | |
| *Platyceras parvum | | | | | |
| *Conularia crustula | | | | | |
| Protocycloceras ? rushense ?. | | | | x | |
| *Nautilus sp. | | | | | |
| *Goniatites sp. | | | | | |
| Phillipsia major ? | | | x | | |
| Phillipsia ? sp. | | x | | | |
| *Petalodus destructor | | | | | |

The correlation of the Brad formation is discussed with that of the Canyon division as a whole at the end of the description of the group.

*Reported by Drake.

## CADDO CREEK FORMATION

*Name and Stratigraphic Position.*—The Caddo Creek formation is named from Caddo Creek which flows through the town of Caddo northwest into the Brazos River and affords excellent exposures of the formation all along the upper part of its course. The formation lies conformably upon the Ranger limestone and includes all the strata from the top of the Ranger limestone to the top of the Home Creek limestone, which is the highest layer in the Canyon group. In the northern area the Home Creek limestone is readily distinguished from the other limestones by its position above a thick massive sandstone and below the fossiliferous shales and ferruginous sands of the Cisco group.

*Extent and Thickness.*—The Caddo Creek formation has been mapped from a point about five miles east of Jacksboro southwest across Jack County to Finis and thence across the northwest corner of Palo Pinto County to Caddo. From Caddo the belt runs southward beneath the Cretaceous sand southeast of Eastland and reappears in the Gorman district, occupying the west end of the Pennsylvanian inlier. South of the Cretaceous area the outcrop of the formation runs from a point southeast of Blake in the Brownwood district to a point near Brady. In the northern area the average width of the outcrop is three miles and its thickness from 100 to 150 feet; in the Colorado River Valley it is only 30 to 50 feet thick and its outcrop is not more than two miles wide. In many places it forms rounded outliers resting on the Brad formation. In Palo Pinto and Stephens counties, owing to the soft and easily eroded character of the overlying beds, the outcrop of the Caddo Creek formation is indented far back by all the streams flowing across the strike, so that it presents a very irregular and dendritic exposure.

### Subdivisions of the Caddo Creek Formation

The Caddo Creek formation consists of two members:

2. Home Creek limestone
1. Hog Creek shale

Both names were given to the members by Drake from creeks in Brown County. In the preliminary paper by Plummer[69] on the stratigraphy of the Pennsylvanian area of north-central Texas, the Home Creek limestone was called the Eastland limestone. It has now been established that this member is the same as Drake's Home Creek bed, and the name "Eastland limestone" has therefore been dropped.

*Hog Creek Shale.*—The Hog Creek bed as exposed in Palo Pinto County consists of a series of sandstones, shales, and rarely a limestone lentil. At the top of this series is a dark reddish-brown, cross-bedded sandstone

[69]Plummer, F. B., Preliminary paper on the stratigraphy of the Pennsylvanian formations of north-central Texas: Am. Assn. Pet. Geol. Bull., vol. 3, pp. 132-50, 1919.

containing in some places remnants of coal plants and in others lenses of conglomerate. This sandstone varies in thickness from 10 to 25 feet and overlies about 75 feet of grayish-yellow shale containing lenses of sand and in a few places lentils of limestone. One or two small collections of fossils have been obtained from the Hog Creek bed, but on the whole it is non-fossiliferous. In the Colorado River Valley this member has about the same characteristics and thickness in its northern exposures as far south as the Gulf, Colorado and Santa Fe Railroad. South of the railroad the clays are somewhat thinner, and the sands pinch out in the district northeast of Brady.

*Home Creek Limestone.*—The Home Creek limestone member is not a persistent member in the extreme northern portion of the Pennsylvanian area. It marks the top of the Canyon group from the Llano Mountains northeastward into southeastern Young County, but northeastward from Finis in Jack County it can not be traced with certainty, because it changes laterally into calcareous sands which are obscured by slump and wash from the more massive sandstones of the basal part of the Cisco group above. At Caddo the Home Creek limestone is composed of two layers which are separated by 5 to 10 feet of calcareous shale. The upper layer is a dark blue, fossiliferous, hard limestone and weathers to a yellow-brown color. The lower layer is an impure, clayey, light gray, poorly bedded limestone 10 to 40 feet in thickness which weathers into large, irregularly shaped slabs and chunks. The same two members are present and have the same characteristics in the Eastland district. In the vicinity of Sipe Springs there is only one bed of limestone. It is characteristically light gray in color, in places stained yellow and brown by iron-bearing waters. The upper layers are slaty and contain abundant *Fusulina,* the lower part is massive and weathers into large blocks. It forms an escarpment of moderate size and where not covered by the Cretaceous sand can be traced easily.

*Detailed Sections.*—The uniformity in the lithologic character of the outcrop throughout its extent is shown by the columnar sections on Plate II. The following descriptions give in detail the individual characteristics of the strata making up the formation.

**Section of Caddo Creek formation 6 miles north of Brad, Palo Pinto County**

**Measured by S. W. Wells. (M in fig. 12)**

| CADDO CREEK FORMATION— | Thickness Feet |
|---|---|
| Home Creek Limestone | |
| 8. Limestone, brownish-yellow, blue on fresh surface | 2 |
| 7. Shale | 5 |
| 6. Limestone, nodular, grayish-white | 6 |
| 5. Shale (covered) | 5 |
| 4. Limestone, massive, contains chert concretions | 24 |
| 3. Shale (covered) | 10 |
| 2. Limestone, massive, iron-stained | 5 |
| Hog Creek Shale | |
| 1. Shale and sandstone, shale predominant, black shale at base and sandstone bed at top | 117 |
| Top of Ranger limestone | |
| Total thickness | 174 |

**Section of Caddo Creek formation four miles southeast of Eastland in a deep valley near head of Leon River**

**Measured by S. W. Wells. (N in fig. 12)**

| | Thickness Feet |
|---|---|
| CADDO CREEK FORMATION— | |
| Home Creek Limestone | |
| 6. Limestone, massive, light gray, weathers to large rounded blocks | 2-4 |
| 5. Shale, yellow gray | 8 |
| 4. Limestone, massive, gray, weathers to angular fragments | 10 |
| Hog Creek Shale | |
| 3. Shale | 20 |
| 2. Sandstone, massive, lenticular, brown | 20 |
| 1. Shale | 43 |
| Top of Ranger limestone | |
| Total thickness | 105 |

**Section of Caddo Creek formation six miles east of Trickham near the Trickham-Brownwood road**

**Measured by Grady Kirby. (O in fig. 12)**

| | Thickness Feet |
|---|---|
| CADDO CREEK FORMATION— | |
| Home Creek Limestone | |
| 8. Limestone, yellow, red spots and iron concretions | 4 |
| 7. Shale, buff | 11 |
| 6. Limestone, gray | 1 |
| Hog Creek Shale | |
| 5. Shale | 8 |
| 4. Limestone, gray, marly | 2 |
| 3. Shale | 8 |
| 2. Limestone, yellow | 2 |
| 1. Shale | 30 |
| Total thickness | 66 |

**Section of Caddo Creek formation five miles south of Bangs, section 37. J. Daniel Survey, Brown County**

**Measured by C. A. Hammill. (P. in fig. 12)**

| | Thickness Feet |
|---|---|
| CADDO CREEK FORMATION— | |
| Home Creek Limestone | |
| 8. Limestone, gray and yellow, heavy-bedded, top shaly and full of *Fusulina*, lower part massive and weathers to large blocks stained with ferruginous matter to reddish and yellowish tints | 4 |
| 7. Shale, buff | 10 |
| 6. Limestone, yellow, sandy,nodular, rotten in places | 1 |
| Hog Creek Shale | |
| 5. Shale, yellow | 8 |
| 4. Limestone lentil, reddish-yellow, *Fusulina* | 1 |
| 3. Shale, yellow | 4 |
| 2. Limestone, gray, nodular, coarse-grained | 1 |
| 1. Shale | 17 |
| BRAD FORMATION— | |
| Ranger limestone, gray, massive, cherty, weathers to fine, honey-combed, iron-stained surfaces. | |
| Total thickness | 46 |

*Paleontology.*—The Caddo Creek formation appears to be much less fossiliferous than most of the Texas Pennsylvanian divisions. During the course of the field work for the Roxana Corporation only a few fragments were collected and on account of lack of opportunity for special investigations no specific paleontologic studies were made. Fossils reported from the Caddo Creek formation in the Colorado River Valley represent only the Home Creek limestone. The following species are reported by Drake.

**Fauna of the Caddo Creek Formation (Drake)**

*Syringopora* sp.
*Marginifera splendens* ?
*Spirifer cameratus*
*Spiriferina kentuckiensis*
*Ambocoelia planoconvexa*
*Composita subtilita*

*Correlation of the Canyon Group.*—As indicated in the faunal tables of the formations of the Canyon given above and as represented in the general faunal table of the Pennsylvanian of Texas on succeeding pages, the fossils of this division are as a whole very similar to those of the Mineral Wells and Graham formations, and with them are most like the fauna of the Wewoka formation. However, the Canyon beds are not on the whole so fossiliferous as the Wewoka nor have they been studied in such detail as to indicate with precision the relations of one fauna to the other. Also it appears that in the clear waters in which the massive limestone members of the Canyon were deposited the character of the invertebrates was, as might be expected, somewhat different from that found in the clastic Wewoka strata. Nevertheless in the shales of the Canyon, especially the Brownwood bed of the Graford, are found many of the most characteristic brachiopods and mollusks which mark the Wewoka fauna. Among these may be mentioned *Productus insinuatus, Marginifera lasallensis, M. splendens, Pustula nebraskensis, Pugnax rockymontana, Cliothyridina orbicularis, Hustedia mormoni, Edmondia gibbosa, Nuculopsis ventricosa, Leda bellistriata, L. bellistriata attenuata, Yoldia glabra, Anthraconeilo taffiana, Schizodus alpinus, Astartella concentrica, Bellerophon crassus wewokanus, Patellostium montfortianum, Euphemus carbonarius, Bucanopsis meekiana, Pharkidonotus percarinatus, Worthenia tabulata, Trepospira depressa, Meekospira peracuta choctawensis, Sphaerodoma gracilis, S. intercalaris, Pseudorthoceras knoxense, Protocycloceras ? rushense ?, Metacoceras cornutum carinatum, Gonioloboceras welleri* and *Gastrioceras hyattanum.* So far as represented in the collections made in the course of the recent field work *Chonetes mesolobus* and some of the other typical Wewoka fossils have not been found, and some, such as *Zaphrentis gibsoni, Agassizocrinus carbonarius, Spirifer texanus, Pteria sulcata, Myalina swallovi,* and *Trachydomia wheeleri,* are found in the Canyon but not in the Wewoka. Of these the last three have been reported in Kansas; *P. sulcata,* a peculiarly distinctive pelecypod first described from Nebraska City by Geinitz, from the Kansas City, Douglas and Permian; *M. swallovi* from the Marmaton to the Permian and *T. wheeleri* from the Kansas City to the Shawnee. *Spirifer texanus* is a very characteristic and readily distinguishable element of the faunas of the Canyon and Graham but is essentially restricted to Texas.

Certainly the Canyon group appears to lack the invertebrate faunal elements which are most typical of the Upper Pennsylvanian and a careful consideration of the paleontologic and stratigraphic evidence available leads to the conclusion that the Canyon is essentially equivalent to the Wewoka and associated formations, approximately Calvin sandstone to Holdenville shale in southern Oklahoma, which in turn appear to represent all or some portion of the beds included in the Marmaton formation of Kansas. It is not at all certain that the change from clastic to calcareous sedimentation in the Kansas region was contemporaneous with that in Texas marked by the transition from the Strawn to the Canyon, but since there is some similarity also in the faunal relationships this may be the case. The southern Oklahoma area, which includes not only the Pennsylvanian rocks from the Wapanucka or possibly Caney strata to the Holdenville shale and higher beds, but, on the south side of the Arbuckle Mountains the Glenn formation, was evidently much nearer an old land area from which much clastic debris was being transported than were the areas in Kansas and Texas, for the section here is uniformly clastic and the thickness of sediments is much greater than either to the north or to the south.

## CISCO GROUP

### GENERAL DISCUSSION

Following the end of the epoch of deposition of the thick calcareous beds of the Canyon group the seas became shallow throughout most of the area of the present Brazos River Valley. Large amounts of coarse sand and gravel were washed over the land and into the shallow waters in Jack County and eastern Young County. Carbonaceous clays, peat beds, and coarse sands were deposited in Stephens County and southeastern Young County, and in Eastland County cross-bedded shallow-water sands containing plant remains were spread over large areas. In the present Colorado River Valley the waters of the Canyon sea probably continued over the area, but the clear waters of the later Canyon epoch were for a time made turbid with coarse sediments, for above the Home Creek limestone in most sections sandy clays and irregularly bedded sandstones are found.

Following the uplift was a long epoch of alternating conditions during which thin, but fairly continuous, deposits of limestone, were laid down in almost regular periodic succession with shale and sandstone. The sediments, which amount in total thickness to about 1000 feet, are now known as the Cisco group. During the middle part of the Cisco epoch marsh conditions appeared and a bed of coal, the Waldrip coal, was laid down across northern Texas. At the end of the epoch clearer waters and calcareous sediments came again into the region now occupied by the valleys of the Colorado and Brazos rivers, and these clear seas extended over broad areas to the west.

To the north in the present valley of the Red River and in southern Oklahoma at the end of the Cisco epoch there were broad, low delta flats converging into an old river plain built by the confluence of imbricating streams which, aided by the hot, moist climate, formed the beginning of a remarkable series of red beds. Thus, the ferruginous calcareous deposits of the upper Cisco merge northward in north Throckmorton, Young and Montague counties into reddish and greenish calcacerous sands, clays, and grits making up a formation of a very different aspect from the upper Cisco beds to the south and west.

*Name and Stratigraphic Relations.*—The Cisco group was named by Cummins[70] from the town of Cisco in Eastland County. As the town is centrally located on the belt of outcrop of the group, and as many excellent exposures of the strata may be seen in this vicinity, no more appropriate name could be chosen. Cummins included in the Cisco group all the interbedded sandstones, limestones, and sandy shales above the massive limestones of the Canyon and below the limestones of the Wichita group. The Cisco was defined by Drake to include all beds between the Canyon group and the Coleman Junction limestone, a limestone thought to contain Permian fossils. On the geologic map (Plate I) the top of the Cisco has been tentatively drawn at the top of the Coleman Junction limestone because the fossils in the limestone seem to have more of a Pennsylvanian than Permian aspect.[71] The line, however, is subject to future revision for should it be established that the fauna of the Coleman Junction limestone is Permian, the top of the Pennsylvanian series would of course have to be placed lower in the section. A collection of Permian ammonites has been made from the shales above the Coleman Junction limestone and the fauna of the Moran limestone is apparently Pennsylvanian, so that the strata possibly in question are between the top of the Moran and the top of the Coleman Junction limestones.

The basal beds of the Cisco group rest upon the Home Creek limestone of the Canyon group. In general the dip and strike of the Cisco beds conforms to that of the Canyon group, and in the Colorado River Valley sedimentation was continuous from one epoch to the next. In the northern area, however, evidence points to an uplift of the land mass to the northeast at the end of Canyon times, and a temporary withdrawal of the sea from portions of Young and northeastern Stephens counties allowing marsh conditions and the development of a thin bed of coal. Following the uplift to the northeast a much greater thickness of sands and shales was deposited in the beginning of the Cisco epoch in Jack and Young coun-

[70]Cummins, W. F., Report on the geology of northwestern Texas: Geol. Surv. Texas, 2nd Ann. Rept., p. 374, 1890.

[71]Correlation by Mr. Plummer. Fossils not collected or studied by Mr. Moore.

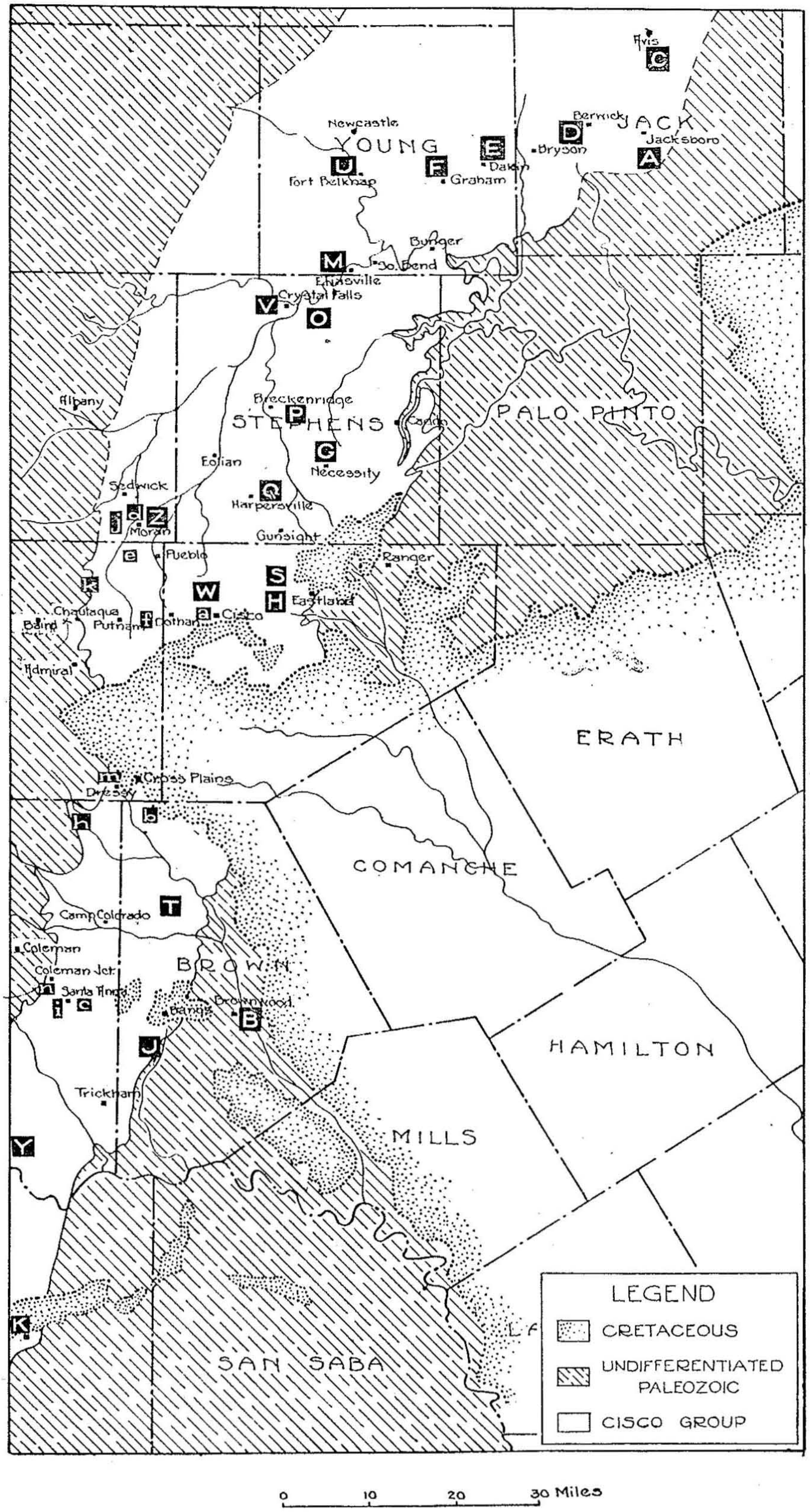



Figure 13. Map showing the area of outcrop of the Cisco group

ties than southward. So far as known the transition was accomplished without any local warpings, and while there is no evidence of prolonged erosion between the two groups of formations there are noteworthy disconformities and an abundance of coarse clastic material. The thickening of the basal Cisco beds in the northern part of the Pennsylvanian area is illustrated in Figure 14.

*Extent.*—The Cisco group of formations outcrops in a belt which is 30 miles wide at the northern end but tapers to about 15 miles at its southern extremity. It extends across the northwestern portion of Jack County, most of Young and Stephens counties, the southeast corner of Shackelford County, the western half of Eastland and Brown counties, the eastern half of Callahan and Coleman counties to the southwest corner of McCulloch County, as shown in Figure 13.

*Lithologic Character.*—The Cisco group consists of a series of sandstones, shales, and limestones and several thin coal seams. Most of the sandstones are confined to the lower portion of the section and to the

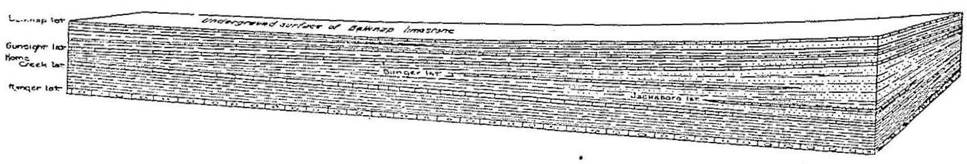



Figure 14. Block diagram showing the thickening of the basal portion of the Cisco group in the northern part of the Pennsylvanian area

stones containing lenses of gravel. The shales are more calcareous, lighter colored, and thinner than the shales of the older formations, and here and there may be seen in the weathered slopes tints of red, yellow, and purple, bright colors which are rarely seen in the beds of the Canyon group. Also some of the shale beds of the Cisco are very fossiliferous. The limestones are much thinner and more ferruginous and more crystalline than those below, and most of them are very persistent and make excellent horizon markers for determining structural relationships.

*Topography.*—The Cisco group of formations gives rise to a very different topography from that of the Canyon group below or the Wichita group above. There are no high, sharply defined cliffs, deep canyons, and rough, angular hills. The relief is smaller and the topographical lines have gentler curves. In travelling east and west, east-facing scarps of less altitude than those of the Canyon group alternate with singular regularity with long, gently westward-dipping, mesquite-covered slopes, wit hhere and there sandstone-capped hills sustaining a growth of black-jack oak intervening to break the monotony.

*Divisions.*—The Cisco group has been divided into six formations limited stratigraphically by persistent and recognizable limestones or calcareous sandstones which occur at the top of each, as follows:

Putnam formation
Moran formation
Pueblo formation
Harpersville formation
Thrifty formation
Graham formation

Each formation contains several mappable members and lentils of limestone and sandstone, and several shale beds; but the divisions are not so clearly distinguished nor in general so easily traced in the field as are those of the Canyon Group.

### GRAHAM FORMATION

*Name and Stratigraphic Position.*—The lowest division of the Cisco group is the Graham formation, named from the county seat of Young County where the formation is typically developed and where in the early days many of the type fossils of the Texas Pennsylvanian were collected by Dr. A. B. Gant, W. F. Cummins, Dr. J. P. Smith, and others. The formation as here defined includes all the strata from the top of the Home Creek limestone in the Canyon group to the base of the first sandstone above the Wayland and Gunsight fossiliferous beds, known as the Avis sandstone. It lies disconformably upon the Canyon group. Younger members of the formation overlap the older beds toward the south and progressively in turn rest upon the Home Creek limestone. At the top the Thrifty formation in places is unconformable upon the upper member of the Graham formation, the Wayland shale having been removed before the deposition of the overlying sandstone. The formation is distinguished from the strata of the Canyon group below by its thinner limestone members and from the strata of the formations above by the very prolific and persistent group of fossils which occur in the shales of the upper members.

*Extent and Thickness.*—The outcrop of the Graham formation has been mapped from Avis, in Jack County, through Jacksboro and Bryson to Graham, in Young County, and thence southwest across the eastern edge of Stephens County through Ivan, Necessity, and Gunsight to Eastland, in Eastland County. South of Eastland it passes beneath the Cretaceous sands and reappears again three miles east of Blake from which place it has been traced through Brown County across the extreme southeast corner of Coleman County to Brady. In northern Jack County the outcrop is 13 miles wide but it narrows progressively southward; in Stephens County it has a width of 10 miles; in Eastland County, 7 miles; in northern Brown County, 3 miles; and in central Brown County, 1 mile. This narrowing of the outcrop is due to the playing out southward of several thick sandstone lentils and limestones and shales which are well developed in Jack County (Figure 14). The thinning may be due partially to erosion of the upper layers of the formation before the deposition of the overlying formation, but largely to non-deposition of the lower member off shore. In Jack County the total thickness of the beds is 600 feet, in Eastland

County, 350 feet, and in Brown County the average thickness is only 60 feet (columnar section No. 2, Plate II). That this unusual thinning is real and not due to error in correlation of beds in the Colorado River Valley with those of Eastland County is proved first by tracing the Waldrip coal above and the massive Home Creek limestone below, two layers that can hardly be mistaken. The interval between these two layers is about 340 feet in northern Brown County and 700 feet in Jack County (columnar section 8, Plate II); further, the very fossiliferous Wayland and Gunsight members at the top of the Graham formation have been traced from Avis, in northern Jack County, to Weedon School, in Brown County, but the lowermost members represented in the north do not appear to be present south of Stephens County.

*Noteworthy Exposures.*—The most noteworthy and accessible locations where the Graham formation is typically exposed are along the road from Barton's Chapel to Avis, in Jack County; along Salt Creek just west of Graham, in Young County; at South Bend on the Brazos River 10 miles southwest of Graham, in Young County; one mile southeast of Gunsight, in Stephens County; and at Byrd's Store and Weedon School, in Brown County.

*Lithologic Character.*—The formation as a whole changes so much in character from its thick massive sandstones and numerous and varied limestones and shale members in Jack County, to its thin, predominantly calcareous shales and limestone phase in Brown County, that in order to describe accurately its characteristics, it is almost necessary to discuss the different members and units separately in the respective areas. One of the most persistent features of the formation is the very prolific and characteristic fauna of the Wayland shale, rich in *Lophophyllum profundum, Marginifera lasallensis,* and other fossils. Another persistent feature is the wide occurrence of the *Campophyllum*-bearing Gunsight member. In the Colorado River Valley near the top of the Graham formation are two thin, persistent limestones a few feet apart which are equivalent to the Gunsight limestone of Stephens County, and which contain abundant specimens of *Campophyllum torquium.* The corals weather out in great quantities, lying strewn along the edge of the outcrop like small pieces of driftwood along a beach. The bed was called by Drake the "Campophyllum bed," and apparently at no other place in the section did this form of life become so numerous or widespread.

*Subdivisions.*—In the Colorado River Valley the Graham formation is divisible into three members. In the northern districts, however, several other mappable units are present in the lower portion of the section which can not be traced into the southern districts. The divisions recognized are as follows:

| Colorado River Valley | Brazos River Valley |
|---|---|
| 3. Wayland shale | 7. Wayland shale |
| 2. Gunsight limestone | 6. Gunsight limestone |
| 1. Bluff Creek shale | 5. South Bend shale and sandstone |
| | 4. Bunger limestone |
| | 3. Gonzales Creek shale and sandstone |
| | 2. Jacksboro limestone |
| | 1. Finis shale and sandstone |

*Finis Shale.*—The oldest portion of the Graham formation may be found in Jack County. The basal strata consist of sandy shale with interbedded sandstone 50 to 100 feet or more in thickness, which rest on the Home Creek limestone at the top of the Canyon group. This member is named the Finis shale. It may be identified southward from its type locality by its position between the massive Canyon limestones and the Jacksboro limestone of the Graham formation.

*Jacksboro Limestone Lentil.*—In the vicinity of Jacksboro, county-seat of Jack County, two limestone beds, separated by about 12 feet of sandy shale and sandstone, appear above the Finis shale. From typical exposures in this area the limestones are named the Jacksboro member. The lower limestone bed has been traced from Jacksboro into the southeast corner of Young County where it is found to lie nearly midway between the Home Creek limestone of the Caddo Creek formation at Finis and the succeeding Bunger limestone of the Graham formation, but it could not be followed south of the Brazos River. It is quite likely that the Caddo-Breckenridge district was at, or close to, sea-level during the beginning of the Graham sub-epoch, as there are coal beds and sandstones carrying plant remains here which do not occur in Jack County. The upper layer of the Jacksboro limestone lentil is well exposed in a quarry southeast of the town of Jacksboro but can be traced southwestward only five or six miles where it changes to a calcareous sandstone. Eastward from Jacksboro it grades into shale. The total thickness of the two beds of the Jacksboro limestone is about 25 feet.

The lower limestone bed of the Jacksboro lentil is dark gray weathering to a rusty yellow in color, hard, crystalline and less than a foot in thickness. Everywhere it is filled with the coral *Campophyllum torquium,* which are so firmly cemented together that they form a part of the rock and do not weather out as do the specimens in the limestone of the Gunsight beds. So closely are the corals spaced that a broken slab of the limestone shows sections of a dozen or more corals in every square half foot. The upper layer is poorly bedded, massive, and shaly, 6 to 18 feet thick, and very fossiliferous in places. This bed is not persistent but grades into shales northeastward and changes to a calcareous sandstone southwestward. The shale intervening between the two limestone beds of Jacksboro, is locally very fossiliferous. The fauna is similar to that of the upper shale beds of the Graham formation but is distinct in its abundance of *Rhipidomella pecosi* and some other fossils, which are absent or only slightly represented in the Graham shale beds.

The type section of the Jacksboro member measured by J. G. Burtt describes the individual strata.

**Section of the lower portion of the Graham formation five miles south of Jacksboro, Jack County**

**Measured by J. G. Burtt. (A in fig. 13)**

| | Thickness Feet |
|---|---|
| GRAHAM FORMATION— | |
| Jacksboro Limestone | |
| 5. Limestone, poorly bedded, shaly, changes to calcareous sand westward | 18 |
| 4. Sandstone, massive, cross-bedded, ferruginous, changes to yellow-gray shale eastward, upper members shaly in places, very fossiliferous | 12 |
| 3. Limestone, hard, smooth, pure, contains an abundance of *Campophyllum torquium* | 4 |
| Finis Sandstone and Shale | |
| 2. Sandstone and shale, poorly exposed | 45 |
| CADDO CREEK FORMATION | |
| Home Creek Limestone | |
| 1. Limestone, thin-bedded, white, contains few poorly preserved corals | 5 |

*Gonzales Creek Shale and Sandstone.*—In southeastern Young County about 230 feet of shale and sandstone occur above the Jacksboro limestone beds. This portion of the Graham is named the Gonzales Creek member, from a creek in Eastland County. South of Young County the Finis and Jacksboro beds become thinner and perhaps pinch out, as the fossiliferous Jacksboro shale bed has not been found in Stephens or Eastland counties. The Gonzales Creek beds, therefore, rest directly on the southern extension of the Finis shale.

The Gonzales Creek beds occur in the Brazos River Valley beneath the Bunger limestone from its outcrop at Bunger south as far as the Cretaceous outcrop south of Eastland. They are not found in the Colorado River Valley where the Bunger limestone appears also to be absent. Northeast from Bunger the beds can not be differentiated definitely farther east than Finis, for the Bunger limestone changes to sandstone and a great thickness of sandstones and conglomerate appears at this horizon, indicating a shore phase of the beds.

The Gonzales Creek beds consist of poorly bedded, lenticular, dark brown sandstones, sandy shales, red clays, gypsiferous black clays, a limestone lentil, and a coal bed. The carbonaceous shale and coal occur in the area near the Brazos River south of Finis and in the outcrop west of Caddo at a horizon about 30 feet below the Bunger limestone lentil and 200 feet above the Home Creek limestone. To the south the coal shales grade into sandy strata. The sandstones are very lenticular and the shales variable, so that no section typical for the beds can be given. In the district northwest of Eastland are two thin, brownish-yellow, impure limestone lentils. The upper occurs about 30 feet below the Bunger limestone and is more or less continuous in the area between Caddo and Eastland. The lower bed lies 80 feet below the Bunger and 175 feet above the Home Creek limestone. It may be seen along the road eight miles due north of Eastland and can be traced southwestward nearly to the town of Mangum, although in many places it is obscured by sandstone debris from the overlying strata. It is a grayish-white, shaly limestone poor in fossils, and in stratigraphic position corresponds to the Jacksboro bed but is doubtless only a lentil as it plays out in southeastern Stephens County and does not extend south of the Cretaceous sand belt. It is important only as a key rock in working the structure of the northwestern portion of the Ranger field. For the most part, the Gonzales Creek beds are irregularly bedded sandstones and shales. The shales just above the coal seam at Finis and one mile west of Caddo are very fossiliferous. The fauna resembles that of the shales near Jacksboro but is characterized by a large number of ramose bryozoans, the rather uncommon brachiopod *Derbya bennetti,* and other forms. This fauna has not been discovered south of Eastland County.

*Bunger Limestone Lentil.*—The prominent limestone lentil that overlies the Gonzales Creek shale and sandstone is named the Bunger limestone lentil from the town of Bunger, a small town in southern Young County seven miles south of Graham. The division is best exposed around the north and west sides of the big curve of the Brazos River five miles south of Graham, and from here it has been traced southward east of Ivan and west of Caddo across the east end of Stephens County to the Cretaceous sand outcrop west of Eastland. South of the Cretaceous sand it has not been recognized. Northeastward from South Bend the limestone has been traced nearly to the Jack County line where it occurs about 225 feet above the Jacksboro limestone. It varies in thickness from two to eight feet in Young County; in Stephens County it is commonly one to three feet thick and forms the top of a low escarpment.

The Bunger limestone lentil in places is dark yellowish-brown, quite dense, and heavy; in other areas it is light gray, impure, and massively bedded. The member is thickest in the South Bend area of Young County and is thinnest in Eastland County. In Stephens County the limestone has a rusty, dark gray color and caps a low escarpment. West of the escarpment it has a wide outcrop and forms an excellent key rock for structural mapping.

*South Bend Sandstone and Shale.*—Above the Bunger limestone lentil and below the lower limestone of the Gunsight bed are 50 to 110 feet of light gray, fine-grained, lenticular, ripple-marked sandstones and blue-gray, sandy, fossiliferous shales. The member is typically exposed at South Bend, in southern Young County, and thins southward. In Eastland County it has an average thickness of 60 feet and does not occur south of the Cretaceous overlap in the Colorado River Valley. In a small outlier two miles northeast of South Bend is a typical exposure of these beds which has been studied by many geologists in examining the structure of the South Bend oil field. The section measured by I. J. Broman is given on page 133.

*Gunsight Limestone.*—The Gunsight limestone has been named for the small town of Gunsight, in Stephens County, located halfway between Breckenridge and Cisco. The bed varies somewhat in different counties but commonly consists of two thin limestone layers separated by 20 to 25 feet of yellow shale. In the Brazos River Valley it is separated from the Bunger limestone below by 60 feet of shale and sandstone, called the South Bend bed. In the Colorado River Valley it rests upon the Bluff Creek bed.

The Gunsight limestone beds have been traced from Avis, in Jack County, 10 miles north of Jacksboro, to Dakin, Graham, and South Bend, in Young County, east of Eliasville, Ivan, and Necessity to Wayland and Gunsight in Stephens County, thence southward, crossing about halfway between Eastland and Cisco, to the Cretaceous overlap north of Romney in Eastland County. South of the Cretaceous sands it has been traced southward across Brown County from a point east of Blake, near Byrds Store, through the Weedon School district and Thrifty to Trickham in Coleman County, and on to the Bend outcrop at Brady in McCulloch County.

The Gunsight limestone layers, because of their extent through the rich oil fields of north Texas, have been used so much for working out structure and correlating beds in separated areas that their characteristics and variations are well known. In Jack County the limestones are obscured in many places by slump and slope wash of the thick overlying sandstones. At Avis, in Jack County, only one layer of limestone is exposed below the sandstone covering. Here it is a thin, ferruginous, hard, grayish-yellow, non-fossiliferous limestone. In Young County two limestone layers are developed in places but do not contain the typical coral beds so prevalent farther south. At the type locality at Gunsight the upper limestone layer is a uniformly thin, light yellowish-gray, densely crystalline bed weathering to smooth-surfaced blocks. The lower layer is separated from the upper by 22 feet of soft yellow clay shale and consists of a soft white or light buff limestone in most places filled with *Campophyllum torquium,* which weather out on exposed slopes so abundantly that in some places they can be scooped up in cart loads. In Brown County about 12 feet of shale separates the two limestones, and both are filled with these corals and also contain *Fusulina* and a few other common fossils.

*Wayland Shale.*—In most places, both in the Brazos and Colorado River Valleys, the Gunsight limestone is overlain by 20 to 100 feet of very fossiliferous shale which is here named the Wayland shale. It constitutes the uppermost member of the Graham formation. By reason of its characteristic and very persistent fauna, it has been possible to trace the Wayland horizon from northern Jack County from point to point in Young, Stephens and Eastland counties into Brown County in the southern part of the Texas Pennsylvanian outcrop. The Wayland shale varies in thickness and in some places is entirely wanting, the basal, more or less conglomeratic sandstone of the Thrifty formation resting directly on the Gunsight limestone. This appears to represent a local break in sedimentation.

*Detailed Sections.*—The following sections describe in more detail the variations of the beds in the different districts. At Avis, though the beds are poorly exposed, they have been recognized by the characteristic group of fossils which has weathered out of the Wayland shale along the base of the escarpment one and one-half miles east of town, where the following section has been measured:

**Section of upper part of the Graham formation in south-facing scarp 1½ miles east of Avis, Jack County**

**(C in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| 4. Sandstone, coarse, reddish-brown, and gray | 15 |
| GRAHAM FORMATION— | |
| Wayland Shale | |
| 3. Shale, light gray, sandy | 75 |
| 2. Shale, yellowish-gray, ferruginous concretions, very fossiliferous | 10 |
| Gunsight Limestone | |
| 1. Limestone, yellow, impure | 1 |

From Avis southwestward to Berwick the limestones are either absent or covered by the loose sand weathered from the Avis escarpment. About one and one-half miles west of Bryson, however, one limestone, and in places two, outcrops in low benches below the sandstone ledge north of the town, and can be traced southwestward to Bryson. The fossiliferous Wayland shales are absent in places, and the coarse conglomeratic Avis sandstone lies in direct contact with the upper limestone bed as shown in the following section:

**Section of the upper part of the Graham formation measured along the roadside 1½ miles west of Berwick to an outlier one mile southwest of town**

**(D in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION | |
| Avis Sandstone | |
| 8. Conglomerate and coarse calcareous sandstone | 10 |
| GRAHAM FORMATION— | |
| Gunsight Limestone | |
| 7. Limestone, hard, dense, impure, weathers to large blocks | 5 |
| 6. Shale, calcareous, in places fossiliferous | 15 |
| 5. Limestone, thin, impure, yellow-gray | 1 |
| South Bend Shale | |
| 4. Sandstone, coarse, brown | 10 |
| 3. Shale, sandy (not exposed) | 110 |
| 2. Sandstone, very calcareous, yellow-brown, highly fossiliferous, especially abundant in Spirifers and *Fusulina* | 1 |
| 1. Shale, dark blue, contains ferruginous concretions. Base not exposed. | 100 |
| Total of Graham formation measured | 242 |

In the section above, the Bunger limestone is not present, and the first limestone bed below Bed No. 1 of the section is the Jacksboro.

Following the sandstone escarpment southwestward to a point north of Dakin and six miles northeast of Graham, both limestone members are present and separated by 25 feet of shale and coarse calcareous sands, as shown in the following section:

**Section of upper part of the Graham formation along small branch one mile north of Dakin, Young County**

**By J. G. Burtt. (E in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| Sandstone, dark red, conglomeratic in places | 10 |
| Sandstone and sandy shale, unfossiliferous | 15 |
| GRAHAM FORMATION— | |
| Gunsight Limestone | |
| Limestone, gray-buff, hard, fossiliferous, weathers into irregular-shaped chunks | 5 |
| South Bend Shale | |
| Shale, gray | 5 |
| Sandstone, dark-colored, massive, coarse-grained, in places containing lenses of pebble conglomerate | 12 |
| Shale, calcareous, sandy | 20 |
| Base not exposed. | |
| Total of Graham formation measured | 42 |

Westward, in the vicinity of Graham, the upper limestone is absent, but the lower bed is found in places where it is not covered by the slump from the overlying sandstone, and in most places a very thin layer of fossiliferous shale lies between the limestone and the conglomerate above. Excellent exposures may be seen along Salt Creek west of town, especially at the dam where the section was described and fossil collections made by Cummins in 1889. A in Figure 15.

