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No. 4329 August 1, 1943

# THE CARBONIFEROUS ROCKS OF THE LLANO REGION OF CENTRAL TEXAS

By

F. B. PLUMMER

Bureau of Economic Geology
John T. Lonsdale, Director

Issued February, 1950

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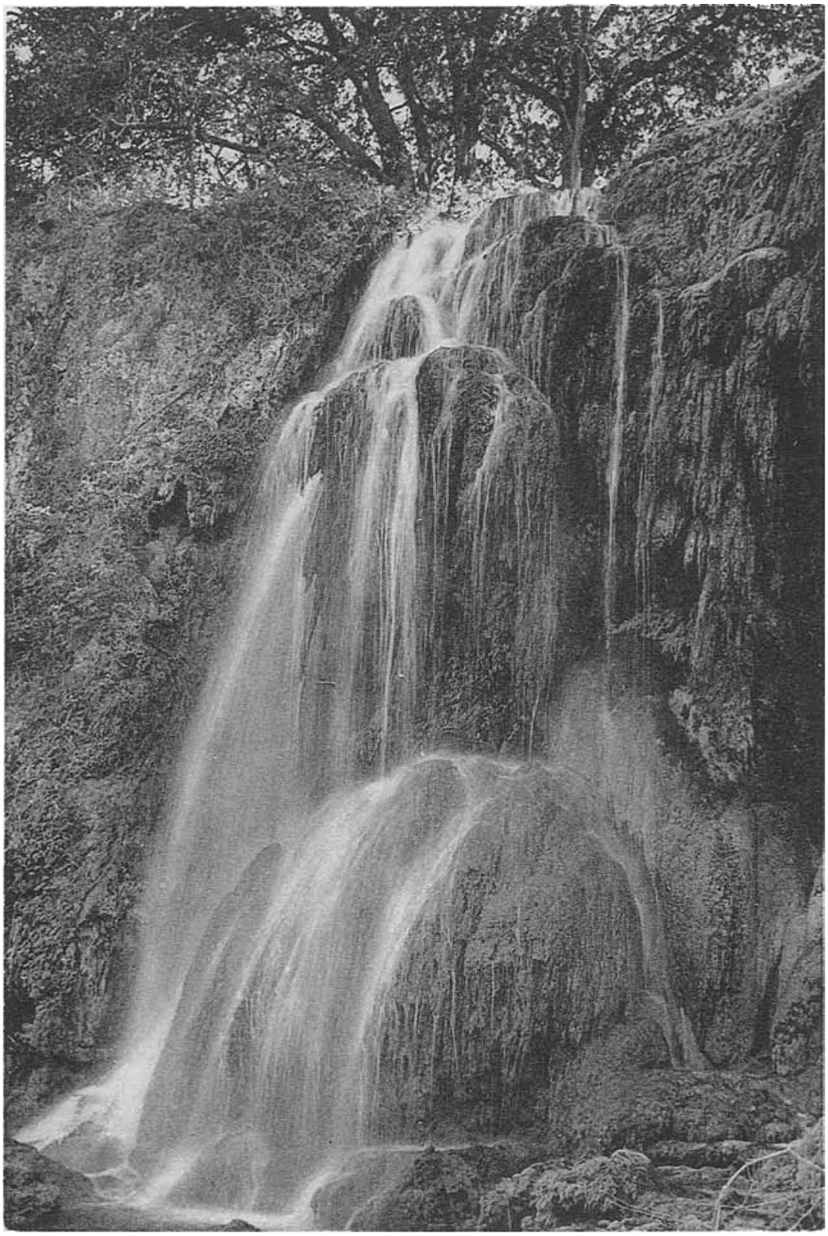

Gorman Falls southeast of Bend, San Saba County, Texas
(photograph by Gordon Fisher).

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

*Sam Houston*

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

*Mirabeau B. Lamar*

# FREDERICK BYRON PLUMMER

## 1886–1947

Frederick Byron Plummer served The University of Texas faithfully and well from 1928 to 1947 as Professor of Petroleum Engineering and Geologist in the Bureau of Economic Geology. A host of former students will always treasure memories of his inspired teaching and generous interest in their welfare. His contributions to knowledge of the geology of Texas cover a wide range of subjects.

The problems of Carboniferous stratigraphy and paleontology of central Texas were a continuing interest with him. His early report with R. C. Moore, "Stratigraphy of the Pennsylvanian Formations of North-central Texas," The University of Texas Bulletin 2132, was the first comprehensive regional report on this subject. The present report in a sense is a progress report of results of his research up to the time of his death. Had he lived it would have been revised and extended. However, it contains so much basic and detailed information that any future progress in this important area of Texas geology will be based on this work.

CONTENTS

## ILLUSTRATIONS

# CARBONIFEROUS ROCKS OF THE LLANO REGION OF CENTRAL TEXAS

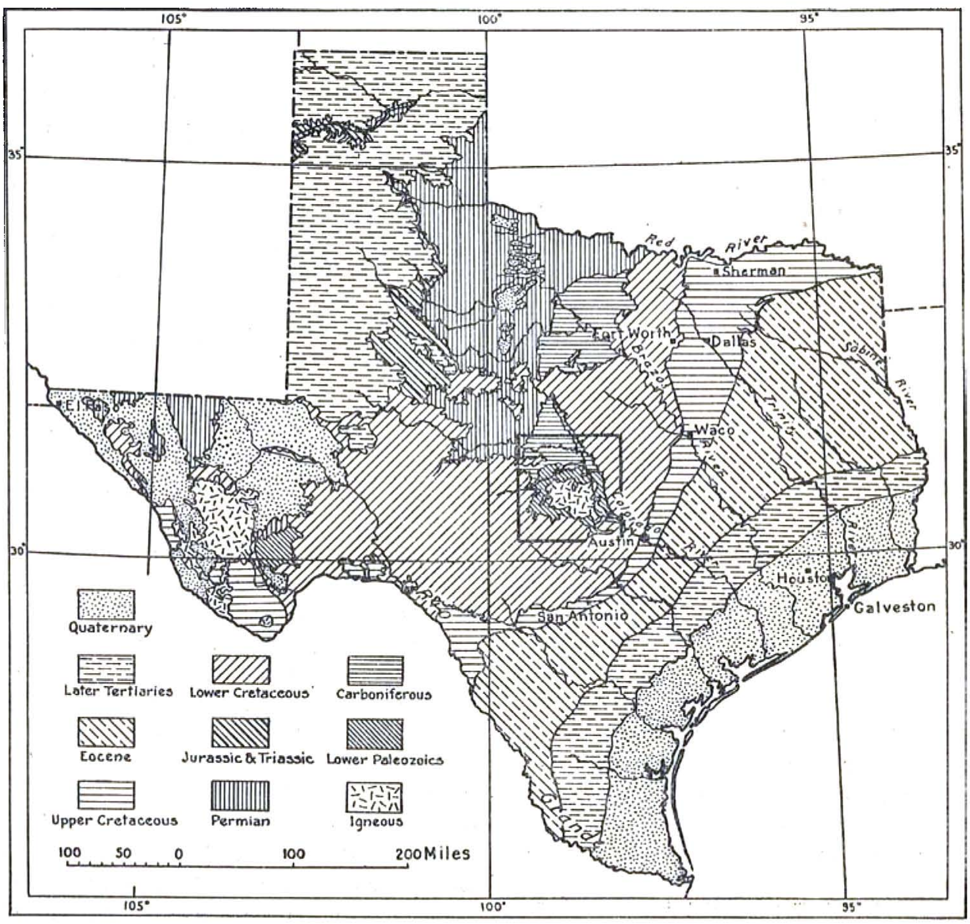
F. B. Plummer

## INTRODUCTION

### Location

This report deals primarily with the Carboniferous rocks of the Llano region in central Texas (fig. 1), which includes McCulloch, San Saba, Burnet, Llano, and Mason counties, the eastern part of Kimble County, the western part of Lampasas County, and the portions of Blanco and Gillespie counties north of the Pedernales River. The area is about 100 miles in diameter with an area of about 8,000 square miles. The Carboniferous rocks generally are exposed in the outer part of this circular area, resting on older Paleozoic rocks and overlain by Cretaceous strata.

The city and county of Llano are centrally situated in this area, and it is from these places that the region has received its name. The name Llano was given to Llano River by the early Spanish explorers who established a mission on this river near the present town of Menard in the early part of the sixteenth century. The name is said to be derived from the Spanish word "llano" meaning prairie or



plain, although some historians have suggested it might have come from a word[1] given by the French to a tribe of Lipan Indians who lived in this region near the river. The town of Llano and Llano County were named by early American settlers for the river.

The region is crossed by U. S. highway No. 87 running north and south from San Antonio to Brady, State highway No. 16 running north and south from Fredericksburg to Goldthwaite, and U. S. highway No. 281 running north and south from San Antonio to Lampasas. It is also crossed by State highway No. 29 running east and west from Austin to Mason. The principal towns are Mason, Brady, San Saba, Llano, Lampasas, Burnet, Fredericksburg, and Johnson City.

## Physiography

The Llano region includes an erosional basin in which rocks of pre-Cambrian age are exposed and a surrounding higher area of Paleozoic and Cretaceous rocks forming in part a dissected plateau. The highest elevations in the area, in excess of 2,200 feet, are on the plateau between Fredericksburg and Mason. The lowest point is where Colorado River flows out of the region southeast of Marble Falls where the elevation is about 650 feet. Therefore, the total relief is about 1,600 feet.

The basin area is the center of an uplift where rocks of pre-Cambrian age are high. These rocks are less resistant to erosion than the rocks of Paleozoic age, thus accounting for the basin. Within the basin area there are several prominences such as Packsaddle Mountain, Riley Mountain, Nigger Head, Putnam Mountain, Hobson Mountain, and others which are composed of resistant rocks. Some of these, such as Hobson Mountain, are composed of pre-Cambrian rocks; some, such as Riley Mountain, are grabens of Paleozoic rocks; and a few, such as Nigger Head, are exhumed monadnocks of resistant rocks that stood on the pre-Cambrian surface.

[1]See State historical marker on State highway No. 16 north of Llano.

The rim of the basin to the south and east is in part a remnant of the surface of the Edwards Plateau held up by the resistant Edwards limestone and in part is composed of Paleozoic rocks. The rim of the basin to the west is not so well defined, being a dissected plateau; the rim of the basin to the north is formed mostly of Paleozoic rocks and only to a slight extent of Cretaceous rocks.

The principal streams in the region are Colorado River and San Saba River on the north and east, Llano River in the central part, and Pedernales River on the south. These are consequent streams which have been superimposed upon the Paleozoic rocks of the region, and their winding courses, inherited from their Tertiary history, have been modified and made more complex by the complicated structure and uneven hardness of the Paleozoic floor. The principal tributary streams are Brady Creek which flows east into San Saba River, Wallace Creek which flows north into San Saba River, Cherokee Creek which flows northeast into Colorado River, and Big Sandy which flows east into Colorado River. Tarr (1890) pointed out that the drainage pattern (fig. 2) shows clearly that the major stream courses were established on a former eastward-tilted plain and that the streams have been entrenched in the ancient pre-Cambrian and Paleozoic rocks without great change in their courses. Minor changes, of course, are everywhere apparent, and examples of shifting and piracy are known, but in general the main streams have held their general directions across the region without regard to the pre-Cambrian core and encircling Paleozoic carbonate rocks. The small tributary streams, on the other hand, are adjusted to local structure. They tend to follow the strike of fault scarps and resistant ledges and in many places to form broad curves where their normal courses are interrupted by hard ledges. Many springs originate in the crevices and fractures produced by the faults, particularly those in the area of the Ellenburger rocks. The numerous springs furnish water for the smaller streams which in turn furnish an all-year supply to Cherokee Creek, Wallace Creek, and to Llano and San Saba rivers. The clear, pure spring water with its beautiful blue-green pools, little cascades, waterfalls, and well-vegetated valleys, adds a touch of beauty and cool delight to a country which during the summer months, at least, is generally dry and hot.

## Climate

The climate of the Llano region is semi-arid. The average precipitation amounts to about 30 inches per year, as shown in

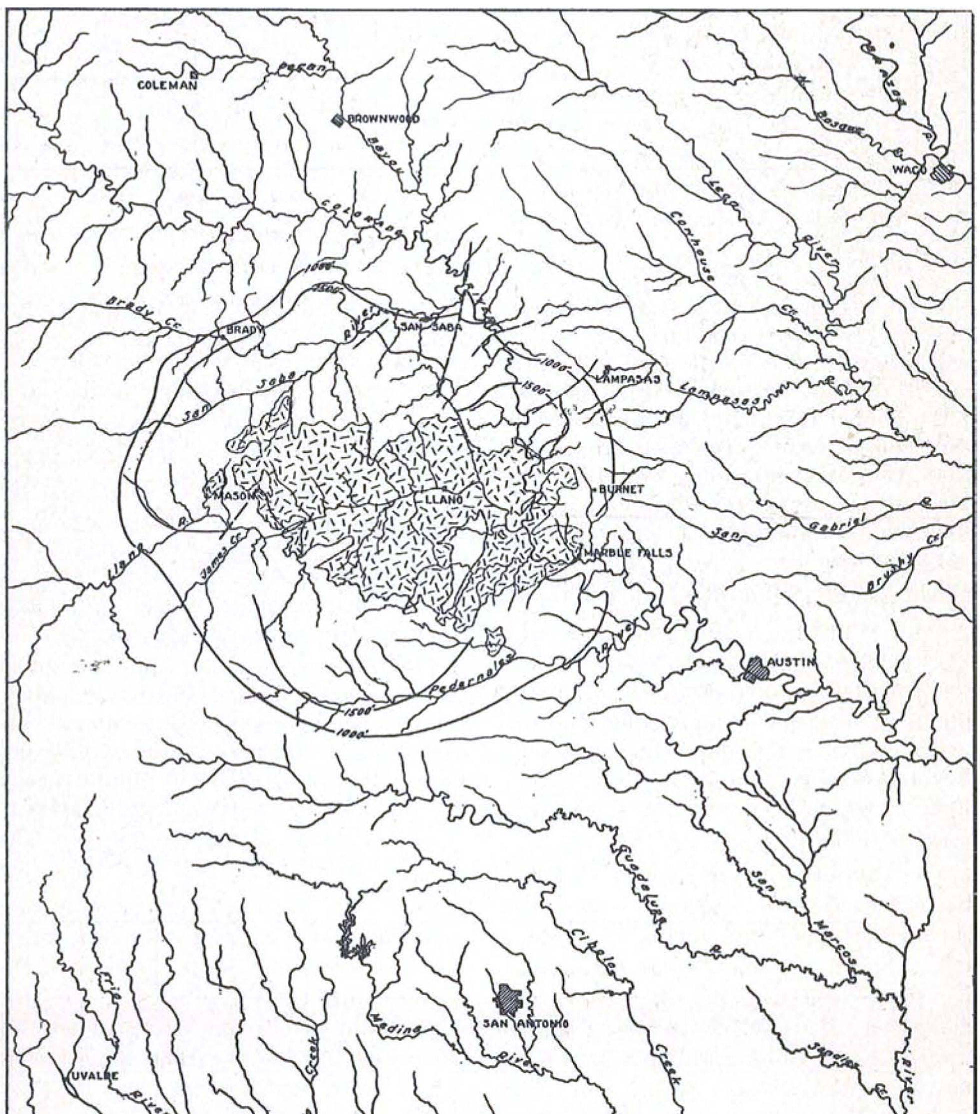



Fig. 2. Principal streams of central Texas showing drainage pattern. Contours are drawn on top of the Ellenburger limestone showing the approximate size of the "uplift." With possible exception of Colorado River, the drainage pattern appears to be unaffected by the Llano uplift.

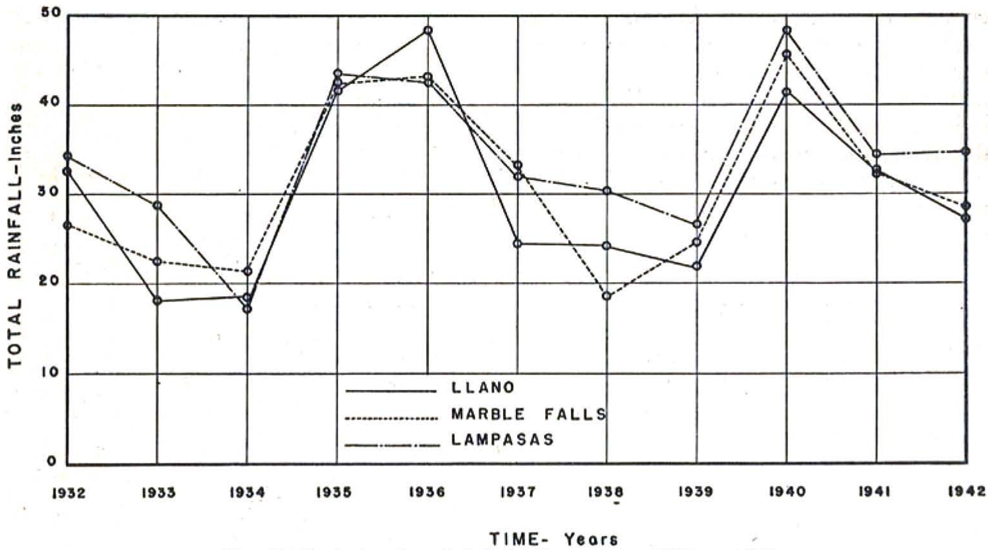



Fig. 3. Variation in rainfall in Texas from 1932 to 1942.

the graph (fig. 3). The rainfall varies considerably from year to year and is very unevenly distributed during the seasons. It is not uncommon for one-third of the annual rainfall to come in a single week and to have periods of drought of 12 to 15 weeks duration. In July, 1938, about 18 inches of rain fell in a single week and less than an inch during the next four months. Usually, most of the rain comes in winter and spring, and the summers are dry and hot. The average annual temperature is about 70.5° F. The daytime winter temperature from November to April ranges from 40° F. to 70° F. with frost frequent at night from November 1 to April 1, especially during periods when the wind is from the north. Summer days are hot, with the daytime temperature ranging from 80° F. to 110° F. and averaging nearly 90° F. The graph (fig. 4) shows the annual temperature range at Llano and Lampasas.

## Vegetation

The vegetation (Tharp, 1939) belongs to plant types adapted to rather severe ranges of temperature, to moderate precipitation, and to rocky slopes. Mesquite, oak, elm, and "cedar" *(Juniperus)* on the upland, and sycamore and pecan in the spring-fed valleys are the most prevalent trees. Mexican persimmon, two species of *Mimosa*, and white brush are the commonest shrubs. Cacti, particularly prickly pear, are widely scattered and attain large size. The grasses (Silveus, 1933; Hitchcock, 1920) are buffalo *(Bulbis dactyloides)*, curly mesquite *(Hilaria belangeri)*, and crowfoot. The distribution and relative abundance of the plant

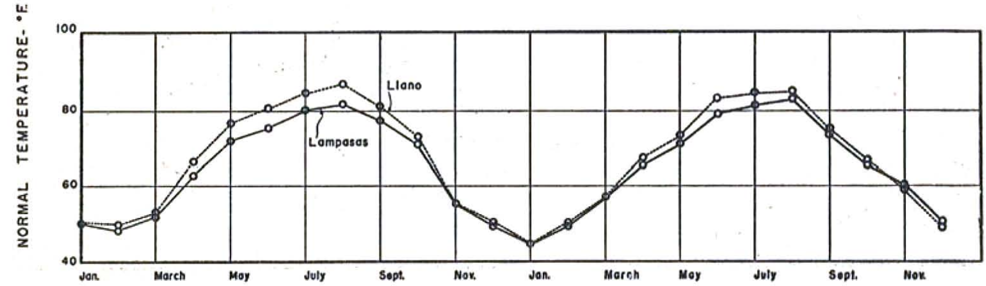



Fig. 4. Annual temperature range at Llano and Lampasas.

life depend much upon the type of rock which affects the thickness and character of the soil. The soils developed from the pre-Cambrian rocks support many types of shrubs, mesquite, post oak, scrubby live oak, and some black jack oak. The dolomites in a portion of the area support a beautiful and natural, park-like growth of widely spaced, broadly spreading live oaks—the floral monarchs of the region—surrounded by a soft carpet of buffalo grass. The limestones of both the Ellenburger group and the Marble Falls formation support in many places a dense growth of cedar and, in places where chert occurs in quantity, post oak. The shale slopes of the Pennsylvanian formations are characterized by mesquite, elm, Mexican persimmon, and white brush; the sandstone slopes of the Strawn group by post oak, black jack oak, mesquite, stunted elm, and by sedge, buffalo, and needle grass *(Stipa leucotricha)*. Most stream valleys support pecan, elm, hackberry, some willow, and sycamore. The grasses of the bottom lands are rescue, curly mesquite, buffalo, and bermuda. In March the south slopes are decorated by the beautiful white, bell-like clusters of the Spanish bayonet *(Yucca treculeana)*. In late spring the open pastures are made prominent by similar, though somewhat smaller, clusters of the no less beautiful species *Yucca glauca*. In early summer all open areas are a mass of bright colors derived from an abundance of flowers. The Texas bluebonnet *(Lupinus texensis)*, false coreopsis *(Thelesperma trifidum)*, phlox *(Phlox pilosa)*, standing cypress *(Gilia rubra)*, firewheel or Indian blanket *(Gaillardia pulchella)*, American star thistle *(Centaurea americana)*, and various cacti among which the prickly pear *(Opuntia lindheimeri)*, claret cup *(Echinocereus triglochidiatus)*, and lady finger *(Echinocereus pentalophus)* are most noteworthy; primroses, mallows, blue bells, daisies, and nightshades combine to produce color combinations to delight the eye of any traveler; for he is beholding Nature's natural gardens at their best.

## Industry

The Llano region is a ranch country. About 60 percent of the land is used for grazing cattle, sheep, and goats; 8 percent for agriculture; and 32 percent for stock farms on which both small crops and small herds of cattle and sheep are raised. The principal crops are oats, corn, sorghums, cotton, pecans, peaches, and watermelon. The areas of outcrop of the pre-Cambrian rocks and the Paleozoic carbonate rocks are used chiefly for grazing. The Smithwick shale outcrop and valley alluvium of the Llano, San Saba, and Colorado rivers support cotton fields, small grain farms, and pecan groves. The peach orchards and watermelon fields are located chiefly on the light, sandy soils of the Strawn group. The ranches range from 200 acres to 70,000 and average about 1,500 acres. The farms range from 40 to 1,000 acres, averaging about 240 acres, and most of them are operated in connection with small grazing plots. The combination of farm and ranch lands is confined for the most part to the Strawn and Lower Cretaceous soils. Here the uplands are utilized to graze sheep or cattle, and the valleys, particularly the shale valleys, for oats, corn, and sorghums.

Nearly all the income of the Llano region is derived from the soil. Industries are few and restricted. The rock quarrying which centers around Llano and Burnet ranks first in importance among the mineral industries. Granite is quarried and sold for monuments and building purposes. Limestone and dolomite are quarried for terrazzo, and aggregate is produced from a large quarry in dolomite south of Burnet. Graphite is concentrated from graphite schist west of Burnet. Dolomite from a quarry south of Burnet was used as an ore of magnesium during World War II, and soapstone is ground at Llano. A cottonseed-oil mill is in operation at Brady. A cotton spinning mill at Marble Falls has long been inactive and the building at present is utilized as a wool-washing plant.

The surface waters of Colorado River have been impounded by four dams in the region, namely, Mansfield (formerly Marshall Ford), Marble Falls, Inks, and

Buchanan. The Marble Falls dam was used to supply water power to the cotton spinning mill and electric power for the town of Marble Falls. The other three are used for flood control and hydroelectric power. The large supply of cheap electric power centrally located is a favorable factor for future mineral or other industrial development.

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*For other references, see pp. 16, 19, 99, and 116.


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# HISTORICAL RESUMÉ

## Previous Geological Work

The first published descriptions of the rocks and fossils of the Llano region were made by Ferdinand Roemer (1847). Roemer, accompanying an exploring party of German colonists under the command of Count Meusebach, entered the region from the south, traveled on horseback from Fredericksburg northwest, crossing Llano River at a shallow ford, and thence northwest to an Indian camp site on San Saba River near the present site of Camp San Saba. He then followed the south side of San Saba River to an old Spanish mission, located 1 mile west of the present town of Menard, and returned up San Saba River to the Indian camp near Camp San Saba, thence up the river valley to an Indian camp near Walnut Springs near the present Jym Sloan ranch house southwest of the town of San Saba. At Walnut Springs a peace treaty was negotiated with the Indian chiefs. Roemer remained in the vicinity of the spring several days making collections of Pennsylvanian fossils. The party then returned to Fredericksburg traveling almost due south and crossing Llano River near the vicinity of Castell (fig. 5). Roemer (1849, 1852) studied the formations, collected fossils, and published descriptions of the fossils he collected and an interesting account of his observations and travels. He was the first to announce the presence of the older Paleozoics (Silurischen Kalkstein), Carboniferous (Kohlen Kalkstein), and Cretaceous (Kreidebildungen) rocks in this area. He described thirteen species of fossils from the Ordovician and Carboniferous. In 1855 and 1856, Dr. G. G. Shumard (1886) accompanied an expedition of Army engineers to explore parts of west Texas and New Mexico. The return route lay down San Saba River valley from Fort McKavitt to Fort Mason and from Fort Mason to Fredericksburg (fig. 5). Dr. Shumard made brief notes on his observations of the geology along this route. B. F. Shumard (1861) confirmed the work of Roemer and first described the Potsdam group (Upper Cambrian) and its fauna. Jules Marcou (1855) compiled the first map showing the extent of Carboniferous rocks in the region. After the pioneer work of Ferdinand Roemer and the Shumards, twenty-three years elapsed before any detailed additional geological observations were published on the region. In 1883 Walcott (1884) visited the area and described the Cambrian rocks. R. T. Hill (1887), in a review of the geology of Texas written in 1887, devoted five pages to the Llano region. He noted especially the importance of the work of Walcott in establishing the Cambrian age of the Potsdam group. Later Hill (1889) named and established the correct age of the Carboniferous rocks at Marble Falls. It was not until 1889, when the Texas Geological Survey was established with E. T. Dumble as State Geologist, that a systematic geological survey of the Llano area was undertaken. These investigations resulted in several publications, one by T. B. Comstock (1890) on the minerals and ores,

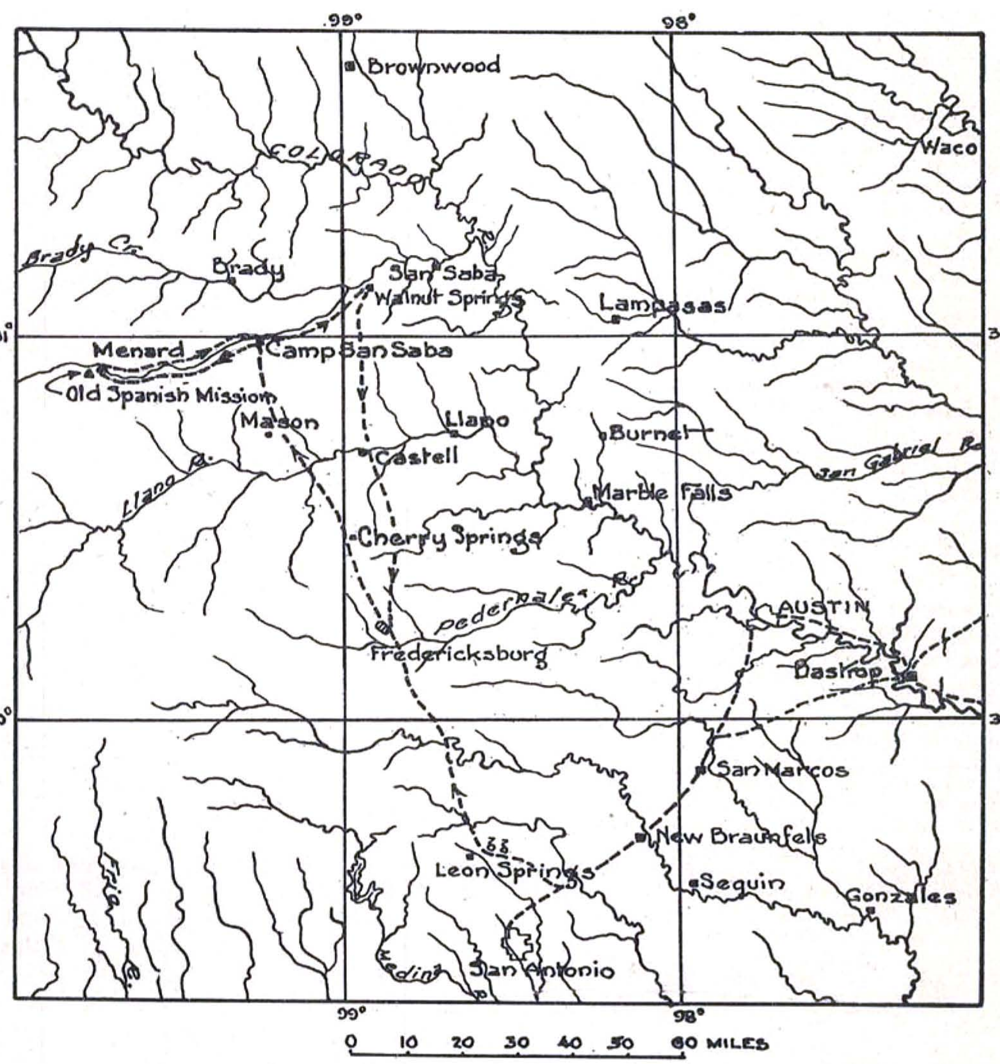


Fig. 5. Route of travel of Ferdinand Roemer in his early explorations through the Llano region.

one by R. S. Tarr (1890) on the coal resources, one by J. A. Taff (1892, pp. 326–366) on the Cretaceous rocks, and two by W. F. Cummins (1890, 1891) on the stratigraphy of the Carboniferous rocks north of the region. Dumble (1890) described the Pennsylvanian rocks in some detail and gave them the name Bend for McAnelly's Bend on Colorado River. N. F. Drake four years later (1893) described the stratigraphy of the Pennsylvanian rocks south of Colorado River, along the north border of the region. In 1898, Sidney Paige (1912) made a detailed geologic map of the Llano and Burnet quadrangles in the central part of the region. Paige (1912) named and described the Wilberns, Cap Mountain, Ellenburger, and Smithwick formations.

In 1916, the Bureau of Economic Geology (Udden, Baker, and Böse, 1916) published the first comprehensive geologic map of the State with the Paleozoic strata of the uplift divided into the following divisions:

Pennsylvanian
Paleozoic, undivided
Cambrian-Ordovician

The discovery of oil at Breckenridge and Ranger in 1918 brought many oil geologists to Texas. Among these, R. C. Moore and F. B. Plummer with the Roxana Petroleum Company, F. W. Reeves and W. C. Bean with the Empire Company, and P. V. Roundy and K. C. Heald of the U. S. Geological Survey studied the geologic section in some detail and collected fossils from the several Carboniferous formations. The work of Plummer and Moore (1922) presented a new map of the Carboniferous formations and differentiated the lower Bend shale as a separate formation having a distinct fauna to which the name Barnett was given. The following divisions of the Carboniferous strata were presented:

Strawn group—
  Mineral Wells
  Millsap Lake
Bend group—
  Smithwick
  Marble Falls
  Barnett

Girty and Moore (1919) discussed the age of the Barnett, and Girty concluded it was of Mississippian age and correlated it with the Moorefield shale of Arkansas and lower Caney shale of Oklahoma. The most outstanding result of the work by Roundy and Heald[2] was the discovery of a fossiliferous crinoidal limestone beneath the Barnett shale at a locality near San Saba which was established by Girty (Roundy, Girty, and Goldman, 1926, pp. 3–4) as Lower Mississippian, probably Boone, age. This new Lower Mississippian formation subsequently was given the name Chappel by Sellards (1933, p. 91). In 1930, C. L. Dake spent six weeks studying the Ellenburger group. and Josiah Bridge and E. O. Ulrich made less extended trips into the region. Dake and Bridge (1932) attempted the first zonation and faunal correlation of the older Paleozoics with strata in other states. N. H. Darton of the U. S. Geological Survey visited the area in 1933 and collected unpublished geologic data from Texas geologists who had worked in the area, checked in the field certain formation contacts, and prepared a new State geologic map (Darton et al., 1937) showing the following divisions of the Paleozoic rocks:

7. Canyon group
6. Strawn group
5. Smithwick shale
4. Marble Falls limestone
3. Ellenburger limestone
2. Wilberns and Cap Mountain limestones
1. Hickory sandstone

The same year, 1937, Josiah Bridge, aided by a grant from The Penrose Bequest of The Geological Society of America, studied the lower Paleozoic rocks on the west side of the uplift, made many collections of fossils, and named the Lion Mountain sandstone member of the Cap Mountain formation. He relocated most of Roemer's type localities, collected topotype material, and, with Girty (1937), redescribed Roemer's Paleozoic fossils with some excellent notes on the geology of the region. With Barnes and Cloud (1947) he revised the stratigraphy of the Upper Cambrian.

Recently Cheney (1940, p. 66) suggested a new classification for the Pennsyl-

[2]Personal communication, 1920.

vanian strata of north-central Texas based largely on subsurface data gained from a study of well logs outside the Llano area. The lower portion of his stratigraphic table is given below.

His members and most of his formations are absent or difficult to recognize in the outcropping section in the Llano region. Cloud, Barnes, and Bridge (1945) revised the stratigraphy of the Lower Ordovician rocks in central Texas, and Barnes, Cloud, and Warren (1945) first described rocks of Devonian age. Barnes, Cloud, and Warren (1947) described two more Devonian formations. Plummer (1947) published a summary of the classification of Lower Pennsylvanian strata in central Texas.

During 109 years from 1836 to 1945 in which geological work has been carried on, descriptions and illustrations of a few of the fossils of the Carboniferous rocks of the area have appeared from time to time in the literature. Altogether about 25 articles dealing with the paleontology of the region are listed in the accompanying bibliography. The most important of these are included in the following table:

*Number of new species of Carboniferous fossils described by paleontologists from 1840 to 1945*

| Author and Date[a] | Number of Species |
|---|---|
| Roemer, F. (1852) | 5 |
| Gabb, W. M. (1862) | 1 |
| Shumard, B. F. (1863) | 1 |
| Cummins, W. F. (1891) | 1 |
| Hyatt, A. (1891) | 3 |
| Hyatt, A. (1893) | 6 |
| Smith, J. P. (1903) | 5 |
| Plummer, F. B., and Moore, R. C. (1922) | 23[b] |
| Cushman, J. A., and Waters, J. A. (1927) | 7 |
| Girty, G. H. (*in* Roundy, Girty, and Goldman, 1926) | 16 |
| Girty, G. H. (1927) | 22 |
| Roundy, P. V. (1926) | 10 |
| Skinner, J. W. (1931) | 1 |
| Thomas, N. L. (1931) | 2 |
| Dunbar, C. O., and Condra, G. E. (1932) | 2 |
| Knight, J. B. (1934) | 2 |
| Plummer, F. B., and Scott, Gayle (1937) | 24 |
| Girty, G. H. (1937) | 5[c] |
| King, R. H. (1938) | 6 |
| Jeffords, R. M. (1942) | 1 |
| Moore, R. C., and Ewers, J. D. (1942) | 1 |
| Thompson, M. L. (1942) | 1 |
| Moore, R. C., and Jeffords, R. M. (1945) | 55 |
| Plummer, Helen Jeanne (1945) | 15 |

[a]The references will be found at the end of this discussion.
[b]Illustrations without descriptions of new species.
[c]Redescribed; see Bridge and Girty (1937).

*Classification of Pennsylvanian formations by M. G. Cheney*

| SERIES | GROUP | FORMATION | MEMBER |
|---|---|---|---|
| Strawn | Millsap Lake | Grindstone Creek | Goen limestone<br>Ricker limestone<br>Santo limestone<br>Buck Creek sandstone |
| | | Lazy Bend | Brannon Bridge limestone<br>Dennis Bridge limestone<br>Kickapoo Falls limestone |
| | | Dickerson<br>Unnamed subsurface formation | |
| Lampasas | Smithwick | Parks<br>Caddo Pool<br>Eastland Lake | McLester sandstone pay<br><br>Lake sandstone pay |
| | Big Saline | Sipe Springs<br>De Leon | McClesky sandstone pay |
| Morrow | Marble Falls | Comyn | McClesky sandstone pay |

This collection of paleontological literature brings together the descriptions of 215 different species of Carboniferous fossils but does not by any means cover the entire faunas. In fact, studies toward the completion of a monograph on the Marble Falls fauna have been under way for a long time. In 1919, R. C. Moore prepared for publication a manuscript of 171 typewritten pages describing 101 species of invertebrates from the Bend group mostly from the Marble Falls division. This manuscript was accepted for publication by the Bureau of Economic Geology as a companion volume to Bulletin 2132, "Stratigraphy of the Pennsylvanian formations of north-central Texas," but was withdrawn by the author when it was learned that another manuscript was being prepared by the late Dr. Girty of the United States Geological Survey. Girty's manuscript was not completed prior to his death and has not been published. Prior to 1945 papers on the ammonites (Plummer and Scott, 1937), crinoids (Moore and Plummer, 1940), corals (Moore and Jeffords, 1945), and Foraminifera (Helen J. Plummer, 1945) have appeared, and papers on the gastropods (Knight, MS.) are now under way.

The geologic succession of sediments now recognized in the Llano region consists of the following divisions:

- Carboniferous—
  - Pennsylvanian—
    - Canyon group
    - Strawn group
    - Smithwick formation
    - Marble Falls group
  - Mississippian—
    - Barnett formation
    - Chappel formation
- Devonian—
    - Zesch formation
    - Bear Spring formation
    - Stribling formation
    - Pillar Bluff limestone
- Ordovician—
    - Ellenburger group—
      - Honeycut formation
      - Gorman formation
      - Tanyard formation
- Cambrian—
    - Wilberns formation
    - Riley formation

## Present Work

Field work for the present publication was conducted intermittently from 1918 to 1937. Detailed mapping and restudy of the section on the western side of the uplift was carried on during the summers of 1937 to 1941 inclusive. The primary objective of the work is a detailed report covering the stratigraphy and paleontology of the Carboniferous rocks. The underlying rocks are discussed only briefly since reports covering them are available. A somewhat more comprehensive but preliminary treatment has been given the overlying (Cretaceous) rocks because no general reports for the region are available.

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## PRE-CARBONIFEROUS STRATA

Directly beneath the outcropping Carboniferous rocks of the Llano uplift are rocks of Devonian, Ordovician, and possibly Cambrian age. Since these rocks are in contact with the Carboniferous rocks either in normal position or by faulting, they will be described briefly. For more detailed descriptions of these rocks, the reader is referred to the publications cited.

### CAMBRIAN SYSTEM

Bridge, Barnes, and Cloud (1947) described or redefined the two formations and eight members that constitute the Upper Cambrian in the Llano uplift of central Texas. The nomenclature now in use for these units in descending order follows:

| Geologic Section | Average Thickness *Feet* |
|---|---|
| Wilberns formation | 580 |
| Pedernales dolomite member / San Saba limestone member | 280 |
| Point Peak shale member | 160 |
| Morgan Creek limestone member | 120 |
| Welge sandstone member | 18 |
| Riley formation | 680 |
| Lion Mountain sandstone member | 37 |
| Cap Mountain limestone member | 280 |
| Hickory sandstone member | 360 |

The Hickory sandstone member of the Riley formation is noncalcareous, non-glauconitic, and yellow, brown, and red. It was deposited on an irregular pre-Cambrian surface having a relief as great as 800 feet at some places. The position of the upper boundary varies throughout the Llano uplift, being placed beneath the first appearance of impure, arenaceous limestone of the Cap Mountain limestone member. The lower part of the Cap Mountain limestone consists of alternating impure, dark brown limestones and calcareous sandstones grading upward into fairly pure granular limestone. The top member of the Riley formation, the Lion Mountain sandstone, is a highly glauconitic sandstone containing in the lower part tangential lenses of limestone composed essentially of trilobites: also rather continuous highly glauconitic limestone beds containing phosphatic brachiopods.

The Welge sandstone member of the Wilberns formation is brown, mostly non-glauconitic, and contains many quartz grains with recomposed faces which glitter in the sunlight. The contact with the Lion Mountain sandstone member of the Riley formation beneath is abrupt. The Welge grades upward into the Morgan

Creek limestone member which is composed predominantly of medium- to coarse-grained, abundantly glauconitic, well-bedded limestone. In many sections there is a shaly zone in the upper part similar to the shale in the overlying Point Peak shale member. The Point Peak shale consists of well-bedded, soft, greenish, calcareous shales with subordinate amounts of fine-grained, compact dolomite; medium- to fine-grained glauconitic limestone; intraformational conglomerate, and, near the top, occasional beds of oolitic limestone, and commonly extensive to scattered stromatolitic bioherms that locally coalesce to form biostromes. The San Saba limestone member of the Wilberns formation is mostly granular limestone, in part somewhat glauconitic and dolomitic. It contains a few beds of sublithographic limestone that might be confused with the limestones of the overlying Ellenburger group. The San Saba limestone member is present mostly in the western part of the Llano uplift and is stratigraphically equivalent to dolomite in the eastern part of the uplift named the Pedernales dolomite. The Pedernales dolomite is fine to coarse grained with the fine-grained portions being mostly yellowish gray to beige and the coarse-grained portions mostly light gray to silvery gray. The Pedernales dolomite member is in part cherty, the cherts being mostly of somber hues, granular, and ranging from highly porous to compact.

### Ordovician System

Cloud, Barnes, and Bridge (1945) described three formations, two members, and various dolomitic and calcitic facies comprising the Ellenburger group of rocks of Lower Ordovician age. Photographs of typical outcrops of limestone in the Ellenburger group are shown on Plate 2. The nomenclature in use for these units in descending order follows:

| Geologic Section | Average Thickness *Feet* |
|---|---|
| Honeycut formation | Absent to 678 |
| Gorman formation | 470 |
| Tanyard formation | 585 |
| Staendebach member | |
| Threadgill member | |

The Tanyard formation overlies the Wilberns formation unconformably in the eastern part of the uplift but appears to be conformable in the western part of the uplift. It is divided into two members each of which contains dolomitic and calcitic facies. The Threadgill member is limestone in the western part of the Llano uplift and predominantly dolomite in the eastern part of the uplift where especially abrupt lateral changes from dolomite to limestone are common. The dolomite is mostly medium to coarse grained and only sparsely cherty. The limestone is mostly sublithographic, nonglauconitic, thin to medium bedded westward, and massive in the eastern part of the uplift.

The upper member of the Tanyard formation, the Staendebach member, is predominantly fine- to medium-grained dolomite, with limestone forming the upper one- to two-thirds of the unit in the northeastern part of the uplift. It contains an abundance of sparingly to abundantly dolomoldic, porcelaneous to chalcedonic chert which weathers to white or bluish-white masses. In most areas the Staendebach member contains abundant quartz druse.

The Gorman formation is the middle unit of the Ellenburger group and is composed in its outcrop area of an upper calcitic and a lower dolomitic facies. The dolomite is predominantly microgranular, which distinguishes it from the dolomites of the Tanyard below. The Gorman formation contains thin sandy limestone beds which likewise distinguish it from the Tanyard and all of the Honeycut formation except for the lower part. The chert of the Gorman tends to be nodular and concretionary and partakes of the character of the chert found in the upper part of the Tanyard and in the Honeycut formations. A stromatolite zone in the upper part of the Gorman formation on Honey Creek, Mason County, is shown in Plate 2, figure B.

The Honeycut formation is truncated by erosion, and it has a thickness ranging from 678 feet along Pedernales River to a feather edge in eastern San Saba County, disappearing entirely in the western part of the uplift. In its type section along

Pedernales River the Honeycut is divisible into three units: an upper predominantly limestone unit, a middle predominantly microgranular dolomite unit, and a lower unit composed of alternating limestone and dolomite beds. The chert in the Honeycut formation is similar to that in the Gorman formation except for cannonball chert which is abundant in the Honeycut formation but noted only near the middle of the Gorman formation. Limestone in the upper part of the Honeycut formation at Pillar Bluff, Burnet County, is shown in Plate 2, figure A.

## Devonian System

Barnes, Cloud, and Warren (1945) described two new Devonian formations in the Llano uplift. Two additional formations were later described by the same writers (1947). At present four formations of Devonian age are recognized, all except one of which are preserved in the Ellenburger either as collapsed structures or as crevice fillings. The Devonian formations named in descending order are as follows:

Zesch formation
Bear Spring formation
Stribling formation
Pillar Bluff limestone

The Pillar Bluff limestone in its type locality in northern Burnet County is a coquina of fossils filling an ancient joint or cave. Pockets of limestone in the Honeycut formation beneath the Stribling formation in Blanco County are provisionally referred to the Pillar Bluff limestone.

The Stribling formation lies with normal stratigraphic contact on the Honeycut formation along Pedernales River in Blanco County and ranges up to 11 feet in thickness. It is composed of limestone which is cherty, irregularly bedded, smooth fracturing, and medium gray to beige-colored.

The Bear Spring formation occupies a portion of a collapse structure south of Honey Creek about 8 miles southwest of Mason. The limestone, in part cherty, is granular, brownish to grayish yellow and in part white to cream-colored. Associated with the Bear Spring formation in the same collapse structure is the Zesch formation, a highly siliceous limestone and leached silica rock, yellowish to brownish in color, containing scattered angular fragments of chert.

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## CARBONIFEROUS STRATA

## MISSISSIPPIAN SYSTEM

### CHAPPEL FORMATION

*Historical account.*—Discovery of rocks of Lower Mississippian age in Texas was made by C. L. Baker[3] in 1917. Baker found a ledge of fossiliferous limestone and conglomerate below the Bend group in the bed of Espey Creek about 3 miles southwest of Lampasas. The fossils were sent to Dr. Stewart Weller, who confirmed the Lower Mississippian age, and their discovery was noted vaguely by Matteson (1919, p. 174) in his account of the oil geology of north central Texas. The importance of this find, however, apparently was not realized by either Baker or Weller, since no adequate account of the discovery or description of the fossils was published by them, and credit for announcing the presence of Lower Mississippian strata goes to later workers.

The first record in the files of the Bureau of Economic Geology of the occurrence of strata in Texas between the Barnett formation and Ellenburger is in an unpublished report by Liddle (1920), written under the direction of Dr. Udden, on the geology of a dam site on San Saba River west of San Saba, submitted to the State Board of Water Engineers in 1920. Liddle describes limestone and "breccia" between the Ellenburger and Marble Falls strata on San Saba River, which he refers to as "Silurian-Devonian hiatus." His horizontal and vertical sections show clearly that his "hiatus rock" is the Chappel formation of later maps, and its position is shown in figure 6. Credit for the first published description of the Lower Mississippian strata in Texas belongs to

[3]Letter from Baker, 1942.

P. V. Roundy, G. H. Girty, and M. I. Goldman (1926). Roundy in 1919, working in Texas with K. C. Heald,[4] collected

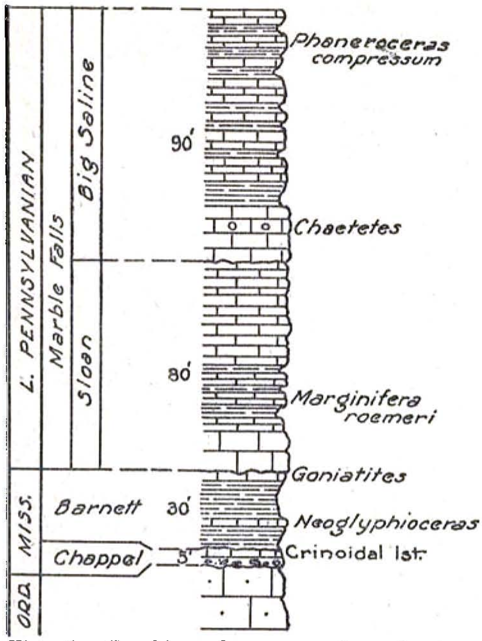


Fig. 6. Graphic columnar section showing stratigraphic relationships and average thicknesses of the Ellenburger (Ordovician) limestone, Mississippian formations, and Lower Pennsylvanian formations in the Llano region.

samples of a crinoidal limestone at the base of the Carboniferous section on the Chappel road 3 miles southeast of San Saba, discovered Mississippian fossils, and later with Girty described the fauna. Dr. Goldman made a petrographic study of the rocks. The formation was referred to as "limestone of Boone age," and it was determined by Roundy and Girty to be Lower Mississippian. Sellards (1933, p. 91) redescribed the strata and named the formation Chappel for Chappel road, since the locality of the discovery, now designated the type locality, was on this road and situated 6 miles northwest of the town of that name. Dake and Bridge (1932, p. 731) discovered the Lower Mississippian strata on the west side of the region at a locality on the northwest side of the White ranch road crossing on Llano River 7 miles southwest of Mason and regarded the fauna as Osage in age. Cheney (1940, p. 67) studied these beds in well sections north of this region and concluded that the formation thickens to the north to about 300 feet in Throckmorton County.

[4]Personal communication, K. C. Heald, December, 1940.

*Extent and thickness.*—The Chappel formation lies unconformably upon the Ellenburger limestone and dolomite and is overlain unconformably by the Barnett formation. It is known to encircle the entire Ellenburger outcrop and it has now been mapped on all sides of the region from Espey Creek west of Lampasas, westward to Llano River southwest of Mason, and southward to Pedernales River northeast of Johnson City (Pl. 4). Although in most places it is rarely over 1 foot thick, it can be traced continuously for many miles (Pl. 1). It is covered by slope wash from the soft Barnett shale in many places and in other places appears to have been removed by erosion before the Barnett was deposited. Yet in almost any district, except in certain areas around Brady in McCulloch County and in the Cypress Creek valley near Cypress Mills, northeastern Blanco County, and those areas where it has been displaced by faults, it can be easily recognized. Its thickness ranges from about 6 inches to more than 50 feet. Its average thickness through a long extent of outcrop is about 1 foot. In a few places, especially in old sink holes and synclines which were apparently formed during or before its deposition, the Chappel is much thicker and comprises several layers of granular limestone which may reach a total thickness of more than 20 feet. In the outcrop on Honey Creek, Mason County, it is more than 50 feet thick and occurs as filling in an ancient sink hole (fig. 9). The limestone is essentially a layer of crinoidal detritus consisting of broken and waterworn fragments of crinoid stems firmly cemented to form a persistent ledge (Pl. 3, A and B). In many places, up to 95 percent of the rock is made up of crinoid fragments; the rest is cementing material and small calcareous particles of sand grade. The color is light yellowish gray, weathering almost white. In a few places the ledge is a white, hard, granular, crystalline limestone containing a few scattered pieces of crinoid stems and, rarely, other fossils. In a few areas, particularly on the north side of the region, the formation consists of two, and in rare places several, layers. Typically, the upper half is hard, compact, crinoidal limestone 8 to 10 inches thick. The lower half is very hard, firmly cemented chert conglomerate made up of rounded cobbles and nodules of chert, a fraction of an inch to 8 inches in diameter derived from the Ellenburger formation and set in a matrix of chert, which serves also as a cementing agent. The conglomerate in most places has a thickness of 6 to 8 inches. The cobbles are white or grayish white, and the matrix is tan colored and light yellowish brown. The Chappel formation is well exposed at the following localities:

*Noteworthy Chappel localities in central Texas*

| LOCALITY | COORDINATES (Pl. 1) | THICKNESS *Feet* | *Inches* |
|---|---|---|---|
| Burnet County— | | | |
| 500′ southwest of Espeyville church | HH-20 | 1 | 6 |
| 2,100′ south of crossing, west of cemetery, 5 miles southeast of Marble Falls (Loc. 27–T–15) | II-39 | 3 | 0 |
| On Marble Falls-Johnson City road, 1 mile south of bridge at Marble Falls, top of hill, few feet east of gate on east side of road (Loc. 27–T–4) | HH-38 | 1 | 0 |
| McCulloch County— | | | |
| West side of small branch, ½ mile north of gate on Voca-Brady road, 4 miles southeast of Brady (Loc. 153–T–79) | J-18 | 14 | 0 |
| Mason County— | | | |
| On Honey Creek, 7 miles southwest of Mason, 3,100′ northwest of road crossing on creek (Loc. 159–T–4) | I-33 | 51 | 6 |
| On Llano River, north side of road, at White's Crossing (Loc. 159–T–2) | I-34 | 28 | 11 |
| Leon Creek, 3 miles south and 1.5 miles east of Erna, 1.5 miles east of west county line (Loc. 159–T–45) | E-32 | 52 | 0 |
| San Saba County— | | | |
| On San Saba-Chappel road, 3 miles southeast of San Saba (Loc. 205–T–21) | X-16 | 3 | 0 |
| On Jack Sloan ranch, 1.4 miles southwest of Hackberry windmill (Loc. 205–T–77) | R-16 | 2 | 2 |
| On Pool Branch, about ¼ mile west of junction with Rough Creek (Loc. 205–T–123) | Z-17 | 3 | 2 |
| On King Branch, 1,300′ north of King Spring, north side of creek, 0.6 of a mile south of Maxwell Crossing (Loc. 205–T–124) | R-17 | 0 | 10 |
| Gibbons ranch, south of San Saba-Brady highway, 1 mile east of McCulloch County line (Loc. 205–T–125) | O-12 | 1 | 0 |

*Lithology.*—In a few places, as at the outcrop on King Branch in San Saba County, a thin, rather soft fossiliferous, grayish shale occurs between the chert conglomerate and the Ellenburger ledges. This shale is very smooth in texture and is about 4 to 8 inches thick. It contains early Mississippian fossils, perhaps Kinderhook in age. At an outcrop southwest of the old Alexander dam site on Colorado River, the Chappel crinoidal limestone overlies a gray, gritty shale or marl about 20 inches in thickness, containing a very few early Mississippian fossils but also some interesting minute crinoids discovered by Moore and Ewers (1942, p. 93). No conglomerate has been observed at the dam site. The following described sections of the Chappel will furnish other details of its stratigraphy and indicate its variations in different parts of the region. They are shown graphically in Plate 4.