**Section of the upper part of the Graham formation at the dam on Salt Creek, one mile west of Graham, Young County**

**(F in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| 5. Conglomerate, hard, massive, made up of angular pebbles in a matrix of sand | 15-20 |
| GRAHAM FORMATION— | |
| Wayland Shale | |
| 4. Shale, dark blue, soft, very fossiliferous | 10 |
| Gunsight Limestone | |
| 3. Limestone, hard, yellow, fossiliferous | 1 |
| 2. Shale, blue, gray, soft | 60 |
| 1. Sandstone, hard, lenticular, cross-bedded | 10 |
| Base not exposed. | |
| Total of Graham formation measured | 81 |

Southwest of Graham the limestone either changes to calcareous sand, is concealed by the sandy debris from the overlying Avis sandstone, or has been removed by erosion before the deposition of the sand, for although the sandstone escarpment may be easily traced southward west along the Graham-South Bend road to the Brazos River, in most places no limestone can be found. Two miles south of South Bend a limestone occurs on the top of an outlier of sand, and 50 feet below it is another limestone lentil that contains large numbers of *Campophyllum*, characteristic of this bed farther south. The correlation of these beds with the typical Gunsight limestone is reasonably certain.

A section measured two miles south of South Bend is as follows:

**Section of the upper part of the Graham formation two miles south of South Bend, Young County**

**By I. J. Broman. (B in fig. 13)**

| | Thickness Feet |
|---|---|
| GRAHAM FORMATION— | |
| Gunsight Limestone | |
| 12. Limestone lentil, gray, exposed on top of hill west of Goode No. 1 well, changes to calcareous sand or is absent northward | 4 |
| 11. Shale | 3 |
| 10. Sandstone, coarse, dark brown | 10 |
| 9. Shale, sandy, covered with loose sand | 15 |
| 8. Sandstone, coarse, reddish-brown | 10 |
| 7. Shale, fossiliferous | 12 |
| 6. Limestone lentil changing to sand eastward, fossiliferous in places, rich in crinoid fragments and in places many *Campophyllum* | 2 |
| South Bend Shale | |
| 5. Sandstone, gray, ripple-marked, grains medium-sized, calcareous | 15 |
| 4. Shale, sandy, light gray, fine-textured | 43 |
| 3. Shale, soft, blue, contains many yellow and red limonite concretions, fossiliferous | 22 |
| 2. Shale, soft, gray, streaks of black shale | 27 |
| Bunger Limestone Lentil | |
| 1. Limestone, hard, gray, massive, thick-bedded | 12 |
| Total thickness | 175 |

Southwest of South Bend only one limestone layer is present. It outcrops east of the town of Ivan, and from here it can be traced southward through the oil fields to Gunsight. It is a buff-colored, slabby, pitted limestone about one and one-half feet in thickness. In places it forms a low escarpment and in others a somewhat slumped ledge near the base of an escarpment formed by higher limestones of the Thrifty formation. In the section at C. J. Mountain seven miles northwest of Breckenridge the limestone lies 100 feet above the Bunger limestone lentil. Three miles north of Necessity, on the Swenson Ranch, both limestones are present and characteristically developed, as shown in the following section:

**Section of the upper part of the Graham formation, Swenson Ranch, 3 miles north of Necessity, Stephens County**

**Measured by J. G. Burtt. (G in fig. 13)**

| | Thickness Feet |
|---|---|
| GRAHAM FORMATION— | |
| Gunsight Limestone | |
| 17. Limestone, light gray, nodular | 5-20 |
| 16. Shale, gray | 20 |
| 15. Limestone, yellow-gray, fossiliferous, *Campophyllum torquium* in abundance | 3 |
| South Bend Shale | |
| 14. Shale | 4 |
| 13. Sandstone, soft, light gray | 8 |
| 12. Shale | 60 |
| 11. Sandstone, soft, lenticular | 10 |
| 10. Shale | 25 |
| Bunger Limestone lentil | |
| 9. Limestone, smooth, yellow, gray, weathers into blocks | 3 |
| 8. Shale, gray | 12 |
| Gonzales Creek shale | |
| 7. Limestone, sandy | 2 |
| 6. Shale | 18 |
| 5. Lignite and black shale | 2 |
| 4. Shale (?), (mostly covered) | 41 |
| 3. Limestone lentil, gray and yellow, pitted surfaces and weathers into angular blocks | 5 |
| 2. Shale | 12 |
| 1. Sandstone, nodular | 6 |
| Total average thickness | 236 |

The upper limestone member occurs in the road at the town of Gunsight, and the lower bed filled with the *Campophyllum* corals forms a low escarpment two miles east of the town. One of the best fossil-collecting localities in north Texas is one mile south of Gunsight between the Breckenridge-Cisco and the Breckenridge-Eastland roads (Figure 16). The fossils are found in the dark Wayland shale just a few feet above the limestone, and the group is exactly the same as that at Wayland, South Bend, Graham, and Avis.

A section measured at the locality one mile south of Gunsight, where a very large and beautifully preserved collection of Wayland shale fossils was obtained, is as follows:

**Section one mile south of Gunsight where road to Cisco branches from road to Eastland**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| 13. Sandstone, dark-brown to reddish, soft, massive, cross-bedded | 15 |
| GRAHAM FORMATION— | |
| Wayland Shale | |
| 12. Shale, light bluish-gray | 65 |
| 11. Shale, sandy | 5 |
| 10. Limestone, yellow, concretionary, very fossiliferous | 1 |
| 9. Shale, dark gray to blue, very fossiliferous | 5 |
| 8. Shale, black, carbonaceous, very fossiliferous | 5 |
| Gunsight Limestone | |
| 7. Limestone, gray, nodular | 2½ |
| 6. Shale, gray, sandy | 7 |
| 5. Sandstone, gray, fine-grained | 2 |
| 4. Shale, buff, calcareous | 11 |
| 3. Limestone, gray, filled with corals | 2 |
| South Bend Shale | |
| 2. Shale (not exposed) | 40 |
| Bunger Limestone (?) | 3 |
| Base not exposed. | |
| Thickness of Graham formation measured | 148½ |

In Eastland County the limestone does not form an escarpment, and good exposures are less frequent than in Stephens County. Collections of the Wayland fossils have been made at the base of the limestone-capped hill near the Cisco and Northwestern Railroad seven miles north of Cisco. The fossil bed is overlain by the typical brown Avis sandstone, and can be traced to the Cretaceous sand area halfway between Eastland and Cisco. About one mile south of Lem, in Eastland County, the beds are typically exposed and show the following section:

**Section of the upper part of the Graham formation four miles west of Eastland, Eastland County**

**Measured by C. A. Hammill. (H in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| 10. Sandstone, gray, calcareous | 3 |
| GRAHAM FORMATION— | |
| Wayland Shale | |
| 9. Clay, light-colored, non-fossiliferous | 25 |
| 8. Clay, light-colored, soft, contains small yellow, ferruginous concretions and many fossils | 15 |
| 7. Clay, dark blue, very fossiliferous | 5 |
| Gunsight Limestone | |
| 6. Limestone, dark blue-gray, weathers to large blocks, very fossiliferous, fossils stand out in relief on weathered surfaces | 2 |
| 5. Shale, dark gray, very fossiliferous | 10 |

| | |
|---|---|
| 4. Shale, light yellow, sandy | 5 |
| 3. Limestone, light gray to brown, sandy, in places nodular, and in other places a sandstone | 2-15 |
| South Bend Shale | |
| 2. Shale, buff-yellow | 60 |
| Bunger Limestone Lentil | |
| 1. Limestone, hard, yellowish-brown, varying to reddish-gray. Fresh surfaces somewhat crystalline and very dark, weathering to small blocks with rough surfaces | 21 |
| Base of formation not exposed. | |
| Total thickness of Graham formation measured | 158 |

*Graham Formation in Colorado River Valley.*—South of the Cretaceous overlap the Graham formation shows a thinning to less than 100 feet and includes basal shales of the Trickham, Campophyllum, and Bluff Creek beds of Drake. The name Campophyllum for the upper limestone member has been dropped and the more appropriate geographic name Gunsight substituted. Good exposures of the formation may be seen along Pecan Bayou, west of Old Byrds Store, at Weedon School, nine miles northwest of Brownwood, and one mile east of Trickham near the Coleman-Brown county line. In this southern area the Gunsight bed is made up of two yellowish-gray limestones characterized by a great abundance of *Campophyllum torquium* and *Fusulina*, and between these two beds are 10 to 20 feet of yellow fossiliferous shale. In places the limestone thickens and the clay parting thins until the series is nearly one single massive limestone bed, filled with corals.

The Bluff Creek bed below consists of sandy clay and thin calcareous sandstones 70 feet thick at the north end, thinning to 30 or 40 feet farther south. In places a thin yellow limestone has been mapped in the middle portion of the shale, and this may be equivalent to the Bunger limestone of Young and Stephens counties. The upper portion of the Bluff Creek bed is in places very fossiliferous, and the fauna is similar to that of the Wayland shale at Gunsight.

The following section measured along the outcrop of the Graham formation in the southern area gives additional details concerning the character of the strata:

**Section of the upper portion of the Graham formation at Weedon School, twelve miles northwest of Brownwood**

**Measured by Grady Kirby. (I in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| Avis Sandstone | |
| 15. Sandstone, conglomeratic in places | 0-60 |
| GRAHAM FORMATION— | |
| Gunsight limestone | |
| 14. Limestone, gray | 4 |
| 13. Shale, yellow, contains limonite concretions, in places very fossiliferous | 10 |
| 12. Limestone, gray, abundance of *Campophyllum torquium* | 1 |
| 11. Limestone, fossiliferous, and calcareous shale | 10 |

| | |
|---|---|
| 10. Limestone, grayish-yellow, filled with *Campophyllum torquium* and *Fusulina* | 1 |
| Bluff Creek Shale | |
| 9. Shale, gray, yellow, fossiliferous | 17 |
| 8. Limestone, reddish-brown, contains crinoid fragments | 2 |
| 7. Shale | 5 |
| 6. Limestone, gray | 7 |
| 5. Shale | 10 |
| 4. Sandstone | 4 |
| 3. Shale | 7 |
| 2. Limestone, contains many *Fusulina* | 2 |
| 1. Shale | 20 |
| Total thickness | 100 |

**Section of the Graham formation five miles south of Bangs, on Richard Nixon, James Bird, and Waller County School Land Survey**
**Measured by C. A. Hammill. (J in fig. 13)**

| GRAHAM FORMATION— | Thickness Feet |
|---|---|
| Gunsight Limestone | |
| 12. Limestone, gray, contains wavy yellow lines, full of *Campophyllum torquium* and *Fusulina*, weathers to rounded boulders and quantities of loose corals | 3 |
| 11. Shale, dark red and yellow | 12 |
| 10. Limestone, gray and yellowish-gray, filled with *Campophyllum torquium* | 3 |
| 9. Shale, buff | 12 |
| 8. Limestone, yellow-gray, weathers to shaly chips, full of *Fusulina* | 1 |
| 7. Shale, yellow | 4 |
| 6. Limestone, gray, in places contains *Fusulina* and corals, forms prominent escarpment | 2 |
| Bluff Creek Shale | |
| 5. Shale, buff, sandy in places | 12 |
| 4. Limestone, gray, nodular, full of *Syringopora* and *Fusulina* | 2 |
| 3. Shale, buff | 9 |
| 2. Limestone, soft, shaly | 1 |
| 1. Shale, buff | 14 |
| Home Creek Limestone | |
| Total thickness | 75 |

Near the south end of the outcrop west of Brady the limestone beds are thicker and the shale partings thinner, as shown in the following section:

**Section of the Graham formation along Live Oak Creek, three miles northwest of Brady, McCulloch County**
**(K in fig. 13)**

| GRAHAM FORMATION— | Thickness Feet |
|---|---|
| Gunsight Limestone | |
| 6. Limestone, hard, bluish, contains *Fusulina*, weathers into rough nodules | 14 |
| 5. Clay | 1 |
| 4. Limestone, massive, bluish-gray, fossiliferous | 10 |
| Bluff Creek Shale | |
| 3. Clay, sandy | 20 |
| 2. Sandstone, calcareous | 10 |
| 1. Clay, sandy, calcareous | 40 |
| Total thickness | 95 |

*Paleontology.*—Fossil collections have been made at a number of different horizons in the Graham formation and at a considerable number of places from north to south across the outcrop. Some of the beds, both limestone and shale, are among the most fossiliferous in the whole north Texas Pennsylvanian. Since, furthermore, the fossils are for the most part excellently preserved, the paleontologic study of the Graham is a fascinating field for the collector. However, the only horizon which has been traced in some detail by means of its fossils is the uppermost member of the formation, which is here named the Wayland shale. Collections have been made from point to point along its outcrop from northern Jack County to Brown County. At every locality where the member is adequately exposed, the prolific and characteristic fauna of this horizon is identified.

The chief fossiliferous horizons of the Graham formation are associated with the Jacksboro, Bunger and Wayland members in the Brazos River Valley, and with the Gunsight and Wayland in the Colorado River Valley.

The Jacksboro limestone, as already indicated, is characterized by a profusion of corals belonging to the species *Campophyllum torquium.* Some parts of the limestone are composed of nothing but this coral. In the shale between the two beds of the Jacksboro is found, in some places, as southeast of Jacksboro (locality 53.8), a very prolific fauna which is very much like that of the other shale faunas of the Graham and the Wewoka. The Jacksboro collection appears to be characterized chiefly by an unusual number of small shells of the brachiopod *Rhipidomella pecosi,* a form which is rather uncommon in other parts of the Graham and most of the Texas Pennsylvanian. It is also marked by the much less prominent development of some of the species like *Lophophyllum profundum* and *Astartella concentrica* which are so abundant in the collections from the Wayland shale. A collection of Jacksboro fossils made from a cut on the Rock Island railroad southeast of Jacksboro is listed below.

Species marked by an asterisk (*) in the following faunal tables of the Jacksboro, Bunger and Wayland members of the Graham formation are also present in the Wewoka formation of southern Oklahoma. Those represented in the Wewoka by doubtfully identified or closely related species are marked by a dagger (†).

**Fauna of the Jacksboro Member, Southeast of Jacksboro (Locality 53.8)**

| | |
|---|---|
| **Lophophyllum profundum* | †*Edmondia* sp. |
| *Campophyllum torquium* | **Nucula anodontoides ?* |
| *Syringopora multattenuata* | **Nuculopsis ventricosa* |
| †*Hydreionocrinus* sp. | **Leda bellistriata* |
| †*Delocrinus* sp. | **Yoldia glabra* |
| †Crinoid stems and plates | *Conocardium* sp. |
| †*Archeocidaris* sp. | *Myalina* sp. |
| †*Fistulipora* sp. | †*Schizodus* sp. |
| †*Tabulipora* sp. | †*Aviculopecten* sp. |
| *Fenestella* sp. | **Astartella concentrica* |
| *Polypora* sp. | †*Bellerophon crassus* |

**Rhombopora lepidodendroidea*
†*Lingula* sp.
*Rhipidomella pecosi*
**Chonetes granulifer ?*
*Chonetes verneuilianus*
**Derbya crassa*
**Productus cora*
**Productus inflatus coloradoensis*
**Marginifera splendens*
**Pustula nebraskensis*
**Pugnax osagensis*
**Rhynchopora illinoisensis*
*Dielasma bovidens ?*
**Spirifer cameratus*
*Spirifer texanus*
**Squamularia perplexa*
**Ambocoelia planoconvexa*
**Spiriferina kentuckiensis*
**Hustedia mormoni*
**Composita subtilita*
**Patellostium montfortianum*
**Euphemus carbonarius*
**Pharkidonotus percarinatus*
*Orestes brazoensis*
**Phanerotrema grayvillense*
**Wortheni tabulata*
**Trepospira depressa*
**Schizostoma catilloides*
**Meekospira peracuta choctawensis ?*
†*Zygopleura* sp.
†*Sphaerodoma* sp.
**Pseudorthoceras knoxense*
**Metacoceras cornutum*
**Metacoceras sculptile ?*
†*Metacoceras* sp.
*Tainoceras occidentale*
**Goniloboceras welleri*
†*Gastrioceras* sp.
†*Griffithides* ? sp.

The Bunger member, in the middle portion of the Graham, is locally fossiliferous, the fossils occurring both in the limestone and the associated calcareous shales. The horizon is not so fossiliferous as the Wayland, nor, locally, as the Jacksboro, and the fossils are not in general so well preserved. Typical collections are those from a short distance west of Finis and southwest of Berwick which contain very abundant *Spirifer cameratus*, *Productus semireticulatus hermosanus ?*, and *Fusulina*, but less common specimens of other species. As a whole the fauna is closely similar to that from the Wayland and the Jacksboro. Since the Bunger is not traced far south of the Brazos, no collections have been made except in the northern area. The following table shows the species which have been identified in the collections made from the Bunger.

**Fauna of the Bunger Limestone Member**

| FAUNA | LOCALITIES | | |
|---|---|---|---|
| | 54.1 | 54.2 | 79.1 |
| †Fusulina sp. | x | x | ........ |
| *Lophophyllum profundum | x | x | ........ |
| *Lophophyllum profundum radicosum | x | ........ | ........ |
| Syringopora multattenuata | ........ | ........ | x |
| †Serpulopsis sp. | x | ........ | ........ |
| †Eupachycrinus tuberculatus | ........ | ........ | x |
| †Eupachycrinus sp. | ........ | ........ | x |
| †Delocrinus sp. | ........ | ........ | x |
| †Crinoid stems | x | x | x |
| †Archeocidaris aculeata | x | ? | ........ |
| Archeocidaris megastylus | x | ........ | ........ |
| Archeocidaris sp. | x | ........ | ........ |
| †Fistulipora nodulifera | ........ | ........ | x |
| Fistulipora n. sp. | x | ........ | ........ |
| †Tabulipora sp. | ........ | x | x |
| Fenestella sp. | x | x | x |
| Polypora sp. | x | x | x |
| *Rhombopora lepidodendroidea | x | x | x |

**Fauna of the Bunger Limestone Member**

| | LOCALITIES | | |
|---|---|---|---|
| | 54.1 | 54.2 | 79.1 |
| †Lingula umbonata | ........ | ........ | x |
| *Lingulipora nebraskensis | x | ........ | ........ |
| Orbiculoidea convexa | x | ........ | ........ |
| Rhipidomella pecosi | x | ........ | ........ |
| Derbya bennetti | ........ | ........ | x |
| *Derbya crassa | x | x | x |
| *Chonetes granulifer | x | x | x |
| Chonetes n. sp. | x | ........ | ........ |
| *Productus cora | x | x | x |
| *Marginifera splendens | x | ........ | ........ |
| †Marginifera lasallensis | x | x | ........ |
| *Productus inflatus coloradoensis | x | x | ........ |
| *Pustula nebraskensis | x | x | x |
| Pustula sp. | ........ | ........ | x |
| *Pugnax osagensis | x | ........ | ........ |
| *Rhynchopora illinoisensis | x | ........ | ........ |
| *Spirifer cameratus | x | x | x |
| *Ambocoelia planoconvexa | x | x | x |
| *Spiriferina kentuckiensis | x | x | ........ |
| *Hustedia mormoni | x | x | ........ |
| *Composita subtilita | x | x | x |
| †Edmondia aspenwallensis ? | x | ........ | ........ |
| *Nucula anodontoides ? | x | ........ | ........ |
| *Nuculopsis ventricosa | x | ........ | ........ |
| *Leda bellistriata | x | x | ........ |
| *Yoldia glabra | x | x | x |
| Parallelodon sp. | x | ........ | ........ |
| Conocardium sp. | x | ........ | ........ |
| †Pseudomonotis hawni | ........ | ........ | x |
| †Deltopecten sp. | ........ | ........ | x |
| *Anthraconeilo taffiana | x | ........ | ........ |
| †Allorisma sp. | ........ | ........ | x |
| *Astartella concentrica | x | ........ | x |
| *Astartella varica ? | x | ........ | ........ |
| *Dentalium sublaeve | x | ........ | ........ |
| †Bellerophon crassus | ........ | ........ | x |
| †Bellerophon sp. | x | ........ | ........ |
| *Patellostium montfortianum | x | ........ | ........ |
| *Euphemus carbonarius | x | x | x |
| *Pharkidonotus percarinatus | ........ | ........ | x |
| Orestes brazoensis | x | ........ | x |
| Pleurotomaria subscalaris ? | x | ........ | ........ |
| *Phanerotrema grayvillense | x | ........ | x |
| *Worthenia tabulata | x | ........ | ........ |
| *Trepospira depressa | x | ........ | x |
| Trepospira sp. | x | ........ | ........ |
| *Schizostoma catilloides | x | ........ | ........ |
| Naticopsis sp. | x | ........ | ........ |
| †Zygopleura nodosa | x | ........ | ........ |
| *Sphaerodoma brevis | x | ........ | ........ |
| *Sphaerodoma paludiniformis | x | ........ | ........ |
| *Sphaerodoma ventricosa | x | ........ | ........ |
| *Orthoceras sp. | x | ........ | ........ |
| †Metacoceras sp. | x | ........ | ........ |

The Wayland fauna at the top of the Graham formation is one of the most varied and the horizon is one of the most abundantly fossiliferous to be found in the Pennsylvanian of Texas or of the whole Mid-Continent


Figure 15. Map showing fossil localities in the vicinity of Graham

region. Most typical exposures of the Wayland shale containing an astonishing profusion of beautifully preserved fossils are found in the vicinity of Gunsight, at one mile south of the town where the road to Cisco branches from the road to Eastland (locality 80.2), five miles east of Cisco on the road to Eastland (locality 89.1), and near Wayland (locality 80.5). Very fossiliferous Wayland shale is found near South Bend a short distance north of the Goode well of the Roxana Petroleum Corporation, near the bridge over the Brazos at South Bend, and on Bass Mountain southeast of the Brazos bridge on the South Bend-Graham road. West of Graham

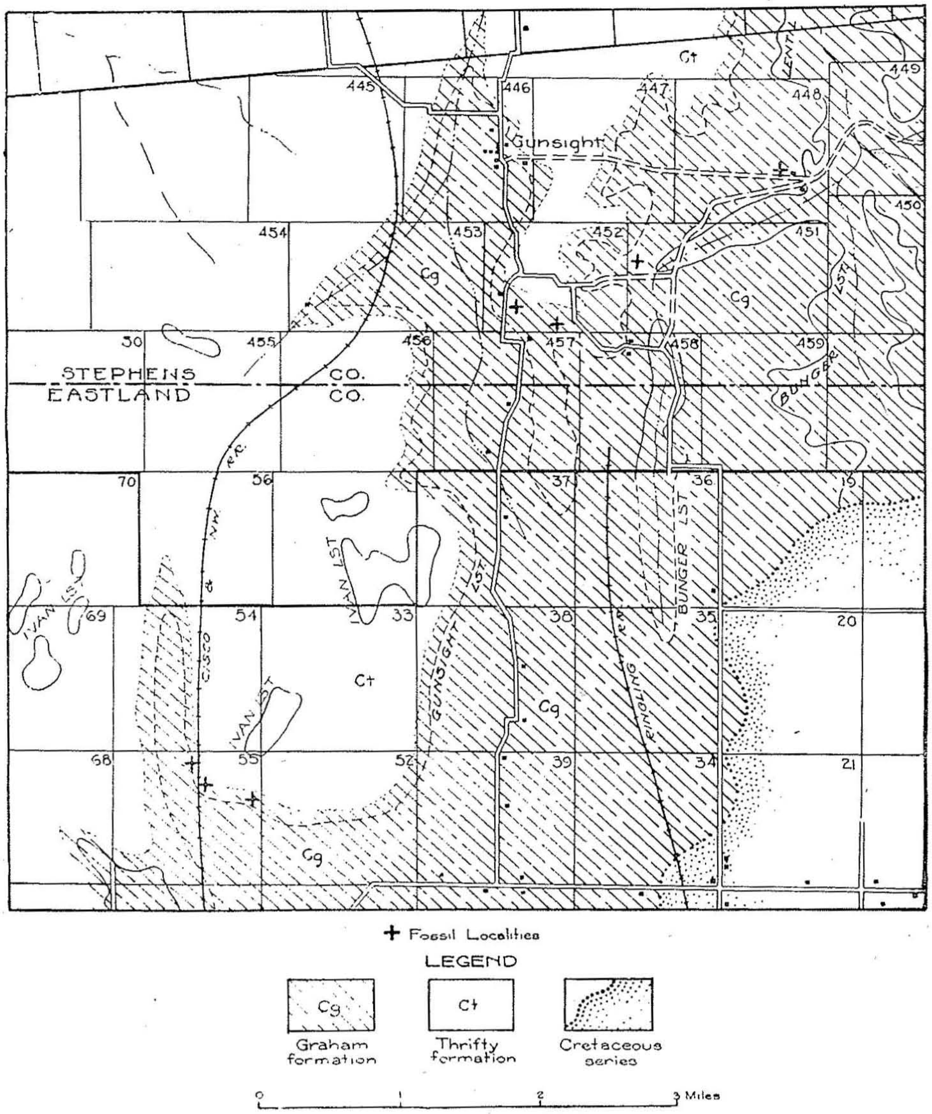



Figure 16. Map showing fossil localities in the vicinity of Gunsight

in the bluffs along Salt Creek are good exposures and abundant fossils. It is here that Cummins made observations and collected fossils which led him to correlate these beds definitely with the Pennsylvanian. Northeastward as far as Avis, the northernmost point reached in the areal work at this horizon, abundant and characteristic fossils are found. In the area south of the Cretaceous overlap the characteristic Wayland fauna is found northwest of Brownwood in the shales between and above the *Campophyllum*-bearing limestones which appear to be equivalent at least in part to the Gunsight member. As has been pointed out in the description of the Graham formation above, the thickness of the section representing this division in the Colorado River Valley is very much less than that found in the north. Since no marked differences are observed in the faunas of the Jacksboro, Bunger and Wayland horizons in the north, it does not appear possible to determine precisely the stratigraphic equivalents of these northern subdivisions of the Graham formation in the south. The collections from the area northwest of Brownwood were made chiefly in the vicinity of the Weedon School near Old Byrd's Store northeast of Thrifty. They are characterized by the prominence of large *Sphaerodoma primigenia* (*S. ponderosa* ?) and by a profusion of *Marginifera lasallensis*. An interesting feature is the discovery here of a considerable number of very minute though adult specimens of pyritized ammonoids, most of which belong, evidently, to undescribed species. The fauna of the Wayland shale, as indicated by the collections from north to south across the Texas area, is as follows:

**Fauna of the Wayland Shale Member, Graham Formation**

| FAUNA | LOCALITIES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 44.1 | 55.8 | 55.9 | 55.10 | 55.13 | 55.14 | 66.1 | 66.2 | 80.2 | 80.5 | 89.1 | 89.2 | 89.3 | 112.1 |
| †Fusulina sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | x |
| *Lophophyllum profundum | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| *Lophophyllum profundum radicosum | x | .... | .... | .... | x | x | x | .... | x | x | x | x | x | x |
| Campophyllum torquium | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | x | .... |
| Aulopora prosseri | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| †Hydreionocrinus subsinuatus ? | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| †Eupachycrinus sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| †Delocrinus sp. | .... | .... | .... | .... | .... | x | .... | .... | x | .... | .... | .... | .... | x |
| †Crinoid stems | x | .... | x | x | x | x | x | x | x | x | x | x | .... | x |
| †Archeocidaris aculeata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x |
| Archeocidaris sp. | .... | x | x | x | .... | x | .... | .... | x | .... | .... | .... | .... | .... |
| *Fistulipora carbonaria | .... | .... | .... | x | .... | .... | .... | .... | x | x | x | .... | .... | x |
| †Fistulipora nodulifera | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... |
| †Tabulipora sp. A | .... | .... | .... | x | .... | .... | .... | .... | x | x | .... | .... | .... | x |
| Tabulipora sp. B | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| Tabulipora sp. C | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... |
| *Chainodictyon laxum ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella sp. | .... | .... | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Polypora sp. | .... | .... | .... | x | .... | .... | .... | .... | x | x | x | .... | .... | .... |
| *Rhombopora lepidodendroidea | .... | .... | x | x | .... | .... | .... | x | .... | x | .... | .... | .... | x |
| †Lingula umbonata ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| *Lingulipora nebraskensis | .... | .... | .... | .... | x | .... | .... | .... | x | .... | x | .... | .... | .... |
| *Roemerella patula | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... |
| *Crania modesta | x | .... | .... | .... | .... | x | .... | .... | x | .... | .... | .... | .... | .... |
| *Derbya crassa | .... | .... | .... | .... | .... | x | .... | .... | x | .... | x | .... | .... | x |
| Derbya sp. | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | x |

| FAUNA | LOCALITIES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 44.1 | 55.8 | 55.9 | 55.10 | 55.13 | 55.14 | 66.1 | 66.2 | 80.2 | 80.5 | 89.1 | 89.2 | 89.3 | 112.1 |
| *Chonetes granulifer ? | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | ---- | ---- | ---- |
| Chonetes verneuilianus | ---- | ---- | x | x | ---- | x | ---- | x | x | ---- | ---- | ---- | ---- | x |
| *Productus cora | x | ---- | x | x | x | x | ---- | x | x | x | ---- | x | ---- | x |
| *Productus pertenuis | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Productus inflatus coloradoensis | ---- | ---- | x | ---- | x | x | x | x | x | x | x | x | ---- | x |
| Productus sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- |
| †Marginifera lasallensis | x | ---- | x | x | x | x | x | x | x | x | x | x | x | x |
| †Marginifera missouriensis ? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| *Marginifera muricata ? | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| *Marginifera splendens | ---- | x | ---- | ---- | x | x | x | ---- | x | x | x | ---- | ---- | x |
| *Pustula nebraskensis | x | ---- | x | x | ---- | x | x | x | x | x | x | x | x | x |
| Pustula punctata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | x | ---- | ---- |
| Pustula n. sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | x | ---- | ---- | x | ---- |
| *Pugnax osagensis | x | x | x | ---- | x | x | ---- | ---- | x | ---- | ---- | x | ---- | x |
| *Pugnax osagensis percostata | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| *Rhynchopora illinoisensis | x | ---- | ---- | ---- | ---- | x | ---- | ---- | x | ---- | ---- | ---- | ---- | x |
| Dielasma sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x |
| *Spirifer cameratus | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Spirifer texanus | x | ---- | x | x | x | x | x | x | x | x | ---- | x | ---- | x |
| Spirifer sp. A. | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | ---- |
| Spirifer sp. B. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Squamularia perplexa | ---- | x | x | ---- | ---- | x | x | ---- | x | ---- | x | x | ---- | x |
| *Ambocoelia planoconvexa | ---- | ---- | x | ---- | ---- | x | x | ---- | x | ---- | ---- | ---- | ---- | x |
| *Spiriferina kentuckiensis | ---- | x | x | x | ---- | x | x | x | x | ---- | x | ---- | ---- | ---- |
| Spiriferina sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Hustedia mormoni | x | x | x | x | x | x | x | x | x | ---- | x | ---- | ---- | x |
| Hustedia sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Composita subtilita | x | x | x | x | ---- | x | x | x | x | x | x | x | x | x |
| Chaenomya sp. | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- |
| †Edmondia aspenwallensis | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | x | ---- | x | ---- | ---- | ---- |
| *Edmondia gibbosa | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| *Nucula anodontoides ? | ---- | ---- | ---- | ---- | x | x | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Nuculopsis ventricosa | x | ---- | x | x | x | x | ---- | x | x | x | x | x | x | x |
| *Leda bellistriata | x | ---- | x | x | x | x | x | x | x | ---- | x | x | ---- | x |
| *Leda bellistriata attenuata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| *Yoldia glabra | ---- | ---- | x | ---- | x | x | ---- | x | ---- | ---- | ---- | x | x | ---- |
| Parallelodon sp. A. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| Parallelodon sp. B. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- |
| †Pinna peracuta | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | x | ---- | ---- | ---- | ---- | ---- |
| *Aviculopinna americana ? | ---- | ---- | ---- | ---- | x | x | x | x | x | ---- | ---- | ---- | ---- | ---- |
| Conocardium sp. | x | ---- | x | x | ---- | x | ---- | x | x | ---- | ---- | x | x | x |
| Myalina recurvirostris ? | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Myalina sp. | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | ---- | x | ---- | ---- |
| *Anthraconeilo taffiana | x | ---- | x | ---- | x | x | ---- | x | x | ---- | ---- | ---- | ---- | x |
| *Schizodus alpina | ---- | ---- | x | ---- | ---- | x | ---- | ---- | x | ---- | ---- | x | ---- | x |
| *Deltopecten texanus | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| †Allorisma terminale ? | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | x | ---- | ---- | x | ---- | ---- |
| Allorisma sp. | ---- | ---- | ---- | ---- | x | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| *Astartella concentrica var. | x | x | x | x | x | x | x | x | x | x | x | x | ---- | x |
| *Dentalium semicostatum | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| †Plagioglypta sp. | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- |
| Bellerophon crassus | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |

| FAUNA | LOCALITIES | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 44.1 | 55.8 | 55.9 | 55.10 | 55.13 | 55.14 | 66.1 | 66.2 | 80.2 | 80.5 | 89.1 | 89.2 | 89.3 | 112.1 |
| *Bellerophon crassus wewokanus | .... | .... | x | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... |
| *Patellostium montfortianum | x | x | x | .... | .... | x | .... | x | x | x | x | .... | .... | .... |
| *Euphemus carbonarius | x | .... | x | x | x | x | .... | x | x | x | x | x | .... | x |
| *Pharkidonotus percarinatus | x | .... | x | x | x | x | .... | x | x | x | x | x | .... | x |
| Orestes brazoensis | x | .... | x | .... | .... | x | .... | .... | x | x | .... | x | x | x |
| *Phanerotrema grayvillense | x | .... | x | x | x | x | x | x | x | x | x | x | x | x |
| *Worthenia tabulata | x | .... | x | x | x | x | x | x | x | x | x | x | x | x |
| Murchisonia sp. | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... |
| *Trepospira depressa | x | .... | x | x | x | x | x | x | x | x | x | x | x | x |
| *Schizostoma catilloides | x | x | x | .... | x | .... | .... | .... | x | .... | x | .... | .... | x |
| *Meekospira peracuta choctawensis | x | .... | x | x | x | x | .... | .... | x | x | .... | .... | x | x |
| *Meeksopira bella ? | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... |
| *Zygopleura rugosa . | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... |
| *Sphaerodoma brevis | .... | .... | .... | .... | .... | ? | .... | .... | ? | .... | .... | .... | ? | x |
| *Sphaerodoma intercalaris | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | x |
| *Sphaerodoma primigenius | x | .... | x | .... | x | x | x | .... | x | .... | .... | .... | .... | x |
| *Sphaerodoma ventricosa | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| †Sphaerodoma sp. | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... |
| *Ianthinopsis gouliana ? | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... |
| Platyceras parvus | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... |
| *Conularia crustula | .... | .... | .... | .... | .... | .... | x | x | x | .... | .... | .... | .... | x |
| †Orthoceras sp. | x | .... | x | x | x | x | x | x | x | x | .... | x | .... | x |
| *Pseudorthoceras knoxense | .... | x | x | .... | x | x | x | .... | x | .... | .... | .... | x | x |
| *Protocycloceras ? rushense ? | .... | .... | x | .... | x | .... | x | .... | x | .... | .... | .... | .... | x |
| *Coloceras liratum | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| *Metacoceras cornutus | .... | .... | x | .... | .... | x | x | x | .... | .... | x | .... | .... | x |
| *Metacoceras perelegans | .... | .... | x | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... |
| *Metacoceras perelegans sinuosum | .... | .... | .... | .... | .... | .... | x | .... | .... | x | .... | .... | .... | .... |
| *Metacoceras sculptile | .... | .... | x | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | x |
| †Metacoceras sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | x |
| Tainoceras occidentale | .... | .... | x | .... | .... | x | x | .... | .... | x | .... | .... | .... | .... |
| *Cyrtoceras peculiare | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... |
| †Cyrtoceras sp. | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... |
| Gonioloboceras goniolobum | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... |
| *Gonioloboceras welleri | x | .... | x | .... | x | x | x | x | .... | .... | .... | .... | .... | x |
| †Pronorites sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| Glyphioceras sp. A. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| Glyphioceras sp. B. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| †Gastrioceras listeri | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| *Gastrioceras angulatum | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | x |
| †Gastrioceras sp. A. | .... | .... | x | .... | x | x | x | .... | .... | .... | .... | .... | .... | .... |
| †Gastrioceras sp. B. | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| †Gastrioceras sp. C. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| †Gastrioceras sp. D. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| Schistoceras hyatti | .... | .... | .... | .... | x | .... | .... | .... | x | .... | x | .... | .... | ? |
| *Dimorphoceras texanum | .... | .... | x | .... | x | .... | x | .... | x | .... | .... | .... | .... | .... |
| Fish tooth | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... |
| Fish spine | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... |

In addition to the fossil species listed in the foregoing table of the Wayland shale, Smith[72] has reported the occurrence of a number of very interesting ammonoids from the outcrops of this division along the banks of Salt Creek west of Graham. These were collected chiefly by Dr. A. B. Gant, who was for many years a resident of Graham. The following species are identified:

**Ammonoids from the Wayland shale near Graham**

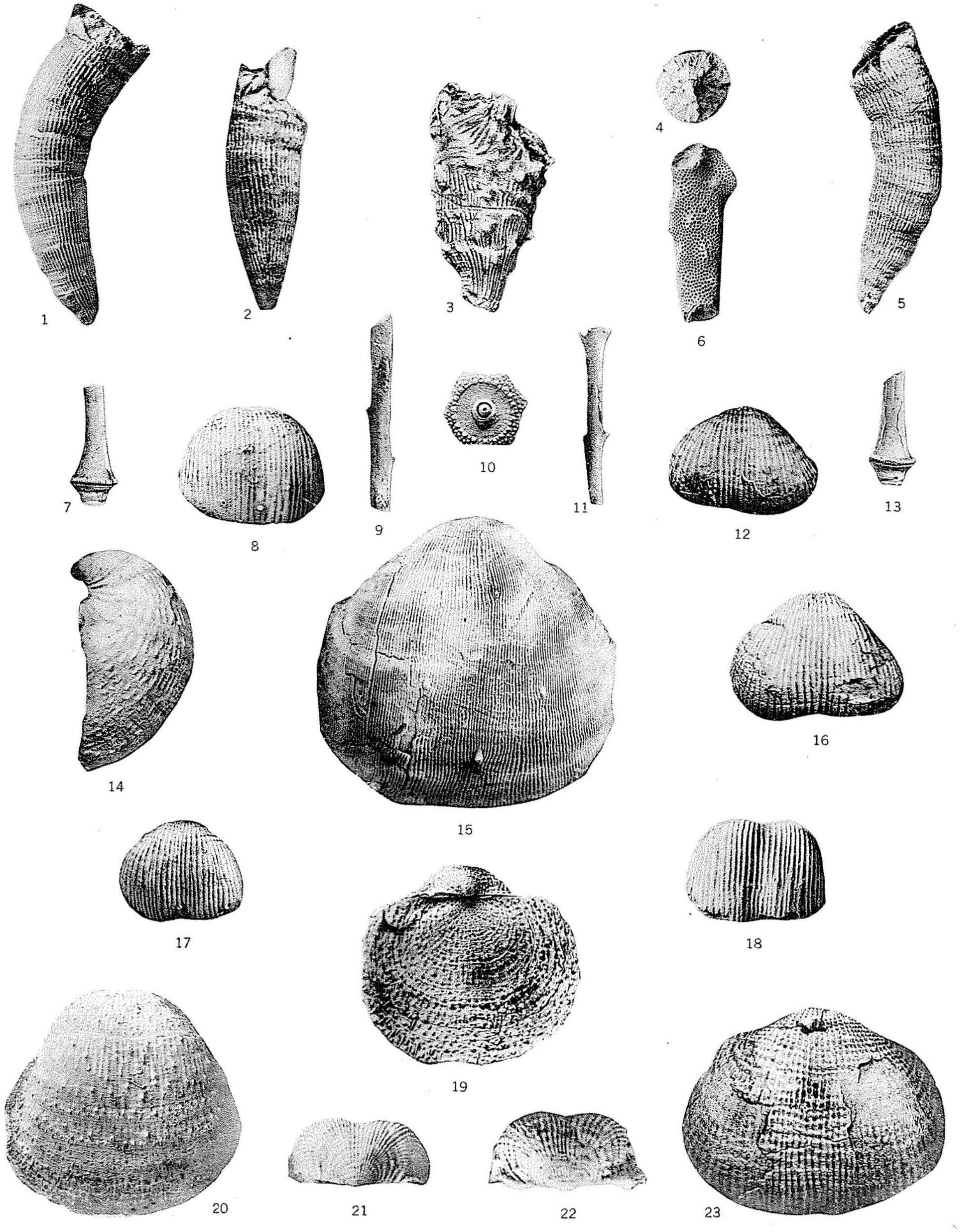
*Shumardites simondsi*
*Gastrioceras globulosum*
*Gastrioceras subcavum*
*Schistoceras hildrethi*
*Schistoceras hyatti*
*Gonioloboceras welleri*
*Dimorphoceras texanum*
*Agathiceras ciscoense*
*Schuchertites grahami*
*Stacheoceras ganti*

The most noteworthy feature in connection with this ammonoid group, as noted by Smith, is the unusually complex suture pattern of most of the species, which, indeed, is very much more like typical Permian ammonoids than those commonly found in the Pennsylvanian. *Stacheoceras, Shumardites, Schuchertites* and probably *Schistoceras* may be regarded as true ammonites.

*Correlation.*—Since the fauna of the Graham formation, represented by the collections from the members here recorded, is very evidently a unit, the stratigraphic correlation of the formation may be discussed as a whole. Aside from the fossils of the limestone beds which belong chiefly to the very common and widely distributed species of corals, *Campophyllum torquium* and *Syringopora multattenuata,* the Graham fauna is distinctively a modification of the Wewoka fauna. It will be observed that almost all of the very common and characteristic Graham fossils are also common and characteristic of the Wewoka. Since, moreover, some of the rarer species, such as *Deltopecten texanus, Lingulipora nebraskensis, Rhynchopora illinoisensis,* and the considerable group of nautiloids and ammonoids which are common to the Wewoka and the Graham but are not found except in association with the characteristic fauna here listed, the essential equivalence of the southern Oklahoma fauna and of that from the basal Cisco can hardly be questioned.

It may be observed that the Graham fauna contains some species which are not reported in the Wewoka, the most important of which are *Chonetes verneuilianus, Derbya bennetti, Marginifera lasallensis, Dielasma bovidens ?, Spirifer texanus, Conocardium* sp., *Myalina* sp., *Orestes brazoensis, Platyceras parvus, Tainoceras occidentale,* and most of the Salt Creek

[72]Smith, J. P., Carboniferous Ammonoids of America, U. S. Geol. Surv., Mon. 42, 1903.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## GRAHAM FOSSILS

Figures 1, 2, 4, 5. *Lophophyllum profundum*, an extremely common and widely distributed fossil coral in the Graham formation. Figure 2 shows the prominent columella which projects strongly because of the weathering of the outer part of the calyx. Figure 4, calyx view of specimen shown in Figure 5. Wayland shale. Figures 1 and 2 from one mile south of Gunsight (80.2), Figures 4 and 5 from southeast of Avis (44.1).

Figure 3. *Lophophyllum profundum radicosum*, a rough, spine-bearing variety. Wayland shale south of Gunsight (80.2).

Figure 6. *Fistulipora nodulifera*, an incrusting bryozoan. Wayland shale south of Gunsight (80.2).

Figures 7, 9, 11, 13. *Archeocidaris* sp. cf. *A. cratis*, fragments of spines. Bunger limestone west of Finis (54.1).

Figures 8, 12, 16, 17, 18 21, 22. *Marginifera lasallensis*, a very characteristic and abundant element in the Wayland shale. Figure 8 from Salt Creek west of Graham (55.9), Figures 12, 16 from south of Gunsight (80.2), Figures 17, 18, 21 from Weedon School northwest of Brownwood (112.1), Figure 22 from east of Cisco (89.1).

Figure 10. *Archeocidaris* sp., an ornamented sea urchin plate. Bunger limestone west of Finis (54.1).

Figures 14, 19, 20. *Pustula nebraskensis*, side, brachial and pedicle views, respectively, of three very perfect specimens from the Wayland shale south of Gunsight (80.2).

Figure 15. *Productus cora*, an unusually large and well preserved specimen from the Wayland shale south of Gunsight, pedicle valve (80.2).

Figure 23. *Productus semireticulatus* aff. *hermosanus*, a partly exfoliated shell which is widely distributed in the Wayland shale. Wayland shale south of Gunsight (80.2).

## GRAHAM FOSSILS

Figure 1. *Spirifer texanus*, side view of a nearly perfect specimen from the Wayland shale, one and a half miles south of South Bend (66.1). Fragments of this species are very common in the Graham formation but complete specimens are rather rare.

Figures 2, 3, 4, 5, 12. *Chonetes verneuilianus*, a common brachiopod in the upper shales of the Graham formation. Figure 2 shows a characteristic pedicle valve, Figure 3 interior of brachial valve, Figures 4 and 5 brachial views of two varieties, all from the Wayland shale south of Gunsight (80.2). Figure 12 is a specimen from the Wayland shale northwest of Brownwood (112.1).

Figures 6, 7. *Squamularia perplexa*, two characteristic specimens from the Wayland shale northwest of Brownwood, pedicle valves (112.1).

Figure 8. *Productus cora*, a pedicle valve, from the Wayland shale south of Gunsight (80.2).

Figure 9. *Marginifera splendens*, a brachial valve from the Wayland shale south of Gunsight (80.2).

Figure 10. *Pugnax osagensis*, pedicle valve, from Wayland shale northwest of Brownwood (112.1).

Figure 11. *Ambocoelia planoconvexa*, a broken, somewhat crushed specimen from the Wayland shale south of Gunsight (80.2).

Figure 13. *Anthraconeilo taffiana*, a right valve, from the Wayland shale south of Gunsight (80.2).

Figure 14. *Lingulipora nebraskensis*, a well preserved but imperfect specimen from the Wayland shale east of Cisco (89.1).

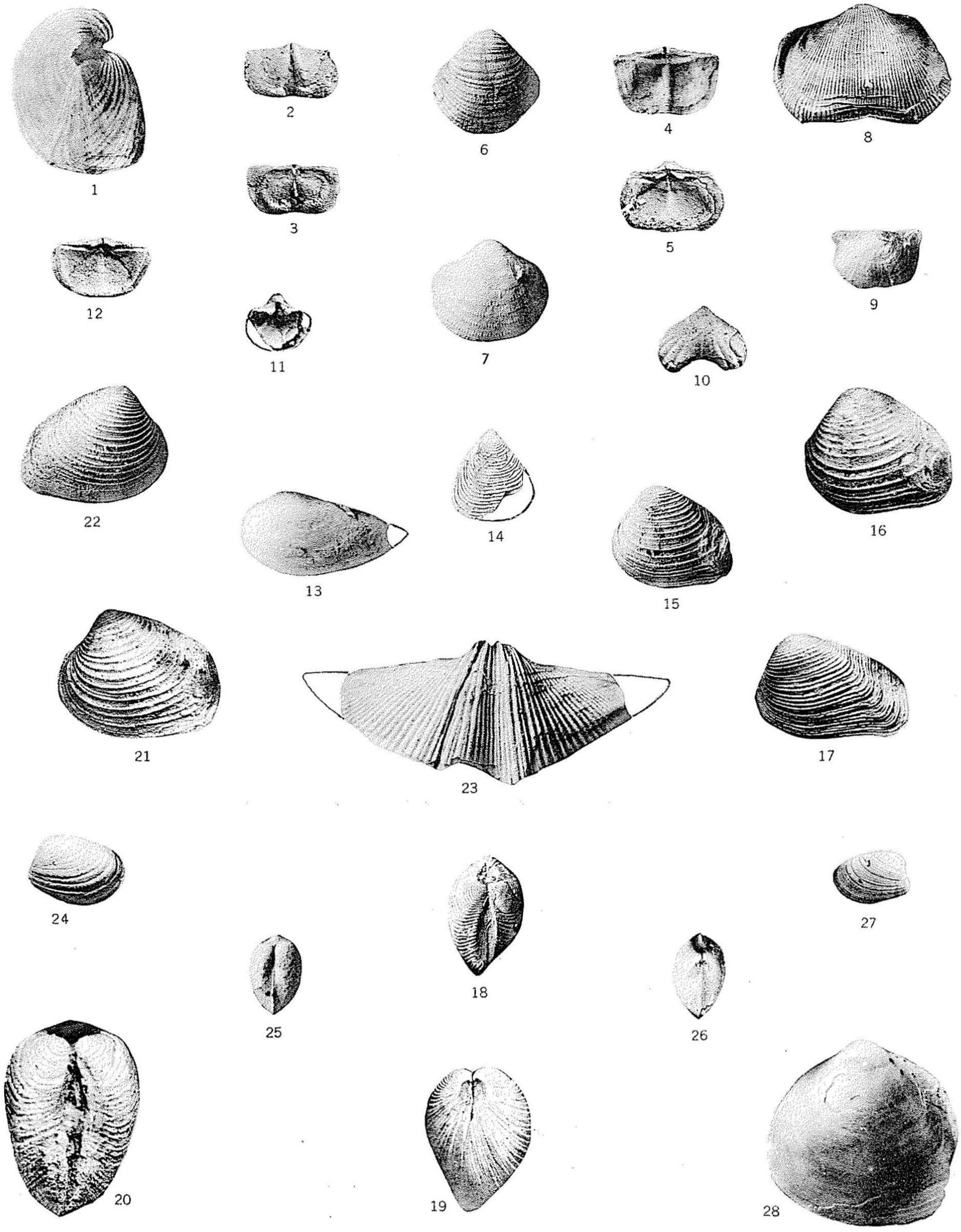
Figures 15, 16. *Crania modesta*, situated near the posterior extremity of *Astartella concentrica*. Almost all the specimens observed are found on this pelecypod and in this position on the valve, indicating that the brachiopod utilized in part waste products from its host. Wayland shale, south of Gunsight (80.2).

Figures 17, 18, 19, 20, 21, 22. *Astartella concentrica* var., an e tremely abundant and characteristic fossil in the Wayland shale. The shells are robust and, as illustrated in Figure 17, some are characterized by an unusual posterior prolongation. All from the Wayland shale south of Gunsight (80.2).

Figure 23. *Spirifer* sp., a nearly complete, very alate pedicle valve. Wayland shale south of Gunsight (80.2).

Figures 24, 25, 26, 27. *Nuculopsis ventricosa*, characteristic examples from the Wayland shale south of Gunsight (80.2).

Figure 28. *Schizodus alpina*, a well preserved, nearly perfect left valve. Wayland shale south of Gunsight (80.2).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ammonoids. Some of these are more or less long-ranging, widely distributed forms, without special significance. *Derbya bennetti* is recorded by Beede and Rogers[73] as ranging from the Cherokee to the Oread subdivisions of the Kansas section, being most abundant in the Iatan and Oread limestones. *Orestes brazoensis* is reported only from the Cherokee shale in Kansas. *Chonetes verneuilianus* and *Tainoceras occidentale* are recorded from the Fort Scott limestone as high as the Wabaunsee formation.

The absence from the Graham fauna of some of the very typical and characteristic fossils, such as *Chonetes mesolobus* and *Cliothyridina orbicularis,* which are found in the Wewoka formation and subjacent beds in Oklahoma and in the Des Moines beds in Kansas, suggests that notwithstanding the broadly similar character of the Graham fauna to that of the Wewoka, it may in fact be slightly younger.

The fauna of the Graham is very evidently distinct from that of the succeeding portion of the Cisco—in fact the change in the aspect of the fossils from the Wayland shale to those from the beds above is one of the most striking observed in the Texas Pennsylvanian. The Thrifty, Harpersville, and the remaining formations of the Cisco have almost no elements which are suggestive of the lower faunas, for while some long-ranging species of course remain, and while a few of the species most characteristic of the Graham and beds below are apparently represented in a few instances in the higher beds, these are by no means the dominant element in the fauna. Among the new species which are introduced above the Graham *Enteletes hemiplicata, Chonetes granulifer meekianus, Derbya cymbula, Allorisma subcuneatum* and abundant large Myalinas may specially be mentioned. In Kansas, where more or less open marine conditions similar to those in Texas prevailed, this change in fauna is noted[74] in passing from the Kansas City into the Lansing and higher formations.

Of the Graham ammonoids, *Schistoceras hyatti, Agathiceras ciscoense, Stacheoceras ganti, Shumardites grahami* and *Schuchertites simondsi* are known only from this formation in Texas, and excepting the first, all are recorded only from the Wayland shale on Salt Creek, west of Graham. The genus *Schistoceras,* which is reported only from North America, contains five described species from beds referred to the Pennsylvanian and one from the lower Permian. *S. hyatti* is found in the Wayland shale at the locality five miles east of Cisco (89.1), on Bass Hill east of South Bend (55.13), south of Gunsight (80.2), near Weedon School northwest of Brownwood (?) (112.1), and on Salt Creek west of Graham, but it is not reported elsewhere. *S. hildrethi,* a second species, is found in the Wayland shale at the Salt Creek locality and in the Pennsylvanian of Guernsey County, Ohio. The remaining species have been recorded from the upper Pennsylvanian of Fulton County, Illinois, (*S. fultonense*) ; from the Mis-

[73]Beede, J. W., and Rogers, A. F., Coal Measures Faunal Studies, Kans, Uiv. Geol. Surv., vol. 9, 1908.

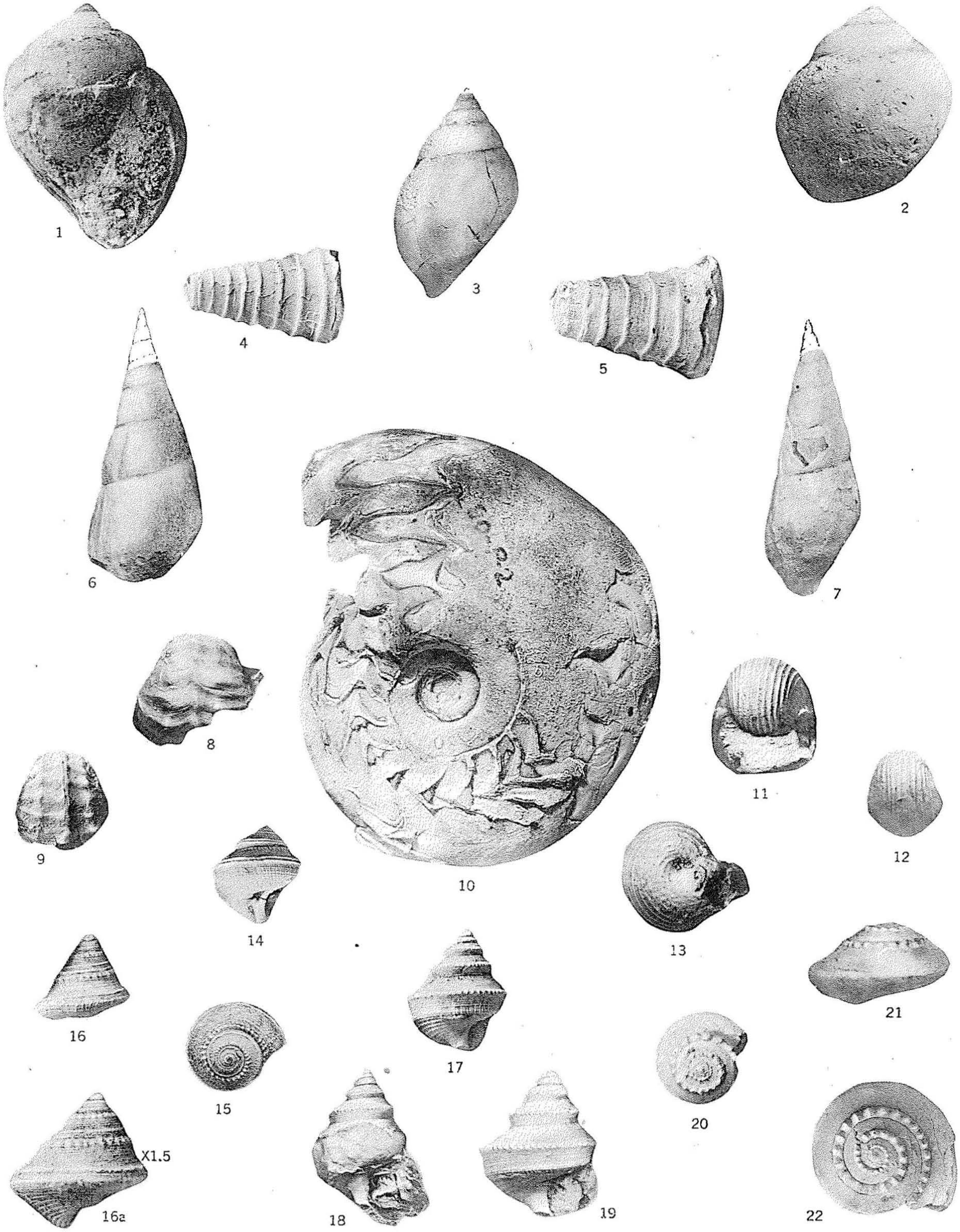
[74]Beede, J. W., and Rogers, A. F., loc. cit.

souri group, Upper Pennsylvanian near Kansas City, Missouri (*S. missouriense*); from the Gaptank formation, Upper Pennsylvanian of West Texas (*S. smithi*); and from the lower Permian Wolfcamp formation of West Texas (*S. diversecostatum*). *Agathiceras* has been found elsewhere in the highest Carboniferous of Russia (*A.* cf. *uralicum*), where, as in the Graham formation, it is very rare, and in the Permo-Carboniferous of Russia, Sicily, China, the East Indies and in West Texas, where, on the other hand, it is rather abundant. *Stacheoceras,* which includes a number of species, as *S. ganti,* which were formerly referred to *Popanoceras,* is elsewhere chiefly represented in the Permo-Carboniferous of West Texas, Sicily and Russia. *Shumardites* and *Schuchertites* are not represented, so far as known, by other species than those in the Graham, but on account of their very complex, ammonitic sutures they are much more suggestive of the Permian than of typical Pennsylvanian species. It is clear from this summary that the stratigraphic indications of this group are in the direction of a very late rather than an early position in the Pennsylvanian.

*Gastrioceras globulosum* is recorded from the "Middle Coal Measures" of Scott County, Arkansas, and *G. subcavum* from the Upper Pennsylvanian of Montgomery County, Illinois. Both *Gonioloboceras welleri* and *Dimorphoceras texanum* have been found in the Mineral Wells formation of the Strawn near Mineral Wells (68.1). A variety of *G. welleri* is recorded also from the Wewoka formation of southern Oklahoma and from the Upper Pennsylvanian of Montgomery County, Illinois.

It is apparent that the ammonoid element of the Graham fauna is much more strongly suggestive of a late than of an early position in the Pennsylvanian and although, on account of the restriction of most of the species to the Texas area, it is not possible to make precise comparison with established horizons in the Pennsylvanian of other parts of the country on this basis, it may be concluded that the Graham formation is Upper Pennsylvanian.

Taking into consideration all of the faunal and stratigraphic information now available it appears to the writer that the Graham is somewhat younger than the Wewoka formation of southern Oklahoma which has been correlated with the horizon of the Marmaton formation of the Kansas section, but older than the Lansing formation of that state. Although the conditions in Kansas were on the whole similar to those in Texas, there was not, apparently, any direct connection of the sea between the two areas. The Kansas rocks do not contain the peculiar ammonoid fauna of the Graham—indeed, as Smith notes, characteristic elements of it are known only from India, the Mediterranean region, and Texas—but otherwise there is greatest similarity in the content of invertebrate life. Since both in Texas and in Kansas the beds overlying the formations mentioned show in the introduction of species which are characteristic of the uppermost divisions of the Pennsylvanian in the Mid-Continent region, the comparable stratigraphic position appears more definite. Neither in Kansas nor in Texas is there evident an important break in sedimentation following respectively the Iola limestone or the Wayland shale, but in Texas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## GRAHAM FOSSILS

Figures 1, 2, 3. *Sphaerodoma primigenia,* two robust and characteristic specimens from the Wayland shale northwest of Brownwood and a variety from the Wayland shale south of Gunsight, respectively (80.2).

Figures 4, 5. *Protocycloceras ? rushense ?,* two well preserved specimens from the Wayland shale south of South Bend (66.1).

Figures 6, 7. *Meekospira peracuta choctawensis,* Wayland shale, south of Gunsight (80.2).

Figures 8, 9. *Pharkidonotus percarinatus,* two typical specimens from the Wayland shale south of Gunsight (80.2).

Figure 10. *Schistoceras hyatti,* a good but imperfect specimen showing both the latero-ventral sutures and portions of the anti-siphonal sutures from an outer whorl which is lost. Wayland shale, south of Gunsight (80.2).

Figures 11, 12, 13. *Euphemus carbonarius,* apertural, "dorsal" and side views of characteristic specimens from the Gunsight shale south of Gunsight (80.2).

Figures 14, 15. *Phanerotrema grayvillense,* side and top views of a well preserved and characteristic specimen from the Wayland shale south of South Bend (66.1).

Figures 16, 16a. *Orestes brazoensis,* a typical specimen from the Wayland shale south of Gunsight (80.2).

Figures 17, 18, 19. *Worthenia tabulata,* characteristic specimens from the Wayland shale south of Gunsight (80.2), northwest of Brownwood (112.1) and north of Wayland (80.5), respectively.

Figures 20, 21, 22. *Trepospira depressa,* characteristic specimens from the Wayland shale south of Gunsight (80.2).

there was a slight interval of erosion which is marked by the removal locally of portions of the Wayland shale and by the occurrence above this horizon of the more or less conglomeratic Avis sandstone member at the base of the Thrifty formation.

The considerably greater thickness of the Graham formation in the northern part of the Texas Pennsylvanian area and its more clastic character in this region have been noted in the description of the formation. So far as known there is no evidence of a break in sedimentation at the end of the Canyon epoch, for the rather thin Home Creek limestone has been traced continuously from the Colorado River Valley into and across the Brazos River Valley. The change in character of the sedimentation and the greater deposition in the north may be correlated with the uplift of the Arbuckle Mountain region in southern Oklahoma which appears to have been initiated at about this time. The great thickness of the clastic Glenn formation and portions of the Lower Pennsylvanian series now exposed on the north side of the mountains began to be eroded and the materials derived from the uplifted portions of these formations were doubtless strewn southward and in part northward into the bordering seas which remained in Texas and Oklahoma. Notwithstanding the influx of this considerable amount of clastic debris, the invertebrate fauna which had existed in the Texas basin and which was present in typical development in the Wewoka area before the uplift of the mountains persisted through the time of Graham deposition. Clastic deposits corresponding in origin and geologic age to the Graham may be found above the horizon of the Wewoka north of the mountains and probably at least in part beneath the horizon of the Franks conglomerates which were formed from the limestones and resistant debris derived from the lower and older formations in the Arbuckles when they had been exposed by erosion.

## THRIFTY FORMATION

*Name and Definition.*—The Thrifty formation has been named for the town of Thrifty located near the center of Brown County. It is defined as including all the strata from the bottom of the Avis sandstone to the top of the Breckenridge limestone, which is typically exposed south of Main Street in the town of Breckenridge. In the northern district the formation may be distinguished from the other members of the Cisco group by its higher and more prominent escarpments, more massive limestones, and its thicker and non-fossiliferous reddish shales. In the southern district the limestones are much less fossiliferous than the other limestones of the group, the shales are tinged with brighter colors and contain in places carbonaceous shales and even coal.

*Extent and Thickness.*—The Thrifty formation has been mapped from Jermyn in Jack County to a point west of Graham in Young County, through Eliasville to the Parks oil field southeast of Breckenridge, and thence southwest of Wayland and Gunsight to Eastland County where it passes beneath the Cretaceous beds southwest of Cisco. It is seen in small outliers at Romney and Bethel in the midst of the Cretaceous sands and appears south of the sand at Blake in Brown County from whence it may be traced southward through Thrifty, west of Bangs and Trickham to the Llano Mountain area southwest of Brady.

The formation varies in thickness from 120 to 200 feet. Unlike the Graham formation, it does not thin to the south and has about the same average thickness in the Colorado River Valley as in Stephens County. In Brown County, at Thrifty, it is 200 feet thick, in Eastland County east of Cisco about 200 feet thick, and in northern Stephens County, east of Crystal Falls, 120 to 150 feet thick.

*Noteworthy Exposures.*—Excellent exposures of the formation may be seen along the prominent escarpments southeast of Breckenridge where the limestone members form the ledges around the north and west side of the old Parks oil field and make the dip slopes on the west side. Therefore they should be well known to oil geologists who have worked in Texas. About halfway between Cisco and Eastland, in Eastland County, and on the north-south road north of Thrifty, in Brown County, are good exposures.

*Lithologic Character.*—The Thrifty formation consists of alternating, more or less lenticular beds of shale, sandstone and limestone. The limestones are thin but persistent for the most part over long distances. They are hard, yellowish-gray, rather evenly bedded, and in most places form more or less prominent escarpments. Their average thickness ranges from 3 to 10 feet. The upper limestones are in general unfossiliferous but the lower contain a few of the common Pennsylvanian species. A limestone which appears in the basal part of the Thrifty southeast of Breckenridge contains numerous corals, *Campophyllum torquium* and *Syringopora multattenuata*, and *Fusulina*.

The shales of the Thrifty formation are grayish-yellow for the most part, but at certain horizons, especially in the lower part, they are purple, red and vari-colored. The shales are not in general fossiliferous.

In many places lentils of rather coarse brown sandstone appear. These are locally conglomeratic, the conglomerates being most noteworthy in the northern area of the formation. Where the sandstones and conglomerates are present, the interval between the limestones is invariably increased. The outcrop of limestones below the sandstone is very commonly obscured by the weathering and slump of the sandstone. The basal subdivision of the Thrifty is a rather persistent, coarse, cross-bedded, dark brown sandstone which in many places grades into grit or conglomerate. Since it rests discomformably on the eroded upper surface of the Graham formation, this sandstone represents a change in conditions at the beginning of the Thrifty epoch.

In the Colorado River Valley the limestones of the Thrifty formation are somewhat more fossiliferous, and locally there are coal beds, which were named by Drake the Chaffin coals.

*Subdivisions.*—The stratigraphic subdivisions of the Thrifty formation which have been recognized in field studies and employed in the mapping are as follows:

*Thrifty formation*—
- Breckenridge limestone member
- Shale
- Blach Ranch limestone member
- Shale, sandstone and conglomerate
- Ivan limestone member
- Shale and sandstone, with locally a limestone lentil
- Avis sandstone member

The members which are designated by stratigraphic names are typically exposed in the area of the Brazos River Valley north of the Cretaceous overlap. The character and thickness of the Thrifty formation in the Colorado River Valley are rather similar to those in the north, and limestones occurring at approximately the same intervals below the top of the formation have been traced across the area and correlated with the members recognized in the Brazos Valley.

*Avis Sandstone.*—The basal stratigraphic division of the Thrifty formation is a persistent but variable deposit of coarse-grained sandstone, grit or conglomerate which ranges in thickness from less than 5 feet to more than 40 feet. It is named from the town of Avis, in Jack County, north of Jacksboro, and it is most typically developed in Jack, Young and Stephens counties. In places it rests on the fossiliferous Wayland shale member of the Graham formation, elsewhere directly on the Gunsight limestone. Locally, toward the south, the Avis appears to be somewhat soft and calcareous. The Avis is correlated by Plummer with sandstone in the Trickham bed of Drake. The thickness and character of the Avis are indicated in sections of the Thrifty formation at various points described below.

*Ivan Limestone Member.*—About 35 to 80 feet above the Avis is a rather persistent lentil of limestone which appears in the vicinity of Ivan, Stephens County. It is not traceable very far to the northeast but southward it has been mapped into Eastland County and it appears to be represented south of the Cretaceous sand area. The Ivan limestone is light yellowish- to brownish-gray in color, massive, locally nodular and is unfossiliferous. It ranges in thickness from about two feet up to seven or eight feet. A limestone occurs in places southeast of Breckenridge in the shale and sandstone interval between the Avis and the Ivan members. It is distinguished from the Ivan by numerous fossil corals but has been confused in some cases with the subjacent Gunsight limestone. The position of this lowest limestone in the Thrifty is about 60 feet below the Ivan in this region.

*Blach Ranch Limestone Member.*—A limestone which occurs about 30 feet in most sections above the Ivan member is here named the Blach Ranch bed, from typical exposures in the vicinity of the Blach Brothers Ranch east of Breckenridge. This limestone is light gray in color, weathering buff or brown, is massive and weathers in large slabs or rounded boulders. It is rather unfossiliferous. In thickness it ranges from an average of 3 or 4 up to 8 feet. The Blach Ranch bed extends somewhat farther northeast than the Ivan limestone and it extends far to the south. It is thought to be equivalent to the Chaffin limestone of Drake in the Colorado River section.

*Breckenridge Limestone Member.*—The uppermost limestone of the Thrifty is named from the county seat of Stephens County which has become an important center of petroleum development. It forms a prominent escarpment in and about the town of Breckenridge and may be traced easily to the northeast and south. It has an average thickness of 3 or 4 feet and like the other limestones in the Thrifty which have been described, it is gray, massive and resistant. It is 25 to 45 feet above the Blach Ranch member. It is identified, as nearly as determinable by Plummer, with the Upper Chaffin bed of Drake.

*Detailed Sections.*—The character of the different beds in the Thrifty formation and their relationships are best illustrated by the following described sections selected from south to north.

**Section of Thrifty formation along a small creek northwest of Bryson, Young County**

**Measured by J. G. Burtt. (L in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| HARPERSVILLE FORMATION— | | |
| 12. | Sandstone and conglomerate, dark red, coarse-grained | 10 |
| THRIFTY FORMATION— | | |
| 11. | Limestone (?), yellow-gray, thin-bedded, lenticular. Breckenridge member | 2 |
| 10. | Shale, gray | 5 |
| 9. | Sandstone and conglomerate, dark red, ferruginous, small angular chert and quartz pebbles evidently derived from strata older than Pennsylvanian | 20 |
| 8. | Limestone, light gray to buff, contains few fossils. Blach Ranch member | 4 |
| 7. | Shale, gray to buff | 2 |
| 6. | Limestone, blue-gray, thins and disappears to east | 2 |
| 5. | Shale, gray | 40 |
| 4. | Sandstone and conglomerate, dark reddish-brown | 20 |
| 3. | Limestone, dark gray | 5 |
| 2. | Shale, gray | 20 |
| 1. | Sandstone and conglomerate, reddish-brown, made up of small light-colored angular pebbles | 25 |
| | Avis member. | |
| | Total thickness of Thrifty formation | 145 |
| GRAHAM FORMATION— | | |
| | Limestone, yellowish-gray, weathers into large angular blocks. Gunsight member | 6 |

**Section two miles northwest of Eliasville, Young County**

**Measured by I. J. Broman. (M in fig. 13)**

| THRIFTY FORMATION— | Thickness Feet |
|---|---|
| 11. Limestone. Breckenridge member | 3 |
| 10. Shale | 7 |
| 9. Sandstone and conglomerate | 25 |
| 8. Shale | 20 |
| 7. Limestone. Blach Ranch member | 8 |
| 6. Shale | 17 |
| 5. Sandstone | 2 |
| 4. Shale | 3 |
| 3. Limestone. Ivan member (?) | 6 |
| 2. Shale | 10 |
| 1. Sandstone, (base not exposed) | 40 |
| Total thickness measured | 141 |

**Section of Thrifty formation on Blach Brothers Ranch four miles east of Crystal Falls**

**Measured by J. G. Burtt. (O in fig. 13)**

| THRIFTY FORMATION— | Thickness Feet |
|---|---|
| 11. Limestone, yellow-gray, weathers to small angular pieces. Breckenridge member | 4 |
| 10. Shale, gray | 12 |
| 9. Sandstone, dark reddish-brown, coarse-grained | 20 |
| 8. Shale | 9 |
| 7. Limestone, light gray, weathers to large rounded boulders. Blach Ranch member | 3 |
| 6. Shale, gray | 10 |
| 5. Sandstone and sandy shale | 32 |
| 5. Limestone, nodular, gray, massive. Ivan member | 7 |
| 3. Shale, reddish, purple, and gray, calcareous | 18 |
| 2. Sandstone, very calcareous, in places limy | 4 |
| 1. Sandstone and sandy shale | ? |
| Base not exposed. | |
| Total thickness measured | 119 |

**Section of lower part of Thrifty formation in the Breckenridge oil field four miles east of Breckenridge and one and one-half miles south of schoolhouse on Caddo-Breckenridge road**

**(P in fig. 13)**

| THRIFTY FORMATION— | Thickness Feet |
|---|---|
| 10. Limestone, light gray, nodular. Blach Ranch member | 3 |
| 9. Shale, yellow and buff | 20 |
| 8. Limestone, yellowish-gray, weathers into large blocks, few fossils. Ivan member | 2 |
| 7. Shale, covered | 10 |
| 6. Sandstone, light gray, soft, calcareous | 10 |
| 5. Shale, gray and reddish | 55 |
| 4. Sandstone, light gray, soft, lenticular, cross-bedded. Avis member | 9 |
| | 109 |

| | |
|---|---|
| GRAHAM FORMATION— | |
| 3. Shale, red and purple. Wayland member | 15 |
| 2. Shale, gray, contains limonite concretions, fossiliferous. Wayland member | 7 |
| 1. Limestone, yellow, gray, smooth. Gunsight member | 2 |
| Total thickness measured | 133 |

**Section of the Thrifty formation in the escarpment two miles northeast of Harpersville, south of Breckenridge oil field, Stephens County**

**Measured by J. G. Burtt. (Q in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| 10. Limestone, bluish-gray, weathers reddish-yellow and buff, slabby. Breckenridge member | 2½ |
| 9. Shale, sandy, changes in places to massively bedded sandstone | 25 |
| 8. Limestone, bluish-gray, weathers to buff and reddish-yellow, slabby and massively bedded. Blach Ranch member | 4 |
| 7. Shale, reddish-yellow, sandy, contains lentils of sand | 24 |
| 6. Limestone, reddish-brown, thick-bedded, weathers to large blocks. Ivan member | 3 |
| 5. Shale, reddish, sandy, interbedded with lenticular sandstones | 35 |
| 4. Sandstone, buff and brown, soft, calcareous. Avis member | 10 |
| Total thickness Thrifty formation | 103½ |
| GRAHAM FORMATION— | |
| 3. Shale, reddish-brown, reddish-yellow, and buff, sandy. Wayland member | 20 |
| 2. Shale, gray and dark, fossiliferous. Wayland member | 15 |
| 1. Limestone, grayish-brown, nodular. Gunsight member | 1 |

**Section of parts of Thrifty and Harpersville formations in hillside three and one-half miles north of Cisco, Eastland County**

**Measured by C. A. Hammill. (R in fig. 13)**

| | Thickness Feet |
|---|---|
| HARPERSVILLE FORMATION— | |
| 6. Limestone, dark gray-brown, weathers into blocks, contains numerous echinoid spines | 2 |
| 5. Shale, yellow, sandy, changes to sand in lower portion | 32 |
| 4. Limestone, gray, weathers into slabby plates, fossiliferous | 3 |
| 3. Shale, buff | 9 |
| THRIFTY FORMATION— | |
| 2. Limestone, bluish-gray, weathers to yellowish-red, breaks into thin slabs | 7 |
| 1. Shale, buff | 17 |

**Section of lower part of Thrifty formation on hill six miles northeast of Cisco, Eastland County**

**(S in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| 12. Limestone, brownish-gray, massive, on weathering breaks into cubical blocks, contains *Fusulina*. Breckenridge member | 3 |
| 11. Shale, buff | 17 |
| 10. Sandstone, light gray, fine-grained | 7 |
| 9. Shale, buff | 22 |
| 8. Limestone, light gray, shaly, weathers to slabs having rough white surfaces. Ivan member | 56 |
| 6. Sandstone, brownish-yellow. Avis member | 5 |
| GRAHAM FORMATION— | |
| Wayland Shale | |
| 5. Shale, light yellow, unfossiliferous | 17 |
| 4. Shale, blue, fossiliferous | 17 |
| 3. Sandstone, dark brown, calcareous | 1 |
| 2. Shale, dark blue, fossiliferous | 9 |
| Gunsight Limestone | |
| 1. Limestone, blue-gray, impure, concretionary, fossiliferous | 2 |

**Section of the Thrifty formation on Jose Padilla Survey, seven miles northeast of Thrifty, Brown County**

**Measured by C. A. Hammill. (T in fig. 13)**

| | Thickness Feet |
|---|---|
| THRIFTY FORMATION— | |
| 15. Limestone (Upper Chaffin bed of Drake), dark blue-gray, fossiliferous. Breckenridge member | 1 |
| 14. Shale, red siderite nodules near centre, sandy in lower part | 47 |
| 13. Limestone (Lower Chaffin bed of Drake), grayish-yellow, weathers to small chips and nodules. Blach Ranch member (?) | 2 |
| 12. Shale | 14 |
| 11. Limestone, gray, nodular, very soft | 1 |
| 10. Shale, varicolored, and red and gray | 15 |
| 9. Limestone (Speck Mountain bed of Drake) reddish-gray. Ivan member | 2 |
| 8. Shale | 15 |
| 7. Sandstone, shaly, calcareous | 2 |
| 6. Shale, light yellow, very sandy | 15 |
| 5. Limestone (Bellerophon bed of Drake), crystalline, weathers to small rounded pebbles | 3 |
| 4. Shale, varicolored | 35 |
| 3. Limestone, light gray, crystalline, lenticular | 1 |
| 2. Sandstone, grayish brown, soft, calcareous. Avis member | 5 |
| Total thickness | 158 |
| GRAHAM FORMATION— | |
| 1. Shale, dark, very fossiliferous. Wayland member Limestone (Gunsight member) at base. | 20 |

The northernmost sections of the Thrifty formation in Young County contain fewer limestone layers, thicker and coarser grained sandstones having numerous lentils of conglomerate and coal plants which indicate near-shore conditions of sedimentation. Southward in Stephens County in the vicinity of Ivan a third limestone appears in the section below the Blach Ranch limestone, and the shales are less sandy but show red and purple colors, have mud cracks, and contain lentils of cross-bedded sand, all being indications of shallow waters and land intervals. Still farther south in Eastland and Brown counties a fourth limestone appears which contains abundant corals and *Bellerophon* shells, and the sandstones are thinner and less numerous. In McCulloch County in the extreme southernmost sections are thin coal beds and carbonaceous shales in the lower part of the sections, whereas the shales and limestones above are very fossiliferous, a sequence that indicates an alternation of coastal swamps and carbonaceous deposits with shallow-water marine sediments.

*Paleontology.*—The Thrifty formation forms a rather noteworthy contrast in the matter of fossil content to the underlying Graham formation, for most of its limestones and shales are much less fossiliferous. In the limestones which contain some invertebrate remains the fossils are for the most part very poorly preserved and fragmentary. During the course of the survey by the geologists of the Roxanan Petroleum Corporation which, so far as the Thrifty formation is concerned, was mainly in the Brazos River Valley, only a few fragmentary fossils, except abundant *Campophyllum torquium*, *Syringopora multattenuata*, *Fusulina* and *Archeocidaris*, were collected and there has not been opportunity for the writers to make a special investigation of the fossil content of this division.

In the Colorado River Valley Drake records fossils from strata which are referred to the Thrifty formation and which give an indication of the fauna at least in this region. The following table shows the species reported by Drake.