*Section of Chappel formation on Espey Creek 300 feet east of road crossing on Hollenbeck ranch 5 miles southwest of Lampasas, Lampasas County* (Loc. 141-T-6; Coord. HH-20, Pl. 1).

| | THICKNESS *Feet* | *Inches* |
|---|---|---|
| 4. Limestone, light gray, thin bedded, hard, crinoidal; in layers 3 to 4 inches thick separated by gray shale partings | 3 | .. |
| 3. Shale, greenish gray, platy, interbedded with thin limestone layers each 1 inch thick | 1 | .. |
| 2. Chert, greenish gray, hard, breaks with conchoidal fracture | .. | 3 |
| 1. Conglomerate, made up of black, rounded, phosphate pebbles ⅛ to 1½ inches in size set in a matrix of coarse, well-rounded sand grains also containing | | |

| | Feet | Inches |
|---|---|---|
| elongate nodules of banded chert; one nodule is 8 inches long and 2 inches in diameter. Few fossils including gastropods and Bryozoa and water-worn fragments of bones, probably shark. The fauna is very different from a typical Chappel fauna | ---- | 1½ |
| Total thickness | 4 | 4½ |

*Section of Chappel formation near head of Battle Branch, near the east line of the Fritz Fuchs ranch, ¾ of a mile up the branch from Pedernales River, Blanco County* (Coord. HH-45, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 2. Limestone, dark gray, crinoidal, made up largely of crinoid detritus; coarsely crystalline, fossiliferous. The fossils are almost altogether crinoid stems, many having pentilobate cross sections. The pure crinoid detritus in most places occurs in layers and lentils in the crystalline rock. It is best exposed on south side of the creek west of the wire fence | 1 | 8 |
| 1. Conglomerate, light gray, made up of rounded and subangular chert pebbles and cobbles set in a matrix of chert | ---- | 5 |
| Total thickness measured | 2 | 1 |

*Section of Chappel formation measured along small branch of Pool Creek of Milliken ranch about ¼ of a mile southwest of junction of Pool Creek and Rough Creek, San Saba County* (Coord. Z-17, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 10. Limestone, light gray, porous, crinoidal, fossiliferous | ---- | 5 |
| 9. Limestone, dark gray and brownish gray, crinoidal | ---- | 8 |
| 8. Limestone, dark gray, soft, somewhat disintegrated, crinoidal | ---- | 3 |
| 7. Shale, yellow, crinoidal | ---- | 10 |
| 6. Limestone, light gray, hard, crinoidal | ---- | 3 |
| 5. Limestone, light gray, hard | ---- | 3 |
| 4. Limestone, light gray, hard | 1 | ---- |
| 3. Limestone, light gray, hard, made up of 3 beds, 4″ thick | 1 | ---- |
| 2. Limestone, gray, crinoidal | 1 | 2 |
| 1. Conglomerate, yellow pebbles and cobbles of chert | 2 | 4 |
| Total thickness measured | 8 | 2 |

The crinoidal limestone of the above section is overlain by dense, black, thinly laminated beds of Barnett shale.

*Section of Chappel formation measured on east side of San Saba-Chappel road at sharp curve in road halfway up steep hill 3 miles southeast of San Saba, San Saba County* (Loc. 205–T–21; Coord. X-16, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 3. Limestone, greenish gray and brownish gray, soft, crinoidal, consisting of great quantities of small crinoid stem fragments | 1 | 3 |
| 2. Limestone, light gray, weathering white, siliceous, soft | 1 | 11 |
| 1. Conglomerate, white, made up of pebbles and cobbles, mostly consisting of white chert | ---- | 10 |
| Total thickness measured | 4 | ---- |

*Section of Chappel formation measured on north side of King Creek 300 feet east of road crossing on Jym Sloan ranch, San Saba County* (Loc. 205–T–69; Coord. R–17, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Barnett— | | |
| 6. Shale, black, thinly laminated, soft, weathering brown, containing limestone concretions and thin layers of limestone, partly covered by talus | 30 | ---- |
| Chappel (total thickness, 2′ 11″)— | | |
| 5. Limestone, gray, hard, crinoidal, in two layers each 7 inches thick | 1 | 2 |
| 4. Clay or shale, yellow, soft, containing a soft layer; represents a soft, somewhat weathered limestone | ---- | 3 |
| 3. Conglomerate, dark gray, hard, siliceous, made up of chert cobbles and boulders apparently derived from the Ellenburger dolomite firmly cemented by silica | 1 | 2 |
| 2. Marl or shale, gray and greenish gray, calcareous, impure, earthy, may represent a layer of partly disintegrated limestone, fossiliferous; the fossils are poorly preserved and difficult to identify | ---- | 4 |
| ——— unconformity ——— | | |
| Ellenburger— | | |
| 1. Limestone, white, dense, hard, containing algal colonies | 50 | ---- |
| Total thickness | 82 | 11 |

*Section of Chappel formation measured along north-flowing branch of Brady Creek on Session ranch about 3¾ miles southeast of Brady, McCulloch County* (Loc. 153-T-79; Coord. J-18, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 20. Limestone, yellowish gray, soft, partly disintegrated and earthy, composed of small crinoid fragments and microfossils including ostracodes | 2 | |
| 19. Limestone, gray, hard, crystalline, crinoidal | | 3 |
| 18. Limestone, gray, hard, crystalline | | 5 |
| 17. Limestone, gray, hard, crystalline | | 3 |
| 16. Limestone, gray, somewhat soft, partially disintegrated | | 2 |
| 15. Limestone, gray, soft | | 4 |
| 14. Limestone, gray, soft | | 3½ |
| 13. Limestone, gray, hard | | 4 |
| 12. Limestone, gray, hard | | 3 |
| 11. Limestone, gray, hard | | 3 |
| 10. Limestone, gray, soft | | 10 |
| 9. Limestone, gray, medium hard | | 4 |
| 8. Limestone, gray, medium hard | | 3 |
| 7. Limestone, gray, medium hard | | 3 |
| 6. Limestone, gray, medium hard | | 3 |
| 5. Limestone, gray, medium hard | | 3 |
| 4. Limestone, gray, medium hard | | 3 |
| 3. Limestone, gray, medium hard | | 2½ |
| 2. Limestone, gray, hard, chert bearing | | 6 |
| 1. Limestone, gray, hard, chert bearing | | 13 |
| Total thickness measured | 8 | 9 |

Between the base of the exposed Chappel limestone measured and the top of the Ellenburger, an interval of 4½ feet is covered by talus, slope wash, and grass. This obscured section may be shale, marl, or conglomerate or both conglomerate and shale. The Ellenburger is well exposed in the bottom of the creek below the detritus. Here it consists of large cobbles and boulders cemented into a hard mass which dips at a rather steep angle and apparently has been broken up, water worn, and recemented before the deposition of the Chappel strata above.

*Section of the Chappel formation measured along a bluff on the east side of Honey Creek, 3,100 feet northwest of creek crossing on Mason-White's Crossing road and 7 miles southwest of Mason, Mason County* (Loc. 159-T-4; Coord. I-33, Pl. 1).

| | THICKNESS Feet |
|---|---|
| 3. Limestone, light gray, crinoidal; weathers to rounded blocks and is composed largely of masses of minute crinoid stems | 25 |
| 2. Limestone, light gray, massive, siliceous, chert bearing, upper portion is composed of gray brecciated chert | 25 |
| 1. Limestone, light gray, crinoidal, fragmental, and quite fossiliferous, containing *Zaphrentis*, button-like sections of crinoid stems, fragments of spirifers, a trilobite, and a few other fossils | 1½ |
| Total thickness measured | 51½ |

This is one of the thickest sections of Chappel in the area. The beds in this bluff dip northward and overlie the Ellenburger limestone in the creek bottom. The two upper layers are separated by a distinct plane of separation. In most places the crinoidal layers protrude beyond the fossiliferous siliceous layer. The thin crinoidal layer occurs at the north end of the bluff beneath the siliceous layer. The locality is situated in a small structural syncline which may possibly represent an old regional low on the old Ellenburger surface, a hollow or sink into which large quantities of detritus accumulated. Because of its structurally low position, it was not removed or reduced by pre-Barnett erosion. The strata form a lentil (fig. 9), which is about 700 feet in length north and south and of unknown width east and west. The massive layers show some cross-bedding, as if the detrital material were washed into the sink or depression and deposited along its sloping edges.

*Section of Chappel formation exposed on east bank of Llano River north of White's Crossing, 9 miles southwest of Mason, Mason County* (Coord. I-34, Pl. 1; fig. 8).

| | THICKNESS Feet | Inches |
|---|---|---|
| 8. Limestone, light gray, almost white, finely crystalline, much jointed; breaks into blocks and round-cornered chunks | 4 | ---- |
| 7. Limestone, light gray, finely crystalline, much cracked and jointed | 10 | ---- |
| 6. Limestone, finely crystalline, thin bedded; the beds 1 inch or even less in thickness | 3 | 3 |
| 5. Limestone, subcrystalline, rough surfaced, covered with many fine cracks, mostly nonfossiliferous | | 8 |

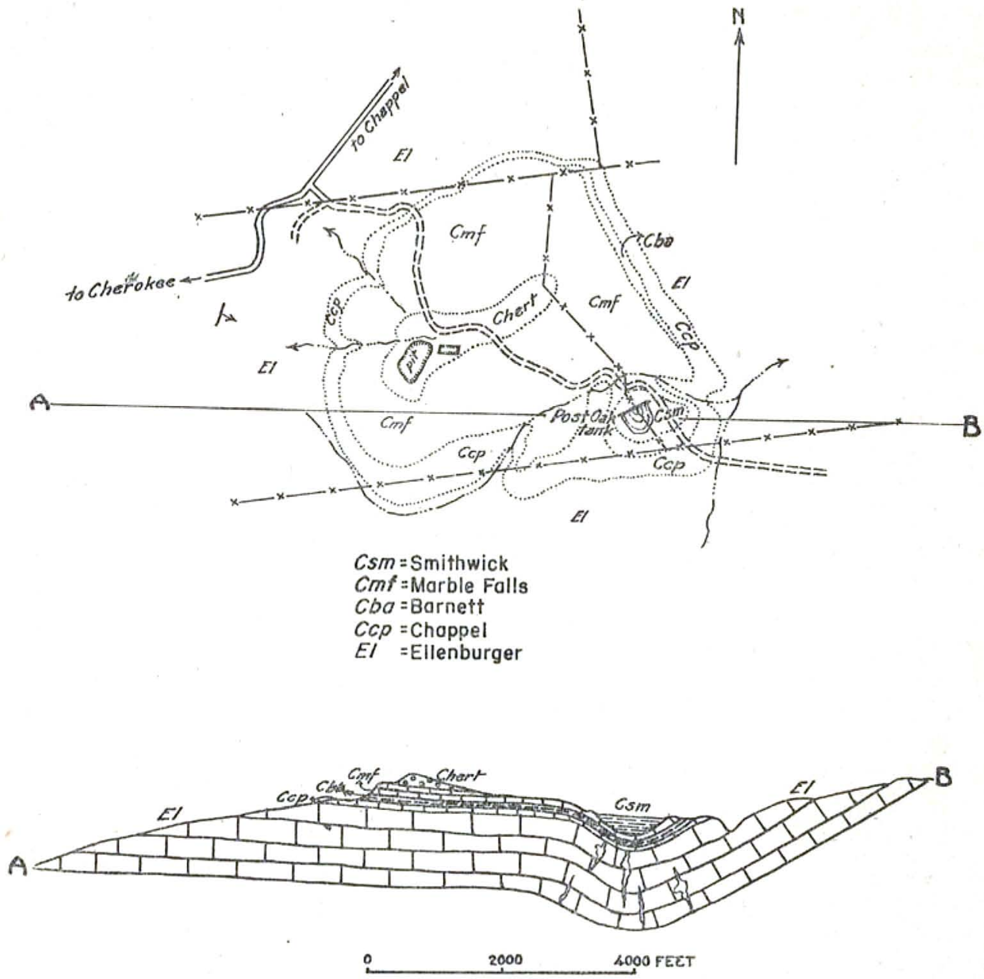


Fig. 7. Map and cross section of Post Oak sink east of Cherokee, San Saba County.

| | THICKNESS Feet | Inches |
|---|---|---|
| 4. Limestone, pinkish gray and greenish gray where freshly broken, soft, composed of a coquina of small crinoid stems, broken into small pieces, and containing a few spirifers and other large fossils | 7 | -- |
| 3. Limestone, pinkish gray and greenish gray where freshly broken, soft, composed of a coquina of small crinoid stems; many fossils, most of them poorly preserved | 3 | -- |
| 2. Limestone, pink, or reddish pink, nodular, hard, crystalline, containing cobbles, finely crystalline | 1 | -- |
| 1. Shale (?) covered by river silt | --- | --- |
| Total thickness measured | 28 | 11 |

The strata described in this section lie in an ancient limestone sink formed by solution of the Ellenburger limestone sometime after the Ellenburger was elevated above the surface of the sea and before the Chappel epoch. The crinoidal detritus has been washed into the sink, buried the talus in its bottom, and filled the sink with limy strata (fig. 8). This sink is about 500 feet long, 300 feet wide, and 30 to 40 feet deep. It contains in the bottom a mass of limestone blocks that fell at the time the sink was formed, probably by collapse of the roof of a cave in the dolomite layers just below. The Chappel sea later covered the sink, and the remainder of the depression not occupied by Ellenburger blocks was completely filled by crinoidal detritus, shells, and shell fragments, which slowly accumulated in the early Mississippian sea.

At least 9 sink holes containing Chappel deposits have been found in this region. All have abnormally thick deposits of coarsely granular Chappel limestone and all are excellent fossil localities. Their localities are listed in the accompanying table (p. 27).

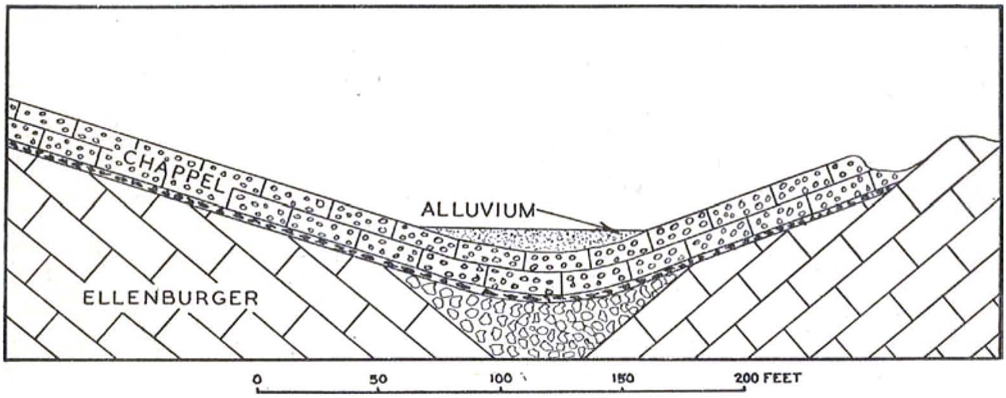


Fig. 8. Cross section through White's Crossing sink, Mason County.

*Subdivisions of the Chappel.*—A review of the sections described above from different places in the region indicates that the Chappel can be differentiated into two facies and subdivided into four members. The two facies, determined in part at least by the topography of the Ellenburger surface on which the Chappel was deposited, are:

1. Normal facies. A thin layer of crinoidal detritus derived from bottom-living crinoids and deposited by ocean currents and waves as a fragmental crinoid detritus or coquina and spread rather evenly over the ocean floor to a depth of 10 to 15 inches.

2. Sink-hole facies. This facies is exemplified by the section at White's Crossing on Llano River in which large quantities of Ellenburger talus, cobbles, crinoid detritus, calcium carbonate, and shells have accumulated to fill a deep depression in the ancient ocean floor, forming a thick lentil of coarsely granular, cross-bedded, fossiliferous material.

Stratigraphically the Chappel may be divided into 4 members as follows:

4. White's Crossing coquina
3. Espey Creek limestone
2. Ives conglomerate
1. King Creek marl

The King Creek marl occurs typically on King Branch on the Sloan ranch, one-fourth mile northwest of King Spring and 300 feet east of the road crossing (Loc. 205–T–124, Coord. R–17, Pl. 1). It is a dark-gray, colloidal, non-laminated, fossiliferous, lumpy, partially cemented hard marl, which fills depressions, cavities, and holes in the Ellenburger surface on which the Chappel formation is deposited. In most places it is less than 1 foot thick. It is quite erratic in distribution and appears to occur only in places where the

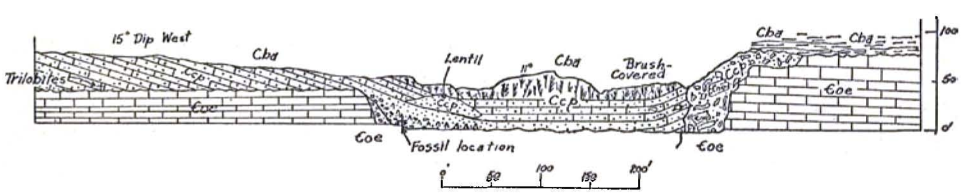


Fig. 9. Cross section through Honey Creek sink, Mason County.

*Location of sink holes containing Chappel formation in the Llano region*

| LOCALITY | COORDINATES (Pl. 1) | SIZE *Feet* | THICKNESS *Feet* |
|---|---|---|---|
| 1. Honey Creek, three-quarters of a mile northwest of the Mason-White ranch road, 7 miles southwest of Mason, Mason Co. (fig. 9; Loc. 159–T–4). | I-33 | 700 N.-S. | 51½ |
| 2. East bank of Llano River at White's Crossing, 8½ miles southwest of Mason, Mason Co. (Loc. 159–T–2). | I-34 | 500 x 300 | 29 |
| 3. Gray's ranch near Calf Creek, 15 miles southwest of Brady, McCulloch Co. (Loc. 153–T–63). | G-22 | 800 x 1800 | 5 |
| 4. Arthur Neal ranch, 5 miles east-southeast of Rochelle on the north side of the Rochelle-Cavern road, McCulloch Co. | N-14 | 100 N.-S.<br>252 E.-W. | 6 |
| 5. U. S. highway No. 87, 7 miles southeast of Brady, McCulloch Co. (fig. 10; Loc. 153–T–110). | I-20 | 300 x 300 | 21 |
| 6. Session ranch, 3¾ miles southeast of Brady, McCulloch Co. (Loc. 153–T–79). | J-18 | 200 N.-S.<br>30 E.-W. | ? |
| 7. East side of Onion Creek, 2½ miles east of Nelin, McCulloch Co. (south of Loc. 153–T–50; fig. 11). | K-15 | 250 N.-S.<br>125 E.-W. | 1 to 3 |
| 8. Jack Sloan ranch east of windmill, ¾ mile southwest of ranch house, San Saba Co. (Loc. 205–T–77). | Q-16 | 300 x 500 | 20 |
| 9. Post Oak sink, 5 miles east of Cherokee, San Saba Co. (Loc. 205–T–64; fig. 7). | Y, Z-22 | 1 mile W.-S.<br>1.1 miles E.-W. | ? |

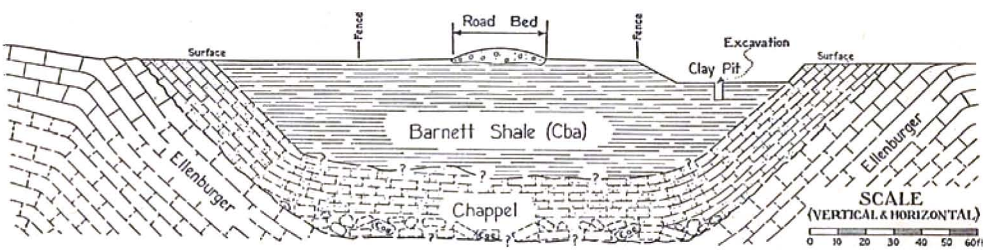


Fig. 10. Cross section through Brady-Mason highway sink, McCulloch County.

Ellenburger had a rough surface so that the silt and clay were protected from erosion before the stronger currents deposited the overlying conglomerate.

The Ives conglomerate is best exposed along Ives Branch on the Gibbons ranch 2½ miles southwest of Hall (Loc. 205–T–125, Coord. O–12, Pl. 1), San Saba County. Other typical exposures are on King Creek one-fourth of a mile below King Spring, Sloan ranch (Loc. 205–T–124, Coord. R–17, Pl. 1); along the old Chappel-Cherokee road one-half mile southwest of Harrell cave (Coord. Z–19, Pl. 1); 1 mile southwest of Loc. 205–T–49 along the Chappel-Cherokee road (Coord. Z–21, Pl. 1); and on Doffelmeyer ranch 1.6 miles west of Parks B. M. (Coord. AA–20, Pl. 1). The rock ranges in color from dark gray to almost white, and in many places is slightly buff or even tan. It is made up almost altogether of silica and consists of large pebbles and cobbles of gray and white chert derived from the Ellenburger, set in a matrix of silica sand and firmly cemented by silica. The rock is so firmly cemented that it breaks with conchoidal fracture into chunks and blocks without regard to the surfaces of the cobbles. Therefore, it is quite difficult or even impossible in many places to free a pebble from the matrix; any measurements of pebbles must be made in cross sections. In most places the pebbles are well rounded and have the appearance of having originated from rounded chert nodules. Rarely one or two pebbles of dolomite can be observed but nowhere are Ellenburger limestone pebbles found. The thickness of the conglomerate in most places ranges from 6 to 14 inches.

The Espey Creek limestone is by far the most persistent member of the Chappel and can be found almost anywhere along the Barnett-Ellenburger contact where good exposures of the two formations occur together. The name is derived from the excellent exposures along Espey Creek southeast of Hallenbeck ranch house, Lampasas County (Loc. 141–T–6, Coord. HH–20, Pl. 1). Other good exposures are along the south side of Battle Branch on the west line of Fuchs ranch 6 miles southwest of Cypress Mills, Blanco County (Loc. 16–T–5, Coord. HH–45, Pl. 1); along a small branch on the Session ranch 3½ miles southeast of Brady, McCulloch County (Loc. 153–T–79, Coord. J–18, Pl. 1). At these localities this member is made up of several layers of crinoidal limestone, each layer having a thickness of from 3 to 8 or even 10 inches, having somewhat wavy bedding planes, and consisting of hard, crystalline limestone containing a profusion of small crinoid stem fragments. In many other places where the member is not more than 1 foot thick, it consists of a single layer containing crinoidal débris or coquina somewhat loosely cemented and sparsely fossiliferous. The fossils are generally small and poorly preserved. The thickness of the member in its normal facies ranges from 6 inches to 4 feet; its common average thickness is only 8 to 12 inches.

White's Crossing coquina, a crinoidal detritus, occurs in limestone sinks and depressions in the Ellenburger where it has escaped post-Chappel erosion. The best known locality is on the east side of Llano River and on the north side of the road at White's Crossing (Loc. 159–T–2, Coord. I–33, Pl. 1); and along Honey Creek 7 miles southwest of Mason, Mason County (Loc. 159–T–4, Coord. I–33, Pl. 1). The member consists of several lenticular layers of massive limestone made up of coquina of crinoid fragments and containing numerous poorly preserved fossils. Large spirifers are predominant, and such forms as *Spirifer grimesi* Hall, *Spirifer carinatus* Rowley, and *Brachythyris burlingtonensis* Weller suggest strongly that these massive layers are Burlington in age. The coquina deposits are very local in extent being confined to sinks and depressions but have a thickness ranging up to 60 feet or more depending upon the depth of the sink hole.

*Microscopic characteristics.*—The most conspicuous feature of the Chappel when viewed under a microscope is its coarsely crystalline texture. The rock appears to be an agglomerate of coarse calcite crystals and crinoid cylinders set in a matrix of water-deposited calcite sand containing a small sprinkling of fine black silt particles. The large calcite crystals are intermingled with sections of crinoid stems also made of crystalline calcite. The typical rhombohedral cleavage of the calcite is quite conspicuous on the faces of the crystals and crinoid sections. Some fragments have the appearance of a mass of imbricated calcite plates. The large calcite crystals range up to 2 mm. in size and the small inter-crystal granules 1/40 to 1/20 mm. in diameter. The small crystals which disintegrate from the loose chunks average half a millimeter in size. Small crystals of pyrite of this same size occur rarely in the material. It is noteworthy that many thin sections show growth of secondary calcite around original calcite grains and calcite fragments derived from crinoid stems.

*Distinguishing features.*—The Chappel formation is easily distinguished from other formations in the region by its high crinoidal content, its crystalline characteristics, its siliceous conglomerate made up of large chert cobbles, and its fossil content which is unlike any other fauna. Everywhere the rock contains small crinoid fragments, the vast majority of which are pieces of crinoid stems; almost no calices or plates occur. In many places the crinoid fragments consist of short sections of crinoid stems, shorter than wide, which have beveled edges so that they look like small buttons. The canal at the center of the stem in most stem plates is small, circular in cross section, and rarely, if ever, large and pentilobate like many of the canal systems of the Pennsylvanian crinoid stems. The Chappel crinoidal bed is distinguished from the crinoidal lentils in the Marble Falls by its lighter color, generally smaller crinoid stems, more beveled and water-worn edges of its stem fragments, by the characteristically more circular cross sections of the central canal openings in these fragments. It is easily distinguished from the Ellenburger limestone by its crinoid content and by its coarsely crystalline texture.

*Paleontology.*—The complete fauna of the Chappel formation has not been studied. Roundy, Girty, and Goldman (1926) studied the type locality. Girty described and illustrated some minute fossils and Roundy described the ostracodes from the limestone. Since then rather extensive collections have been made from several localities in San Saba, McCulloch, and Mason counties, and an interesting new chapter in Mississippian paleontology will be written when all these forms are studied and identified. The fauna as now known from preliminary work by ourselves and from the published work by Roundy and Girty consists of about 60 genera and 117 species recorded in the following list, and of these the more characteristic and common species are figured in Plate 5.

*Fossils from the Chappel formation*

Anthozoa—
- Cladochonus sp.
- Cyathaxonia minor Weller
- Palaeacis? sp.

Brachiopoda—
- Lingula halli White
- Leptaena analoga (Phillips)
- Leptaena convexa Weller
- Schuchertella morsei Foerste
- Schellwienella inflata (White and Whitfield)
- Schellwienella crenulicostata Weller
- Schellwienella planumbona Weller
- Streptorhynchus tenuicostatum Weller
- Chonetes illinoisensis Worthen
- Chonetes missouriensis Weller
- Chonetes logani Norwood and Pratten
- Chonetes burlingtonensis Weller
- Chonetina subcarinata Girty
- Avonia blairi (Miller)
- Dictyoclostus mesicostalis (Weller)
- Dictyoclostus crawfordsvillensis (Weller)
- Dictyoclostus calhounensis (Moore)
- Productus marginicinctus Prout
- Productus newtonensis Moore
- Linoproductus cutirostris (Winchell)
- Linoproductus ovatus (Hall)
- Productella sublaevis Weller
- Cancrinella sampsoni (Weller)
- Cancrinella parvula (Winchell)
- Pustula pusilla? (Girty)
- Pustula inconspicua Girty
- Echinoconchus morbillianus (Winchell)
- Rhipidomella burlingtonensis (Hall)
- Rhipidomella perminuta Girty
- Rhipidomella missouriensis (Swallow)
- Rhipidomella oweni (Hall and Clarke)
- Rhipidomella thiemei (White)
- Schizophoria subelliptica (White and Whitfield)
- Schizophoria chouteauensis Weller
- Schizophoria sedaliensis Weller
- Schizophoria poststriatula Weller
- Schizophoria swallovi (Hall)
- Camarophoria bisinuata (Rowley)
- Camarotoechia chouteauensis Weller
- Camarotoechia elegantula Rowley
- Leiorhynchus greenianum (Ulrich)
- Pugnoides boonensis (Shumard)
- Shumardella obsolens (Hall)
- Rhynchopora hamburgensis (Weller)
- Rhynchopora pustulosa (White)
- Rhynchopora beecheri Gregor
- Rhynchopora persinuata (Winchell)
- Rhynchopora cooperensis (Shumard)
- Centronella? emaciata Rowley
- Selenella subcircularis Girty
- Centronelloidea rowleyi (Worthen)
- Cranaena globosa Weller
- Dielasma subspatulatum Weller
- Dielasma burlingtonense (White)
- Dielasmella calhounensis Weller
- Cyrtina burlingtonensis Rowley
- Cyrtina neogenes Hall and Clarke
- Delthyris novamexicana (Miller)
- Delthyris similis Weller
- Spirifer pikensis Rowley
- Spirifer latior Swallow
- Spirifer missouriensis Swallow
- Spirifer insculptus Rowley
- Spirifer carinatus Rowley
- Spirifer pellaensis Weller
- Spirifer keokuk Hall
- Spirifer grimesi Hall
- Spirifer mortonanus Miller
- Punctospirifer subtextus (White)
- Punctospirifer solidirostris (White)
- Punctospirifer subellipticus (McChesney)
- Brachythyris burlingtonensis Weller
- Brachythyris fernglenensis (Weller)
- Brachythyris chouteauensis (Weller)
- Brachythyris suborbicularis (Hall)
- Brachythyris semiplicata (Hall)
- Brachythyris peculiaris (Shumard)
- Brachythyris? simulans Girty
- Spiriferella plena (Hall)
- Spiriferella? schucherti (Rowley)
- Acanthospira aciculifera (Rowley)
- Martinia sulcata Weller
- Ambocoelia unionensis Weller
- Ambocoelia levicula Rowley
- Reticularia cooperensis (Swallow)
- Reticularia pseudolineata (Hall)
- Ptychospira sexplicata (White and Whitfield)
- Eumetria altirostris (White)
- Eumetria osagensis (Swallow)
- Eumetria perstrialis Rowley
- Hustedia texana Girty
- Hustedia parvicostata Girty
- Hustedia problematica Girty
- Hustedia subaequalis Girty
- Athyris lamellosa (Léveillé)
- Cleiothyridina glenparkensis Weller

Cleiothyridina prouti (Swallow)
Cleiothyridina obmaxima (McChesney)
Cleiothyridina incrassata (Hall)
Cleiothyridina tenuilineata (Rowley)
Composita pentagonia Weller
Composita opposita (White and Whitfield)
Composita corpulenta (Winchell)
Composita globosa Weller

Gastropoda—
Bembexia aff. B. lativittata Girty
Orthonychia ungula Weller
Pleurotomaria sp.?
Platyceras glenparkense Weller

Pteropoda—
Hyolithes parvulus Girty

Cephalopoda—
Orthoceras sp.

Trilobita—
Proetus roundyi Girty

Ostracoda—
Aurigerites texanus Roundy
Paraparchites sp.
Healdia ampla Roundy
Xestoleberis? subcorbuloides Jones and Kirby

*Correlation.*—Inspection of this list indicates that the Chappel formation is Lower Mississippian in age, ranging perhaps from lower Kinderhook through Burlington. It is certain that the Chappel strata in the different outcrops, particularly in the different sink holes where the formation is the most fossiliferous, are not exactly the same age. The faunas in some of the sink-hole facies differ markedly from each other and from the somewhat dwarfed, less well-developed fauna of the type locality in the central San Saba area. For example, the fauna from the limestone sink at White's Crossing with its robust forms such as *Spirifer grimesi* Hall, *Spirifer carinatus* Rowley, *Brachythyris suborbicularis* (Hall), *Rhipidomella missouriensis* (Swallow), *Schizophoria poststriatula* Weller, *Orthonychia ungula* Weller, and others, indicates strong affinities with lower Burlington. The collections from the sink on the Jack Sloan ranch in San Saba County and from the sink on the Gray ranch in McCulloch County appear to be more closely related to Kinderhook forms. The fauna from the thin section prevalent in most places along the top of the Ellenburger outcrop, on the other hand, is impoverished and the shells are poorly preserved. It is characterized by the trilobite *Proetus roundyi* Girty, which is one of the commonest fossils at many localities. The fauna does not correlate exactly with any of the well-known faunal units of the Mississippi Valley but appears to be more a mixture of several faunas, as if the thin layer was accumulating slowly while a much thicker section of beds was being laid down in Arkansas and Missouri. This relationship, perhaps, may have led Girty to refer to the Chappel as "beds of Boone age," and to regard the Boone as an assemblage of several paleontological zones, as undoubtedly is true. The exact correlation of the Chappel will, therefore, have to await a more detailed study of the fauna. A preliminary correlation with the standard section of Missouri, Illinois, and New Mexico is indicated in the accompanying faunal chart.

### Fossil Localities

The more important fossil localities from which the Chappel fauna has been collected are listed below:

**16–T–5 (HH–45,** Pl. 1).—Blanco County, 2 miles south and one-half mile west of Cypress Mills in the bed of Battle Branch. It is reached by taking the Cypress Mills-Pedernales Falls road south from Cypress Mills, driving a distance of 3 miles to the H. D. Fuchs ranch house, then driving west along a secondary ranch road a distance of 1 mile to a fence line, and then walking south 600 feet to Battle Branch. The locality is along the creek on the east side of the fence.

**27–T–4 (HH–38,** Pl. 1).—Burnet County, 1 mile due south of Marble Falls on east side of Burnet-Johnson City highway. It is reached by driving south on the Johnson City highway a distance of exactly 1 mile from the bridge over Colorado River and stopping at a gate on the east side of the road near the top of the hill. The locality is in the secondary road bed just east of the gate.

**27–T–12 (HH–37,** Pl. 1).—Burnet County, on the south bluff of Colorado River, 0.8 of a mile east of Colorado River bridge at Marble Falls. It is reached by taking the secondary road 0.1 of a mile south of the south end of the Colorado River bridge and driving about 1 mile east to a camp at the Alexander dam site, then walking back along the south side of the river from the old dam a distance of about 500 feet. The locality is near the top of the bluff in shale at the top of the Ellenburger escarpment.

**27–T–18 (II–39,** Pl. 1).—Burnet County, 4 miles south and 2.5 miles east of the Marble Falls bridge at Marble Falls. It is reached by taking the Marble Falls-Johnson City road, traveling 1.25 miles south to the road fork, taking the left-hand road going southeast a distance of 0.8 of a mile to a road fork, continuing south on the right-hand branch a distance of 1 mile to a gate and secondary road, turning east through the

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gate and traveling along a second-class road a distance of 2 miles to Fowler's ranch on main fork of Doublehorn Creek, walking south up Doublehorn Creek 2,100 feet to outcrop in bottom of the creek.

**27–T–22 (H–21,** Pl. 1).—Burnet County, 5 miles southwest of Lampasas, 0.1 of a mile south of Lampasas-Naruna road. It is reached by traveling the Lampasas-Naruna road a distance of 5.5 miles to a gate and secondary road leading to Pillar Bluff Creek and along the secondary road to the creek crossing. The locality is along the bank and in the bed of Pillar Bluff Creek east of the road crossing.

**27–T–24 (H–22,** Pl. 1).—Burnet County, 6 miles west and 2.5 miles south of Lampasas. It is reached by taking the San Saba-Nix road, traveling 3 miles west to a road fork, turning sharply south, and traveling to Espeyville. The fossils are in the Chappel limestone in the bottom of a small branch 0.1 of a mile due south of the old Espeyville church west of the road.

**134–T–12 (D–34,** Pl. 1).—Kimble County, 4.75 miles east and 2 miles south of London on the bank of Salty Creek about 2 miles upstream from Llano River. It is reached by following the road from London to Pfluger ranch headquarters on Saline Creek, taking the ranch road which leads up the west side of a dim road which leads down to Salty Creek. The fossils occur in a pinkish crinoidal limestone on the banks of the creek south of the point where the road ends. Many trilobites occur here.

**153–T–39 (M–14,** Pl. 1).—McCulloch County, 5 miles east and 1.5 miles south of Rochelle. It is reached by taking the Rochelle-Richland Springs and Cavern road about 6.5 miles east. The locality is 1.5 miles east of Arthur Neal's house along the east side of a small northeast-flowing branch about 0.1 of a mile north of the road.

**153–T–63 (G–22,** Pl. 1).—McCulloch County, about 10 miles southwest of Brady, 3.75 miles south and 1 mile west of Davis School. It is reached by taking the road from Davis School to Gray ranch and driving southwest from the ranch house along the ranch road leading to Camp Creek, a distance of 2.25 miles. The locality is on the hillside on the west side of the sink near a sharp curve in Camp Creek.

**153–T–79 (J–18,** Pl. 1).—McCulloch County, 4.5 miles southwest of Brady, 0.5 of a mile south of Brady Creek on Session ranch. It is reached by taking the Brady-Voca road to a pasture gate on the north side of the road 4.5 miles southwest of Brady at a point where the road turns sharply due south, then walking northeast 0.25 of a mile to a branch of Brady Creek and down the branch about 0.25 of a mile to the outcrop of Chappel rocks. The locality is on the west bank of the branch.

**153–T–110 (I–20,** Pl. 1).—McCulloch County, 6 miles south and 2 miles east of Brady on Brady-Mason road. It is reached by driving on Brady-Mason road 6 miles southeast of the courthouse to a gate and windmill on the west side of the road. The locality is at a small clay pit at the side of the road, 0.5 of a mile southeast of the windmill. The best fossils have been collected on the west side of the highway.

**159–T–2 (I–34,** Pl. 1).—Mason County, 10 miles southwest of Mason on the east bank of Llano River at White's Crossing. It is reached by taking the Mason-White's Crossing road to Llano River. The locality is on the north side of the highway about 400 feet north of the concrete slab crossing Llano River.

**159–T–4 (I–33,** Pl. 1).—Mason County, 7.5 miles southwest of Mason courthouse on the east bank of Honey Creek. It is reached by taking the Mason-White's Crossing road to Honey Creek and walking up Honey Creek 3,000 feet. The locality is on the lower ledge of Chappel limestone near the base of the cliff.

**159–T–13 (G–34,** Pl. 1).—Mason County, on White's ranch 5 miles west of White's Crossing and 0.75 of a mile south of Llano River. It is reached by taking the White's Crossing road, turning north on a secondary road 4.9 miles west of White's Crossing, and driving north to the ranch house. The locality is about 1,700 feet north of the ranch on the north bank of Pecan Creek at a point where the creek bends sharply eastward.

**159–T–19 (G–35,** Pl. 1).—Mason County, 3.5 miles southwest of White's Crossing and 1 mile south of windmill. It is reached by taking the Mason-White's Crossing road, turning south on the road to Mill Creek 3.9 miles west of White's Crossing, and driving south 1.25 miles. The locality is on the south side of Mill Creek road in exposures along the road.

**159–T–45 (E–32,** Pl. 1).—Mason County, on north line of the L. B. Eckert ranch, 1 mile east of Mason-Kimble County line and 3 miles south and a little east of Erna. It is reached by taking the Mason-London road through Streeter, turning south at the small village of Erna, located near the Menard-Mason County line, riding south along the secondary road for 3.75 miles to a windmill and water tank, then turning east on the road to L. B. Eckert ranch, a distance of 1 mile, and walking north up a small branch leading to Leon Creek. The locality is along the north fence line of Eckert ranch, 900 feet west of the branch of Leon Creek.

**205–T–21 (X–16,** Pl. 1).—San Saba County, 2.75 miles southeast of San Saba on the east side of the San Saba-Chappel road. It is reached by driving out the San Saba-Chappel road 2.75 miles to a point where the road makes a sharp curve ascending a steep escarpment. The locality is on the east side of the road. This is the type locality from which Roundy and Girty described Chappel fossils for the first time.

**205–T–58 (T–18,** Pl. 1).—San Saba County, 9 miles southwest of San Saba, 1½ miles west of San Saba-Wallace Creek road. It is reached by taking the San Saba-Wallace Creek road to Pebbly Point School, going west over a secondary ranch road, and following this road northwest a distance of 1.5 miles. The locality is on the west side of a prominent hill in the base of the shale slope capped by Marble Falls limestone.

**205–T–77 (Q–16,** Pl. 1).—San Saba County, 7 miles due south, 0.8 of a mile west of Richland Springs, southeast of windmill on Jack Sloan ranch. It is reached by taking the Richland Springs-Maxwell Crossing road south from Richland Springs for 9.5 miles, then turning off abruptly south at a secondary road which is 1.5 miles east of a road corner where there is a prominent windmill known as Hackberry Well, and driving 1.4 miles down the road to the windmill and pen. The locality is on the east side of the pen.

**205–T–123 (Z–17,** Pl. 1).—San Saba County, 4.5 miles west, 1.75 miles north of Bend. It is reached by taking the San Saba-Bend road to Rough Creek Crossing, turning south through a gate 0.1 of a mile east of the crossing, and driving 0.25 of a mile to Pool Branch; then walking west up Pool Branch about 0.2 of a mile to the first small stream entering Pool Branch from the southwest and walking up the southwest branch 1,000 feet to the outcrop. The outcrop is on the bottom of the creek.

**205–T–124 (R–17,** Pl. 1).—San Saba County, 9.25 miles south, 1 mile east of Richland Springs, and 0.6 of a mile south of Maxwell Crossing on San Saba River at King Branch. It is reached by taking the San Saba-Richland Springs road to Harkeyville, turning south at Harkeyville and going to Sloan School on the south side of San Saba River, continuing 2 miles southwest from Sloan School toward Maxwell Crossing to a road fork, and then continuing straight ahead for 0.75 of a mile on a secondary road to King Branch and walking down the branch a distance of about 300 feet to the outcrop. The outcrop is on the north side of the creek at the base of the creek at the base of a steep shale slope.

**205–T–125 (O–12,** Pl. 1).—San Saba County, 2.4 miles southwest of Hall. It is reached by taking the new San Saba-Brady highway, turning off 0.1 of a mile west of the west county line and traveling northeast on the old road a distance of 1.9 miles to a ranch house on the south side of the road, then going south on a secondary road leading south from the ranch house a distance of about 0.25 of a mile to a small branch creek valley. The chert conglomerate is exposed along the sides of the creek valley on the top of the Ellenburger dolomite over a distance of nearly a mile. This locality is the best exposure of the basal conglomerate.

## BARNETT FORMATION

*Historical account.*—The strata now referred to the Barnett formation have been known since the days of the earliest geological work in central Texas. Gabb (1862) named a fossil *Goniatites entogonum*, which was collected from these strata 3 miles southwest of Lampasas. B. F. Shumard (1863), Cummins (1890, pp. 147–148), Tarr (1890-A, p. 202), Hyatt (1893, pp. 467–474), J. P. Smith (1903), Udden, Baker, and Böse (1916, p. 42), R. C. Moore (1919, p. 229), Girty (1919), Girty and Moore (1919, pp. 419–420), and Roundy (1926, pp. 5–23), all contributed to the knowledge of these beds. Moore and Girty were the first to differentiate them from the overlying Marble Falls strata. Girty (1919) showed that these lower shales were Upper Mississippian in age and not Pennsylvanian and confirmed the opinion that they deserved separate formation rank. The lower black and brown shales, however, remained without a name until 1921, when Plummer and Moore (1922, p. 23) designated them Barnett for the excellent exposures just north of Barnett Falls and Barnett Springs in San Saba County. Later Plummer and Scott (1937, p. 15) showed that a persistent limestone about 1 foot thick below the base of the Marble Falls and in the top of the Barnett was also Mississippian in age and, therefore, belonged in the Barnett. Sellards (1933, pp. 92–94) followed the usage of Plummer and Moore and correctly defined the Barnett to include all Mississippian strata between the Chappel formation below and Marble Falls above, and this definition is now generally accepted by all workers in central Texas.

*Extent and thickness.*—The Barnett formation occurs as a narrow band of outcrop between the Marble Falls and Ellenburger along almost the entire area of the Ellenburger outcrop as shown on Plate 1. It is quite thin and entirely absent in places around Brady and absent along most of the Ellenburger border south of Colorado River in the Marble Falls, Spicewood, and northeast Kimble County districts. Elsewhere it is recognized in the field and on aerial maps as a narrow belt of mesquite trees and white brush between an area of post oak and black jack oaks on one side and live oaks, mesquite, and somewhat open grassland on the other. In most places the outcrop of Barnett is only 100 to 150 feet wide, winding, and where not interrupted by faults, very persistent. In many places it is the site of country roads, since the soft shale is much more favorable for road building than the rough, scarp-forming Marble Falls limestone on the one side and the boulder-strewn Ellenburger dolomite on the other. In San Saba County a map of some of the pasture roads is almost a map of the outcrop. In other places the Barnett outcrop is marked by a chain of small cultivated fields which are the only tillable land in large stretches of rough pasture land. These features stand out clearly on aerial and geologic maps of McCulloch, San Saba, and Lampasas counties.

In lithology and thickness the Barnett formation is the most uniform of the stratigraphic units in the region. Across western Lampasas and San Saba counties, except where affected by structure, it has a uniform thickness of 30 to 40 feet. In McCulloch County it is only from 5 to 31 feet thick and in places is absent or obscured by talus from the overlying Marble Falls. In Mason County on Honey Creek valley it reaches a maximum thickness of 90 feet. In subsurface well sections north of the outcrop in Mills and Brown counties it is thought to have a thickness of 50 to 100 feet. Typical sections are illustrated in figure 11 and Plate 6.

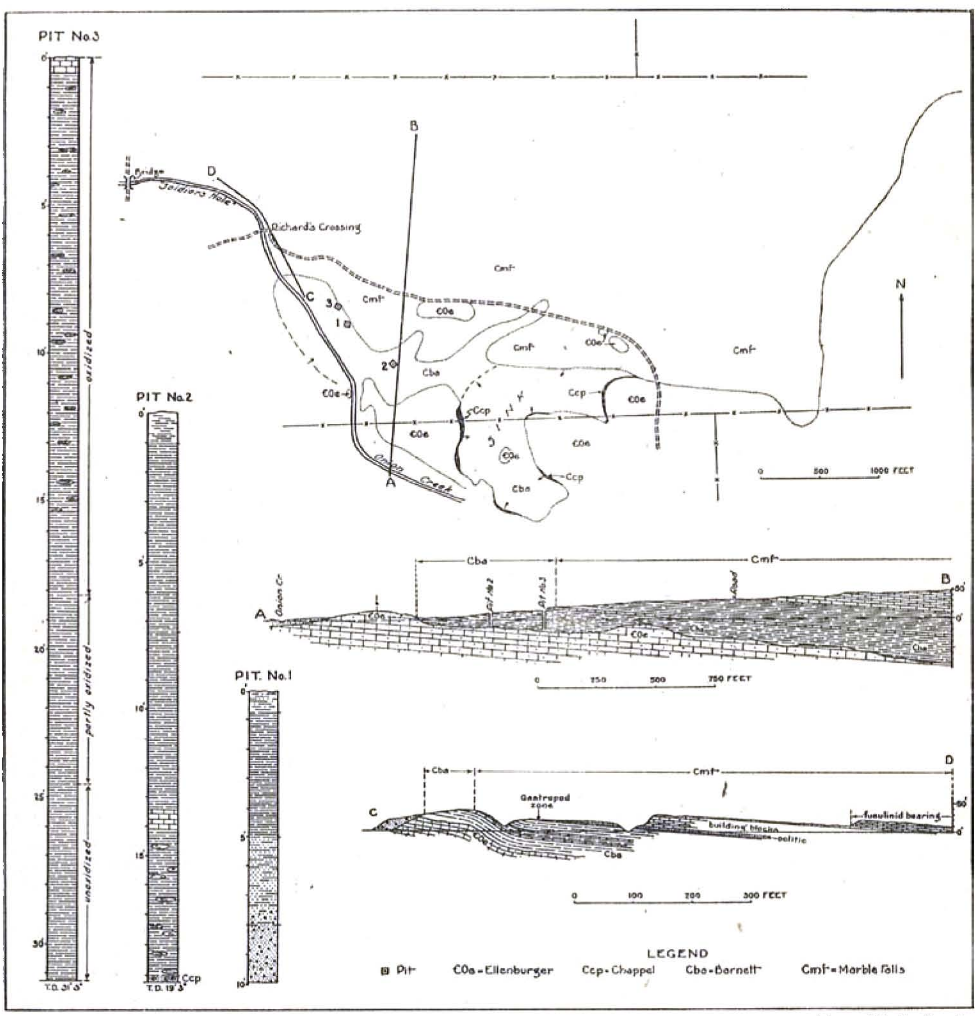


Fig. 11. Outcrop of Barnett shale and Ellenburger limestone in Onion Creek valley, McCulloch County, cross sections showing relationships of the strata, and columnar sections of the Barnett shale penetrated in three pits.

*Lithology*.—Throughout the northern part of the region from central Lampasas County to the eastern border of McCulloch County, the Barnett formation consists of an upper hard, black, subcrystalline, petroliferous, fossiliferous, goniatite-bearing limestone averaging a foot in thickness and a lower dense, black, soft, thin-bedded, petroliferous, fossiliferous shale, weathering brown and containing in most places large, flattened, ellipsoidal, calcareous concretions 8 to 36 inches in diameter. The shale is 30 to 39 feet thick. About 10 to 15 feet from the bottom, a thin, calcareous, highly fossiliferous siltstone occurs. Most of the ellipsoidal concretions are below the siltstone zone in the lower quarter of the shale section. Throughout the western part of the region, in central McCulloch County around Brady and in Mason County west of Mason, crystalline, crinoidal, and in some places oolitic limestone layers come into the section to replace part of the shale, probably the upper portion of the formation. The lower portion of the shale and the *Neoglyphioceras* limestone is absent in many places around Brady, and in other places all the Barnett was removed by erosion before the deposition of the upper Marble Falls so that the Marble Falls rests directly on the Ellenburger, as shown on the map, Plate 1, and in figure 13.

The details of the stratigraphy of this formation and changes in the lithology are best illustrated by the following described sections:

*Section on Doublehorn Creek, 4,000 feet northwest of Doublehorn School, Burnet County* (Loc. 27-T-13; Coord. II-38, Pl. 1).

| | THICKNESS Feet |
|---|---|
| 3. Marble Falls limestone, black, thin bedded, fossiliferous, containing productids, trilobites, compositas, crinoid stems, and other fossils | 30 |
| 2. Barnett shale, brown, soft, petroliferous, containing ellipsoidal concretions | 15 |
| 1. Chappel limestone, light gray, crinoidal | ½ to 1 |

This locality is 250 feet west of the road crossing where the creek makes a sharp curve and crosses the road and halfway up the east-facing bluff.

*Section of Barnett shale 4.4 miles west of Lampasas and 2½ miles east of Espeyville church on east edge of Hallenbeck pasture about 0.6 of a mile east of ranch house, Lampasas County* (Loc. 141-T-11, Coord. HH-20, Pl. 1).

| | THICKNESS Feet |
|---|---|
| 4. Shale, black, hard, somewhat too solidified to form shaly limestone. glauconitic and oolitic | 2½ |
| 3. Shale, black, thinly laminated, fissile, containing large elliptical, firmly cemented, siltstone concretions 1 to 2 feet long and 6 inches to 1 foot thick; fossiliferous, contains many minute pelecypods and goniatites. Goniatites occur commonly in the concretions | 25 |
| 2. Limestone, black, moderately hard, impure, somewhat shaly | 4 |
| 1. Shale, black, hard, petroliferous; contains a few spherical concretions, smaller than those described above, fossiliferous, contains *Neoglyphioceras* | 11 |
| Total thickness | 42½ |

*Section of Barnett shale 2½ miles due east of Bend on Colorado River, San Saba County* (Coord. CC-18, Pl. 1).

| | THICKNESS Feet |
|---|---|
| 2. Limestone, dark bluish gray, fossiliferous, containing *Goniatites* sp. | ½ |
| 1. Shale, black, fissible, well laminated, fairly evenly bedded and petroliferous. Beds range from small fractions of an inch to 1 inch in thickness and contain a few medium-sized, calcareous spheroidal concretions | 9½ |
| Total thickness of the Barnett exposed | 10 |

*Section of Barnett formation along bottom and sides of a west-flowing stream valley, north side of the San Saba-Bend road about 1 mile southeast of the junction of the San Saba-Bend road and San Saba-Lometa road, 100 yards east of tank at the type locality of the Barnett formation, northeast of Barnett Springs, San Saba County* (Loc. 205-T-70; Coord. Y-15, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 10. Limestone, bluish gray, fossiliferous, containing *Goniatites choctawensis* Shumard and other Mississippian fossils | | 8 |

| | THICKNESS Feet | Inches |
|---|---|---|
| 9. Shale, black, marly and clayey, weathering grayish yellow, somewhat ferruginous, evenly and thinly laminated, laminations ¼ to 1 inch apart, lower portion weathering to form thin, slate-like plates | 26 | |
| 8. Limestone or siltstone, grayish white, fossiliferous | --- | 2 |
| 7. Shale, black, weathering brown, petroliferous | 1 | 10 |
| 6. Limestone, grayish white, fossiliferous | --- | 2 |
| 5. Shale, black and brown, strongly petroliferous, containing some brown limonite and some calcite | 2 | 10 |
| 4. Limestone, gray, hard, fossiliferous | ---- | 4 |
| 3. Shale, black, weathering yellowish brown, hard, yielding strong odor of oil when freshly broken and containing large ellipsoidal concretions which range in size from 6 inches in diameter to 3′ x 2′ x 1′ | 1 | 4 |
| 2. Limestone, gray, fossiliferous, hard | ---- | 5 |
| 1. Shale, black, weathering brown, hard, fissile, petroliferous, resting on grayish-white, crinoidal limestone of Chappel age | 6 | 7 |
| Total thickness of the Barnett | 40 | 4 |

The upper 28 feet of the above section are exposed in the valley bottom and along the valley walls; the lower 10 feet were examined by digging a pit 4 feet square and 10 feet deep to the top of the Chappel limestone.

*Section of Barnett formation along San Saba-Chappel road at steep escarpment located about 3 miles southeast of San Saba at old lime kiln, San Saba County* (Loc. 205-T-10; Coord. X-16, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 8. Limestone, dark bluish-gray, almost black, fossiliferous, containing many *Goniatites*, *Leiorhynchus*, and a few other fossils, highly petroliferous | ---- | 10 |
| 7. Shale, brown, weathering yellowish brown, containing considerable calcite and ferruginous material between shale laminae | 8 | ---- |
| 6. Siltstone, grayish brown, slightly fossiliferous | ---- | 6 |
| 5. Shale, brown, weathering yellowish gray, soft, petroliferous | 2 | ---- |
| 4. Siltstone, grayish brown, finely granular, petroliferous | ---- | 5 |
| 3. Shale, brown, weathering yellowish, somewhat variegated, composed of alternating layers of blue, brown, and black shale containing some ferruginous material and gypsum, thinly bedded, fairly evenly laminated, arenaceous, containing some gypsum and some calcite and large spheroidal concretions, which are quite petroliferous when fresh. Concretions occur most commonly in the lower portion of the bed | 24 | -- |
| 2. Limestone or siltstone, brownish gray, fossiliferous, containing *Neoglyphioceras* in large numbers, which are easily recognized by their minute, even lirations and compressed, flattened, disc-like shapes | ---- | 5 |
| 1. Shale, brown weathering yellow brown, petroliferous, glauconitic, containing large numbers of conodonts at base | 2 | -- |
| Total thickness measured | 38 | 2 |

*Section on Leonard ranch, 100 yards east of Baker Spring and about one-fourth mile north of Leonard ranch house, San Saba County* (Coord. S-14, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Marble Falls formation— | | |
| 9. Limestone, dark gray, mottled, subcrystalline | 2 | -- |
| Barnett formation— | | |
| 8. Limestone, bluish black, finely crystalline, fossiliferous, containing *Goniatites*, *Nuculoceras*, and other Upper Mississippian fossils | ---- | 8 |
| 7. Shale, yellowish gray, weathering yellow, soft | 6 | ---- |
| 6. Siltstone, brownish gray, petroliferous | ---- | 2 |
| 5. Shale, yellowish gray, soft | 3 | ---- |
| 4. Siltstone, yellowish brown | -- | 3 |
| 3. Shale, brown, weathering yellowish brown, soft | 3 | ---- |
| 2. Limestone, brownish gray | -- | 3 |
| 1. Shale, brown, weathering rusty yellowish gray, soft, ferruginous, containing small spheroidal concretions | 12 | ---- |
| Total thickness measured | 27 | 4 |

The lower 10 feet were exposed more clearly by digging a pit through the talus and soil to the top of the Chappel limestone.

*Section on west side of Turkey Roost Creek on Sloan ranch about one-half mile south of red gate on west side of ranch road, San Saba County* (Loc. 205-T-74; Coord. R-17, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Marble Falls formation— | | |
| 5. Limestone, black, thin bedded, hard, subcrystalline, chert bearing. The chert consists of dense, black, irregularly shaped chert nodules. The limestone and chert are fossiliferous, containing chonetids, productids, etc. | 2 | .... |
| Barnett formation (38 feet)— | | |
| 4. Limestone, black, hard, petroliferous, oolitic, containing *Goniatites, Caneyella*, etc. | 2 | 6 |
| 3. Shale, brown, weathering yellowish gray, containing large, spheroidal, dense, subcrystalline, petroliferous concretions and one or two thin layers of siltstone | 24 | .... |
| 2. Siltstone, bluish gray, fossiliferous, containing *Neoglyphioceras* | .... | 6 |
| 1. Shale(?), covered by silt, shale, and water of a small stream, containing spheroidal concretions | 11 | .... |
| Total thickness of section | 40 | .... |

*Section on west side of valley, 1,600 feet west of Honey Creek and 2,200 feet northwest of White's Crossing road, Mason County* (Loc. 159-T-3; Coord. I-33, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Marble Falls formation (30 feet)— | | |
| 16. Limestone, dark gray, in places bluish black, massive, siliceous, containing layers and nodules of black chert, many of which contain large numbers of minute fusulinids and small fossils filled with quartz crystals | 10 | .... |
| 15. Shale, soft, dark brown, mostly covered with talus and chert nodules from the overlying limestone | 20 | .... |
| Barnett formation (67 feet, 8 inches)— | | |
| 14. Limestone, dark gray, nearly black, fine grained, nodular, very fossiliferous, containing ammonites, of which *Goniatites choctawensis* Shumard is commonest, and large numbers of brachiopods, mostly spirifers and productids | 1 | .... |
| 13. Shale, dark brown, poorly exposed | 2 | .... |
| 12. Limestone, dark gray or black, hard, dense, finely crystalline, containing large numbers of goniatites, especially *Goniatites choctawensis* Shumard | 1 | .... |
| 11. Limestone, dark brownish gray, made up of thin beds of rough, granular, friable, soft, gray, coarsely crystalline, crinoidal limestone. The crinoid fragments are small and consist of stems and small plate fragments. The thin beds of limestone are interbedded with thin layers of shale | 11 | .... |
| 10. Limestone, dark gray, soft, granular, friable, coarsely crystalline, fossiliferous, containing mostly crinoid fragments | 1 | .... |
| 9. Shale, or soft, weathered limestone, containing thin layers of weathered limestone 1 to 4 inches thick made up of large quantities of small crinoid fragments and containing many specimens of *Leiorhynchus* | 9 | .... |
| 8. Limestone, dark gray, moderately hard, coarsely crystalline, standing out as a more resistant ledge. The rock is made up apparently of a mass of closely cemented, small calcite crystals and grains | | 8 |
| 7. Shale, interbedded with thin bands of soft, granular limestone 1 to 2 inches thick | 7 | 6 |
| 6. Limestone, dark brownish gray, oolitic, having a smooth surface and containing in some places minute fragments of crinoid stems, less than 2 mm. in diameter. In places the rock is almost a coquina of small crinoid detritus | 2 | .... |
| 5. Shale, covered by detritus | 5 | .... |
| 4. Limestone, weathered and altered to a white, calcareous, soft rock. A fresh fragment of this layer indicates that the rock was originally a dense black limestone containing oolites, minute shell fragments, and numerous fossils; among these can be identified *Spirifer, Caneyella*, and *Neoglyphioceras*; the rock weathers to a chalk-like fibrous caliche | 1 | |
| 3. Shale, brown, mostly covered | 6 | .... |
| 2. Limestone, brownish gray, soft, thin bedded, fine grained, | | |

| | THICKNESS Feet | Inches |
|---|---|---|
| silty, having a decided odor of oil when freshly broken, and which weathers into small irregularly shaped chunks and plates a fraction of an inch thick; the surface of some contain impressions of productids, pelecypods, etc. | | 6 |
| 1. Shale, or bleached and weathered. shaly limestone, white or brownish white, soft, earthy, resembling caliche, containing beds of thin, silty limestone 1 to 2 inches thick which have a distinct petroliferous odor. The fine calcium carbonate dissolves rapidly in acid and leaves a thick network of siliceous veinlets and insoluble sandy grains | 20 | |
| Total thickness of section | 97 | 8 |

The above section is located about a thousand feet north of a prominent fault. The strata dip rather steeply at angles of from 15° to 32° toward the south. Some of the layers have slumped badly. and others are poorly exposed, so that it is very difficult to measure the dip accurately and to calculate the exact thickness. The Barnett formation here is thicker and contains relatively less shale and more limestone than at any other locality in the region. The fossils are numerous in many of the limestone layers, especially in the upper crinoidal beds. *Goniatites choctawensis* Shumard and *Leiorhynchus carboniferum* Girty are the commonest species.

*Section of the Barnett formation on east side of Honey Creek, 4,500 feet north of White's Crossing road, Mason County* (Loc. 159-T-4; Coord. I-33. Pl. 1).

| | THICKNESS Feet |
|---|---|
| 5. Shale(?), covered by detritus | 10 |
| 4. Limestone, dark gray, hard, made up of a coquina-like mass of small crinoid stems | 1 |
| 3. Shale, brown, mostly covered by talus, but containing at least one layer about 2 inches thick of finely granulated oolitic limestone | 3 |
| 2. Limestone, dark gray or brownish gray, crystalline, containing many minute crinoidal fragments in the lower part | 2 |
| 1. Shale, brownish gray, silty, containing thin layers of brown, soft siltstone which gives off a strong odor of petroleum when broken. The layers which occur about 5 feet below the top contain fossils, small brachiopods, and small pelecypods, among which *Caneyella* is common; small cephalopods are conspicuous | 21 |
| Total thickness of section | 37 |

*Subdivisions.*—These detailed descriptions show that the Barnett formation can be separated in some places into two members, as follows:

2. Upper member, containing the *Goniatites* fauna and consisting of a black, very fossiliferous, fragmental limestone about 8 inches thick at the top followed below by about 25 feet of nonfossiliferous. brown, carbonaceous, plant-bearing shale.

1. Lower member, containing the *Neoglyphioceras* fauna and consisting of a thin siltstone band 2 to 4 inches thick at the top, characterized by large numbers of neoglyphioceratids and caneyellas followed downward by about 15 feet of black and brown fissile shale containing large spheroidal calcareous concretions (Pl. 7). The black shale and rarely the concretions carry minute caneyellas, other small pelecypods, and rarely large *Orthoceras* shells, in some places 6 inches or more in diameter. Conodonts occur at the base, in some places in large quantities.

Two distinct facies of the Barnett are distinguishable, a shale facies and a limestone facies. The shale facies described above with its two divisions is remarkably persistent and can be identified easily and traced with little difficulty across the northern part of the region from the Cretaceous outcrop in Lampasas County across San Saba County to Onion Creek in eastern McCulloch County. In McCulloch County west of Onion Creek, the Barnett formation thins, appearing to be absent in most places, or represented by only a foot or two of *Leiorhynchus*-bearing limestone at a few localities. The *Neoglyphioceras* fauna has not been found in McCulloch County or anywhere on the west side of the uplift. In Mason County on the west side of the region, particularly in the Honey Creek valley, the Barnett is represented by a section more than 50 feet thick, made up of alternating layers of black shale 1 or 2 feet thick and thin crinoidal and oolitic limestones containing *Goniatites* and *Leiorhynchus* at several different horizons, but no neoglyphioceratids. In most places, however, the lower layers of the Barnett are very poorly exposed and commonly are altered by weathering agencies, so that it is impossible to determine the fossil content. The limestone facies, however, appear to be prevalent from Brady southward into Mason County and westward to Kimble County, although in many places the strata are poorly exposed, thin, or entirely absent. The overlying basal Marble Falls formation in this area, in many places, is shale, obscuring the Barnett outcrop and complicating mapping procedure. In places a thin pebble and nodular conglomerate lies between the remnants of Barnett and Marble Falls, and it is thought that in some places much of the Barnett outcrop was removed by erosion before the Marble Falls strata were deposited. In other places the outcrop of the upper Barnett appears to have overlapped the basal Barnett beds. The Marble Falls strata, too, as will be pointed out later, are probably younger in age in the vicinity of Brady than the basal Marble Falls beds in the Lampasas and San Saba areas, so that longer hiatuses may have occurred in the Brady area than farther east and north between both the Chappel and Barnett and the Barnett and Marble Falls.

*Microscopic characteristics.* — Microscopically the Barnett limestone layers differ markedly from the Chappel below and Marble Falls limestone strata above. The *Goniatites* limestone which marks the top of the Barnett formation is characterized by its texture and fossil content. Under the microscope it is seen to be made up of fossils and oolite grains set in a matrix of grayish and chocolate-colored crystalline limestone. The oolite grains are light gray, almost white, distinctly lighter colored than the matrix. They are generally spherical in shape although many are elongate, being twice or even four times as long as wide. The spherical oolites range from 0.1 to 0.3 mm. in diameter and have tiny dark centers about one-fifth the diameter of the sphere. The elongate oolites range from 0.05 to 0.1 mm. in width and from 0.2 to 0.4 mm. in length and have a narrow dark rod in their center, about the size of a tiny spine or spicule, surrounded by several concentric layers which in most specimens have smooth outer surfaces. One elongate oolite appears to have formed around a tiny spine.

Another oolite is curved and appears to have formed around a curved or broken spine. Most oolites are separated from each other by distances greater than their diameters, so that an area 1.4 mm. square contains not more than 25 oolites. The limestone fossils are largely small ammonoids mixed with a few large ammonoids, tiny pelecypods, and brachiopods. Samples from widely separated localities resemble each other so closely, that even with extended microscopic examination it is difficult or impossible to distinguish one sample from another, but easy to distinguish any sample from hand specimens collected from the oolitic layers in the overlying Marble Falls limestone. The oolitic layers in the Marble Falls have much greater concentration of oolite grains, less limestone matrix, the grains are more nearly spherical and are associated with crinoid fragments and contain no ammonites.

The shale layers in the Barnett are generally more brown in color, less gray or black, and contain more plant material, spores, traces of plant leaves, and other small fragments, than does the Marble Falls shale. Generally, also, the Barnett shale contains more silt and fewer sponge spicules. The silt is calcareous, exceedingly fine, and the large number of laminations per inch exhibited in the shale and polished sections of the siltstone concretions indicate that the Barnett accumulated very slowly.

The *Neoglyphioceras* limestone band contains no oolite but is made up of a mass of thin, flat, rather large shell fragments firmly cemented in a matrix of exceedingly fine calcareous silt and limestone. In many places the flat, thin shell fragments are derived from lirate, thin-shelled ammonoids, so that the rock can be easily distinguished by the fragments of shells marked with parallel ridges. The larger shell fragments bear ridges 0.3 mm. wide. The ridges are of uniform size and are uniformly spaced about 1 mm. apart. The small shells show ridges about a third this size and are spaced about 0.3 mm. apart. In other samples very thin-shelled, impoverished pelecypods may be present, but on the whole the aspect of the rock and fauna indicates water less rich in calcium carbonate and shell-building material than the oolitic layer described above.

*Distinguishing features.* — The noteworthy features of the Barnett not already described are its petroliferous content and large spheroidal concretions. The Barnett formation has long been known for its petroliferous character. This characteristic has been described by Udden, Baker, and Böse (1919, p. 42), R. C. Moore (1919, p. 218), Udden (1919-B, p. 92), and Plummer and Moore (1922, p. 25). In fact, because of its "oil showings," both on the outcrop and in well sections, it has been regarded as a good example of an oil source bed or even as a possible commercial oil shale. Through the coöperation of the Work Projects Administration a project was set up in San Saba County under the supervision of Mr. J. K. Petty (MS., 1939) to sample the shale throughout its outcrop. Pits were dug at favorable localities located 5 to 10 miles apart and fresh samples of the shale obtained at intervals 1 foot apart vertically wherever possible. The outcrop of the shale and locations of the test pits are presented in the map, Plate 22, and detailed sections of the shale are shown on Plate 6. The samples of the shale were tested for their oil content by Bruce F. Grant in the laboratories of the Petroleum Engineering Department of The University of Texas. Altogether about 80 tests were run. The results of the tests are shown graphically in Plate 22. The petroleum content of the shale varies from 6 to 40 gallons per ton. A variation in petroleum content occurs both vertically in the section and laterally along the outcrop. In general, the upper layers, which contained the most carboniferous matter, yield more oil than the lower layers, which contain the most silt. Along the outcrop the richest yields of oil have been found in the eastern and east-central part of San Saba County and the leanest on the western side. It was found that the variation in the petroleum content is due largely to weathering and oxidation rather than to geographic position. The yellow, long-exposed, highly oxidized samples contained very little oil.

The spheroidal concretions (Pl. 7A) in the lower Barnett are of considerable interest and vary considerably in size. In the roadside outcrop about 5 miles south of San Saba, they average about 4½ inches long and 2½ inches thick. In the well-known outcrop along the road winding around the hill to the old lime kiln 3½ miles southeast of San Saba, they attain lengths up to 21 inches long and 12 inches thick. The concretions are brownish gray, symmetrical in shape, rather rough surfaced, and very thinly laminated, having about 11 laminations per centimeter. The laminations are horizontal, nearly parallel, and slightly wavy, and they resemble generally the laminations of the shale in which they lie. Rarely they are fossiliferous. One contains a large *Pseudothoceras* and others, the same fauna found in the associated shale (Pl. 8). It is concluded that these concretions are not algal in origin but are due, like most concretions, to local cementation by calcium carbonate around a central point of local electrical potential set up in the saline colloidal mud at the time the Barnett mud was first deposited. Several of the concretions were sectioned. Most of them are dense, subcrystalline, and, as far as could be determined, do not have a central kernel or fragment of clay or other foreign substance which would tend to produce a point of electrical potential, such as would be expected to explain cementation according to the electrolytic theory. One concretion, however, apparently formed around a large *Pseudorthoceras.*

The Barnett formation can be readily distinguished from the Chappel formation below and the Marble Falls limestone above by the following characteristics:

1. Fauna.—No fossils in other formations resemble even remotely the nearly spherical *Goniatites choctawensis* Shumard, with its prominent transverse furrows and sharply angulated suture line; the strongly lirated, flattened thin-shelled *Neoglyphioceras;* or the tiny, triangular, winged pelecypod shells of *Caneyella.* Some typical species of the Barnett fauna are shown on Plate 8.

2. Petroliferous content.—The calcareous layers and concretions when broken with a hammer have a strong odor of oil. In many places fossil cavities in the upper limestone layer contain free oil. One large goniatite when broken open contained a teaspoonful of light-yellow petroleum. Some of the beds in the Marble Falls are petroliferous, but the odor of oil is never so strong nor so persistent as in the Barnett.

3. Concretions.—The large spheroidal concretions 6 inches to 3 feet in diameter and a few inches to a foot thick are characteristic of the lower portion of the Barnett.

4. Oolites.—The oolitic matrix spread between many small and large fossils is a distinguishing characteristic of the upper Barnett.

*Paleontology.*—The fauna of the Barnett has not yet been studied thoroughly. Girty, Roundy, Heald, Moore, and the author have made extensive collections along the outcrop of the shale and limestone. Plummer and Moore (1922) illustrated some of the significant fossils. Roundy (Roundy, Girty, and Goldman, 1926) described some of the ostracodes and conodonts from a locality 3½ miles southeast of San Saba, and Hyatt (1891. 1893), J. P. Smith (1903), and Plummer and Scott (1937) have described the ammonoids. Girty (1909, 1911, 1915) in his papers on the Caney shale, Batesville sandstone, and Moorefield shale of Arkansas, has also described many species that occur in the Barnett strata so that the assemblage of fossils is now well known. Two distinct faunas are represented in the section as follows:

1. Fauna of the *Neoglyphioceras* zone.—This fauna occurs in the shale, calcareous siltstone. and limestone layers below the upper *Goniatites* ledge, and in most places below the middle of the formation, rarely in some of the lower concretions and in the shale itself. The following fossils have been identified from the shale and thin siltstones of this lower zone:

*Fossils from the Neoglyphioceras zone of the Barnett formation*

Brachiopoda—
- Martinia glabra? (Martin)
- Lingula batesvillae Girty
- Orbiculoidea batesvillensis Weller
- Camarotoechia agrestis Girty
- Moorefieldella eurekensis (Walcott)

Pelecypoda—
- Nuculana vaseyana (McChesney)
- Caneyella wapanuckensis? Girty
- Posidonomya, n. sp.
- Posidonomya vaughani (Girty)
- Deltopecten batesvillensis (Weller)

Gastropoda—
- Bembexia nodimarginata (McChesney)
- Plagioglypta annulostriata (Meek and Worthen)

Ammonoidea—
- Neoglyphioceras caneyanum (Girty)
- Neoglyphioceras newsomi (Smith)
- Lyrogoniatites entogonus (Gabb)

Nautiloidea—
- Actinoceras vaughanianum Girty

Ostracoda—
- Sansabella sulcata Roundy
- Kirkbya lindahli? Ulrich
- Kirkbya lindahli var. arkansana Girty
- Amphissites chappelensis Roundy

2. Fauna of the upper limestone or *Goniatites choctawensis* zone.—This fauna occurs in a black, in most places oolitic, and very fossiliferous limestone at the top of the Barnett formation, and constitutes a very interesting ammonoid assemblage, which has an important bearing on the correlation of the Barnett, since similar forms occur in Oklahoma, Arkansas, England, and Germany. Spherical, involute ammonoids are by far the most common fossils. The following species have been identified from this upper zone:

*Fossils from the Goniatites zone of the Barnett formation*

Brachiopoda—
- Leiorhynchus carboniferum Girty
- Chonetes choteauensis Mather

Pelecypoda—
- Caneyella wapanuckensis? Girty

Ammonoidea—
- Goniatites choctawensis Shumard
- Nuculoceras barnettense Plummer and Scott
- Nuculoceras incisum (Hyatt)
- Cravenoceras richardsonianum (Girty)
- Eumorphoceras bisulcatum Girty

In addition to these two common assemblages which may be collected at most localities along the outcrop, there are a few areas where a limestone facies replaces the shale beds. These areas yield a somewhat more diversified fauna than found in the shale and thin calcareous bands enumerated above. A larger number of brachiopods occur, fewer ammonoids, and thin zones made up of deltopectens, or leiorhynchids, or even trilobites, forms which may be absent or quite rare in the shale. The best known of these limestone facies is a locality 1,600 feet west of Honey Creek and about 7½ miles southwest of Mason in Mason County. Here the following fossils have been identified, although doubtless many more occur.

*Fossils from limestone members of Barnett formation, west side of Honey Creek valley, Mason County*

Brachiopoda—
- Composita sp.
- Dictyoclostus inflatus (McChesney)
- Productus elegans (Norwood and Pratten)
- Leiorhynchus carboniferum Girty
- Camarotoechia laxa Girty

Pelecypoda—
- Deltopecten batesvillensis (Weller)
- Edmondia crassa Girty
- Deltopecten, n. sp.
- Nuculana nasuta? (Hall)
- Nuculana vaseyana (McChesney)

Cephalopoda—
- Goniatites choctawensis Shumard
- Cravenoceras richardsonianum (Girty)
- Orthoceras sp.

Another limestone facies fauna occurs in a few places in cavities or small depressions in the Ellenburger dolomite immediately back of the Chappel and Barnett outcrops. The best of these localities is near the junction of the ranch roads on

| Barnett Fauna | 141-T-1 | 141-T-3 | 141-T-4 | 141-T-5 | 141-T-6 | 141-T-7 | 141-T-11 | 141-T-17 | 153-T-50 | 153-T-63 | 153-T-66 | 153-T-83 | 159-T-1 | 159-T-3 | 159-T-4 | 159-T-49 | 159-T-58 | 159-T-63 | 205-T-4 | 205-T-6 | 205-T-10 | 205-T-24 | 205-T-27 | 205-T-38 | 205-T-49 | 205-T-54 | 205-T-58 | 205-T-70 | 205-T-74 | 205-T-85 | 205-T-98 | 205-T-110 | 205-T-115 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BRACHIOPODA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Lingula batesvillae Girty | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Lingulidiscina batesvillensis (Weller) | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| Lingulidiscina caneyana Girty | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Orthotetes kaskaskiensis (McChesney) | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | |
| Chonetes choctawensis Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| Productus cestriensis Worthen | | | | | | | | | | | | | X | X | | | | X | | | | | | | | | | | | | | | |
| Dictyoclostus coloradoensis (Girty) | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Dictyoclostus inflatus (McChesney) | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Pustula pusilla (Girty) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| Linoproductus ovatus (Hall) | | | | | | | | | | | | | | X | | | X | | | | | | | | | | | | | | | | |
| Productus parvus Meek and Worthen | X | | | | | | | | | | | | | X | | | | X | | | | | | | | | | | | | | | |
| Camarotoechia purduei Girty | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Camarotoechia laxa Girty | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | |
| Leiorhynchus carboniferum Girty | | | | | | X | | | X | | | | X | X | X | X | X | X | | | X | X | | | X | X | X | | | | | | |
| Leiorhynchus polypleurum Girty | X | | | | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | |
| Leiorhynchus greenianum (Ulrich) | | | | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | |
| Camarophoria explanata (McChesney) | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Moorefieldella eurekensis (Walcott) | | | | | | | | | | X | | | | | | | | X | | | | | | | | | | | | | | | |
| Martinia marginalis Girty | | | | | | X | | | | | | | | | | | | X | | | | | | | | | | | | | | | |
| Wellerella osagensis (Swallow) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Girtyella cedarensis Weller | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| Spirifer arkansanus Girty | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spirifer increbescens Hall | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Spirifer moorefieldanus Girty | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Martinia contracta (Meek and Worthen) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| Martinia glabra? (Martin) | X | | | X | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Eumetria marcyi (Shumard) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| Composita sulcata Weller | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| Composita subquadrata (Hall) | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Composita pusilla (Girty) | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Composita aff. humilis (Girty) | | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | |
| PELECYPODA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Deltopecten batesvillensis (Weller) | | | | | | | | | | | | X | X | X | | | | | | | | | | | | | X | | | | | | |
| Deltopecten? caneyanus Girty | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Edmondia crassa Girty | | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | |
| Nucula rectangula McChesney | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| Nuculana nasuta (Hall) | | | | | | | | | | | | X | | | | | | | | | | | | | | | | | | | | | |
| Nuculana vaseyana (McChesney) | | | | | | | | | | | | | X | X | | | | | | | | | X | | | X | | | | | | | |
| Caneyella vaughani Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | | | |
| Caneyella wapanuckensis? Girty | | | | | | | | | | | X | | X | | | | | | | | | X | | | | | | | X | X | | X | |
| GASTROPODA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bembexia nodomarginata (McChesney) | | | | | | | | | | | | | | X | | | X | | | | | | | | | X | | | | | | | |
| CEPHALOPODA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nautiloidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cycloceras bollianum Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Actinoceras vaughanianum Girty | | | | | | | | | | | | | | | | | X | | | | | | | | | | | X | | | | | |
| Cartorizoceras (?) hyattianum Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coelonautilus grotiosus Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Trizonoceras typicale Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Trizonoceras lepidum Girty | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PSEUDORTHOCERATIDAE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| "Orthoceras" aff. crebriliratum Girty | | | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ammonoidea | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Neoglyphioceras caneyanum (Girty) | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | | | | |
| Lyrogoniatites entogonus (Gabb) | | | | X | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Lyrogoniatites newsomi (Smith) | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | | | |
| Nuculoceras barnettense Plummer and Scott | | | | | | | X | | | | | | X | | | | | | | | | X | | | X | | X | | | | X | | X |
| Nuculoceras incisum (Hyatt) | | X | | X | X | | | | | | | | | | | | | | | | | X | | | | | X | | | | | | X |
| Cravenoceras richardsonianum (Girty) | | X | X | | | | | | | | | | X | | | | | | X | | | X | | | | | | | | | | | |
| Adelphoceras meslerianum? Girty | | | | | | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |
| Eumorphoceras bisulcatum Girty | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | X | X | |
| Goniatites choctawensis Shumard | | | | X | X | | | | | | | | | | | | | | | | | X | | | | | | | | | | | |

Chart 2. Distribution of Barnett species at numerous localities in central Texas.

the Gray ranch, McCulloch County. Another locality is in the valley of Honey Creek about 8 miles southwest of Mason in Mason County, where the facies is apparently at or near the top of the Barnett and consists of a coquina of *Leiorhynchus* and *Composita* shells in a matrix of grayish-brown limestone and has been referred to as the *Leiorhynchus* zone. The leiorhynchids in places occur in great numbers and can be broken out fairly easily to yield a large variety of fairly good specimens. Along with the leiorhynchids the following fossils have been identified from the Gray ranch (153–T–63) and Pillar Bluff Creek (27–T–23) localities:

*Fossils from Barnett formation at Pillar Bluff and Gray ranch*

Crinoidea—
- Crinoid stems

Bryozoa—

Brachiopoda—
- Camarotoechia agrestis Girty
- Striatifera pileiformis (McChesney)
- Leiorhynchus carboniferum Girty
- Leiorhynchus polypleurum Girty
- Composita aff. humilis (Girty)
- Composita sulcata Weller
- Spirifer arkansanus Girty
- Spirifer leidyi Norwood and Pratten
- Productus cestriensis Worthen
- Productus parvus Meek and Worthen
- Dielasma shumardanum (Miller)
- Moorefieldella eurekensis (Walcott)
- Martinia glabra? (Martin)
- Lingulidiscina newberryi var. caneyana Girty
- Lingulidiscina batesvillensis (Weller)

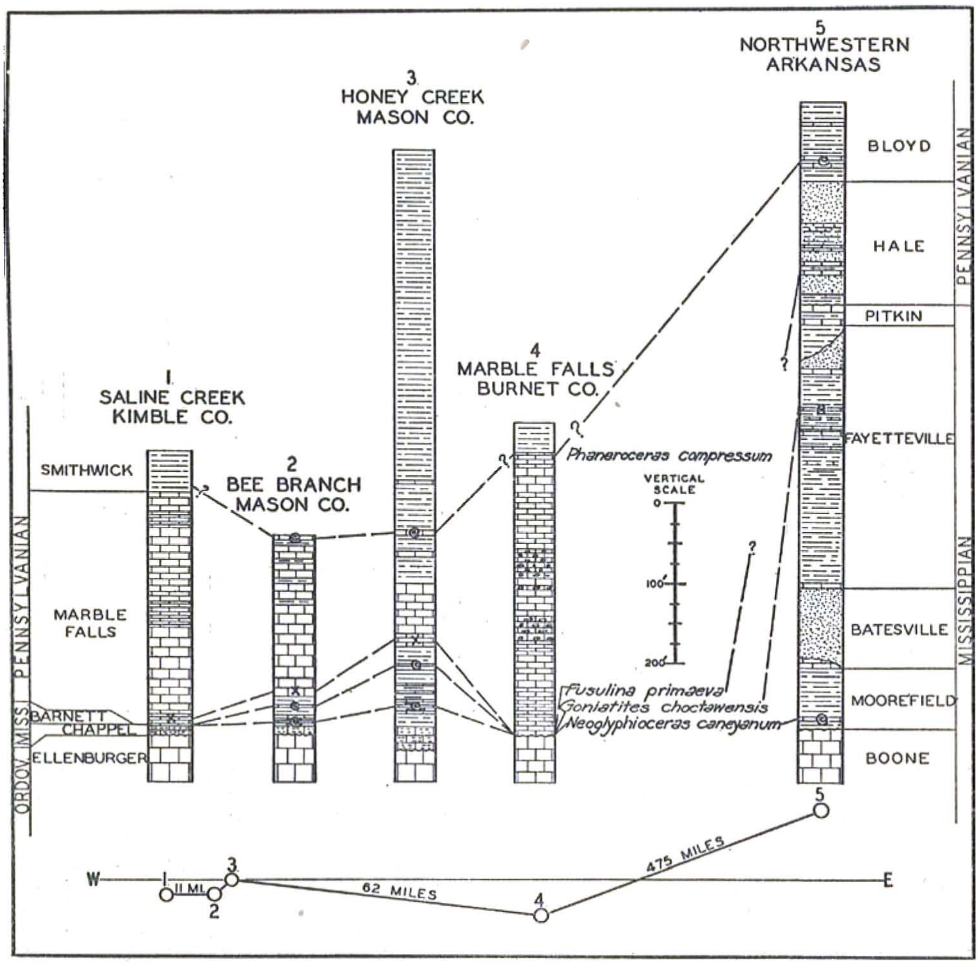


Fig. 12. Columnar sections and correlations of the Texas and Arkansas formations that are Chester equivalents.

Gastropoda—
- Platyceras sp.?

Cephalopoda—
- Orthoceras

Trilobita—
- Paladin mucronatus (Girty)

The most characteristic and common fossils from the Barnett are illustrated in Plate 8. The fauna by localities is presented in chart 2 (p. 41).

*Correlation.*—The fauna of the Barnett shale is essentially the same as that found in the Moorefield shale of Arkansas and the Caney shale of Oklahoma described by Girty (1909, 1911). It has several species found in the White Pine shale of Nevada described by Walcott (1884), and in the Chester series of Illinois, described by McChesney (1859), Weller (1914), and others, and many forms common to the Paradise formation of Arizona described by Hernon (1935). There can be no doubt that the Barnett fauna, occurring as it does in a comparatively thin section of rocks hardly exceeding 40 feet in thickness, represents the time equivalent of the fauna in a much thicker series of rocks in Oklahoma, Arkansas, Illinois, and Arizona. A tentative correlation of the Texas and Arkansas sections is shown in figure 12. A tabulation of the fossils described from these sections and others is given in the accompanying table (p. 44).

Thirty-one species identified from the Barnett in Texas, out of a total of 65 species, or 48 percent, occur in the Moorefield shale of Arkansas. Twelve species, or 18 percent, are known in the Caney shale of Oklahoma; 11 species, or 17 percent, in the Batesville sandstone of Arkansas; and 23 species, or 35 percent, in the Fayetteville shale of Arkansas. The faunas of the Chester group of Illinois, Helms formation of west Texas, and White Pine formation of Nevada are still incompletely known. However, 10 of the 65 species, or 15 percent, from the Barnett occur in a list of species compiled by Weller (1914) and McChesney (1859) from the Chester. The fauna of the Helms formation of Trans-Pecos Texas has not been described. In the collections of the Bureau of Economic Geology the following species have been identified provisionally:

*Fauna of the Helms formation of west Texas*

Brachiopoda—
- Dictyoclostus inflatus (McChesney)
- Productus parvus Meek and Worthen
- Striatifera sp.
- Pustula pusilla (Girty)
- Echinochonchus biseriatus (Hall)
- Productus elegans Norwood and Pratten
- Hustedia sp.
- Leiorhynchus carboniferum Girty
- Martinia sp.
- Chonetes choctawensis Girty
- Camarotoechia laxa Girty
- Orthotetes kaskaskiensis (McChesney)
- Linoproductus ovatus (Hall)
- Composita sp.
- Eumetria acuticosta Weller
- Productella sp.
- Dielasma shumardanum (Miller)
- Spirifer leidyi Norwood and Pratten
- Punctospirifer transversa (McChesney)

Pelecypoda—
- Deltopecten batesvillensis (Weller)
- Allorisma sinuatum McChesney
- Schizodus circulus Worthen
- Caneyella percostata Girty

Trilobita—
- Paladin mucronatus (Girty)

Nine out of 65 species, or 14 percent of the Barnett species, occur in this list from the Helms. On the other hand, 10 species out of the 25 in the Helms, or 40 percent, occur in the Chester lists from Illinois.

These comparisons indicate clearly that the Barnett faunas correlate with the Moorefield of Arkansas and not with the Fayetteville or Pitkin. The Barnett faunas probably also are the time equivalent of the lower part (Okaw and older beds) of the Chester of Illinois and Helms of west Texas. The reason for the larger percentage of forms more common to the Moorefield than to the Chester and Helms is due largely to similarity of facies. The Moorefield and Barnett yield essentially a black-shale fauna; the Helms and much of the Chester that has yielded the described fossils are limestones. A larger number of productids, orthotetids, spirifers, and compositas, therefore, occur in the Chester and Helms; more pectens, leiorhynchids, and ammonoids are found in the Moorefield and Barnett. All four faunas may represent more or less equivalent time space in the Upper Mississippian period. Clearly they all belong in the Chester series. A complete list of the Barnett fauna in the collections of the Bureau of Economic Geology is given in chart 2.

*Fossils from the upper Chester formations of Texas, Oklahoma, Arkansas, and Illinois*

| Barnett Fauna | Helms | Moore-field[a] | Bates-ville[b] | Fayette-ville[c] | Caney[d] | Chester[e] |
|---|---|---|---|---|---|---|
| *Brachipoda* | | | | | | |
| Lingula batesvillae Girty | | x | | x | | |
| Lingulidiscina batesvillensis (Weller) | | | x | | x | |
| Orthotetes kaskaskiensis (McChesney) | x | | | x | | x |
| Chonetes choctawensis Girty | x | | | | x | |
| Dictyoclostus inflatus (McChesney) | x | x | x | x | | x |
| Linoproductus ovatus (Hall) | x | x | x | x | x | x |
| Productus parvus Meek and Worthen | x | | | | | x |
| Pustula pusillus (Girty) | x | x | | | | |
| Productus cestriensis Worthen | x | x | x | x | | x |
| Camarotoechia agrestis Girty | | | | | | |
| Camarotoechia laxa Girty | x | x | | | | |
| Leiorhynchus carboniferum Girty | x | x | | x | | |
| Leiorhynchus polypleurum Girty | | x | | | | |
| Leiorhynchus greenianum (Ulrich) | | | | | | |
| Wellerella osagensis (Swallow) | | | | | | |
| Camarophoria explanata (McChesney) | | | | | | x |
| Moorefieldella eurekensis (Walcott) | | x | | x | | |
| Harttina marginalis Girty | | x | | | | |
| Girtyella cedarensis Weller | | | | | | |
| Spirifer arkansanus Girty | | x | | x | | |
| Spirifer increbescens Hall | | x | x | x | | x |
| Spirifer moorefieldanus Girty | | x | | | | |
| Martinia contracta (Meek and Worthen) | | | | | | x |
| Martinia glabra? (Martin) | | x | | | | |
| Eumetria marcyi (Shumard) | | x | x | x | | |
| Composita sulcata Weller | | | | | | x |
| Composita subquadrata (Hall) | | x | | | | x |
| Composita pusilla (Girty) | | x | | | | |
| Composita aff. humilis (Girty) | | | | | | |
| *Pelecypoda* | | | | | | |
| Deltopecten batesvillensis (Weller) | x | x | x | x | | |
| Deltopecten? caneyanus Girty | | x | | | | |
| Edmondia crassa Girty | | x | x | | | |
| Nucula rectangula McChesney | | x | x | x | | |
| Nuculana nasuta (Hall) | | x | | | | |
| Nuculana vaseyana (McChesney) | | x | | x | | |
| Caneyella vaughani Girty | | x | | x | x | |
| Caneyella wapanuckensis? Girty | | x | | x | x | |
| Caneyella, n. sp. | | | | | | |
| *Gastropoda* | | | | | | |
| Bembexia nodomarginata (McChesney) | | x | | x | | |
| *Cephalopoda* | | | | | | |
| Orthoceras aff. crebriliratum Girty | | | | | x | |
| Actinoceras vaughanianum Girty | | | | | x | |
| Neoglyphioceras caneyanum (Girty) | | x | x | x | x | |
| Goniatites choctawensis Shumard | | x | x | x | x | |
| Girtyoceras meslerianum (Girty) | | x | x | x | x | |
| Nuculoceras barnettense Plummer and Scott | | | | | | |
| Nuculoceras incisum (Hyatt) | | | | | | |
| Cravenoceras richardsoninum (Girty) | | x | | x | x | |
| Pyrogoniatites entogonus (Gabb) | | | | | | |
| Neoglyphioceras newsomi (Smith) | | | | | | |
| Eumorphoceras bisulcatum Girty | | x | | | x | |
| *Trilobita* | | | | | | |
| Paladin mucronatus (Girty) | x | | x | x | | |
| *Ostracoda* | | | | | | |
| Kirkbya lindahli? Ulrich | | | | x | | |
| Kirkbya arkansana Girty | | | | x | | |
| Sansabella sulcata Roundy | | | | | | |
| Amphissites chappelensis Roundy | | | | | | |

| Barnett Fauna | Helms | Moorefield[a] | Batesville[b] | Fayetteville[c] | Caney[d] | Chester[e] |
|---|---|---|---|---|---|---|
| *Conodonta* | | | | | | |
| Prioniodus healdi Roundy | — | — | — | — | — | — |
| Prioniodus peracutus Hinde | — | — | — | — | — | — |
| Gnathodus texanus Roundy | — | — | — | — | — | — |
| Gnathodus bicuspidus Roundy | — | — | — | — | — | — |
| Polygnathus bilineatus Roundy | — | — | — | — | — | — |
| Polygnathus taffi Roundy | — | — | — | — | — | — |
| Polygnathus texanus Roundy | — | — | — | — | — | — |
| Polygnathus? claviger Roundy | — | — | — | — | — | |
| Lonchodus simplex (Pander) | — | — | — | — | — | — |
| Lonchodus? lineatus (Pander) | — | — | — | — | — | — |

[a]Girty, 1911; [b]Girty, 1915; [c]Croneis, 1930; [d]Girty, 1909; [e]Weller 1911; and McChesney, 1859

### Fossil Localities

The more important fossil localities from which the Barnett fauna has been collected are listed below:

**27–T–4 (HH–38,** Pl. 1).—Burnet County, 1 mile due south of Marble Falls on east side of Burnet-Johnson City highway. It is reached by driving south on the Johnson City highway a distance of exactly 1 mile from the bridge over Colorado River and stopping at a gate on the east side of the road near the top of the hill. The locality is in the ditch on the east side of the main road which is north of the pasture gate.

**27–T–13 (II–38,** Pl. 1).—Burnet County, 4 miles southeast of Marble Falls and 0.75 of a mile northwest of Doublehorn School on the Marble Falls-Spicewood road. It is reached by taking the Marble Falls-Spicewood road and driving to the first bridge across Doublehorn Creek. The locality is on the steep slope at the top just above the Ellenburger, 400 feet west of the bridge and 1,000 feet west of Slit Rock Spring.

**27–T–23 (II–20,** Pl. 1).—Burnet County, on Pillar Bluff Creek 4.5 miles southwest of Lampasas. It is reached by taking the Lampasas-Burnet road north 1 mile and turning west on the old Llano road which branches off from the Burnet road just north of the Hancock Park, then traveling 3.75 miles to a gate and pasture road leading to Pillar Bluff Creek. The creek is about ⅛ of a mile south of the gate. The locality is along the east side of a black shale slope about halfway between the gate and the creek.

**141–T–1 (II–20,** Pl. 1).—Lampasas County. 4 miles southwest of Lampasas. It is reached by taking the Lampasas-Nix road and turning due south along a country road 3 miles west of Lampasas, then taking the south fork 1.25 miles southwest and continuing southwest a distance of 0.9 of a mile to a ranch house and windmill, then turning south again and traveling over a dim road a distance of 0.75 of a mile to Espey Creek, and then walking down Espey Creek to the outcrop of the Barnett. The locality is in a steep bank of black shale on the north side of the creek.

**153–T–49 (J–18,** Pl. 1).—McCulloch County, 4.5 miles southeast of Brady, 0.5 of a mile south of Brady Creek on Session ranch. It is reached by taking the Brady-Voca road to a pasture gate on the north side of the road 4.5 miles southwest of Brady at a point where the road turns sharply due south, then walking northeast 0.25 of a mile to a branch of Brady Creek and down the branch about 0.25 of a mile to the outcrop of Chappel rocks. The locality is in soft yellow shale just above the Chappel outcrop and 200 to 300 feet nearer Brady Creek.

**153–T–50 (K–15,** Pl. 1).—McCulloch County, 2 miles east and ⅓ of a mile north of Sweden School. It is reached by taking the old road to Rochelle which follows the Santa Fe railroad a distance of 6 miles, turning sharply south to Sweden School and then going east 1.5 miles, then turning north and going 0.5 of a mile to an iron bridge over Onion Creek and walking 1,000 feet down the creek toward the southeast. The locality is on the east side of the creek.

**153–T–63 (G–22,** Pl. 1).—McCulloch County, about 10 miles south-southwest of Brady, 3.75 miles south and 1 mile west of Davis School. It is reached by taking the road from Davis School to Gray ranch and driving southwest from the ranch house along the ranch road leading to Camp Creek, a distance of 2.25 miles. The locality is on the hillside on the west side of the sink near a sharp curve in Calf Creek.

**153–T–83 (I–19,** Pl. 1).—McCulloch County, 4 miles southeast of Brady and 1 mile east of Brady-Mason highway. It is reached by driving down the Brady-Mason highway 4.75 miles south of the courthouse and turning off on the ranch road leading to L. Brooks ranch, 1.25 miles east of the highway, then walking north along the fence line west of the ranch house a distance of 1,300 feet to an east-west fence, then walking east along the east fence line 1,000 feet and north 300 feet. The locality is in a thin oolitic limestone outcropping along a gentle northwest slope.

**159–T–3 (I–33,** Pl. 1).—Mason County, 8 miles southwest of Mason courthouse, west of Honey Creek. It is reached by taking the Mason-White's Crossing road to Honey Creek, walking up Honey Creek about 800 feet, and then due southwest 1,600 feet along the Ellenburger-Barnett contact, crossing a wire fence. The locality consists of alternating shales and limestones in a steep, prominent slope. This is one of the best fossil localities in the Barnett.

**159–T–13 (G–34,** Pl. 1).—Mason County, on White's ranch, 5 miles west of White's Crossing and 0.75 of a mile south of Llano River. It is reached by taking the White's Crossing road and turning north on a secondary road 4.9 miles west of White's Crossing and driving north to the ranch house. The locality is just above the Chappel limestone in brown shale and dark limestones.

**159–T–45 (E–32,** Pl. 1).—Mason County, on north line of the L. B. Eckert ranch, 1 mile east of Mason-Kimble County line and 3 miles south and a little east of Erna. It is reached by taking the Mason-London road through Streeter and turning south at the small village of Erna, located near the Menard-Mason County line, and riding south along the secondary road for 3.75 miles to a windmill and water tank, then turning east on the road to L. B. Eckert ranch, a distance of 1 mile, and walking north up a small branch leading to Leon Creek. The locality is an inconspicuous shale exposure along the branch near the contact of the Barnett and the Marble Falls.

**205–T–10 (X–16,** Pl. 1).—San Saba County, 2 miles southeast of San Saba courthouse. It is reached by taking the San Saba-Chappel road and traveling a distance of 2.75 miles from the courthouse to a point where the road makes a sharp curve in ascending a steep escarpment. The fossils occur in two horizons in the shale which outcrops around the curve. The upper horizon is in a black, thin limestone near the old lime kiln at the top of the hill. The lower zone is in thin bands of limestone about 2 inches thick in the bottom of the ditch at the sharp curve and at the contact of the Chappel and Barnett in the old road just east of the present highway.

**205–T–38 (W–17,** Pl. 1).—San Saba County, 5.6 miles south of San Saba on the east side of the San Saba-Llano highway. It is reached by taking the Llano highway and traveling 5.6 miles south to a large shale pit on the east side of the road. The locality is in the limestone at the top of the pit and in concretions in the pit.

**205–T–54 (Z–19,** Pl. 1).—San Saba County, 1.5 miles west of Chappel and ⅓ of a mile south of Harrell's Cavern. It is reached by taking the San Saba-Chappel road for a distance of 14 miles to a point where the road turns abruptly eastward. Turn southwest through a gate and travel 0.25 of a mile along the pasture road to a point where the road turns north to a ranch house. The locality is in a west-facing escarpment about ⅛ of a mile from the house.

**205–T–58 (T–17,** Pl. 1).—San Saba County, 9 miles southwest of San Saba, 1.5 miles west of San Saba-Wallace Creek road. It is reached by taking the San Saba-Wallace Creek road to Pebbly Point School, following west over a secondary ranch road, and going northwest a distance of 1.5 miles. The locality is in the shale on the west side of a prominent hill capped by Marble Falls limestone.

**205–T–70 (Y–15,** Pl. 1).—San Saba County, 5 miles east of San Saba courthouse and 0.25 of a mile north of the San Saba-Bend road. It is reached by taking the San Saba-Lometa road and traveling a distance of 3½ miles to a road intersection, turning southeast on the road to Bend and following 1.25 miles, stopping at a point about 0.25 of a mile east of a sharp east bend in the road, then walking due north 1,300 feet along a north-flowing branch. The locality is in the shale and thin layers of limestone along the banks of the creek. This is the type locality of the Barnett northeast of Barnett Springs.

**205–T–74 (R–17,** Pl. 1).—San Saba County, 3.75 miles southwest of Sloan School and 1.5 miles south of San Saba River. It is reached by taking the San Saba-Brady road a distance of 4.5 miles to Harkeyville, then turning southeast on the Harkeyville-Maxwell Crossing road through Sloan community to Maxwell Crossing on San Saba River. The locality is about 1.75 miles due south of Maxwell Crossing on Turkey Roost Creek. It is possible to drive to the locality by taking the Sloan ranch road which turns off from the Maxwell Crossing road 0.25 of a mile east of Maxwell Crossing, going south by King Spring to Turkey Roost Creek a distance of 2 miles, and then walking down the creek to the west end of the Barnett shale outcrop. The fossils are in a limestone at the top of the shale exposure.

**205–T–85 (R–13,** Pl. 1).—San Saba County, 1.75 miles south and 0.75 of a mile east of Richland Springs. It is reached by taking the south road from Richland Springs which runs west of the Richland Springs cemetery, and traveling 1.5 miles to a sharp bend in the road. Then take the K. Taylor ranch road through a gate, travel to the ranch house, a distance of almost 1 mile, and then walk southwest up a small creek, a distance of about 0.25 of a mile. The locality is in the shale slope on the north side of the creek.

## Pennsylvanian System

### MARBLE FALLS GROUP

*Historical account.*—The strata now designated Marble Falls were first recorded by Ferdinand Roemer (1847) who described the strata as "beds of black, hard limestone containing large elliptical masses of black chert which can be definitely designated Carboniferous limestone because of the numerous organic remains." He collected fossils from the beds at a locality in a small branch of San Saba River near an Indian camp, probably King Branch on the Sloan ranch about 9 miles southwest of San Saba. Later in his pioneer work on Texas paleontology (1852), he described four species of these Carboniferous fossils, as follows:

| ROEMER'S NAME | PRESENT DESIGNATION |
|---|---|
| Orthis arachnoidea Phillips | Derbyia crassa Meek and Hayden |
| Terebratula pugnus Sowerby | Wellerella osagensis (Swallow) |
| Productus cora d'Orbigny | Dictyoclostus morrowensis (Mather) |
| Productus flemingii Sowerby | Marginifera roemeri Girty |

Thus, he established definitely his discovery and had the honor of describing the first fossils from the Marble Falls beds.

The Carboniferous strata of Roemer were first named by Hill (1889, p. 289; 1901, pp. 94, 97) who called them "encrinital" or Marble Falls for the well-known exposures at Marble Falls on Colorado River. The second name, Bend Division, used to designate all the black shales and limestones on Colorado River at Bend, is usually ascribed to Cummins (see Hill, 1901, p. 94). Nevertheless, the name was first published by Dumble (1890, p. lxv). Paige (1911, pp. 55–56) restricted the Marble Falls formation to include the section of limestone exposed at Marble Falls on Colorado River at the type locality and designated the black shales in the upper part of the division, Smithwick. Udden, Baker, and Böse (1916) followed Paige's classification except that they included in the Marble Falls and Bend groups a lower brown shale found in San Saba County and in well logs between the typical Marble Falls limestone of Paige and the Ellenburger formation. No other changes were made in the definition of the Marble Falls until 1921 when Plummer and Moore (1922, p. 33), in an account of the Pennsylvanian formations of north-central Texas, restricted the formation so that it would not include the lower brown shale bed, a bed 30 to 40 feet in thickness, carrying an entirely different fauna and found by Girty (1919) to be Upper Mississippian in age. Since the lower shale bed is so poorly exposed at Marble Falls that it was not seen by Hill or Paige or noted in Paige's description (1911, p. 56) of the type section, the description of Plummer and Moore is essentially the same as that of Hill and of Paige. This nomenclature was adopted by Sellards (1933, p. 100) and is well established through 35 years of usage.

Cheney (1940) on the basis of subsurface studies of well sections and lithologic correlation, substituted the term Lampasas for Bend and divided the Marble Falls formation of former authors into two divisions on the basis of an unconformity marked by a conglomerate in the middle of the formation and because of supposed differences in the faunas above and below the unconformity. The upper and largest portion he named Big Saline group and the lower, smallest portion, Marble Falls group. The latter name is a rather unfortunate choice because when one changes so drastically the definition of a formation, the name should be changed also in order to avoid confusion. It seems better, therefore, in this present paper to adhere to the long-accepted usage of Paige, Udden, and Sellards and to retain the name Marble Falls with the rank of a group rather than to change the meaning of a term so well established by usage. The accepted terminology is listed in the accompanying table.*

[*Editor's note. The author published this classification with slight change in wording in the following papers: Lower Pennsylvanian strata of the Llano region—summary of classification: Jour. Paleontology, vol. 21, pp. 142–146, March 1947; and Summary of classification of the Pennsylvanian formations of Texas, with special reference to the Lower Pennsylvanian of the Llano region: Jour. Geol., vol. LV, pp. 193–201, May 1947.]

*Classification of Lower Pennsylvanian formations*

| SERIES | GROUP | FORMATION | MEMBERS EAST OF CAVERN RIDGE | MEMBERS WEST OF CAVERN RIDGE |
|---|---|---|---|---|
| Bend (type section) = Atoka | | Smithwick | Siltstone facies<br>Shale facies | |
| | Marble Falls | Big Saline | Brister Bluff | Soldiers Hole |
| | | | Lemons Bluff | Lemons Bluff |
| | | | Aylor Bluff | Brook |
| | | | Gibbons conglomerate | Gibbons conglomerate |
| Morrow | | Sloan | Undivided | |

*Extent and thickness.*—The Marble Falls group of limestones is one of the most interesting of the series of Carboniferous deposits in Texas because it is the most variable in lithology and paleontology, and the most complicated stratigraphically and structurally, the thickest, and the least well known. It is also the group of beds which contains most of the deep oil in north-central Texas oil fields and furnishes water for the ranches in the San Saba River valley. It consists generally of dark gray and black, siliceous, fossiliferous limestones and black shales. The outcrop of the Marble Falls group is shown on the map, Plate 1. The beds occur in isolated patches on the east side of the region in the valley of Pedernales River, in Cypress Creek, in the Colorado River valley near Marble Falls, along Sulphur Creek near Lampasas, and on the west side of the region in the valley of Llano River and in Brady Creek valley. An extensive belt crosses the northern portion of the area extending from the vicinity of Nix in western Lampasas County to a point 4 miles south of Brady in McCulloch County.