**Fauna of the Thrifty formation**

| | |
|---|---|
| *Fusulina cylindrica* | *Enteletes hemiplicata* |
| *Lophophyllum profundum* | *Pugnax osagensis* |
| *Campophyllum torquium* | *Spirifer cameratus* |
| *Syringopora multattenuata* | *Squamularia perplexa* |
| *Hydreionocrinus acanthophorus* | *Ambocoelia planoconvexa* |
| *Archeocidaris* sp. 1, 2 | *Spiriferina kentuckiensis* |
| *Tabulipora carbonaria* | *Dielasma bovidens* |
| *Fenestella* sp. | *Hustedia mormoni* |
| *Septopora biserialis* | *Composita subtilita* |
| *Derbya crassa* | *Pinna peracuta* |
| *Chonetes granulifer* | *Allorisma subcuneatum* |
| *Productus pertenuis* | *Worthenia tabulata* ? |
| *Productus cora* | *Bellerophon crassus* |
| *Productus costatus* | *Schizostoma catilloides* |
| *Pustula nebraskensis* | *Conularia crustula* |
| *Pustula punctata* | *Phillipsia* sp. |
| *Marginifera splendens* ? | |

The most noteworthy feature in connection with this list is the disappearance of a large number of the species which were found in the Graham formation and the introduction of some new elements, particularly *Enteletes hemiplicata* and true *Chonetes granulifer* which are abundant in the succeeding Harpersville formation. *Allorisma subcuneatum* and *Pinna peracuta* are important elements in the faunas of the higher divisions of the Cisco.

*Correlation.*—In so far as the fauna of the Thrifty formation is known it may be referred with little question to a horizon younger than the Wewoka. On the basis of the similar change in fauna in the Kansas section the Thrifty formation of Texas may be correlated with the horizon of the Lansing formation of the Kansas section.

### HARPERSVILLE FORMATION

*Name and Definition.*—The Harpersville formation has been named from the small town of Harpersville in Stephens County located 10 miles south of Breckenridge. The formation includes all the strata from the top of the Breckenridge limestone to the top of the Saddle Creek limestone or its equivalent stratum. The Saddle Creek limestone has been mapped by Drake in the Colorado River Valley, and in the northern district it is best described as the limestone forming the top of the tank hill at Cisco. The Saddle Creek bed lies about 60 to 80 feet above Coal Bed No. 6 of Texas reports. Northward the limestone changes to a calcareous sandstone. At its horizon, there is nearly everywhere a prominent escarpment which is easily traceable, so that the formation is everywhere readily mappable. The Harpersville formation as thus defined includes the well-known Waldrip strata of Drake and the Saddle Creek bed of the Colorado coal field. It is easily distinguished by the characteristic carbonaceous and ferruginous shales containing siderite and limonite concretions associated with Coal Bed No. 6 and by its persistent fauna rich in crinoid fragments, large *Chonetes meekianus* and *Myalina* shells which occur chiefly in the shales and limestones above the coal.

*Extent and Thickness.*—The Harpersville formation is easily followed from the north-central part of Young County through Newcastle and old Fort Belknap to Crystal Falls on Clear Fork of the Brazos River and thence south across Stephens County through Breckenridge and Harpersville to Cisco. In the Colorado River Valley south of the Cretaceous sand it appears east of the town of Crosscut and runs southwestward in a belt of outcrop averaging three and one-half miles wide through Grosvenor and Rockwood to Waldrip on the Colorado River. From Waldrip the outcrop narrows to about two miles and strikes due south to the Cretaceous sand belt southwest of Lohn postoffice.

The Harpersville formation has a thickness of 200 to 275 feet throughout its extent, and its outcrop, except at the very southern extremity, is from three to five miles wide.

*Noteworthy Exposures.*—Excellent exposures of the Harpersville formation may be seen along Salt Fork of the Brazos River just south of old Fort Belknap and along the road east of Newcastle in Young County, along Clear Fork of the Brazos River west of Crystal Falls in Stephens County, north of Cisco in Eastland County, along the Brownwood-Coleman road halfway between Bangs and Santa Anna in Brown County, and at Waldrip near the Colorado River in McCulloch County.

*Lithologic Character.*—The Harpersville formation consists of basal beds of coarse thick sandstones, which grade in places to conglomerates; middle beds composed of an alternation of fossiliferous buff and yellow-brown limestones, irregularly bedded calcareous sandstones, carbonaceous and ferruginous shales, and thin beds of coal; and upper beds consisting of a thick, massive, coarse, persistent sandstone capped in many places by a hard gray limestone. The conglomerates of the lower part of the formation are made up of hard subangular pebbles of quartzite and chert a quarter inch to an inch in diameter, in a matrix of brown sand. The limestones are, with the exception of the uppermost, not very persistent and grade laterally into clastic materials. The associated carbonaceous shales in the middle part of the formation are quite persistent and are distinguished by their large and small bright red concretions of hematite, brown siderite, and black hematite nodules. In many places adjacent to the coal beds the shales contain much sulphur and many gypsum crystals. The coal beds are variable in thickness and quality and do not lie at exactly the same horizon in all outcrops, though they are confined to an interval of 80 to 100 feet. In places there are two or more coals in the same section. Except in a few localities, as at Cisco and Newcastle, the coal is shaly, thin, and of inferior quality and is made up of a mass of fragile, poorly preserved plant remains showing fragments of leaves and stems. Most of the shales above the coal are very fossilferous and contain a fauna rich in Pennsylvanian forms. The upper limestone which caps the formation is dense, crystalline, dark gray, fossiliferous, and forms a prominent escarpment. It changes in the north into a massive calcareous sandstone. Locally there are found other limestones in the upper part of the Harpersville, one characterized by its abundant content of *Myalina subquadrata,* and another which is yellow to buff, massive and very fossiliferous.

*Harpersville Formation in the Brazos River Valley.*—In the northern part of the Harpersville outcrop, in the Brazos River Valley, the following members have been differentiated in the course of field studies.

*Harpersville Formation*—

- Saddle Creek limestone member
- Shale and sandstone
- Belknap limestone lentil
- Shale, sandstone, limestone and coal
- Crystal Falls limestone lentil
- Sandstone and shale

The character of the Harpersville formation changes in detail from place to place so that it is difficult to trace individual beds for considerable distances. Three of the limestones are sufficiently persistent to permit the application of stratigraphic names, the bed at the top of the formation and two in the middle portion. The lowermost limestone, which is here named the Crystal Falls lentil, from the town of Crystal Falls in Stephens County, occurs 40 to 80 feet above the base of the formation. It consists of yellow or gray limestone, weathering locally red or purple, with an average thickness of 2 or 3 feet. It is traced north from its outcrop just west of Crystal Falls into Young County but it has not been identified definitely to the south in Eastland County.

The next higher persistent limestone is typically developed in northern Stephens and in Young counties. It is named the Belknap bed, from old Fort Belknap in Young County. It occurs about 60 to 80 feet above the Crystal Falls limestone and 30 to 50 feet below the top of the formation. The Belknap is yellow to buff in color, has a thickness of 2 to 4 feet and is locally very fossiliferous. Typical exposures are found in the vicinity of Newcastle, Young County, where it lies above the workable coal bed. Since the uppermost limestone of the Harpersville is absent in this region, the Belknap has been miscorrelated with it by some workers.

A thin limestone appears in northern Stephens County, about 20 feet above the Belknap, which is made up almost wholly of the shells of *Myalina subquadrata.* This *Myalina* bed is traceable for long distances by the many specimens of this pelecypod which weather out from it.

The topmost limestone of the formation has been identified with the Saddle Creek limestone of Drake in the Colorado coal field, and is one of the most persistent subdivisions of the Harpersville formation. It is much thinner in the Brazos River Valley than in the south, its average thickness being about 1 to 3 feet. North of Stephens County it grades into calcareous sandstone, the escarpment of which has been traced as far as Shackelford County. The Saddle Creek bed is not very fossiliferous. A shale below the Saddle Creek limestone and just above the coal in Eastland and Stephens counties is recognizable on account of the prolific and varied fauna which has been obtained from it.

Northwest of Newcastle in northern Young County and southeastern Clay County the formation is made up largely of thick beds of coarse sand and shale and a few limestones.

*Harpersville Formation in the Colorado River Valley.*—In the Colorado River Valley the Harpersville formation consists of a persistent dark gray limestone at the top, the Saddle Creek member, and beneath it a series of blue clays, carbonaceous and ferruginous shales, containing lenses of sandstone and a few conglomerate beds, and three limestone beds, buff, yellow, and brown in color. The three limestones were designated the Waldrip beds 1, 2, and 3 by Drake. The uppermost of these three limestone layers contains many *Fusulina* and, more rarely, other fossils, so that it is quite easily recognized and possibly is to be correlated with the Belknap limestone of the Brazos River Valley. The coal is black, very thin-bedded, soft, and shaly, and contains a mass of coal plant leaves and fragments.

This coal has been worked in the vicinity of Waldrip and Rockwood but is too thin and of too low a grade to be profitable.

*Detailed Sections.*—Typical sections of the Harpersville formation selected from the work of several geologists are presented below to show the characteristics in the different areas. It will be seen that although the formation contains a greater proportion of sandstone and conglomerate in the northern districts and varies with respect to individual strata in different areas, as a whole the character of the formation is quite uniform throughout the extent of its outcrop across north Texas extending for over 180 miles.

**Section of the Harpersville formation on Graham Ranch, seven miles south of Newcastle, Young County**

**Measured by J. G. Burtt. (U in fig. 13)**

| | Thickness Feet |
|---|---|
| HARPERSVILLE FORMATION— | |
| 15. Sandstone, dark reddish-brown, contains lenses of conglomerate | 25 |
| 14. Limestone, buff, nodular, very fossiliferous. Belknap member | 2 |
| 13. Shale, buff, red, and bright purple | 15 |
| 12. Sandstone, dark red, ferruginous | 30 |
| 11. Sandstone, shaly | 6 |
| 10. Coal, black, thin-bedded, bony | 2 |
| 9. Shale, gray, contains coal plants | 10 |
| 8. Limestone, gray, fossiliferous | 4 |
| 7. Shale | 16 |
| 6. Limestone, nodular, weathers to reddish surface. Crystal Falls member | 2 |
| 5. Shale, gray, sandy, contains lentils of sand | 28 |
| 4. Limestone, gray, weathers to rounded nodules forming upper bench | 6 |
| 3. Sandstone, yellow, soft | 10 |
| 2. Shale, gray to buff | 44 |
| Total thickness | 200 |
| THRIFTY FORMATION— | |
| Limestone, yellow-gray. Breckenridge member | 3 |

**Section of Harpersville formation along Clear Fork of Brazos River west of Crystal Falls, Stephens County**

**Measured by J. Armstrong. (V in fig. 13)**

| | Thickness Feet |
|---|---|
| HARPERSVILLE FORMATION— | |
| 15. Limestone, buff, sandy. Saddle Creek member | 1 |
| 14. Shale, contains lenses of sand and conglomerate | 50 |
| 13. Limestone, yellow-brown, weathered surfaces have the appearance of sunbaked clay, shaly, impure | 1-3 |
| 12. Shale, varicolored, contains lenses of sand | 63 |
| 11. Limestone, light to brownish-gray, nodular, lightest colored where most weathered. Belknap member | 1-4 |
| 10. Shale, gray, contains lenses of thick sand | 20 |

| | | |
|---|---|---|
| 9. | Limestone, gray to yellow, lenticular, contains large oval-shaped concretions of limestone | 5 |
| 8. | Shale, gray and black, contains ferruginous concretions | 5 |
| 7. | Coal | 1 |
| 6. | Shale | 10 |
| 5. | Limestone, yellow, weathers to purplish-red surface | 1 |
| 4. | Shale, contains lenses of sand | 20 |
| 3. | Limestone, yellow, weathers to red and purple shades. Crystal Falls member | 1 |
| 2. | Shale, contains lenses of sand | 48 |
| | Total thickness | 231 |
| THRIFTY FORMATION— | | |
| 1. | Limestone, blue-gray, massive, solid, smooth surfaced, blotched with small rounded darker blotches in matrix of lighter gray limestone, non-fossiliferous. Breckenridge member | 4 |

**Section of Harpersville formation, three miles northwest of Cisco, Eastland County**

**Measured by C. A. Hamill. (W in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| HARPERSVILLE FORMATION— | | |
| 18. | Limestone, dark grayish-blue, medium fine-grained, contains small calcite crystals, sparingly fossiliferous, thick-bedded, forms prominent scarp, weathers to slabs and blocks with rough surfaces. Saddle Creek member | 2 |
| 17. | Shale, gray and blue, sandy, fossiliferous | 45 |
| 16. | Coal, black, soft, poor | 3 |
| 15. | Shale | 25 |
| 14. | Coal, black, medium hard, good grade, mined northeast of Cisco | 2½ |
| 13. | Sandstone, dark brown in upper portion, light brown and gray in lower part, shaly in places | 50 |
| 12. | Shale, gray | 5 |
| 11. | Limestone, gray and brown, weathers to small rounded masses | 1½ |
| 10. | Shale, buff | 26 |
| 9. | Sandstone, buff, calcareous, shaly | 1 |
| 8. | Shale, gray and red, contains iron nodules at top | 17½ |
| 7. | Limestone, blue-gray, thick-bedded, fossiliferous | 5 |
| 6. | Shale, buff | 44 |
| 5. | Limestone, dark gray, weathers to rough pitted surface | 1 |
| 4. | Shale | 21½ |
| 3. | Sandstone and conglomerate, dark gray to brown calcareous, breaks off into large blocks, angular pebble conglomerate at top | 64 |
| 2. | Limestone, dark gray to brown, weathers to small blocks and nodules, characterized everywhere by large quantities of echinoid spines that weather out of the rock | 2 |
| 1. | Shale, yellowish-gray, sandy, contains lentils of sandstone in lower portion | 32 |
| | Total thickness | 348 |
| | Thrifty formation, Breckenridge limestone at base. | |

**Section of Harpersville formation on south side of Coon Mt., section 39, to base of Indian Mt., section 649, two and one-half miles north of Grosvenor, Brown County**

**(X in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| CRETACEOUS— | | |
| 21. | Sandstone, yellow, white, limy, friable. Coon Mt. sandstone of Drake | 22 |
| HARPERSVILLE FORMATION— | | |
| 20. | Limestone, blue-gray, weathers to large pieces. Saddle Creek member | 2 |
| 19. | Shale, gray | 11 |
| 18. | Shale, brilliantly colored, red, green, contains gypsum | 5½ |
| 17. | Shale, red and blue | 11 |
| 16. | Sandstone, gray, thin-bedded | 5 |
| 15. | Shale, varicolored | 26 |
| 14. | Sandstone, light gray | 1 |
| 13. | Shale, light gray, contains siderite nodules | 22 |
| 12. | Shale, blue, contains carbonaceous siderite nodules | 2 |
| 11. | Shale, yellow | 12½ |
| 10. | Sandstone, dark gray | 3 |
| 9. | Shale, varicolored | 12 |
| 8. | Sandstone, light gray | 2 |
| 7. | Shale, varicolored, sandy at base | 16½ |
| 6. | Limestone, dark blue-gray, contains *Fusulina* and other fossils. No. 3 of Drake's Waldrip bed | 11 |
| 5. | Shale, gray and varicolored, contains ferruginous concretions | 47 |
| 4. | Limestone, grayish-yellow, weathers to small yellow pieces and is nodular. No. 2 of Drake's Waldrip bed | 2 |
| 3. | Shale, buff | 14 |
| 2. | Limestone, gray, nodular, very rotten, No. 1 (?) of Drake's Waldrip bed | 1 |
| 1. | Shale, sandy, contains some sandstone | 32 |
| | Total thickness of Harpersville formation | 237½ |

**Section of Harpersville formation, between Rockwood and Bull Creek, McCulloch County**

**Measured by N. F. Drake.[75] (Y in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| 13. | Limestone. Saddle Creek member | 6 |
| 12. | Clay | 50 |
| 11. | Limestone , dark blue, gray, or brown, hard, brittle, contains abundant *Fusulina*. No. 3 of Drake's Waldrip bed | 1 |
| 10. | Clay, sandy, mostly light red | 10 |
| 9. | Sandstone, white, massive | 5 |
| 8. | Clay, shaly, pink to blue | 15 |
| 7. | Limestone, hard, massive, weathers to dark gray. No. 2 of Drake's Waldrip bed | 2 |

[75]Drake, N. F., The Colorado Coal Field: Geol. Surv. Texas, 4th Ann. Rept., p. 413, 1892.

| | | |
|---|---|---|
| 6. | Clay, blue | 30 |
| 5. | Limestone No. 1, white, rotten, impure | 1½ |
| 4. | Clay, blue, with little shaly sandstone near top and siderite nodules in central part | 75 |
| 3. | Coal | 2 |
| 2. | Clay, blue | 50 |
| 1. | Sandstone | 10 |
| | Total thickness | 257½ |

*Paleontology.*—The fauna of the Harpersville formation is determined from a considerable number of collections both in the Brazos and Colorado river valleys.In the north the collections were made chiefly from the Belknap limestone member in the vicinity of Newcastle (localities 55.1 to 55.6 inclusive) and near the town of Loving (loc. 55.11), from beds above and below the Belknap near Breckenridge (loc. 64.1, 65.1, 65.4), from the shale in the upper part of the Harpersville just above the main coal bed near Cisco and Putnam (loc. 88.1 to 88.7, inclusive, 89.4 to 89.6), from the Saddle Creek limestone at Crosscut (105.2) and northwest of Brownwood (112.2, 112.4 to 112.6). These collections represent, then, chiefly the middle and upper parts of the formation. The coal bed near the middle of the formation and the superjacent fossiliferous shale and limestone may be traced without difficulty for long distances along the outcrop, the fauna retaining essentially the same features both in the north, as far as examined, and in the south.

In addition to a somewhat greater prominence of crinoid and bryozoan remains in the Harpersville which include a number of species such as *Cystodictya* n. sp., Fenestellas, Polyporas and Septoporas, which are not common below, the presence of abundant *Chonetes granulifer meekianus,* a robust, alate shell which appears to be associated with the higher part of the Pennsylvanian, and of *Enteletes hemiplicata,* gives an aspect to the fauna which is entirely different from that of the Graham. Among the pelecypods *Myalina subquadrata* and other species of this genus, *Allorisma subcuneatum* and *Pinna peracuta* are the most important. The characteristic group of pelecypods, gastropods and cephalopods which appears to be associated everywhere with the Wewoka group of invertebrates in the different formations where it is found, is here almost entirely lacking.

The following table shows the species which have been identified from the Harpersville formation in Texas.

**Fauna of the Harpersville Formation**

| FAUNA | LOCALITIES | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 55.1 | 55.2 | 55.3 | 55.4 | 55.5 | 55.6 | 55.11 | 64.1 | 65.1 | 65.4 | 88.2 | 88.6 | 89.4 | 105.2 | 112.2 | 112.6 |
| Fusulina sp. | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- |
| Lophophyllum profundum | x | x | ---- | x | ---- | x | x | ---- | ---- | x | ---- | ---- | ---- | ---- | x | x |
| Lophophyllum profund. radicosum | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | x |
| *Campophyllum torquium | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |
| Axophyllum rude | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- |
| Spirorbis sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- |
| Hydreionocrinus sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | x | x | ---- | ---- | ---- |
| Delocrinus hemisphericus | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Delocrinus sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | x | ---- | x | ---- | ---- | ---- |
| Crinoid stems and plates | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Archeocidaris aculeata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Archeocidaris sp. | ---- | x | x | ---- | x | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x |
| Fistulipora nodulifera | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Fistulipora sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | ---- |
| Tabulipora spinulosa ? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Fenestella gracilis | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Fenestella limbata ? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Fenestella perelegans | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Fenestella conradi-compactilis | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| Fenestella trinodata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Fenestella sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | x | ---- | ---- |
| Polypora spinulifera | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Polypora sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- |
| *Septopora biserialis | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Septopora biserialis nervata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Septopora robusta | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Septopora sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | x | ---- | x | ---- | ---- |
| Rhombopora lepidodendroidea | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | x | ---- | x | ---- | ---- | ---- |
| Rhombopora sp. | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Cystodictya n. sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | x | ---- |
| Streblotrypa ulrichi | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | x | ---- |
| Lingula umbonata ? | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| Enteletes hemiplicata | x | x | ---- | x | ---- | ---- | ---- | ---- | ---- | x | x | ---- | ---- | ---- | x | ---- |
| Derbya crassa | ---- | x | ---- | ---- | ---- | ---- | ---- | x | ---- | x | x | ---- | x | ---- | ---- | ---- |
| Derbya cymbula | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Meekella striatocostata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- |
| Chonetes granulifer meekianus | x | x | x | x | x | x | x | ---- | x | x | x | ---- | x | x | x | x |
| Chonetes sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Productus cora | x | x | x | x | ---- | x | x | ---- | x | ---- | x | ---- | ---- | ---- | x | x |
| Productus coloradoensis ? | ---- | x | ---- | ---- | ---- | x | ---- | ---- | x | ---- | ---- | x | ---- | ---- | ---- | ---- |
| Productus pertenuis ? | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| *Productus semireticulatus | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Marginifera splendens | x | x | ---- | ---- | ---- | ---- | ---- | ---- | x | x | ---- | ---- | ---- | ---- | x | ---- |
| Marginifera muricata ? | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Pustula punctata | x | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |
| Pustula nebraskensis | x | x | ---- | ---- | ---- | ---- | ---- | x | ---- | x | x | ---- | ---- | ---- | x | ---- |
| Pustula symmetrica ? | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| *Pugnax uta | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Dielasma bovidens | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- |

*Reported by Drake.*

| FAUNA | LOCALITIES | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 55.1 | 55.2 | 55.3 | 55.4 | 55.5 | 55.6 | 55.11 | 64.1 | 65.1 | 65.4 | 88.2 | 88.6 | 89.4 | 105.2 | 112.2 | 112.6 |
| Spirifer cameratus | x | x | x | x | x | x | x | | x | | x | | x | x | x | x |
| Ambocoelia planoconvexa | x | | | | | | | | | | | | | | | |
| Spiriferina kentuckiensis | x | x | | | | | | | x | | | | | | x | x |
| Hustedia mormoni | | | | | | | | | | x | x | | | | | |
| Composita subtilita | | x | | | x | | | | | x | x | | x | | | |
| Anthraconeilo taffiana | | | | | | | | | | | | | ? | | | |
| Pinna peracuta | x | x | | | | | | | x | | | | x | | | |
| Myalina recurvirostris | | | | | | | | x | | | | x | | | | |
| Myalina kansasensis ? | | | | | | | | | | | | | x | | | |
| Myalina subquadrata | | | | | | | | x | x | | | | x | | | |
| Myalina sp. | | x | | | | | | x | | | | | | | | |
| Streblopteria hertzeri | | | | | | | | | | | | | | | | x |
| Aviculopecten sp. | | | | | | | | | | | | x | | | | |
| *Aviculopecten occidentalis | | | | | | | | | | | | | | | | |
| Deltopecten vanvleeti | x | | | | | | | | | | | | | | | x |
| Allorisma subcuneatum | | | | | | x | | | | | x | | x | | x | x |
| Astartella concentrica | | | | | | | | | | | | x | | | | |
| Bellerophon sp. | x | | | | | | | | | | | | | | | |
| Euphemus carbonarius | | | | | | | | | | | | x | | | | |
| Pharkidonotus percarinatus | | | | | | | | | | | | | x | | | |
| Worthenia tabulata | | | | | | | | | | | | x | | | | |
| Phanerotrema grayvillense | | | | | | | | | | | | | x | | | |
| Schizostoma catilloides | | | | | | | | | | | | | | | x | |
| Plagioglypta sp. | | | | | | | | | | | | x | | | | |
| Orthoceras sp. | | | | | | | | | | | | x | | | | |
| Griffithides scitulus ? | | | | | | | | | x | | | | | | | |

*Correlation.*—Since the Harpersville formation follows without break the strata included in the Thrifty formation, and since the fauna so far as known is evidently a typical Upper Pennsylvanian assemblage, the writers believe that the formation may be correlated approximately with the Douglas and perhaps some portion of the Shawnee formations of the Kansas section.

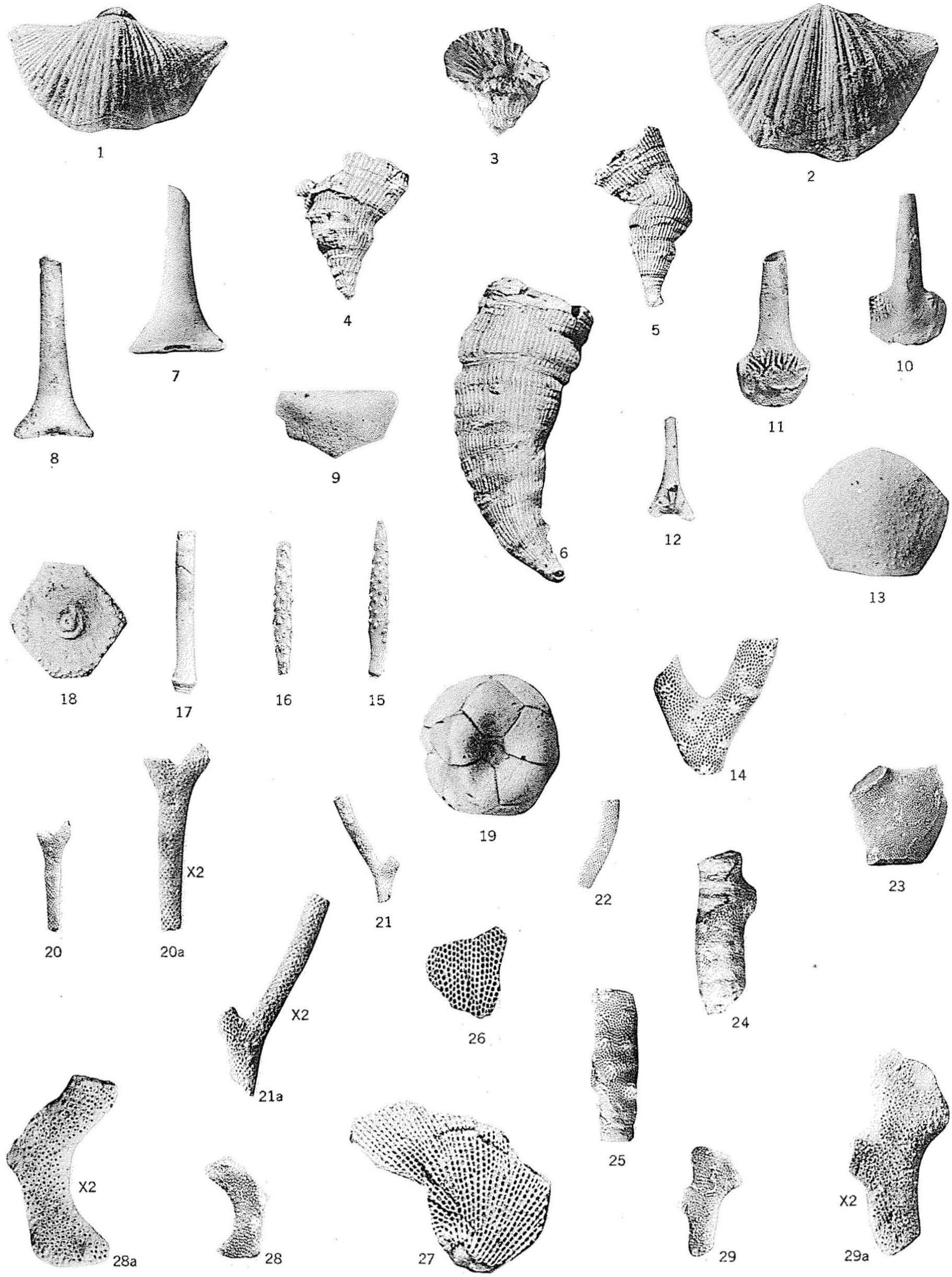
Dr. David White,[76] in discussing the correlation of fossil plant-bearing beds associated with the coal in the Harpersville at Newcastle, identified this horizon with a stage in the Monongahela of the Appalachian trough near the top of the Pennsylvanian, a correlation with which the invertebrates and the other stratigraphic evidence which has been obtained agree.

## PUEBLO FORMATION

*Name and Definition.*—The Pueblo formation has been named from the town of Pueblo, located on the M., K. & T. Railroad in the northeast corner of Callahan County, where the strata are typically exposed along the valley of Battle Creek. This formation comprises all the strata from the top of

**Reported by Drake.*

[76]Bull. Am. Assn. Petro. Geol., vol. 3, pp. 148, 149, 1919.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## HARPERSVILLE FOSSILS

Figures 1, 2. *Spirifer cameratus*, brachial and pedicle valves of characteristic specimens from the upper part of the Harpersville west of Thrifty (112.2).

Figures 3, 4, 5, 6. *Lophophyllum profundum*. Upper part of Harpersville southwest of Grosvenor (112.6).

Figures 7, 8. *Delocrinus* sp., spines of a robust species. Upper part of Harpersville southwest of Grosvenor (112.6).

Figure 9. *Delocrinus* sp., radial plate, possibly belonging to same species as Figures 7 and 8. Upper part of Harpersville west of Thrifty (112.2).

Figures 10, 11. *Hydreionocrinus* sp., outer and inner views of two characteristic spine-bearing plates. Belknap limestone, northeast of Newcastle (55.2).

Figure 12. *Delocrinus* sp., a small spine. Belknap limestone northeast of Newcastle (55.1).

Figure 13. *Ulocrinus occidentalis*. Upper part of Harpersville limestone southwest of Grosvenor (112.6).

Figure 14. *Fistulipora* sp. Upper part of Harpersville west of Thrifty (112.2).

Figures 15, 16. *Archeocidaris aculeata*, two small ornamented sea urchin spine. Upper part of Harpersville west of Thrifty (112.2).

Figure 17. *Archeocidaris* sp. Upper part of Harpersville west of Thrifty (112.2).

Figure 18. *Archeocidaris* sp., a plate. Belknap limestone northeast of Newcastle (55.2).

Figure 19. *Delocrinus hemisphericus*, calyx bottom view. Belknap limestone northeast of Newcastle (55.1).

Figures 20, 20a, 21, 21a. *Rhombopora lepidodendroidea*, characteristic specimens from the upper part of the Harpersville west of Thrifty (112.2). Figure 22, same, from southwest of Grosvenor (112.6).

Figure 23. *Tabulipora* sp. Upper part of Harpersville west of Thrifty (112.2).

Figures 24, 25. *Fistulipora nodulifera*, two characteristic specimens from the upper part of the Harpersville west of Thrifty, encrusting crinoid stems (112.2).

Figures 26, 27. *Polypora spinulifera*, two specimens showing reverse and obverse sides from upper part of Harpersville, from west of Thrifty and southwest of Grosvenor, respectively (112.2), (112.6).

Figures 28, 28a, 29, 29a. *Cystodictya* n. sp., from upper part of Harpersville west of Thrifty (112.2).

## HARPERSVILLE FOSSILS

Figures 1, 12. *Productus cora*, characteristic specimens from the Belknap limestone northeast of Newcastle (55.1) and (55.2), respectively.

Figures 2, 3, 4, 5. *Chonetes meekianus*, a very robust species of the *C. granulifer* type with pronounced alate form. Characteristic specimens showing respectively a pedicle valve, a brachial valve, interior of pedicle valve and interior of brachial valve. Figure 3 is from the upper Harpersville west of Thrifty (112.2), the remaining specimens from a similar horizon northwest of Cisco (88.3).

Figure 6. *Pustula punctata*, a rather poorly preserved specimen from the Belknap limestone northeast of Newcastle (55.2).

Figures 7, 8, 9, 10. *Spiriferina kentuckiensis*, characteristic specimens showing variation in examples from upper part of Harpersville west of Thrifty (112.2).

Figure 11. *Aviculopecten hertzeri*, a well preserved specimen from the upper Harpersville southwest of Thrifty (112.6).

Figure 13. *Aviculopecten vanvleeti.* Upper Harpersville southwest of Grosvenor (112.6).

Figures 14, 15. *Hustedia mormoni*, typical but somewhat crushed examples from the upper Harpersville northwest of Cisco (88.3).

Figure 16. *Orthoceras* sp. Upper part of Harpersville west of Thrifty (112.2).

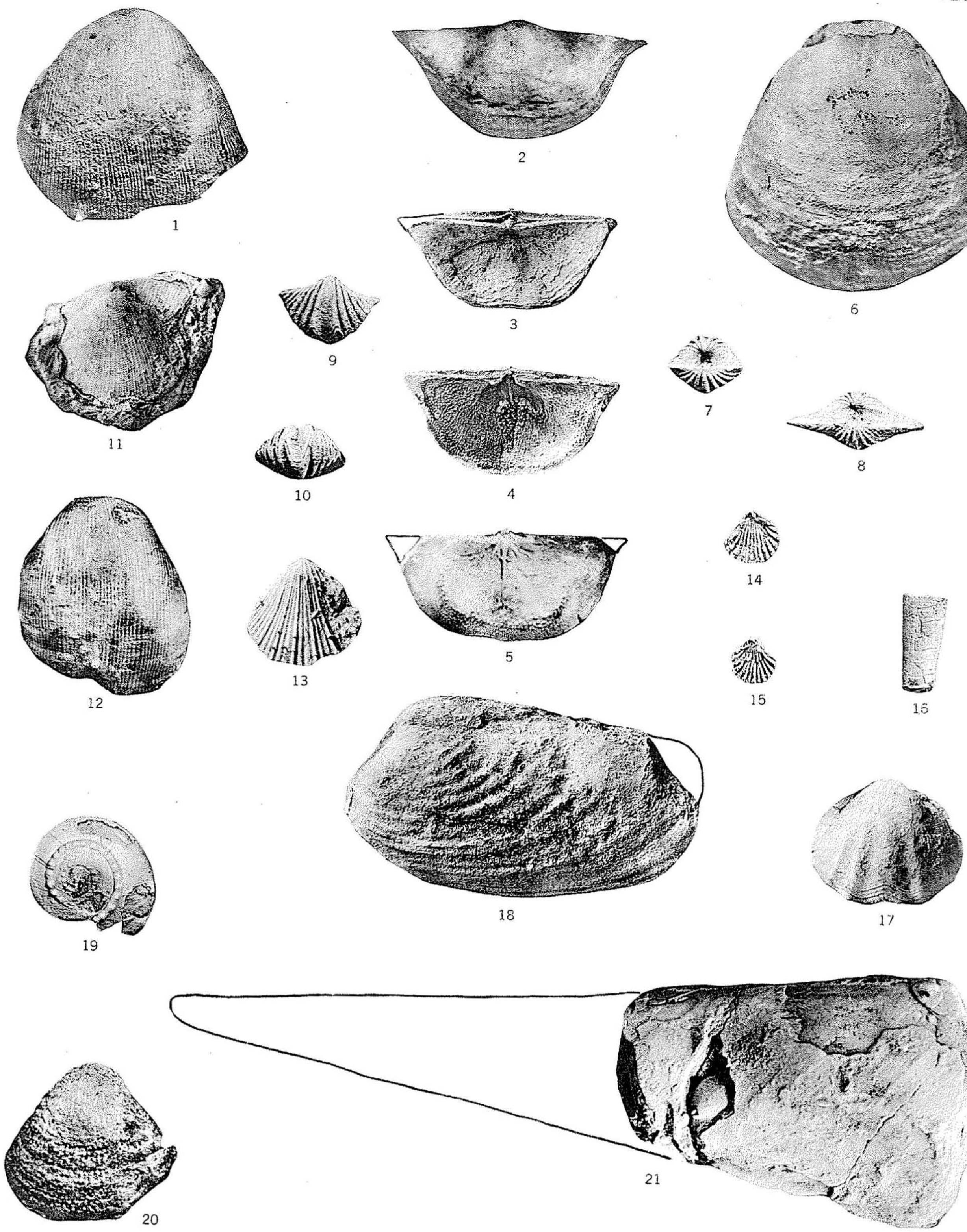
Figure 17. *Enteletes hemiplicata*, a characteristic specimen from the Belknap limestone northeast of Newcastle (55.1).

Figure 18. *Allorisma subcuneatum.* Upper part of Harpersville southwest of Grosvenor (112.6).

Figure 19. *Trepospira depressa.* Upper part of Harpersville west of Thrifty (112.2).

Figure 20. *Pustula nebraskensis*, a characteristic specimen from the Belknap limestone northeast of Newcastle (55.1).

Figure 21. *Pinna peracuta*, portion of a specimen from the Belknap limestone northeast of Newcastle (55.2).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the Saddle Creek limestone or its equivalents to the top of the Camp Colorado limestone which outcrops at old Fort Camp Colorado in Coleman County and on each side of Salt Creek near Pueblo. It lies conformably upon the Harpersville formation and is overlain by the basal clays of the Moran strata. Limited as it is by the prominent and persistent Camp Colorado and Saddle Creek limestones, the Pueblo formation is one of the easiest of all of the Cisco units to identify and to trace in mapping.

*Extent and Thickness.*—The Pueblo formation has been mapped from Woodson in the southwest corner of Throckmorton County southward through Eolian to the southwest corner of Stephens County. In the northeast corner of Callahan and northwest corner of Eastland counties it has a very tortuous outcrop due to the gentle dip of the strata and the indentation of its beds by the numerous tributaries of Battle Creek, so that its outcrop follows the bottom of the valley for many miles back into the overlying formation. From the northeast corner of Eastland County its outcrop runs southward just west of the town of Cisco to Nimrod where it passes beneath the Cretaceous overlap. The Pueblo formation may be seen again in the northwest corner of Brown County west of the town of Crosscut. From there it has been mapped in a fairly uniform belt, having an average width of two and one-half miles, southwest through Camp Colorado to the Santa Fe Railroad two miles west of Santa Anna and thence southwest to the Colorado River west of Waldrip. North of the Cretaceous overlap it has a quite uniform thickness of 150 to 175 feet. In the Colorado River Valley it has about the same average thickness, although one measurement near Santa Anna showed a thickness of 205 feet.

*Noteworthy Exposures.*—The formation is in most places well exposed at almost any point along the line of outcrop, since the Camp Colorado limestone is a good escarpment marker and the belt of outcrop is covered with but little vegetation. It has been especially studied in the valley of Battle Creek near Pueblo, along the roads northwest of Cisco, at the type locality east of old Camp Colorado in Coleman County, and on the Brownwood-Coleman road west of Santa Anna.

*Lithologic Character.*—The Pueblo formation is one of the simplest and most uniform of the Cisco group. It consists of a massive, fossiliferous limestone at the top, succeeded downward by a sandy shale 75 to 125 feet thick, containing a few thin beds of calcareous shale, a middle bed of limestone, and a lower shale containing a few lenses of calcareous sandstone and rarely a thin yellow limestone. The limestone at the top is a hard, impure, buff to gray rock which in places contains much dark colored chert. It weathers in small yellow chips with rounded, cracked surfaces. The shales are red, grayish-pink, and buff tinged with purple and red. The upper layers are commonly sandy and contain thin layers of calcareous sandstone. The lower shales are less argillaceous, more calcareous, and in places are characterized by the presence of iron concretions. The shales are not, so far as observed, fossiliferous, but fossils are found in the limestones. Those in the uppermost limestone are locally abundant.

*Subdivisions.*—The subdivisions of the Pueblo formation which have been made in the north and south districts are as follows:

| **Colorado River Valley** | **Brazos River Valley** |
|---|---|
| Camp Colorado limestone | Camp Colorado limestone |
| Shale (Bed 13 of Drake) | Shale |
| Stockwether limestone | Eolian limestone |
| Camp Creek shale[77] | Shale |

In the northern part of the area the shale beneath the Eolian limestone member has an average thickness of about 50 to 60 feet. It contains much reddish-brown sandstone. The Eolian member is blue or bluish-gray, hard, crystalline and weathers in large, rectangular, yellowish-brown blocks. Its average thickness is but one foot and it does not form a prominent or persistent escarpment. The upper shale is 75 to 125 feet thick and, like the lower division, contains much sand. The Camp Colorado limestone has an average thickness of 3 to 6 feet. It forms a prominent, very persistent escarpment which is characteristically bare of trees. Chert nodules are common at this horizon northwest of Cisco. The bed contains fossils at nearly all points.

In the Colorado River Valley the Camp Colorado limestone is similar to the bed described farther north. The Stockwether limestone named by Drake in this region, may be equivalent to the Eolian limestone of the northern area but this is uncertain. Drake[78] states: "Most of the bed (Camp Colorado) by its containing many black chert nodules, is made distinct from the Stockwether bed, in which chert is of a yellow color; as it is distinguished from the near overlying beds, because those beds do not contain chert nodules."