The thickness of the Marble Falls varies markedly in different locations along the outcrop and in its several isolated exposures due to overlap of upper beds on to older Paleozoic rocks with resulting incomplete sections, erosion of upper beds, nondeposition of middle beds, and lenticular thickening of certain layers in certain reef facies. The thickness of measured sections, therefore, varies from 33 feet to more than 400 feet, as shown in the accompanying table. In general the Marble Falls section is thickest in synclinal areas and thinnest over structural ridges and arches. Generally, it is more uniformly thick in subsurface sections north of the Llano area than on the outcrop along its contact with the Mississippian strata and thinner in the western part of the region in McCulloch and Mason counties than in the eastern part in Lampasas and Burnet counties. The thickening is exhibited most by the more massive, crinoidal layers and least by thin-bedded siliceous layers, as indicated by a comparison of the plotted sections shown in Plate 9. The following table shows thicknesses at points where sections have been measured:

*Measured thicknesses of the Marble Falls group*

| | Feet | Inches |
|---|---|---|
| Blanco County— | | |
| Pedernales River and Battle Creek near Pedernales Falls | 404 | |
| Burnet County— | | |
| Colorado River near Marble Falls (type locality) | 341 | 5 |
| Kimble County— | | |
| Mouth of Big Saline Creek | 224 | 5 |
| Llano County— | | |
| South Fork Honey Creek | 366 | 6 |
| Lampasas County— | | |
| Duncan ranch, northwest of Naruna | 123 | — |
| Along Espey and Donalson creeks west of Lampasas | 240 | 2 |
| McCulloch County— | | |
| South end Long Valley, Campbell ranch (incomplete) | 198 | 2 |
| Onion Creek, 7 miles east of Brady | 99 | 6 |
| Shropshire Lake, southeast of Brady (153–T–85) | 33 | 6 |
| San Saba County— | | |
| Cottonwood Creek, east side Cherokee Creek valley, south of Bend | 236 | |
| Ben Lively ranch, Cherokee Creek valley | 281 | |
| Artesian well section, near Bend | 415 | |
| Rough Creek crossing, Bend-San Saba road | 149 | 6 |
| Highway south of San Saba | 148 | |
| Ernest Connor ranch, east side Wallace Creek valley | 220 | |
| Turkey Roost Creek, Sloan ranch | 192 | |
| Lemons Camp | 121 | |
| East side Long Valley, Sorrel ranch | 345 | |

*Lithology and sections.*—The Marble Falls group is made up essentially of dark-gray and black, siliceous, fossiliferous limestone ledges, generally thin bedded, containing some layers of black shale and grading eastward into a shale facies, although the facies change takes place with the exception of the upper beds east of the area of outcrop. This change in facies of the upper beds has caused much confusion among geologists because, when in the shale facies, the beds are persistently mistaken both on the outcrop and in well sections for the Smithwick shale. The lithology of the Marble Falls formation can be best shown by the graphic sections (Pl. 9) and by the following described sections:

*Section of Marble Falls limestone measured along Battle Branch from Chappel outcrop to Pedernales River below Pedernales Falls, Fuchs ranch, Blanco County* (Coord. HH-45, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Cretaceous— | | |
| Travis Peak formation— | | |
| 24. Conglomerate, large, well-rounded cobbles in a matrix of coarse, red sand partially cemented with calcium carbonate | ---- | ---- |
| Pennsylvanian— | | |
| Marble Falls group— | | |
| 23. Limestone, dark gray, massively bedded; layers 1 to 3 feet thick with prominent partings, mostly covered with talus | 21 | 6 |
| 22. Limestone, dark gray, massively bedded, nonfossiliferous; thin chert layers on its upper surface | 6 | 6 |
| 21. Limestone, thin bedded, black, shaly, beds ⅛ to 3 inches thick. In some horizons the rock resembles a tough, black shale more than a limestone. The thicker limestone slabs have a tendency to break into long, rectangular blocks having "fence-post" shapes, resembling some of the layers at the top of the section in the Cherokee Valley | 20 | 6 |
| 20. Limestone, light gray, massive, crystalline, medium grained; weathers to a rough, etched, and very serrate surface like the massive beds below. Its upper surface forms the trail leading from Fuchs camp grounds to the swimming hole below the falls | 18 | 6 |
| 19. Upper chert bed, limestone, black, or very dark gray, hard, and forming a cliff; made up of more than 50 percent chert in thin layers separated by thin layers of limestone ¼ to 2 inches thick; weathers to a very rough, pitted surface | 12 | - |
| 18. Limestone, massive, light gray, almost white, weathering to rough, serrate surfaces; forming the prominent and picturesque cliffs north of Pedernales Falls | 33 | -- |
| 17. Limestone, gray, massive, dolomitic, slightly oolitic; contains the interesting natural tunnel excavated by water action above the falls | 10 | -- |
| 16. Limestone, gray, containing thin layers of chert arranged in beds about 8 inches thick, separated by layers of limestone | 6 | 6 |
| 15. Limestone, gray, massive, nonfossiliferous, forming cliff on east side of first valley above the falls | 22 | 6 |
| 14. Limestone, dark gray, massive, containing chert in thin layers separated by thin layers of limestone | 5 | ---- |
| 13. Limestone, gray, massive. The beds are 1 to 5 feet thick, stand up as a steep cliff on the north side of the river, and dip downstream toward the east at an angle of 11°. | 55 | ---- |
| 12. Limestone, light gray, massive, hard, forming steep cliff, fairly evenly bedded. The beds are 2 to 5 feet thick, form prominent strike ledges across the river bed, and contain a few large crinoid stems and a zone of medium-sized corals, *Amplexocarinia? corrugata* (Mather), which occurs 35 to 40 feet above the base of bed 18. These constitute the coral zone in the section | 34 | ---- |
| 11. Limestone, light gray, crystalline, massively bedded, containing layers or lentils of dark gray rock and characterized by beds of beautiful oolitic rock. In fact, the whole layer is more or less oolitic, dissolving and weathering more easily than ledges above and below so that the cliff in places is undercut at this horizon, and at one point an interesting grotto has been developed. In places the layer is dolomitic | 10 | ---- |
| 10. Limestone, light gray, crystalline, containing numerous crinoid fragments and somewhat thinner bedded than the layers above. The beds are 6 to 24 inches thick and somewhat oolitic | 10 | ---- |
| 9. Limestone, dark gray; some layers are dense black, thin bedded, and shaly. Most beds are 1 to 6 inches thick. One series of beds about 8 feet below the top, which is about 4 feet thick, is a good building stone, having beds 8 to 14 inches thick with smooth, parallel surfaces. Other horizons are made up of thin, sandy, calcareous, and carbonaceous layers containing plant remains. Other layers are interbedded with thin sheets ¼ inch thick of a siliceous chert-like material made up largely of sponge spicules. Another bed about 4 feet thick which occurs 14 feet below the top contains sponge or algal nodules and has a mottled surface | 26 | |

| | THICKNESS Feet | Inches |
|---|---|---|
| 8. Limestone, conglomerate, made up of round and subangular nodules of limestone resembling cobbles, crinoid fragments, and *Bellerophon* shells. The coarse material is set in a matrix of calcareous sand and large oolite grains consolidated to form a hard ledge. This noteworthy layer constitutes the *Bellerophon* zone | -- | 8 |
| 7. Limestone, dark gray, almost black, siliceous, carbonaceous, petroliferous, thin bedded, shaly. The beds are 2 to 6 inches thick and have smooth, parallel surfaces and produce excellent flagstones. One thin seam 1½ inches thick on a slab 3 feet above the base, is made up of large numbers of linoproductids cemented into a solid mass and constituting a noteworthy productid zone. The whole weathers to form a brick-red, light, siliceous rock, commonly referred to as "cotton rock" and resembling closely the Lemons Bluff beds of the Lampasas section | 8 | 4 |
| 6. Limestone, dark gray, almost black, very petroliferous, thin bedded. The layers are about ½ inch thick and grade laterally into more massive ledges, especially on cliff faces where the bedding planes are obscure | 10 | 6 |
| 5. Limestone, dark gray, weathering to a blue gray, and having rough, serrate surfaces | 12 | 7 |
| 4. Limestone, black, fine grained, thin bedded; breaks and weathers into flagstones 3 to 4 inches thick which have smooth surfaces | 3 | 6 |
| 3. Limestone, dark gray, crystalline, containing thin chert partings; the chert constitutes less than 50 percent of the rock. It is resistant enough to produce a low ridge. It is also fossiliferous; one layer about 14 inches thick is made up almost entirely of crinoids. Weathers to produce good flagstones | 15 | 6 |
| 2. Limestone, dark gray, almost black, finely crystalline; weathers to roughly etched and wavy surfaces having a blue-gray color. Evenly bedded; the layers are 12 to 15 inches thick. Fossiliferous, containing a few very large crinoid stems, a few corals, many echinoid spines, and sponge spicules | 40 | |
| 1. Limestone, black, shaly, very thin bedded. The beds are only a fraction of an inch thick and weather into thin wedge-shaped chips resembling hard black shale. It is somewhat petroliferous at its base and resembles a little the Barnett shale but contains no Barnett fossils. For the most part it is unfossiliferous. The upper ledges, however, yield the following fossils: large spirifers, a globose productid, *Composita*, many ostracodes, many minute spicules and spines, and minute crinoid stems which have a star-shaped cross section. The layers also contain a small percent of dense, black chert nodules which weather out on long exposed and little eroded surfaces to form small, kitchen-midden-like piles of chert detritus. The upper layers are somewhat thicker bedded, harder, and weather to black, slate-like flags which in some places have mottled surfaces. The lower bed lies unconformably upon crinoidal Chappel limestone | 28 | -- |
| Total thickness measured | 410 | 1 |

*Section of Marble Falls strata, measured from Alexander dam site to Marble Falls dam at Marble Falls along north side of Colorado River* (Coord. HH–37, Pl. 1; fig. 13).

| | Feet | Inches |
|---|---|---|
| 19. Limestone, dark gray, finely crystalline, uniformly grained; mottled with comparatively few algal markings, and forming upper falls at Marble Falls and top of cliff at mill site | 20 | - |
| 18. Limestone, black, fine grained; contains much black chert and forms face of prominent cliff at Marble Falls | 11 | 3 |
| 17. Limestone, black, fine grained, shaly, thin bedded, nodular beds separated by wavy partings containing fossils: *Linoproductus, Bellerophon, Cancrinella(?)*, and many large corals, *Amplexocarinia?*. Coral zone is about 3 feet above base | 10 | |
| 16. Limestone, bluish black, hard, fine grained (measured at old wagon road) | 2 | 3 |
| 15. Limestone, dark gray and black, finely crystalline, varying from thin bedded to massively bedded. One massive layer 7 feet thick forms a steep cliff near the top of the bed. The upper surface of this bed is rough and nodular as if produced by sponge or chert nodules. Another massive ledge 3 feet thick at the base | 36 | -- |
| 14. Limestone, black, thin bedded, shaly, having irregular, wavy bedding planes and made up of beds 2 to 4 inches thick | 4 | -- |

| | | THICKNESS | |
|---|---|---|---|
| | | *Feet* | *Inches* |
| 13. | Limestone, dark gray, weathering to a bluish-gray color. Finely and uniformly crystalline, fairly evenly bedded. The beds are 2 to 4 inches thick and form a cliff along the Colorado River bluff. The limestone is for the most part nonfossiliferous. Some layers contain small amounts of chert, show algal and sponge markings, and a few large, long crinoid stems. The surfaces of the ledges are marked by minute white blotches and weather to very rough, etched surface having minute sharp, serrate ridges separated by cusps and valley-like depressions. Surface appearance resembles the well-known ledges at Pedernales Falls | 34 | 6 |
| 12. | "Upper Chert bed." Limestone, gray, fine grained, indistinctly bedded, cherty, contains more than 50 percent chert. Hard, forms distinct cliff along the bluff and a cascade in Colorado River. Surface of the limestone nodular, marked with chert nodules derived probably from sponge masses. The chert is brownish-black, foraminiferal, and its surface is pitted with minute fossil cavities. In many cases it weathers to a tripoli-like cotton rock | 7 | 2 |
| 11. | "Blue Limestone bed." Limestone, light gray, weathering blue gray, and marked by minute white blotches. Hard, noncherty, uniformly finely crystalline, mostly nonfossiliferous, fairly thick bedded. Breaks in large rectangular blocks and weathers on exposed surfaces to very roughly etched and serrately ridged surface; breaks with conchoidal fracture resembling in this respect Ellenburger limestone | 10 | 5 |
| 10. | "Algal bed." Limestone, black or dark chocolate, very fine grained. Breaks into small black chips, chert bearing. The chert is in the form of nodules and irregular-shaped, thin lentils. The chert is dense, black, and very sparingly fossiliferous, broken by many joints and cracks, but some layers will make building blocks. Contains corals (probably *Zaphrentis*), *Bellerophon*, *Marginifera*, echinoid spines, and Bryozoa. The most characteristic feature is the dark chocolate-colored blotches set in a light gray background and giving to the surface of the rock a distinctly mottled appearance. These dark blotches are interpreted as algal markings. The algal markings extend through most of the ledge, 12 to 14 feet thick. The ledge breaks into more or less smooth-surfaced blocks which will make a good building stone and take a good polish, bringing out the characteristic mottled markings | 22 | 4 |
| 9. | Limestone, gray, massive, finely crystalline, containing thin stringers of chert, a fraction of an inch to 2½ inches thick. Amount of chert increases upward. No fossils | 8 | 6 |
| 8. | Limestone, gray, massive, fine grained, uniform. Mostly noncherty, occurring in layers 2 to 4 inches thick | 4 | ---- |
| 7. | Pebble conglomerate, made up of angular and little-rounded pebbles of limestone ¾ of an inch in size (maximum) in a matrix of sand made up of limestone grains and large quantities of small crinoid fragments | 1 | 6 |
| 6. | Nodular chert bed. Limestone, dark gray or black, fine grained, massive; contains stringers and nodules of chert which constitute more than 50 percent of the ledge. Weathers to a rough, nodular surface. Lower layers contain oolite | 28 | |
| 5. | Sand, yellowish gray, consolidated, made up of coarse grains of limestone, small crinoid fragments, and small limestone pebbles ¼ of an inch in size. The layer is porous and water bearing. Springs issue from this horizon | 1 | -- |
| 4. | Limestone, gray, coarsely crystalline, massively bedded, nonfossiliferous, and containing no chert except a few indistinct sponge nodules containing sponge spicules appearing on the surface of a ledge 2 feet below the top of the bed. The bed is distinctly lighter in color than the layers above and below, so that it stands out as a light gray band along the crest of a small anticline showing in the bluff on the south side of the river | ---- | 5 |
| 3. | Limestone, black or very dark gray, subcrystalline, containing elongate and irregular-shaped darker masses interpreted as originating from sponge masses, but possibly of algal origin. The black masses are generally circular in cross section. They are 1½ inches in diameter, 8 to 10 inches long, and cylindrical or elbow-shaped. Other masses have quite irregular shapes. Many are distinctly cherty and cut with many fine calcite veinlets. The bed contains a few fossils; namely, small and large crinoid stems, sponge masses, and a small linoproductid. The beds grade upward into slightly lighter gray, less cherty limestone; and the sponge masses are slightly smaller toward the top | 10 | ---- |

| | THICKNESS Feet | Inches |
|---|---|---|
| 2. Limestone, dark gray or black, fine grained, thin bedded. Beds in layers 3 to 6 inches thick. Fossiliferous containing in its upper portion *Ethelocrinus texasensis* Moore and Plummer, crinoid stems (large, smooth, and deeply corrugated), Bryozoa, small *Punctospirifer*, a few small corals of *Michelinia* type, numerous corals belonging to the genus *Zaphrentis, Linoproductus,* and other brachiopods. The bed also contains layers and lentils of chert which contain many minute fossils, crinoid fragments, brachiopods, and Foraminifera. The upper thin layers have shale partings which contain crinoid stems and Foraminifera. The shaly layers weather more easily than the massive beds above, so that the massive ledge along the cliff side is undercut, and in places a shelter or grotto is produced | 42 | - |
| 1. Limestone, dark gray, massive, fine grained, cliff forming, reef-like rock. The layer contains few thin cherty layers in the middle portion, but most of the rest of the thick, cliff-forming ledge is nonbedded. Contains large and small crinoid stems, few if any other fossils, and but little chert. The rock is distinctly petroliferous, especially near its base, and when broken gives distinct odor of oil. The ledge contains in its upper portion a lentil of thin, cherty beds that may possibly be the same beds described in layer No. 2, but are apparently separated from No. 2 by more massive beds. The ledge is cut by a nearly vertical fault at its west end. West of the fault there is a distinct unconformity between this massive ledge and the overlying thin limestone beds of layer No. 2 | 83 | 6 |
| Total thickness measured | 336 | 10 |

*Subdivisions.*—The Marble Falls group may be divided into two formations and several lentils as follows:

- Big Saline formation—
  - West area—
    - Soldiers Hole lentil
    - Lemons Bluff member
    - Brook lentil
    - Gibbons conglomerate
  - East area—
    - Brister Bluff lentil
    - Lemons Bluff member
    - Aylor Bluff member
    - Gibbons conglomerate
- Sloan formation

The west and east areas are separated by Cavern Ridge, an elevation of Ellenburger rocks extending north and south along the west edge of San Saba County (Pl. 1). With the exception of the Lemons Bluff member the lentils on the west side of the ridge do not have the same fauna as those on the east and are not exactly equivalent in age. Stratigraphic relationships are shown in the cross section, Plate 9.

### SLOAN FORMATION

*Name and extent.*—The Sloan formation of the Marble Falls group is best exposed along San Saba River and its branches on the Sloan, Lemons, and Gibbons ranches, southwest of San Saba and along Colorado River above Alexander dam site at Marble Falls in Burnet County. The dark, thin-bedded strata between the Barnett shale and the massive, coarsely crystalline *Chaetetes*-bearing Aylor Bluff limestone are exposed most typically along the bluff opposite Lemons Camp on San Saba River. They are exposed also along the north side of King Branch on Sloan ranch and along the upper portion of Turkey Roost Creek on Sloan ranch.

Sloan strata have been found also at the base of the Marble Falls section on Colorado River below Marble Falls along the Marble Falls-Barnett contact from Cherokee Creek west across San Saba County to the Llano-San Saba highway in the Wallace Creek valley, 13 miles by road southwest of San Saba (Pl. 13B), and at a few places along the contact of the Marble Falls and Barnett on the Sloan and Gibbons ranches in western San Saba County. The formation is present in most synclinal areas east of the San Saba-McCulloch County line and absent on the structural highs where it was removed by erosion before the deposition of the Big Saline formation. It has not yet been discovered west of Cavern Ridge on the west San Saba County line and is thought to be absent on the Brady uplift in McCulloch County and along the granite ridge in Mason County (map, Pl. 1). It has not been identified east of Cherokee Creek, in Colorado River exposures south of Bend, or in Lampasas County. It is possible, however, that the usual oolitic bed south of Bend may be Sloan in age.

The accompanying section measured at the type locality on San Saba River, opposite Lemons Camp, is typical:

*Section of the Sloan formation on San Saba River opposite Lemons Camp, San Saba County* (Coord. R-17, Pl. 1; fig. 13).

| | THICKNESS Feet | Inches |
|---|---|---|
| 4. Limestone, dark gray, thin bedded, subcrystalline, granules look like redeposited dolomite grains, not very fossiliferous except near base; contains thin lentils of chert and a few sponge-like nodules; may represent the mottled beds of other sections. Lower layers contain plant leaves and stems; other layers contain small chonetids | 38 | ---- |
| 3. Limestone, black, subcrystalline, having smooth surfaces; weathers to rounded, smooth boulders and pebbles. The limestone layers are interbedded with thin, black shale. Both the shale and limestone layers are fossiliferous, containing large numbers of *Marginifera roemeri* Girty, productids, chonetids, etc. | 28 | ---- |
| 2. Limestone, black, hard, crystalline, containing more than 25 percent black chert, which occurs in large nodules, fossiliferous, contains corals, productids, etc. | 14 | ---- |
| 1. Limestone, dark gray, glauconitic, conglomeratic, contains phosphate nodules, small chert pebbles, water-worn fossils | 1 | 6 |
| Total thickness measured | 81 | 6 |

*Description.*—The Sloan formation is distinctly thin bedded. The beds are uneven, have rough surfaces, and contain distinctive fossils. The basal bed in most places is a subcrystalline to crystalline, dense black, cherty limestone 4 to 16 feet thick which, in most places, has more than 40 percent black chert. This chert member is overlain by 50 to 100 feet of thin-bedded, black, subcrystalline, fossiliferous limestone. The lower layers in most places are fossiliferous. They contain *Ethelocrinus texasensis* Moore and Plummer, *Marginifera roemeri* Girty, *Wellerella osagensis* (Swallow), *Derbyia crassa* Meek and Hayden, *Dictyoclostus morrowensis* (Mather), *Linoproductus nodosus* (Newberry), *Paeckelmannia*, and many others. The fossils are less common in the upper layers, and one horizon near the top is yellowish gray in color, lighter in density, and contains many impressions of plant stems and leaves of a reed-like plant. In certain places, particularly along the bluffs of Turkey Roost Creek on the Sloan ranch and in a small branch of Wallace Creek 13 miles southwest of San Saba, shale partings 2 to 30 inches thick occur between the limestone layers (Pl. 13B). In most places these shales are fossiliferous and some of the best fossils from the Sloan formation come from these inter-limestone shale zones.

*Paleontology.*—The following fossils have been collected from the Sloan formation, and a few of the typical species are shown on Plate 11. The corals have been identified by R. C. Moore and R. M. Jeffords (1945); the gastropods by J. Brookes Knight; and the other species, by the author.

*Fossils collected from the Sloan formation*

Anthozoa—
- Stereocorypha annectans Moore and Jeffords
- Lophophyllidium adapertum Moore and Jeffords
- Barytichisma crassum Moore and Jeffords
- Barytichisma callosum Moore and Jeffords
- Barytichisma repletum Moore and Jeffords
- Cladochonus fragilis Mather
- Amplexocarinia corrugata (Mather)

Crinoidea—
- Ethelocrinus texasensis Moore and Plummer
- Cibolocrinus punctatus Moore and Plummer
- Diphuicrinus croneisi Moore and Plummer

Brachiopoda—
- Chonetes choteauensis? Mather
- Juresania wilberana (McChesney)
- Paeckelmannia sp.
- Horridonia globosa (Mather)
- Marginifera roemeri Girty
- Linoproductus nodusus (Newberry)
- Dictyoclostus morrowensis (Mather)
- Rhynchopora illinoisensis (Worthen)
- Rhynchopora magnicosta Mather
- Spirifer opimus Hall
- Punctospirifer campestris (White)
- Punctospirifer transversus (McChesney)
- Composita ozarkana Mather
- Composita deflecta Mather
- Composita elongata Dunbar and Condra

Cleiothyridina orbicularis (McChesney)
Squamularia? perplexa (McChesney)
Hustedia miseri Mather

Pelecypoda—
Edmondia, n. sp.
Myalina wyomingensis (Lea)
Myalina congeneris Walcott
Leda sp.
Parallelodon obsoletus (Meek)
Posidonia sp.
Pterinopectinella, n. sp.
Aviculopecten halensis Mather
Lithophaga sp.
Pleurophorus occidentalis Meek and Hayden
Allorisma reflexum Meek

Gastropoda—
Worthenia tabulata (Conrad)
Trepospira sp. indet.
Colpites cf. C. minutus (Sayre)
Naticopsis aff. N. subovata Worthen
Orthonychia, n. sp.
Meekospira peracuta (Meek and Worthen)
Pharkidonotus, n. sp.

Ammonoidea—
Phaneroceras nolinense (Cox)

*Correlation*.—It is rather difficult to correlate the Sloan fossil assemblage with the fauna of other districts because most of the older Pennsylvanian species of Oklahoma, Arkansas, and Illinois have been identified by paleontologists 20 years or more ago before modern splitting of genera and species into narrow limits of differentiation was undertaken. However, it has been possible to compare our species of brachiopods with the collections in the Walker Museum, and Moore and Plummer (1940) and Moore and Jeffords (1945) have assembled, studied, and redescribed all the crinoids and corals of the Morrow of Oklahoma and Arkansas and the Marble Falls of Texas. The accompanying table (p. 55) is a list of the Texas fauna with similar or very closely related forms identified from Oklahoma and Arkansas.

All the coral identifications are by Moore and Jeffords (1945) and the gastropods by J. Brookes Knight. The list is a preliminary one. Many more forms that have not yet been identified occur both in Texas and the other states. It will be noted, however, from this table that out of 26 species of brachiopods, corals, and crinoids, 8 of the fossils, apparently mostly the long range forms, occur in the Hale formation of Arkansas, 15 in the Morrow of Oklahoma, and 5 in the upper Pottsville of Kentucky. None except the long range forms like *Hustedia miseri* Mather, *Composita ozarkana* Mather, and others occur in formations younger than the Morrow. It is concluded, therefore, that the Sloan formation of the Marble Falls may be correlated with the upper Morrow and upper Pottsville formations.

### Fossil Localities[5]

**27–T–5 (HH–37,** Pl. 1).—Burnet County, 0.4 of a mile south and 0.7 of a mile east of Marble Falls on the north bluff of Colorado River 0.7 of a mile east of the bridge. It is reached by taking the Johnson City road south from Marble Falls to the bridge across Colorado River a distance of 0.4 of a mile, then walking down the north side of the river along the Marble Falls bluff. The locality occurs in the limestone strata, particularly in the shale partings about 0.75 of a mile below the bridge. The best collection has come from a grotto in the cliff side where the strata are oolitic and easily broken. The specimens are numerous but rather poorly preserved. *Marginifera roemeri* Girty and *Ethelocrinus texasensis* Moore and Plummer have been collected here.

**205–T–4 (W–16,** Pl. 1).—San Saba County, 3.5 miles due south and 1 mile west of San Saba courthouse on the San Saba-Llano highway near the contact of the Marble Falls-Barnett strata. It is reached by taking the San Saba-Llano road and driving about 4 miles south of Llano almost to the second crossing of Simpson Creek. The locality is 0.1 of a mile north of the bridge near the fault which can plainly be seen from the bank on the east side of the highway.

**205–T–43 (T–18,** Pl. 1).—San Saba County, 9 miles due south, 1 mile due east of Algerita and 10 miles southwest of San Saba. It is reached by taking the San Saba-Brady road 2.5 miles west of San Saba courthouse, turning southwest on the San Saba-Wallace Creek road and driving about 10 miles south to the Marble Falls-Ellenburger contact. Near this point a dim road leads off to the west to an old water tank about 0.1 of a mile from the road. From the water tank walk down the creek about 300 feet to a steep bluff on the east side of the creek. Fossils occur along the bluff. Most of the best specimens have come from shale partings in the limestone about 10 feet above the base. Most of the fossils have been collected from this shale, but many more can be obtained by digging out the shale, spreading it on the ground, and carefully examining it for the good specimens.

**205–T–65 (R–16,** Pl. 1).—San Saba County, 0.5 of a mile south and 0.2 of a mile west of Maxwell Crossing. It is reached by taking the San Saba-Brady road to Harkeyville, turning southwest at Harkeyville on the road to Sloan community, traveling 1.4 miles to a road running

[5]The large ranches in San Saba County are privately owned. Before entering these ranches, it is best to see the owners and get permission and directions for passing through the ranch.

*Regional occurrence of Sloan fossils*

| Sloan Fauna | Sloan, Texas | Morrow, Oklahoma | Arkansas: Hale | Arkansas: Brentwood | Arkansas: Kessler | Upper Pottsville, Kentucky |
|---|---|---|---|---|---|---|
| *Foraminifera* | | | | | | |
| Millerella marblensis Thompson | x | — | — | — | — | — |
| *Anthozoa* | | | | | | |
| Stereocorypha annectans Moore and Jeffords | x | — | — | — | — | — |
| Lophophyllidium adapertum Moore and Jeffords | x | — | — | — | — | — |
| Barytichisma crassum Moore and Jeffords | x | — | — | — | — | — |
| Barytichisma callosum Moore and Jeffords | x | — | — | x | — | — |
| Barytichisma repletum Moore and Jeffords | x | — | — | — | — | — |
| Cladochonus fragilis Mather | x | — | x | — | — | — |
| Amplexocarinia corrugata (Mather) | x | — | x | — | — | — |
| *Brachiopoda* | | | | | | |
| Chonetes choteauensis Mather | x | x | — | — | — | — |
| Juresania wilberana (McChesney) | x | — | — | — | — | — |
| Paeckelmannia sp. | x | — | — | — | — | — |
| Horridonia globosa (Mather) | x | x | — | x | — | — |
| Marginifera roemeri Girty | x | — | — | — | — | — |
| Linoproductus nodosus (Newberry) | x | x | — | — | — | x |
| Dictyoclostus morrowensis (Mather) | x | x | x | x | x | — |
| Rhynchopora illinoisensis (Worthen) | x | — | — | — | — | — |
| Rhynchopora magnicosta Mather | x | — | — | — | | — |
| Spirifer opimus Hall | x | x | — | x | — | — |
| Punctospirifer campestris (White) | x | x | x | x | x | — |
| Punctospirifer transversus (McChesney) | x | — | — | — | | — |
| Composita ozarkana Mather | x | x | x | x | x | — |
| Composita deflecta Mather | x | x | — | x | — | — |
| Composita elongata Dunbar and Condra | x | | — | — | | — |
| Cleiothyridina orbicularis (McChesney) | x | | — | — | | x |
| Squamularia? perplexa (McChesney) | x | x | x | x | x | x |
| Hustedia miseri Mather | x | x | x | x | x | — |
| *Pelecypoda* | | | | | | |
| Edmondia, n. sp. | x | — | — | — | — | — |
| Parallelodon obsoletus (Meek) | x | — | — | — | — | — |
| Myalina wyomingensis (Lea) | x | — | — | — | — | — |
| Myalina congeneris Walcott | x | — | — | — | — | — |
| Leda sp.? | x | — | — | — | — | — |
| Posidonia sp.? | x | — | — | — | — | — |
| Pterinopectinella, n. sp. | x | — | — | — | — | — |
| Aviculopecten halensis Mather | x | — | — | — | — | — |
| Lithophaga sp.? | x | — | — | — | — | — |
| Pleurophorus occidentalis Meek and Hayden | x | — | — | — | — | — |
| Allorisma reflexum Meek | x | — | — | — | — | — |
| *Gastropoda* | | | | | | |
| Worthenia tabulata (Conrad) | x | — | — | — | x | x |
| Trepospira, sp. indet. | x | — | — | — | — | — |
| Colpites aff. C. minutus (Sayre) | x | — | — | — | — | — |
| Naticopsis aff. N. subovata Worthen | x | — | | | — | — |
| Orthonychia, n. sp. | x | x | x | x | x | — |
| Meekospira peracuta (Meek and Worthen) | x | — | — | ? | — | x |
| Pharkidonotus, n. sp. | x | — | — | ? | — | — |
| *Ammonoidea* | | | | | | |
| Phaneroceras nolinense (Cox) | x | — | — | — | — | — |
| *Crinoidea* | | | | | | |
| Ethelocrinus texasensis Moore and Plummer | x | — | | x | — | — |
| Cibolocrinus punctatus Moore and Plummer | x | x | — | x | — | — |
| Diphuicrinus croneisi Moore and Plummer | x | x | — | x | — | — |

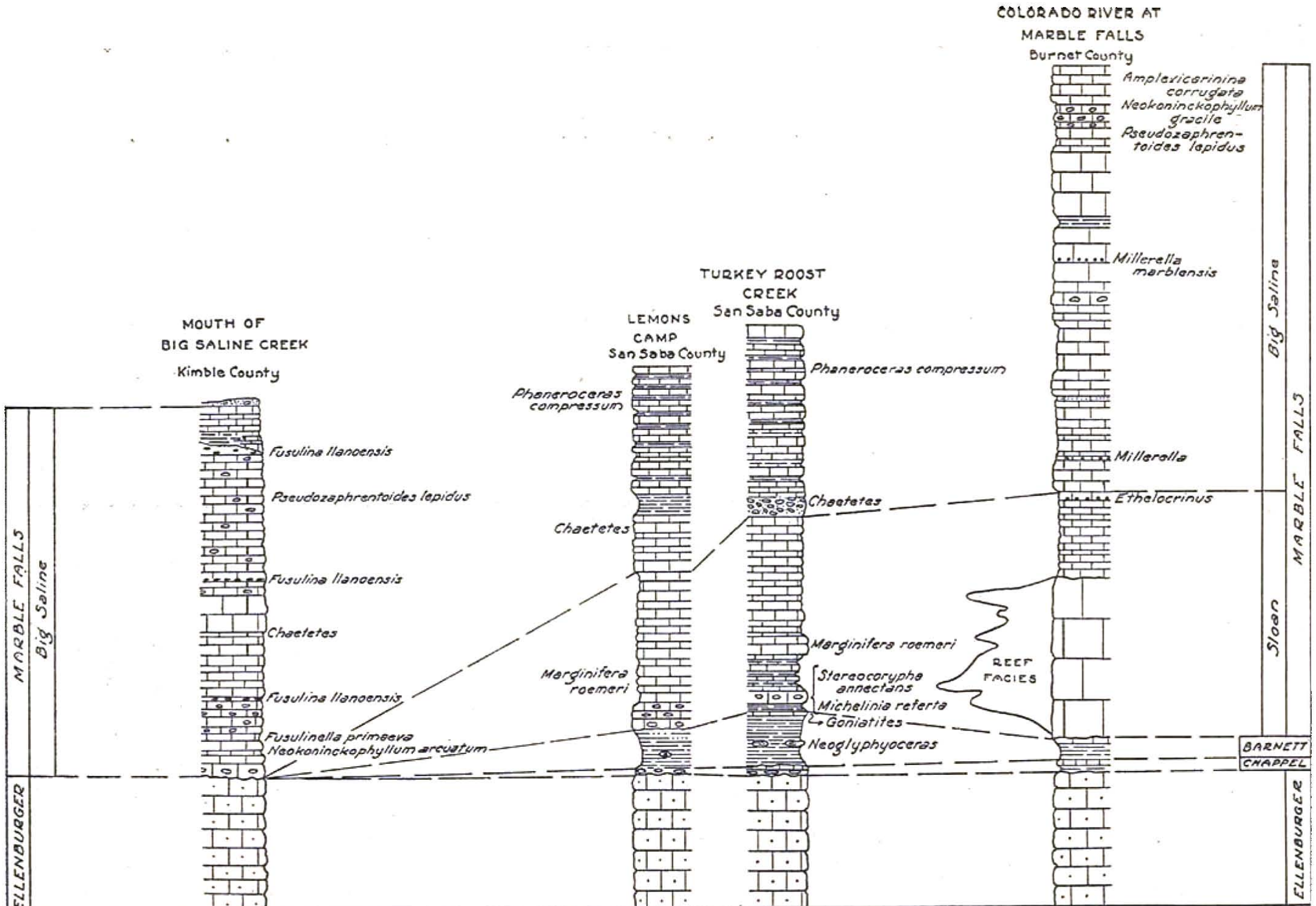


Fig. 13. Columnar sections of strata of the Big Saline group south of Colorado River.

due west, taking the west road and following the main traveled highway to the Sloan community, a distance of about 7.5 miles beyond the white house to a road fork leading to San Saba River at Maxwell Crossing. Then take the road to Maxwell Crossing and continue along a secondary ranch road 0.4 of a mile, turning abruptly south over a rough pasture road leading to King Spring. Proceed about 0.2 of a mile to a pasture gate. The fossil locality is just inside the gate on the northwest slope of a hill. Great quantities of *Marginifera roemeri* Girty and its associated group of fossils occur here.

**205–T–84 (R–17,** Pl. 1).—San Saba County, 1.3 miles south and 0.5 of a mile west of Maxwell Crossing. It is reached by following the same directions given above and continuing south from Locality 205–T–65 at the Sloan ranch gate, a distance of 1.6 miles to Turkey Roost Creek, then walking down the creek about 0.5 of a mile to the contact of the Marble Falls-Barnett formations. By following a dim pasture road, it is possible to drive most of the way. The fossils occur in the strata on both sides of the creek below a rather conspicuous limestone conglomerate. The conglomerate is thought to be Big Saline in age and the strata above the conglomerate are Lemons Bluff. This is a rather difficult locality to reach but a very interesting one.

**205–T–92 (R–15,** Pl. 1).—San Saba County, 6.6 miles due south of Richland Springs on the Jack Sloan ranch. It is reached by taking the Richland Springs-Maxwell Crossing road to the Jack Sloan ranch house, a distance of 9 miles; then proceeding 0.4 of a mile east of the Jack Sloan ranch houses to a wire gate and dim road leading north into the pasture, driving up the dim road a distance of 0.4 of a mile to a large caliche pit. Large numbers of fossils occur in the bottom and the sides of the caliche pit.

**205–T–98 (R–15,** Pl. 1).—San Saba County, 2.7 miles south and 3.6 miles west of Algerita on the Leonard ranch. It is reached by taking the San Saba-Brady road to Algerita, continuing 1.5 miles west of Algerita, turning due south on the road to Leonard ranch and proceeding to the ranch, a distance of 3.5 miles; then taking the road from Leonard ranch house south toward Baker Springs and driving a distance of 0.9 of a mile to a point at the foot of a rather steep hill where the road is crossed by an east-west flowing branch. Walk up the branch a distance of about 0.3 of a mile to the contact of the Marble Falls and Barnett. The fossils occur in the limestone layers just above the Barnett shale. This is the locality where a very interesting sandstone dike resembling the masonry of an ancient concrete dam and originating at the unconformity above the Sloan strata penetrates the upper Marble Falls beds.

### BIG SALINE FORMATION

*Description.*—The Big Saline formation was named by Cheney (1940) using the excellent exposures along Big Saline Creek in Kimble County as the type locality (Pl. 13A). The formation consists of coarsely crystalline, fairly massively bedded, fossiliferous, light-gray limestone weathering white and containing many layers and nodules of dark-gray and black chert. The most common and most conspicuous fossils are tiny fusulinids which occur in great numbers and very large, elongate, cylindrical colonies of a coral belonging to the genus *Chaetetes.* The beds vary greatly in thickness and, in general, thin by non-deposition of lower beds on uplifts and domes (fig. 13). The typical beds can be traced from Big Saline Creek in Kimble County eastward to Honey Creek in Mason County, and from the Gray ranch 5 miles southwest of Brady in Mason County to the Neal ranch, 1 mile west of the McCulloch County line where they play out against the Hall uplift and Cavern Ridge. East of these ridges other beds occur which are similar in appearance, contain the same gastropods, and are regarded as belonging to the Big Saline formation although they do not contain the same fusulinids and ammonoids. The accompanying section shows the succession of beds of the Big Saline formation at the type locality on Big Saline Creek, Kimble County.

*Section of Big Saline formation on Llano River, near mouth of Big Saline Creek, Kimble County*
(Coord. II–35, Pl. 1; fig. 13).

| | THICKNESS Feet | Inches |
|---|---|---|
| Strawn group— | | |
| 16. Limestone, black weathering yellowish gray, crinoidal, contains glauconite, small green and gray chert and limestone pebbles, fusulinids, resembles the stratification along an old sea beach | 1 | - |
| Big Saline formation— | | |
| 15. Shale, black, weathering yellow, thinly bedded, unfossiliferous for the most part | 6 | - |
| 14. Limestone, gray, crinoidal, made up of quantities of crinoid fragments poorly preserved, grades laterally into shale | 1 | — |

| | | THICKNESS Feet | Inches |
|---|---|---|---|
| 13. | Limestone, black, fine grained, subcrystalline, hard, weathering yellow, containing the alga *Taonurus caudigalli* (Vanuxem), dense black chert, fusulinids, and *Phaneroceras compressum* (Hyatt) | 1 | 6 |
| | ——unconformity—— | | |
| 12. | Limestone, gray, uniformly finely crystalline and chert bearing. The chert is light gray, almost white and in the form of small nodules which contain minute sponge spicules. The limestone is medium to thin bedded. The beds range from 2 to 12 or 14 inches in thickness. The upper layers contain quantities of large *Chaetetes* corals, many fusulinids (*Fusulina llanoensis* Thomas), compositids, horn corals, and a few other marine fossils | 75 | .... |
| 11. | Limestone, light gray, almost white, massive, weathers to brecciated chip-like fragments, having yellowish stain. No chert or fossils were found, but the rock contains dark-colored productid spines and some layers appear to be made up of angular chunks of limestone 1 inch to 1¼ inches in size. The whole section appears to be a reef-like limestone and is probably of reef origin | 21 | .... |
| 10. | Limestone, dark gray, hard, very finely crystalline to subcrystalline, chert bearing. The chert is dark gray and somewhat speckled and contains white sponge spicules. In places the limestone contains sponge or algal markings in the form of black blotches having irregular shapes. The beds are 1 inch to 14 inches thick, exposed along the face of the cliff, and consist of 3 divisions as follows: | 31 | |
| | c. Massive *Chaetetes*-bearing layer — 2 ft. | | |
| | b. Mottled algal or sponge-bearing beds — 6 ft. 2 in. | | |
| | a. Evenly bedded mostly nonfossiliferous beds containing echinoid spines especially prominent in a layer 15 inches below the top — 23 ft. | | |
| 9. | Shale, gray, soft, calcareous, containing numerous well-preserved fossils—*Schizophoria*, *Spirifer*, horn corals, *Phaneroceras*, *Pronorites*, productids | .... | 6 |
| 8. | Limestone, gray, finely crystalline, chert bearing. The chert is in the form of dense black nodules and stringers 3 inches thick and 36 inches long. The layer is fossiliferous, contains minute fusulinids (*Fusulinella primaeva)*, other minute fossil fragments, small Foraminifera, and large *Chaetetes* colonies. The base of the stratum is distinctly uneven as if deposited on a wavy surface. The top is also uneven and very rough. A distinct shale parting occurs at the top which is 6 inches thick and forms a prominent cleft in the cliff side. The *Chaetetes* bed forms a good marker horizon which can be easily recognized and traced locally for some distance | 1 | 4 |
| 7. | Limestone, gray, subcrystalline, slightly shaly, grading upward from base into harder, highly fragmental mottled layers which form the base of the cliff and are apparently made up of a mass of small nodules and fragments, angular to subround, and from a fraction of an inch to 1½ inches in size | 15 | .. |
| 6. | Limestone, dark gray, subcrystalline to crystalline, thin bedded; the beds are 3 to 6 inches thick and contain a few echinoid spines and minute fragments of spines and other minute fossils | 9 | 9 |
| 5. | Limestone, gray with pink tinge, finely crystalline to subcrystalline, massively bedded; consists of one single bed and contains a few small gray blotches which apparently are not nodules. Also contains chert nodules 3 to 8 inches in diameter; dark gray in color, containing minute organic markings but no fusulinids or identifiable Foraminifera | 1 | 10 |
| 4. | Limestone, gray, strongly mottled with a mass of darker gray, small, nodular-like bodies ¼ of an inch to 1 inch in diameter. Thin bedded, consisting altogether of 11 beds, each about 3 inches thick | 4 | . |
| 3. | Limestone, gray, nodular, marked with fine white streaks of calcite. The bed is separated into two halves by an uneven wavy parting in the middle. The lower half of the bed contains small corals, small flakes of chert, and small nodules. The nodules appear to be algal in origin and consist of blotches of darker limestone cemented in a lighter matrix. The nodules average about 1 inch in size | 1 | 6 |
| 2. | Limestone, gray, crystalline; contains angular pebbles of chert, and pebbles of Ellenburger dolomite 1½ inches in diameter. The pebbles are rather sparsely scattered 5 or 6 to the square foot. They are angular or subangular with rounded edges and corners. One of the largest pebbles consists of a fragment of a much water-worn *Chaetetes*. The base of the section is poorly exposed, but the rock apparently lies directly upon the Ellenburger | 4 | — |

| | THICKNESS Feet | Inches |
|---|---|---|
| Ellenburger formation— | | |
| 1. Limestone, white, subcrystalline, smooth-surfaced rock which breaks with a distinctly conchoidal fracture | 50+ | |
| Total thickness measured | 224 | 5 |

The Big Saline strata can be traced eastward from the type locality along the edge of the Cretaceous overlap into Mason County where they are exposed on the downthrown sides of many of the normal faults. The strata carry exactly the same fauna, but the massive beds thin toward the northeast.

*Section of Big Saline formation and subjacent rocks along secondary road at Mill Creek, White's ranch, Mason County* (Coord. H-35, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Big Saline formation— | | |
| 8. Limestone, black, weathering dark, yellowish-gray, hard, subcrystalline, containing large numbers of well-preserved *Phaneroceras compressum* (Hyatt), *Neospirifer cameratus* (Morton), and other fossils | 4 | 6 |
| 7. Shale, covered by soil and alluvium | 3 | |
| 6. Limestone, black, hard, fossiliferous, interbedded with thin beds of soft black shale which are about 3 feet in thickness. The limestone beds are about 10 feet thick, have smooth surfaces, and break into slabs. One ledge has numerous large nautiloids 8 to 9 inches in diameter, *Spirifer rockymontanus* Marcou, *Pharkidonotus*, n. sp., *Syringopora*, and others | 35 | |
| 5. Limestone, black, hard, chert bearing. The chert is black, and occurs in the shape of nodules, small lentils, and uneven thin layers which contain numerous small fusulinids (*Fusulina llanoensis* Thomas) | 60 | |
| Barnett shale— | | |
| 4. Shale, brownish black, containing thin beds of limestone mostly covered with soil and brush | 18 | |
| Chappel formation— | | |
| 3. Limestone, grayish white, crinoidal, made up of a coquina of small crinoid fragments | 6 | |
| 2. Limestone or shale covered with soil | 9 | |
| Ellenburger— | | |
| 1. Limestone, white, hard, subcrystalline; breaks with a smooth conchoidal fracture and contains a multitude of minute calcite veins and fine cracks plainly visible on smooth surfaces | 50 | |
| Total thickness | 185 | 6 |

*Section of Big Saline formation and older rocks measured on Honey Creek just northwest of White's Crossing road, Mason County* (Coord. I-33, Pl. 1).

| | THICKNESS Feet |
|---|---|
| Big Saline formation— | |
| 10. Limestone, black, weathering yellow, fossiliferous; contains *Phaneroceras compressum* (Hyatt), nautiloids, and *Taonurus caudagalli* (Vanuxem) | 3 |
| 9. Shale, black, mostly covered with alluvium, gravel, and soil | 56 |
| 8. Limestone, black, weathering yellow, fossiliferous; contains *Phaneroceras compressum* (Hyatt) | 3 |
| 7. Shale, black, mostly covered with gravel | 20 |
| 6. Limestone, dark gray, subcrystalline, smooth surfaced, evenly bedded having shale partings between some of the beds; contains algal markings. Beds range from 6 inches to 3 feet in thickness, containing *Chaetetes*, *Composita*, and other fossils | 40 |
| 5. Limestone, gray, crystalline, well bedded. The beds are about 1 foot thick. Few fossils | 55 |
| 4. Limestone, dark gray, partly oolitic; contains small fusulinids in upper ledge. The upper ledge is more resistant and forms low falls in the creek | 14 |

| | THICKNESS *Feet* |
|---|---|
| 3. Limestone, black, hard, subcrystalline, chert bearing; chert nodules are black although they weather to a buff color. The beds occur in the form of 12 resistant layers 4 to 6 inches thick which produce small ridges across the creek. About 25 percent of the rock is made up of black chert which contains many fine white spicules, smaller Foraminifera, and fusulinids. The fusulinids, which are the well-known form *Fusulina llanoensis* Thomas, are especially abundantly prominent in the next to lowest chert layer | 8 |
| Barnett shale— | |
| 2. Shale, brown, petroliferous, fossiliferous; contains several thin beds of limestone 3 to 12 inches thick. The shale is soft, brown, petroliferous in layers a foot or more in thickness which alternate with soft oolitic, somewhat altered, brown limestone. The harder layers are fossiliferous; the fossils are poorly preserved but very numerous, pelecypods, caneyellas, bryozoans, and others | 42 |
| Chappel limestone— | |
| 1. Limestone, pinkish white, hard, compact, massive, crystalline, crinoidal, having a rough granular surface. The crinoidal detritus is most plentiful in lower portion. Conglomerate cobbles occur at the base in some places | 10 |
| Total thickness | 251 |

*Section of Big Saline formation measured along Little Brady Creek 1,000 feet northeast of Smith ranch house and 240 feet east of wire fence, McCulloch County* (Coord. L–14, Pl. 1).

| | THICKNESS *Feet* | *Inches* |
|---|---|---|
| Big Saline formation— | | |
| 6. Limestone, gray massive; contains fusulinids (*Fusulina llanoensis* Thomas), *Chaetetes*, and a few other fossils | 6 | .. |
| 5. Limestone, dark grayish blue, hard, subcrystalline; contains some black chert and weathers into chips and slabs having rough surfaces. It is fossiliferous, containing large shells of *Pharkidonotus*, n. sp., many productids, and a few fusulinids | 3 | ---- |
| 4. Limestone, dark gray, hard, subcrystalline, breaks with a conchoidal fracture and has a distinct odor of petroleum | 1 | 10 |
| 3. Limestone, black, weathers light yellow, thin bedded, breaks into flags 1/4 inch to 3 inches thick, averaging about 1 inch thick, fossiliferous, contains productids and a *Derbyia* | 4 | --- |
| 2. Limestone, black, weathering a light cream color, dense, subcrystalline, breaks with a conchoidal fracture and along bedding planes and joint lines to produce rectangular blocks 1 foot thick and 18 inches long which form excellent building blocks | 3 | 6 |
| 1. Limestone, black, subcrystalline; breaks to form hard curved chips 1 inch to 2 inches thick; contains numerous fossils, large *Dictyoclostus morrowensis* (Mather), *Chonetes dominus* R. H. King, *Spirifer rockymontanus* Marcou, and others. Contains also one chert lentil of dense black unfossiliferous chert. Bottom unexposed. Total thickness exposed | 7 | 6 |
| Total thickness | 25 | 10 |

*Microscopic characteristics.*—The microscopic characteristics of the Big Saline beds have been described by Udden (1919-A) and Udden and Waite (1927). The most striking feature of the limestone when viewed in thin section under the microscope is its sponge-spicule content. Particularly the middle layers, now referred to as Lemons Bluff beds, consist of a mass of sponge spicules cemented with calcium carbonate to form a thin solid ledge difficult to cut with the ordinary rock saw. When dissolved in acid, in many places the silica content of the rock will amount to more than 50 percent by volume. Thin sections of the upper beds also reveal in most places large numbers of Foraminifera. Outlines of these fossils are particularly well preserved in the chert, where they can be seen with a hand lens.

*Microfossils found in Big Saline formation*[a]

Foraminifera—
- Pseudostaffella sp.
- Fusulina llanoensis Thomas
- Fusulinella primaeva (Skinner)

[a]All identifications are by Helen J. Plummer.

Millerella marblensis Thompson
Cribrostomum marblense H. J. Plummer
Reophax bendensis H. J. Plummer
Reophax emaciatus H. J. Plummer
Hyperammina bulbosa Cushman and Waters
Ammodiscus semiconstrictus Waters
Glomospirella umbilicata (Cushman and Waters)
Endothyra distensa H. J. Plummer
Endothyranella armstrongi subsp. sobrina H. J. Plummer
Endothyra rotaliformis Warthin
Bradyina sp.
Globivalvulina biserialis Cushman and Waters
Polytaxis scutella (Cushman and Waters)

Bryozoa—
Ostracoda—

Some of these microfossils occur in the cherts of the upper member in the form of moulds so that long cavities are found scattered profusely through the chert nodules.

*Distinguishing features.*—The characteristics that distinguish the Big Saline group of beds from other Carboniferous formations may be summarized as follows:

1. Its black, nodular chert marked by tiny cavities and Foraminifera.
2. Its algal content expressed by the interesting, strikingly mottled beds in the upper portion of the Big Saline member (Pl. 10B) and the characteristic markings of *Taonurus caudagalli* (Vanuxem) found on the surface of the Lemons Bluff limestone.
3. The siliceous content of the Lemons Bluff member due to great quantities of sponge spicules. In its uppermost levels this member weathers to yield lightweight, buff-colored fragments called "cotton rock," a feature not found in other Carboniferous formations.
4. The Big Saline formation has some rather massive, thick, coarsely crystalline layers made up largely of large crinoid fragments. The crinoid-bearing beds of the Big Saline are distinguished from the crinoidal limestone of the Chappel formation by the fact that the cross sections of the crinoid stems are generally much larger and in many places have a more complex central vertical canal through the center of the stem. The central canal of some of the Pennsylvanian crinoids is pentagonal in cross section, having a central tube surrounded by five connecting lobes. All the Chappel crinoid stems have a simple round canal in the center of the stem.
5. The rich faunas present in the middle and upper layers of the Big Saline enable one to distinguish the formation readily with little experience from the Sloan formation below.

*Subdivisions of the Big Saline formation.*—The Big Saline formation may be subdivided on a basis of lithology and paleontology into a series of 4 to 7 members, most of which are discontinuous and may be best referred to as lentils. These are as follows:

| WEST AREA | EAST AREA |
|---|---|
| Soldiers Hole lentil | Brister Bluff lentil |
| Lemons Bluff member | Lemons Bluff member |
| Brook lentil | Aylor Bluff member |
| Gibbons conglomerate | Gibbons conglomerate |

The stratigraphic positions of these lentils are shown in the sections, Plate 9, and are described in the following paragraphs.

*Gibbons conglomerate.*—A basal conglomerate marks the contact of the Big Saline and Sloan formations in some places. In other places a thin, glauconitic sand intervenes containing phosphatic nodules, and in many others the Big Saline limestones or shales lie directly on Barnett or even Ellenburger strata with or without a thin conglomerate at the base of the Big Saline. In a few places the basal Big Saline strata consist of limestone nodules intermingled with water-worn casts of *Bellerophon* shells. In still other localities a thin layer of beautifully banded, nearly spherical algal "biscuits" marks the contact of the Big Saline and older strata. The type section of the Gibbons conglomerate is a thin pebble conglomerate 6 inches to 1 foot thick which occurs between the Big Saline and Barnett in an exposure one-fourth of a mile north of the new San Saba-Brady road on the Gibbons ranch 2½ miles south of Hall, 0.4 of a mile east of the point where the road crosses the west-facing Marble Falls escarpment. The conglomerate is 8 inches to 1 foot thick and is distinctly a pebbly conglomerate made up of pebbles three-fourths of an inch to 1 inch in diameter, set in a matrix of coarse sand or very small pebbles. The large pebbles as a whole are remarkably uniform in size; the largest is 1 inch in diameter and the smallest three-fourths of an inch, unless the coarse matrix material is considered. The matrix grains average 1 mm. to 3 mm. in size. The pebbles of the conglomerate consist of subangular limestone and chert mostly derived, it is thought, from the Ellenburger dolomite. The conglomerate ledge is consolidated and, where broken, fractures across the pebbles without distintegration, although a few pebbles weather out by solution and can be picked up on the surface. The type section along the right-of-way is shown in the accompanying table.

*Section north of new San Saba-Brady highway, 2¾ miles south of Hall, San Saba County* (Loc. 205–T–102; Coord. O-13, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Big Saline formation— | | |
| 4. Limestone, dark gray, crystalline, chert bearing; badly slumped, but fossiliferous and containing *Neospirifer cameratus* (Morton) and other typical Marble Falls fossils. *Marginifera haydenensis* Girty was collected 15 feet from the base | 18 | .. |
| 3. Gibbons conglomerate, dark gray, containing limestone and chert pebbles of uniform size set in a matrix of coarse, pebbly sand | 1 | 2 |
| Barnett formation — | | |
| 2. Shale, mostly covered and forming a smooth, grassy slope | 15 | .. |
| 1. Limestone, dark gray, almost black, fossiliferous, containing *Leiorhynchus carboniferum* Girty and other Mississippian fossils and fairly well exposed in the creek bottom | 1 | .. |
| Total thickness | 35 | 2 |

Since no fossils have been found immediately underneath the conglomerate, one cannot be positive that the conglomerate is actually at the base of the Big Saline, but it is thought to be.

Other exposures where a thin conglomerate occurs at the contact of the Big Saline and older beds are as follows:

1. Doublehorn Creek valley between Fowler and Cox ranches and at road crossing over Doublehorn Creek, east of Fowler ranch house, Burnet County (Coord. H–39, Pl. 1).
2. Road cut on San Saba-Llano road 5 miles south of San Saba (Loc. 205–T–40; Coord. W–17, Pl. 1).
3. Small gully northwest of large earthen tank, north of highway about 0.5 of a mile east of Lemons ranch house, San Saba County (Coord. R–16, Pl. 1).
4. North side of Brady Creek on Session ranch, 3 miles east of Brady, McCulloch County (Coord. J–17, Pl. 1).
5. East of spillway of Shropshire Lake, 3 miles northeast of Brady, McCulloch County (Loc. 153–T–85; Coord. J–17, Pl. 1).
6. Around the prominent outlier on the White ranch, 0.5 of a mile south of the old Cavern road and 2.5 miles west of the line between San Saba and McCulloch counties (Coord. M–14, Pl. 1).
7. Locality 205–T–113 on small branch 0.5 of a mile south of Leonard ranch house, San Saba County (Coord. S–15, Pl. 1).

The conglomerate on the White ranch outlier consists of chert cobbles one-fourth inch to 4 inches in diameter, angular and subangular, firmly cemented in a chert matrix. The cobbles are a mixture of black, white, and gray chert, with the black, older Marble Falls beds completely eroded away at this locality, and the white chert derived from the Ellenburger dolomite.