The following sections show the uniform character of the Pueblo formation along the outcrop. Following the Harpersville epoch, during which a continuous change in the shorelines caused an alternation of beach deposits and non-marine peat beds, there was evidently a quiescent epoch during which a shallow sea expanded over the entire north Texas area, supported an abundant marine life, and received deposits of muds and at rare intervals deposits of sands and calcareous oozes in a uniform manner.

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[77]Detailed mapping of the western part of Brown County has shown that the Coon Mountain sandstone bed, No. 11 of Drake's section, is largely Cretaceous sands overlapping several of the Pennsylvanian beds. Therefore it has been omitted from this list.

[78]Drake, N. F., loc. cit., p. 418.

**Section of the Pueblo formation in valley of Sandy Creek, six miles east of Moran, Block 7, T. & P. R. R. Survey**
**Measured by P. L. Applin. (Z in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUEBLO FORMATION— | | |
| 16. | Limestone, blue-gray, hard, crystalline, weathers to yellow-brown or buff and to small blocks and chips; forms the top of a continuous escarpment about 75 feet high | 6 |
| 15. | Shale | 2 |
| 14. | Sandstone, brown | 1 |
| 13. | Shale | 17 |
| 12. | Sandstone, brown | 1 |
| 11. | Shale | 77 |
| 10. | Sandstone, red | 2 |
| 9. | Shale | 5 |
| 8. | Limestone, blue, crystalline, hard, weathers to yellow-brown, exposed on surface as large rectangular blocks and fragments; does not form distinctive escarpment, and ledge likely to be intermittent rather than continuous. Eolian member | 1 |
| 7. | Shale | 3 |
| 6. | Sandstone, red | 2 |
| 5. | Shale | 6 |
| 4. | Sandstone, brown | 1 |
| 3. | Shale | 5 |
| 2. | Sandstone, brown | 2 |
| 1. | Shale | 32 |
| | Total thickness | 163 |

HARPERSVILLE FORMATION—

Limestone, gray, crystalline, massive, forms high escarpment. Saddle Creek member.

**Section of Pueblo formation along Putnam-Cisco road, west of Cisco, Eastland County**
**Measured by C. A. Hammill. (A in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUEBLO FORMATION— | | |
| 14. | Limestone, gray, heavy, massive, fossiliferous, weathers into rectangular yellowish blocks. Camp Colorado member | 4 |
| 15. | Shale, buff and reddish | 16 |
| 12. | Sandstone, dark brown, calcareous, weathers into large slabs | 1 |
| 11. | Shale, yellow | 8 |
| 10. | Limestone, yellowish-gray, thin, impure, weathers into small pieces | ½ |
| 9. | Shale, variegated, sandy in places | 35 |
| 8. | Sandstone, red, ferruginous, calcareous, non-fossiliferous, platy | 1 |
| 7. | Shale, buff | 12 |
| 6. | Sandstone, brown sandy shale changing to massive sandstone | 2 |
| 5. | Shale, buff | 13 |
| 4. | Limestone, blue-gray, fossiliferous, forms low escarpment one mile west of Cisco. Eolian member | 1 |
| 3. | Shale, variegated, sandy in places | 50 |
| 2. | Sandstone, light gray, calcareous | 1 |
| 1. | Shale, brown (Saddle Creek limestone at base). | 10 |
| | Total thickness | 154½ |

**Section of Pueblo formation along Cross Plains-Crosscut road from four and one-half to five miles south of Cross Plains**

**(B in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUEBLO FORMATION— | | |
| 13. | Limestone, dark pinkish-blue, hard, crystalline, weathers to pinkish-gray and yellow-gray, rough nodular pieces having rough cracked surfaces, forms low scarp. Camp Colorado member | 3 |
| 12. | Shale, buff, sandy | 5 |
| 11. | Sandstone, reddish-brown, calcareous | 2 |
| 10. | Shale, buff, sandy | 6 |
| 9. | Limestone, pink or red, rough, impure, sandy, weathers to small nodules | 1 |
| 8. | Shale, pink and purple clay shale, contains hematitic nodules | 11 |
| 7. | Sandstone, reddish-brown, fine-grained, lenticular | 4 |
| 6. | Shale, yellow, pink, and blue, soft, clayey | 35 |
| 5. | Limestone, gray, hard, weathers to small rounded pieces that contain much white and pink chert in the form of nodules; the chert is fossiliferous and contains poorly preserved corals, crinoids, and brachiopods. Stockwether member | 2 |
| 4. | Shale, varicolored, contains occasional thin sandy layer | 66 |
| 3. | Sandstone, reddish-brown, conglomeratic | 1 |
| 2. | Sandstone, thin-bedded, impure, calcareous, approaches a limestone | 1 |
| 1. | Shale, yellow, contains near centre a lense of dark brown sandstone (Saddle Creek limestone at base). | 23 |
| | Total thickness | 160 |

**Section of Pueblo formation along G. C. & S. F. R. R. from one-half to three miles east of Santa Anna**

**Measured by P. L. Applin. (C in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUEBLO FORMATION— | | |
| 12. | Limestone, yellow, gray, hard, fossiliferous. Camp Colorado member | 2 |
| 11. | Shale, red and pinkish-gray | 68 |
| 10. | Limestone, gray, weathers to thin plates | 1 |
| 9. | Shale, covered by slump | 14 |
| 8. | Sandstone, gray, calcareous | 5 |
| 7. | Shale | 10 |
| 6. | Limestone, gray, impure, weathers to thin plates. Stockwether member (?) | 1 |
| 5. | Shale | 39 |
| 4. | Limestone, blue-gray, weathers to small flat chips | 2 |
| 3. | Shale, yellow, buff, sandy | 38 |
| 2. | Sandstone, brown, calcareous | 5 |
| 1. | Shale, yellow and red (Saddle Creek limestone at base). | 20 |
| | Total thickness | 205 |

*Paleontology.*—The fossils from the Pueblo formation can not be reported in detail, for collections were not made systematically even in the region where field work was done. A number of miscellaneous collections of a few common, more or less well preserved fossils and fossil fragments were made by geologists during the course of mapping, but for the most part these have not been preserved or catalogued and are not available for the present report.

The following list of species which have been observed from the Pueblo indicates the general faunal character of the division, which is not materially different from that of the subjacent Harpersville formation.

**Fauna of the Pueblo Formation**

| FAUNA | LOCALITIES 88.8 | 88.9 | 88.10 | 88.11 | 112.8 |
|---|---|---|---|---|---|
| Lophophyllum profundum | | | | | x |
| Lophophyllum profundum radicosum | | | | | x |
| *Campophyllum torquium | | | | | |
| Axophyllum rude | | | | | ? |
| Sponge sp. | x | | | | |
| Crinoid stems | x | x | x | x | x |
| Hydreionocrinus sp. | x | | x | | x |
| Archeocidaris sp. | x | | | | |
| Fistulipora nodulifera ? | x | | | | x |
| Fenestella sp. | x | | | | |
| *Septopora biserialis | | | | | |
| Orbiculoidea sp. | | | x | | |
| Derbya crassa | | | | | x |
| Derbya cymbula | x | | x | | |
| Enteletes hemiplicata | | | | | x |
| Chonetes granulifer meekianus | | | | | x |
| Productus semireticulatus var. | x | | | | |
| *Productus costatus | | | | | |
| Marginifera splendens | | | | | x |
| Marginifera lasallensis | | | | | ? |
| Pustula nebraskensis | | | x | | |
| Pugnax osagensis | | | | | x |
| *Spiriferina kentuckiensis | | | | | |
| Dielasma bovidens | | | | | x |
| *Composita subtilita | | | | | x |
| Myalina recurvirostris | | | | x | |
| Myalina subquadrata | | | x | | |
| Myalina kansasensis | x | | | | |
| Myalina sp. | | x | | | |
| Schizodus wheeleri | | | x | | |
| Chaenomya leavenworthensis | | | x | | |
| Pinna peracuta | | | | | x |
| Aviculopecten sp. | | | x | | |
| Allorisma subcuneatum | | | x | | |
| Astartella concentrica | x | | | | |
| Bellerophon sp. | | x | | | |
| Pharkidonotus percarinatus | ? | | | | |
| Euomphalus sp. | | x | | | |
| Schizostoma catilloides | x | | | | |

| FAUNA | LOCALITIES 88.8 | 88.9 | 88.10 | 88.11 | 112.8 |
|---|---|---|---|---|---|
| Worthenia tabulata | x | | | | |
| Naticopsis sp. | | x | | | |
| *Platyceras parvum | | | | | |
| Murchisonia sp., 1, 2 | | x | | | |
| Sphaerodoma sp. aff., S. intercalaris | | x | | | |
| Orthoceras sp. | x | | | | |
| Phillipsia sangamonensis | | | | | ? |

*Correlation.*—In so far as it is possible to make a correlation with the distant section in the north part of the Mid-Continent Region, the Pueblo formation is probably equivalent in time to some portion of the Shawnee formation.

## MORAN FORMATION

*Name and Definition.*—The Moran formation has been named from the town of Moran, in Shackelford County, where it is typically and excellently exposed in the hillside west of the town, and forms the escarpments around the Moran oil field.

The formation lies conformably upon the Camp Colorado limestone and is overlain conformably by the Putnam formation. It is defined to include all the strata from the top of the Camp Colorado limestone to the top of the Sedwick limestone, which forms the highest yellow ledge in the Moran oil field and outcrops west of the town of Sedwick, or its equivalent yellow limestone of the Colorado River Valley. The formation is characterized nearly everywhere in the northern district by three thin, bright yellow, persistent limestone beds at its top, the middle one of which contains in places great numbers of beautiful white, silicified, small, coiled gastropod casts, so that in most places it is easily recognized.

*Extent and Thickness.*—The Moran formation has been mapped in a continuous outcrop from Salt Fork of the Brazos River at the Shackelford-Stephens county line southward through Moran to Dothan, on the T. & P. Railroad. Three miles south of Dothan it is buried beneath the Cretaceous sand. In the northwest corner of Shackelford County its outcrop has been cut back southward into the overlying Putnam formation for nearly 10 miles by the erosion of Deep Creek, forming a very dendritic, irregularly shaped exposure along Deep Creek Valley and its tributaries. A small patch of the formation is exposed two and one-half miles northwest of Nimrod in Eastland County. From Cross Plains on the south side of the Cretaceous deposits, the formation has been mapped southwestward through Santa Anna to the Colorado River about six miles west of Waldrip.

The Moran formation has a fairly uniform thickness throughout its extent of 150 to 200 feet. Its thickness increases somewhat in the extreme northern end of its outcrop, where there are greater thicknesses of sandstones within its strata; and it thins a little in the Colorado River Valley.

*Noteworthy Exposures.*—The upper beds of the Moran formation are perhaps best seen along the escarpments around the Moran oil field and northwest of Hart School on the Putnam-Moran road. The basal beds are excellently exposed along the Texas and Pacific Railroad tracks near Dothan. There are also excellent exposures three miles south of Cross Plains, Callahan County, and in the valleys west of Burkett, in Coleman County. The most accessible place near the Colorado River Valley is along the Gulf, Colorado and Santa Fe Railroad tracks at Santa Anna and along the escarpments south of town.

*Lithologic Character.*—The Moran formation is of quite uniform character throughout its outcrop. Its upper portion consists of a series of thin, bright yellow, fossiliferous limestones interbedded with yellow, gray and red calcareous shales. The limestones do not commonly form prominent scarps and for this reason the top of the formation is less clearly marked topographically and is less quickly recognized in the field than any of the other north Texas divisions. The lower half is made up of yellow, red, and gray shales in places sandy and containing lentils of gray, impure, sandy limestone and thin, yellow, brown, calcareous, fossiliferous sandstones. In the Colorado River Valley the lower beds are thinner, less sandy, and contain thick yellow limestone lentils. It has not been proved that the upper bright yellow limestones are exactly the same beds in separated districts. It is quite likely that they are a series of lentils that come in and play out laterally, although confined to a thin stratigraphic interval. Nearly everywhere three or four of the thin limestones are present in the section, and the yellow limestones at Moran have actually been traced from Putnam nearly to Hubbard Creek, over 25 miles distant.

The limestones are fine-textured, ferruginous, in many places fossiliferous and thin-bedded, and make excellent horizon markers for mapping structure. The sandstones are thin, dark brown, fine-grained, ferruginous, many of them fossiliferous, irregularly bedded, and changing laterally into brown limestone or pinching out. Certain layers contain many large *Allorisma subcuneata* and large *Myalina* shells. The shales of the upper strata are commonly yellow, red, and green; the lower shales are gray, blue, and yellow and many contain ferruginous concretions and carry a few fossils. The shells commonly belong to the small types, such as bryozoans, Derbyas, crinoids, rarely Productids of the *semireticulatus* type, and Pinnas. The faunas are nowhere large and varied like those in the lower Cisco and Strawn beds.

*Subdivisions.*—The subdivisions of the Moran formation, which have been made in part by Drake in the Colorado coal field, and in part during the course of the field work upon which this report is based, may be indicated as follows:

| Colorado River Valley | | Brazos River Valley | |
|---|---|---|---|
| Sedwick limestone | 15-25 | Sedwick limestone | 60 |
| Santa Anna shale | 25-75 | Shale with lenses of sandstone | 100 |
| Horse Creek limestone | 5-15 | Dothan limestone | 4 |
| Watts Creek shale | 50-75 | Sandy shale | 60 |

Because of the lack of opportunity for detailed stratigraphic study of these strata it has been impossible to correlate the divisions recognized in the Colorado River Valley with the strata in the section along the Texas and Pacific Railroad. Therefore, the names first given in the Colorado River region can not be applied definitely to those in the north. It is known, however, that the groups of beds which are listed in both sections are equivalent to each other as a whole, for the Camp Colorado and the Coleman Junction limestones, below and above, respectively, have been identified in both areas with some certainty.

The subdivisions of the Moran in the Colorado River Valley have not been traced definitely into the Brazos River Valley, but the general character of the upper and lower parts of the formation is similar. The Watts Creek bed as seen in the southern area is a bluish to reddish sandy shale with a thickness of about 50 to 75 feet. Locally there are thin beds and lenses of sandstone. The lowermost strata of the Moran in the Brazos region are similar in character but contain locally a number of very thin sandy limestones. Since the equivalent of the Horse Creek limestone has not definitely been recognized in the north, the thickness of the Watts Creek in the latter area can not be indicated with exactness.

The Horse Creek limestone, named from eastern Coleman County, is described at its type locality as a hard, massive, light gray bed, 5 to 15 feet in thickness. It is approximately equivalent in stratigraphic position to the Dothan limestone of the Brazos River section, a prominent bed in the lower one-third of the formation which has been mapped for a number of miles in the vicinity of Dothan. It is not certain, however, that the Dothan bed of the north is a continuation of the Horse Creek bed.

The application of the name Horse Creek to this member is of doubtful validity, since Drake appears to have given the same term to a subdivision of the Strawn. Since, however, detailed study of the section in the Colorado area has not been made, it has not seemed desirable to substitute a new name.

The bluish and reddish sandy shale above the Horse Creek division of the Moran formation in the Colorado River Valley has been designated the Santa Anna bed by Drake. It is for the most part very poorly exposed but may be observed in the buttes at the town of Santa Anna and is represented at various points to the north where exposures are found. Its average thickness in the region of its type locality is 25 to 75 feet. Northward the Moran formation appears to be somewhat thicker than in the south and the shale above the Dothan, a part of which is without doubt equivalent to the Santa Anna bed, is greater in thickness. As observed in the section along the Texas and Pacific Railroad east of Dothan, the shale interval between the top of the Dothan limestone and the base of the limestone beds at the top of the formation is approximately 100 feet. Also, it is possible that a part of the strata included with this upper division of limestones in the north is not all represented in the limestone and shale division at the top of the formation in the Colorado River Valley.

In the southern area of Pennsylvanian, 15 to 25 feet of limestones interstratified with shale, lying at the top of the Moran formation as here defined, were designated by Drake as "Bed No. 18," this being the eighteenth subdivision of the Cisco differentiated by him, measured upward from the base. In the north this division of limestones is approximately 60 feet thick.

The persistent and prominent limestone at the top of the Moran was designated by the name Sedwick in the course of the field work, but it appears desirable to apply a geographic term to the entire limestone division in the formation above the Santa Anna bed. The Sedwick member may then be defined to include the series of thin yellow limestones with interbedded shales which lies at the summit of the Moran formation. The upper bed of the Sedwick is 1 to 2 feet in thickness. It is a rather dirty yellow color, contains numerous small stringers of calcite, and locally contains rather numerous fossils and is more or less cherty.

The next lower bed in the Sedwick member, designated in the field work as the Hart School bed, occurs 3 to 12 feet below the top limestone. It is 2 to 6 feet in thickness and is characterized by an abundance of small silicified gastropods and other fossils.

*Detailed Sections.*—The character of the Moran formation is well shown in the following stratigraphic sections measured at various points along the outcrop.

**Section of upper part of Moran formation, Moran oil field, Shackelford County**

**Measured by P. L. Applin. (D in fig. 13)**

| | Thickness Feet |
|---|---|
| MORAN FORMATION— | |
| Sedwick Member | |
| 11. Limestone, yellow, fragmentary, thin, contains numerous stringers of calcite | 1 |
| 10. Shale, yellow, and gray | 11 |
| 9. Limestone, bright yellow, evenly bedded, contains silicified fossil casts | 2 |
| 8. Shale, yellow, concretionary, not generally exposed | 19 |
| 7. Limestone, grayish-yellow, concretionary, not generally exposed | 1 |
| 6. Shale | 1 |
| 5. Limestone, yellow, weathers to rounded boulder-shaped pieces | 2 |
| Shale Member | |
| 4. Shale | 10 |
| 3. Sand, reddish-brown, calcareous | 3 |
| 2. Shale | 12 |
| 1. Sandstone, red, calcareous, breaks into angular pieces | 1 |
| Total thickness | 63 |

**Section of upper part of Moran formation along valley northwest of Hart School sec. 2969, T. E. & L. Survey, about six miles north of Putnam**

**Measured by P. L. Applin. (E in fig. 13)**

| | Thickness Feet |
|---|---|
| MORAN FORMATION— | |
| Sedwick Member | |
| 10. Limestone, dirty yellow, contains few fossil fragments and much calcite, weathers to small platy fragments | 2 |
| 9. Shale, yellow | 3 |
| 8. Limestone, yellow, contains many gastropods usually silicified, outcrops on road at Hart School | 3 |
| 7. Shale, white and gray | 19 |
| 6. Limestone, bright yellow, crystalline, mottled red in places, weathers to angular fragments | 2 |
| 5. Shale, yellow | 1 |
| 4. Limestone, blue, hard, crystalline, yellow stains on weathered surface | 2 |
| 3. Limestone, shaly | 4 |
| 2. Shale, yellow, sandy | 3 |
| 1. Limestone and sandstone, rock varies from hard, blue, crystalline limestone through sandy limestone to brown sandstone | 3 |
| Total thickness | 42 |

**Section of Moran formation along T. & P. R. R. from Putnam to the outcrop of Camp Colorado limestone east of Dothan, Callahan County**

**Measured by C. A. Hammill. (F in fig. 13)**

| | Thickness Feet |
|---|---|
| MORAN FORMATION— | |
| Sedwick Member | |
| 20. Limestone, bright yellow, platy | 1 |
| 19. Shale, red and yellow | 8 |
| 18. Limestone, bright yellow, hard, impure, weathers into small pieces | 6 |
| Shale Member | |
| 17. Shale, yellow | ½ |
| 16. Sandstone, yellowish-gray | 1 |
| 15. Shale | 2 |
| 14. Sandstone, yellowish-gray | 2 |
| 13. Shale | 3 |
| 12. Sandstone, yellowish-gray | 2 |
| 11. Shale | 39 |
| 10. Sandstone, gray, calcareous, fossiliferous | 2 |
| 9. Shale | 25 |
| 8. Sandstone, calcareous | 1 |
| 7. Shale | 9 |
| Dothan Member | |
| 6. Limestone, gray, sandy, impure, outcrops along railroad tracks west of Dothan | 3 |
| Shale Member | |
| 5. Shale, buff | 27 |
| 4. Limestone, yellowish-gray, thin, platy, fossils | 6 |
| 3. Shale, yellowish | 6½ |
| 2. Limestone, yellow-gray, thin, rotten, fossils | ½ |
| 1. Shale, yellow | 5 |
| (Camp Colorado limestone at base). | |
| Total thickness | 149½ |

**Section of the Moran formation along an east-west line, four miles south of Cross Plains**

**Measured by C. A. Hammill. (G in fig 13)**

| | Thickness Feet |
|---|---|
| MORAN FORMATION— | |
| Sedwick Member | |
| 21. Limestone, yellowish, sandy, weathers platy and rough, contains *Myalina* and little chert | 2 |
| 20. Shale, yellow | 10½ |
| 19. Limestone ,yellow, platy, shaly, fossiliferous, contains many gastropods and silica | 2 |
| Santa Anna Member | |
| 18. Shale, brown | 2 |
| 17. Limestone, bright yellow, shaly, and platy | 1 |
| 16. Shale, yellow | 15½ |
| 15. Sandstone, light gray, very friable, calcareous, weathers to angular blocks | 1 |
| 14. Shale, yellow | 11 |
| 13. Sandstone, dark brown, weathers to small rounded pieces | ½ |
| 12. Shale, yellow | 24 |
| Horse Creek Member (?) | |
| 11. Limestone, white, hard, weathers yellow, uneven texture, blotches of coarse-grained crystals set in fine-grained matrix | 8 |
| 10. Shale, red and yellow | 14 |
| 9. Limestone, red, sandy, thin, fossiliferous, contains *Myalina* and *Aviculopecten* shells | ½ |
| 8. Shale, red | 6 |
| 7. Sandstone, calcareous, fossiliferous, many *Myalina subcuneata* | 1 |
| 6. Shale, red and yellow | 14 |
| 5. Limestone, gray, fossils, fragments of crinoids, *Pinna peracuta*, and Productids | 3 |
| Watts Creek Member | |
| 4. Shale, red and yellow, having lentils of dark gray limestone weathering dark brown, contains nodules formed around gastropods and *Fusulina* | 13 |
| 3. Sandstone, dark reddish-brown, unevenly bedded | 10 |
| 2. Limestone, crinoidal, lenticular, changes to calcareous sand | 2 |
| 1. Shale, red and yellow, contains occasional thin sandstone and limestone lentils | 50 |
| (Camp Colorado limestone at base). | |
| Total Thickness | 191 |

**Section of upper part of Moran formation along southwest side of Pecan Bayou across sections 195, 191, 190, and 176 on Gray Ranch oil field, Coleman County**

**Measured by P. L. Applin. (H in fig. 13)**

| | Thickness Feet |
|---|---|
| PUTNAM FORMATION— | |
| 20. Limestone, bluish, hard, crystalline, stained with yellow on weathered surfaces, weathers to small rounded boulders | 1 |
| 19. Shale | 7 |
| 18. Limestone, light yellow, flaky | 2 |
| 17. Shale | 3 |
| 16. Limestone, light yellow, crystalline, weathers to rounded boulders | 2 |
| 15. Shale, yellow | 6 |

| | | |
|---|---|---|
| 14. | Limestone, dark gray to yellow-brown, weathers to large rectangular blocks | 1 |
| 13. | Shaly, yellow | 6 |
| | Total thickness measured | 28 |
| MORAN FORMATION— | | |
| Sedwick Member | | |
| 12. | Limestone, brown | 1 |
| 11. | Shale | 9 |
| 10. | Shale, brown | 10 |
| 9. | Limestone, bright yellow, hard, crystalline, weathers to rough boulders and large blocks | 3 |
| 8. | Shale | 6 |
| 7. | Limestone, yellow, hard, crystalline | 1 |
| Santa Anna Member | | |
| 6. | Shale | 10 |
| 5. | Sandstone, brown, limy | 2 |
| 4. | Shale | 52 |
| 3. | Sandstone, brown and gray, heavy | 5 |
| 2. | Shale | 1 |
| Horse Creek Member | | |
| 1. | Limestone, gray, sandy in places, slightly conglomeratic | 2 |
| | Base not exposed. | |
| | Total thickness measured | 102 |

**Section of Moran formation along an east-west line two miles south of Santa Anna, Coleman County**

**Measured by P. L. Applin. (I in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUTNAM FORMATION— | | |
| 14. | Limestone, yellow-gray, forming escarpment | 3 |
| 13. | Shale, yellow | 5 |
| 12. | Limestone, yellow, weathers into large blocks | 2 |
| 11. | Shale, yellow-gray, tinged with red | 38 |
| 10. | Sandstone, brown and sandy shale, not well exposed | 34 |
| 9. | Shale | 6 |
| | Total thickness measured | 88 |
| MORAN FORMATION— | | |
| Sedwick Member | | |
| 8. | Limestone, massive, yellow | 7 |
| Santa Anna Member | | |
| 7. | Shale | 58 |
| Horse Creek Member | | |
| 6. | Limestone, yellow, weathers to rounded boulder-like pieces; forms low escarpment | 3 |
| 5. | Shale | 9 |
| 4. | Limestone, grayish-yellow | 1 |
| 3. | Shale | 5 |
| 2. | Limestone, gray, weathering yellow | 1 |
| Watts Creek Member | | |
| 1. | Shale | 29 |
| | (Camp Colorado limestone at base). | |
| | Total thickness | 133 |

*Paleontology.*—The silicified fossils in the upper yellow limestones of the Moran formation are the most distinctive paleontologic feature of this horizon. So far as observed no other horizon contains a similar distinguishing feature and it was possible in the course of field work to identify and to trace the limestones on this basis with considerable ease. The fauna consists almost entirely of mollusks, most of which are gastropods, but as these are chiefly in the form of casts it has not been possible satisfactorily to identify them specifically. Most of them appear to belong to the genera *Murchisonia, Sphaerodoma, Bellerophon* and *Pleurotomaroids. Myalina* is not uncommon.

*Correlation.*—The Moran formation, occurring as it does not far below the Wichita group of the Permian, and resting upon formations which are correlated with the higher Pennsylvanian divisions of other areas, must be equivalent to strata elsewhere which belong to the very late portion of the Pennsylvanian. It may be correlated approximately with the lower part of the Wabaunsee formation of Kansas.

## PUTNAM FORMATION

*Name and Definition.*—The name Putnam has been given to the uppermost division of the Cisco group which is typically exposed on the hillside west of the town of Putnam, located on the Texas and Pacific Railroad in Callahan County. The formation lies conformably upon the Moran strata and is overlain conformably by the marine strata of the Permian Wichita series. The formation includes all the strata from the top of the Sedwick limestone or its equivalent to the top of the Coleman Junction limestone, a persistent limestone bed which outcrops at Coleman Junction and may be traced northward capping a prominent escarpment across the Pennsylvanian area. The base of this division, as thus defined, is at the top of the uppermost of several thin yellow limestones which lie 125 to 175 feet below the top of the Coleman Junction escarpment.

It can be recognized in the field as the highest formation which contains noticeable sandstone strata and thin limestone lentils. Above it everywhere are the high escarpments, the thick limestone and marl beds of the Albany facies of the Wichita (Permian) series.

*Extent and Thickness.*—The Putnam beds form a prominent belt of outcrop which has been mapped from the valley of the Salt Prong of Hubbard Creek, southwest of Sedwick, through Putnam to the Cretaceous sand four or five miles east of Admiral, in Callahan County. South of the Cretaceous it extends southwestward from near the town of Dressy, five miles west of Cross Plains, through Coleman Junction to Coleman River, near the center of the south line of Coleman County. It has not been mapped as yet south of the river. In Callahan and Shackelford counties the formation has an average thickness of 125 to 175 feet and an outcrop four to five miles wide. In Coleman County its thickness runs from 125 to 150 feet and its outcrop is rarely over two and one-half to three miles wide.

*Lithologic Character.*—The Putnam formation consists of a persistent, easily recognizable, escarpment-making limestone, the Coleman Junction bed, from 3 to 15 feet thick, at the top, and a series of 125 to 175 feet of shale below. The upper layers of the shales are buff, pink, and red in color, grading downward into blue-gray and dark blue, carbonaceous beds. The shales contain three or four lentils of buff and dull dirty yellow limestones and one or two layers of thin, brown, very calcareous sandstones. The beds are in most places fossiliferous. The best collection is from the upper Coleman Junction limestone and from certain calcareous lentils which lie about 60 feet below the top. There are more limestone lentils in the section studied in northeastern Coleman and in Callahan counties than in southern Coleman and McCulloch counties and in the northern outcrop in Shackelford and Throckmorton counties. The Coleman Junction limestone in northern Shackelford County, north of the Cretaceous sand, consists of a lower grayish or light buff limestone three feet thick overlain by a bright, very ferruginous layer one foot thick. On weathering, the bright yellow bed breaks up into rounded yellow pieces which slump down and mingle with the light gray blocks, forming a characteristic trail around the hillside that can not be mistaken.

*Subdivisions.*—The strata which are included in the Putnam formation have been divided by Drake in the Colorado River Valley into the following beds.

2. Coleman Junction limestone
1. Santa Anna Branch beds

The Santa Anna Branch clay bed, as described by Drake at his type locality along Santa Anna Branch, corresponds almost exactly to the section of the Putnam beds below the Coleman Junction limestone as measured by Applin south of Santa Anna (See Section I, p. 182). Therefore although it is possible in some of Drake's other sections that he has included in the bottom of his Santa Anna Branch beds yellow limestones equivalent to lentils in the top of the Moran formation, the Santa Anna Branch beds are regarded as essentially equivalent to the strata between the Coleman Junction limestone and the yellow limestone strata at the top of the Moran formation, and the name has been retained.

In the southern area the Coleman Junction limestone is buff and gray to yellow in color and forms a prominent escarpment. In many places it contains quite an abundant fauna. The species so far collected are all of the Upper Pennsylvanian type, or very closely related forms, so that it has seemed best to include this limestone in the Pennsylvanian series. On the whole, the Putnam formation is a fairly uniform, easily traceable unit and its upper member, the Coleman Junction limestone, forms a fitting dividing line between the thin limestones, sandstones and bright-colored shales of the Cisco, and the massive white limestones and thick marl beds of the Wichita-Albany group of Permian age.

*Detailed Sections.*—The following observations of the strata which are included in the Putnam formation show its character at various points along its outcrop from north to south.

**Section of Putnam formation along an east-west line, west from the Moran oil field, Shackelford County**

**(J in fig. 13)**

| | Thickness Feet |
|---|---|
| PUTNAM FORMATION— | |
| Coleman Junction Member | |
| 13. Limestone, bright yellow, fragmentary, highly ferruginous | 1 |
| 12. Limestone, gray, chunky | 1 |
| Santa Anna Branch Member | |
| 11. Shale | 4 |
| 10. Sandstone, brown, hard, calcareous | 1 |
| 9. Shale | 9 |
| 8. Limestone, mottled, gray and yellow, sandy | 1 |
| 7. Shale | 26 |
| 6. Limestone, mottled, gray and yellow, weathers into small nodules not well exposed | 2 |
| 5. Shale | 18 |
| 4. Limestone, gray, sandy in places, consists almost entirely of fossil fragments | 2 |
| 3. Shale | 8 |
| 2. Sandstone, brown, ripple-marked | 1 |
| 1. Shale, in valley and outcrops (interval by projection) | 100 |
| Total thickness | 174 |

**Section of Putnam formation on west side of Deep Creek valley, 18 miles northeast of Baird, Sections 60 and 61, Orphan Asylum Survey, Callahan County**

**(K in fig. 13)**

| | Thickness Feet |
|---|---|
| PUTNAM FORMATION— | |
| Coleman Junction Member | |
| 10. Limestone, bright yellow weathers to rounded lumps | 1 |
| 9. Limestone, light gray, massive, in many places fossiliferous, weathers to large rough surface blocks and slabs | 3 |
| Santa Anna Branch Member | |
| 8. Shale, gray and buff | 25 |
| 7. Limestone, gray | 2 |
| 6. Shale, gray, calcareous | 38 |
| 5. Sandstone, brown, calcareous | 10 |
| 4. Shale | 12 |
| 3. Limestone lentil, gray, impure, shaly, changes laterally to calcareous shale | 3 |
| 2. Shale | 18 |
| 1. Limestone, very fossiliferous | 1 |
| (Shale at base of formation poorly exposed). | |
| Total thickness measured | 113 |

**Section of Putnam formation, two miles east of Admiral, Sections 44 and 45**

**(L in fig. 13)**

| | Thickness Feet |
|---|---|
| PUTNAM FORMATION— | |
| Coleman Junction Member | |
| 9. Limestone, yellow, pinkish in places, weathering to small dark yellow fragments | 5 |
| Santa Anna Branch Member | |
| 8. Shale, yellow, gray | 22 |
| 7. Limestone, mottled yellow and gray, soft, sandy, fossiliferous | 2 |
| 6. Sandstone, brown, calcareous | 2 |
| 5. Shale | 10 |
| 4. Sandstone, brown, heavy, ripple-marked | 2 |
| 3. Shale, reddish brown, fossiliferous | 33 |
| 2. Shale, gray, concretionary | 1 |
| 1. Limestone, mottled yellow and gray, weathers to small rounded boulders | 5 |
| (Base of section not exposed). | |
| Total thickness measured | 82 |

**Section of Putnam formation along small stream valley, two miles west of Dressy, Callahan County**

**Measured by C. A. Hammill. (M in fig. 13)**

| | Thickness Feet |
|---|---|
| PERMIAN—WICHITA GROUP— | |
| 21. Limestone, gray, fine-grained, compact, heavy, weathers white or yellow, weathered surface has cracked appearance due to veins of calcite, weathers to small rounded chunks, fossiliferous | 1 |
| 20. Shale, yellow | 12 |
| 19. Limestone, yellow, thin, shaly, medium fine-grained, contains minute crystals of calcite set in a dull yellow matrix, weathers to small rounded pieces, non-fossiliferous | 1 |
| 18. Shale, yellow | 1½ |
| 17. Sandstone, brown, medium-grained, earthy, calcareous, well cemented, weathers into blocks having dark brown, rough, pitted surface, non-fossiliferous | 1 |
| 16. Shale, yellow | 19 |
| Total thickness measured | 35½ |
| PENNSYLVANIAN—CISCO GROUP— | |
| PUTNAM FORMATION— | |
| Coleman Junction Member | |
| 15. Limestone, yellowish-brown, upper layer thick, close-grained, hard, platy, very fossiliferous, shells not well preserved, weathers into platy pieces having smooth surface. Beneath upper layer several layers of grayish limestone, fine-grained, and fossiliferous. At base very calcareous sandstone 8 inches thick | 3 |
| Santa Anna Branch Member | |
| 14. Shale, white, very calcareous in upper portion, lower part dull buff yellow | 22 |

| | | |
|---|---|---|
| 13. | Limestone, yellow to brownish, medium fine-grained, weathers to small slabs, fairly well preserved fossils, Bryozoa, *Derbya crassa*, *Productus semireticulatus* var., *P. cora*, *Pinna peracuta*, *Schizostoma catilloides* | 1 |
| 12. | Shale, yellow | 32 |
| 11. | Limestone, gray, heavy, dense, crystalline weathers into large rectangular, smooth-surfaced blocks, sparsely fossiliferous | 1 |
| 10. | Shale, yellow | 2 |
| 9. | Limestone, gray to dark blue, shaly, concretionary, sandy, nonfossiliferous, weathers to small blue-gray concretionary nodules | 2 |
| 8. | Shale, blue, contains near the base a thin seam about 1 inch thick of grayish limestone filled with bryozoans and pelecypods | 10 |
| 7. | Limestone, buff, shaly, rough-surfaced | 1 |
| 6. | Shale, yellow | 17 |
| 5. | Limestone, dull yellow, medium to coarsely crystalline, weathers to small blocks of light brown color, few fossils, sand stands out in relief on weathered surfaces | 1 |
| 4. | Shale, yellow | 8 |
| 3. | Limestone, buff, shaly, weathers into rounded cobbles, sparsely fossiliferous | 2 |
| 2. | Shale, covered by valley alluvium; interval obtained by projection | 75 |
| | Total thickness | 177 |
| MORAN FORMATION— | | |
| 1. | Bright yellow sandy limestone | 2 |

**Section of Putnam formation along east-west road, three miles South of Coleman Junction**

**Measured by P. L. Applin. (I in fig. 13)**

| | | Thickness Feet |
|---|---|---|
| PUTNAM FORMATION— | | |
| Coleman Junction Member | | |
| 9. | Limestone, yellow, concretionary | 21 |
| 8. | Shale, yellow, calcareous | 51 |
| 7. | Limestone, yellow, weathers to large blocks | 2 |
| Santa Anna Branch Member | | |
| 6. | Shale, yellow, and red | 38 |
| 5. | Sandstone, and sandy shale, brown, calcareous | 34 |
| 4. | Shale | 6 |
| 3. | Limestone, yellow, massive | 7 |
| 2. | Shale | 58 |
| | Total thickness | 217 |
| MORAN FORMATION— | | |
| 1. | Limestone, bright yellow, concretionary | 3 |

**Section of Putnam formation in Colorado River valley.**

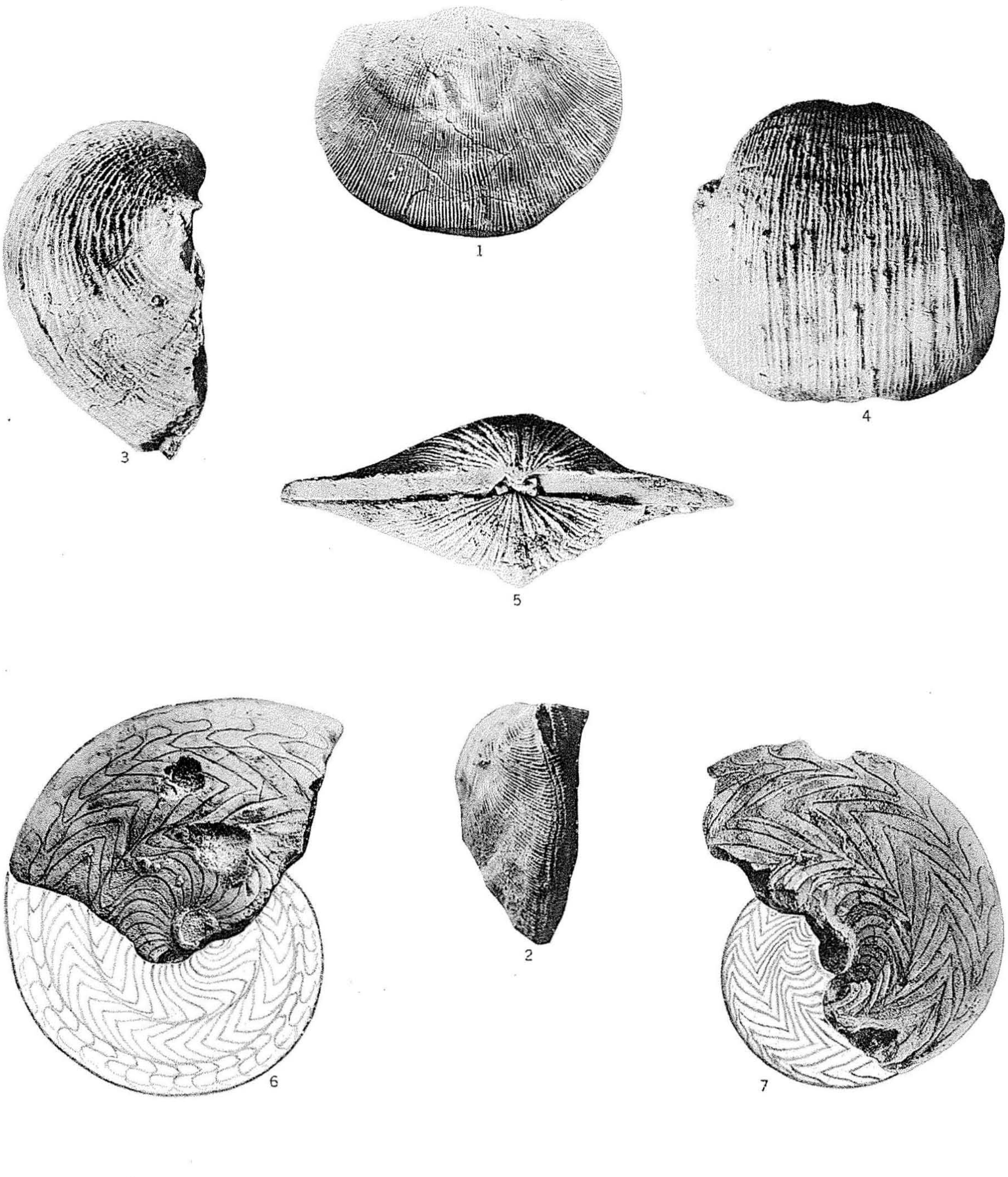
**Measured by N. F. Drake.[79] (N in fig. 13)**

| | Thickness Feet |
|---|---|
| PUTNAM FORMATION— | |
| (Measured ½ mile south of Coleman Junction) | |
| Coleman Junction Limestone | |
| 4. Limestone, nodular, concretionary structure, brown and yellowish limestones in layers from 6 to 12 inches thick | 10-20 |
| (Measured near mouth of Santa Anna Branch, south of Coleman Junction) | |
| Santa Anna Branch Shale | |
| 3. Clay, red, sandy | 40 |
| 2. Sandstone, shaly | 4 |
| 1. Clay, yellowish and pink, with some blue, sandy clay and also two or three feet of carbonaceous shale at the base | 75 |
| Total average thickness | 129-139 |

*Paleontology.*—The fossils which have been observed in the Putnam formation are similar to those found in the other divisions belonging to the upper part of the Cisco group and elsewhere at the summit of the Pennsylvanian series. Aside from some observations by Plummer, however, made in the field in the course of work on a part of the area in which the Putnam outcrops, there has not been given specific study to the paleontology of this division. Without question there are many species at this horizon which are not recorded. Although the Coleman Junction limestone was included by Drake with the Permian, Plummer did not find within the Putnam formation any of the fossils, especially the complex-sutured ammonites, which appear to characterize the Admiral and succeeding Permian formations, and although this is not conclusive evidence that some portion of the Putnam should not be included in the Permian it is his opinion that it belongs rather to the uppermost Cisco than to the overlying division. The position at which the line at the top of the Pennsylvanian should be drawn in the Texas area is very similar to the problem in the Kansas section where the base of the Permian has been variously placed at the base of the Wreford, the base of the Cottonwood, at the Neva and even beneath the Elmdale shale. There was evidently no marked change in either area at the conclusion of Pennsylvanian time and the only indication of the Permian appears to be in the transition in the invertebrate faunas. Consequently it is believed that the division line should tentatively be drawn at the most readily identifiable and easily traceable stratigraphic horizon which appears to mark the greatest change in the faunas. Accordingly the top of the Putnam formation and of the Cisco group is here drawn at the top of the Coleman Junction limestone.

The fossils which have been observed in the Putnam are shown in the following list:

[79]Drake, N. F., the Colorado Coal Field, Geol. Surv. Texas, 4th Ann. Rept., p. 420, 1892.


1
3
4
5
6
2
7

**GRAHAM AND UPPER CISCO FOSSILS**

Figures 1, 2. *Derbya cymbula*, brachial valve and side view of a characteristic specimen from the Coleman Junction limestone near Putnam.

Figures 3, 4. *Productus semireticulatus* var. cf. *hermosanus*, a very robust, well preserved, and characteristic specimen from the Coleman Junction limestone near Putnam.

Figure 5. *Spirifer cameratus*, Saddle Creek limestone northwest of Cisco (89.6).

Figure 6. *Dimorphoceras texanum*, a typical but fragmentary specimen from the Wayland shale, Graham formation, south of South Bend (66.1).

Figure 7. *Gonioloboceras welleri*, a typical but fragmentary specimen from the Wayland shale, Graham formation south of South Bend (66.1).

**Fauna of the Putnam formation**

*Derbya crassa*
*Productus cora*
*Productus semireticulatus* var.
*Pinna peracuta*
*Aviculopecten occidentalis*
*Allorisma subcuneatum*
*Bellerophon crassus*
*Bulimorpha* ? sp.

*Correlation.*—On account of its stratigraphic position at the top of the Pennsylvanian the Putnam formation may be correlated with the corresponding portion of the Kansas section which is included in the Wabaunsee formation.

## PENNSYLVANIAN-PERMIAN DIVISION LINE

It is not easy to draw a definite line of division between the Pennsylvanian and Permian rocks in north-central Texas. The division as made by Cummins[80] was based largely upon the lithologic character of the sediments, and Drake offers no good reason for drawing his line at the bottom of the Coleman Junction limestone rather than at the top, or at some other nearby horizon.

Ammonites of Permian aspect occur in strata south of Coleman 114 feet above the Coleman Junction limestone, so that the beds 100 feet higher are quite surely of Wichita age. (See section p. 193.) Obviously the question as to just which stratum is the first to contain Permian forms can be settled only by a careful study of large collections of the fossils. The fauna of these beds is not sufficiently well known as yet. Not unlikely it will be found that no sharp line can be drawn, but that in north Texas a general gradation from the Pennsylvanian into the Permian has taken place without any abrupt change. If this is true, one line appears to be as acceptable as another close to it, and therefore, the persistent Coleman Junction limestone, which is a good horizon marker for the top bed of the "thin limestone strata" of the Cisco group, has been chosen as the most readily traceable and suitable line of division.

[80]Cummins, W. F., Geology of northwestern Texas, Geol. Surv. Texas, 3rd Ann. Rept., p. 375, 1889.

## PERMIAN-WICHITA GROUP

### GENERAL DISCUSSION

*Name.*—The name Albany was given by Cummins to the limestone and shale strata overlying the Cisco group in the Brazos Valley. Later he found that his new formation was equivalent to the Permian "Red Beds" strata, named the Wichita formation, in the Red River Valley, and the name Albany was dropped. However, there is such a striking difference between the massive, white, escarpment-making limestones and marls of the Permian in the vicinity of Albany and the typical red beds facies of the strata in the Wichita district that there has been a tendency among geologists to refer to the division as the Albany-Wichita group and to speak of the marine limestone facies of the Brazos Valley as "Albany Beds" and the red strata of the Red River as "Wichita Red Beds."

*Extent.*—The lower portion of the "Albany" strata has been mapped in connection with the working out of the structure of the north Texas area and has been included on the map, Plate I. The area covered includes a belt about 12 miles wide extending from Albany south through Baird to Coleman, and embraces a thickness of strata averaging over 700 feet. The area is west of the more promising oil district of Texas so that the group has not been studied in so much detail as the Pennsylvanian strata; and since, also, the Permian really belongs outside of the scope of this paper, it will be sufficient to define the new formations shown on the map, show the relation of these to the division proposed by Drake for the Colorado Valley, and to describe briefly the group as a whole.

*Lithologic Character.*—The "Albany" consists throughout Shackelford, Callahan, and Coleman counties, of a series of thick limestone strata separated by thick shale and marl beds containing thin limestone lentils. Practically no sands are known in the section. The thick limestone forms high prominent escarpments which have an average strike of N. 15 degrees E., whereas the dip of the beds is toward the west and amounts to 30 to 40 feet per mile. The limestone strata are bluff to light gray and white, in places tinged with a little red, hard and crystalline, and contain a few fossils, although not fossiliferous as a rule. The strata on the top of the escarpment consist of a series of layers 1 to 3 feet thick separated by thin shale partings. The upper layers in each escarpment weather in most places to nodular or irregularly shaped platy fragments. Certain layers, however, that form benches below the top, are characterized by weathering to large, massive rectangular blocks that make excellent building material. The shales down the sides of the escarpment are variously colored, red, yellow and gray being common. Toward the base, where the shales are less exposed, blue and even dark colors are prevalent. The shale beds in all the formations thin toward the south and the limestone thickens until in the section along the Colorado River over 50 per cent of the strata consists of solid limestone.

*Divisions.*—In classifying the Wichita group the same system has been followed as that employed for the Pennsylvanian strata, that of choosing the persistent and easily recognizable escarpment-making limestones as horizon markers to separate the thick group into members and formations. In this way the lower beds of the group have been separated into the following formations:

3. Clyde
2. Belle Plains
1. Admiral

## ADMIRAL FORMATION

The Admiral formation is named for the town of Admiral, a small village located in Callahan County 10 miles east of Baird. It is defined to include all the strata between the top of the persistent Coleman Junction limestone and the top of the Elm Creek limestone as mapped and described by Drake. In the field the formation is topographically expressed by a continuous high escarpment capped by white, thick, irregularly bedded limestones 20 to 50 feet thick overlying 250 to 300 feet of soft, chalky, white, gray, blue and more rarely red, calcareous shale containing thin layers and lentils of white and buff limestone.

The Admiral formation may be traced easily by following the first or easternmost high escarpment of the Albany-Wichita group southward from Albany, in Shackelford County, almost due south through the center of Shackelford, Callahan, and Coleman counties. The center of the belt of outcrop strikes through the towns of Chautauqua, Admiral, and Coleman.

In the Colorado Valley the formation includes the following beds described by Drake:

6. Elm Creek limestone
5. Coleman limestone and shale
4. "Bed No. 5"—limestone and marly clay
3. Indian Creek clay bed
2. Hordes Creek limestone lentil
1. Lost Creek shale bed

The following sections include all the essential characteristics of the Admiral formation and further description of the individual strata will be omitted.

**Section of Admiral formation along the Baird-Putnam road from the escarpment two miles east of Baird to town of Chautauqua**

**Measured by P. L. Applin. (Q in fig. 13)**

| ADMIRAL FORMATION— | Thickness Feet |
|---|---|
| 8. Limestone, gray, weathers to rounded boulders. Elm Creek member | 2 |
| 7. Shale | 18 |
| 6. Limestone, gray, massive, weathers to rounded boulders | 4 |
| 5. Shale | 24 |
| 4. Limestone, yellow, heavy | 1 |
| 3. Shale, valley slope | 247 |
| 2. Limestone, yellow, changes in places to white and pink colors and weathers to angular fragments | 1 |
| 1. Shale | 25 |
| (Top of Coleman Junction limestone). | |
| Total thickness | 322 |

**Section of Admiral formation along Santa Fe Railroad, three and one-half miles southwest of Coleman, Coleman County**

**Measured by P. L. Applin. (R in fig. 13)**

| ADMIRAL FORMATION— | Thickness Feet |
|---|---|
| Elm Creek Limestone | |
| 22. Limestone, blue-gray, bouldery, crystalline, weathers to nodular fragments | 4 |
| 21. Shale | 8 |
| 20. Limestone, blue-gray, bouldery, crystalline, weathers to buff color | 4 |
| 19. Shale, dark | 6 |
| 18. Limestone, blue-gray, crystalline, weathers to large blocks | 2 |
| "Coleman Clay" (Drake) | |
| 17. Shale, grayish-yellow | 22 |
| 16. Limestone, yellow-gray | 2 |
| 15. Shale, black | 34 |
| 14. Limestone, muddy brown | 1 |
| 13. Shale, dark gray | 17 |
| 12. Limestone, thin gray | 1 |
| 11. Shale | 11 |
| 10. Sandy, shale | 3 |
| 9. Shale | 58 |
| Coleman Limestone | |
| 8. Limestone, yellow-gray | 3 |
| 7. Shale, yellow | 9 |
| "Bed No. 5" (Drake) | |
| 6. Limestone, gray | 3 |
| Indian Creek Shale | |
| 5. Shale | 34 |
| 4. Sandstone, red-brown, very calcareous. Fossiliferous, carries good Permian fauna including many Ammonites | 5 |
| 3. Shale | 66 |
| Hordes Creek Limestone | |
| 2. Limestone, brown to gray, shaly | 2 |
| Lost Creek Shale | |
| 1. Shale | 46 |
| (Top of Coleman Junction Limestone). | |
| Total thickness | 341 |

The fauna of the lower strata of the Permian which are here included in the Admiral formation, is indicated by collections made by Mr. Burtt and Mr. Applin in the vicinity of Coleman (localities 111.1 to 111.3) and in part by species reported by Drake. These, as indicated by preliminary examination, contain the following forms.

**Fauna of the Admiral Formation**

| FAUNA | Localities 111.1 | 111.3 |
|---|---|---|
| Sponge sp. | x | x |
| *Syringopora sp. | ........ | ........ |
| Archeocidaris sp. | x | x |
| Fenestella sp. | ........ | x |
| Septopora biserialis | x | ........ |
| Productus semireticulatus var. cf. hermosanus | x | x |
| *Productus pertenuis | x | ........ |
| Hustedia mormoni | x | ........ |
| Composita subtilita | x | x |
| Pinna peracuta | ........ | x |
| Myalina recurvirostris | ........ | x |
| *Myalina subquadrata | ........ | ........ |
| Schizodus sp. | ........ | x |
| Parallelodon sp. | ........ | x |
| *Aviculopecten sp. | ........ | ........ |
| Allorisma subcuneatum | ........ | x |
| *Bellerophon crassus | ........ | x |
| Bellerophon sp. | ........ | x |
| Euphemus carbonarius | x | x |
| Pleurotomaria sp. | ........ | x |
| Worthenia sp. | x | ........ |
| Strophostylus sp. | ........ | x |
| Turbo sp. | x | ........ |
| Meekospira sp. | x | ........ |
| Platyceras parvum | ........ | x |
| Schizostoma catilloides | ........ | x |
| Holopella sp. | x | ........ |
| Sphaerodoma sp. | x | ........ |
| *Murchisonia terebratula | ........ | ........ |
| *Murchisonia trinodolineata | ........ | ........ |
| Murchisonia sp. | x | x |
| Naticopsis sp. | x | ........ |
| Zygopleura sp. | x | ........ |
| Orthoceras sp. | x | x |
| Nautilus sp. | ........ | x |
| Metacoceras sp. | ........ | x |
| Ammonites | ........ | x |
| Reptile bones | ........ | x |

## BELLE PLAINS FORMATION

The Belle Plains formation is named for the town of Belle Plains, an old frontier post, where the remnant of several spacious stone buildings built out of the limestone of this formation testifies to the industry of the early settlers in Callahan County. The formation is defined to include all the strata between the top of the Elm Creek limestone and the next persistent escarpment-forming stratum, named by Drake the Bead Mountain bed, which forms the top of the high escarpment west of Baird.

The Belle Plains formation, like the Admiral below, consists of thick massive limestone strata at its top forming a high, prominent escarpment overlying white, gray, and blue calcareous shale and marl. In many places along its escarpment there is a thin, quite persistent, buff or yellowish-brown lentil that forms a prominent bench about half way up the side of the escarpment, is a good horizon marker in mapping the structure of the Baird district, and aids in distinguishing the formation from the one below.

The Belle Plains formation may be easily traced from near the center of the north line of Shackelford County south across Salt Prong of Hubbard Creek, about 4 miles west of Albany, through Baird to the Santa Fe Railroad, about 7 miles west of Coleman, and to the Colorado River near the mouth of Elm Creek. Its outcrop on the average is 6½ miles wide and its thickness 300 feet in Callahan County and 200 to 250 feet in Coleman County.

The formation includes the following beds described by Drake in the Colorado coal field:

4. Bead Mountain limestone
3. Valera shale
2. Jagger Bend limestone
1. "Bed No. 8" shale

The formation is fairly uniform throughout its extent and the following two sections give a good idea of its character in Callahan and Coleman counties:

**East-west section of Belle Plains formation along R. R. tracks, from top of escarpment west of Baird to escarpment two miles east of town**

**Measured by P. L. Applin**

| | Thickness Feet |
|---|---|
| BELLE PLAINS FORMATION— | |
| 16. Limestone, blue-gray, thick, massive, weathers to large rough-surfaced blocks, sparsely fossiliferous. Bead Mountain member | 5 |
| 15. Shale | 40 |
| 14. Limestone, yellow, hard, weathers to smooth surface | 2 |
| 13. Shale | 58 |
| 12. Limestone | 2 |

| | | |
|---|---|---|
| 11. | Shale | 82 |
| 10. | Limestone, light yellow, fossiliferous fragmental | 2 |
| 9. | Shale, yellow, hard, massive, weathers to form medium-sized blocks | 8 |
| 8. | Limestone | 1 |
| 7. | Shale | 34 |
| 6. | Limestone, yellow, weathers to form smooth-surfaced thin shales | 1 |
| 5. | Shale, reddish-yellow | 7 |
| 4. | Limestone, gray, platy, in places massive | 1 |
| 3. | Shale | 46 |
| 2. | Limestone, yellow, impure, shaly | 1 |
| 1. | Shale | 19 |
| | (Top of Elm Creek limestone). | |
| | Total thickness | 309 |

**Section of Belle Plains formation along south side of Turtle Bayou, ten miles northwest of Coleman; sections 28, 29, 30, and 31, C. H. & H. R. R., Blk. 2, Coleman County**

**Measured by L. E. Wells**

| | | Thickness Feet |
|---|---|---|
| | BELLE PLAINS FORMATION— | |
| | Bead Mountain Limestone | |
| 50. | Limestone, gray, hard, sandy, few fossils | 2 |
| 49. | Shale | 3 |
| 48. | Limestone, gray, massive, hard, fossiliferous, breaks into large blocks | 3 |
| 47. | Shale | 2 |
| 46. | Limestone, gray, hard, massive, breaks into large blocks, contains *Syringopora* | 3 |
| 45. | Shale | 2 |
| 44. | Limestone, gray, hard, massive, weathers into large blocks and small round fragments | 5 |
| 43. | Valera shale, alternating beds of thin limestone and thick shale with thin sandy shales | 28 |
| 42. | Limestone, yellow, hard, massive, top breaks into square plates | 2 |
| 41. | Shale | 2 |
| 40. | Limestone, gray, hard | 1 |
| 39. | Shale, dark | 9 |
| 38. | Limestone, gray to brown, hard, massive at base, thin platy bed on top | 2 |
| 37. | Shale, yellowish to gray, contains thin layers of sandy shale and shaly sand | 35 |
| 36. | Limestone, yellow, hard, blocky, top frequently weathers reddish, contains shale partings in middle, is fossiliferous, many gastropods | 2½ |
| 35. | Shale, gray | 12 |
| 34. | Limestone, reddish, shaly, having pitted surface | 1 |
| 33. | Shale | 2 |
| 32. | Limestone, yellow, platy, sandy | 1 |
| 31. | Shale, not exposed | 10 |
| 30. | Limestone, yellow, very sandy | 1 |
| 29. | Shale, not exposed | 5 |
| 28. | Limestone, gray, porous | 1 |
| 27. | Shale, gray, contains a six inch sandy bed near middle | 11 |
| 26. | Limestone, gray, hard, weathers into blocks | 1 |

| | | |
|---|---|---|
| 25. | Shale, largely concealed, contains near middle very thin sandy lime | 16 |
| 24. | Limestone, gray, thin | 1 |
| 23. | Shale, bluish-gray, limy, contains thin sandy partings | 28 |
| 22. | Limestone, gray, thin, platy, weathers to yellow on surface, cherty and contains *Syringopora* | 1 |
| 21. | Shale, dark gray, weathers light | 4 |
| 20. | Limestone, yellow, sparsely fossiliferous | 1 |
| 19. | Shale, gray | 4½ |
| 18. | Limestone, gray to red, thin, platy, sandy | 1 |
| 17. | Shale | 4 |
| 16. | Limestone, gray, stained with yellow on weathered surface | 1 |
| 15. | Shale, covered | 11 |
| 14. | Limestone, shaly | 1 |
| 13. | Shale, with thin partings of sandstone | 34 |
| 12. | Limestone | 2 |
| 11. | Shale | 4 |
| 10. | Limestone, gray, massive | 5 |
| 9. | Shale | 5 |
| 8. | Limestone, yellow, shaly | 5 |
| 7. | Shale | 10 |
| 6. | Limestone, grayish, sandy, flaggy at top, lower part massive | 15 |
| 5. | Shale, blue and yellow mixed | 57 |
| 4. | Limestone, gray, hard, sandy, with thin shale partings | 13 |
| 3. | Shale, not exposed | 57 |
| 2. | Limestone, gray, weathers yellow | 1 |
| 1. | Shale | 19 |
| | (Top of Elm Creek limestone). | |
| | Total thickness | 447 |

## CLYDE FORMATION

The Clyde formation is named from the town of Clyde, located on the Texas and Pacific Railroad 8 miles west of Baird. It is a poor name because in the vicinity of the town the Permian strata are covered by Cretaceous sand and it is necessary to go several miles south of town to get good exposures. However, this is the only locality along its outcrop available as a name and will serve the purpose until a better may be found. It is made to include all the strata between the top of the Bead Mountain limestone bed, capping the escarpment at Baird, and the top of the Talpa limestone bed, as described by Drake. It is the westernmost formation of the "Albany" limestone strata along the Texas and Pacific Railroad where it is overlain by red beds. In the Colorado Valley it is overlain by higher limestone strata that outcrop two miles east of Talpa on the Santa Fe Railroad. Only the east or lower beds of the formation are included on the geologic map. Its outcrop averages 9 miles in width and its thickness averages 475 feet.

The uppermost beds of Drake's section in the Colorado River Valley are included in this formation as follows:

Talpa limestone
Grape Creek shale and limestone bed
"Bed No. 12" shale

The formation consists of a series of massive and thin-bedded gray and buff limestones separated by thick marly beds which have the same appearance and characteristics as the younger formations just described. No complete sections of the Clyde formation have yet been measured.[81]

## THE STRUCTURE OF THE PENNSYLVANIAN FORMATIONS

*Structure of the Bend Strata.*—The structure of the Pennsylvanian area of north-central Texas has been very completely worked out by the geologists of the various oil companies and is quite well known through the publications of Hager,[82] Sellards,[83] Pratt,[84] and Adams.[85] These authors have shown the Ellenburger (Ordovician) limestone and overlying Bend group to have been folded at the end of the Bend epoch into a broad plunging arch which extends from the Llano Mountains north to the northern part of Young County and possibly as far as the Red River (See map Figure 17). The deformation is not shown in the surface strata; but from well records it is known that the axis of the arch extends through Brownwood, Cisco, Breckenridge, and Eliasville. The westward dip is on the average about 40 feet per mile and the eastward slope about 30 feet. (See cross-section Plate IX.) The northward plunge of the axis averages 35 feet in a mile so that the top of the Bend group, which outcrops at San Saba, is 1450 feet deep at Brownwood, 2700 feet at Cross Plains, and about 3100 feet at Cisco. The arch is by no means a simple, uniformly shaped, plunging geo-anticline, as indicated by the earlier structural maps. The uniform northward plunge is restricted in many places by cross-

[81]The rocks here referred to the Clyde and Belle Plains formations, together with the higher formations, were critically studied in southwestern Coleman and in Runnels counties, and the results were published on pages 10 to 32 of Bulletin No. 1816 of the Bureau of Economic Geology in 1919.

On the Colorado River the rocks are richly fossiliferous and show very closely the grouping of the strata. Thus, the Jagger Bend beds belong with the Elm Creek beds rather than with the Bead Mountain beds. The layers from the top of the Jagger Bend beds to the top of the Bead Mountain beds form a strikingly characteristic unit. The Grape Creek beds stand intermediate between the Bead Mountain and the Talpa beds, and may well be left separate, while the Talpa and Paint Rock beds are two formations sufficiently closely related to go in one and the same group.

The discordance between these groups and those used in the text above is rather small, but not negligible. J. W. B.

[82]Hager, Dorsey, The Bend Arch in north-central Texas, Bull. Am. Inst. Min. Eng., No. 138, June, 1918.

[83]Sellards, E. H., On the Underground Position of the Ellenburger Formation in north-central Texas. Univ. Texas Bull. 1849, 1919.

[84]Pratt, W. E., Geologic Structure and Producing Areas in North Texas Petroleum Fields. Am. Assn. Pet Geol., vol. 3, 1919, pp. 44-70.

[85]Adams, H. H., Geological Structure of Eastland and Stephens Counties, Texas. Am. Assn. Pet. Geol., vol. 4, No. 2, 1920, pp. 157-168.

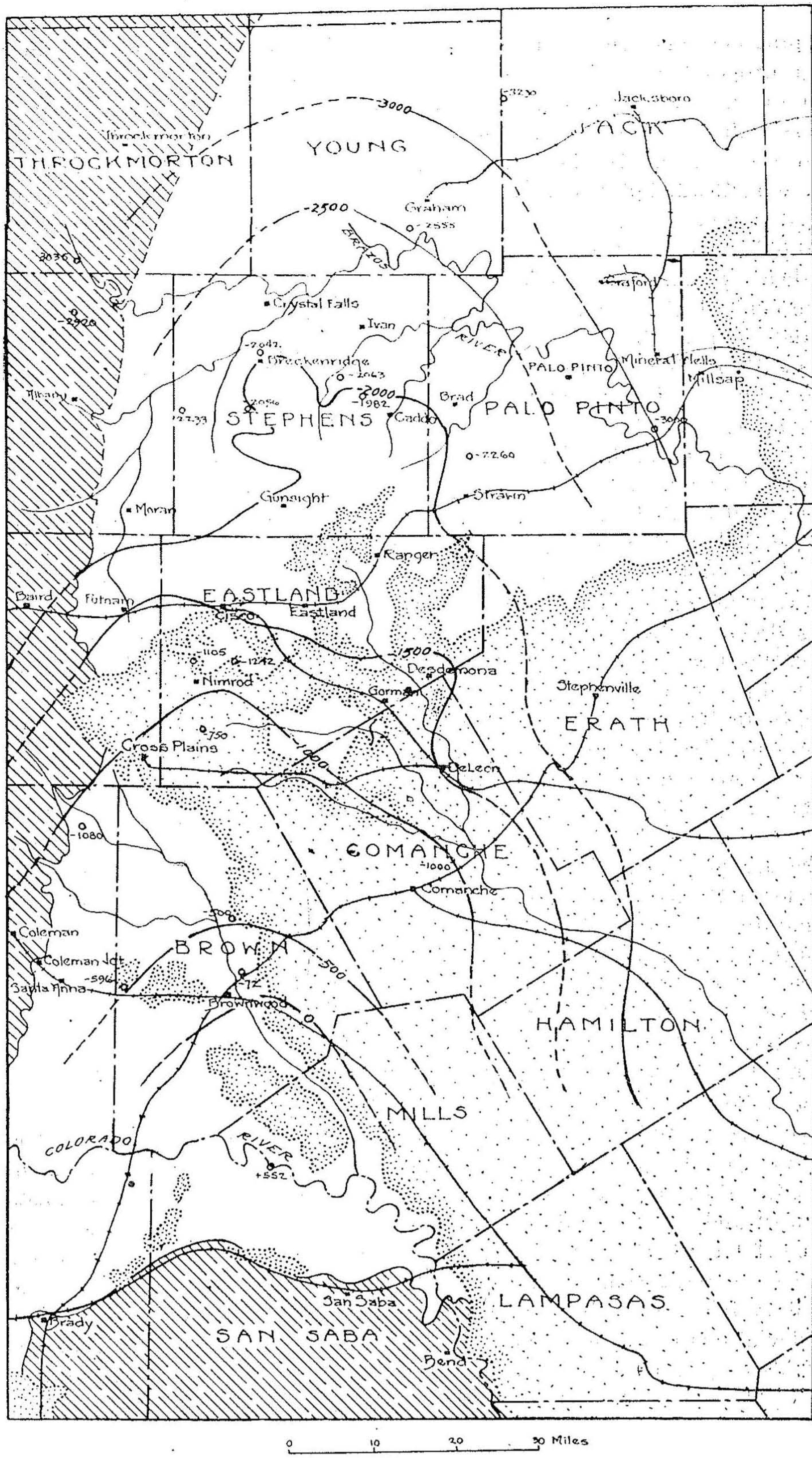



Figure 17. Generalized structure map showing dip of Bend group. Contours drawn on top of Marble Falls limestone. Datum sea level.

warping and terracing, and in the vicinity of Breckenridge a dome of quite large proportions is developed in the Bend and older strata. Structural contours drawn on the top of the Marble Falls limestone, in those areas where sufficient numbers of wells have been drilled to enable accurate correlations to be made, show that the curve of the contour lines produced by the northward plunge is not an even one but is warped into a great number of undulations produced by minor abnormal structural features such as small folds and terraces. The axes of many of the minor folds extend northeast at an acute angle to the axis of the major arch. The most prominent of these minor folds is the Gorman anticline which extends northeast from the main arch in the vicinity of Cross Plains through Rising Star, Sipe Springs, and Gorman to Desdemona. Another well-known but smaller and more restricted fold or terrace is in the vicinity of Ranger, a third is at Caddo, and a fourth at Ivan; all located on the east side of the arch. There are, however, many other small, less well known, abnormal structures developed on the west side, such as the Morris Ranch fold located about 9 miles northeast of Coleman, and the Putnam fold located in the vicinity of Putnam and Dothan in Callahan County. The shape of these secondary structures is in most cases that of broad, gentle, plunging anticlines with several "high points" or terraced spots along its axis. Less commonly, as for example at Breckenridge, there are domes developed of broad dimensions and rather gentle dips. The amount of the dip rarely averages over two or three degrees in either the domal or anticlinal structures. Very few faults have been recognized in the subsurface structure, and it is quite certain that there are no faults of large extent or displacement north of the Llano Mountains. The folding at the end of the Bend epoch was of the gentle warping type, such as might be produced by a gentle uplift of lighter segments and a settling of the border areas. There was no intense deformation beneath the area of younger Pennsylvanian rocks. The structure of the Bend arch is not at all manifest at the surface, while the minor secondary folds are in most cases indicated in the surface strata by very small warpings, a fact that suggests that the secondary folds were produced a little later and by a different set of earth forces than those that produced the arch. Probably the latter set of forces was instituted at the end of the Bend epoch and continued with less and less intensity on through and following the deposition of the Upper Pennsylvanian beds.

*Structure of the Strawn Strata and Overlying Pennsylvanian Beds.*—The structure of the younger Pennsylvanian strata including the Strawn, Canyon, and Cisco groups, is on the whole exceedingly simple, and consists of a west and northwest dipping monocline superimposed upon the gently arched folds of the underlying Bend. (See cross-section Plate IX.) There is no indication of the Bend arch and only slight evidence of the secondary folds of the Bend strata in the formations at the surface. The only deviations from the normal northwest and west dips are small plunging folds or terraces, commonly referred to as "noses," and small faulted areas. The noses are in most cases less than one mile wide and are two to three miles long. The small structures rarely occur singly; several may be associated to form small anticlinoria, or more commonly they occur in beds of slight deformation associated with small terraces and other small warpings. In several cases there will be a small fold plunging westward and a second at its side trending north or northwest with a sharp syncline between (See diagram Figure 18). Quite commonly, as for example in southern Young County, a series of these noses and terraces arranged in a belt trending northeast-southwest appear to lie over larger subsurface folds or faults developed in the Bend. The largest "nose" or terrace is located four miles south of Breckenridge in Stephens County and overlies the south side of the large Breckenridge dome of the Bend strata, on which has been developed a very productive oil field.

There are few faulted areas in north Texas, as is to be expected in an area where the folds are so gentle. The only places worth mentioning are located 10 miles south of Strawn on the Allen Ranch, in Eastland County, and 12 miles north of Graford, near Bartons Chapel, in Jack County, respectively. On the Allen Ranch there is a series of five or six faults, arranged nearly parallel to each other, extending northwest-southeast one-half to two and one-half miles long and having displacements of from 0 to 80 feet. The amount of throw varies in the several faults and along the plain in the same fault. The downthrow side is in most cases on the downdip side although one or two of the smaller displacements are on the updip side. In the area near Bartons Chapel the faults are arranged *en enchelon,* and the movement along the fault plane was nearly vertical.

*The Origin of the Surface Folds and Faults.*—The cause of the north Texas surface folds and their relation to the larger subsurface structural features has been a subject of much interest to geologists and many hypotheses have been suggested, of which the following are accepted as the more plausible explanations:

1. That all the small "noses" and terraces are located over larger folds in the Bend strata and represent small post-Cisco movements along the old lines of pre-Strawn folding.

2. That the Strawn formation was laid down on a very uneven Bend surface that contained escarpments and ridges similar to the topography today. That during the latter periods there has been a settling in the pre-Strawn valleys and slight lateral movements in the upper sediments. That the old Bend ridges have acted as buffers to the lateral pressures and produced a wrinkling at the surface which is responsible for the belted alignment of the small areas of deformation.

3. That there was a series of faults or fault zones produced at the end of the Bend epoch trending in northeast-southwest lines. That later slight movements in post-Cisco times along these old fault planes produced slight wrinkles at the surface.

4. That the folds at the end of the Bend epoch were all connected with the uplift that produced the Llano Mountains and were caused by isostatic adjustments of the earth's crust involving the upward movement of lighter granitic masses and the settling of surrounding basic deposits. That these

forces have not been active since the beginning of the Strawn epoch, and that all later movements have had no relation to the pre-Strawn upheaval but have been brought about by local causes such as adjustment to load during epochs of rapid deposition, chemical changes during the induration of the sediments, slight contractions due to crustal shortening, etc., and that the location of the small surface "noses" over the larger folds in the Bend is purely chance.

It is difficult to choose one of the above hypotheses which is entirely applicable to a given area. It is thought that the second suggestion, that of a very uneven surface of the Bend, is least sound because neither along the outcrop nor in sections constructed from well logs is there indicated a hilly surface at the top of the Bend. It is more probable that no one of the above causes or set of causes is entirely responsible for the north

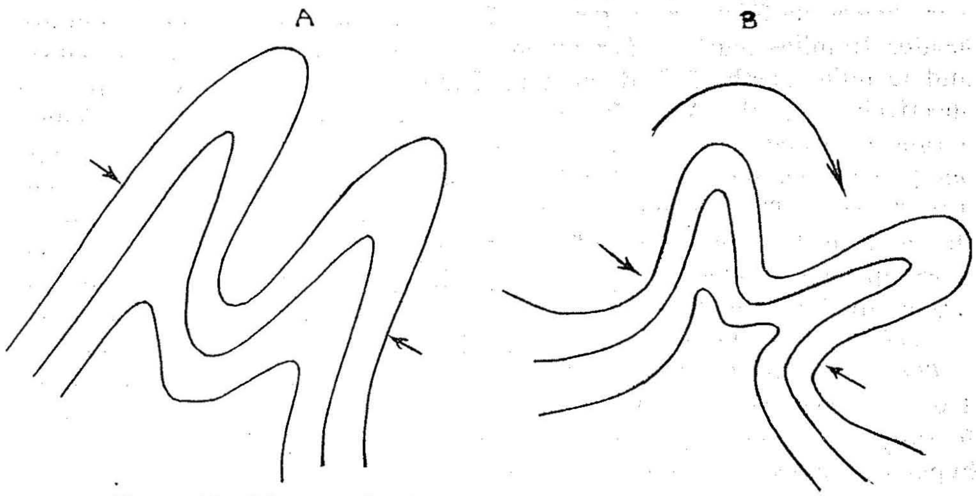



Figure 18. Diagram showing types of folding of surface strata

Texas surface structure, but that all of the factors have played a part. The surface fold south of Breckenridge, the series of "noses" at Ranger, and the syncline at Gorman are all located over so prominent subsurface folds in the Bend, that although they are of very different shape and much smaller extent, yet they must have some relation to the structure beneath. On the other hand there are undoubtedly anticlines in the Bend that have no expression on the surface. Near the town of Ivan, in Stephens County, there seems to be a prominent subsurface fold, although the dips at the surface are almost normal and indicate that there has been no folding in the Ivan district since the deposition of the Cisco beds. There are also many small wrinkles and "noses" on the surface which as far as known are not located over or near subsurface anticlines. They are undoubtedly due to local movements much younger in age than those that produced the large folds of the Bend and of different type. A common example of this class is the small, double plunging fold or "nose" illustrated in Fig. 18. In many cases the small "noses" of the double fold run at acute or even right angles to each other, forming a finger-shaped structure (See diagram B Figure 18). The shape of these folds suggests that they were produced by a contortional or twisting movement. A straight lateral shove directed in the direction of strike would develop plunging anticlinoria of the type of A in Figure 18. A contortional movement operating at the same time might form the finger shapes and "twisted terraces" illustrated by diagram B, Figure 18. The twisted type of structures seems to have no relation to the larger subsurface folds. They occur as commonly over synclinal areas in the Bend strata as over anticlines. The best explanation for the origin of the small faulted areas is that offered by Fath[86] who states:

"Horizontal movements along lines of weakness in the deep lying (strong) rocks (of the basement complex), with the consequent drag of the overlying weak sediments, would tear the lower parts of these sediments along a narrow belt parallel to the deep-seated movements, and short fractures would open which would trend at an angle of about 45 degrees with the direction of the movements. The adjustments of the overlying weak strata to these fractures would result in the belts of short normal faults characteristic of the region."

This explanation might apply not only to the faulted belts but also to the narrow belts of abnormal folding and twisting that are commonly associated with the few faults found in the north Texas district. Doubtless the belts of contorted strata may grade downward into series of normal faults caused by the drag.

*Summary.*—The origin of the structural features of the Pennsylvanian rocks may therefore be summarized as falling under two chief causes, as follows:

1. The upward movement of lighter acidic granitoid masses in the earth's strata produced by the settling of heavier basic masses due to overloading along the ancient shore line and perhaps producing the first movements along the Balcones Fault line. The point of greatest intensity of uplift was in the Llano Mountains, but at the same time a large arch was produced extending northward from the mountains nearly as far as the present Red River Valley.

2. Local adjustments due to relief of stress in the upper strata, and slight movements along old lines of weakness in the competent strata below that produced small faults and belts of gently folded strata at the surface, and finally contortional movements caused perhaps by lateral slipping along an old subsurface fault producing the double "spreading finger"-shaped folds.

*Age of the Pennsylvanian Folds.*—The major folding of the Bend strata that produced the Llano uplift and the Bend arch took place before the deposition of the Strawn beds, during the post-Bend—pre-Strawn epoch, possibly continuing during the deposition of the earliest Millsap strata. The folding of the upper Pennsylvanian formations took place during later periods and at different epochs. Following the Bend arch upheaval changes seem to have been gradational, and the earth movements slow and more or less continuous, and not of the type that leave plain records. However, there are fragmentary evidences of crustal movements in the Strawn beds that did not affect the overlying strata of the Canyon or Cisco. The anticlines near Locker and Regency in the Colorado River Valley, and on the Allen Ranch in the Brazos River Valley, all located within the Strawn

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[86]Fath, A. E. The Origin of the Faults, Anticlines, and Buried Granite Ridges of the Mid-Continent Oil and Gas Field, U. S. Geol. Surv., Prof. Paper 128-C, 1920.

beds, are much more steeply folded and faulted than any of the gently plunging folds and faults mapped in the Canyon and Cisco outcrops near by. The structural contours drawn on the oil sand of a portion of the Strawn oil field, show a small dome, whereas a carefully made contour of the Palo Pinto limestone, which outcrops at the surface, indicates only a small plunging anticline or "nose." Higher up in the section there are small local folds in clays near Eastland and in a sandstone east of Weedon School, in Brown County, which do not show in the overlying strata of the Cisco group. There is evidence therefore that the small surface folds of the Pennsylvanian strata were instituted early in the Pennsylvanian period and continued with lessened intensity throughout the latter epoch of the period and on through the Permian. In the later periods there has been very little folding in the north Texas Pennsylvanian area.

## SUMMARY OF THE PHYSICAL HISTORY OF THE PENNSYLVANIAN PERIOD IN NORTH CENTRAL TEXAS

The completion of the new geologic map and the comparative study of sections throughout the north Texas area have thrown additional light on the physical history of the Pennsylvanian period in Texas. From east to west the geologic section above the Bend becomes progressively thinner, not only because of the pinching out of the basal beds, but also because of the thinning of individual layers of sandstone and shale. In the well log sections extending from east to west many of the thick sandstone and conglomerate layers play out toward the west and their places are taken by thinner layers of shale. The limestones in the section become thicker and more numerous in all the formations. The Cisco group for example, at its outcrop in Stephens County, is predominantly shale, with thin layers of limestone and calcareous sandstone. The excellent log of the Spur well[87] shows that the upper layers of the Cisco in Dickens County, 120 miles west of the outcrop, are represented by 400 feet of limestone and a little marl. The same change on a smaller scale takes place from north to south. The thick sandstones and marls seen in the section in Jack and Young counties are absent or replaced by thinner strata in the Brownwood district, and limestones become more numerous in all divisions toward the southwest. The thickening and lithologic change toward the west and southwest do not take place equally in all formations. Although apparent in nearly all formations, there are a few beds that show the change much more markedly. Thus the Smithwick shale of the Bend group is much thicker and contains more sandstone layers and fewer limestones in the Mineral Wells district than it does 50 miles to the west in the vicinity of Breckenridge. The Millsap formation thins rapidly toward the west and is entirely absent south of the Colorado River. The Graham formation of the Cisco group thins from 300 to 400 feet in Jack County to less than 100 feet in McCulloch County, and all the thick sandstone and conglomerate lentils found in Jack County play out abruptly in Stephens County.