The conglomerate of the Shropshire Lake locality (153–T–85) consists of elongate, calcareous nodules perhaps of algal origin, limestone cobbles, and water-worn fossils, including the following forms: *Spirifer*, *Bellerophon*, *Allorisma*, Bryozoa, and a few fusulinids—a fauna quite different from the one associated with the conglomerate pebbles in San Saba County. The rock is cemented by a silty, calcareous matrix which weathers in places to a rusty yellowish-brown color and is about 2 feet thick. The section at this place is as follows:

*Section of Big Saline strata near spillway at Shropshire Lake, 3 miles southeast of Brady, McCulloch County* (Loc. 153–T–85; Coord. J–17, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Brook member (?)— | | |
| 12. Limestone, gray, containing many fusulinids | 2 | .. |
| 11. Shale (?), covered by soil and grass | 3 | .. |

| | Thickness Feet | Inches |
|---|---|---|
| 10. Limestone, dark gray, hard, smooth surfaces, fossiliferous, containing *Euomphalus*, small gastropods, *Zaphrentis*, and bellerophons | 1 | 6 |
| 9. Shale (?), covered by grass | 2 | .. |
| 8. Limestone, dark gray, massive, smooth surfaced, unfossiliferous for the most part | 3 | |
| 7. Shale (?), covered by grass | 5 | .... |
| 6. Limestone, dense, hard, brittle, contains a few fossils and has a smooth surface. The fossils are bellerophons and ammonites (?) | 1 | .. |
| 5. Shale (?), covered | 4 | 6 |
| 4. Limestone, dark gray, subcrystalline, dense, fossiliferous, containing bellerophons, nautiloids, etc., much jointed, weathering into rounded nodules | 5 | 6 |
| Gibbons conglomerate lentil— | | |
| 3. Conglomerate, nodules and cobbles of black Marble Falls limestone and many algal or fucoidal (?) nodules set in a matrix of subcrystalline, nearly black limestone, fossiliferous, containing fucoids (?), *Spirifer*, *Squamularia*, echinoid spines and plates, corals resembling *Campophyllum*, and other Marble Falls fossils. The limestone is fairly soft and breaks into chips and small chunks. It forms the sluiceway of the lake | 3 | . |
| Barnett formation— | | |
| 2. Shale, covered with soil | 2 | |
| 1. Limestone, gray, oolitic, containing *Leiorhynchus* and other Mississippian fossils | 1 | |
| Total thickness measured | 33 | 6 |

The chert conglomerate on Doublehorn Creek east of the Fowler ranch is made up largely of chert and weathers to form a gravel slope resembling a terrace. Most of the Barnett is absent in this area, and the chert gravel represents the basal layer of the overlapping Big Saline formation. The older rocks are uplifted in a fault block in this region. The section is shown in the accompanying table.

*Section of lower Marble Falls strata southwest of Fowler ranch house in valley of Doublehorn Creek, Burnet County* (Coord. II-39, Pl. 1).

| | Thickness Feet | Inches |
|---|---|---|
| Big Saline formation— | | |
| 4. Limestone, gray, thin bedded, containing sponge spicules | 20 | |
| 3. Shale, black, mostly covered, no fossils obtained | 6 | ... |
| 2. Gibbons conglomerate, derived largely from chert and in the form of chert cobbles, 1 to 3 inches or more in size, may represent a disintegrated chert layer | .. | 3 |
| Ellenburger dolomite— | | |
| 1. Limestone, white, dolomitic, crystalline | 50 | ... |
| Total thickness measured | 76 | 3 |

resemble the limestone at the top of the Barnett. Many water-worn, poorly preserved fossils, such as corals, *Orthotetes*, *Marginifera*, crinoids, and others, similar to forms in the Sloan, occur in the sandy matrix between limestone cobbles. Some of the sand is cemented into a hard rock and contains veins of white calcite. The conglomerate grades upward into a coarse, limy sandstone layer which is about 1 foot

The most interesting exposure of the basal glauconite sand and conglomerate is in a small branch one-half mile south of the Leonard ranch headquarters and about 900 feet west of the Leonard ranch-Berry Springs road. It consists of a dark-gray, coarse, fossiliferous, glauconitic sand containing a large number of subrounded cobbles and pebbles from a small fraction of an inch up to 10 inches in diameter. The pebbles are black, subcrystalline limestone, have a petroliferous odor, and thick. The exposure of the conglomerate lentil is about 30 feet long east and west, 1 foot thick at each end, and thickens to 4 feet in the middle. It grades laterally into medium to coarse-grained sand.

The sand layer contains a few scattered, coarse pebbles, is glauconitic, resembles the sand forming the matrix for the conglomerate pebbles, and can be traced for some distance along the valley side between the Barnett and Big Saline formations. At one point just west of the conglomerate exposure two sandstone dikes apparently originating from the glauconitic contact protrude 20 to 30 feet up into the Marble Falls strata. The dikes are on each side of the valley, nearly opposite each other, and may have been at one time connected, forming a single dike, although there is no evidence to support this view. The dike on the north side of the creek is the larger. It is 34 feet high, 17 feet wide, and 130 feet long. It weathers into large spherical blocks or boulders 5 to 8 feet in diameter which roll down the valley side or remain suspended upon the top of the vertical ledge, making the dike appear to have been built up in the form of a wall of huge boulders. The dike on the south bank is situated 60 feet east of the other. It is 16 feet wide, 20 feet high, and at least 100 feet long. It is almost directly above and south of the conglomerate lentil described above. The material of the dikes is exactly like that of the sand at the contact of the Marble Falls and Barnett but does not contain many coarse pebbles, and it is thought that the dikes were derived from the sandy portion of the Gibbons conglomerate member, having been squeezed upward into the then soft marls of the Marble Falls just as quicksand tends to flow when pressed.

*Brook lentil.*—The Brook lentil makes up the basal layers of the Big Saline formation in Kimble, Mason, and McCulloch counties and contains *Fusulinella primaeva* (Skinner) and in many places a characteristic zone of small turreted gastropods now being described and illustrated by Dr. J. Brookes Knight. The beds occur between the Gibbons conglomerate lentil and the Lemons Bluff member, where it is present, and otherwise between the Gibbons conglomerate or older rocks and the Soldiers Hole limestone beds. The member extends from the mouth of Big Saline Creek in Kimble County to Little Brady Creek south of Rochelle in McCulloch County where it pinches out against the Ellenburger uplift southwest of Hall (Pl. 1). The stratigraphic position of the lentil is shown in Plate 9. In most places the lentil consists of black, dense, subcrystalline, cherty, fossiliferous limestone in beds 3 to 18 inches thick, and in some places the limestone layers are interbedded with dense black shale. It is characterized everywhere by the presence of *Fusulinella primaeva* (Skinner) which occurs in most places in great numbers. A typical section at the type locality near Brook ranch is given below.

*Section of the Brook lentil along abandoned highway 3½ miles south and 1 mile east of Brady and ¾ of a mile northwest of Brook ranch headquarters* (Loc. 153-T-1; Coord. H-19, Pl. 1).

| | THICKNESS Feet |
|---|---|
| 5. Limestone, black, hard, subcrystalline, occurring in 3 or 4 layers 1 foot to 18 inches thick, and containing large numbers of minute fusulinids. Very numerous turreted gastropods and many *Bellerophon*-like gastropods. The gastropods in many places are silicified. The limestone layers are separated by shale partings | 3 to 5 |
| 4. Shale, black, soft, covered with soil | 8 |
| 3. Limestone, black, hard, finely crystalline, fossiliferous | 1 |
| 2. Shale, black or dark gray, weathered to caliche | 9 |
| 1. Conglomerate, made up largely of casts of *Bellerophon*-like fossils, small chert nodules and calcareous nodules in some places; contains minute fusulinids | 1 to 2 |
| Total thickness | 22 to 25 |

*Aylor Bluff member.*—The Aylor Bluff member of the Big Saline formation occurs in the area east of Cavern Ridge and lies stratigraphically between the overlying Lemons Bluff member and the underlying Sloan formation in the sections where the Sloan formation is present. In other places it intervenes between the Lemons Bluff and Barnett or older strata (Pl. 9). It is thought to be about equivalent in age to the Brook lentil beds of McCulloch County but may be older, since it differs from the Brook lentil beds in texture and fossil content. The Aylor Bluff beds are more massive, more coarsely crystalline, thicker, and contain more oolite, but do not contain the minute fusulinids so characteristic of the beds of the Brook lentil. Aylor Bluff beds extend somewhat intermittently from the mouth of Brady Creek in San Saba County to the big bend in Colorado River east of the town of Bend. The member is apparently thickest in the synclinal areas and thins out on Ellenburger structural ridges. It is probably present in the type Marble Falls section at Marble Falls on Colorado River, but its limits cannot be easily recognized.

The Aylor Bluff member is typically a light-gray, coarsely crystalline, somewhat oolitic, massive, crinoidal, lenticular limestone (Pl. 13A). It is less siliceous than the Lemons Bluff beds above, thicker bedded, more coarsely crystalline, and contains less chert. The chert is lighter colored, in many places gray or speckled instead of black, and contains fewer fossils and fewer Foraminifera. The fossils in the limestone in most places are not represented by many species, but they are large in size. They include large crinoid stems, spirifers, productids, and large globular colonies of the coral *Chaetetes*. In a few places, the limestone shows cross-bedding, as if the calcium carbonate particles and fossil fragments had been built up as a heap or reef, and that some of the upper material had been washed off the top and deposited in layers down an inclined slope. These more massive, more coarsely crystalline beds are apparently separated from the Sloan beds below by an unconformity. The lower surface of the Big Saline formation is uneven. It overlaps the Sloan beds and rests on Barnett and in some places on Ellenburger dolomite. In places, a thin, nodular conglomerate separates the Aylor Bluff and older beds. In other places, the member rests directly upon the black Sloan beds without any marked change. The Aylor Bluff member is quite variable in thickness, thinning out altogether over anticlines and arches, and thickening in synclinal areas. The conclusion is that warping of the strata took place after deposition of the Sloan formation, resulting in erosion on the highlands, and that more detrital calcium carbonate was washed in or accumulated by accretion in the lower, deeper areas. It may be, however, that formerly the distribution of the Aylor Bluff beds was more uniform and that it has been removed by erosion on the anticlinal areas before deposition of the younger Lemons Bluff beds above. In the section along Turkey Roost Creek these massive Aylor Bluff beds thin, within half a mile, from 60 feet or more to 6 feet and are replaced by a thick, coarse limestone conglomerate made up of large limestone cobbles of Sloan aspect and containing numerous *Chaetetes* colonies like those found elsewhere in the Aylor Bluff beds. A section of the member west of Lemons Camp is as follows:

*Section of the Aylor Bluff lentil at bluff on San Saba River west of Lemons Camp, San Saba County* (Coord. Q–17, Pl. 1).

| | THICKNESS *Feet* |
|---|---|
| 3. Limestone, gray, weathering to light gray, fairly thin bedded. The beds are 2 to 6 inches thick and weather to small gray chips. The bedding planes are not very distinct | 10 |
| 2. Limestone, dark gray, weathering to light gray, chert bearing. The bedding planes are not distinct, but the surfaces of the layers are mottled by algal markings and contain numerous *Chaetetes* in the upper layers. The beds stand out as a vertical cliff. Two indistinct, intra-formational limestone conglomerate layers, spaced about 20 inches apart, may be observed on the face of the cliff. They are 3 to 4 inches thick and made up of rounded limestone pebbles ¼ inch to 2 inches in diameter | 9 |
| 1. Limestone, dark gray, weathering to light gray, finely oolitic in texture, rather massively bedded. The beds are 1 to 5 feet thick and contain a little gray chert and a few fossils, *Michelinia* and small crinoid stems. The layer appears to overlap the chert-bearing beds below and to dip less steeply than the lower strata showing cross-bedding in the cliff side. The base of the ledge is not exposed because of a small fault | 20 |
| Total thickness measured | 39 |

South of the Bend-San Saba road crossing on Rough Creek these coarsely crystalline, reef-like beds are 85 feet thick, and the bottom is not exposed. On Colorado River in the thick section at Marble Falls, the beds appear to be at least 120 feet thick. In the section at Marble Falls, however, the boundaries of the Big Saline and other divisions are difficult to recognize. The best present interpretation is shown in the columnar section (Pl. 9).

The fossils from the Aylor Bluff member are in most places poorly preserved, and but few collections are available. The fossils which have been studied are common long-range brachiopods and large bellerophons. These appear to be more nearly related to the Big Saline fauna than to the Sloan assemblage. It is possible that when more detailed and more extensive collecting is done. the fauna will prove these beds to be Sloan in age and not Big Saline. But so far we have not found any very typical Sloan fossils in the few and small collections made from the Aylor Bluff strata. and the exact age of the Aylor Bluff beds remains an interesting problem.

*Lemons Bluff member.*—In the western area the Lemons Bluff member occurs between the Brook lentil containing the *Fusulinella primaeva* (Skinner) zone of minute fusulinids and the Soldiers Hole lentil containing large fusulinids of the type of *Fusulina llanoensis* Thomas. In the eastern area the beds intervene between the Aylor Bluff beds and Brister Bluff lentil. The member extends from Brook ranch in McCulloch County eastward to Indian Bluff in Lampasas County.

The Lemons Bluff beds consist of a black, subcrystalline, uniformly bedded, siliceous, chert-bearing limestone, weathering to yellowish- and grayish-brown tints, and are made up in many places of a great quantity of minute sponge spicules. The layers are 2 to 12 inches thick (Pl. 10A) and are characterized by flat, smooth surfaces, which yield in many places good building blocks and flagstones and weather to produce a lightweight siliceous rock. The individual layers in many places are separated by thin partings of shaly limestone, so that a cliff face weathers to give the impression of a masonry wall, each layer standing out in relief. The most characteristic feature of the Lemons Bluff member is its high percentage of silica due largely to its sponge spicule content. Analyses of the rock indicate from 15 to 63 percent silica with a 20 or 40 percent silica content common, making the rock essentially a siliceous limestone. Over 200 analyses of the strata from different levels in typical sections have been made by I. W. Walling. The results of the analyses are shown graphically in Plate 9.

The Lemons Bluff contains in most places a characteristic fauna. The best index fossils are *Phaneroceras compressum* (Hyatt), *Pharkidonotus*, n. sp. (a large noded gastropod belonging to the Bellerophonidae), and *Straparolus savagei* Knight (a low-coiled, smooth-surfaced gastropod). Other common fossils are:

Paralegoceras texanum (Shumard)
Spirifer rockymontanus Marcou
Neospirifer cameratus (Morton)
Neilsonia, n. sp.
Amphiscapha subquadrata (Meek and Worthen)
Nuculana cf. N. bellistriata (Stevens)

The surfaces of the limestones in many places are covered with impressions of the common alga, *Taonurus caudigalli* (Vanuxem).

This limestone member changes to shale beds in Colorado River valley and outcrops at McAnelly Bend and along Colorado River bluffs west of Bend as shale containing thin bands of dense black limestone. Here the member has long been regarded by geologists as typical Smithwick shale. It varies in thickness from a few feet to 125 feet. It overlies the Brook beds unconformably in the western part of the uplift and is thought to be unconformably in contact with the Aylor Bluff beds in the eastern part of the region. A typical section measured along the bluffs of Turkey Roost Creek on the Sloan ranch is as follows:

*Section of Lemons Bluff member measured on bluffs of Turkey Roost Creek, Sloan ranch, San Saba County* (Coord. R–17, Pl. 1; fig. 13).

| | THICKNESS Feet |
|---|---|
| Lemons Bluff beds— | |
| 6. Limestone, black, evenly bedded (beds are 6 to 12 inches thick), subcrystalline, weathering to yellowish brown, siliceous, smooth surfaced, breaks into rectangular blocks which make good building stone. Very siliceous, the rock disintegrates upon weathering, where acid waters are present, to yield a siliceous earth resembling tripoli. Some layers contain much chert. The chert is in the form of black nodules which weather to a reddish brown color with black centers. Many chert nodules contain Foraminifera, which appear as moulds producing tiny open cavities in the hard rock | 25 |
| 5. Limestone, black, evenly bedded (beds are 2 to 3 feet thick), crinoidal; some of the layers are made up of a mass of crinoidal fragments, small, very numerous, and evenly distributed. Other layers are somewhat harder, thicker, and are fossiliferous, containing large bellerophons (*Pharkidonotus*, n. sp.), large ammonoids (*Phaneroceras compressum*), *Euomphalus*, and spirifers | 8 |
| 4. Limestone, black, evenly bedded, resembling the layers above but containing numerous large nautiloids | 2 |
| 3. Limestone, black, subcrystalline, evenly bedded; the beds are 6 to 18 inches thick and separated by shale or soft limestone partings 2 or more inches thick so that on the cliff side each harder layer stands out conspicuously and can easily be traced laterally. Most of the layers are unfossiliferous | 30 |
| 2. Limestone, black, evenly bedded; the beds are thinner, averaging 4 inches, and in places apparently grading into soft, gypsiferous shale which is generally covered with talus | 20 |
| Gibbons conglomerate— | |
| 1. Conglomerate, light gray, weathering white, made up of a mass of well-rounded limestone pebbles cemented in a limestone matrix. The pebbles range in size from ¼ inch to 2½ inches, averaging about 1 inch | 3 |
| Total thickness measured | 88 |

*Section of Lemons Bluff limestone at Indian Bluff on Donalson Creek west of Lampasas, Lampasas County* (Loc. 142–T–12; Coord. H–20, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| 7. Limestone, pinkish brown, chert bearing, siliceous, thin bedded, weathers to lightweight slabs | 13 | 6 |
| 6. Limestone, gray, fossiliferous, contains crinoids, productids, and nodules 1 to 3 inches in size made up of oolitic grains | 1 | -- |
| 5. Limestone, gray, subcrystalline, thin bedded. The beds are ½ inch to 12 inches thick and have smooth surfaces. Some layers are separated by soft shale partings and break into thin slabs and chips; petroliferous and for the most part unfossiliferous. The rock weathers to yellow and pinkish-brown, lightweight, sponge spicule-bearing, siliceous slabs | 43 | -- |
| 4. Limestone, dark gray and black, subcrystalline, thin to medium bedded; the layers range from 1 to 22 inches thick and have wavy, uneven surfaces, mostly unfossiliferous. The upper 9½ feet contain blotches of black, organic masses which may have originally been sponge or algal masses. The black nodules give a mottled appearance to the surfaces of the layers so that they are locally referred to as mottled beds | 12 | 6 |
| 3. Limestone, black, subcrystalline, rough surfaced, chert bearing, forming a hard ledge which crosses the creek and forms a sort of natural low-water bridge. The ledge dips southeast at an angle of 30° | 2 | 6 |
| 2. Limestone, black, subcrystalline, weathering to very rough nodular surfaces; containing large nodules of dense black chert 2 to 11 inches in diameter | -- | 6 |
| 1. Limestone, dark gray, almost black, subcrystalline, thin bedded; the beds range from 2 to 6 inches in thickness and have smooth, wavy surfaces containing a few fossils and some chert | 6 | -- |
| Total thickness measured | 79 | -- |

The stratigraphic relationship of the Lemons Bluff member with the beds below is unconformable. It thins by loss of its lower layers against bioherms of the Aylor Bluff member, is separated from the Aylor Bluff member in places by pebbles, nodules, or by banded spherulites known as "algal biscuits," that are described elsewhere in this volume. It overlaps on to the Sloan formation in places and may or may not be separated from the Sloan by a conglomerate of cobbles largely derived from the Aylor Bluff beds. In the western region it lies unconformably upon the Brook lentil and in most places is separated from it by a conglomerate of limestone pebbles, fossils, and limestone nodules.

The fauna of the Lemons Bluff beds is large. Spirifers predominate, but in places large gastropods belonging to the genus *Pharkidonotus* are very common. Productids are less common than in the lower beds, yet hurriedly made collections sometimes yield more than a dozen specimens. No fusulinids have been found as far as known but pseudostaffellids and other Foraminifera are very common and have been found at widely separated localities. The best index fossil is *Phaneroceras compressum* (Hyatt). Fortunately this fossil is fairly common and has been collected in the black limestones of this upper member from Lampasas County line on the east to 15 miles west of Mason on the west. This fossil with its common accompanying assemblage, namely, *Spirifer opimus* Hall, *Spirifer matheri* Dunbar and Condra, *Spirifer rockymontanus* Marcou, *Pharkidonotus*, n. sp., and *Straparolus savagei* Knight, serves to distinguish this member at once from the Sloan formation. Several of the typical species found in the Lemons member are shown on Plate 14. Fossils of the Lemons Bluff are listed below. Pelecypods are not included. The corals have been identified by Moore and Jeffords (1945), the gastropods by J. Brookes Knight, and the Foraminifera by H. J. Plummer.

*Most common species in the Lemons Bluff member*

Foraminifera—
- Cribrostomum marblense H. J. Plummer
- Pseudostaffella sp.
- Millerella marblensis Thompson

Anthozoa—
- Empodesma imulum Moore and Jeffords
- Lophophyllidium extumidum Moore and Jeffords
- Lophophyllidium idonium Moore and Jeffords
- Paracaninia? sana Moore and Jeffords
- Michelinia referta Moore and Jeffords
- Striatopora religiosa Moore and Jeffords
- Cladochonus texasensis Moore and Jeffords
- Chaetetes favosus Moore and Jeffords

Brachiopoda—
- Rhipodomella pecosii (Marcou)
- Chonetes dominus R. H. King
- Chonetina sp.
- Paeckelmannia derelicta R. H. King
- Horridonia bullata (Mather)
- Horridonia globosa (Mather)

Gastropoda—
- Pharkidonotus, n. sp.
- Straparolus savagei Knight

Ammonoidea—
- Phaneroceras compressum (Hyatt)
- Paralegoceras texanum (Shumard)
- Branneroceras branneri (Smith)

Arthoceratoidea—
- Rayonnoceras, n. sp.

Nautiloidea—
- Ephippioceras divisum (White and St. John)
- Coloceras sp.
- Metacoceras sp.
- Endolobus conchiferus (Hyatt)
- Titanoceras sp.
- Titanoceras illinoisense (McChesney)
- Solenochilus branneri A. K. Miller, Dunbar, and Condra

The exact age and correlation of the Lemons Bluff member with strata in other regions is not yet fully established. It contains many Morrow species, many of which are long-range types and cannot be used for correlation. On the other hand, it contains few, if any, fossils which are restricted to the Atoka of Oklahoma or equivalent beds. Finally it contains several interesting forms not yet found either in the Morrow of Oklahoma and Arkansas or in the Atoka; namely, *Paralegoceras texanum* (Shumard), *Phaneroceras compressum* (Hyatt), *Pharkidonotus*, n. sp., *Straparolus savagei* Knight, *Rayonnoceras* sp., and others. The fact that it overlies the Sloan formation, thought to be upper Morrow, and overlaps the Brook lentil with its well-developed fusulinids, not known in the Morrow, appears to be evidence that it is post-Morrow. It is thought to be, however, somewhat older than the Cherokee shale. The accompanying table shows the fossils of the Lemons Bluff beds, those that are common to the lower members of the Marble Falls, and those that occur in the Morrow of Oklahoma and Arkansas.

*Stratigraphic range of the Lemons Bluff fauna*

| Lemons Bluff Fauna | Sloan, Texas | Soldiers Hole, Texas | Morrow, Oklahoma | Arkansas | | |
|---|---|---|---|---|---|---|
| | | | | Hale | Brent-wood | Kessler |
| *Anthozoa* | | | | | | |
| Empodesma imulum Moore and Jeffords | — | — | — | — | — | — |
| Lophophyllidium extumidum Moore and Jeffords | — | x | — | — | — | — |
| Lophophyllidium idonium Moore and Jeffords | — | — | — | — | — | — |
| Paracaninia? sana Moore and Jeffords | — | — | — | — | — | — |
| Michelinia referta Moore and Jeffords | — | — | — | — | — | — |
| Striatopora religiosa Moore and Jeffords | — | — | — | — | — | — |
| Cladochonus texasensis Moore and Jeffords | — | — | — | — | — | — |
| Chaetetes favosus Moore and Jeffords | | x | — | — | — | — |
| *Brachiopoda* | | | | | | |
| Rhipodomella pecosii (Marcou) | — | — | x | — | x | — |
| Chonetes dominus R. H. King | — | x | — | — | ? | — |
| Chonetina sp. | — | — | — | — | — | — |
| Paeckelmannia derelicta R. H. King | — | — | — | — | — | — |
| Horridonia bullata (Mather) | — | — | — | — | x | — |
| Horridonia globosa (Mather) | x | x | x | — | x | — |
| Cancrinella boonensis (Swallow) | — | — | x | x | x | x |
| Marginifera welleri (Mather) | — | x | x | x | x | x |
| Marginifera haydenensis Girty | — | x | — | — | — | — |
| Linoproductus platyumbonus Dunbar and Condra | — | x | — | — | — | — |
| Linoproductus meniscus Dunbar and Condra | — | — | — | — | — | — |
| Avonia sublineata (Mather) | — | — | x | x | x | x |
| Pustula pusilla (Girty) | — | — | — | — | — | — |
| Buxtonia sp. | — | — | — | — | — | — |
| Echinoconchus semipunctatus (Shepard) | — | — | ? | ? | ? | ? |
| Dictyoclostus hermosanus (Girty) | — | — | — | — | — | — |
| Dictyoclostus morrowensis (Mather) | x | x | x | x | x | x |
| Leiorhynchus rockymontanum (Marcou) | — | — | — | — | — | — |
| Wellerella osagensis (Swallow) | — | — | — | — | — | — |
| Rhynchopora magnicosta Mather | x | — | — | — | x | — |
| Dielasma subspatulatum Weller | — | x | x | x | x | x |
| Spirifer matheri Dunbar and Condra | — | x | x | — | x | x |
| Spirifer occidentalis Girty | — | — | — | — | — | — |
| Spirifer opimus Hall | x | x | — | — | — | ? |
| Spirifer rockymontanus Marcou | — | x | x | — | x | x |
| Neospirifer cameratus (Morton) | — | x | — | — | — | — |
| Neospirifer goreii (Mather) | — | x | — | — | — | — |
| Composita ozarkana Mather | x | x | x | x | x | x |
| Composita ovata Mather | — | — | x | x | x | x |
| Composita deflecta Mather | x | — | x | — | x | — |
| Squamularia? perplexa (McChesney) | x | — | x | x | x | x |
| *Pelecypoda* | | | | | | |
| Solenomya, n. sp. | — | — | — | — | — | — |
| Solenomya subradiata Herrick | — | x | — | — | — | — |
| Pleurophorus subcostatus Meek and Worthen | — | — | — | — | — | — |
| Astarella varica McChesney | — | — | — | — | — | — |
| Leda bellistriata Stevens | — | — | — | x | — | — |
| Posidonomya fracta Meek | — | — | — | — | — | — |
| Posidonia sp. | x | — | — | — | — | — |
| Schizodus sp. | — | — | — | — | — | — |
| Acanthopecten coloradoensis (Newberry) | — | — | — | — | — | — |
| Aviculopecten, n. sp. | — | — | — | — | — | — |
| Aviculopecten coxanus Meek and Worthen | — | — | — | — | — | — |
| Allorisma terminale Hall | — | x | — | — | — | — |
| Allorisma costatum Meek and Worthen | — | x | — | — | — | — |

*Stratigraphic range of the Lemons Bluff fauna* (concluded)

| Lemons Bluff Fauna | Sloan, Texas | Soldiers Hole, Texas | Morrow, Oklahoma | Arkansas | | |
|---|---|---|---|---|---|---|
| | | | | Hale | Brent-wood | Kessler |
| *Gastropoda** | | | | | | |
| Worthenia tabulata (Conrad) | x | — | — | — | — | x |
| Straparolus savagei Knight | — | — | — | — | — | ? |
| Straparolus, n. sp. | — | x | — | — | — | — |
| Donaldina, sp. indet | — | — | — | — | — | — |
| Pharkidonotus, n. sp. | x | — | — | — | — | ? |
| Pharkidonotus percarinatus (Conrad) | — | ? | — | — | | — |
| Cymatospira, n. sp. | — | — | — | — | — | — |
| *Cephalopoda*—Nautiloidea | | | | | | |
| Ephippioceras divisum (White and St. John) | — | — | — | — | — | — |
| Coloceras sp. | — | — | — | — | — | — |
| Metacoceras sp. | — | — | — | — | — | — |
| Endolobus conchiferus (Hyatt) | — | — | — | — | — | — |
| Titanoceras sp. | — | — | — | — | — | — |
| Titanoceras illinoisense (McChesney) | — | — | — | — | — | — |
| Solenochilus branneri A. K. Miller, Dunbar, and Condra | — | — | — | — | — | — |
| *Cephalopoda*—Ammonoidea | | | | | | |
| Phaneroceras compressum (Hyatt) | — | — | — | — | — | — |
| Paralegoceras texanum (Shumard) | — | — | — | — | — | — |
| Branneroceras branneri (Smith) | — | — | x | ? | — | — |
| *Cephalopoda*—Orthoceratoidea | | | | | | |
| Rayonnoceras, n. sp. | — | — | — | — | — | — |

*All gastropods identified by J. Brookes Knight.

Only 10 species of the 70 identified from the Lemons Bluff member occur in the Sloan beds, 19 in the Soldiers Hole member, 14 in the Morrow of Oklahoma, 9 in the Hale, and 15 in the Brentwood of Arkansas, and 11 have been reported from the Kessler. Probably a somewhat larger number occurs in the Atoka of Oklahoma and Arkansas, but the fauna of the Atoka is not sufficiently well known at present to make worthwhile comparisons.

*Soldiers Hole lentil.*—The Soldiers Hole lentil is a massive reef-like series of limestone beds which form the upper layers of the Big Saline formation in Kimble, Mason, and McCulloch counties and are characterized by large fusulinids having the general aspect of *Fusulina llanoensis* Thomas and by globular colonies of *Chaetetes*. The lentil extends from Big Saline Creek in Kimble County to the Ellenburger ridges south of Hall near the San Saba-McCulloch County line. The limestone is everywhere coarsely crystalline, crinoidal, and in many places oolitic. The lentil is massively bedded and in places shows few bedding planes and everywhere is generally much lighter colored than the thin-bedded Lemons Bluff beds below. It contains much less chert, and the chert nodules where present are generally lighter in color than typical chert from the other members of the Big Saline. It is thought that this lentil or series of lentils represents a series of accumulations of detrital material in the upper part of the Marble Falls group of beds and that this facies should be thought of as a series of rather rapidly deposited reef-like accumulations of coarse and fine calcareous materials consisting of oolite, crinoid detritus, coral masses, etc. The lentils, because of their coarse texture and oolitic content, are in most places porous and permeable and constitute water-bearing and oil-bearing horizons in areas where the rock is beneath the surface. Sections showing stratigraphic relations and thicknesses of the Soldiers Hole lentil are shown in the columnar sections (Pl. 9) and in the accompanying table.

*Section measured at Onion Creek between Richards ranch road crossing and the iron bridge on the road between Sweden School and Satuit at Soldiers Hole 6 miles east and 2½ miles north of Brady* (Coord. K–15, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Soldiers Hole lentil— | | |
| 6. Limestone, light gray, almost white, massively bedded, crystalline, containing large fusulinids, corals, crinoid stems, and a few productids and many fairly large colonies of *Chaetetes.* The lower ledge is somewhat harder than the upper ledges; about 4 feet thick and strongly mottled with dark gray, almost black blotches | 28 | — |
| Lemons Bluff beds— | | |
| 5. Limestone, dark gray, almost black, weathering brownish buff and reddish buff; occurs in layers 6 to 40 inches thick separated by conspicuous bedding planes that permit it to break easily into building blocks and flagstones. The limestone is quite siliceous, contains large quantities of sponge spicules and numerous, fairly well-preserved fossils among which *Pharkidonotus* and large productids are most common | 30 | — |
| Brook lentil— | | |
| 4. Limestone, light gray, hard, poorly bedded; the beds 1 to 2 feet thick, finely oolitic | 5 | 6 |
| 3. Limestone, hard, massive, poorly bedded, crystalline, fossiliferous; contains numerous small fusulinids identified as *Fusulinella primaeva* (Skinner) | 4 | — |
| 2. Limestone, hard, black, poorly crystalline, containing numerous small, high-spired gastropods | 1 | — |
| 1. Shale, containing 2 or 3 layers of thin, ferruginous, nodular limestone and many limestone nodules of irregular shape 1 to 6 inches in diameter; in places quite fossiliferous but generally poorly exposed and covered by grass | 30 | — |
| Total thickness measured | 98 | 6 |

The fauna of the Soldiers Hole member is shown in the following list, and several characteristic species are shown on Plate 14. The corals are identified by Moore and Jeffords (1945), the gastropods by J. Brookes Knight, the Foraminifera by H. J. Plummer.

*Fossils from the Soldiers Hole member*

Foraminifera—
- Fusulina llanoensis Thomas
- Cribrostomum marblense H. J. Plummer
- Endothyranella armstrongi subsp. sobrina H. J. Plummer
- Endothyra distensa H. J. Plummer
- Polytaxis scutella (Cushman and Waters)
- Bradyina sp.

Anthozoa—
- Lophophyllidium extumidum Moore and Jeffords
- Amplexocarinia corrugata (Mather)
- Pseudozaphrentoides lepidus Moore and Jeffords
- Pseudozaphrentoides spatiosus Moore and Jeffords
- Rodophyllum texanum Moore and Jeffords
- Neokoninckophyllum simplex Moore and Jeffords
- Neokoninckophyllum gracile Moore and Jeffords
- Michelinia latebrosa Moore and Jeffords
- Chaetetes eximius Moore and Jeffords
- Chaetetes subtilis Moore and Jeffords
- Chaetetes favosus Moore and Jeffords

Brachiopoda—
- Orthotetes robusta (Hall)
- Orthotetes kaskaskiensis (McChesney)
- Chonetes dominus R. H. King
- Horridonia globosa (Mather)
- Marginifera gallatinensis (Girty)
- Marginifera haydenensis Girty
- Marginifera welleri (Mather)
- Linoproductus sp.
- Linoproductus platyumbonus Dunbar and Condra
- Dictyoclostus morrowensis (Mather)
- Spirifer matheri Dunbar and Condra
- Spirifer opimus Hall
- Spirifer rockymontanus Marcou
- Neospirifer cameratus (Morton)
- Neospirifer goreii (Mather)
- Punctospirifer transversa (McChesney)
- Composita ozarkana Mather
- Composita elongata Dunbar and Condra
- Composita trilobata Dunbar and Condra
- Composita gibbosa Mather
- Composita wasatchensis Mather
- Cleiothyridina orbicularis (McChesney)
- Schizophoria resupinoides (Cox)
- Roemerella sp.

Pelecypoda—
- Allorisma costatum Meek and Worthen
- Allorisma terminale Hall
- Solenomya subradiata Herrick

Gastropoda—
- Euphemites, sp. indet.
- Orthonychia, n. sp.
- Mourlonia, n. sp.
- Pharkidonotus, n. sp.

Ammonoidea—
- Pronorites llanoensis Plummer and Scott

*Brister Bluff lentil.*—Coarsely crystalline, crinoidal, and oolitic limestones overlie the Lemons Bluff member in synclinal areas in Lampasas and San Saba counties (Pl. 9). The strata are particularly well exposed in the upper part of the bluffs at Rough Creek near the crossing of the Bend-San Saba highway. These upper beds have the same large fossils, the same *Chaetetes* colonies, the same general appearance, and occur at the same stratigraphic positions as the Soldiers Hole limestone in McCulloch County; but strange to say, so far no large fusulinids have been found in them. One cannot, therefore, be certain that they are exactly the same age as the Soldiers Hole lentil.

One of the most striking features of the Brister Bluff beds is the presence of layers of limestone 3 to 10 feet or more thick having a distinctive mottled appearance. The markings consist of irregular-shaped black blotches 1 inch to 6 inches in size scattered through and over the surfaces of the limestone ledges. Some of the blotches have the shape of fucoids and look like flattened, bent, or curved broken pieces of large twigs. Still others are simply elongate blotches (Pl. 10B). These peculiar structures are thought by some to owe their dark color to disintegrated sponge masses and by others to marine algae. Similar mottled limestone occurs in the Soldiers Hole lentil and possibly at other horizons in the Big Saline formation. A description of the type section of the Brister Bluff lentil at Rough Creek is included below.

*Section of Marble Falls formation at Rough Creek crossing on Bend-San Saba road, from mouth of Pool Branch to top of escarpment north of highway, San Saba County* (Loc. 205–T–16; Coord. AA–16, Pl. 1).

| | THICKNESS *Feet* | *Inches* |
|---|---|---|
| Brister Bluff lentil— | | |
| 8. Limestone, white, massively bedded, weathers to large blocks and boulders which cap the top of the bluff; contains large crinoid stems, echinoid spines, large, nodular colonies of *Chaetetes* | 20 | — |
| Lemons Bluff member— | | |
| 7. Limestone, black, subcrystalline, weathering yellow, thin bedded; beds separated in some places by thin partings of shale. The limestone beds are 8 to 10 inches thick and have wavy nodular surfaces. The limestone, especially in the lower beds, is fossiliferous, contains large linoproductids, crinoids, spirifers, chonetids, and bryozoans. The upper layer contains numerous small turreted gastropods and a few specimens of *Pharkidonotus*, n. sp. | 43 | — |
| Aylor Bluff member— | | |
| 6. Limestone, dark gray, cherty, mottled, algal, subcrystalline, brittle. The chert is black and gray, nonfossiliferous. Some of the chert nodules are distinctly banded. The ledge forms a steep side of the cliff, and its top makes a prominent bench along the east side of the bluff which is on the north side of the mouth of Pool Branch | 7 | — |
| 5. Limestone, dark gray, weathering light gray, very cherty, extends to top of cliff, and upper surface forms a south-facing point on a prominent cliff north of Pool Branch | 32 | — |
| 4. Limestone, dark gray, thin bedded | 4 | — |
| 3. Limestone, gray, massive, forms middle portion of bluff north of mouth of Pool Branch | 17 | 6 |
| 2. Limestone, thin bedded. The beds are about 1 inch thick and weather to form a prominent recess near the base of the bluff north of mouth of Pool Branch | 1 | — |
| 1. Limestone, massive, weathers into small, rough chips and has a rough surface somewhat brecciated; forms prominent bluff crossing Pool Branch and having the appearance of a fault scarp. Contains at least one band of dense black, nodular chert. It is fossiliferous and contains large crinoid stems, productids, and chonetids | 24 | — |
| Total thickness measured | 148 | 6 |

The fossils of the Brister Bluff lentil have not been collected or studied in detail. In general, the brachiopods and corals appear to be quite similar to those collected and identified from the Soldiers Hole lentil. No fusulinids, however, have been found and Bryozoa are more common. The Bryozoa were all collected from the north bluff of Rough Creek above the Lemons Bluff member one-fourth of a mile downstream from the San Saba-Bend road crossing at locality 105-T-118. A list of bryozoans identified from the lentil by M. K. Elias is given below:

*Bryozoa from Brister Bluff lentil*
(identified by M. K. Elias)

Fenestella stabilis Elias, n. sp. (MS.)
Fenestella cf. cingulata Ulrich
Fenestella sp.
Phyllopora, n. sp., aff. cribrosa Mather
Septopora aff. crebripora Mather
Rhombopora cf. lepidodendroides
Sulcoretepora (Cystodictya) aff. occellata Ulrich
Sulcoretepora (Cystodictya) aff. lophodes Condra
Sulcoretepora, n. sp.
Prismopora parvipora Elias, n. sp. (MS.)
Amplexopora aff. cingulata Ulrich
Polypora (Polyporella), n. sp.[a]

[a]Location in stratigraphic section is in some doubt.

*Distinguishing characters of members of Big Saline formation.*—The chert in the Aylor Bluff beds is less fossiliferous, lighter colored, and in many places more speckled than that in the Lemons Bluff beds above. This speckled character, in which little, irregular gray or black blotches occur on a nearly white mass, is a criterion for distinguishing the Aylor Bluff member of the Big Saline. Another criterion for distinguishing the Aylor Bluff member is its oolitic content. Lentils and beds rich in oolites occur in many sections in this bed. The oolites are tiny, averaging 0.05 to 0.1 mm. in diameter, thin-walled, and have concentric structure when observed in cross section. In general, also, the Aylor Bluff member is more coarsely crystalline and has a much higher content of crinoid fragments, fewer sponge spicules, and less chert than the Lemons Bluff beds. The Lemons Bluff member is distinguished by its high silica content. The Sloan formation resembles the Lemons Bluff member of the Big Saline in its thin sections but generally has fewer sponge spicules, more productid spines, more large fossils, and fewer Foraminifera. The Brook member is distinguished by its minute fusulinids; the Soldiers Hole member is distinguished by its large fusulinids. As far as known, fusulinids do not occur in the Sloan or Lemons Bluff beds, but a *Pseudostaffella*-like form occurs in the Lemons Bluff. In many places, much black chert and some glauconite occur at the base of the Aylor Bluff member. The Soldiers Hole lentil is distinguished by its fossils, *Fusulina llanoensis* Thomas and *Fusulina*, n. sp.

*Paleontology of the Big Saline formation.*—Large colonies of *Chaetetes*, large long-range brachiopods, *Neospirifer cameratus* (Morton), *Dictyoclostus morrowensis* (Mather), *Linoproductus platyumbonus* Dunbar and Condra, and *Schizophoria resupinoides* (Cox) are most common and can be found mixed with fragments of large crinoid stems at almost any locality. Pelecypods and gastropods are rare. Fusulinids, especially *Fusulina llanoensis* Thomas, are common in nearly all exposures of the Soldiers Hole lentil west of the San Saba-McCulloch County line, but absent as far as known east of McCulloch County. All the brachiopods found in the Big Saline and most of the other fossils except the fusulinids and Bryozoa occur in greatest abundance in the Lemons Bluff member. It is thought that an unconformity exists in the section east of McCulloch County and that either the *Fusulinella primaeva*-bearing strata were not deposited or else deposited, elevated relatively, and removed by erosion before the overlying black Lemons Bluff beds were laid down. On King Branch and along Turkey Roost Creek on Sloan ranch in western San Saba County, the Lemons Bluff beds lie directly upon the Sloan beds or are separated by a lenticular layer of coarse cobble conglomerate containing *Chaetetes* and other fossils similar to those in the Aylor Bluff member. A preliminary list of the Big Saline fauna as a whole is given in the accompanying list, and a few of the typical species are shown on Plate 12.

The corals have been identified by Moore and Jeffords (1945); the fusulinids by N. L. Thomas (1931), Skinner (1931), Thompson (1942-A), and Dunbar (personal communication); the gastropods by J. Brookes Knight; and the Foraminifera by Helen J. Plummer. Occurrences of fossils in the Marble Falls group, by localities, are presented in chart 3 (in the pocket).

*Comparison of the faunas of the Big Saline and Sloan formations of Marble Falls group and the occurrence of the same species in correlative formations north and northeast of Texas.*

| Big Saline Fauna | Sloan, Texas | Morrow, Oklahoma | Arkansas | | |
|---|---|---|---|---|---|
| | | | Hale | Brentwood | Kessler |
| *Foraminifera* | | | | | |
| Fusulina llanoensis Thomas | — | - | — | | — |
| Cribrostomum marblense H. J. Plummer | — | x* | — | x | — |
| Millerella marblensis Thompson | — | — | — | x | — |
| *Anthozoa* | | | | | |
| Lophophyllidium extumidum Moore and Jeffords | — | — | — | — | — |
| Amplexocarinia corrugata (Mather) | — | — | x | — | — |
| Pseudozaphrentoides lepidus Moore and Jeffords | — | — | — | — | — |
| Pseudozaphrentoides spatiosus Moore and Jeffords | — | — | — | — | — |
| Rodophyllum texanum Moore and Jeffords | — | — | — | — | — |
| Neokoninckophyllum simplex Moore and Jeffords | — | — | — | — | — |
| Neokoninckophyllum gracile Moore and Jeffords | — | — | — | — | — |
| Michelinia latebrosa Moore and Jeffords | — | — | — | x | — |
| Chaetetes eximius Moore and Jeffords | — | — | — | — | — |
| Chaetetes favosus Moore and Jeffords | — | — | — | — | — |
| Chaetetes subtilis Moore and Jeffords | — | — | — | — | — |
| *Brachiopoda* | | | | | |
| Orthotetes robusta (Hall) | — | x | x | x | x |
| Orthotetes kaskaskiensis (McChesney) | — | — | — | — | — |
| Chonetes dominus R. H. King | — | — | — | — | — |
| Horridonia globosa (Mather) | x | x | — | x | x |
| Marginifera gallatinensis (Girty) | ? | x | x | — | — |
| Marginifera haydenensis Girty | — | — | — | — | — |
| Marginifera welleri Mather | — | x | x | x | x |
| Linoproductus sp. | — | — | — | — | — |
| Linoproductus platyumbonus Dunbar and Condra | — | — | — | — | — |
| Dictyoclostus morrowensis (Mather) | x | x | x | x | x |
| Spirifer matheri Dunbar and Condra | — | — | - - | — | — |
| Spirifer opimus Hall | x | x | x | x | x |
| Spirifer rockymontanus Marcou | — | x | x | x | x |
| Neospirifer cameratus (Morton) | — | — | — | — | — |
| Neospirifer goreii (Mather) | — | x | — | x | x |
| Punctospirifer transversa (McChesney) | — | x | x | x | x |
| Composita ozarkana Mather | — | — | x | x | — |
| Composita elongata Dunbar and Condra | x | — | — | — | — |
| Composita trilobata Dunbar and Condra | — | — | — | — | — |
| Composita gibbosa Mather | — | x | x | x | x |
| Composita wasatchensis Mather | — | — | — | — | — |
| Cleiothyridina orbicularis (McChesney) | x | — | — | — | — |
| Schizophoria resupinoides (Cox) | — | x | x | x | x |
| Roemerella sp. | — | — | — | — | — |
| *Pelecypoda* | | | | | |
| Allorisma costatum Meek and Worthen | — | — | — | — | — |
| Allorisma terminale Hall | — | — | — | — | — |
| Solenomya subradiata Herrick | — | — | — | — | — |
| *Gastropoda* | | | | | |
| Euphemites, sp. indet. | — | x | x | x | - |
| Straparolus, n. sp. | — | — | - | ? | - |
| Orthonychia, n. sp. | — | — | x | x | x |
| Mourlonia, n. sp. | — | — | - | | |
| Pharkidonotus, n. sp. | — | — | - | | - |
| *Cephalopoda* | | | | | |
| Pronorites llanoensis Plummer and Scott | — | — | | | |

*Morrow of Kansas.

It will be noted from this list of Big Saline fossils that 2 corals out of 11, 12 brachiopods out of 24, and 1 foraminifer also occur in the Morrow. It is also evident, however, that all these forms are long-range species which commonly occur in all three members of the Morrow, at least five of them occur in the Sloan below, and some occur in the Atoka group above. The fact that the Big Saline formation contains fossils unknown in the Morrow and many forms known in the Atoka and also in the Cherokee shales which overlie the Morrow group in Oklahoma indicates that at least part of the strata of the Big Saline are younger than Morrow. They have been placed in the Lampasas[6] division of the Pennsylvanian by Cheney (1940) and by Moore and Jeffords (1945). On the other hand, the ammonites in the Lemons Bluff member of the Big Saline appear to be somewhat older than the Atoka and more closely related to the ammonoid fauna in the Kessler limestone in southern Oklahoma thought by Decker[7] and Morgan (1924) to be in the Wapanucka. The best index fossils in the Big Saline beds are thought to be *Pronorites llanoensis* Plummer and Scott, *Fusulinella primaeva* (Skinner), and *Millerella marblensis* Thompson. Of these *Pronorites llanoensis* occurs in the Atoka, *Fusulinella primaeva* or a similar form occurs in the Derryan of New Mexico in strata thought to be younger than the Morrow, and *Millerella marblensis* is found in the Morrow of Arkansas and Oklahoma, but the exact range of this fusulinid in adjacent regions is unknown; it probably ranges throughout the Atoka, Derryan, and Morrow.

[6]Use of the term "Lampasas" to designate a division of the Pottsville in Texas is unfortunate. First, the type locality is designated by Cheney as the outcrops along the western border of Lampasas County. The western border of the county is Colorado River. The Colorado River exposures are the type locality for the Bend so long used by Texas geologists to signify a division of Pennsylvanian strata. Immediately west of the river and forming a part of the border region occur thick beds of alluvium and shales and sandstones of Strawn age. Four-fifths of Lampasas County is covered with Lower Cretaceous. The picturesque city of Lampasas is situated in the midst of the beautiful cut plain of the lower Comanchean strata made famous by the excellent descriptions of R. T. Hill. When any Texas geologist hears the word "Lampasas" he immediately thinks of Cretaceous prairies with their wide-open spaces. If a major division of the Pottsville is necessary the word Derryan, Atokan, or Bendian is much to be preferred. These words signify Pennsylvanian. Lampasas signifies Cretaceous.

[7]Personal communication to the author.

The following list gives the more important fossil localities in the Big Saline formation. They are arranged according to the different members of the formation.

#### Fossil Localities

Brook Lentil

**153–T–1 (I–19,** Pl. 1).—McCulloch County, 3.75 miles south of Brady courthouse and west of a bridge across branch on the old Brady-Mason highway now abandoned. It is reached by taking the new Brady-Mason highway and driving south a distance of 4.75 miles from Brady courthouse to the road leading east to Brook ranch. Drive down the Brook ranch road 0.3 of a mile to the old Brady-Mason highway, then walk or drive north on the old road 0.7 of a mile to an old abandoned iron bridge. The fossils are in the limestone outcrop on the west side of the bridge. This is a rather famous old locality where fossils were collected by Schuchert and which have been illustrated by Dunbar and Condra (1932).

**153–T–85 (J–17,** Pl. 1).—McCulloch County, 3 miles east and 1.5 miles south of Brady courthouse. It is reached by taking the old, southernmost Brady-Rochelle road, going due east from the north side of the courthouse square, following a main road going east to Brady Creek, crossing Brady Creek, and continuing east a distance of 2.6 miles from the courthouse; then turning due south and traveling 2 miles to the south end of Shropshire Lake. The fossils occur in the limestone west of the spillway.

**153–T–134 (I–19,** Pl. 1).—McCulloch County, 4½ miles south and 1¼ miles east of Brady courthouse near top of ridge on west side of old Brady-Mason road 0.3 of a mile south of the old concrete bridge across the creek about 0.6 of a mile northwest of Brook ranch headquarters. It is reached by taking the new Brady-Mason highway and driving south a distance of 4.75 miles from Brady courthouse on a road leading east to Brook ranch. Drive down the Brook ranch road 0.3 of a mile to the old Brady-Mason highway. Then walk or drive north on the old highway a distance of 0.4 of a mile to the top of the ridge. The fossils are in a limestone outcrop along the edge of the road. Small gastropods occur in great numbers and can be etched out of the rock with hydrochloric acid. This is the type locality from which the gastropods described by J. Brookes Knight were collected.

Lemons Bluff Member

**141–T–4 (II–20,** Pl. 1).—Lampasas County, 4 miles west and 1.5 miles south of Lampasas. It is reached by taking the Lampasas-Nix road, traveling a distance of 3 miles west of Lampasas and turning due south on the road to Espeyville and Nauna. Follow the road a distance of 2 miles; then take the left fork to the south of an old stone house at the fork of the roads and travel 0.9 of a mile to a house and windmill. Turn off sharply south to a dim pasture road leading to the Hollinbeck ranch and drive down the secondary ranch road a distance of about 0.8 of a mile to Espey Creek; then either walk down the creek or drive down the secondary road along the side of the creek to the Marble Falls outcrop. The fossils occur in the lower layer of the Marble Falls limestones exposed along the banks and in the bed of the creek. Several large nautiloids have been collected here.

**159–T–11 (H–35,** Pl. 1).—Mason County, 1.5 miles west and 1.3 miles south of White's Crossing on Llano River. It is reached by taking the White's ranch road west from White's Crossing a distance of 1.9 miles on a rather dim ranch road leading due south; follow this ranch road south a distance of about 1.6 miles to Bee Branch, the second branch to be crossed on this rough road. The fossils are plentiful in the limestone outcropping in the branch.

**205–T–1 (BB–18,** Pl. 1).—San Saba County, 0.9 of a mile southwest of Bend on the right bank of Colorado River. It is reached by taking the San Saba-Bend road from Bend and traveling a distance of 0.8 of a mile; then turn abruptly to the right and travel down to the flat Marble Falls ledges which slope down to the river. The fossils are in the black shale at the water's edge. Some trilobites occur in the limestone at the contact with the upper black shale layers.

**205–T–46 (V–15,** Pl. 1).—San Saba County, 3.5 miles west and 1.25 miles south of the San Saba courthouse. It is reached by taking the San Saba-Brady road and turning off at the road fork, a distance of 2.5 miles; then taking the south fork and traveling on the San Saba-Wallace Creek road a distance of 1.25 miles to Flat Branch and walking south a distance of 0.2 of a mile from the bridge to a cut in an old abandoned road. The fossils occur in black, shaly limestone and shale which is believed to be at the Marble Falls-Smithwick contact.

**205–T–59 (W–15,** Pl. 1).—San Saba County, quarry in southeast edge of town of San Saba southwest of San Saba Springs. It is reached by taking the San Saba-Chappel road from the courthouse square and driving southeast to the last street running east to the east edge of the city limits north of San Saba Springs and driving east to the quarry which is a prominent pit in the Marble Falls limestone. The fossils are in a thin black shale parting in the bottom of the quarry, between the Lemons Bluff and Aylor Bluff members. It is uncertain to which member the shale belongs.

**205–T–67 (S–15,** Pl. 1).—San Saba County, 2.5 miles south and 3 miles west of Algerita on the north bank of San Saba River. It is reached by taking the San Saba-Brady road to Algerita, traveling 2.25 miles, and turning due south to Leonard's ranch. Then follow the road south again 0.25 of a mile to a road fork and turn southeast, proceeding 0.6 of a mile to the Ellis Crossing on San Saba River. The fossils are in the limestone and shale breaks along the bluff just west of the road crossing. The locality can also be reached by taking the San Saba-Brady road to Harkeyville, turning south on the San Saba-Sloan Community road, and traveling a distance of 8 miles to Ellis ranch road. Finally, turn due north on the Ellis ranch road to the river and ford over to the north side. The crossing is difficult and somewhat dangerous when the river is high.

**205–T–75 (U–16,** Pl. 1).—San Saba County, 6.5 miles west and 2 miles south of San Saba, or 1.75 miles west and one-quarter of a mile north of Wallace Creek School. It is reached by taking the San Saba-Brady road, traveling a distance of 2.5 miles from the courthouse, and turning southwest on the San Saba-Wallace Creek road. Follow the road 2.5 miles southwest, turn west for a distance of 1 mile, and then go southwest on the old San Saba-Mason road about 1.8 miles from Wallace Creek bridge. The fossils are on the north side of the creek in a low bluff of black shale and thin black limestones about 300 feet north of the road. The lithology and fauna are very similar to the locality on Colorado River, 1 mile west of Bend.

**205–T–116 (BB–19,** Pl. 1).—San Saba County, 2.1 miles south and 2 miles west of the town of Bend at the top of the bluffs on the east bank of Cherokee Creek. It is reached by taking the Bend-Chappel road to the second crossing of Cherokee Creek, then stopping on the north side of the creek and walking down the east bank a distance of about one-third of a mile. The best collection is in the upper thin layers of the limestone south of an east-west fence.

**205–T–117 (AA–19,** Pl. 1).—San Saba County, 0.3 of a mile north and 0.25 of a mile west of the schoolhouse at Chappel. It is reached by taking the Chappel-San Saba road to the road fork about 0.25 of a mile west of Chappel schoolhouse and walking up the hill to the first limestone outcrop which dips steeply east. The fossils are in the first limestone layer on the north side of the road. The ledges here contain large numbers of the fusulinid *Pseudostaffella* sp.

Soldiers Hole Lentil

**134–T–2 (D–35,** Pl. 1).—Kimble County, 3.25 miles east and 3.5 miles south of London, at the mouth of Big Saline Creek on the north bank of Llano River. It is reached by taking the London-Junction road and traveling 0.7 of a mile southwest from the center of London, on a road running due south past the cemetery. Go 0.5 of a mile to a road corner, then turn east 1 mile to the second road corner and ranch gate. Proceed east through the gate and follow Pfluger ranch road east across Saline Creek and southeast to Pfluger ranch house. The locality is on the north bank of Llano River, on the east side of Big Saline Creek, 0.3 of a mile due south of the old ranch house. The best fossils have been collected from a prominent shale break in the face of the limestone bluff. This is the type locality of the Big Saline member.

**134–T–6 (C–34,** Pl. 1).—Kimble County, 2.5 miles south and 2 miles east of London near the base of the bluff on the south side of Big Saline Creek, 0.3 of a mile north and 0.2 of a mile west of the north goat sheds and windmill on Morgan ranch. It is reached by taking the London-Junction road and traveling southwest 0.7 of a mile, then taking the road due south by the cemetery a distance of 0.5 of a mile to a road corner, turning east and going 1 mile to a second road corner, and then turning due south on the road to Morgan ranch. The Morgan ranch headquarters are 1 mile south of the road corner. Go by the ranch house and southeast on a secondary ranch road; take all road forks leading to the left and travel a distance of 1.75 miles to the goat shed and windmill, then go due north down a small branch 0.3 of a mile to Big Saline Creek. Walk up the creek 0.2 of a mile along the steep bluff. The best fossils were obtained in a shale break near the base of the bluff. The locality can also be reached by following the directions given for 134–T–2, proceeding to Pfluger ranch house, and then walking up Big Saline Creek a distance of 2 miles. The trip up Big Saline canyon is long but very interesting as there are fine fossiliferous exposures along the canyon.

**134–T–22 (D–32,** Pl. 1).—Kimble County, 3.6 miles south and 0.3 of a mile west of Erna. It is reached by taking the Mason-London road to Erna, a small hamlet on the Mason-Menard County line. Travel due south on the Erna-Eckert ranch road 4 miles to the L. B. Eckert windmill, then walk due west across the pastures 0.6 of a mile, following a small west fork of Cedar Creek at the wire fence between the Eckert and Slater pastures. The fossils are in the white limestone in the creek bed beneath and near the fence line. The fossils are numerous and rather well preserved.

**153–T–40 (M–14,** Pl. 1).—McCulloch County, 2.75 miles east and 1.5 miles south of Rochelle in Little Brady Creek, 0.25 of a mile east of Smith ranch house. It is reached by taking the road going southeast from Rochelle to Rochelle cemetery a distance of about 2 miles. Then go due south 0.7 of a mile to a road corner, turn due east, and follow the road exactly 1 mile. Then continue east on a rather poor ranch road to the Smith ranch headquarters a distance of 0.4 of a mile from the last road corner, and walk east 0.2 of a mile to Little Brady Creek. The locality is in the limestone ledge in the bottom and along the sides of the creek. This is the easternmost locality from which the *Fusulina llanoensis* Thomas has been collected.

**153–T–77 (I–18,** Pl. 1).—McCulloch County, about 2 miles south and 2 miles east of Brady courthouse on the south side of Brady Creek. It is reached by taking the Brady-Voca road and traveling southeast from Brady courthouse a distance of 3.5 miles to where the road changes from the southeast direction to a nearly east direction; then walk north 0.6 of a mile along an east-facing Marble Falls escarpment and east 0.2 of a mile to a rather pronounced, small, isolated hill about 700 feet south of Brady Creek. The fossils occur in shales around the foot of the slope on the cone-shaped hill.

**159–T–1 (I–33,** Pl. 1).—Mason County, 4.5 miles south and 4.75 miles west of Mason courthouse. It is reached by taking the Mason-White's Crossing road to Honey Creek, a distance of about 8 miles from Mason courthouse, then walking up the creek 0.2 of a mile to the Ellenburger-Barnett contact. The fossils occur in the limestones in the bottom and along the banks of the creek especially on the east side. The lower ledges containing the fusulinids are thought to be in the Big Saline member. The upper yellow ledges near the road are in the Lemons Bluff member.

### Brister Bluff Lentil

**141–T–15 (JJ–20,** Pl. 1).—Lampasas County, three-fourths of a mile west and 1¾ miles south of Lampasas. On the banks and in the north bed of a small creek beneath an electric power high line and near an old railroad right-of-way in gray limestone above the Lemons Bluff beds.

**205–T–118 (AA–17,** Pl. 1).—San Saba County, south of San Saba about one-fourth of a mile due east of San Saba-Bend road crossing on Rough Creek and 4½ miles in a straight line due northwest of Bend. The fossils are in the limestone on the north side of Rough Creek opposite Holland Spring cascade. The fossils occur in the light-gray layers of the Brister Bluff member above the yellow limestone beds of the Lemons Bluff member. Bryozoa are conspicuous.

## SMITHWICK FORMATION

*Historical account.*—The Smithwick formation was named by Sidney Paige (1911) for the old town of Smithwick in Burnet County. The formation was defined by him to include the black shales and lenticular sandstone strata exposed in the Burnet quadrangle between the Marble Falls formation and overlying Cretaceous deposits east of Marble Falls. He designated the type locality as the exposures along Colorado River southwest of old Smithwick (Pl. 15A) situated on the north bank of Colorado River at Smithwick Bend, 2.1 miles southwest of the present town of that name. The locality was the site of an old mill and two-story stone building, built by Noah Smithwick in 1857. During 50 years, this historic old building was used as a general store and for Masonic Lodge meetings, although the mill had long since disappeared. In 1940, due to the rise of the waters in Lake Travis, the building was abandoned.

Shale is exposed along Wall Bluff on the south side of the river west of Smithwick Bend. It rests unconformably upon an eroded surface of the Marble Falls limestone at the mouth of Doublehorn Creek and dips eastward at an angle of 3 to 5 degrees for a distance of nearly half a mile, as shown in the cross section, Plate 16, and photographs, Plate 15. This excellent exposure of nearly 600 feet of continuous section is within the area submerged by the waters of Lake Travis back of Mansfield (formerly Marshall Ford) dam, so that this splendid locality has been partially drowned.

Since the work of Paige, the name Smithwick has been used in the publications of Udden, Baker, and Böse (1916, p. 43), Girty (1909, p. 71), Moore (1919, p. 217), Plummer and Moore (1922, p. 55), Sellards (1935, p. 101), and Cheney (1940, p. 80) to distinguish the black shale beds above the Marble Falls formation and below the sandstones and sandy shales of the Strawn group (Middle Pennsylvanian). Cheney (1940, pp. 66, 80) recently proposed changing the rank from formation to group and including it in his Lampasas series.

The Smithwick formation, as now defined, at the type locality includes the strata above the Brister Bluff lentil and Lemons Bluff beds with their abundance of sponge spicules and typical Bendian fauna and below typical Strawn beds carrying a Des Moines fauna. Through west and central San Saba County, it includes all the shale below the Strawn group and above the black Marble Falls limestone. In eastern San Saba County near Bend, the basal Smithwick is 60 feet above the top of the limestone, and the base is marked by the first appearance of the coral *Hadrophyllum aplatum* Cummins, now named *Cumminsia aplata* (Cummins) by Moore and Jeffords.

*Extent and thickness.*—The outcrop of the Smithwick formation is shown on the map (Pl. 1). It is best exposed on the southeast side of the region along the Colorado River bluffs and on the north side of the region in Cherokee, San Saba, and Wallace Creek valleys, and near Long Valley. It appears to be absent in outcrop in McCulloch County west of Long Valley and west of Rochelle. Around Brady it is overlapped by Strawn and Canyon beds. It is present in Honey Creek valley southwest of Mason and possibly in Kimble County southeast of London. In the subsurface, it is thought to be present in most wells drilled north of the region, except perhaps in some of the holes drilled on top of the highest structures. No Smithwick has been found, for example, on the structure southwest of Lampasas. Its thickness varies from a few feet to 600 feet (Pl. 16). It has been stated by Jones (1929) and others that the Smithwick thickens markedly in subsurface sections east and northeast of the region. At least some of the apparent thickening probably is due to change in facies of the Marble Falls from limestone to shale east of the region. Furthermore some of the thick shale sections in wells may include Strawn shales resembling Smithwick. The shale is thickest in the structural synclines and thinnest on the anticlines and buried ridges. It appears that deformation and faulting of the Carboniferous strata in this region commenced before the end of Marble Falls time and that the Smithwick accumulated in greater amounts in the troughs and grabens during and following the deformation. The shales overlap on to the buried ridges and around the rim of the troughs exemplified by Cherokee Valley and Long Valley. In several places, the transgression of black shale strata is marked by an angular unconformity and basal conglomerate.

*Lithology.*—The Smithwick shale is a black, fissile, siliceous shale that in most places is unfossiliferous but at a few places contains an ammonoid and gastropod fauna quite unlike the Sloan fauna, somewhat similar to the Big Saline fauna, and quite similar to that of the Atoka formation of Oklahoma. At the type locality on Colorado River the shale near its base contains *Ambocoelia, Lingula, Orbiculoidea,* and other minute fossils. Above, the formation consists of a thick section of black, soft, slightly ferruginous and gypsiferous, unfossiliferous shale containing thin lentils of firmly cemented, hard siltstone, displaying on its bedding surfaces, impressions of plant leaves, stems, animal tracks, and trails. Southwest of Bend along the Colorado River bluffs in San Saba County, the lower few feet of beds of the Smithwick are fossiliferous, soft, very thinly laminated, black shale. These are overlain by nonfossiliferous shale containing at the top thin, hard beds of siltstone 2 to 12 inches thick, marked by tracks and trails. In Wallace Creek valley southwest of San Saba (Pl. 15B), the shale is dense, black, soft, and contains numerous ferruginous concretions but less siltstone. Three miles east of Rochelle, along the bluff east of the Rochelle conglomerate escarpment, the soft black shale contains many limonite concretions and is quite fossiliferous. The fauna is characterized by the well-known ammonoid *Gastrioceras smithwickense* Plummer and Scott. Along Honey Creek southwest of Mason, south of the highway, the shale is black, fissile, ferruginous, and the lower 50 feet are fossiliferous. The upper layers are covered largely by gravel from a stream deposit, and no siltstones have been observed.

The accompanying sections give other details concerning typical exposures of this formation.

*Section of Smithwick formation along Colorado River at its type locality west of Smithwick, measured from Marble Falls limestone outcrop on Wall ranch eastward to river bank opposite old Smithwick* (Coord. JJ–38, Pl. 1).

| | THICKNESS *Feet* |
|---|---|
| 7. Sandstone, brownish gray, hard, calcareous, uniformly grained, evenly bedded, occurs in beds 10 to 12 inches thick; weathers out into large slabs which are piled up on the surface by the flood waters of Colorado River in a conspicuous rock pile and which would furnish an excellent building stone. The surfaces of the slabs are ripple marked. The ripples are mostly of the type of stream current ripples, but some slabs show beautiful wave ripples. The beds dip east about 14 degrees and occur in overlapping layers. The total thickness is difficult to measure because of the rock-pile covering. It is at least 30 feet and may be as much as 42 feet thick. The bed appears to thicken eastward toward the fault and to thin out into a thin ledge of 3 feet, or less, to the west | 30 |
| 6. Shale, grayish black, soft, silty, weathers to greenish-gray color, and contains some thin siltstone layers 1 inch or less thick. The exposure for the most part is covered by Colorado River terrace gravel and slump blocks of the overlying sandstone, and soil | 30+ |
| 5. Sandstone, brownish gray, in places yellowish gray, streaked and stained with brown and black ferruginous material, uniformly grained, fairly even textured, calcareous, hard, much jointed. Some areas weather to rough, rounded surfaces; other areas break into blocks and slabs. The surface of the slabs shows current markings and very commonly casts of clay balls. Some surfaces are covered with rounded pits 2 to 3 inches in diameter and colored with ferruginous stains. One slab shows indistinct ripple marks of the river-current type. Other surfaces show the characteristic plant stems(?) and worm(?) markings so common in Smithwick sand layers. The sandstone has slumped down the soft shale slope in great blocks. The most characteristic feature of the sandstone is the intricate joint lines, many of which have been filled with calcareous veinlets. The thickness of the sandstone varies from 18 or 20 feet at the east to 0 at the west. The slump blocks near the middle of the lentil vary from 3 to 6 feet in thickness. Average estimated thickness | 8 |
| 4. Conglomerate, the lower slab of the sandstone lentil is composed of brown, ferruginous conglomerate. The layer is made up of pebbles and cobbles of siltstone and sandstone and ferruginous concretions derived from the Smithwick along with a few banded chert pebbles of unknown origin and a few pebbles from the Ellenburger. The pebbles are rounded and subangular. The smaller pebbles, which are most numerous, average ½ to ¾ of an inch. Larger ones are 1½ to 2 inches. The average thickness is | 1 |
| 3. Shale, black, weathering greenish gray, soft, silty, beautifully laminated, containing a few thin limonite seams a fraction of an inch in thickness and a few limonite concretions. In places the shale shows cross-bedding | 140 |

| | THICKNESS *Feet* |
|---|---|
| 2. Sandstone lentil, small siltstone lentil 4 feet thick and 50 feet long, thinning at each end. Hard, calcareous, fine-grained sand, almost a silt, containing many impressions of plant stems, broken by many cracks and joints; dips east about 6° | 1 |
| 1. Shale, coal-black, fissile, hard, splintery, unfossiliferous except at very base where one or two small gastropods have been collected, much jointed, but containing no concretions. It rests apparently conformably upon Marble Falls limestone. The upper surface of the limestone is uneven, showing solution cavities and has a brown oxidized color appearing to have been weathered before the shale was deposited | 88 |
| Total thickness measured | 301 |

*Subdivisions.*—The Smithwick shale has not been subdivided into members. The lower 50 to 75 feet of the Smithwick contains marine fossils and was certainly laid down in marine waters. The upper portion appears to have been deposited in shallow littoral waters where fine silts were spread over the black mud and where ripple marks and tracks of marine animals and plants could be preserved and fossilized. Three facies in the Smithwick sediments can be recognized as follows:

Siltstone facies
Fissile black shale facies
Conglomerate facies

The conglomerate is found between the black shale and Marble Falls limestone where upper black shale overlaps on to anticlinal structures and buried ridges. The black shale facies is the normal facies and occurs in most places where the Smithwick formation outcrops. The siltstone facies occurs near the top of the formation, rarely near the middle, and represents, it is thought, a shallowing of the Smithwick sea toward the end of the Smithwick epoch.

*Microscopic characteristics.*—The Smithwick shale is generally a rather hard, brittle, subcrystalline, siliceous shale consisting of the following minute mineral grains: montmorillonite, kaolinite, chlorite, mica, quartz, limonite, pyrite, and organic material. Most of the particles are less than 0.002 mm. in diameter and can be identified only by petrographic methods. The shale grades upward into somewhat more silty, more ferruginous, and more calcareous shale containing the lentils of siltstone.

*Distinguishing features.*—The Smithwick shale is distinguished from the black shale of the Marble Falls formation below and the blue-gray shales of the Strawn group above by the following criteria:

1. The Smithwick contains no hard limestone beds and may contain lentils and more or less continuous layers of hard siltstone. The siltstone is harder and less friable than the sandstones of the Strawn. The surfaces of the hard siltstones are covered by numerous tracks of marine animals, and impressions of plants. The Strawn sandstones are coarser, have less smooth surfaces, and much fewer and less well-preserved organic markings.
2. The shale layers from the Strawn are softer, disintegrate more quickly in water, and are more calcareous.
3. The Smithwick in places contains rather large, brick-red ferruginous concretions, some of which are pseudomorphous probably after marcasite or pyrite. The Strawn shale in places contains small, hard limonite concretions commonly called ironstones, but rarely contains the red concretions.
4. The Smithwick is generally blacker, more fissile, and contains a larger proportion of organic matter, more silica, and less of calcium carbonate than the Strawn shales.
5. The fossils of the Smithwick, where present, are distinctive, and such forms as *Cumminsia aplata* (Cummins), *Gastrioceras smithwickense* Plummer and Scott, and *Paeckelmannia derelicta* R. H. King enable one to distinguish the Smithwick easily from the Marble Falls or Strawn.

*Paleontology.*—The fauna of the Smithwick is less well known than that of almost any other Carboniferous formation in the Midcontinent. With the exception of the ammonoids (Plummer and Scott, 1937), chonetids (R. H. King, 1938), crinoids (Moore and Plummer, 1940), and corals (Moore and Jeffords, 1945), no detailed paleontologic studies have been undertaken, and many of the species are new to science. The fauna in general is that which belongs in a black carbonaceous shale facies. Large gastropods (bellerophons, euomphalids, and others) and pelecypods (*Nuculana, Yoldia,* and others) predominate; brachiopods are in the minority; ammonoids, many preserved as pyrite or hematite casts, are found at a few localities. The greater part of the shale section is barren of mollusks or other animal remains. A few of the species are shown on Plate 7.

Two different fossil assemblages occur within the Smithwick formation. Both are found within 75 feet of the top of the Marble Falls limestone. The two assemblages, however, have never been found in the same section, and since the Smithwick sediments transgress and overlap on to structural ridges of older rock, the lower beds of Smithwick shale in different sections do not represent the same age. Accordingly these two different assemblages undoubtedly are from different zones and represent different periods of deposition. They are as follows:

1. *Cumminsia aplata* zone.—Found in the lower part of the Smithwick shale across northern San Saba County, occurring at 0 to ±25 feet above the Marble Falls.
2. *Gastrioceras smithwickense* zone, which has been found at only a few localities and is thought to belong, when present, at about 50 to 75 feet above the base of the formation. It occurs at Bend on Colorado River and at a locality 3 miles east of Rochelle in McCulloch County at a horizon thought to be about 50 feet above the top of the Marble Falls formation. Unfortunately exposures in the Smithwick are generally poor, and fossils from this zone are rare.

The accompanying chart presents the Smithwick species by localities, and the most typical of these are shown in Plate 17. The list is incomplete but will serve to give a fair idea of the character of the fauna. Final and more comprehen sive studies will add many new species and may change markedly the interpretation and correlations based on these preliminary studies. The corals have been identified by Moore and Jeffords (1945), and the gastropods by J. Brookes Knight.

#### Fossil Localities

The more important fossil localities from which the Smithwick fauna has been collected are listed below:

**27–T–7 (JJ–38,** Pl. 1).—Burnet County, 6 miles southeast of Marble Falls on the south bank of Colorado River, 1.75 miles east of Doublehorn School. It is reached by taking the highway south from Marble Falls, turning east 1.5 miles south of the Marble Falls bridge, then turning east again 0.9 of a mile south of the road fork and 0.1 of a mile south of Flat Rock Creek. Drive to Doublehorn School, and continue southwest from Doublehorn School a distance of 2.5 miles to Rockvale Church; travel 1 mile southeast of Rockvale Church to a gate and pasture road leading north a distance of 3 miles to Colorado River. The locality is on the south bank of the river at the contact of Smithwick and Marble Falls limestone. The locality probably will be covered by the water of Mansfield dam (Marshall Ford) reservoir (Lake Travis) when the reservoir is full.

**153–T–6 (M–14,** Pl. 1).—McCulloch County, 3.5 miles due east of Rochelle, 0.9 of a mile south of Rochelle-San Saba highway. It is reached by driving east on the Rochelle-San Saba highway 3.5 miles to a gate and a road leading south from the point where the highway curves northward; drive 0.5 of a mile down the pasture road, then walk south along the north-south fence line a distance of 0.4 of a mile. The locality is about 500 feet east of the fence in shale exposures at the south end of a rather steep bluff capped with gravel.

**159–T–9 (I–33,** Pl. 1).—Mason County, 7 miles southwest of Mason on the south bank of Honey Creek, 2,000 feet south of locality 159–T–23. It is reached by walking down the creek 2,000 feet south of the White's Crossing road to the point where the creek turns abruptly southwest. The locality is in shale on the south bank of the creek.

**159–T–23 (I–33,** Pl. 1).—Mason County, 7 miles southwest of Mason on the south side of White's Crossing road at Honey Creek. It is reached by taking the Mason-White's Crossing road and driving a distance of 7 miles to Honey Creek. The locality is in black shale at the water's edge at the south edge of the road, just south of the concrete slab.

**159–T–24 (I–33,** Pl. 1).—Mason County, 8 miles southwest of Mason and 0.5 of a mile northeast of White's Crossing. It is reached by taking the Mason-White's Crossing road and driving 8.5 miles to a point where Honey Creek cuts closely to the south side of the highway, then walking down Honey Creek about 0.1 of a mile to the prominent exposure of black Smithwick shale at the curve in the creek. The fossils are in the shale on the west side of the stream near the base of the exposure.

# Smithwick Fauna

| | 67-T-14 | 55-T-33 | 134-T-1 | 134-T-5 | 134-T-9 | 153-T-6 | 153-T-56 | 159-T-8 | 159-T-9 | 205-T-1 | 205-T-4 | 205-T-13 | 205-T-26 | 205-T-50 | 205-T-71 | 205-T-76 | 205-T-77 | 205-T-79-A | 205-T-112 | Honey Cr. Llano Co |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTHOZOA | | | | | | | | | | | | | | | | | | | | |
| *Hapsiphyllum tumidum* Moore & Jeffords | | | | | | | | | | | | | | | X | | | | | |
| *Hapsiphyllum retusum* Moore & Jeffords | | | | | | | | | | | | | | | | | | | | X |
| *Zaphrentoides eccentricus* Moore & Jeffords | | | | | | | | | | | | | | X | | | | X | | |
| *Cumminsia aplata* (Cummins) | | | | | | X | | | | X | | X | | X | X | | | X | | |
| *Michelinia referta* Moore & Jeffords | | | | | | | | | | | | | | | X | | | | | |
| *Palaeacis testata* Moore & Jeffords | | | | | | X | | | | | | | | | | | | | | |
| *Zaphrentis* sp | | X | | X | | | | | | | | | | | | | | | | |
| *Neokoninckophyllum arcuatum* Moore & Jeffords | | | X | | | | | | | | | | | | | | | | | |
| BRYOZOA | | | | | | | | | | | | | | | | | | | | |
| *Fenestella* cf *F. regalis* Ulrich | | X | | | | | | | | | | | | | | | | | | |
| BRACHIOPODA | | | | | | | | | | | | | | | | | | | | |
| *Orbiculoidea missouriensis* (Shumard) | | | | | | | | X | | X | | | | | | | | | | |
| *Paeckelmannia derelicta* King | | | | | | X | | | | X | | X | | | X | | X | | | |
| *Linoproductus* sp. | | X | | | | | | | | | | | | | | | | | | |
| *Marginifera muricatina* Dunbar & Condra | | | | | | X | | | | | | | | | | | | | | |
| *Dictyoclostus portlockianus* (Norwood & Pratten) | | | | | | X | | | | | | X | | | | | | | | |
| *Wellerella osagensis* var *immatura* Dunbar & Condra | | | X | | | | | | | | | | | | | | | | | |
| *Ambocoelia planoconvexa* (Shumard) | X | X | | X | | X | | | | X | | | | | | | | X | | |
| *Cleiothyridina* sp | | X | | X | | | | | | X | | X | | | | | | | | |
| *Cleiothyridina sublamellosa* (Hall) | | X | | X | | | | | | X | | X | | | | | | | | |
| *Hustedia brentwoodensis* Mather | | | | X | | | | | | | | | | | | | | | | |
| *Juresania nebrascensis* (Owen) | | | | | | | | | | | | X | | | | | | | | |
| PELECYPODA | | | | | | | | | | | | | | | | | | | | |
| *Solenomya* sp. | | X | | | | | X | | | | | | | | | | | | | |
| *Edmondia ovata* Meek & Worthen | | X | | | | | X | | | | | | | | | | | | | |
| *Edmondia glabra* Meek | | | | | | | | | X | | | X | | | | | | | | |
| *Nucula*, n. sp. | | | | | | | | | | | | X | | | | | | | | |
| *Nucula*, n sp | | X | | | | | | | | | | | | | | | | | | |
| *Nuculopsis ventricosa* (Hall) | | X | | | | X | | | | | | | | | | | X | X | | |
| *Nuculana bellistriata* (Stevens) | X | | | | | X | | | X | | | X | | | | | | | | |
| *Nuculana*, n sp | | X | | | | X | | | X | | | | | | | | | | | |
| *Nuculana arata* (Girty) | | X | | | | | | | | | | | | | | | | X | | |
| *Conocardium* ? *sniderii* Morgan | | X | | | | X | | X | | | | X | | X | X | | | | | |
| *Allorisma* sp | | | | | | | | | | | | | | | | | | | | |
| GASTROPODA | | | | | | | | | | | | | | | | | | | | |
| *Pharkidonotus*, n sp | X | X | X | X | X | | | | | X | X | X | | X | X | | | | | |
| *Euphemites*, n sp | | | | | | | | | | X | | | | | | | | | | |
| *Neilsonia*, n sp | | X | | | | X | | | X | X | | X | | | | | | | | |
| *Glabrocingulum*, n sp | X | X | | X | | X | | | | X | X | X | | | | | | | | |
| *Trepospira*, n sp | X | | | | | | | | | | | | | | | | | | | |
| *Goniospira* sp | | | | | | | | | | | | | | | | | | X | | |
| New g and new sp | | X | | | | X | | | X | | | | | | | | | X | | |
| *Straparolus savagei* Knight | | X | | | | X | | X | | X | | X | | X | X | | | X | | |
| *Amphiscapha subquadrata* (Meek & Worthen) | | | | X | | | | | | | | | | | | | | | | |
| *Straparolus*, n. sp. | | | | | | | | | | | | X | | | X | | | X | | |
| *Soleniscus (Macrocheilina) ventricosus* (Hall) | | X | | | | | | | | | | | | | | | | X | | |
| New g and n sp | | X | | | | X | | | X | X | | X | | | | | | | | |
| CEPHALOPODA | | | | | | | | | | | | | | | | | | | | |
| Pseudorthoceratidea | | | | | | | | | | | | | | | | | | | | |
| *Orthoceras wapanuckense* Girty | | | | | | | | | | | | | | | | | | X | | |
| *Pseudorthoceras knoxense* (Mc Chesney) | X | X | | | | | | | | X | | X | | X | | | | | | |
| *Mooreoceras normale* Miller, Dunbar, & Condra | | | | | | X | | | | | | | | | | | | | | |
| *Bactrites postremus* Miller | | X | | | | X | | | | | | | | | | | | | | |
| *Dolorthoceras*, n sp | | | | | | | | | | | | | | | | | | | | |
| *Dolorthoceras*, n sp | | | | | | X | | | | | | X | | X | X | | | X | | |
| *Rayonnoceras hueconense* Miller, Dunbar, & Condra | | | | | | | | | | | | X | X | | | | | | | |
| Nautaloidea | | | | | | | | | | | | | | | | | | | | |
| *Brachycycloceras normale* Miller, Dunbar, & Condra | | X | | | | X | | | | | | | | | | | | | | |
| *Coloceras* sp | | | | | | | | | | | | | | | | | | | | |
| *Liroceras liratum* (Girty) | | X | | | | | | | | | | | | | | | | | | |
| *Temnocheilus* sp | | X | | | | | | | | | | | | | | | | | | |
| *Metacoceras* sp | | X | | | | X | | | | | | | | | | | | | | |
| *Solenochilus* sp | | X | | | | | | | | | | | | | | | | | | |
| Ammonoidea | | | | | | | | | | | | | | | | | | | | |
| *Pronorites* sp | | | | X | | | | | | | | | | | | | | | | |
| *Pronorites arkansasensis* Smith | X | X | | | | X | | | | | | | | | | | | X | | |
| *Daraelites (Boesites) scotti* Miller & Furnish | | X | | | | X | | | | | | X | | | | | | | | |
| *Nuculoceras smithwickense* Plummer & Scott | | | | | | X | | | | | | | | | | | | | | |
| *Phaneroceras compressum* (Hyatt) | | X | | | | | | | | X | | X | X | | | X | | X | | |
| *Paralegoceras* sp | | | | | | | | | | | | | | | | X | | X | X | |
| *Paralegoceras shumardi* (Plummer & Scott) | | | | | | | | | | | | | X | | | | | | | |
| *Glaphyrites hyattianus* (Girty) | | | | | | | | | | | | | | | | | | X | | |
| *Glaphyrites angulatus* (Girty) | | | | | | X | | | X | | | | | | | | | | | |
| *Glaphyrites raymondi* Plummer & Scott | | | | | X | | | | | | | | | | | | | X | | |
| *Gonioloboceras* sp. | | | | | | X | | | | | | | | | | | | | | |

Chart 4. Distribution of Smithwick species at several localities in central Texas.

**205–T–1 (BB–18,** Pl. 1).—San Saba County, 0.8 mile southwest of the town of Bend on the bluffs on Colorado River, about 60 feet above the water level. It is reached by taking the San Saba-Bend road to Bend, coming back 0.8 mile on the same road, and traveling along the water's edge at the base of the steep north-facing shale bluff. The fossils occur in the black shale along the bluff about 60 feet above the water. The shale at the base of the bluff and limestone outcrop along the water's edge is Marble Falls in age. Some of the best fossils occur in concretions; some are found loose in the bottoms of small gullies.

**205–T–13 (BB–18,** Pl. 1).—San Saba County, 1.25 miles southwest of Bend in gullies on the east side of the Bend-Chappel road. It is reached by taking the Bend-San Saba road from Bend, traveling a distance of 1.2 miles, then turning south at the fork and traveling on the Chappel road, a distance of about 0.1 of a mile. The fossils occur in gullies on the east side of the highway. This is the type locality for several of the Smithwick species.

**205–T–14 (AA–18,** Pl. 1).—San Saba County, 1.75 miles west, 0.5 of a mile north of Bend, and about one-third of a mile east of Bend-San Saba road. It is reached by taking the Bend-San Saba road from Bend for 3.5 miles and turning east through a gate on the road leading to the river. The locality is in gullies on the south side of the road about 0.5 of a mile from the gate.

**205–T–50 (S–15,** Pl. 1).—San Saba County, 10.25 miles west, 1.75 miles south of San Saba, and 0.75 of a mile due east of Sloan School. It is reached by taking the San Saba-Brady road to Harkeyville, then turning southwest on the Sloan Community road and traveling southwest a distance of 8.5 miles to a point 0.5 of a mile north of Sloan School. Then turn through a pasture gate, drive southeast 0.75 of a mile, and turn abruptly east over a rather dim winding road leading to a tank, a distance of 0.5 of a mile. The locality is in shale on the southwest edge of the tank on the Ellis ranch.

**205–T–71 (Q–15,** Pl. 1).—San Saba County, 6.5 miles south and 3 miles west of Richland Springs. It is reached by taking the Richland Springs-Maxwell Crossing road 8 miles to a point where the road turns abruptly east, going through a gate and driving due west along the fence 0.75 of a mile to a sink and water tank, on Gibbons ranch. The fossils are in shale along the edge of the tank.

**205–T–76 (S–15,** Pl. 1).—San Saba County, 4.5 miles southwest of Algerita on the west side of the San Saba-Sloan Community road, 0.5 miles north of the Sloan School. It is reached by taking the San Saba-Sloan Community road to Sloan School then going back 0.5 of a mile. The fossils are in gullies on the west side of the road, between the road and the old cemetery known as Ellis cemetery.

**205–T–79 (S–14,** Pl. 1).—San Saba County, 4.5 miles southeast of Richland Springs and 3 miles west and 0.5 of a mile south of Algerita, 1.5 miles north of Leonard's ranch. It is reached by taking the Algerita-Leonard ranch road to Leonard ranch, taking the old north road from Leonard ranch to Dry Creek and traveling a distance of 1.3 miles north of the ranch house, then walking or driving one-third of a mile due east through the ranch to a branch of Dry Creek. The fossils are in gullies excavated near the head of the branch. This is one of the best localities for collecting the coral *Cumminsia aplata* (Cummins).

## STRAWN GROUP

*Historical account.*—The term Strawn was first used by Dumble (1891) to denote the coal-bearing beds in Brazos River valley in the vicinity of Strawn and Gordon, Palo Pinto County. Equivalent beds in Colorado River valley were designated Milburn. Dumble's classification of the Pennsylvanian strata was as follows:

| COLORADO RIVER VALLEY | BRAZOS RIVER VALLEY |
|---|---|
| Waldrip series | Cisco series |
| Brownwood series | Ranger series |
| Milburn series | Strawn series |
| Richland sandstones | Gordon sandstone |

Cummins (1891, p. 374) more clearly defined the Strawn series to include the strata between the base of the coal seam east of the town of Strawn and the limestone series west of Strawn, replaced the term Gordon by Millsap, and stated incorrectly that the Millsap division was missing in the Colorado River valley section. Drake (1893, p. 371) did not recognize Dumble's Milburn and Richland divisions but referred all the Pennsylvanian strata east of the Rochelle conglomerate and below the Travis Peak (Cretaceous) formation to the Strawn division. He then proceeded to divide this division into 20 members or beds and mapped each of these subdivisions. Plummer and Moore (1922, p. 61) and Sellards (1933, p. 105) followed Drake's classification. No detailed maps of the Strawn group of beds in Colorado River valley have been published since the work of Drake 50 years ago. Cheney (1940, pp. 66 and 97) has restricted the Strawn to include the strata in the Brazos Valley between the Salesville shale and the Smithwick shale, changed the rank of the division from group to series, and reclassified the subdivisions in the Brazos Valley to give them the rank of formations. The equivalents of this new division and formation were not defined by him for the Colorado River valley region because markedly to the north and northeast due to a steep north dip of the underlying Smithwick strata toward the Mineral Wells geosyncline. Some thicknesses of the Strawn are furnished in the accompanying table.

*Thickness of Strawn strata in wells drilled along the outcrop in northern San Saba County*

| Farm | Location | Type of Record | Thickness *Feet* |
|---|---|---|---|
| Winkler | 1½ miles from north and 4 miles from west county line | Well log | 630 |
| Moore | 9,240 feet from Nelin and 2,200 feet from west line of Hernandez survey and 7 miles northeast of San Saba | Well log | 215 |
| Moore | 8 miles northeast of San Saba on Hernandez survey | Well log | 435 |
| Cummings | 3 miles west of Regency and 3 miles northeast of Locker | Well log | 395 |
| Shaw | 2 miles north of Locker | Well log | 450 |
| Heatherly | 17½ miles northwest of San Saba and 2½ miles southeast of Bowser | Well log | 275 |
| Blackard | 2 miles south of Bowser | Well log | 290 |

changes in lithology and absence of fossils make correlation of the individual beds difficult.

*Extent and thickness.*—Since the present report is concerned mainly with the Carboniferous strata below the Strawn in the Llano region, a study of the Strawn group as a whole and its many subdivisions will not be considered and no attempt made to establish new units. It is proposed to describe only those strata outcropping south of Colorado River and to use as far as possible the nomenclature established by Drake.

Beds of Strawn age border the north side of the Llano region, immediately north of the Smithwick outcrop (map, Pl. 1) and extend along the valley of Colorado River from the Cretaceous cuesta on the east to a point about 5 miles east of the town of Brady on the west. Everywhere they are separated by a marked unconformity from the Smithwick below, overlap toward the south on to the more steeply inclined older strata of Smithwick age, in some places cover completely the black shales and rest upon an eroded surface of the Marble Falls limestone. Because of this unconformity, the thickness of the Strawn strata varies greatly from place to place. They are thinnest along the southern border and thicken

The strike and dip of the Strawn beds do not correspond to those of Smithwick and Marble Falls. On the north side of the uplift across San Saba County, the regional dip of the Smithwick and Marble Falls formation is toward the north and northeast at an average angle of about 4°. The Strawn strata, on the other hand, in Colorado River valley strike north and south and dip west at an angle of about 3°. This strike continues southward south of the river to a point about 1 mile or less from the southern boundary of the Strawn outcrop, and there the direction of strike turns abruptly west following the contour of the regional structure of the Marble Falls limestone (Pl. 1).

*Lithology.*—The Strawn strata south of Colorado River comprise alternating layers of bluish-gray and dark-gray, sandy shale and coarse-grained, soft, friable, calcareous sandstones. In some places, the sandstones are massive and show little bedding; in other places, they are highly cross-bedded, indicating littoral and deltaic origin. In other places, they are quite thin bedded and contain impressions of plants, tracks and trails of shallow-water organisms, and rarely a few marine fossils. Some layers are highly ferruginous; at least one stratum is beautifully banded with orange, red, and pastel shades. Most layers are quite friable, porous, permeable, and contain water. At depth, however, the water in many places is mineralized and is not potable. The shales are soft, in many places poorly laminated, somewhat jointed, sandy and silty, and contain very few large fossils, although Foraminifera are rather consistently present in varying abundance. The Strawn sediments appear to have been deposited rapidly in shallow seas, in lagoons, and even on mud flats above the strand line. Mud cracks and river ripples are very common in the thin interbedded sandstone and shale layers. In a very few places the shales are fossiliferous, but the specimens are poorly preserved. Many of the shale layers contain yellowish-brown concretions of limonite ranging in size from a fraction of an inch to 5 inches. In several places thin layers of limestone conglomerate occur. One of these is located 0.15 of a mile east of Colony School, San Saba County (Coord. AA–16), and may be referred to as the Colony School conglomerate. It is a basal conglomerate and occurs at the contact of the Strawn and Marble Falls limestone. The layer is about 1 foot thick and is made up of well-rounded pebbles ranging from the size of large sand grains to an inch in diameter and set in a matrix of reddish-brown sand, resembling the sandstone of the Strawn layers above. Most of the larger pebbles are derived from the Marble Falls limestone. Another locality is on the west side of the Lometa-Bend road 5¾ miles by road south of the Lometa-San Saba highway. This layer is an intraformational conglomerate, 6 to 8 inches thick in a bed of Strawn shale. The layer is made up of pebbles of Marble Falls limestone, evidently derived from a rocky foreland and washed out some distance into the muddy bottoms. The pebbles are one-fourth to 1½ inches in size, are subrounded, and are mixed with a few brachiopods, crinoid stems, and Bryozoa. Such conglomerate layers are very local in extent. The following sections will furnish other details of the stratigraphy of this interesting series of beds.

*Section of Strawn sandstone along Colorado River below Shadrick Mill east of railroad bridge over Colorado River, Mills County* (Drake, 1893, p. 377) (Coord. AA–13, Pl. 1).

| | THICKNESS *Feet* |
|---|---|
| 29. Shaly sandstone | 5 |
| 28. Massive sandstone | 2 |
| 27. Shaly sandstone | 3 |
| 26. Massive sandstone | 2 |
| 25. Clay | ½ |
| 24. Massive sandstone | 3 |
| 23. Shaly clay and dark-blue sandstone | 3 |
| 22. Sandstone | 3 |
| 21. Flaggy sandstone | 5 |
| 20. Sandstone | 3 |
| 19. Smooth, flaggy sandstone | 2 |
| 18. Massive sandstone | 4 |
| 17. Massive sandstone | 5 |
| 16. Massive sandstone | 3 |
| 15. Shaly sandstone | 2 |
| 14. Massive sandstone | 5 |
| 13. Massive sandstone | 4 |
| 12. Shaly sandstone | 1 |
| 11. Massive sandstone | 6 |
| 10. Massive sandstone | 10 |
| 9. Massive sandstone | 4 |
| 8. Flaggy sandstone | 4 |
| 7. Massive sandstone | 6 |
| 6. Massive sandstone | 3 |
| 5. Massive sandstone | 3 |
| 4. Shaly and massive sandstone | 7 |
| 3. Clay | 2 |
| 2. Massive sandstone | 5 |
| 1. Flaggy sandstone—layers varying from 3 to 6 inches | 15 |
| Total thickness | 120½ |

*Section of basal Strawn along Big Uncle Creek 1½ miles west of Richland Springs, San Saba County* (Coord. Q–11, Pl. 1).

| | THICKNESS *Feet* |
|---|---|
| Strawn— | |
| 6. Sandstone, brownish gray, thick bedded, friable, hard | 12 |
| 5. Sandstone, grayish brown, thin bedded, calcareous, weathers to form thin flagstones, fine grained, fossiliferous, evenly laminated; contains in its lower 4 feet thin fossiliferous layers containing crinoids, spirifers, and much glauconite. The lower layer contains a few black pebbles. Most characteristic feature is its uniformly thin bedding | 15 |
| 4. Sandstone, yellowish gray, soft, friable, thin bedded, glauconitic, fossiliferous, breaks into thin plates | 10 |
| 3. Shale, greenish gray, exposed in clay pit and contains a 1-foot layer of pebble conglomerate | 5 |

| | THICKNESS *Feet* |
|---|---|
| 2. Shale, gray, soft, containing many iron concretions but no fossils | 5 |
| Marble Falls— | |
| 1. Limestone, black, thin bedded, fossiliferous | ? |
| Total thickness | 47 |

*Subdivisions.*—Drake (1893, p. 374) divided the Strawn strata into 20 beds on the basis of lithology as follows:

20. Ricker bed
19. Antelope Creek bed
18. Indian Creek bed
17. Comanche Creek bed
16. Wilbarger Creek bed
15. Buffalo Creek bed
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. Fox Ford bed
5. Bed No. 8
4. Shadrick Mill bed
3. Elliott Creek bed
2. Burnt Branch bed
1. Lynch Creek bed

The first bed is predominatingly shale; the second, sand; the third, shale; and so on up to the 20th bed at the top, which is made up of sandstones and conglomerates. It is now known that most of the sandstone layers are quite lenticular, play out laterally, and are replaced by another lentil higher or lower in the section, so that detailed mapping by modern methods of all Drake's units is quite difficult, if not impossible. It is probably better, for the present at least, to describe these rather complex strata as a single unit and map them as a single formation with lenticular members until some better mode of subdivision and correlation is devised.

*Textural and mineralogical characteristics.*—The texture of the Strawn strata is much coarser than that of the Smithwick. The sand grains in the sandstone layers are coarser, less angular, and less firmly cemented, and the shales contain more silt and fine sand. The following screen analyses show the textural characteristics of several representative samples:

*Size analyses of grains of Strawn sand in percent by weight*

(Analysis by Joe Moore, 1942)

| **Size of grains** *Millimeters* | **Locality 1** *Percent* | **Locality 2** *Percent* |
|---|---|---|
| Larger than 0.495 | 0.1 | 0.3 |
| 0.495–0.351 | 0.4 | 2.4 |
| 0.351–0.246 | 2.8 | 19.0 |
| 0.246–0.175 | 26.8 | 50.1 |
| 0.175–0.124 | 38.4 | 20.1 |
| 0.124–0.088 | 1.6 | 3.6 |
| 0.088–0.061 | 5.4 | 0.9 |
| Smaller than 0.061 | 9.5 | 3.9 |
| Iron carbonate | 1.1 | 1.1 |

Locality 1. Bend-Lometa road one-half mile south of Cretaceous-Pennsylvanian contact and 6 miles south of Lometa-San Saba highway.

Locality 2. San Saba-Bend road, south side of road, near Milliken ranch house, 0.8 of a mile west and 0.2 of a mile south of Colony School.

*Distinguishing features.*—It is rather easy to distinguish Strawn shale from the Smithwick. The Smithwick shale is generally darker colored, harder, more jointed, more siliceous, less calcareous, and disintegrates less easily in water than the Strawn shale. The concretions in the Strawn shale are small, yellowish-brown, limonitic "claystones." The concretions in the Smithwick are rarer and commonly are larger (5 to 6 inches in diameter), dark red in color, and known as paint rock by the Indians. The Smithwick concretions evidently have been derived from marcasite or pyrite by oxidation and are now in the form of limonite and disintegrated hematite. The thin siltstone lentils in the Smithwick are much harder, less friable, much finer grained than those in the Strawn and in most places have a grayish color and contain veins of impure calcite along fractures. Most of the Smithwick sandstone slabs have intricate markings resembling tracks or trails of marine animals and water plants (Pl. 18A). The Strawn slabs are rough surfaced or marked with coarser, less well-preserved fucoidal markings, ripple-like marks, and mud-ball-like blotches. In general the Smithwick sediments are marine, near-shore deposits. The Strawn appears to be a combination of shallow-water marine and coastal plain fluviatile and strand-line deposits alternating in a rhythmic manner. Where fossils can be obtained, the two divisions can be easily distinguished. The Strawn beds are characterized by *Chonetes robusta* R. H. King, *Mesolobus mesolobus* (Norwood and Pratten), *Marginifera muricatina* Dunbar and Condra, *Pseudoparalegoceras;* the Smithwick by *Cumminsia aplata* (Cummins), *Paeckelmannia derelicta* R. H. King, *Pharkidonotus*. n. sp., and *Straparolus savagei* Knight. A more detailed account of the paleontology of these formations is given elsewhere in this publication.

*Special features.*—The beautiful color bands in the Strawn sandstone are striking features of certain layers. These color bands are especially well exposed in quarries on the Buttrill ranch located one-fourth of a mile north of the San Saba-Lometa highway, 2 miles east of Red Bluff (Coord. BB–14), also in the Carlisle quarry located 1.9 miles west and 1 mile north of Nix (Coord. EE–18), and in the Faught quarry located 2.5 miles west of Nix (Coord. EE–18), Lampasas County. The sandstone is dark yellow or yellowish orange in color, fine grained, evenly textured, and marked with indistinct bedding planes. The surface of the rock is banded with beautiful purplish-red streaks alternating with orange-yellow bands which represent the original color of the rock. The red bands are spherical and ellipsoidal in shape, 1 to 2 inches wide, spaced 4 to 6 inches apart, and surround a central red core or nucleus which is 1 inch to 6 inches in diameter. Some of the bands are so perfectly shaped and evenly spaced that the face of the rock which furnishes a cross section through the center of the sphere or ellipsoid resembles a well-designed and nicely painted target having a central red bull's eye surrounded by alternating red and yellow bands. The outer red circles in some cross sections reach 5 feet in diameter but commonly range from 14 inches to 3 feet. The outer red bands are narrower or thinner than the bands close to the central nucleus. The rock is cut also by black ferruginous veins resembling dark hematite. These peculiar banded structures extend through a ledge about 8 feet thick which outcrops along a south-facing low escarpment and are situated in most places 5 or 10 feet below the top of the escarpment. The ledge is underlain by sandy shale and overlain by coarse, non-banded, ferruginous sandstone and conglomerate as shown by the following section measured at the Buttrill rock quarry:

*Section of sandstone of Strawn age in Buttrill rock quarry west of Lometa, Lampasas County* (Coord. BB–14, Pl. 1).

| | THICKNESS *Feet* |
|---|---|
| 3. Sandstone and conglomerate, brown, made up of coarse sand and pebbles up to three-fourths of an inch in diameter set in a matrix of brown ferruginous sand | 10 |
| 2. Sandstone, orange yellow, even textured, with medium-sized grains, poorly bedded, but breaking rather easily into thin slabs 2 to 4 inches thick containing beautiful spheroidal banded structures | 10 |
| 1. Shale, yellowish gray, sandy, mostly covered with sand from upper ledges | 15 |
| Total thickness | 35 |

The banded rock breaks, when quarried along cleavage planes, into blocks about 10 to 15 inches thick, 18 to 48 inches long, and 12 to 32 inches wide. These blocks have fairly even faces and show the banded structure beautifully when freshly broken. They can be split also with a hammer and chisel into slabs and flagstones 3 to 4 inches thick. These slabs are much in demand for paving terraces and interior decoration and are marketed under the name of "rainbow rock." The interesting ledge can be traced laterally across country for several miles. The origin of these unique bands is thought to be a physical-chemical phenomenon due to supersaturation of iron salts in the sea water. They are known as Liesegang's rings.

*Paleontology.*—The conditions of sedimentation of the Strawn were those of rapid deposition of silt and sand in muddy coastal marine waters alternated with fluviatile and eolian beach and coastal plain deposits. The muddy water was apparently not very favorable for deposition and preservation of numerous marine fossils. A few of the layers of thin-bedded calcareous sandstone and calcareous shales contain poorly preserved fossils, most of which are quite fragmentary as if broken up during sedimentation. In the following list of species the gastropods were identified by J. Brookes Knight, the fusulinids by C. O. Dunbar. Characteristic fossils in the Strawn group are shown in Plate 19.

*Fauna of the Millsap Lake formation of the Strawn group, in an outcrop 3 miles northeast of Saluit, McCulloch County* (Loc. 153–T–7; Coord. M–14, Pl. 1).

Foraminifera—
- Fusulina rickerensis Thompson

Anthozoa—
- Lophophyllum radicosum Girty
- Lophophyllum profundum Milne-Edwards & Haime

Crinoidea—
- Platycrinus sp.
- Ethelocrinus

Brachiopoda—
- Crania modesta White & St. John
- Derbyia bennetti Hall & Clarke
- Derbyia crassa Meek & Hayden
- Rhipodomella carbonaria (Swallow)
- Rhipodomella carbonaria var. subcircularis R. H. King
- Chonetina robusta R. H. King
- Marginifera splendens (Norwood & Pratten)
- Marginifera muricatina Dunbar & Condra
- Dictyoclostus sp.
- Rhynchopora magnicosta Mather
- Juresania nebrascensis (Owen)
- Mesolobus mesolobus (Norwood & Pratten)
- Mesolobus mesolobus var. rochellensis R. H. King
- Spirifer rockymontanus Marcou
- Neospirifer dunbari R. H. King
- Punctospirifer kentuckyensis (Shumard)
- Cleiothyridina orbicularis McChesney

Gastropoda—
- Baylea subconstricta (Meck & Worthen)
- Orthonema marvinwelleri?

*Correlation.*—The above fossil list, although meager and probably quite incomplete, indicates clearly that these Strawn strata belong in the Des Moines division of the Pennsylvanian and probably are, for the most part, equivalent to the Garner and upper part of the Millsap Lake formations of the Brazos Valley region of north-central Texas.

#### Fossil Localities

The best collections of fossils have come from the Elliott Creek member and the Comanche Creek shale. The best locality is as follows:

**153–T–7** (**M–14**, Pl. 1).—McCulloch County, 3.3 miles due east of Rochelle. It is reached by taking the Rochelle-San Saba road and traveling east for 3.7 miles to where the road turns northeast, then turning due south through a gate and following a secondary road south 0.5 of a mile to the point where the secondary road turns southeast, going down a rather steep hill. At this point, leave the car and walk east about 0.1 of a mile to a wire fence and follow the fence south 0.3 of a mile to a small branch stream on the west side of the fence; then walk down the small branch a few hundred feet to the shale exposure on the east side of the branch.

### CANYON GROUP

*Historical account.*—The term Canyon was applied by Cummins (1891, p. 374) to designate the beds of massive limestone that occur in the vicinity of Canyon in Palo Pinto County, and along Jim Ned Creek in Brown County. They were described briefly by means of sections and a map (Cummins, 1891, Pls. 6, 7, and 8), and later the unit was defined more definitely by Drake (1893, p. 387). Drake drew the base at the bottom of a *Chaetetes*-bearing limestone known as the "coral" limestone bed, and the top at the upper surface of a *Campophyllum*-bearing bed which occurs about 80 feet above the Home Creek limestone. Plummer and Moore interpreted Cummins' boundaries closely (1922, p. 87) and limited the Canyon division to include the strata between the top of the Home Creek limestone at Caddo and the base of the Palo Pinto limestone in Palo Pinto County or beds of equivalent age. The top of the Home Creek limestone in the Colorado River valley was identified as the top of the upper of three persistent limestones that occur 75 to 100 feet above the top of the Ranger limestone and about 350 feet above the top of the Adams Branch limestone (fig. 14); the bottom was identified as the base of the Rochelle conglomerate. Sellards (1933, p. 110) followed the same usage. Hudnall and Pirtle (1931) and Nickell (1938, p. 91) used about the same boundary for the top[8] but raised the base of the Canyon group to a thin non-persistent, unnamed limestone about 100 feet above the Capps limestone. Bullard and Cuyler (1935, p. 199) used the upper Home Creek limestone as the top

[8]Due to difficulties in tracing the outcrop of the upper Home Creek limestone across the alluvium-covered area of the Colorado River valley there is some uncertainty whether Hudnall, Nickell, and Bullard and Cuyler used exactly the same limestones, but their sections are essentially the same (fig. 14); also see discussion by Nickell (1938).

boundary and the base of the Rochelle conglomerate for the lower boundary plane; Cheney (1940, p. 87), revised again the Canyon division and made the Canyon group include the strata between the top of the Home Creek limestone and the base of the Lake Pinto sandstone lentil in the middle of the Mineral Wells formation in the Brazos River valley. This change was advocated by Cheney in order to make the division boundary between the Strawn and Canyon agree as nearly as possible with that between the Missouri and Des Moines divisions long in use in the Middle West and Midcontinent regions. Cheney (1940, p. 90) regards the Brazos River sandstone as equivalent to the Rochelle conglomerate, and, therefore, in the Colorado River valley places the lower boundary of the Canyon at a limestone above the Rochelle described as occurring about 100 feet above the Capps limestone.

The problem of establishing the upper boundary of the Canyon is simplified by a definite and characteristic cephalopod assemblage consisting of *Uddenites schucherti* Böse, *Glaphyrites kansasensis* (Miller and Gurley), *Wiedeyoceras pingue* A. K. Miller and Cline, *Agathiceras ciscoense* Smith, *Marathonites ganti* (Smith), *Schistoceras missouriense* (Miller and Faber), *Liroceras liratum* (Girty), *Domatoceras sculptile* (Girty), *Neodimorphoceras texanum* (Smith), and *Gonioloboceras welleri* Smith, and others. This remarkable assemblage occurs below the Gunsight limestone and above the Bunger limestone of Plummer and of Nickell, the lower Gunsight limestone of Bullard and Cuyler, and has been found at numerous localities from McCulloch County on the south to Jack County on the north, definitely marking the lower shales of the Graham formation as pointed out by Plummer and Hornberger (1935, pp. 63–

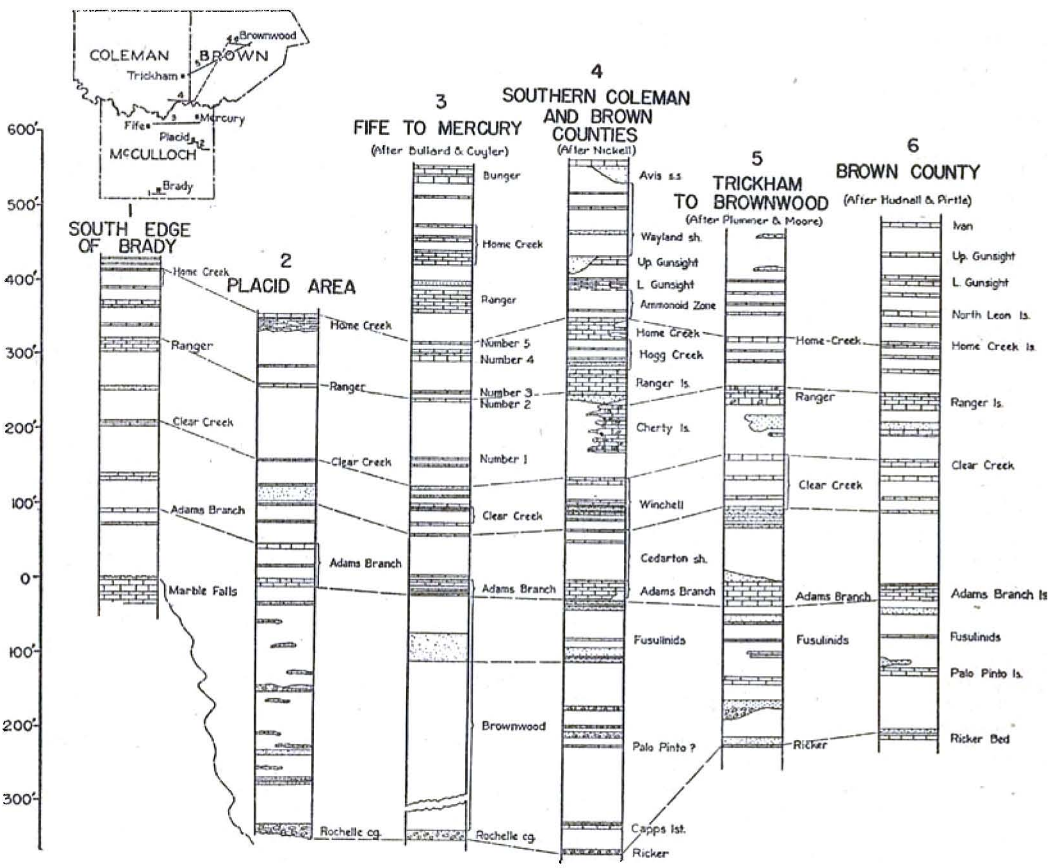


Fig. 14. Stratigraphy of the Canyon group, showing differences in interpretations of stratigraphic boundaries by different geologists. Sections 1 and 2 were measured by F. B. Plummer.