These changes in character of the sediments indicate that the old land mass from which the Pennsylvanian sediments were derived was situated

[87]Udden, J. A., The Deep Boring at Spur, Univ. Texas Bull. No. 363, 1914.

to the east and northeast of the present area of outcrop. Old schists and other ancient rocks have been struck in holes drilled in Grayson County about 60 miles east of Jack County. The shore line oscillated back and forth in the different epochs; at times high land must have been quite near at hand, as evidenced by the large fan-like deposits of gravel. Perhaps the mean position of the shore line was not far from the old Balcones Fault line. During the Bend epoch the land was low and furnished largely carbonaceous muds and calcareous oozes. During the latter part of the Bend epoch a little fine sand was washed into the Mineral Wells area. Following the Bend epoch there was a broad uplift in the Llano Mountains and across the area to the north a broad arch was formed which brought the sea bottom at or above sea level in the vicinity of the present Colorado River Valley, and possibly at high points along the top of the arch. At the same time there was a deep depression in the Mineral Wells and Jacksboro areas, into which thick deposits of mud and sand were rapidly washed. During the Millsap epoch the Mineral Wells embayment continued to fill up and the epoch ended with shallow water and conditions favorable for widespread peat deposition. Following Millsap times there was probably another uplift of the land mass, at least conditions set in favorable for rapid erosion on the land and deposition of thick deposits of sand conglomerate and shale, each bed of which seems to have been washed down an inclined slope and deposited in a near by bay in such a way that each younger bed overlapped offshore the bed below. At the end of the Strawn epoch there is evidence of a slight uplift in the Llano Mountains so that the basal beds of the Canyon limestone were not deposited and in their place came conglomerate layers washed in from a southern direction. During most of the Canyon epoch there were repeatedly long intervals of time in which the sea received almost no clastic sediments, and thick extensive layers of limestone accumulated over broad areas. At the beginning of the Cisco epoch there was another uplift of the land confined this time largely to the northeastern part of the old Texas coast line, so that deposition was greatly increased in the northern area, and large quantities of sand and conglomerate were washed into a shallow sea in Jack and Young counties, while conditions farther south in the present Brown and McCulloch county areas continued about the same as in the previous epoch. The climate was warm and the sea shallow and able to support a very prolific invertebrate life. The shores teamed with small shelled animals, and huge colonies of corals thrived in the shallow waters. At the end of the Graham subepoch of early Cisco times the sea retreated from the north Texas area for a short interval and the youngest clay beds of the Graham formation were removed in certain places by erosion. The interval of erosion was short, however, and the sea soon returned, spreading along its advancing beach an extensive deposit of sand. During the remainder of the Cisco epoch there were intervals of shallow water alternating with intervals when the land was at or above the sea level. Thin beds of limestone, cross-bedded wind-blown sand, thin seams of coal, brackish water deposits of clay, and gypsiferous and ferruginous muds were laid down in alternation throughout the entire area, so that although changes were frequent they were of a type which affected the northern and southern areas nearly equally. To the westward, in the districts now covered by the Permian deposits, as far as known the sea was fairly continuous and receiving calcareous deposits now represented almost wholly by limestone strata.

## SUMMARY OF THE PALEONTOLOGY AND CORRELATION OF THE TEXAS PENNSYLVANIAN

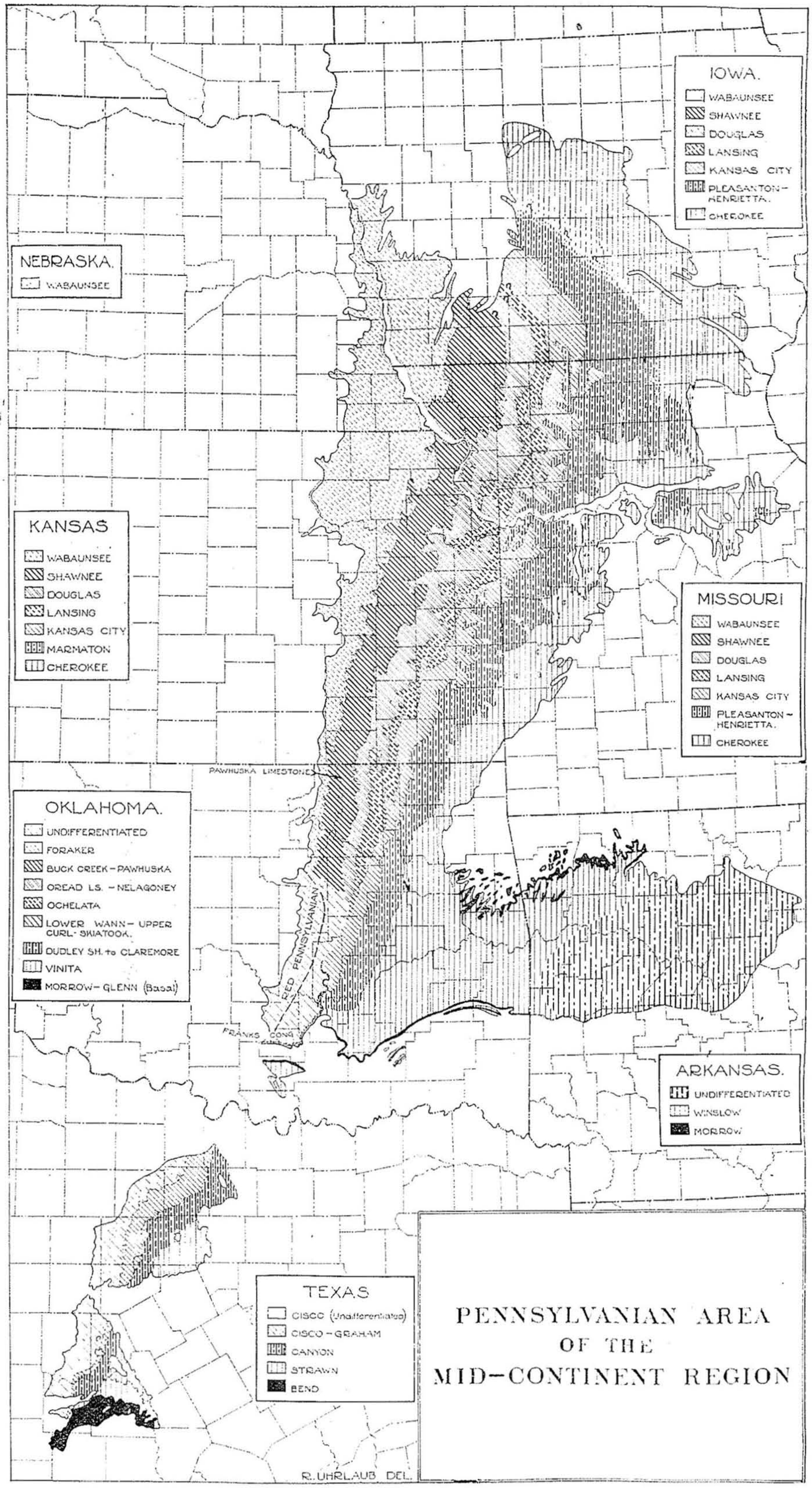
In the table following is shown the distribution of invertebrate fossils in the formations which have been described in this report on the Pennsylvanian stratigraphy of the north Texas region. While from the nature of the study and the conditions under which it has been prepared, it has not been possible to give critical and equally detailed study to the faunal or broader stratigraphic features which are most desirable, it is believed that sufficient evidence is available for a much more satisfactory delineation of the relations of the Texas Pennsylvanian than has been possible on information published heretofore.

It will be observed that the fauna of the Bend group is as a whole notably different from that of the succeeding Pennsylvanian divisions. It contains a considerable proportion of species, also, which have not been observed in other formations, but as has been indicated there is abundant evidence to show that it belongs to a very early stage in the Pennsylvanian period. On the basis of similar constituent faunal elements and correspondence in stratigraphic position, it is correlated with the Wapanucka limestone of southern Oklahoma and the Morrow group of northern Arkansas and northeastern Oklahoma. Beds from which fossils have recently been collected at the base of the Glenn formation on the south side of the Arbuckle Mountains appear to correspond to the Wapanucka horizon and may also be correlated with some portion of the Bend.

The Bend is unconformably overlain by the Strawn group composed of clastic sediments which overlap in a direction from east to west and were evidently derived chiefly from an old land mass, Llanoria,[ss] lying to the southeast and east. The Llano or Central Mineral Region of Texas was apparently an essentially positive element even in Strawn time, for in the vicinity of Brady, in McCulloch County, Canyon and Cisco beds are shown to be in contact with the Bend (see geologic map, Plate I). The fauna of the Millsap formation contains some elements which are similar to the Bend but is certainly considerably younger than that group. The stratigraphic relations of the Millsap to the Bend are not known but it is not improbable that only a slight break, if any, occurs between them. At all events, since the Mineral Wells formation contains a distinctive fauna very closely related to the Wewoka in southern Oklahoma, and that reported from the underlying beds, the lower portion of the Strawn is without doubt equivalent to a part of the series between the Wapanucka limestone and the Calvin sandstone, very possibly including at least a portion

[ss]The name Llanoria is applied to an ancient land mass which extended from the Llano region to the Sabine area and probably included very much of southeastern Texas, in mss. by H. D. Miser.

Plate XXVI


IOWA.
WABAUNSEE
SHAWNEE
DOUGLAS
LANSING
KANSAS CITY
PLEASANTON-HENRIETTA.
CHEROKEE
NEBRASKA.
WABAUNSEE
KANSAS
WABAUNSEE
SHAWNEE
DOUGLAS
LANSING
KANSAS CITY
MARMATON
CHEROKEE
MISSOURI
WABAUNSEE
SHAWNEE
DOUGLAS
LANSING
KANSAS CITY
PLEASANTON-HENRIETTA.
CHEROKEE
PAWHUSKA LIMESTONE
OKLAHOMA.
UNDIFFERENTIATED
FORAKER
BUCK CREEK-PAWHUSKA
OREAD LS. -NELAGONEY
OCHELATA
LOWER WANN-UPPER CURL-SKIATOOK.
DUDLEY SH. to CLAREMORE
VINITA
MORROW-GLENN (Basal)
RED PENNSYLVANIAN
FRANKS CONG.
ARKANSAS.
UNDIFFERENTIATED
WINSLOW
MORROW
TEXAS
CISCO (Undifferentiated)
CISCO-GRAHAM
CANYON
STRAWN
BEND
PENNSYLVANIAN AREA
OF THE
MID-CONTINENT REGION
R. UHRLAUB DEL.

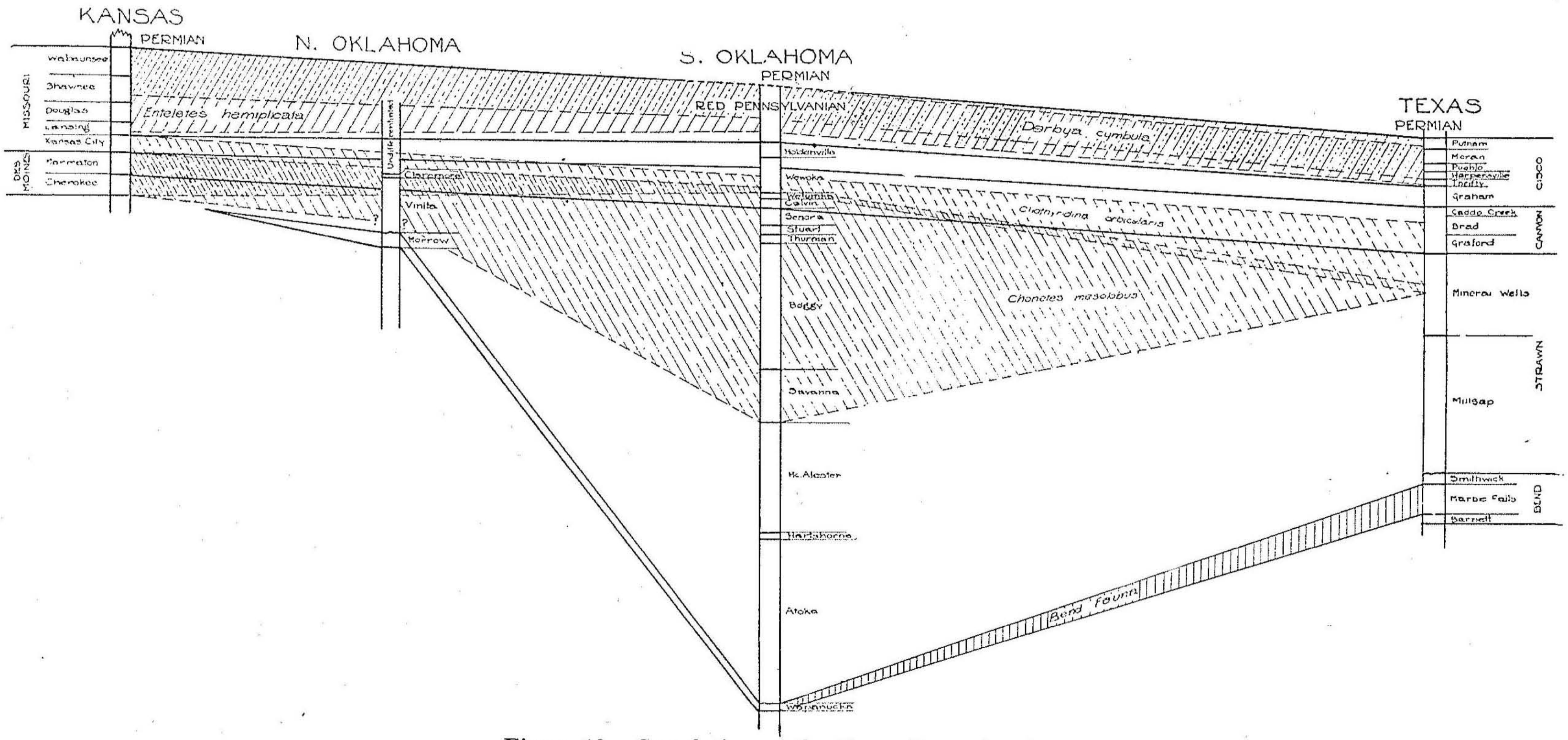



Figure 19. Correlation of the Texas Pennsylvanian

of the Atoka formation; also, since the section on the northeast side of the Arbuckle is believed to be represented on the south side by the strata included in the Glenn formation, by a portion of the lower Glenn. The fossiliferous Mineral Wells formation which belongs in the upper part of the Strawn may be correlated tentatively with a higher portion of the southern Oklahoma Pennsylvanian section, McAlester shale or above, but below the Wewoka. In general stratigraphic position and in the invertebrate fauna which is known, accordance exists.

On the general map of the Mid-Continent Pennsylvanian the Strawn of Texas is represented by light, vertically ruled lines. The geological divisions of the states to the north, to all or part of which the Strawn corresponds, are similarly marked. In Oklahoma the divisions include the strata from the top of the Wapanucka limestone to the base of the Calvin sandstone-Claremore formation-Fort Scott limestone, which is a horizon marking the change in the northern part of the state and in Kansas and Missouri from the clastic deposits of the Vinita-Cherokee into the more calcareous series overlying. In the Pennsylvanian area south of the Arbuckle Mountains, the major portion of the Glenn is regarded as belonging to the same division of time as that represented by the deposits on the northeast side of the mountains above the Wapanucka, and accordingly it may be included as a part of the lower Pennsylvanian deposits to which the Strawn belongs. In Kansas, Missouri, and Iowa, the vertically ruled area includes the Cherokee shale, which, while similar in lithologic character and fauna to the thick section in Oklahoma and Texas which is here discussed, represents only the later, upper part of that series, marking the encroachment of the seas on the lands at a time considerably later than the time of the Bend-Wapanucka-Morrow to the south.

The Canyon group includes limestone deposits which represent fairly open, clear water conditions, although there is very much shale and some sandstone in the division as a whole. The fauna, while including some species which are not observed elsewhere, is marked by the presence of many characteristic species from the Wewoka formation, and the middle and older, rather than the upper, Pennsylvanian divisions of other regions. The Canyon may be correlated with the upper part of the Pennsylvanian series northeast of the Arbuckle Mountains, approximately Calvin to Holdenville, inclusive, within which is the Wewoka formation.

The Canyon is shown on the general map of the Mid-Continent region in dark, vertically ruled, full and broken lines. The stratigraphic divisions in the Pennsylvanian outside of Texas with which the Canyon is here correlated are similarly represented. In southern Oklahoma this includes the portion of the Colgate area section above the Calvin which has just been mentioned. Farther north it includes the Claremore formation, Lenapah limestone and intervening beds, and a portion of the strata above the Lenapah which are approximately equivalent to the Dudley shale of Kansas. The Lenapah horizon has been traced across eastern Oklahoma and is found to occur just above the Wewoka, so there appears to be relatively little question, in view also of the similarity of faunal character, of the equivalence of the Wewoka and associated adjacent beds to the Marmaton formation of Kansas. In Kansas the beds regarded as equivalent to the Canyon are comprised essentially in the Marmaton formation, which is the area shown in corresponding ruling on the map. The continuation of the Marmaton in Missouri and Iowa includes the Henrietta and Pleasanton formations as described in recent Missouri reports.

The Cisco contains two main faunal groups, one in the Graham formation which is very similar to the Wewoka, and a second in the strata included in the Thrifty to Putnam formations. The contrast in these groups is very obvious and the characteristic fossils from the two portions of the Cisco may be distinguished readily. The Graham fauna, in spite of its evident relation to the Wewoka fauna, lacks some of the typical fossils of the latter which are most suggestive of the older Pennsylvanian; and contains other fossils, such as the unique group of Permian-like ammonoids, which are strongly suggestive of the Upper Pennsylvanian. In view of these faunal characters and the similarity in the change to the fauna which succeeds, the Graham formation is correlated with the lower part of the Upper Coal Measures which is included in the Kansas City formation of the Kansas and Missouri sections, and it is believed to be younger than the Wewoka formation of southern Oklahoma.

The upper portion of the Cisco group contains a typical Upper Pennsylvanian group of invertebrate fossils which is mainly characterized by the disappearance of many of the types which had been dominant in the earlier stages, and by the appearance of a few species which, because of their occurrence and wide distribution only in this part of the system, are readily identified as markers of it. The formations from the Thrifty to the Putnam are correlated with the divisions of the Kansas section, Lansing to Wabaunsee, inclusive, but there is no precise equivalence between the individual stratigraphic groups, so far as known, nor is this likely. In Texas, as in Kansas, the transition from the uppermost Pennsylvanian to the Permian is without stratigraphic break and the exact line of division can not be placed very satisfactorily.

On the map the outcrop of the Graham formation in Texas is represented by the same convention, light diagonal ruling, as that for the Kansas City formation in Kansas and Missouri. In Oklahoma the continuation of this division has not been traced definitely across the state. Indeed, on account of changes in the lithologic character of the strata to the south, it is not apparent that readily determinable, mappable units precisely equivalent to the divisions farther to the north can be differentiated. From the known strike of the beds and the position of the Lenapah horizon to the east, it appears that strata equivalent to the Kansas City formation are present in eastern Seminole County, Oklahoma, beneath the conglomerate (Seminole) which under the direction of McCoy[89] has been traced south into the Franks conglomerate. It may be observed that if this is the case, and the Graham is, as believed, approximately equivalent in age to the

[89]McCoy, A. W., Personal communication.

Kansas City beds, the uplift of the Arbuckle Mountains, which occurred in post-Glenn time, may have occurred as late as after Kansas City time; or, as seems more probable in view of the considerably thicker, more clastic character of the Graham in its northern outcrops and the consequent indication of very active erosion north of the Texas basin, that the uplift was initiated at about the close of Marmaton, that is, of Des Moines time; that during Kansas City time debris from the thick section of Lower Pennsylvanian clastics equivalent to the Glenn and Atoka to Wewoka sections above the mountain area, was spread to the south and north, and that toward the close of Kansas City time much of the material from the old Paleozoic and Pre-Cambrian rocks which eventually were exposed in the mountains, was accumulated on the flanks and spread outward at the horizon or horizons represented by the Franks (Seminole) conglomerates.

The remaining portion of the Cisco of Texas is not differentiated on the map of the Mid-Continent region. In Kansas, Missouri and Iowa, the divisions of the Lansing, Douglas, Shawnee and Wabaunsee are shown, but these can not be traced far into Oklahoma. It is perhaps noteworthy that the lower portion of this Upper Pennsylvanian series, especially in Oklahoma and southern Kansas, is characterized by a marked increase in the proportion of coarse clastic material which may have been derived from the uplifted area to the south and west.[90]

The following correlation table and Figure 19 show some of the relations of the Texas formations described in this report as indicated by the recent studies. As more complete evidence is obtained both from Texas and other parts of the Mid-Continent region, it will be possible to ascertain more definitely these relations and equivalences.

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[90]The discovery of crystalline rocks directly beneath the Permian in the vicinity of the Wichita Mountains, in western Oklahoma (Beckham County) and the Panhandle of Texas, indicates that a land area in late Pennsylvanian time in this region may have contributed importantly to the sediments now found in the Upper Pennsylvanian strata of Oklahoma and Kansas.

## CORRELATION OF TEXAS PENNSYLVANIAN

| TEXAS | | OKLAHOMA | KANSAS | | MISSOURI | | ARKANSAS |
|---|---|---|---|---|---|---|---|
| Permian | | Permian | Permian | | | | |
| CISCO | Putnam | Partly Differentiated | MISSOURI | Wabaunsee | MISSOURI | Wabaunsee | ? |
| | Moran | | | Shawnee | | Shawnee | |
| | Pueblo | | | Douglas | | Douglas | |
| | Harpersville | | | Lansing | | Lansing | |
| | Thrifty | | | Kansas City | | Kansas City | |
| | Graham | | | | | | |
| CANYON | Caddo Creek | Holdenville | DES MOINES | Marmaton | DES MOINES | Marmaton | Undifferentiated |
| | Brad | Wewoka | | | | | |
| | Graford | Wetumka | | | | | |
| | Palo Pinto | Calvin | | Cherokee | | Cherokee | |
| ? | | Senora | | | | | |
| | | Stuart | | | | | |
| | | Thurman | | | | | |
| STRAWN | Mineral Wells | Boggy | | | | | Winslow |
| | | Savanna | | | | | |
| | ? | | | | | | |
| | Millsap | McAlester | | | | | |
| | | Hartshorne | | | | | |
| | | | | | | | ? |
| | ? | Atoka | | | | | |
| BEND | Smithwick | | | | | | |
| | | Wapanucka | | | | | |
| | Marble Falls | ? | | | | | |
| | Barnett | Caney | | | | | Morrow |

## FAUNA OF THE TEXAS PENNSYLVANIAN

| SPECIES | Bend | | | Strawn | | Canyon | | | Cisco | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| **Protozoa** | | | | | | | | | | | | | | | |
| Fusulina sp. | | x | | | x | x | x | | x | x | x | | | | |
| **Porifera** | | | | | | | | | | | | | | | |
| Somphospongia sp. | | | x | | x | x | | | | | | | | | |
| Amblysiphonella sp. | | | | | | | | x | | | | | | | |
| Paleospongia sp. | | | | | | D | | | | | | | | | |
| **Coelenterata** | | | | | | | | | | | | | | | |
| Hadrophyllum aplatum | | | x | | | | | | | | | | | | |
| Zaphrentis gibsoni | | | | x | | x | | | | | | | | | |
| Zaphrentis sp. | | x | | x | | x | D | | | | | | | | |
| Amplexus corrugatus | | x | | | | | | | | | | | | | |
| Lophophyllum profundum | | x | | | x | x | x | | x | D | x | x | | | |
| Lophophyllum profundum radicosum | | | | | x | | x | | x | | x | x | | | |
| Lophophyllum sp. | | | | | | x | | | | | | | | | |
| Campophyllum torquium | | x | | x | x | x | x | | x | D | D | D | | | |
| Axophyllum rude | | x | | | | | | | | | x | x | | | |
| Michelinia eugeneae | | ? | | | | D | | | | | | | | | |
| Michelinia n. sp. | | x | | | | | | | | | | | | | |
| Michelinia sp. | | | | x | | | | | | | | | | | |
| Aulopora prosseri | | | | | | | | | x | | | | | | |
| Syringopora multattenuata | | | | | | x | x | | x | | | | | | |
| Syringopora sp. | | | | | D | | | D | D | | | | | | D |
| Chaetetes milleporaceus | | x | | | | x | | | | | | | | | |
| Chaetetes sp. | | | | | | D | D | | | | | | | | |
| **Vermes** | | | | | | | | | | | | | | | |
| Serpulopsis sp. | | | | | | | | | x | | | | | | |
| Spirorbis sp. | | | | | | | | | | | x | | | | |
| Tubicola ? sp. | | x | | | | | | | | | | | | | |
| **Echinodermata** | | | | | | | | | | | | | | | |
| Hydreionocrinus acanthophorus | | | | | D | D | | | | D | | | | | |
| Hydreionocrinus mucrospinus | | | | | x | | | | | | | | | | |
| Hydreionocrinus patulus | | | | | | | x | | | | | | | | |
| Hydreionocrinus subsinuatus | | | | | | | | | ? | | | | | | |
| Hydreionocrinus sp. | | | | | x | x | x | | x | | x | x | | | |
| Agassizocrinus carbonarius | | | | | | x | | | | | | | | | |
| Cromyocrinus n. sp. | | x | | | | | | | | | | | | | |
| Ulocrinus occidentalis | | | | | x | | | | x | | | | | | |
| Eupachycrinus magister ? | | | | | | x | | | | | | | | | |
| Eupachycrinus tuberculatus | | | | | D | | | | x | | | | | | |
| Eupachycrinus sp. | | x | | | | x | | | x | | | | | | |
| Delocrinus hemisphericus | | | | | ? | | | | | | x | | | | |
| Delocrinus sp. | | | | | | x | x | | x | | | | | | |

D indicates species reported by Drake.

| SPECIES | Bend | | | Strawn | | Canyon | | | Cisco | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| Archeocidaris aculeata | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... | .... |
| Archeocidaris megastylus | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Archeocidaris mucronatus | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Archeocidaris norwoodi ? | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Archeocidaris sp. | .... | x | .... | .... | .... | x | D | .... | x | x | x | x | .... | .... | x |
| **Bryozoa** | | | | | | | | | | | | | | | |
| Fistulipora carbonaria | .... | x | .... | .... | .... | x | x | .... | x | .... | .... | .... | .... | .... | .... |
| Fistulipora nodulifera | .... | .... | .... | .... | .... | x | .... | .... | x | .... | x | ? | .... | .... | .... |
| Fistulipora n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Fistulipora sp. | .... | .... | .... | .... | x | x | .... | .... | x | .... | x | .... | .... | .... | .... |
| Batostomella sp. | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Tabulipora spinulosa ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Tabulipora carbonaria | .... | .... | .... | .... | .... | .... | .... | .... | .... | D | .... | .... | .... | .... | .... |
| Tabulipora heteropora | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Tabulipora sp. | .... | x | .... | x | .... | x | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Chainodictyon laxum ? | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Fenest lla conradi-compactilis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella compressa | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Fenestella gracilis | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella limbata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella modesta | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Fenestella perelegans | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella trinodata | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Fenestella cf. multispinosa | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Fenestella sp. | .... | x | .... | x | .... | x | x | .... | x | D | x | x | .... | x | x |
| Polypora bassleri | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... |
| Polypora spinulifera | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Polypora sp. | .... | x | .... | .... | x | x | x | .... | x | .... | x | .... | .... | .... | .... |
| Pinnatopora sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Septopora biserialis | .... | x | .... | .... | .... | .... | .... | .... | .... | D | D | D | .... | .... | ? |
| Septopora biserialis nervata | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Septopora sp. | .... | x | .... | .... | .... | x | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Septopora robusta | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Rhombopora lepidodendroidea | .... | x | .... | .... | x | x | .... | .... | x | .... | x | .... | .... | x | .... |
| Rhombopora attenuata | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Rhombopora persimilis | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Rhombopora tabulata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Rhombopora sp. | .... | x | .... | .... | .... | x | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Cystodictya lineata | .... | ? | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cystodictya n. sp. A | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cystodictya n. sp. B | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |
| Cystodictya sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Prismopora n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Glyptopora n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Streblotrypa ulrichni | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... |

D indicates species reported by Drake.

| SPECIES | Bend | | | Strawn | | Canyon | | | Cisco | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| **Brachiopoda** | | | | | | | | | | | | | | | |
| Lingula albapinensis | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Lingula umbonata | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... | .... |
| Lingula sp. | .... | .... | x | .... | x | x | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Lingulipora nebraskensis | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Orbiculoidea convexa | .... | .... | .... | .... | .... | D | D | .... | x | D | .... | .... | .... | .... | .... |
| Orbiculoidea caneyana | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Orbiculoidea batesvillensis | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Orbiculoidea missouriensis | .... | .... | .... | .... | .... | .... | D | .... | D | .... | .... | .... | .... | .... | .... |
| Orbiculoidea n. sp. | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Orbiculoidea sp. | .... | .... | x | .... | .... | x | .... | .... | .... | .... | .... | x | .... | .... | .... |
| Roemerella patula | .... | .... | .... | .... | x | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Roemerella ? sp. | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Crania modesta | .... | .... | .... | .... | .... | x | D | .... | x | .... | .... | .... | .... | .... | .... |
| Rhipidomella pecosi | .... | x | .... | .... | x | .... | x | .... | x | .... | .... | .... | .... | .... | .... |
| Orthotichia schuchertensis | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Enteletes hemiplicata | .... | .... | .... | .... | .... | .... | .... | .... | .... | D | x | x | .... | .... | .... |
| Schellwienella ? sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Orthotetes ? kaskaskiensis | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Derbya crassa | .... | .... | .... | .... | x | x | D | .... | x | D | x | x | .... | x | D |
| Derbya bennetti | .... | .... | .... | .... | .... | ? | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Derbya cymbula | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | x | .... | x | x |
| Derbya sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Meekella striatocostata | .... | .... | .... | .... | .... | D | D | .... | .... | .... | x | .... | .... | .... | D |
| Chonetes choteauensis | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes granulifer | .... | .... | .... | .... | x | x | D | .... | x | D | x | .... | .... | .... | .... |
| Chonetes granulifer meekanus | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | x | x | .... | .... | .... |
| Chonetes mesolobus | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes mesolobus decipiens | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes laevis | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes mesolobus euampygus | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes verneuilianus | .... | .... | .... | .... | x | x | D | .... | x | .... | .... | .... | .... | .... | .... |
| Chonetes n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Chonetes sp. | .... | .... | x | .... | .... | .... | .... | .... | x | .... | x | .... | .... | .... | .... |
| Productus coloradoensis | .... | ? | .... | .... | x | x | .... | .... | x | .... | ? | .... | .... | .... | ? |
| Productus cora | .... | x | .... | x | x | x | x | .... | x | D | x | .... | .... | x | .... |
| Productus costatus | .... | .... | .... | .... | .... | D | D | .... | D | D | .... | D | .... | .... | .... |
| Productus insinuatus | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Productus inflatus | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Productus morrowensis | .... | x | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Productus nanus | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Productus pertenuis | .... | .... | .... | .... | x | .... | D | .... | x | D | ? | .... | .... | .... | D |
| Productus parvus | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Productus semireticulatus | .... | .... | .... | .... | .... | D | D | .... | D | .... | D | x | .... | x | D |
| Productus sp. | .... | x | .... | .... | .... | x | x | .... | .... | .... | .... | .... | .... | .... | .... |
| Marginifera lasallensis | .... | .... | .... | .... | x | ?D | x | .... | x | ?D | .... | x | .... | .... | .... |
| Marginifera missouriensis | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| Marginifera muricata | .... | .... | .... | x | .... | .... | ?D | ?D | ? | .... | ? | .... | .... | .... | .... |
| Marginifera haydenensis | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Marginifera ingrata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Marginifera splendens | .... | ? | .... | .... | x | x | x | ? | x | D | x | x | .... | .... | .... |
| Marginifera sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pustula bullata | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pustula globosa | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pustula moorefieldana pusilla | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pustula nebraskensis | .... | x | .... | .... | x | x | x | .... | x | D | x | x | .... | .... | .... |
| Pustula punctata | .... | x | .... | .... | x | x | x | .... | .... | D | x | .... | .... | .... | .... |
| Pustula symmetrica | .... | .... | .... | .... | .... | D | D | .... | .... | .... | ? | .... | .... | .... | .... |
| Pustula sublineata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pustula n. sp. | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Pustula sp. | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... |
| Avonia ? arkansana | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Avonia ? arkansana multilirata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Avonia n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Leiorhynchus carboniferum | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Leiorhynchus carboniferum polypleurum | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Pugnax osagensis | .... | x | .... | .... | .... | .... | D | .... | x | D | D | x | .... | .... | .... |
| Pugnax osagensis percostata | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Pugnax rockymontanus | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Rhynchopora illinoisensis | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Dielasma bovidens | .... | x | .... | ? | .... | x | D | .... | ? | D | x | x | .... | .... | .... |
| Dielasma sp. | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer cameratus | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer marcoui | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer organensis | .... | .... | .... | .... | .... | D | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer rockymontanus | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer texanus | .... | .... | .... | .... | .... | x | D | .... | x | .... | .... | .... | .... | .... | .... |
| Spirifer n. sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spirifer sp. | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Squamularia perplexa | .... | x | .... | x | x | x | D | .... | x | D | .... | .... | .... | .... | .... |
| Squamularia transversa | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Ambocoelia planoconvexa | x | x | .... | x | x | D | x | x | x | D | x | .... | .... | .... | D |
| Spiriferina kentuckiensis | .... | x | .... | x | x | x | x | x | x | D | x | D | .... | .... | .... |
| Spiriferina transversa | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Spiriferina spinosa | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Hustedia mormoni | .... | .... | .... | .... | x | D | x | .... | x | D | x | .... | .... | .... | x |
| Hustedia miseri | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Athyris sp. | .... | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cliothyridina orbicularis | .... | .... | .... | .... | x | .... | x | .... | .... | .... | .... | .... | .... | .... | .... |
| Cliothyridina hirsuta | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cliothyridina sublamellosa | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Cliothyridina sp. | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Composita subtilita | ? | .... | .... | x | x | x | x | x | x | D | x | D | .... | D | x |
| Composita subquadrata | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Composita wasatchensis | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| **Pelecypoda** | | | | | | | | | | | | | | | |
| Solenomya n. sp. | | x | | | | | | | | | | | | | |
| Solenomya sp. | | | | x | | | | | | | | | | | |
| Sanguinolites sp. | | x | | | | | | | | | | | | | |
| Chaenomya leavenworthensis | | | | | | | | | | | | x | | | |
| Chaenomya sp. | | | | | | | | | x | | | | | | |
| Edmondia aspenwallensis | | | | | | x | | | x | | | | | | |
| Edmondia gibbosa | | | | | | x | | | x | | | | | | |
| Edmondia sp. | | | | x | | | | | x | | | | | | |
| Nucula anodontoides ? | | | | | x | x | | | x | | | | | | |
| Nucula rectangula | | x | | | | | | | | | | | | | |
| Nuculopsis ventricosa | | | | | x | x | x | | x | | | | | | |
| Nuculopsis ? sp. | | | | | x | | | | | | | | | | |
| Leda bellistriata | x | x | x | | x | x | x | | x | | | | | | |
| Leda bellistriata attenuata | | ? | ? | | x | x | | | x | | | | | | |
| Leda nasuta | | ? | | | | | | | | | | | | | |
| Yoldia glabra | | | | | x | x | | | x | | | | | | |
| Parallelodon obsoletus | | | | | | x | | | | | | | | | |
| Parallelodon sangamonensis | | | | | | | x | | x | | | | | | |
| Parallelodon sp. | | x | | | | | | | x | | | | | | x |
| Leptodesma spergenense robustum | | ? | | | | | | | | | | | | | |
| Aviculopinna americana | | | | | | | | | ? | | | | | | |
| Pinna peracuta | | | | | | x | | | x | D | x | x | | x | x |
| Pinna sp. | | x | | | | | | | | | | | | | |
| Conocardium obliquum | | x | | | | D | D | | D | | | | | | |
| Conocardium sp. | | x | x | | | x | | | x | | | | | | |
| Pteria sulcata | | | | | | x | | | | | | | | | |
| Leiopteria n. sp. | | x | | | | | | | | | | | | | |
| Pseudomonotis hawni | | | | | | x | | | x | | | | | | |
| Myalina kansasensis | | | | | | | | | | | ? | x | | | |
| Myalina recurvirostris | | | | | ? | x | | | ? | | x | x | | | |
| Myalina subquadrata | | | ? | | | x | x | | x | | x | x | | | D |
| Myalina swallovi | | | | | x | x | | | | | | | | | |
| Myalina sp. | | | | | x | | | | x | | x | x | | | |
| Anthraconeilo taffiana | | | | | x | x | | | x | | ? | | | | |
| Schizodus affinis | | | | | ? | | | | | | | | | | |
| Schizodus alpinus | | | | | | ? | | | x | | | | | | |
| Schizodus depressus | | x | | | | | | | | | | | | | |
| Schizodus wheeleri | | | | | | x | | | D | | | x | | | |
| Schizodus sp. | | | | | x | | | | x | | | | | | x |
| Aviculopecten occidentalis | | | | | | ? | D | | | | D | | | x | D |
| Aviculopecten n. sp. | | x | | | | | | | | | | | | | |
| Aviculopecten sp. | | | | x | D | x | D | | x | | x | x | | | D |
| Acanthopecten carboniferus | | ? | | | | | | | | | | | | | |
| Acanthopecten n. sp. | | x | | | | | | | | | | | | | |
| Deltopecten texanus | | | | | | | | | x | | | | | | |
| Deltopecten vanvleeti | | | | | | | | | | | x | | | | |
| Deltopecten sp. | | | | | | | | | x | | | | | | |