64), by Plummer and Scott (1937, p. 17), and by Williams (1938, pp. 191–192). The second limestone below this cephalopod zone marks the top of the Canyon division as originally established by Cummins. It is the uppermost of three thick, light-gray limestones which in most places can be easily distinguished from the thinner yellow limestones of the Cisco division above.

The problem of correlating the lower boundary of the Canyon division is more complicated due to an erosional hiatus in the Colorado River valley, and to a lack of definite fossil zones. The fauna of the Keechi Creek shale below the Palo Pinto limestone of the Brazos Valley is abundant, beautifully preserved, and quite well known (Plummer and Hornberger, 1935, pp. 40–41). Yet no assemblage like it or like that of the Salesville shale below has been found in the Llano region. It may be that change in facies of the sediments is responsible for the absence of these fossils, or that the Llano area was dry land during the Salesville and Keechi Creek epochs. In the Llano region south of Colorado River, the Comanche Creek shales of Drake contain a prolific Millsap Lake or Des Moines fauna characterized by *Mesolobus mesolobus* and *Fusulina rickerensis.* The Rochelle conglomerate rests unconformably upon this bed east of Rochelle, and the shales immediately above the Rochelle conglomerate contain a fauna noteworthy for its Canyon or Missouri division forms, most of which occur in the Graford and Palo Pinto formations and in the Kansas City group of strata. A list and discussion of the correlation of these fossils is presented elsewhere in this volume. The Rochelle conglomerate, when traced northeastward, thins out, is changed to a marine sand before Colorado River is reached, and disappears beneath Cretaceous gravel deposits (Pl. 20). The sandy horizon can be traced northward, however. It is thought to occur just above the Ricker bed east of Brownwood and is tentatively correlated with the first sandstone layer immediately below the Palo Pinto limestone in Palo Pinto County. The base of the Canyon in the Llano region, therefore, is set at the bottom of the Rochelle conglomerate and its equivalent sandstone zone. South of Colorado River, this horizon marks the division between the Missouri and Des Moines series.

*Extent and thickness.*—The Canyon group of beds is bounded on the east by the Rochelle conglomerate or sandstone of equivalent age and on the west by the upper layer of the Home Creek limestone. Except where covered by Cretaceous sands, the group of beds has been mapped from Colorado River southward to Rochelle and then southwestward to Brady, as shown on the maps, Plate 1 and Plate 20. The lower series of limestones and shales, known as the Adams Branch limestone, overlap the Rochelle conglomerate west of Onion Creek and rest on the Marble Falls limestone, forming the basal beds of the Canyon from Onion Creek southward to Brook ranch where all the Canyon beds disappear beneath the Cretaceous marls. The thickness of the Canyon group of beds varies from 425 to 725 feet. It is thickest in the sections between Colorado River and Mercury and thinnest in the sections south of Brady, as shown in figure 14.

*Lithology.*—The Canyon group of beds in the Llano region, with the exception of the lowermost division, which contains sandstone and conglomerate, consists predominantly of thick marine, fossiliferous, calcareous shales and four intervals of limestones alternating in a sort of rhythmic succession. The lower part of the Canyon group is composed predominantly of sandy shale with lentils of sandstone and conglomerate. The upper part contains a series of sandy shales, non-sandy, calcareous, fossiliferous shales, rather thick fossiliferous limestone, and a few thin layers of sandstone. South of Colorado River, the lower limestone, known as the Adams Branch member, forms a very prominent escarpment which extends nearly due south from Mercury to Rochelle. Near Rochelle the escarpment becomes less prominent, the limestones thin somewhat, some of the layers disappear, and the series swings southwestward in the direction of Brady, forming several low escarpments in place of the single prominent one, until the beds finally disappear beneath the Cretaceous cover southwest of Brady (map, Pl. 20). Other details regarding the stratigraphy and lithology are furnished by the following described sections:

*Section of lower part of Canyon group, measured along an east-west line through Rugged Mountain from Adams Branch escarpment east to a point 1 mile east of Rochelle-Cowboy road, McCulloch County* (Line C–D, Pl. 20).

| | THICKNESS Feet | Inches |
|---|---|---|
| 17. Limestone, gray, brittle, subcrystalline, irregularly bedded; the bedding planes are somewhat wavy and the ledge is poorly fossiliferous but contains *Triticites* | 13 | ---- |
| 16. Shale, gray, calcareous, fossiliferous | 15 | ---- |
| 15. Limestone, bluish gray, weathering yellowish gray, hard, subcrystalline | ---- | 6 |
| 14. Shale, gray, calcareous | 3 | ---- |
| 13. Sandstone, brownish gray, evenly bedded, fine grained, marine | 2 | ---- |
| 12. Shale, gray, sandy; partly covered by slope wash and grass, but containing at least one lentil of sandstone and grading downward into red, maroon, and purple, nonfossiliferous shale at the base | 90 | ---- |
| 11. Conglomerate (caps both Rugged Mountain and Rough Mountain), dark reddish brown, moderately coarse, pebble conglomerate made up of pebbles ¼ to 1 inch in size, subangular to angular in shape and consisting of green, gray, black, and black and white banded pebbles of chert set in a matrix of rather coarse quartz sand. The conglomerate varies in thickness from place to place, plays out northward into a layer of coarse, cross-bedded sand, contains cross-bedding and ripple markings, and appears to be nonmarine in origin possibly merging northward and westward with marine sediments | 8 | ---- |
| 10. Shale, red, gray, and purple, containing 3 or 4 lentils of rather soft, friable sandstone | 82 | ---- |
| 9. Sandstone, gray, fine grained, cross-bedded | 5 | ---- |
| 8. Shale, red and purplish gray, containing a rather prolific fossiliferous zone near the top characterized by large numbers of the gastropod *Amphiscapha catilloides* (Conrad) | 30 | ---- |
| 7. Sandstone, gray, fine grained | 3 | ---- |
| 6. Conglomerate, gray, made up of small subangular pebbles | ---- | 4 |
| 5. Shale, red | 4 | ---- |
| 4. Sandstone, fine grained, calcareous | 1 | ---- |
| 3. Shell bed, thin layer made up largely of well-preserved productids and other fossils in places cemented to form a hard calcareous layer containing many pelecypods | ---- | 3 |
| 2. Shale, gray, containing at least 3 lentils of sandstone | 53 | ---- |
| 1. Rochelle conglomerate, dark reddish brown, cross-bedded, made up of subangular chert pebbles averaging ¾ of an inch in size | 12 | ---- |
| Total thickness | 322 | 1 |

*Section of middle part of Canyon group measured along road south of Placid to escarpment 1.4 miles east of Placid at Loc. 153–T–21, McCulloch County* (map, Pl. 20).

| | THICKNESS Feet | Inches |
|---|---|---|
| Cedarton member— | | |
| 13. Sandstone, dark reddish brown, massive, poorly bedded and somewhat cross-bedded near the base, grading upward into thin beds near the top, moderately hard, somewhat friable sandstone made up of quartz grains fairly uniform in size, subrounded to subangular in shape; surface of the sandstone forms a dip slope leading down to the town of Placid | 17 | ---- |
| 12. Shale | 4 | ---- |
| 11. Limestone, reddish and yellowish brown, sandy, has a rough corrugated surface, contains fragments of fossils | 1 | ---- |
| 10. Shale, forming grass-covered slope | 26 | ---- |
| 9. Limestone, dark gray, weathering light yellowish gray, subcrystalline, smooth surfaced, containing many fragments of thin-shelled brachiopods, pelecypods, and very small crinoid fragments | 1 | 3 |
| 8. Shale, not exposed, forms a field one-fourth mile wide | 6 | 6 |

| | Thickness Feet | Thickness Inches |
|---|---|---|
| Adams Branch limestone— | | |
| 7. Limestone, dark gray, hard, heavy, unevenly bedded, the bedding planes form wavy patterns, subcrystalline, contains algal markings, a few fossils, large fusulinids, and calcite veins, weathers to form very rough surfaced boulders and nodules | 6 | 6 |
| 6. Shale, dark gray, weathering light yellow and greenish gray, fossiliferous, contains a good fauna, including *Neospirifer*, *Chonetina*, *Treposporia*, *Punctospirifer*, and other typical Canyon forms | 25 | — |
| 5. Limestone, bluish gray, weathering yellow and yellowish brown, hard, breaks into thin platy fragments having rough surfaces, subcrystalline, hard, made up of large quantities of very small crinoid fragments indicating that the crinoids must have been small forms. The surface of the rock is quite rough and contains many small granules | 4 | — |
| Brownwood shale member— | | |
| 4. Shale, bluish gray, weathering light yellow, soft calcareous, contains much gypsum and weathers to produce a white powdery gypsiferous caliche-like mass | 22 | 6 |
| 3. Limestone, gray, weathering yellowish gray, occurs in beds 4 to 12 inches thick. The bedding planes are uneven, somewhat wavy. The limestone is quite hard, subcrystalline, and cut by many joint lines. It breaks with a conchoidal fracture and along joint lines to produce irregular-shaped chips and small chunks. The rock is fossiliferous, contains *Triticites* (probably *T. irregularis*), *Composita*, and other brachiopods. Fusulinids are most common in a zone about 3 feet below the top | 9 | — |
| 2. Shale, occupying a slope mostly covered by grass and talus, but exposed in a few places along the road ditches. Light yellowish gray, gypsiferous at the top, soft, sandy and contains a few thin layers or lentils of gray and brown sandstone. One of these sandstone ledges occurs 22.4 feet below the top of the shale. It is 11 inches thick, fine grained, cross-bedded, resembling somewhat wind-blown sand. The total thickness of the shale bed is | 22 | 5 |
| 1. Sandstone, brown, coarse grained, contains small angular chert pebbles up to one-half inch in diameter. The pebbles are unevenly and rather sparsely scattered throughout the sandstone which occurs in layers about 4 inches thick separated by clay and silt partings. The clay also contains a few pebbles which may have been originally in the sandstone. This sandstone may be the northward extension of the Rough Mountain conglomerate bed which occurs above the main Rochelle conglomerate | 1 | 4 |
| Total thickness measured | 146 | 6 |

*Section of middle and upper part of Canyon group measured along east-west road passing along south side of city of Brady from Brady Creek on the east to the Home Creek limestone on the west* (Coord. H-18 to H-16, Pl. 1).

| | Thickness Feet | Thickness Inches |
|---|---|---|
| Cisco group— | | |
| 26. Limestone, bluish gray, hard, unfossiliferous | 1 | — |
| 25. Shale, mostly covered with grass | 27 | — |
| 24. "*Campophyllum*" bed. Limestone, hard, bluish gray, weathering light gray, fossiliferous; contains many horn-shaped corals, probably belonging to the genus *Caninia* | 1 | 6 |
| 23. Shale, covered | 5 | — |
| 22. Limestone, dark gray, hard | 1 | — |
| 21. Shale covered | 4 | — |
| Canyon group— | | |
| 20. Upper Home Creek limestone. Dark gray, or buff, coarsely crystalline, slightly fossiliferous, contains many yellow, vein-like markings of a dark yellowish-brown color. These markings may represent algal markings. No fusulinids observed | 1 | 6 |
| 19. Shale | 21 | — |
| 18. Middle Home Creek limestone. Gray, hard, fossiliferous, weathers to a light yellowish-brown color; contains small fossils and small crinoid stems. Breaks into small blocks and irregular chunks. Fossils are very poorly preserved | 1 | 2 |
| 17. Shale, covered | 17 | 6 |
| 16. Lower Home Creek limestone. Gray, hard, fossiliferous; contains *Squamularia* and *Composita*. No fusulinids observed | 7 | — |
| 15. Shale, covered | 22 | 6 |
| 14. Limestone | 1 | — |
| 13. Shale, covered | 18 | — |

| | THICKNESS Feet | Inches |
|---|---|---|
| 12. Ranger limestone. Dark gray, thin bedded; beds 2 to 5 inches thick, bedding planes uneven; quite fossiliferous. Fossils consist of small corals, *Composita*, *Dielasma*, and others, but no fusulinids noted. Upper layers break up to form small angular chunks | 19 | 6 |
| 11. Shale, blue gray, weathering to a caliche-like, powdery sub-soil; mostly covered with grass. One layer near the base is distinctly red | 45 | -- |
| 10. Sandstone, dark brownish, tinged with yellowish-brown streaks, thin bedded. In layers 2 to 6 inches thick, each layer thinly laminated; fine grained, almost a siltstone. The top layers are somewhat more friable | 3 | -- |
| 9. Shale, covered | 42 | 6 |
| 8. Upper Clear Creek limestone. Dark gray, hard, thin bedded. The beds are 2 to 4 inches thick, separated by uneven bedding planes. Two thicker and somewhat harder ledges at the top ranging from 12 to 18 inches thick. The ledge is exposed at Bear Creek southwest of Brady | 6 | 9 |
| 7. Shale, mostly covered | 62 | 6 |
| 6. Lower Clear Creek limestone. Hard, more massively bedded than layers above | 13 | -- |
| 5. Shale, mostly covered by grass and soil | 46 | -- |
| 4. Adams Branch limestone, upper ledge. Light gray, thin bedded, fossiliferous; contains many *Triticites* | 5 | 1 |
| 3. Shale, covered | 14 | -- |
| 2. Adams Branch limestone, lower ledge. Gray, hard, poorly exposed | 1 | -- |
| 1. Brownwood shale. Sandy, covered by soil and alluvium | 70 | -- |
| Total thickness measured | 457 | 6 |

*Subdivisions.*—Drake (1893, p. 387) has divided these Canyon strata into 12 divisions; 11 of these can be recognized in the Llano region and have been described by Bullard and Cuyler (1935, pp. 199–221) and by Nickell (1938, p. 94). They are shown in the accompanying graphic sections (fig. 14, sections 3 and 4) and are described in the following paragraphs.

*Rochelle conglomerate.*—The lowest division is a basal conglomerate known as the Rochelle conglomerate. Its outcrop extends from Onion Creek east of Nelin northeast to a point 3 miles east of Rochelle on the San Saba-Rochelle highway and then swings northward, thins abruptly, and thins out at the Rochelle-Hall road as illustrated on the map (Pl. 20). It is made up of angular and subangular pebbles one-eighth inch to 2½ inches in diameter, the average size being about three-fourths of an inch. The coarse pebbles are set in a matrix of very fine pebbles and unevenly graded, coarse sand (Pl. 18B). At least 90 percent of the pebbles are chert. They are white, cream-colored, black, green, and banded black and white, and green and white. The gray, white, and cream-colored pebbles predominate. The member in most places has little or no bedding, but in a few places there is distinct cross-bedding like that found in fluviatile deposits. Tables showing typical screen analyses and counts showing percentage distribution of rock types are given below:

*Size analyses of pebbles of Rochelle conglomerate*
(Percent by weight)

| Size *Millimeters* | Locality 1[a] *Percent* | Locality 2[a] *Percent* | Locality 3[b] *Percent* | Locality 4[b] *Percent* |
|---|---|---|---|---|
| Larger than 64 mm. | 0 | 0 | 0.0 | 0.0 |
| 32–64 | 53 | 0 | 17.0 | 0.0 |
| 16–32 | 22 | 26 | 28.0 | 0.0 |
| 8–16 | 7 | 35 | 26.0 | 0.0 |
| 4–8 | 6 | 7 | 10.0 | 0.0 |
| 2–4 | 4 | 6 | 8.0 | 39 |
| 1–2 | 3 | 8 | 5.0 | 28 |
| 0.5 –1 | 1 | 9 | 2.5 | 16 |
| 0.25 –0.5 | 1 | 3 | 1.5 | 6 |
| 0.125 –0.25 | 1 | 3 | 1.5 | 7 |
| 0.0635–0.125 | 1 | 2 | 0.0 | 0.2 |
| 0.0311–0.0635 | | -- | 0.5 | 1 |
| Smaller than 0.0311 | | -- | -- | 1 |

[a]Analyses made by H. X. Bay (1932).
[b]Analyses made by Bruce Grant.

Locality 1. About 4.2 miles east of Rochelle on the Rochelle-San Saba road, near top of a prominent escarpment.
Locality 2. About 5 miles southwest of Rochelle on the old Rochelle-Brady road.
Locality 3. East side of Onion Creek, 1.9 miles east and 0.5 of a mile north of Nelin, McCulloch County.
Locality 4. Type locality of Rochelle conglomerate 4 miles east and 1.3 miles north of Rochelle on Rochelle-San Saba road, near top of prominent escarpment near locality 1.

*Shape analysis of Rochelle conglomerate, by H. X. Bay (1932)*

| | Percent |
|---|---|
| Angular | 54.0 |
| Subangular | 34.0 |
| Curvilinear | 11.2 |
| Subround | 0.6 |
| Round | 0.0 |

*Distribution of rock types in Rochelle conglomerate pebbles over 32 mm. in size from Satuit, McCulloch County.*

| | Percent |
|---|---|
| Chert, banded, gray brown and white | 2.7 |
| Chert, banded, brown, black, and white | 4.0 |
| Chert, banded, red and white | 1.35 |
| Chert, banded, gray and white | 7.0 |
| Chert, banded, green and white | 8.0 |
| Chert, banded, green and brown | 1.35 |
| Chert, gray green | 4.0 |
| Chert, light green | 2.7 |
| Chert, dark green | 18.0 |
| Chert, dark gray, smooth fracture | 5.4 |
| Chert, dark gray, rough fracture | 8.0 |
| Chert, light gray, smooth fracture | 7.0 |
| Chert, light gray, rough fracture | 2.7 |
| Chert, white | 9.4 |
| Chert, black | 5.4 |
| Chert, brown | 5.4 |
| Chert, translucent | 9.4 |
| Quartz | 2.7 |

Chert greatly predominates among the larger pebbles and quartz among the smaller pebbles and grains. Quartzite pebbles are present in some places but are generally rare. Fragments of limonite and clay or shale occur in some exposures. The green cherts are noteworthy and perhaps characteristic of the Rochelle, since they were not found by Bay (1932) in the similar conglomerates of the Brazos River valley.

The thickness of the Rochelle conglomerate throughout most of its extent is fairly uniform, varying from 8½ to 18 feet as shown in the following table:

*Thicknesses of the Rochelle conglomerate at localities shown on Plate 20*

| | THICKNESS Feet |
|---|---|
| West side of Onion Creek at iron bridge 2.8 miles east and 0.6 mile north of Nelin (Loc. 153-T-55) | 13.25 |
| South of Rochelle cemetery, northeast of Satuit | 12.00 |
| East of Rochelle cemetery | 13.00 |
| Type locality, San Saba-Rochelle highway 4 miles east of Rochelle | 12.00 |
| Rochelle-Hall road, 5 miles northeast of Rochelle | 8.50 |

North of the Rochelle-Hall road, the conglomerate plays out, and a sandstone comes into the section at about the same horizon. The sandstone differs markedly from the sandy layers in the conglomerate. It is dark gray, contains fragments of crinoids and brachiopods, and is much cross-bedded by thin, well-laminated bedding planes. It is thought that this sandstone represents a beach, or near-shore, facies of the conglomerate, and that the cross-bedding is that of beach bedding. If this interpretation is correct the conglomerate has thinned laterally from a maximum of 15 feet to 3 feet at the Hall road and has graded from nonmarine into marine sediments.

The Rochelle conglomerate east of Rochelle rests unconformably upon dark-gray and dark-maroon, soft, sandy shale of Strawn age and to the southwest of Rochelle overlaps on Marble Falls limestone. The Strawn shale below the conglomerate contains a few phosphatic nodules at the top and at least one bed of very fine-grained, light-gray, finely cross-bedded sandstone 1 to 2 feet thick. No fossils have been found in the shale. The Rochelle gravel appears to have been washed out by shifting streams over a nearly flat coastal plain, and to have merged laterally into sandy marine deposits. The conglomerate dips northward and westward and is buried beneath younger Pennsylvanian deposits. At Rochelle, 3 miles west of the outcrop, it is penetrated in shallow water wells, furnishes a fairly good water, and is said by drillers to be made up mostly of sand with very little gravel.

*Brownwood shale member.*—The second member in the Canyon, and the one which overlies the Rochelle conglomerate, is the

Brownwood shale. It is red, purple, and gray in color, soft, sandy, somewhat ferruginous, and in places highly fossiliferous, as shown by the fossil lists included in the paragraphs on paleontology. The fossils are shallow-water marine forms; such species as *Juresania symmetrica* (McChesney), *Chonetina flemingi* var. *plebeia* Dunbar and Condra, *Edmondia aspinwallensis* Meek, *Worthenia tabulata* (Conrad), *Amphiscapha catilloides* (Conrad), and *Aviculopecten arctisulcatus* Newell are very common. The shale is quite sandy throughout, contains at least a dozen sandstone lentils and layers and one bed of conglomerate, which is designated Rough Mountain conglomerate lentil to distinguish it from the Rochelle. The Rough Mountain conglomerate is a small lentil, which extends from the point where the Rochelle-Cowboy road leaves the Rochelle-San Saba road north a distance of about 3 miles to a water tank on Baker's ranch (Pl. 20). The conglomerate resembles very closely the Rochelle and undoubtedly was derived from the same source. It is made up of the same subangular chert pebbles but is somewhat coarser and has a greater maximum thickness and less extent. Typical screen analyses of the conglomerate are included below:

*Screen analyses of Rough Mountain conglomerate*[a]

| SIZE *in mm.* | SIZE *in inches* | PERCENT *by weight* |
|---|---|---|
| Larger than 25.4 | Larger than 1 | 3.27 |
| 19.1 to 25.4 | 0.75 to 1 | 8.35 |
| 12.7 to 19.1 | 0.50 to 0.75 | 17.93 |
| 6.35 to 12.7 | 0.25 to 0.50 | 29.95 |
| 2.0 to 6.35 | 0.079 to 0.25 | 22.18 |
| 0.833 to 2.0 | 0.032 to 0.079 | 9.33 |
| 0.59 to 0.833 | 0.023 to 0.032 | 3.22 |
| 0.42 to 0.59 | 0.0165 to 0.023 | 1.10 |
| 0.297 to 0.42 | 0.0117 to 0.0165 | 1.60 |
| 0.250 to 0.297 | 0.0097 to 0.0117 | 0.75 |
| 0.175 to 0.250 | 0.0069 to 0.0097 | 0.55 |
| 0.147 to 0.175 | 0.0058 to 0.0069 | 0.30 |
| 0.074 to 0.147 | 0.0029 to 0.0058 | 1.25 |
| Smaller than 0.074 | Smaller than 0.0029 | 0.007 |
| | Lost in washing | 3.22 |
| | Total | 99.787 |

[a]Analyzed by E. A. Workman and collected 1 mile north of San Saba-Rochelle road on west side of Rochelle-Cowboy road.

The thickness of the Rough Mountain conglomerate varies more than the Rochelle. On the east side of the Rochelle-Cowboy road about 2 miles north of the San Saba-Rochelle highway (Pl. 20, section C–D), it is 6 feet thick; along the road one-fourth of a mile north (Pl. 20), it measures 9½ feet. On the east side of Rough Mountain (Pl. 20), it is 20 feet thick. Here the section is made up of alternating beds of gravel and coarse sand exhibiting cross-bedding like that found in stream terraces. The foreset beds dip toward the southwest at angles ranging from 10° to 30° from the horizontal. Traced westward from Rough Mountain and northward along the base of the Adams Branch escarpment (Pl. 20), the conglomerate thins, and finally grades into a coarse-grained, cross-bedded sandstone 1 mile west and one-half mile north of the east side of Rough Mountain (map, Pl. 20). This conglomerate lentil undoubtedly originated as an alluvial fan or apron washed out on to a nearly flat coastal plain by a stream heading far to the eastward in a region where novaculites and other chert-bearing formations predominated.

The upper part of the Brownwood shale above the Rough Mountain conglomerate and below the Adams Branch limestone is made up of shale with a few thin, fine-grained sandstone layers. In many places the lower portion of the shale, when weathered, is colored red, purple, and greenish gray and is nonfossiliferous. The upper portion is gray and bluish-gray sandy shale containing at least one layer of sandstone and, near the top, a bed of impure limestone 6 to 8 inches thick. A few fossils have been found in these shales. The total thickness of the Brownwood shale measured 3½ miles north of Rochelle is 325 feet.

*Paleontology*.—The fauna of the Canyon group in the Llano region is known from a few rather meager collections made in the vicinity of Rochelle, Placid, and Brady. Brachiopods predominate, but pelecypods and gastropods are well represented. Corals are much rarer than in the Strawn and Bend formations; a few crinoids occur and fusulinids may be collected from the limestones. The following list is representative but not exhaustive.

*Fauna of the Canyon group*

| Canyon Species | 25–T–4 | 153–T–21a | 153–T–23 | 153–T–98 | 153–T–99 | 153–T–100 | 153–T–105 | 153–T–112 | 153–T–113 | 153–T–115 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Foraminifera* | | | | | | | | | | |
| Triticites irregularis (Schellwien and Staff) | x | | | | | | | | x | x |
| Triticites sp. | | | | | | | x | | | |
| *Anthozoa* | | | | | | | | | | |
| Lophophyllidium profundum var. radicosum (Girty) | | | | | | | | x | | |
| *Brachiopoda* | | | | | | | | | | |
| Orbiculoidea missouriensis (Shumard) | | x | | | | | | | | |
| Derbyia crassa (Meek and Hayden) | | | | x | | | | | | |
| Derbyia crassa var. subcircularis Dunbar and Condra | | x | | | | | | | | |
| Derbyia crassa var. texana Dunbar and Condra | | | | | | | | x | | |
| Chonetina flemingi (Norwood and Pratten) | | x | | | | | | | | |
| Chonetina flemingi var. plebeia Dunbar and Condra | | | | x | x | | x | x | | |
| Chonetina rostrata Dunbar and Condra | | | | x | | | | | | |
| Ambocoelia planoconvexa (Shumard) | | | | | | | | x | | |
| Juresania symmetrica (McChesney) | | | | x | | | | | | |
| Echinoconchus sp.? | | | | | | | | x | | |
| Echinoconchus semipunctatus (Shepard) | | | | | | | | x | | |
| Marginifera lasallensis (Worthen) | | | | | | | | x | x | |
| Marginifera muricatina Dunbar and Condra | | | | | | | | x | | |
| Marginifera wabashensis (Norwood and Pratten) | | x | | | | | | | | |
| Dictyoclostus americanus Dunbar and Condra | | | | | | | | | x | |
| Dictyoclostus crassicostatus Dunbar and Condra | | x | | | | | | | | |
| Cryptacanthia whitei Dunbar and Condra | | x | | | | | | | | |
| Neospirifer sp.? | | | | | | | | x | | |
| Neospirifer latus Dunbar and Condra | | | | | | | | x | | |
| Neospirifer dunbari R. H. King | | | | | | | x | | | |
| Neospirifer texanus (Meek) | | x | | | | | | | | |
| Punctospirifer kentuckyensis (Shumard) | | | | | | | | x | | |
| Composita subtilita (Hall) | | | | | | | | x | | |
| Composita trilobata Dunbar and Condra | | | | | | | x | x | | |
| Composita ovata Mather | | | | | | | x | | | |
| Composita argentea (Shepard) | | x | | | | | | | | |
| *Pelecypoda* | | | | | | | | | | |
| Pleurophorus sp.? | | | | x | | | | | | |
| Nucula anadontoides Meek | | | | x | x | | | | | |
| Nuculopsis ventricosa (Hall) | | | | | | | | | | |
| Nuculana attenuata (Meek) | | x | | | | | | | | |
| Nuculana arata (Hall) | | x | | | | | | | | |
| Myalina wyomingensis (Lea) | | | | x | | | | | | |
| Conocardium parrishi Worthen | | x | | | | | | x | x | |
| Myalina sp. | | | | x | | | | | | |
| Septimyalina perattenuata (Meek and Hayden) | | | | | | x | | | | |
| Astartella concentrica (Conrad) | | | | | x | x | | | | |
| Aviculopecten arctisulcatus Newell | | | | x | | | | | | |
| *Gastropoda* | | | | | | | | | | |
| Sphaerodoma primogenium (Conrad) | | | x | | | | | | | |
| Allorisma costatum Meek and Worthen | | | | | | | | | | |
| Worthenia tabulata (Conrad) | | | x | | x | | | | | |
| Trepospira discoidalis Newell | | x | x | | x | | | | | |
| Pharkidonotus cf. P. percarinatus (Conrad) | | | x | | x | x | | | | |
| Amphiscapha catilloides (Conrad) | | | x | | x | x | | | | |
| Meekospira peracuta (Meek and Worthen) | | | x | | x | x | | | | |
| Orthonychia parvum (Swallow) | | | | | | | | x | | |
| Bucanopsis meekiana (Swallow) | | | x | | | | | | | |
| Euphemites, sp. indet. | | | x | | | | | | | |
| Phymatopleura modosa (Girty) | | | x | | | | | | | |
| Glabrocingulum cf. G. grayvillense (Norwood and Pratten) | | | x | | x | x | | | x | |
| *Cephalopoda* | | | | | | | | | | |
| Liroceras liratum (Girty) | | x | | | | | | | | |

*Stratigraphic range of some Canyon fossils*

| Canyon Species | Stratigraphic Position | North Texas: Strawn | North Texas: Canyon | North Texas: Cisco | Cherokee | Marmaton | Kansas City | Lansing | Douglas | Shawnee | Wabaunsee |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Brachiopoda* | | | | | | | | | | | |
| Orbiculoidea missouriensis (Shumard) | A | x | x | x | x | x | x | x | x | x | x |
| Derbyia crassa (Meek and Hayden) | B | x | x | x | x | x | x | x | x | x | x |
| Derbyia crassa var. subcircularis Dunbar and Condra | A | — | — | — | — | — | — | — | x | — | — |
| Derbyia crassa var. texana Dunbar and Condra | A | — | — | x | — | — | — | — | — | — | — |
| Chonetina flemingi (Norwood and Pratten) | A | — | — | — | — | x | x | x | — | — | — |
| Chonetina flemingi var. plebia Dunbar and Condra | B | — | — | — | — | — | x | x | — | — | — |
| Chonetina? rostrata Dunbar and Condra | B | | — | x | — | — | — | x | — | — | — |
| Ambocoelia planoconvexa (Shumard) | A | x | x | x | x | x | x | x | x | x | x |
| Juresania symmetrica (McChesney) | B | — | — | — | — | — | x | x | — | — | — |
| Echinoconchus semipunctatus (Shepard) | A | — | — | — | — | — | x | x | x | — | — |
| Dictyoclostus crassicostatus Dunbar and Condra | A | — | — | — | — | — | x | x | x | x | — |
| Dictyoclostus americanus Dunbar and Condra | D | — | — | — | — | x | x | x | x | x | — |
| Marginifera wabashensis (Norwood and Pratten) | A | — | x | — | — | — | x | x | x | x | — |
| Marginifera lasallensis (Worthen) | AD | — | x | x | — | — | x | x | x | x | — |
| Cryptacanthia whitei Dunbar and Condra | A | — | — | — | — | x | x | — | — | — | — |
| Neospirifer dunbari R. H. King | C | — | x | x | — | x | x | x | x | x | x |
| Neospirifer latus Dunbar and Condra | A | — | — | — | — | x | x | — | — | — | — |
| Neospirifer texanus (Meek) | A | — | — | — | | x | | — | — | — | — |
| Punctospirifer kentuckyensis (Shumard) | A | x | x | x | x | x | x | x | x | x | x |
| Composita subtilita (Hall) | A | x | x | x | x | x | x | x | x | x | x |
| Composita argentea (Shepard) | A | x | x | x | x | x | x | — | — | — | — |
| Composita ovata Mather | C | — | x | — | x | x | x | x | x | x | x |
| Composita trilobata Dunbar and Condra | CA | — | — | — | — | — | x | x | — | — | — |
| *Crinoidea* | | | | | | | | | | | |
| Apographiocrinus exculptus Moore and Plummer | D | — | — | — | — | — | — | — | — | — | — |
| Athlocrinus nitidus Moore and Plummer | B | — | — | — | — | — | — | — | — | — | — |
| Delocrinus benthobatus Moore and Plummer | B | x | — | — | — | — | — | — | — | — | — |
| Endelocrinus parvus Moore and Plummer | D | — | x | — | — | x | — | x | — | — | — |
| Paradelocrinus subplanus Moore and Plummer | D | x | — | — | — | x | — | — | — | — | — |
| Parulocrinus pustulosus Moore and Plummer | B | — | — | — | — | — | — | — | — | — | — |
| Plaxocrinus lobatus Moore and Plummer | B | — | — | — | — | — | — | — | — | — | — |
| Plaxocrinus omphaloides Moore and Plummer | B | — | — | — | — | — | — | — | — | — | — |
| Sciadocrinus disculus Moore and Plummer | B | — | — | — | — | — | — | — | — | — | — |
| *Fusulinids* | | | | | | | | | | | |
| Triticites irregularis (Schellwien and Staff) (1)[a] | A | — | x | — | — | — | — | — | — | — | — |
| Triticites irregularis (Schellwien and Staff) (4)[a] | B | — | x | — | — | — | — | — | — | — | — |

[a]Form 1; form 4; see White (1932).
A. Shale between Adams Branch limestone beds.
B. Brownwood shale, near base.
C. Probably Ranger, near top of Placid beds.
D. Top of Brownwood shale just below Adams Branch.

It will be noted at once that most of the species are rather long ranging forms and are not useful for close correlation. The assemblage as a whole, however, is composed of forms that occur for the most part in the Missouri division of the Pennsylvanian, and most of the forms occur in the Graford formation in Palo Pinto County and in the Kansas City and Lansing group of northern Midcontinent. The geographic and stratigraphic occurrences of the crinoids, brachiopods, gastropods, and fusulinids are shown in the accompanying tables. The most typical ones are illustrated in Plate 21. The identifications of the gastropods have been checked by J. Brookes Knight.

*Fusulinid zones in the Canyon and Strawn groups in central Texas*

| GROUP | FORMATION | ZONE |
|---|---|---|
| Cisco | Graham | Triticites cullomensis |
| Canyon (Top of Caddo Creek limestone to top of Lake Pinto sandstone) | Caddo Creek | Triticites acutus |
| | Brad | Triticites ohioensis |
| | Graford | Triticites irregularis (large form) |
| | Palo Pinto | Triticites irregularis (large form) |
| | Whitt | Triticites irregularis (small form) |
| | Lone Camp | (Not present in Llano region) |
| Strawn (Bottom of Lake Pinto sandstone) to top of Smithwick shale) | Mineral Wells (restricted) | No fusulinids found |
| | Santo | Fusulina? rickerensis |
| | Millsap Lake | Fusulinella meeki<br>Fusulinella haworthi<br>Fusulinella euthusepta<br>Fusulinella prolifica |

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### Fossil Localities

Fossil localities in the Canyon group are as follows:

**153–T–21 (M–10,** Pl. 1).—McCulloch County. Shale layers between limestone beds on north side of road near top of Adams Branch escarpment, 1.4 miles east of paved highway at Placid. Locality 153–T–21 is in the shale 15 to 20 feet below the massive Adams Branch limestone. Locality 153–T–21a is in the shale above the massive limestone and below the less massive limestone which caps the top of the escarpment. It is reached by driving on the highway to Placid, turning east at Placid, and taking the Cowboy road 1.4 miles to the top of the escarpment.

**153–T–23 (M–12,** Pl. 1).—McCulloch County. Shale below Rough Mountain conglomerate 3.5 miles east and 2.5 miles north of Rochelle. The locality is reached by going to Rochelle, driving northeast on the Placid road a distance of 0.9 of a mile to a road running due east. Take the road running due east and travel 1¾ miles, then turn north on the Cowboy road and travel 2½ miles to the first road turning due east. Then continue north on the same road 0.1 of a mile to a conglomerate-capped hill on the west side of the road. The fossils are in the shale 0 to 20 feet below the conglomerate.

**153–T–98 (M–11,** Pl. 1).—McCulloch County. Four and one-half miles east and 3¾ miles north of Rochelle in a small saddle between two ridges 406 feet north of Myers' house on the west side of a small tank. It is reached by going to Rochelle, traveling northeast on the road to Placid, and turning off on the first main highway running east at a point about 0.9 of a mile northeast of Rochelle, traveling 1¾ miles due east, then turning north and traveling 2¾ miles to a second road going due east. Drive 0.9 of a mile on this road to a gate and secondary road running south. Travel south on the secondary road toward Myers' house to the tank about one-half mile south to the main road. The fossils are in a shale below the top of the ridge.

**153–T–99 (L–13,** Pl. 1).—McCulloch County. Two and nine-tenths miles east and 1.3 miles north of Rochelle. It is reached by going 0.9 of a mile on the Placid road from Rochelle, turning due east and traveling 1¾ miles, then turning north on the Cowboy road and going 1.2 miles. The fossils are near the bottom of a small valley or gully about 1,000 feet due east of the road at this point. The best collecting was on the south side of the valley in red shale beneath the conglomerate beds.

**153–T–100 (M–11,** Pl. 1).—McCulloch County. Three and four-tenths miles east and 4.3 miles north of Rochelle on the west side of the highway. It is reached by taking the Rochelle-Placid road and driving northeast 0.9 of a mile, turning due east and going 1¾ miles to a north road leading to Cowboy. Take the Cowboy road and drive north 4 miles to a road running east. The fossils are in a grayish-yellowish shale on the southeast and the southwest sides of a low hill located about 750 feet north and 500 feet west of the T-road running east.

**153–T–113 (L–12,** Pl. 1).—McCulloch County. One and four-tenths miles east and 1.8 miles north of Rochelle. This locality is reached by driving to Rochelle and taking the Rochelle-Placid road and driving east and north a distance of 2.2 miles to the Price ranch. Turn to the right and drive about 0.1 of a mile toward Price ranch house. Then leave the car and follow the fence running due east a distance of about 0.4 of a mile to the Adams Branch escarpment. The fossils are on the north side of the fence at the head of a gully just below the Adams Branch limestone.

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## POST-CARBONIFEROUS STRATA

### Cretaceous System

#### GENERAL RELATIONSHIPS

Strata of Lower Cretaceous age border the Llano region on all sides except the north and form a natural boundary which limits mapping and stratigraphic studies of the Paleozoic formations (map, Pl. 1). Everywhere the Cretaceous strata lie unconformably upon the older formations and dip gently toward the southeast. The contact of the Cretaceous with the Paleozoic and pre-Cambrian rocks is that of a progressive overlap.

In the Colorado River valley east of Marble Falls in Burnet County, basal Travis Peak gravel is in contact with the Paleozoics. But if one follows the Cretaceous contact from east to west toward the interior of the region, and to topographically higher elevations, younger and stratigraphically higher members of the Lower Cretaceous come in contact with the Ellenburger and older rocks, until, in the Shin Oak hills northeast of Pontotoc in San Saba County, Comanche Peak beds are in contact with the Cambrian, indicating clearly that the Llano region was an island during the Travis Peak and Walnut epochs, that as time elapsed the island became smaller, and that finally, during the late Comanche Peak or early Edwards epochs, the area was entirely submerged (Taff, 1892; Cuyler, 1931; Barnes, 1941).

The Cretaceous units recognized in central Texas are listed as follows:

Fredericksburg group—
  Edwards limestone
  Comanche Peak limestone
  Walnut clay

Trinity group—
  Paluxy sand (northeastern part of area only)
  Glen Rose limestone
  Travis Peak formation—
    Hensell sand
    Cow Creek limestone
    Sycamore sand

These units are described briefly in the following pages. References to literature on the Cretaceous are given in the bibliography following the descriptions.

### TRAVIS PEAK FORMATION

*Distribution and thickness.*—The distribution of the Travis Peak formation is indicated on the accompanying map (Pl. 1) by a letter symbol, Kt. It outcrops along the east, south, and west borders of the Llano region and is deeply indented by the major stream courses. It is particularly well developed along the eastern side of the uplift in Burnet, Comanche, and Mills counties and is beautifully exposed in Hamilton, Lynch, and Elliott creek valleys, tributaries of the Colorado. On the south side of the region it is best seen along the tributaries of the Pedernales, and on the west side of the region it may be seen along the Llano River valley, particularly at Yates Crossing southwest of London, and along the base of Brady Mountain in McCulloch County. North of the Llano region, if ever deposited, it has been removed by erosion.

Where the Travis Peak sequence is complete, as in the deeper valleys and well sections east of the region, it consists of a basal conglomerate grading upward into sand, a middle limestone replaced laterally by red clay, and an upper pebbly sand grading upward and laterally into a fine sand. Due to overlap the formation thins toward the higher areas and transgresses upward in the section. In some places only the upper sand is present, and in others the entire formation has pinched out, except a few feet or even only a few inches of pebbly conglomerate. Measurements of thickness of the Travis Peak formation at several localities are shown in the accompanying table.

*Thicknesses of the Travis Peak formation*

| LOCALITY | THICKNESS *Feet* | AUTHORITY |
|---|---|---|
| U. S. Army water well at Camp Hood, Bell County | 250 | F. B. Plummer |
| City water well at Burton, Burnet County | 130 | F. B. Plummer |
| Burnet-Llano road 3 miles west of Burnet, Burnet County | 93 | F. B. Plummer |
| Type locality below Travis Peak post office on Cow Creek, Travis County | 263 | Cuyler (1931, p. 1) |
| Hickory Creek, Burnet County | 263[a] | Hill (1901, p. 135) |
| Hammett's Crossing, Pedernales River, Travis County | 217 | Cuyler (1931, p. 37) |
| Deadman's Hole, Hays County | 209[a] | Cuyler (1931, p. 37) |
| Pedernales Falls, Fuchs' ranch, Blanco County | 151.5 | Damon (1940, p. 17) |
| Cox's Crossing, Pedernales River, Travis County | 260[a] | Cuyler (1931, p. 25) |
| Rebecca Creek, Comal County | 120[a] | Cuyler (1931, p. 25) |
| Specks Crossing, Guadalupe River, Comal County | 118 | Cuyler (1931, p. 25) |
| Leon Springs, Bexar County | 480[a] | A. Deussen[b] |
| Brady Mountain, Highway 87, McCulloch County | 18 | H. G. Damon |
| Yates Crossing on Llano River, Kimble County | 20 | H. G. Damon |
| Old Llano road west of Hancock Park, Lampasas County | 50 | H. G. Damon |
| McNett Creek, Jones ranch near Wheeler ranch line, Lampasas County | 28 | H. G. Damon |
| Along Antelope and Elliott creeks, Lampasas County | 55 | H. G. Damon |

[a]Complete section.
[b]Sellards, E. H., The geology and mineral resources of Bexar County: Univ. Texas Bull. 1932, pp. 21—22, 1919.

*Sycamore sand.*—The Sycamore sand outcrops in the valleys leading into Colorado and Pedernales rivers on the east side of the region. It consists typically of a basal conglomerate grading upward into a coarse sand. The lower conglomerate is made up of subrounded cobbles 3 to 6 inches in diameter set in a matrix of finer dolomite, chert, sandstone, quartzite, granite, and quartz. In most places Ellenburger cobbles greatly predominate. The largest cobble noted in several sections was an Ellenburger chert fragment 7 inches in diameter. The conglomerate has a pink or reddish-gray color, and the overlying sand is reddish brown. In places both the conglomerate and sand are quite firmly cemented with a calcareous cement and may weather to form large boulders and blocks resembling concrete. Analyses of the size, shape, and lithology of the conglomerate and sand have been made by Damon (1940, pp. 8–56) and Bruce Grant. Six of these analyses are included in the accompanying table.

The distribution of the conglomerate, its type of cross-bedding, and the shape and mode of assorting the pebbles, according to Damon (1940), suggest strongly that the conglomerate was originally of nonmarine origin and was deposited by streams as terraces or as a series of alluvial aprons spreading outward from the central part of the region. The gravel

*Size-frequency distribution of cobbles and pebbles from the Sycamore conglomerate*
(Percent by weight)

| SIZE *Millimeters* | LOCALITY NUMBERS 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Larger than 256 | 11.0 | — | — | — | — | — |
| 128–256 | 23.0 | 2.0 | — | 3.5 | 15.0 | — |
| 64–128 | 12.5 | 20.0 | — | 8.0 | 19.5 | — |
| 32– 64 | 5.0 | 23.5 | — | 21.0 | 18.5 | — |
| 16– 32 | 4.5 | 5.0 | 30.0 | 9.0 | 16.9 | 20.53 |
| 8– 16 | 2.0 | 2.0 | 20.2 | 8.5 | 16.2 | 40.94 |
| 4– 8 | 1.0 | 0.3 | 12.0 | 6.9 | 3.8 | 13.89 |
| 2– 4 | 3.5 | 0.5 | 4.9 | 5.0 | 3.2 | 12.20 |
| 1– 2 | 11.0 | 2.2 | 4.6 | 5.8 | 2.2 | 6.42 |
| 0.5 – 1 | 12.5 | 10.0 | 11.4 | 6.7 | 1.8 | 2.62 |
| 0.25 –0.5 | 5.0 | 16.3 | 8.9 | 11.6 | 1.7 | 1.59 |
| 0.125 –0.25 | 1.2 | 2.5 | 3.2 | 6.5 | 1.1 | 0.88 |
| 0.0625–0.125 | 0.6 | 0.6 | 2.2 | 1.9 | 0.9 | 0.69 |
| 0.032 –0.0625 | — | 0.5 | 1.3 | 0.7 | 0.2 | 0.18 |
| 0.015 –0.032 | — | — | — | 4.9 | — | — |
| Smaller than 0.015 | 3.2 | 1.6 | 1.3 | — | — | — |
| Clay | 4.0 | 3.0 | — | — | — | — |

Localities—

1. At Pedernales Falls (Fuchs' ranch near Slide Rock, 4 miles south of Cypress Mills Post Office) from near base of conglomerate. (Analyzed by Gordon Damon.)
2. On Hickory Creek, 1 mile south of B. M. 835 on Marble Falls-Bertram road. Near base of conglomerate. (Analyzed by Gordon Damon.)
3. Near mouth of Spanish Oak Creek on Austin Marble Falls road. Near top of conglomerate. (Analyzed by Bruce Grant.)
4. Elliott Creek at crossing of old Lometa-Goldthwaite road. Probably about middle of conglomerate. (Analyzed by Gordon Damon.)
5. Top of cut, north of road, 2.4 miles north and 0.5 of a mile west of Hall. Near base of conglomerate overlying Strawn. (Analyzed by Gordon Damon.)
6. Overlying Rochelle conglomerate, 1.5 miles west of No. 5 near base of conglomerate. (Analyzed by Gordon Damon.)

*Size-frequency analyses of sand grains from Sycamore sand in water wells east of region.* (Analyzed by Ernest Merkt.)

(Percent by weight)

| SIZE *Millimeters* | LOCALITY 1 *Percent* | LOCALITY 2 *Percent* |
|---|---|---|
| Larger than 0.42 | 7.12 | 6.88 |
| 0.42 –0.246 | 34.51 | 35.76 |
| 0.246–0.147 | 47.69 | 41.07 |
| 0.147–0.105 | 8.96 | 10.83 |
| 0.105–0.088 | 0.69 | 1.29 |
| 0.088–0.074 | 0.65 | 1.61 |
| Smaller than 0.074 | 0.29 | 2.21 |

Locality 1. U. S. Army Water Well No. 2, Gatesville Camp, Coryell County.
Locality 2. U. S. Army Water Well No. 6, Gatesville Camp, Coryell County.

deposits undoubtedly were later worked over to some extent by the encroaching Lower Cretaceous sea. The lithologic character and the size analysis of the pebbles are shown in the accompanying table by Damon.

The thickness of the Sycamore sand varies greatly. It is thickest in Pedernales River valley and in water wells drilled east of the region, and thinnest in central Burnet County where it pinches out against Paleozoic rocks, and elsewhere where pre-Cretaceous topography is high. Typical measurements are shown in the accompanying table.

*Lithologic analyses of pebbles from conglomerate in Sycamore sand*

| Locality | Type of particle and size in mm. | Dolomite | Limestone[a] | | | Chert | | Quartz | Feldspar |
|---|---|---|---|---|---|---|---|---|---|
| | | E | E | M | B | C | M | | |
| 1 | Cobble, 64–128 | 100 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| | Pebble, 8–16 | 75 | -------- | -------- | -------- | 25.0 | -------- | -------- | -------- |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | 76.0 | -------- | 24.0 | -------- |
| 2 | Cobble, 64–128 | 100 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| | Pebble, 8–16 | 80 | -------- | -------- | -------- | 11.0 | -------- | 8.0 | 1.0 |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | 15.2 | -------- | 80.0 | 4.8 |
| 3 | Pebble, 8–16 | 35 | 50 | -------- | -------- | 5.0 | -------- | 10.0 | -------- |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | 3.8 | -------- | 77.0 | 19.2 |
| 4 | Cobble, 64–128 | 100 | -------- | -------- | -------- | -------- | -------- | -------- | -------- |
| | Pebble, 8–16 | 36 | -------- | -------- | -------- | 54.0 | -------- | 10.0 | -------- |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | 7.0 | -------- | 92.0 | 1.0 |
| 5[b] | Cobble, 64–128 | 28.5 | 28.5 | 21.5 | -------- | 18.0 | 3.6 | -------- | -------- |
| | Pebble, 8–16 | 32.0 | 17.0 | 8.5 | 6.2 | 13.0 | 19.0 | 4.3 | -------- |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | -------- | -------- | 100.0 | -------- |
| 6 | Cobble, 64–128 | 4.0 | 11.5 | 28.0 | 27.0 | 15.5 | -------- | 4.0 | -------- |
| | Pebble, 8–16 | 9.0 | 18.0 | 38.0 | -------- | 29.0 | 6.0 | -------- | -------- |
| | Sand, 0.25–0.5 | -------- | -------- | -------- | -------- | -------- | -------- | 100.0 | -------- |

[a]M, Marble Falls; B, Barnett; C, Chappel; E, Ellenburger.
[b]No. 5 sample contains also limestone pebbles from the Wilberns formation, 4.2 percent, and from the Chappel, 2 percent.

Localities—
1. At Pedernales Falls (Fuchs' ranch near Slide Rock, 4 miles south of Cypress Mills Post Office), near base of conglomerate, Blanco County.
2. On Hickory Creek, 1 mile south of B. M. 835 on Marble Falls-Bertram road, near base of conglomerate, Burnet County.
3. Near mouth of Spanish Oak Creek on Austin-Marble Falls road near top of conglomerate.
4. Elliott Creek at crossing of old Lometa-Goldthwaite road, probably about middle of conglomerate, Mills County.
5. Top of cut north of road, 2.4 miles north and 0.5 of a mile west of Hall near base of conglomerate overlying Strawn (analyzed by Grant), San Saba County.
6. Overlying Rochelle conglomerate, 1.5 miles west of No. 5 near base of conglomerate, San Saba County.

*Thicknesses of the Sycamore sand*

| LOCALITY | THICKNESS *Feet* | AUTHORITY |
|---|---|---|
| Water wells at Camp Hood, Bell County | 75 | F. B. Plummer |
| Water well at Insane Asylum, Austin, Travis County | 318 | F. B. Plummer |
| Cox's Crossing, Pedernales River, Burnet County | 93 | R. H. Cuyler |
| Hammett's Crossing, Pedernales River, Travis County | 62 | R. H. Cuyler |
| Below Pedernales Falls, Fuchs' ranch, Blanco County | 55 | H. G. Damon |
| Hickory Creek, Burnet County | 50 | R. H. Cuyler |
| Water well at Burton, Burnet County | 50 | F. B. Plummer |
| West side of Hamilton Creek valley, Burnet County | 30 | F. B. Plummer |
| Smithwick-Marble Falls road at B. M. 899 | 22 | F. B. Plummer |
| Cypress Creek, north of Burleson house | 4 | F. B. Plummer |

*Cow Creek limestone.*—The Cow Creek limestone, lying between the upper and lower sand members of the Travis Peak formation, is well exposed at its type locality along Cow Creek, near Hamilton Pool, Travis County, and also about 2 miles below Cox's Crossing on Pedernales River. It is a local shallow-water, marine limestone, interbedded with shale and thin shell beds in Blanco, Burnet, and Travis counties in the southeastern part of the region. In the central part of the region it thins, changes to two or three shell beds separated by sand, and plays out against Paleozoic rocks. Eastward, it is replaced by red clay, marl, and greenish-gray silt. Its extent southward has not been ascertained.

This limestone member consists of hard, grayish-white, rather thick, subcrystalline, evenly bedded layers about 1 foot thick. In some places, however, it carries thin layers rather rich in oysters and other shallow-water forms. It resembles the Glen Rose limestone, but is distinctly harder, less granular, and more distinctly bedded. The accompanying table shows its thickness at several localities.

*Thicknesses of the Cow Creek limestone*

| LOCALITY | THICKNESS *Feet* | AUTHORITY |
|---|---|---|
| Hickory Creek, Burnet County | 27 | R. H. Cuyler |
| Cox's Crossing, Pedernales River, Travis County | 56 | R. H. Cuyler |
| Hammett's Crossing, Pedernales River, Travis County | 76 | R. H. Cuyler |
| Deadman's Hole, Travis County | 65 | R. H. Cuyler |
| Cow Creek, type locality at Travis Peak, Travis County | 27 | J. A. Taff |

*Section of Cow Creek limestone on Hickory Creek* (measured by Taff (1892) and revised by the author).

| | THICKNESS *Feet* |
|---|---|
| 3. Shell breccia, cross-bedded, containing many small rounded grains and pebbles of quartz, flint, and granite; also many fossils including *Trigonia*, small bivalves, and an ammonite | 7 |
| 2. Shell conglomerate; worn fragments of oyster shells and other molluscs mixed with sand and small pebbles, stratified and cross-bedded | 5 |
| 1. Shale, bluish gray, interstratified with calcareous sand containing many shell fragments | 15 |
| Total thickness | 27 |

At Deadman's Hole in Travis County, the member consists almost altogether of hard, gray to grayish-white limestone in beds about 1 foot thick. Some of the layers contain fossils.