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| Streblopteria hertzeri | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- |
| Lima retifera | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Modiolus n. sp. | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Allorisma subcuneatum | ---- | ---- | ---- | ---- | ? | D | ? | ---- | ---- | D | D | x | ---- | x | x |
| Allorisma terminale | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Allorisma sp. | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |
| Astartella concentrica | ---- | ---- | ---- | ---- | x | x | ---- | ---- | x | ---- | x | x | ---- | ---- | ---- |
| Astartella varica | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ? | ---- | ---- | ---- | ---- | ---- | ---- |
| Caneyella n. sp. | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Pleurophorus sp. | ---- | ---- | ---- | ---- | ---- | D | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| **Gastropoda** | | | | | | | | | | | | | | | |
| Bellerophon crassus | ---- | ---- | ---- | ---- | D | x | ---- | ---- | x | D | ---- | ---- | ---- | x | D |
| Bellerophon crassus wewokanus | ---- | x | x | ---- | x | x | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |
| Bellerophon sp. | ---- | x | x | ---- | ---- | x | ---- | ---- | x | ---- | x | x | ---- | ---- | x |
| Patellostium montfortianum | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ? |
| Euphemus carbonarius | ---- | x | ---- | ---- | x | x | D | ---- | x | ---- | x | ---- | ---- | ---- | x |
| Euphemus nodocarinatus | ---- | ---- | ---- | ---- | ---- | D | D | ---- | D | ---- | ---- | ---- | ---- | ---- | ---- |
| Bucanopsis meekiana | ---- | ---- | x | ---- | x | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Pharkidonotus percarinatus | ---- | ---- | ---- | ---- | x | x | x | ---- | x | ---- | x | x | ---- | ---- | ---- |
| Pleurotomaria sphaerulata | ---- | ---- | ---- | ---- | ---- | D | D | ---- | D | ---- | ---- | ---- | ---- | ---- | ---- |
| Pleurotomaria subscalaris | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ? | ---- | ---- | ---- | ---- | ---- | ---- |
| Pleurotomaria sp. | ---- | ? | ---- | ? | D | ---- | ---- | ---- | D | ---- | ---- | ---- | ---- | ---- | ? |
| Worthenia tabulata | ---- | ---- | ---- | ---- | ---- | x | x | ---- | x | D | x | x | ---- | ---- | ---- |
| Worthenia ? sp. | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Phanerotrema grayvillense | ---- | ---- | ---- | ---- | x | x | x | ---- | x | ---- | x | ---- | ---- | ---- | ---- |
| Phanerotrema n. sp. | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Orestes brazoensis | ---- | ---- | ---- | ---- | ---- | x | D | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |
| Murchisonia terebratula | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | D |
| Murchisonia trinodolineata | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | D |
| Murchisonia sp. | ---- | x | ---- | x | x | x | ---- | ---- | x | ---- | ---- | x | ---- | ---- | x |
| Goniospira lasallensis | ---- | ---- | ---- | ---- | x | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Orthonema carbonaria | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Bembexia nodomarginata | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Trepospira depressa | ---- | ---- | ---- | ---- | x | x | x | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |
| Euomphalus n. sp. A. | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Euomphalus n. sp. B. | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Euomphalus sp. | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- |
| Schizostoma catilloides | ---- | x | ---- | x | x | D | x | ---- | x | D | x | x | ---- | ---- | x |
| Schizostoma subquadrata | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Turbo n. sp. | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Turbo sp. | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| Strophostylus sp. | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x |
| Naticopsis altonensis giganteus | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Naticopsis wheeleri | ---- | ---- | ---- | ---- | D | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Naticopsis sp. | ---- | ---- | ---- | x | x | ---- | x | ---- | ---- | ---- | ---- | x | ---- | ---- | x |
| Loxonema ? sp. | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| Zygopleura rugosa | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |
| Zygopleura nodosa | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- | x | ---- | ---- | ---- | ---- | ---- | ---- |

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| Zygopleura multicostata | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Zygopleura plebia | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Zygopleura n. sp. | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Zygopleura sp. | .... | .... | .... | .... | x | .... | .... | .... | x | .... | .... | .... | .... | .... | x |
| Hemizyga sp. | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Bulimorpha inornata | .... | .... | .... | .... | x | .... | .... | .... | D | .... | .... | .... | .... | D | .... |
| Bulimorpha nitidula | .... | .... | .... | .... | .... | .... | .... | .... | D | .... | .... | .... | .... | .... | .... |
| Bulimorpha sp. cf. B. chrysalis | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Bulimorpha ? sp. | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x | .... |
| Meekospira bella | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... |
| Meekospira peracuta | .... | x | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Meekospira peracuta choctawensis | .... | .... | .... | .... | x | .... | x | .... | x | .... | .... | .... | .... | .... | .... |
| Meekospira sp. | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | x |
| Sphaerodoma brevis | .... | .... | .... | .... | x | .... | x | .... | x | .... | .... | .... | .... | .... | .... |
| Sphaerodoma gracilis | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Sphaerodoma intercalaris | .... | .... | .... | .... | .... | x | .... | .... | x | .... | .... | ? | .... | .... | .... |
| Sphaerodoma medialis | .... | .... | .... | .... | .... | D | D | .... | .... | .... | .... | .... | .... | .... | .... |
| Sphaerodoma paludiniformis | .... | .... | .... | .... | x | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Sphaerodoma primigenia | .... | .... | .... | .... | x | .... | D | .... | x | .... | .... | .... | .... | .... | .... |
| Sphaerodoma texana | .... | .... | .... | .... | .... | D | D | .... | D | .... | .... | .... | .... | .... | .... |
| Sphaerodoma ventricosa | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Sphaerodoma sp. | .... | x | x | x | .... | x | x | .... | x | .... | .... | .... | .... | .... | x |
| Holopella stevensana | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Holopella sp. | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Trachydomia wheeleri | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Platyceras parvum | .... | x | .... | .... | .... | .... | D | .... | x | .... | .... | D | .... | .... | x |
| Porcellia sp. | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Ianthinopsis gouldiana | .... | .... | .... | .... | .... | .... | .... | .... | ? | .... | .... | .... | .... | .... | .... |
| Dentalium semicostatum | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Dentalium sublaeve | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Plagioglypta meekiana | .... | .... | .... | .... | x | .... | .... | .... | x | .... | ? | .... | .... | .... | .... |
| Conularia crustula | .... | .... | .... | x | x | D | D | .... | x | D | .... | .... | .... | .... | .... |
| **Cephalopoda** | | | | | | | | | | | | | | | |
| Orthoceras annulato-costatum | .... | .... | .... | .... | .... | .... | .... | .... | D | .... | .... | .... | .... | .... | .... |
| Orthoceras sp. | x | x | x | .... | x | x | .... | .... | x | .... | x | x | .... | .... | x |
| Pseudorthoceras knoxense | .... | .... | .... | .... | x | .... | x | .... | x | .... | .... | .... | .... | .... | .... |
| Protocycloceras ? rushense ? | .... | .... | .... | .... | x | x | D | .... | x | .... | .... | .... | .... | .... | D |
| Nautilus sp. | .... | x | .... | .... | .... | D | D | .... | D | .... | .... | .... | .... | .... | x |
| Coloceras liratum | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Metacoceras cornutum | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |
| Metacoceras cornutum carinatum | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Metacoceras perelegans | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| Metacoceras cornutum sinuosum | .... | .... | .... | .... | .... | .... | .... | .... | x | .... | .... | .... | .... | .... | .... |

D indicates species reported by Drake.

| SPECIES | Bend | | | Strawn | | Canyon | | | Cisco | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barnett | Marble Falls | Smithwick | Millsap | Mineral Wells | Graford | Brad | Caddo Creek | Graham | Thrifty | Harpersville | Pueblo | Moran | Putnam | Permian |
| Metacoceras sculptile | | | | | | | | | x | | | | | | |
| Metacoceras walcotti | | x | | | | | | | | | | | | | |
| Metacoceras sp. | | | | | x | | | | x | | | | | | x |
| Tainoceras occidentale | | | | | | | | | x | | | | | | |
| Cyrtoceras peculiare | | | | | | | | | x | | | | | | |
| Cyrtoceras sp. | | x | | | | | | | | | | | | | |
| Gonioloboceras goniolobum | | | | | | | | | x | | | | | | |
| Gonioloboceras welleri | | | | | x | x | | | x | | | | | | |
| Goniatites sp. | | | | | | D | D | | D | | | | | | |
| Pronorites n. sp. | | | | | | x | | | | | | | | | |
| Pronorites sp. | | | | | | | | | x | | | | | | |
| Schuchertites grahami | | | | | | | | | x | | | | | | |
| Gastrioceras angulatum | | | | | | | | | x | | | | | | |
| Gastrioceras compressum | | x | x | | | | | | | | | | | | |
| Gastrioceras globulosum | | | | | | | | | x | | | | | | |
| Gastrioceras hyattanum | | | | | | x | | | | | | | | | |
| Gastrioceras kingi | | ? | | | | | | | | | | | | | |
| Gastrioceras listeri | | | | | | | | | x | | | | | | |
| Gastrioceras subcavum | | | | | | | | | x | | | | | | |
| Gastrioceras sp. | | | x | | | | | | x | | | | | | |
| Paralegoceras n. sp. | | x | x | | | | | | | | | | | | |
| Paralegoceras sp. | | | x | | | | | | | | | | | | |
| Schistoceras hildrethi | | | | | | | | | x | | | | | | |
| Schistoceras hyatti | | | | | | | | | x | | | | | | |
| Dimorphoceras texanum | | | | | x | | | | x | | | | | | |
| Agathiceras ciscoense | | | | | | | | | x | | | | | | |
| Popanoceras parkeri | | | | | | | x | | | | | | | | |
| Stacheoceras ganti | | | | | | | | | x | | | | | | |
| Shumardites simondsi | | | | | | | | | x | | | | | | |
| Glyphioceras incisum | x | x | | | | | | | | | | | | | |
| Glyphioceras cumminsi | x | x | | | | | | | | | | | | | |
| Glyphioceras n. sp. | | x | | | | | | | | | | | | | |
| Glyphioceras sp. | | | | | | | | | x | | | | | | |
| **Trilobita** | | | | | | | | | | | | | | | |
| Phillipsia missouriensis | | ? | | | | | | | | | | | | | |
| Phillipsia major | | | | | | | ? | | | | | | | | |
| Phillipsia sangamonensis | | | | | | | | | | | | x | | | |
| Phillipsia ? sp. | | | | | | x | x | | D | D | | D | | | |
| Griffithides scitulus | | x | | ? | ? | x | | | | | ? | | | | |
| Griffithides scitulus major | | x | | | | | | | | | | | | | |
| Griffithides sp. | | x | | | x | | | | x | | | | | | |
| **Pisces** | | | | | | | | | | | | | | | |
| Helodus ? sp. | | x | | | | | | | | | | | | | |
| Edestus minor | | | x | | | | | | | | | | | | |
| Petalodus destructor | | | | | | D | D | | D | | | | | | |

D indicates species reported by Drake.

# Plate XXVII

## DISTRIBUTION OF SPECIES COLLECTED BY DRAKE IN COLORADO COAL FIELD OF TEXAS.

| | STRAWN | | CANYON | | | | | | | | | | | CISCO | | | | | | | | | | | | | | | | | ALBANY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drake's Section | Elliot Creek shale | | Coral lst | Brownwood clay | Adams Branch lst | Cedarton shale | Clear Creek lst | Bed No 7 (shale) | Cherty lst | Hog Creek sh. | Home Creek lst | Bluff Creek sh. | Campophyllum lst | Trickham shale | Bellerophon lst | Speck Mt clay | Speck Mt lst | Lohn clay | Parks Mt ss. & cgl | Chaffin lst | Waldrip clay & 3 limes | Saddle Creek lst | Camp Creek clay | Coon Mt ss & cgl | Stockwether lst | Bed No 13 (clay) | Camp Colorado lst | Hords Creek ss & sh | Horse Creek lst | Santa Anna ss & clay | Bed No 18 (lst) | Santa Anna Branch clay | Coleman Jc lst | Lost Creek clay | Hords Creek lst | Indian Creek clay | Bed No 5 (lst) | Coleman clay | Elm Creek lst | Bed No 8 (clay) | Jagger Bend lst | Valera clay | Bead Mt lst | Bed No 12 (clay) | Grape Creek lst | Talpa lst | Paint Rock lst |
| New Section | | | Graford | | | Brad | | | | Caddo Creek | | Graham | | Thrifty | | | | | | | Harpersville | Pueblo | | | | | | Moran | | Putnam | | | | Admiral | | | | | | Belle Plains | | | | | | | |
| Fusulina cylindrica | | | | X | X | | | | X | | | X | X | | X | | X | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Somospongia sp. | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Zaphrentis sp. | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lophophyllum (Cyathaxonia) | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lophophyllum profundum (L. proliferum) | | | | X | X | X | X | X | X | | | X | | X | | X | | X | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| Campophyllum torquium | | | | | | | | | X | | | | X | | X | | | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Michelinia eugenae | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Syringopora sp. | X | | | | | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | X | | X | | X | | X | X | |
| Chaetetes sp. | | | | X | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydreionocrinus acanthophorus | X | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Eupachycrinus tuberculatus | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Archaeocidaris sp. | | | | X | | | X | | X | | | | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Stenopora carbonaria | | | | | | | | | | | | | | | | X | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fenestella sp. | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Septopora biserialis (Synocladia biserialis) | | | | | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lingula umbonata | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orbiculoidea convexa (Discina convexa) | | | | X | | X | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orbiculoidea missouriensis? (Discina nitida) | | | | | | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Derbya crassa (Hemipronites crassus) | | | | X | | X | | | X | | | X | X | X | | | | X | | | X | | | | | | X | | | | | X | | | | | | | | | | | | | | X | X |
| Meekella striaticostata | | | X | X | X | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |
| Chonetes granulifer | | | | | X | | | | X | | | X | | X | | X | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chonetes verneuilianus | X | | | X | | X | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Productus pertenuis | | | | | | | | | X | | | | | X | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | X | X | X |
| Productus cora | | | | X | X | X | | X | X | | | X | X | X | | | | | | X | X | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| Productus costatus | | | X | X | | X | X | | X | | | | X | X | | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Productus semireticulatus | | | | X | | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | X | | | | X | | X | | X | | | | X | X | X |
| Pustula nebrascensis | | | | X | | | | X | X | | | X | | X | | | | X | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pustula punctata | | | | X | X | X | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pustula symmetrica | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Marginifera muricata? (Productus flemingi) | | | | | | X | | | X | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Marginifera lasallensis? (Productus longispinus) | X | | X | X | X | X | | | X | | | X | | | | | | X | | | | X | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Enteletes hemiplicata (Syntrielasma hemiplicata) | | | | | | | | | | | | | | X | X | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pugnax uta (Rhynchonella uta) | | | | | | X | | X | X | | | X | | X | | | | X | | X | X | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Spiriferina kentuckiensis | X | | | X | | X | | X | X | | X | | | X | | | | X | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Spirifer cameratus | X | | X | X | | X | X | X | X | | X | X | X | X | | X | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spirifer organensis | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spirifer texanus | | | | | | X | | | X | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Squamularia perplexa (Spirifer lineatus) | | | X | X | X | X | | | X | | | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ambocoelia planoconvexa (Spirifer planoconvexus) | | | | X | X | X | | X | X | | X | X | | X | X | | | X | | | X | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| Composita subtilita (Seminula subtilita) | | | X | X | X | X | X | X | X | | X | X | X | X | | X | | X | | X | | X | | | | | X | | | | | | X | | | | | | X | X | X | | | | | | X |
| Dielasma bovidens | | | | X | | X | | | X | | | X | | | | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Hustedia mormoni | | | | X | | X | | | X | | | X | X | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nuculopsis ventricosa (Nucula ventricosa) | | | | X | | X | | X | X | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Leda bellistriata (Nuculana bellistriata) | | | X | X | | X | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pinna peracuta | | | | | | | | | | | | | | X | | | | | | X | | | | | | | | | | | | | X | | | | X | | X | | | | | | X | X | X |
| Conocardium obliquum | | | | X | | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Myalina subquadrata | | | | X | X | X | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | X | X |
| Schizodus wheeleri | | | X | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aviculopecten sp. | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | |
| Aviculopecten occidentalis | | | | X | | X | | X | | | | | | | | | | | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | X |
| Lima retifera | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Allorisma subcuneatum | | | | X | | | | | X | | | | | X | | | | | | X | X | | | | | | | | | | | | X | | | | | | X | | X | | | | X | X | X |
| Pleurophorus sp. | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lonqispina plicatula (?) | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pleurotomaria sp. | X | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | X | X | X |
| Pleurotomaria sphaerulata | | | | X | | X | | X | X | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Worthenia tabulata | | | | X | | | | X | | | | X | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orestes bragaensis (Pleurotomaria brazoensis) | | | | X | | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Murchisonia sp. | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | X | X | X |
| Murchisonia terebratula | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | |
| Murchisonia? trinodolineatus | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | |
| Bellerophon crassus | X | | | | | | | | | | | | | X | X | | | | | X | | | | | | | | | | | | | X | | X | | X | | X | | | | | | X | X | X |
| Pharkidonotus percarinatus (Bellerophon percarinatus) | | | | | X | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Euphemus carbonarius (Bellerophon carbonarius) | | | | X | X | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| Euphemus nodocarinatus (Bellerophon nodocarinatus) | X | | | X | | X | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Schizostoma catilloides (Euphemus rugosus) | | | | X | X | X | | X | | | | X | | X | | | | X | | | | | | | | | | | | | | | | | | | | | X | | | | | | | X | X |
| Sphaerodoma medialis | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sphaerodoma texana | | | | X | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sphaerodoma primigenia (Macrocheilus primigenius) | | | | | | X | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Platyceras parvum | | | | | | | | X | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | X | | | | | | X | X | X |
| Naticopsis wheeleri | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bulimorpha inornata (Bulimorphopsis inornata) | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| Bulimorpha nitidula (Bulimorphopsis nitidula) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |
| Orthoceras rushense | | | | X | | X | | X | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Orthoceras annulato-costatum | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nautilus | | | | X | | X | | | | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | |
| Goniatites | | | | X | | | | | X | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Gonioloboceras goniolobum (Goniatites goniolobus) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Phillipsia | | | | X | | | | | X | | | | | X | | | | X | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| Petalodus destructor | | | | X | | | | X | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Conularia crustula | | | | X | | | | X | | | | X | | X | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## FOSSIL LOCALITIES

44.1. Small outlier one mile southeast of Avis, northern Jack County, eight miles north of Jacksboro. Wayland shale member, Graham formation. J. G. Burtt, F. B. Plummer, R. C. Moore, Coll.

53.1. Limestone just west of Graford-Jacksboro road six miles south of Jacksboro, on point due west of Stradley schoolhouse and about one-quarter mile west of turn in road. Lower ledge of Jacksboro limestone member, Graham formation. J. G. Burtt, Coll.

53.2. One-half mile south of Indian Springs schoolhouse, east of pasture road which runs north from the east-west road on the north side of Section 2745, T. E. & L. Survey, Jack County. Shale just below Ranger limestone member, Brad formation. J. G. Burtt, Coll.

53.3. North of east-west road on north side of Section 2749, T. E. & L. Survey, Jack County, east of first turn in pasture road below the Ranger limestone, southeast of two houses. Shale just below Ranger limestone member, Brad formation. J. G. Burtt, Coll.

53.4. Five miles south of Jacksboro, south side of hill on east side of Jacksboro-Graford road, one-half mile southeast of Oliver farm house and one and a quarter miles north of Stradley schoolhouse. Lower ledge of Jacksboro limestone member, Graham formation. J. G. Burtt, Coll.

53.5. One and a quarter miles east and a little south of Stewarton on the Rock Island Railroad east of Jacksboro, one-half mile south of the Jacksboro-Vineyard road. Ranger limestone member, Brad formation. J. G. Burtt, Coll.

53.6. Nine miles east of Jacksboro, on outlier one-quarter mile southwest of schoolhouse on Jacksboro-Wizard Wells road. Shale below Ranger limestone, Brad formation. J. G. Burtt, Coll.

53.7. Three and one-half miles northeast of Jacksboro, one mile southeast of road corner where Jacksboro-Bowie road turns northeast in the J. W. Buckner Survey, on end of point east and just above cattle pond. Shale in middle part of Jacksboro limestone member, Graham formation. J. G. Burtt, Coll.

53.8. Cut along Rock Island Railroad about three miles southeast of Jacksboro. Very fossiliferous shale in middle part of Jacksboro limestone member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

53.9. Five miles south of Jacksboro on Jacksboro-Graford road where it jogs one-eighth mile to the west. Limestone made up of *Campophyllum torquium* and *Syringpora* sp. Lower ledge of Jacksboro limestone member, Graham formation. J. G. Burtt, Coll.

54.1. Three miles west of Finis on the Graford-Graham road where the road enters a deep shale cut. Bunger limestone member, Graham formation. F. B. Plummer, Coll.

54.2. Prominent mound one mile southwest of Berwick, one-half mile south of wagon road leading west from Berwick. Shale and limestone in South Bend member, Graham formation. J. G. Burtt, F. B. Plummer, R. C. Moore, Coll.

54.3. Two miles east of Bryson on Jacksboro-Graham road, southwest part of Lewis Knight Survey. Very abundant *Chonetes verneuilanus*. South Bend shale member, Graham formation. F. B. Plummer, Coll.

55.1. Road corner one-half mile east of Newcastle and south of Coal Mine No. 5, Belknap Coal Company, limestone outcrop on south side of road. The limestone is 110 feet above the coal. Belknap limestone member, Harpersville formation. J. G. Burtt, F. B .Plummer, R. C. Moore, Coll.

55.2. Four miles east and one and a half miles north of Newcastle, south side of hill on east side of country road which branches from Newcastle-Graham road four miles east of Newcastle. Section 615, T. E. & L. Survey. Belknap limestone member, Harpersville formation. J. G. Burtt, F. B. Plummer, R. C. Moore, Coll.

55.3. Six miles east and two miles north of Newcastle, a quarter mile east and a quarter mile south of road corner. A large outlier in Section 603, T. E. & L. Survey. Belknap limestone member, Harpersville formation. J. G. Burtt, F. B. Plummer, R. C. Moore, Coll.

55.4. Four miles east and two and a half miles north of Newcastle in northeast corner of Section 616, T. E. & L. Survey, where secondary road running north turns westward across escarpment of Belknap limestone. Belknap limestone member, Harpersville formation. J. G. Burtt, Coll.

55.5. Five miles northeast of Newcastle, one-half mile south of east-west road and on east side of Salt Creek, southeast corner of Section 613, T. E. & L. Survey. Belknap limestone member, Harpersville formation. J. G. Burtt, Coll.

55.6. Seven miles east and four miles north of Newcastle, on west side of main north-south road, in Section 622, T. E. & L. Survey. Belknap limestone member, Harpersville formation. J. G. Burtt, Coll.

55.7. Four miles southeast of Newcastle on prominent sandstone-capped outlier a quarter mile north of road corners on Graham-Cisco road, in Section 438, T. E. & L. Survey. Belknap limestone member, Harpersville formation. F. B. Plummer, R. C. Moore, Coll.

55.8. Five miles southwest of Graham, three-quarters mile west of Graham-South Bend road, one and a half miles due north of the Brazos River bridge. Wayland shale member, Graham formation. J. G. Burtt, Coll.

55.9. One mile west of Graham courthouse, on west bank of Salt Creek, one-eighth mile north of road. Cummins' type locality. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

55.10. Fork of road one and a half miles southwest of Graham, where Graham-South Bend road branches from Graham-Throckmorton road. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

55.11. One-half mile east and south of town of Loving, on Gulf, Texas and Western Railroad. Limestone outcrops near coal mine, 100 feet above coal. Belknap limestone member, Harpersville formation. J. G. Burtt, Coll.

55.12. Point on wagon road east of east line, southeast part of Brazos Indian Reservation, along the Brazos River on survey marked "John Conner, Delaware chief." Shale above Home Creek limestone, basal part Finis shale member, Graham formation. J. G. Burtt, Coll.

55.13. One mile southeast of bridge over the Brazos River on Graham-South Bend road, on prominent outlier known as Bass Hill, east of Brazos River. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

55.14. One mile west of Graham on bluff south of Graham-South Bend and Graham-Throckmorton road, west of Salt Creek, on side of bluff facing east toward Graham. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

64.1. Five miles north and four miles west of Breckenridge, about one hundred yards northwest of the Crudgington well No. 1, of Humble Oil and Refining Company. *Myalina* bed fifty feet above Belknap limestone member, Harpersville formation. J. Armstrong, Coll.

65.1. Six miles north of Breckenridge, one-half mile west of road on small outlier in east part of Section 1219, T. E. & L. Survey, about one-half mile south of Ball well No. 1. Shale below Belknap limestone member, Harpersville formation. J. Armstrong, Coll.

65.2. Two miles north of Breckenridge courthouse on east side of escarpment one mile west of Breckenridge-Crystal Falls road, just above coal bed in northeast corner of Section 7. Shale below Belknap limestone member, Harpersville formation. J. Armstrong, Coll.

65.3. One and a quarter miles northwest of Breckenridge on east point of hill one-eighth mile south of country road which turns west one-half mile north of Breckenridge. Shale below Belknap limestone member, Harpersville formation. J. Armstrong, Coll.

65.4. Three miles west and two miles north of Breckenridge, on west side of hill due south of schoolhouse, on J. M. Evans Survey. Shale below Belknap limestone member, Harpersville formation. J. Armstrong, Coll.

66.1. One and a half miles south of South Bend, about 1800 feet due north of Goode well No. 1, Roxana Petroleum Corporation. Wayland shale member, Graham formation. F. B. Plummer, John Suman, Coll.

66.2. One-quarter mile west of South Bend-Eliasville road, along road cut and north of road about 300 yards east of Brazos River bridge. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

66.3. One mile southeast of Fox Hollow schoolhouse, three and a half miles south and two and a half miles east of northwest corner of Palo Pinto County, on Mrs. C. F. Crandill ranch. Top of Ranger limestone member, Brad formation. A. McLeod, Coll.

67.1. South part of the town of Graford, Section 1713, T. E. & L. Survey, southwest corner. Lower part of Adams Branch limestone member, Graford formation. J. G. Burtt, Coll.

67.2. Three miles northwest of Graford where main road crosses high escarpment. Upper part of Adams Branch limestone, Graford formation. F. B. Plummer, R. C. Moore, Coll.

67.3. Two miles north of the gate at Dalton ranch-house where the Graham road leaves the Graford-Pickwick road, on small outlier one-half mile south of west-flowing creek, two and three-quarters miles southeast of Gordon Mountain. Shaly limestone in Brad formation about 160 feet above top of Graford formation. J. G. Burtt, Coll.

67.4. South side of Kyle Mountain, five miles north of Palo Pinto. Upper part of Brownwood shale member, Graford formation. J. G. Burtt, Coll.

67.5. Small outlier on west side of Wolf Mountain, seven miles west of Palo Pinto. Brownwood shale member, Graford formation, 170 feet below top of Adams Branch limestone. J. G. Burtt, Coll.

67.6. Foot of steep escarpment on north side of Brazos River, two miles northwest of Kyle Mountain, three miles west of Graford-Palo Pinto road bridge over the Brazos. Brownwood shale member, Graford formation, about 250 feet below top of Adams Branch limestone. J. G. Burtt, R. C. Moore, Coll.

67.7. Along road two miles east of Pickwick, one mile north of McAdams Peak on Pickwick-Graford road. Ranger limestone member, Brad formation. J. G. Burtt, Coll.

67.8. Two miles southeast of town of Pickwick on Brazos River, first limestone bench of McAdams Peak. Ranger limestone member, Brad formation. J. G. Burtt, Coll.

67.9. Two and a half miles west of Brazos River bridge on Palo Pinto-Graford road, north from bridge about one and three-quarters miles to first pasture gate, west and southwest on pasture road to fork below high escarpment. Upper part Brownwood shale member, Graford formation. J. G. Burtt, Coll.

67.10. Escarpment just west of the town of Graford. Adams Branch limestone member, Graford formation. Donally, Coll.

68.1. Shale pit one-half mile east of Mineral Wells on north side of Mineral Wells-Fort Worth road, at base of slope of steep escarpment to the north. East Mountain shale member, Mineral Wells formation. F. B. Plummer, R. C. Moore, Coll.

68.2. Extreme west end of Fourth Street, Mineral Wells, at base of steep slope. East Mountain shale member, Mineral Wells formation. F. B. Plummer, R. C. Moore, Coll.

68.3. North end of the "Cove," Mineral Wells, at base of steep escarpment east of the town. East Mountain shale member, Mineral Wells formation. F. B. Plummer, R. C. Moore, Coll.

68.4. West side of dam of Lake Pinto, one mile west of Mineral Wells. East Mountain shale member, Mineral Wells formation. F. B. Plummer, Coll.

68.5. South slope of prominent escarpment, north of Mineral Wells-Fort Worth road, about one and a half miles northeast of Mineral Wells. Upper part of East Mountain shale member, Mineral Wells formation. J. G. Burtt, R. C. Moore, Coll.

68.6. South end of outlier capped with sandstone in southwest part of Mineral Wells, near base of steep slope and just above a small pond and dam. East Mountain shale member, Mineral Wells formation. J. G. Burtt, R. C. Moore, Coll.

68.7. Limestone just above talus slope on high point east of Brazos River bend where Keechi Creek joins the river. Keechi Creek member, Mineral Wells formation, about 40 feet below Palo Pinto limestone. J. G. Burtt, Coll.

76.1. Limestone on south side of Brazos River, just west of bridge at Dennis, southwest Parker County. Millsap formation. F. B. Plummer, R. C. Moore, Coll.

76.2. One-half mile northeast of Rayville, Parker County, on small stream just south of Weatherford-Stephensville road. Millsap formation. R. C. Moore, Coll.

76.3. Limestone exposed on small southeast-flowing stream at Rayville, Parker County. Millsap formation. R. C. Moore, Coll.

76.4. Limestone at Kickapoo Falls, southwestern Parker County. Millsap formation. R. C. Moore, Coll.

76.5. Limestone one-eighth mile below Kickapoo Falls. Millsap formation. R. C. Moore, Coll.

78.1. Small knoll just west of sharp turn in road four miles west of Palo Pinto, one mile north of point where Palo Pinto-Gordon road branches from Palo Pinto-Caddo road. Palo Pinto limestone. F. B. Plummer, Coll.

78.2. Metcalf's Gap, two miles east of Brad, on Caddo road, escarpment on north side of road. Adams Branch limestone member, Graford formation. F. B. Plummer, Coll.

79.1. One and a half miles west of Caddo on Caddo-Breckenridge road a quarter mile west of fork of Caddo-Graham road, on south side of prominent limestone-capped hill. Bunger limestone and upper part Gonzales Creek members, Graham formation. F. B. Plummer, R. C. Moore, Coll.

79.2. Seven miles west of Strawn, Brownwood shale member, Graford formation, 90 feet above Palo Pinto limestone. R. L. Six, Coll.

79.3. Escarpment five miles west of Strawn. Adams Branch limestone member, Graford formation. R. L. Six, Coll.

79.4. Four miles east and three and one-half miles south of LaCasa. Shale 80 feet below Ranger limestone, Brad formation. R. L. Six, Coll.

80.1. One mile south of Gunsight and one mile east of Gunsight-Eastland road. *Campophyllum torquium*-bearing limestone in lower part of Thrifty formation. F. B. Plummer, R. C. Moore, Coll.

80.2. One mile south of Gunsight, just south of fork between Gunsight-Cisco and Gunsight-Eastland roads, on south side of prominent escarpment. Exceedingly fossiliferous Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

80.3. Two miles due east of Gunsight on country road near house at fork where road turns southwest in Section 448. Lower part of Thrifty formation. F. B. Plummer, Coll.

80.4. One and a half miles southeast of Necessity, one-half mile north of Necessity-Wayland road, in southeast corner of Section 34. Wayland shale member, Graham formation. J. G. Burtt, Coll.

80.5. One mile north of Wayland, just west of point where road turns east, south of the east-west road, northeast corner of Section 35. Wayland shale member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

80.6. Five miles south and two miles east of Necessity, Section 76, T & P. Survey, Block 6, southwest of farmhouse. Gonzales Creek shale member, Graham formation. S. W. Wells, Coll.

81.1. Seven miles east and two miles south of Moran on Moran-Cisco road, a quarter mile east of point where it turns east after two miles south. Shale below Saddle Creek limestone, Harpersville formation. P. Applin, R. C. Moore, Coll.

81.2. One-half mile east of corner where road proceeding east from Moran turns at right angles north and south, Section 41, T. & P. Survey, Block 9. Shale below Saddle Creek limestone, Harpersville formation. P. Applin, R. C. Moore, Coll.

88.1. Six miles northwest of Cisco, a quarter mile west of Cisco-Moran road, on east point of escarpment in Section 488. Fifty-five feet below Saddle Creek limestone, Harpersville formation. J. G. Burtt, Coll.

88.2. Six and one-half miles north of Cisco on east side of Cisco-Moran road where road turns one mile west near an old coal mine in Section 483. Shale below Saddle Creek limestone, Harpersville formation. F. B. Plummer, R. C. Moore, Coll.

88.3. Three and one-half miles northwest of Cisco on the Cisco-Moran road where the road descends steeply over limestone escarpment, east side Section 500. Shale below Saddle Creek limestone, Harpersville formation. F. B. Plummer, R. C. Moore, Coll.

88.4. Four and one-half miles northwest of Cisco on Cisco-Moran road where railroad first crosses road, Section 495. Shale below Saddle Creek limestone, Harpersville formation. F. B. Plummer, R. C. Moore, Coll.

88.5. Two miles south and one mile west of Cisco on the Cisco-Nimrod road where west road crosses steep escarpment, Section 85. Shale below Saddle Creek limestone, Harpersville formation. R. C. Moore, Coll.

88.6. Six and one-half miles north and one mile east of Putnam on the Putnam-Moran road, north of the road corner in the southeast part of Section 3197. Shale below Saddle Creek limestone, Harpersville formation. F. B. Plummer, Coll.

88.7. About five miles northwest of Cisco, 600 yards east of road near center of Section 483. Fifty feet below Saddle Creek limestone, just above coal bed, Harpersville formation. F. B. Plummer, R. C. Moore, Coll.

88.8-88.11. Pueblo formation near Pueblo and east of Putnam.

89.1. Five miles east of Cisco on Cisco-Eastland road, about 1000 feet north of corner where road, after turning one-quarter mile north, turns again due east. Wayland shale member, Graham formation. Very fossiliferous. F. B. Plummer, I. J. Broman, R. C. Moore, Coll.

89.2. Six miles northeast of Cisco, three and one-half miles east of the west Cisco-Breckenridge road, and two miles west of the east Cisco-Breckenridge road, the easternmost outlier of concretionary limestone, in the northwest corner of Section 55. Wayland shale member, Graham formation. C. A. Hammill, Coll.

89.3. One-half mile north of locality 89.2. Shale 30 feet above Gunsight limestone. Wayland shale member, Graham formation. C. A. Hammill, Coll.

89.4. One mile northwest of Cisco in valley north of college, near old coal mine. Shale about 60 feet below Saddle Creek limestone, Harpersville formation. F. B. Plummer, C. A. Hammill, R. C. Moore, Coll.

89.5. Seven miles due north of Cisco, three miles east of Cisco-Moran road, on east side of prominent hill, Section 474. Saddle Creek limestone, Harpersville formation. C. A. Hammill, Coll.

89.6. Three and one-quarter miles north of Cisco on west Cisco-Breckenridge road where road descends escarpment just north of Section 82. Saddle Creek limestone, Harpersville formation. C. A. Hammill, Coll.

90.1. About five miles northwest of Gorman on J. M. Thompson farm, Survey 19, about 60 feet below top of Graford formation. Numerous elongated *Fusulina*. C. R. Stauffer, Coll.

103.1. About four miles southwest of Gorman, a quarter mile north of corner, one mile west of Rudd well No. 1. Brownwood shale member, Graford formation, about 200 feet below top of Adams Branch limestone. F. B. Plummer, Coll.

105.1. At town of Bethel on Cisco-Rising Star road, Section 153, N. B. Mitchell Survey. An outcrop of Pennsylvanian in the midst of the Cretaceous area, lower part of Thrifty formation. F. B. Plummer, R. C. Moore, Coll.

105.2. Northeast part of the town of Crosscut. Saddle Creek limestone, Harpersville formation. F. B. Plummer, Coll.

106.1. Five miles west and one mile south of Cross Plains, one mile and a half south of Dressy, Callahan County, on south side of east-west road, Section 64. Coleman Junction limestone member, Putnam formation. F. B. Plummer, Coll.

106.2. One-half mile south of the Callahan-Coleman county line two and a half miles west of the Coleman-Baird road, middle of Section 108. Bead Mountain limestone, Belle Plains formation. F. B. Plummer, Coll.

111.1. Four and one-half miles south and one mile west of Coleman on north side of two small outliers, on south side of G. C. & S. F. Railroad, east side of creek. Just below Coleman limestone member, Admiral formation. P. L. Applin, Coll.

111.2. Three miles south and one mile west of Coleman, in northeast part of Section 294, on southwest side of large outlier of Coleman limestone member, Admiral formation. J. G. Burtt, Coll.

111.3. One mile west of Coleman, just south of pond in north part of Section 280. Elm Creek limestone member, Admiral formation. P. L. Applin, Coll.

112.1. One-eighth mile northeast of Weeden School, 10 miles northwest of Brownwood, four miles south and one mile west of New Byrd's Store, at foot of escarpment on north side of road. Wayland shale member, Graham formation. G. Kirby, F. B. Plummer, R. C. Moore, Coll.

112.2. About five miles west of Thrifty, near Bee Branch Schoolhouse west of Brownwood. Hill on south side of Thrifty road. Shale about 50 feet below Saddle Creek limestone, Harpersville formation. R. C. Moore, Coll.

112.3. One mile north of Weeden School and three miles southwest of New Byrd's Store, just north of fork in road, near southwest corner of Section 50. Wayland shale member, Graham formation. R. C. Moore, Coll.

112.4. At cemetery one and a half miles west of Grosvenor, in middle of Section 44. Shale below Saddle Creek limestone, Harpersville formation. C. A. Hammill, R. C. Moore, Coll.

112.5. One-quarter mile north of 112.4, on east side of road opposite farmhouse. Shale below Saddle Creek limestone, Harpersville formation. C. A. Hammill, R. C. Moore, Coll.

112.6. Five miles southwest of Grosvenor and one and a half miles northeast of Bee Branch Schoolhouse, on west side of road in Section 88. Shale below Saddle Creek limestone, Harpersville formation. R. C. Moore, Coll.

112.7. Three miles north and one and a quarter miles east of Thrifty, on southeast part of J. K. Kuykendall farm. Gunsight limestone member, Graham formation. F. B. Plummer, R. C. Moore, Coll.

112.8. Ten miles east and four miles north of Coleman, on road one mile east of Camp Colorado. Camp Colorado limestone member, Pueblo formation. F. B. Plummer, Coll.

112.9. Four miles west and two miles north of Grosvenor, east of point in road where low escarpment of yellow limestone appears. Camp Colorado limestone member, Pueblo formation. C. A. Hammill, R. C. Moore, Coll.

112.10. Four miles west and three miles north of Grosvenor. Three-quarters mile north of 112.9. Camp Colorado limestone, Pueblo formation. C. A. Hammill, R. C. Moore, Coll.

129.1. Two and one-half miles west of Brownwood on Brownwood-Bangs road, near point where creek crosses road below escarpment of Adams Branch limestone. Brownwood shale member, Graford formation. G. Kirby, F. B. Plummer, C. A. Hammill, R. C. Moore, Coll.

129.2. One mile south of Brooksmith, at foot of escarpment, a quarter mile north of main road, along secondary road to Clear Creek. Brownwood shale member, Graford formation. G. Kirby, F. B. Plummer, Coll.

136.1. South of Placid, McCulloch County, 200 feet below Adams Branch limestone. Upper part of Strawn. A. McLeod, Coll.

150.1. Limestone along road and in creek bed four miles southwest of Lampasas, on road to Bend. Marble Falls limestone. R. C. Moore, Coll.

150.2. On secondary road one mile south of Bend, San Saba County. Marble Falls limestone. R. C. Moore, Coll.

151.1a. Limestone near bed Rough Creek at point where road from San Saba to Bend crosses the stream. About five miles northwest of Bend. Marble Falls limestone. R. C. Moore, Coll. Bed 2 in section.

151.1b. Same locality. Bed 7 in section. R. C. Moore, Coll.

151.1c. Same locality. Bed 10 in section. R. C. Moore, Coll.

151.2. Limestone on road from Bend to Chappel about one and a half miles east of Chappel, Marble Falls limestone. R. C. Moore, Coll.

151.3. Point midway between Bend-San Saba road and Colorado River, about two miles northwest of sharp bend in the river southwest of Bend. Smithwick shale. R. C. Moore, Coll.

151.4. On Bend-Chappel road a few hundred feet south of intersection with Bend-San Saba road, about two miles southwest of Bend. Smithwick shale. R. C. Moore, Coll.

151.5. Banks of Colorado River along sharp bend one and a half miles southwest of town of Bend. Upper part Marble Falls limestone. R. C. Moore, Coll.

151.6. Bluff on upper Cherokee Creek 10 miles southwest of Bend, on Bend-Cherokee road. Basal bed of Marble Falls limestone. F. B. Plummer, Coll.

151.8. Point where San Saba-Chappel road crosses escarpment of Ellenburger limestone about two miles southeast of San Saba. Barnett shale. R. C. Moore, Coll.

151.9. On San Saba-Bend road about one mile southeast of Barnett Springs. Barnett shale. F. B. Plummer, Coll.

152.1. Wallace Creek, six miles southwest of San Saba. Barnett shale. R. C. Moore, Coll.

152.2. Limestone six miles south and one mile east of Algerita, about seven miles southwest of San Saba. Marble Falls limestone. R. C. Moore, Coll.

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