The fauna of the Cow Creek limestone has been studied by Cuyler (1931), who lists 31 genera and 49 species. Most of the species are new and have not yet been published. The following forms have been described by Cragin, Shumard, Hill, Roemer, Wells, and others, and are in the collections at The University of Texas.

*Fossils from the Cow Creek limestone*

Anthozoa—
- Orbicella travisensis Wells
- Siderastrea cuyleri Wells

Pelecypoda—
- Cucullaea gracilis Cragin
- Cucullaea terminalis Conrad
- Ostrea camelina Cragin
- Ostrea franklini Coquand
- Ostrea alternans (Cragin)
- Trigonia concentrica (Cragin)
- Liopistha jurafacies (Cragin)
- Arctica medialis (Conrad)
- Arctica roemeri (Cragin)
- Cyrena arkansasensis Hill
- Astarte pikensis (Hill)
- Phacoides potosinus (Costillo and Aguilera)
- Protocardia mulistriata (Shumard)

Gastropoda—
- Nerinea texana Roemer

Cephalopoda—
- Dufrenoya roemeri (Cragin)

*Hensell sand.*—This upper member of the Travis Peak formation outcrops above the Cow Creek beds in Colorado and Pedernales River valleys on the southeast side of the region. Where the underlying Cow Creek limestone has thinned out, the Hensell sand becomes the basal sand of the Cretaceous. It may be equivalent to the lower portion of the Gillespie formation in Gillespie County, a name given to the Lower Cretaceous sand of that region by Hill and Vaughan (1898, p. 221) and is possibly present as a sand and conglomerate between the Glen Rose and Paleozoic rocks in certain localities on the west side of the region.[9] East of the region, it appears to be a very fine-grained, greenish-gray sand above a thick, dark-red or maroon clay and is called "upper Trinity sand" by water-well drillers. The member consists of conglomerate, composed in most places of fine cobbles or pebbles at the base and overlain by very fine, silty, cross-bedded sand. The thickness varies considerably, but in many places it reaches a maximum of 60 to 100 feet, as shown in the accompanying table.

[9]Barnes (1941) has confirmed Hill and Vaughan's (1898, p. 221) conclusion that at least the upper portion of the Gillespie sand is the shore facies of the Glen Rose limestone.

*Thicknesses of the Hensell sand*

| LOCALITY | THICKNESS *Feet* | AUTHORITY |
|---|---|---|
| Travis Peak on Hickory Creek, Travis County | 263 | R. H. Cuyler |
| Hickory Creek, Burnet County | 40 | R. H. Cuyler |
| Cox's Crossing, Travis County | 50 | R. H. Cuyler |
| Hammett's Crossing, Travis County | 79 | R. H. Cuyler |
| Deadman's Hole, Travis County | 72 | R. H. Cuyler |
| Rebecca Creek, Comal County | 45 | R. H. Cuyler |
| Specks Crossing, Comal County | 40 | F. B. Plummer |
| Camp Hood water wells, Bell County | 70 | F. B. Plummer |
| Bertram City water well, Burnet County | 26 | E. H. Sellards |
| Artesian wells at Austin (natatorium well), Travis County | 525 | J. A. Taff |

The Hensell sand comprises largely angular and subrounded quartz grains from 1/4 to 1/2 mm. in size, although the lower layers in many places are much coarser. In places, the sand contains much fine silt and some calcareous cementing material, so that the permeability is lowered considerably. The silt occurs both mixed with the fine sand and in thin layers between sand beds. The member in some places also contains several thin layers of oyster shells more or less broken and water worn and, in places, it is cemented to form a highly calcareous lentil of sandy limestone in the sand. The following table shows the grain size ratios.

*Size analysis of sand from Hensell sand of the Travis Peak formation in percent by weight*

(Analysis by Ernest Merkt)

| Size of grains *Millimeters* | Sample A *Percent* | Sample B *Percent* |
|---|---|---|
| Greater than 0.42 | 42.08 | 22.28 |
| 0.25 –0.42 | 33.85 | 37.50 |
| 0.149–0.25 | 16.57 | 29.26 |
| 0.074–0.149 | 5.63 | 8.49 |
| 0.063–0.074 | 0.54 | 0.90 |
| 0.053–0.063 | 0.74 | 0.79 |
| Less than 0.053 | 0.34 | 0.64 |

Sample A. Water well No. 2, city of Bertram; depth 330 feet.

Sample B. Water well No. 4, U. S. Army, Gatesville Camp; depth 510–515 feet.

Two types of cross-bedding occur: One resembles the bedding found in barrier beaches and another has strong foreset beds, indicating deltaic deposition. In both types, however, the sand appears to be of shallow-water and near-shore origin. The oyster and gastropod shell beds clearly indicate marine, near-shore conditions. This upper sand marks a transgressing sea epoch, which culminated in deposition of the thick beds of Glen Rose limestone.

## GLEN ROSE LIMESTONE

*Distribution and thickness.*—The Glen Rose limestone overlies the Travis Peak formation in the topographically lower areas of the Llano region along the Colorado, Pedernales, and Llano river valleys and overlaps on to the Paleozoic rocks in the topographically higher areas on the divides between these valleys. The Llano region was an island during Travis Peak time, and the Glen Rose sea transgressed over the island, nearly enveloping it. Accordingly, the Glen Rose sediments in their basal portion exhibit a beach and shallow-water facies. The Glen Rose formation thins toward the higher elevations and pinches out against the highest points on the Paleozoic surface. The thickness, therefore, varies markedly from place to place, the character of the sediments changes from limestones to marls, and then to basal sandy and pebbly facies as the elevated regions are approached. Only a few Glen Rose sections have been measured, but those will serve as typical examples:

*Thicknesses of the Glen Rose limestone*

| LOCALITY | THICKNESS *Feet* |
|---|---|
| Water well at Bertram, Burnet County | 235.0 |
| Burnet-Austin road, 2 miles east of Burnet | 67.5 |
| Burnet-Llano road, 2 miles west of Burnet | 74.0 |
| Brady-Coleman road at Brady Mountain (measured by H. G. Damon) | 75.5 |
| 1 mile west of Erna, Menard County | 45.0 to 100 |

*Lithology.*—The Glen Rose limestone in its shoreward facies is dark-gray, sticky, colloidal marl, weathering light gray, forming poor caliche-like soils, and containing several layers of light-gray to nearly white limestone. Some of the limestone layers near the bottom are made up largely of small *Turritella*-like shells, are very porous, and in a few places are impregnated with asphalt. Farther away from the shore line in central Lampasas County, the Glen Rose consists of alternating layers of granular, subcrystalline limestone and soft marly clay. The limestone layers resist erosion more easily than the marl, so that the hillsides are sculptured in the form of a series of step-like benches which produce a striking physiographic feature in the landscape. These benches are characteristic of the Glen Rose. Farther east in Williamson, Coryell, and Bell counties the Glen Rose formation is made up almost entirely of gray and bluish-gray, rather hard, non-crystalline, granular limestone containing thin partings of black shale or marl. The granular texture of the limestone is a characteristic feature of the Glen Rose. Under the microscope, much of the material appears to be made up of black and white small, more or less rounded limestone grains averaging about 1/10 of a millimeter in diameter. In some layers, the black and white grains are present in about equal quantities. In others, white grains predominate and the black ones appear to be suspended in the gray matrix. Some of them appear to be, and probably are, small oolites. Many of them, however, are small limestone grains which were formed along the coast lines, probably by granular precipitation of calcium carbonate due to aeration of calcium bicarbonate sea water. The grains were washed along the coast and seaward by currents and deposited just like silt or sand grains on the sea-bottom. The limestone is nearly pure calcium carbonate. When dissolved in acid, generally less than 2 percent of insoluble residue is obtained. Although the Glen Rose contains a few porous and permeable zones, for the most part the permeability is low. Cores through a typical section on Lampasas River near Maxdale, Bell County, furnished the following porosity and permeability measurements (Plummer and Tapp, 1943).

*Permeability, porosity, and specific gravity of Glen Rose limestone, Maxdale district, Bell County.*

| DEPTH *Feet* | SPECIFIC GRAVITY | POROSITY *Percent* | RADIAL PERMEABILITY *Millidarcys* |
|---|---|---|---|
| 18.5 | ---- | ---- | 0.397 |
| 20.5 | 2.619 | 16.5 | 2.200 |
| 22.5 | 2.700 | 18.22 | ---- |
| 25.0 | 2.677 | 17.33 | ---- |
| 26.0 | 2.642 | ---- | ---- |
| 28.5 | 2.530 | ---- | 0.828 |
| 30.5 | ---- | ---- | 0.340 |
| 32.0 | 2.621 | 13.62 | ---- |
| 33.25 | 2.677 | 17.87 | ---- |
| 33.5 | 2.691 | 16.18 | ---- |
| 35.0 | 2.621 | 16.03 | ---- |
| 39.0 | 2.609 | 16.40 | ---- |
| 40.5 | 2.692 | 18.83 | ---- |
| 41.0 | ---- | ---- | 0.227 |
| 42.0 | ---- | ---- | 8.150 |
| 43.0 | ---- | ---- | 0.417 |
| 44.5 | 2.665 | 17.02 | ---- |
| 47.0 | ---- | ---- | 1.324 |

On the north side of the uplift in San Saba and eastern McCulloch counties, the Glen Rose limestone is missing. At Rochelle in eastern McCulloch County, Walnut marl lies directly on Marble Falls limestone. In western McCulloch County along the base of Brady Mountain, Damon found 50 to 75 feet of limestone and marl below the Walnut marl which he referred to the Glen Rose. In western Mason County near the Kimble County line along the base of Blue Mountain and along the escarpment west of Erna in eastern Menard County, the strata below the Walnut consist of marl, sandy marl, and sand at the bottom, having a total thickness of about 100 feet. This sand and sandy marl facies is probably all of Glen Rose age, although the lower 55 feet of the section resembles closely in lithology and appearance the Hensell sand of the Travis Peak formation. Still farther west at London there is a limestone present below the Walnut clay. At the base of the section at Yates Crossing on Llano River, the coarse conglomerate has been tentatively referred to the Travis Peak formation, although this too may be of Glen Rose age. It is apparent, therefore, that the Glen Rose thins and grades to a marl and finally to silt and sand around the higher elevations in the pre-Cretaceous topography.

*Paleontology.*—The Glen Rose limestone has not yet been subdivided into members or zones by means of fossils. In central Texas on the east and northeast side of the Llano region, a prominent and persistent zone of small turreted gastropods belonging to the genera *Cassiope* and *Cerithium* occurs near the base of the Glen Rose and can be traced laterally for many miles. Marion Whitney (1937, p. 5) found that an echinoid, *Salenia texana* Credner, occurred in a definite zone about 275 feet above the base of the formation. F. L. Whitney[10] states that a small pelecypod, *Nuculana*, occurs in large numbers in a definite zone that can be traced from Cow Creek to Shoal Creek. In core tests at Mansfield Dam (formerly Marshall Ford Dam) it was found 278 feet above the base, at Cow Creek 100 feet above the base, and at Shoal Creek, 47 feet above the base. On the south and southeast sides of the region, several zones containing an abundance of the large foraminifer *Orbitolina texana* (Roemer) occur in the lower part of the formation. In water wells southeast of Gatesville in Coryell County, these interesting forms, which characterize the Glen Rose, were collected from two horizons. one 10 feet above the base and the other 150 feet above the base. Some of the marly layers interbedded with the limestone layers contain numerous ostracodes and small charas. On the whole, microfossils are less common in the Glen Rose than in some of the other Cretaceous formations. On the other hand, casts of certain large fossils, especially large gastropods and pelecypods, are quite common. The following forms have been identified by Marion Whitney (1937):

*Fossils identified from the Glen Rose limestone*

Echinoidea—
- Pentacrinus, n. sp.
- Leiocidaris, n. sp.
- Salenia texana Credner
- Salenia mexicana Schlüter
- Salenia, n. sp.
- Goniopygus, n. sp.
- Orthopsis, n. sp.
- Pseudodiadema texanum (Roemer)
- Pseudodiadema, n. sp.
- Diplopodia texanum (Roemer)
- Holectypus planatus Roemer
- Holectypus, n. sp.
- Pyrina, n. sp.
- Enallaster texanus (Roemer) (Heteraster, according to Adkins)
- Enallaster obliquatus Clark
- Hemiaster whitei Clark
- Hemiaster comanchei Clark

Brachiopoda—
- Rhynchonella, n. sp.
- Kingena, n. sp.

Pelecypoda—
- Nucula, n. sp.
- Cucullaea terminalis Conrad
- Cucullaea gratiola Hill
- Cucullaea gracilis Cragin
- Cucullaea, n. sp.
- Arca texana (Roemer)
- Arca, n. sp.
- Perna, n. sp.
- Ostrea, n. sp.
- Exogyra weatherfordensis Cragin
- Exogyra, n. sp.
- Alectryonia alternans (Cragin)
- Alectryonia, n. sp.
- Trigonia, n. sp.
- Hinnites, n. sp.
- Neithea irregularis (Böse)
- Pecten stantoni Hill
- Pecten, n. sp.
- Plicatula, n. sp.
- Spondylus, n. sp.
- Lima wacoensis Roemer
- Anomia, n. sp.
- Modiola concentrice-costellata Roemer
- Modiola branneri Hill
- Modiola, n. sp.
- Mytilus, n. sp.
- Homomya knowltoni (Hill)
- Homomya, n. sp.
- Pholadomya, n. sp.
- Anatina, n. sp.
- Liopistha (Psilomya) solida (Cragin)
- Liopistha (Psilomya) jurafacies (Cragin)
- Liopistha (Psilomya), n. sp.
- Liopistha (Psilomya) alta (Roemer)
- Cypricardia compacta (White)
- Cypricardia, n. sp.
- Arctica texana (Conrad)
- Arctica, n. sp.
- Arctica medialis (Conrad)
- Arctica gibbosa (Giebel)
- Arctica roemeri (Cragin)
- Astarte, n. sp.
- Crassatellites, n. sp.
- Cardita, n. sp.
- Toucasia texana (Roemer)
- Toucasia, n. sp.
- Monopleura marcida White
- Monopleura subtriquetra Roemer
- Immanitas, n.sp.
- Lucina (Phacoides), n. sp.
- Corbis, n. sp.
- Cardium congestum Conrad
- Cardium, n. sp.
- Cardium subcongestum Böse
- Granocardium, n. sp.
- Protocardia texana Conrad
- Protocardia multistriatum (Shumard)
- Meretrix texana (Conrad)
- Meretrix, n. sp.

[10]Personal communication, 1945.

Cyprimeria texana (Roemer)
Tapes decepta (Hill)
Tapes, n. sp.
Corbula, n. sp.
Panopea henselli (Hill)
Panopea, n. sp.
Gastropoda—
Pleurotomaria, n. sp.
Turbo, n. sp.
Nerita, n. sp.
Purpuroidea, n. sp.
Tylostoma, n. sp.
Lunatia pedernalis (Hill)
Natica, n. sp.
Amauropsis, n. sp.
Siliquaria, n. sp.
Pleurocera branneri (Hill)
Nerinea, n.sp.
Nerinea texana Roemer
Nerinella cf. circumvoluta (Cragin)
Nerinella, n. sp.
Cerithium, n. sp.
Strombus, n. sp.
Harpagodes, n. sp.
Fusus, n. sp.
Trochactaeon, n. sp.
Cylichna, n. sp.

The following corals have been identified by Wells (1932):

Glen Rose—
Tiarasmilia casteri Wells
Astrocoenia whitneyi Wells
Astrocoenia scyphoidea Wells
Parasmilia bullardi Wells
Aplosmilia tolmachoffana Wells
Stephanocoenia guadalupae Wells
Connectastrea infundibuliformis Wells
Cyathophora haysensis Wells
Eugyra cuyleri Wells
Orbicella travisensis Wells
Orbicella whitneyi Wells
Orbicella comalensis Wells
Theocosmilia, n. sp.
Blothrocyathus harrisi Wells
Hydnophora blancoensis Wells
Siderastrea cuyleri Wells
Isastrea whitneyi Wells
Complexastrea glenrosensis Wells
Centriastrea vaughani Wells
Cyathomorpha camoni Wells
Diploastrea harrisi Wells
Siderofungia irregularis Felix
Polyphyllastrea simondsi Wells
Meandraraea plummeri Wells
Meandraraea sp. cf. M. tulae (Felix)
Microsolena texana Wells
Dimorpharaea sp. cf. D. barcenai (Felix)
Heterocoenia hilli Wells
Astreopora leightoni Wells
Epiphaxum labyrinthicum Wells
Comalia fasciculata Wells
Polytremacis hancockensis Wells

## PALUXY SAND

The Paluxy sand extends in a narrow band only a few feet thick around the east and northeast border of the Llano region, across central Burnet and north-central Lampasas counties. and occurs at the base of Cretaceous outliers north of the region. In most places it is less than 10 feet thick. The following table shows a number of measured thicknesses in the east and northeast part of the region. No true Paluxy sand has yet been recognized south or west of the Paleozoic rocks.

*Thicknesses of the Paluxy sand*

| LOCALITY | THICKNESS *Feet* |
|---|---|
| Steep hill 3 miles north of Bertram, Burnet County | 10 to 15 |
| From 3 to 5½ miles south of Bertram, Burnet County | 20 |
| Bachelor Peak, Williamson County | 10 to 15 |
| Santa Anna Mountain, Santa Anna, Coleman County | 100 |

The Paluxy sand is made up of remarkably uniform, fine-grained quartz sand which averages only 0.1 of a millimeter in diameter and grades upward into silty marl. In places it is somewhat cemented by a calcareous cement but is not so highly indurated as the Travis Peak below. Its chief importance in this region is as a shallow-water supply for ranches and farms. At Santa Anna it has been used as a source of glass sand. It also serves as an important stratigraphic zone in geological work, marking the division between the Fredericksburg and Trinity divisions and designating the top of the Glen Rose formation. The sandy zone can be located in most wells on the east side of the region. The size of the sand grains is shown in the following screen analysis:

*Size-distribution of sand grains from Paluxy sand at a depth of 65 feet, Bertram city water well No. 2, Burnet County.*

(Analysis by Ernest Merkt)

| Size in millimeters | Percent by weight |
|---|---|
| Greater than 0.84 | 2.54 |
| 0.250–0.84 | 1.86 |
| 0.102–0.250 | 18.62 |
| 0.074–0.102 | 64.32 |
| 0.063–0.074 | 5.80 |
| 0.074–0.053 | 6.04 |
| Less than 0.053 | 1.82 |

## WALNUT CLAY

*Distribution and thickness.*—The Walnut clay, as originally defined, comprises a definite shell conglomerate and marl zone that can be traced around the Llano region, except on the north, and which can be found to overlap on the Paleozoic rocks at many of the higher topographic points, particularly in the vicinity of Nix in Lampasas County, Goodrich ranch and Potatotop Mountain in Burnet County, at Rochelle and along Brady Mountain in McCulloch County. In these places there are generally only a few inches of sand and pebble conglomerate at the base followed by typical fossiliferous marl. The thickness of the marl varies considerably in different places from 15 to 50 feet or more. At the type locality it is 60 feet thick, and in Lampasas County it is said by Adkins to reach a thickness of nearly 100 feet (1933, p. 330). The following thicknesses were measured in the Llano region:

*Thicknesses of the Walnut clay*

| LOCALITY | THICKNESS *Feet* |
|---|---|
| One mile east of Burnet, Burnet County | 30 |
| North end of Long Mountain, east side of Goodrich ranch northwest of Burnet, Burnet County | 21 |
| Perry Mesa, Goodrich ranch, Burnet County | 21 |
| One-fourth mile east of Rochelle, McCulloch County | 60 |
| Shovel Mountain, Blanco County | 30 |

*Lithology.*—In the Llano region, the Walnut clay is a distinctly light yellow or dark-cream, somewhat nodular, fossiliferous marl, distinctly yellower than the formations above and below. On steep slopes it is largely covered by the talus from the overlying nodular Comanche Peak limestone. On gentle slopes and in valleys, the clay forms an area of cultivated fields. Recently, because of its high marl content, it has been utilized as a topping in road construction and many "caliche" pits are located along its outcrop. These sites in many places have become good localities for collecting fossils.

*Paleontology.*—Fossils are common in the Walnut, and in many localities large numbers can be collected. Unfortunately, many of the specimens are in the form of casts of the shell interior. Large numbers of echinoids *(Heteraster* and *Salenia)*, oysters (*Exogyra texana* Roemer), and thin, disc-like pelecypods (*Cyprimeria texana* Roemer) are especially common and help to identify the Walnut. The well-known shell beds, made up of countless numbers of the common gryphaeas, so characteristic of the Walnut in north Texas, are less common in the Llano region. They have been found only in Lampasas County, particularly a few miles south of Lometa. The following fossils from the Walnut of the Llano region have been identified by Adkins:

*Fossils identified from the Walnut clay*

Echinoidea—
- Phymosoma texanum (Roemer)
- Tetragramma aff. hilli (Clark)
- Holectypus planatus Roemer
- Heteraster adkinsi Lambert
- Heteraster bohmi (de Loriol)
- Heteraster mexicanus (Cotteau)
- Heteraster aff. obliquatus (Clark)
- Heteraster texanus (Roemer)
- Heteraster aff. texanus (d'Orbigny)
- Heteraster sp.
- Epiaster whitei (Clark)
- Hemiaster comanchei Clark

Annelida—
- Serpula sp.

Pelecypoda—
- Cardita posodae Böse
- Corbis (Mutiella) roblesi Böse
- Cyprimeria texana (Roemer)
- Cyprimeria sp.
- Exogyra texana Roemer
- Homomya bravoensis Böse
- Homomya jurafacies Cragin
- Homomya aff. ligeriensis (d'Orbigny)
- Homomya solida Cragin
- Gryphaea marcoui Hill and Vaughan
- Inoceramus aff. concentricus Parkinson
- Leptosolen?
- Modiola stonewallensis Cragin
- Pecten (Neithea) irregularis Böse
- Pecten (Neithea) occidentalis Conrad
- Pecten sp.
- Protocardia filosa Conrad
- Protocardia texana (Conrad)
- Pteria aff. aguilerae (Böse)
- Pteria pedernalis (Roemer)
- Pholadomya pedernalis Roemer
- Pholadomya sancti-sabae Roemer
- Remondia robinsi (White)
- Pinna comancheana Cragin
- Pinna guadalupae Böse
- Tapes sp.
- Trapezium texanum (Roemer)
- Trigonia emoryi Conrad
- Anchura sp.
- Anchura subfusiformis (Shumard)
- Lunatia pedernalis Hill (not Roemer)

Gastropoda—
- Turritella granulata var. cenomanensis d'Orbigny

Turritella sp.
Tylostoma chihuahuense Böse
Tylostoma elevatum (Shumard)
Tylostoma mutabile Gabb
Ammonoidea—
Engonoceras, n. sp.
Engonoceras stolleyi Böhm
Metengonoceras hilli Böhm
Oxytropidoceras acutocarinatum (Shumard)
Oxytropidoceras chihuahuense (Böse)
Oxytropidoceras trinitense (Gabb)
Oxytropidoceras, n. sp.

**Fossil Localities**

Numerous fossils have been collected from the following localities:

**27–T–9 (FF–25).**—Burnet County. North end of Long Mountain 2.1 miles southeast of Perry B. M. This locality is reached by taking the Burnet-Lampasas road and traveling 9.7 miles north of Burnet to crossroads. At crossroads, turn west and travel 1.6 miles, then turn west through a gate and go along a winding secondary road to Houck ranch house, a distance of 4½ miles; then proceed a distance of 0.9 of a mile to the northwest end of Long Mountain. The road at this point bends around the end of the mountain and turns due south. The fossil locality is on the northwest end of Long Mountain, on the south and east sides of the road just south of the bend (map, Pl. 1).

**27–T–19 (FF–24).**—Burnet County. Three and one-half miles south and 2.4 miles west of Naruna on south side of Perry Mesa, Goodrich ranch. The locality is reached by taking the road leading southwest from Naruna to the Goodrich ranch and traveling 3.4 miles from Naruna to the old ranch house near a small pond, then continuing 0.4 of a mile farther to a goat shed on the south side of a prominent mesa. The fossil locality is on the south side of the mesa near the goat shed, a few hundred feet north of the road.

**141–T–16 (FF–12).**—Lampasas County. Three miles east and 3 miles north of Lometa. The locality is reached by starting at the schoolhouse in Lometa and going north 0.3 of a mile, turning northeast and going 0.2 of a mile to a T-road, then turning sharply north on the T-road and traveling north 0.5 of a mile and then northeast 2.2 miles to another T-road leading north. Take the north road and drive 0.3 of a mile to a steep hill. The fossil locality is on the west side of the road and on the south side of a steep hill. Many excellent echinoids have been collected here.

**153–T–131 (K–13).**—McCulloch County. One-fourth of a mile north of Rochelle on new highway to San Saba, west of railroad. The locality is a good exposure at the top of a low hill along a road cut and excavation on the north side of the road.

COMANCHE PEAK LIMESTONE

*Distribution and thickness.*—The Comanche Peak limestone outcrops in a narrow band along the steep slopes of the flat-topped, Edwards limestone-capped mesas and ridges in Burnet and Lampasas counties on the east, on the slopes of outliers and mesas of Edwards limestone in McCulloch and Mason counties on the west, and below the Edwards outcrop in Blanco and Gillespie counties on the south. It thus forms a very winding, highly indented band along divides and at the heads of small branches around the north and south sides of the region and along many scattered mesas and ridges on the west side. It is also present on a few scattered Cretaceous remnants in Llano and San Saba counties near the center of the region. It has not yet been mapped in detail throughout its extent.

Adkins and Arick (1930, p. 33) regard the boundary between the Comanche Peak and the Edwards to be the point where the more or less nonstratified nodular layers change to well-bedded, thick strata containing in this southern area a rudistid fauna. In most places fossils do not occur near the boundary, and some geologists draw the upper boundary of the Comanche Peak where chert and dense subcrystalline limestone layers having conchoidal fractures first appear. In Burnet County, near the contact between the Comanche Peak and Edwards, there is a thick, massive, finely crystalline to granular limestone about 12 feet thick, overlain by an "oolitic"[11] bed 2 to 3 feet thick. This layer caps many escarpments, forms a very conspicuous cliff-forming ledge, and in many places shows up prominently both in the topography and in aerial photographs. Above the "oolite" ledge, typical oak brush or "schinery," so characteristic of the Edwards Plateau, appears, and below the ledge the steep slopes are covered with Spanish oak or cedar. Because of this sharp change in lithology and vegetation, most geologists draw the line between the Edwards and Comanche Peak at the base of the massive, cliff-forming limestone.

[11] The "oolite" ledge is composed mainly of miliolids, calcareous Foraminifera.

The following table shows some measured sections of the Comanche Peak in the Llano region:

*Thicknesses of the Comanche Peak limestone*

| LOCALITY | THICKNESS *Feet* |
|---|---|
| Burnet-Austin highway 2¼ miles east of Burnet, Burnet County (Coord. JJ–30, Pl. 1) | 30 |
| Burnet-Llano highway 2 miles west of Burnet, Burnet County (Coord. HH–30, Pl. 1) | 29 |
| Road 1⅓ miles due west of Erna, Menard County (Coord. D–30, Pl. 1) | 95 |
| Shovel Mountain, Blanco County | 55 |

*Lithology and boundaries.*—The Comanche Peak limestone in the Llano region is essentially a nodular limestone. The nodules are 2 to 5 inches in diameter, white or cream-colored, noncrystalline, and set in a matrix of chalky marl; a section exposed along a roadside or stream bank looks like a huge pile of large solidified biscuits. Generally, the strata are poorly bedded and sparsely fossiliferous, although some of the layers near the base are exceptions. The base of the formation is generally placed at the contact with the underlying predominant clay strata containing numerous fossils. The distinction, however, is a lithologic one. The Walnut clay in most places grades into the Comanche Peak limestone and there is no sharp lithologic or paleontologic boundary. For this reason, some geologists[12] believe that the Walnut and Comanche Peak beds should not be made separate formations. The upper boundary is also somewhat of a problem.

The Comanche Peak limestone appears to be a facies transition from the calcareous clays and marls of the Walnut to the thick, dense, massively-bedded limestones of the Edwards. The Comanche Peak contains alternating layers of limestone and marl quite similar to those in the Walnut. Above these alternating layers the marls give way to limestones. In most places, however, the limestone layers appear to be made up of a mass of nodules or to be a dense limestone which has a peculiar fracture so that it breaks up and separates to form a mass of large nodules. Many of the nodules contain fragments and complete casts of fossils as if the calcareous ooze forming the rock had been precipitated around shell fragments to form concretions and the concretions had never quite joined to form a solid limestone layer. The whole formation consists of about 94 percent nodular limestone, 5 percent marl, and perhaps 1 percent casts of fossil fragments of oyster shells, etc., like those in the Walnut below. Because of this conglomeratic-like lithology the Comanche Peak disintegrates and erodes more easily than the resistant cliff-forming and mesa-capping layers of Edwards above, and, therefore, outcrops mainly around the sides and bases of the Edwards outliers and along the upper slopes of the Walnut clay valleys.

The origin of the nodular structure of the Comanche Peak limestone is one of the interesting problems of the region. The thick limestone beds of the Glen Rose quite definitely are made up of granules which formed along the shores by precipitation from bicarbonate waters and were deposited like sediments in deeper waters. Some of the layers are distinctly oolitic. Many of them contain Foraminifera and foraminiferal limestone and occur in the lower beds of the Edwards. The Comanche Peak nodules, on the other hand, are more dense, more compressed, and more like concretions or marl balls. They appear to have formed by direct precipitation and accretion around some calcium carbonate kernel or around some precipitating agent, and perhaps were rolled back and forth by currents on muddy bottoms before coming to rest. They are now piled up to a thickness of 20 to 50 feet and are more or less cemented together. The exact method of accretion of the biscuit-like nodules is unknown, and the whole problem is worthy of much more thorough investigation. This peculiar type of limestone sedimentation, whatever its origin, is very widespread and fairly uniform in thickness and appearance. The nodular bed can be traced eastward across Williamson, Coryell, and into middle Bell County, a distance of 100 miles or more.

*Paleontology.*—The fauna of the Comanche Peak formation has never been

[12]F. L. Whitney, personal communication.

monographed. The ammonites are considered by Adkins and Arick (1930, p. 34) to be the most characteristic fossils, although even those are so similar to the ammonites in the Walnut that it requires careful measurements and selection of varietal differences to distinguish differences. Adkins has identified the following fossils from the Comanche Peak of central Texas.

*Fossils identified from the Comanche Peak formation*

Echinoidea—
- Heteraster adkinsi Lambert

Pelecypoda—
- Corbis (Mutiella) roblesi Böse
- Cyprimeria texana (Roemer)
- Cardita posodae Böse
- Cardium subcongestum (Böse)
- Homomya aff. ligeriensis (d'Orbigny)
- Inoceramus aff. concentricus Parkinson
- Pecten (Neithea) occidentalis Conrad
- Pinna guadalupae Böse
- Pteria pedernalis (Roemer)
- Protocardia filosa Conrad
- Tapes whitei Böse
- Trigonia emoryi Conrad
- Anchura subfusiformis (Shumard)
- Anchura kiowana Cragin
- Exogyra texana Roemer

Gastropoda—
- Turritella aff. granulata var. cenomanensis d'Orbigny

Ammonoidea—
- Oxytropidoceras acutocarinatum (Shumard)
- Oxytropidoceras trinitense (Gabb)

Three from this list, *Oxytropidoceras acutocarinatum* (Shumard), *Pecten (Neithea) occidentalis* Conrad, and *Exogyra texana* Roemer, are very common, easy to recognize, and characteristic of the Walnut and Comanche Peak formations. They serve, therefore, as useful aids in the identification of these two Lower Cretaceous units.

### Fossil Localities

The following fossil localities in the Comanche Peak formation have an abundance of fossils. The localities are shown on the map, Plate 1, and are easily reached.

**27–T–25 (HH–30).**—Burnet County. On the north side of Burnet highway (State highway No. 29), 3¾ miles west of Burnet, along the steep slope above caliche pit and below Edwards limestone.

**27–T–26 (JJ–30).**—Burnet County. On the Burnet-Austin highway (State highway No. 29), 1.1 miles east of Burnet and 0.2 of a mile south of Burnet, top of small mesa above Walnut caliche pit.

**27–T–27 (JJ–30).**—Burnet County. On the Burnet-Austin highway (State highway No. 29), 2.2 miles east of Burnet below Edwards limestone.

**27–T–28 (JJ–32).**—Burnet County. Ridge, 0.2 of a mile north of Thurston School 3¾ miles south and 1¼ miles east of Burnet. The locality is reached by driving south from Burnet on the old Marble Falls highway (located about 1½ miles east of the present highway), a distance of 4.1 miles to a road going east. Drive east 1.8 miles to the schoolhouse and walk north to the ridge.

**153–T–131 (K–13).**—McCulloch County. Road cut 0.3 of a mile northeast of Rochelle, on northwest side of highway (U. S. highway No. 190. The Comanche Peak limestone is on the ridge above the caliche pit.

**141–T–18 (HH–17).**—Lampasas County. On the north side of Lampasas-Lometa highway (U. S. highway No. 190), 7½ miles northwest of Lampasas on ridge above caliche pit.

### EDWARDS LIMESTONE

*Distribution and thickness.*—The Edwards limestone caps the tops of the mesa ridges and upland flats that rise above or border the Glen Rose limestone on the east, south, and west, and forms the top of the outer rim around the Llano region. The rock is easily recognized as the resistant ledge capping most of the elevations in central Lampasas County. It forms the characteristic topography of flat-topped hills and steep slopes called by R. T. Hill the Lampasas cut plain. In McCulloch, Mason, and Kimble counties on the west it caps most of the prominent flat-topped elevations and is the resistant rock forming the top of Blue Mountain and Brady Mountain. Its outcrop in places is very much dissected by streams and is winding and dendritic. In other places only small remnants remain, and it stands out as isolated outliers in some places many miles distant from the main escarpment.

The Edwards limestone appears to exist in three facies. In the Burnet and Lampasas region a white, massive, thick, fine-grained, even-textured ledge 5 to 9 feet thick occurs at the base of the formation. This ledge is very persistent and is made up of fine oolite-like granules which may have originated as foraminiferal shells of miliolids or miliolid-like forms. Above this ledge the formation consists of thin ledges of limestone which breaks with a conchoidal fracture and is so smooth and fine grained that its surface has the appearance of glazed china. These layers contain a few small, hard, dark-colored, chert nodules. Upward in the sections the hard layers become somewhat thicker and in many places the proportion of chert nodules increases. These thicker chert-bearing layers grade upward and laterally into a rudistid reef facies which constitutes the third lithologic division. The rudistid rock consists of a mass of large curved horn, coral-like rudistids belonging to the genera *Caprina* and *Caprinula, Eoradiolites, Toucasia*, and others, forming a twisted mass. This facies is quite cavernous, containing many holes where fossils have dissolved away and unfilled voids between the fossils. This rudistid facies generally has a reddish-brown stain derived from weathering and soil formation. The stain is most noticeable on the under surface of the limestone and along joint planes and cavities. When freshly broken, however, the rock is creamy white. The thickness of the Edwards varies from 30 to 60 feet. It is apparently somewhat thicker on the west side of the region than on the east, but its characteristics are the same everywhere. Typical sections of the Edwards limestone are as follows:

*Section of Cretaceous strata on Llano-Burnet road on north-facing hill, 3 miles west of Burnet, Burnet County* (Coord. HH-30, Pl. 1).

| | THICKNESS Feet |
|---|---|
| Edwards (12 feet)— | |
| 8. Limestone, light gray, thin bedded, hard, breaks with conchoidal fracture, subcrystalline, lithographic texture | 6.5 |
| 7. Limestone, white to light gray, weathering cream-colored, massive, unbedded, oolitic; made up largely of a mass of minute miliolids | 5.5 |
| Comanche Peak (105.5 feet)— | |
| 6. Limestone, gray, nodular, mostly covered by talus from above and interbedded with some marl | 56.0 |
| 5. Limestone, light gray, marly, forms steep slope and weathers to small, angular chunks containing a few fossils among which is *Exogyra texana* | 48.0 |
| 4. Limestone, gray, hard, fossiliferous, producing a conspicuous ledge | 1.5 |
| Walnut— | |
| 3. Marl, gray, silty, mostly covered with talus | 14.5 |
| Glen Rose(?) or Paluxy(?) (107.5 feet)— | |
| 2. Sand, greenish gray, extremely fine grained, almost a silt, much cross-bedded, somewhat consolidated, calcareous, and interbedded with thin layers of marl | 38.0 |
| 1. Sand, reddish brown, coarse, containing many pebbles and having a coarse, pebble conglomerate at the base | 55.0 |

*Section of Cretaceous formations on Shin Oak Mountain 13 miles southwest of San Saba in San Saba County* (Coord. T-21, Pl. 1).

| | THICKNESS Feet | Inches |
|---|---|---|
| Edwards— | | |
| 3. Limestone, light gray to white, hard, breaks with conchoidal fracture, mostly unfossiliferous | 6 | 2 |
| Walnut— | | |
| 2. Marl, chalky, soft, fossiliferous, interbedded with at least four layers of fairly hard, chalky limestone | 43 | . |
| Basal conglomerate— | | |
| 1. Limestone, light gray, hard, subcrystalline, containing a great number of small, subangular to angular chert pebbles a fraction of an inch in size | 2 | 5 |

*Section of Cretaceous formations on road 2 miles west of Erna in Menard County* (Coord. D-30, Pl. 1).

| | THICKNESS Feet |
|---|---|
| Edwards (82 feet)— | |
| 5. Limestone, light gray to white, thick bedded, chert bearing, mostly unfossiliferous | 37 |
| 4. Limestone, light gray to white, thin bedded, chert bearing, containing many turritellid-shaped gastropods; mostly limestone at the base | 45 |
| Comanche Peak— | |
| 3. Limestone, light gray, soft, nodular, weathering yellowish gray | 95 |
| Walnut and Glen Rose (180 feet)— | |
| 2. Clay, light gray to white, weathering yellowish, very silty in places, almost a fine sand | 135 |
| 1. Sand, yellowish gray, fine textured, fairly pure, resembles Paluxy more than Travis Peak | 45 |

The thickness of the Edwards limestone on the outcrop in the Llano region varies greatly according to its geographic position. Thus, near the center of the region on the top of Shin Oak Mountain in southwestern San Saba County, it is 6 feet thick.

In the eastern edge of the region on the Burnet-Llano road 3 miles west of Burnet at the top of a south and west-facing escarpment it is 12 feet thick. On the Burnet-Austin highway, 1½ to 2 miles east of Burnet, it is 14.5 feet thick. On Shovel Mountain in Blanco County, it is 25 feet thick. In the western part of the region 3 miles west of Erna in Menard County, it is 82 feet thick. Outside the Llano region, Eifler (1930) records the following thicknesses:

*Thicknesses of the Edwards limestone surrounding Llano region*

| LOCALITY | THICKNESS *Feet* |
|---|---|
| Western Bexar County | 400 to 500 |
| Kerrville-Bandera highway south of Kerrville, incomplete section | 223 |
| Hays County | 330 to 350 |
| Travis County (composed of three sections) | 234 |
| Georgetown, Williamson County | 108 |
| Denton County, Goodland (includes Edwards and Comanche Peak together) | 40 to 70 |

Thus, the formation thins northward and thickens to the south. In Mexico it is said to be in some places 3,000 feet or more thick.

The Edwards can be identified in the Llano region by its greater hardness and characteristic tendency to form cliffs and is the cap rock on most of the prominent mesas of the surrounding country. It can be distinguished easily from the Comanche Peak below by the finer texture of its upper layers, by the uniformly granular oolitic-like miliolid layer near its base, and by its masses of queer-looking rudistids. Another distinguishing feature of the Edwards limestone is its chert content. Chert nodules are in many places present in large numbers and are much more plentiful than in any other Cretaceous formation. The chert is dark gray to light grayish black and bluish black in color and occurs in the form of thin layers but more commonly in ellipsoidal and kidney-shaped nodules, and also in some places as replacements of aragonite in fossils. Some of the fossils, particularly the gastropods, are silicified and may be etched out by hydrochloric acid.

*Paleontology.*—The paleontology of the Edwards limestone has not been studied in detail. Individual fossils have been identified and described by Roemer (1888), C. A. White (1883), Hill (1893), Adkins (1928), and Eifler (1930). Adkins has presented the most complete list which has been slightly modified by the present author.

*Fossils identified from the Edwards formation*

Anthozoa—
- Pleurocora coalescens Roemer
- Pleurocora texana Roemer
- Cladophyllia furcifera Roemer
- Coelosmilia americana Roemer
- Parasmilia austinensis Roemer

Echinoidea—
- Goniopygus zitteli Clark
- Holectypus planatus Roemer
- Heteraster texanus (Roemer)

Brachiopoda—
- Kingena wacoensis (Roemer)

Pelecypoda—Rudistids—
- Monopleura marcida White
- Monopleura pinguiscula White
- Toucasia patagiata (White)
- Toucasia texana Roemer
- Caprina crassifibia Roemer
- Caprina occidentalis Conrad
- Caprina anguis (Roemer)
- Eoradiolites angustus Adkins
- Eoradiolites quadratus Adkins
- Praeradiolites edwardsensis Adkins

Pelecypoda—
- Lucina acutilineata Conrad
- Pecten duplicicosta (Roemer)
- Pecten (Neithea) texanus Roemer
- Pecten (Neithea) subalpinus Böse
- Pecten (Neithea) occidentalis Conrad
- Lima wacoensis Roemer
- Gryphaea marcoui Hill and Vaughan
- Chondrodonta munsoni (Hill)
- Cyprimeria texana (Roemer)
- Protocardia texana (Conrad)

Gastropoda—
- Trochus texanus Roemer
- Solarium? planorbis (Roemer)
- Natica (Amauropsis) avellana Roemer
- Nerinea pellucida Cragin
- Nerinea austinensis Roemer
- Nerinea cultrispira Roemer
- Cerithium austinense Roemer
- Cerithium bosquense Shumard
- Cerithium proctori Cragin
- Neritina apparata Cragin
- Tylostoma tumidum Shumard

Ammonoidea—
- Engonoceras emarginatum (Cragin)
- Engonoceras pierdenale (v. Buch)

The fauna is essentially molluscan and is characterized by its abundance of pelecypods, especially those belonging to the

Chamacea and Rudistaceae. Gastropods are numerous, corals and echinoids less numerous, and cephalopods rare. Several genera and species of corals have been noted by Eifler (1930) as fairly abundant at certain horizons as follows:

Cladophyllia furcifera Roemer
Pleurocora coalescens Roemer
Pleurocora texana Roemer
Parasmilia austinensis Roemer

Of these *Cladophyllia furcifera* is most common. Eifler (1930) also lists the following rudistids which are common in the rudistid zones of the upper Edwards:

Requienia texana Roemer
Monopleura marcida White
Radiolites davidsoni Hill
Toucasia patagiata (White)

The formation is recognized paleontologically by this molluscan and coral assembly rather than by any specific index fossil or series of fossils. In fact, in no other formation, except rarely in the Glen Rose, is there such an abundance of rudistids which, together with the abundant miliolids, serve to enable one to correlate the formation throughout the region.

*Correlation.*—The Edwards is middle Albian in age and when traced northward, merges with the upper part of the Goodland formation of north Texas. Southward in Mexico, it is represented by the El Abra limestone which contains the same fossil assemblage. Westward the Edwards can be traced across the Edwards Plateau where it is found capping some of the mesas in the Fort Stockton region.

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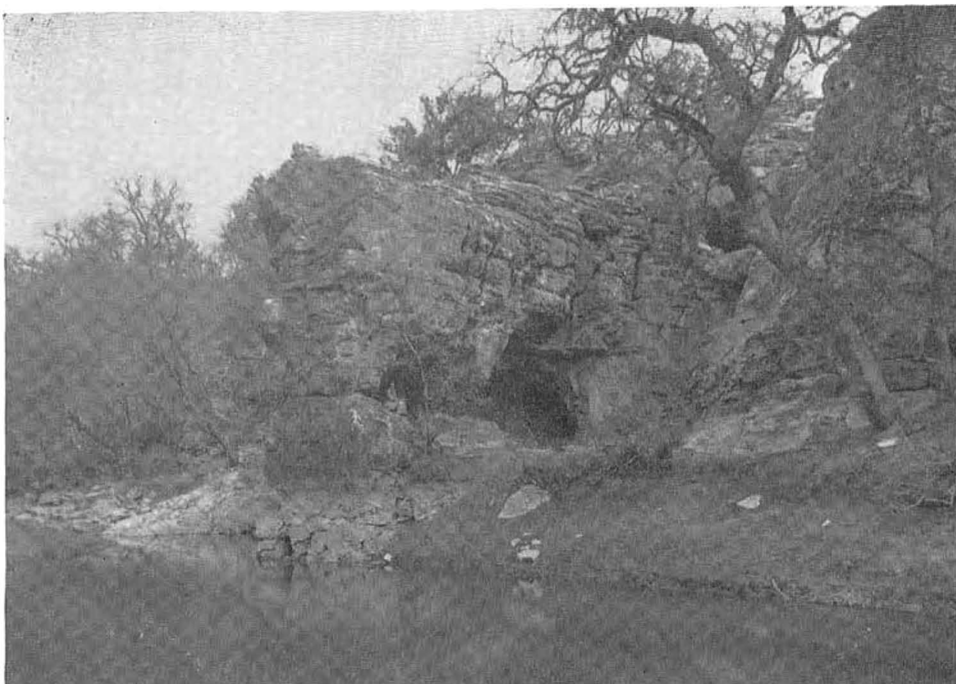

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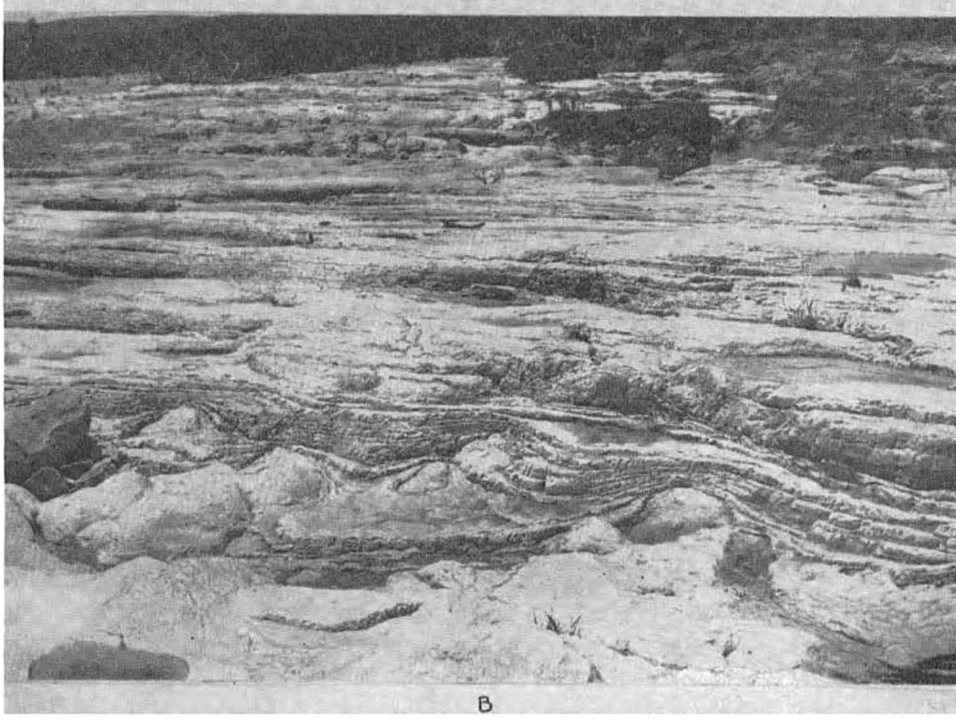

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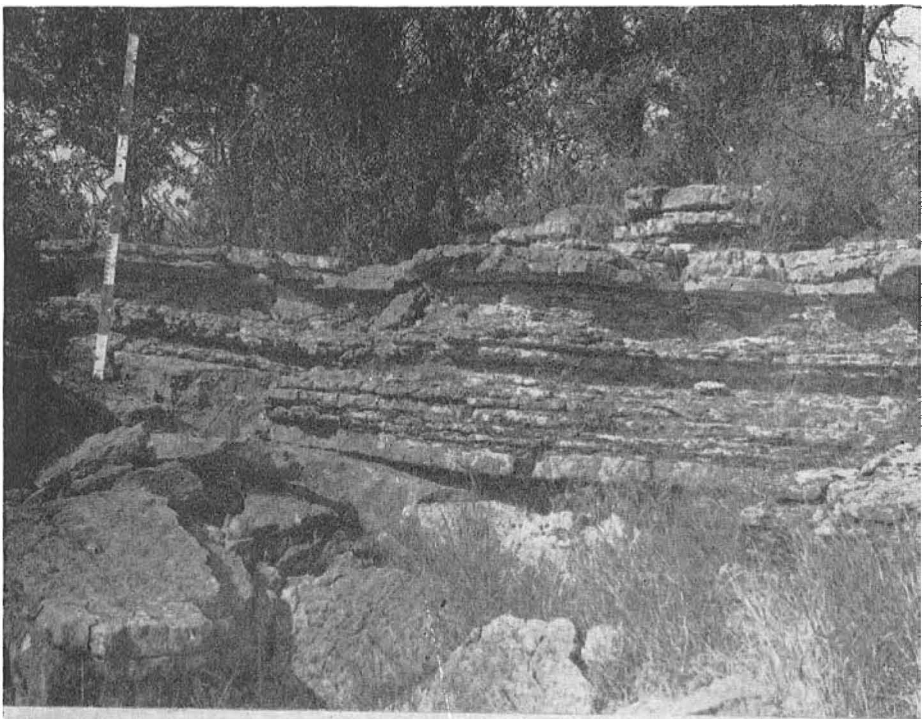
Ellenburger limestone. A, Outcrop at Pillar Bluff, Burnet County, showing bedding and jointing (photograph by Dana). B, Banded structure due to algae and concentric precipitation around a central core.



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B

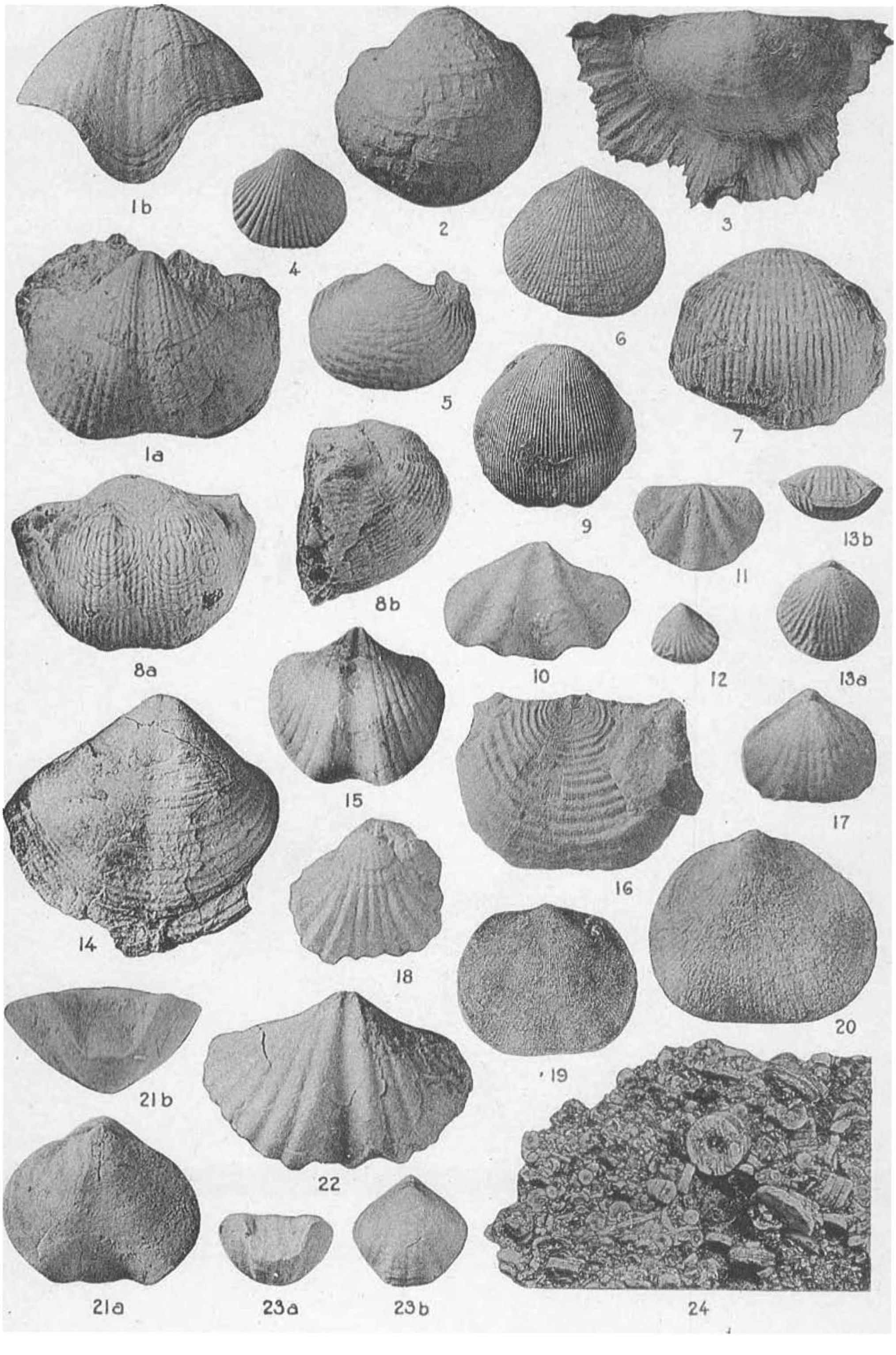
Chappel limestone. A, Portion of a lentil of limestone deposited in an ancient sink (photograph by Dana). B, Close-up view showing the crinoidal coquina of a typical ledge (photograph by Fisher).

## PLATE 5

Chappel Fossils

FIGURES—

1. *Spirifer grimesi* Hall, x1, from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–35. (Specimen P–13317.) *a*, Ventral view; *b*, anterior view.
2. *Avonia blairi* (Miller), ventral view, x2, from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–13. (Specimen P–13278A.)
3. *Athyris lamellosa* (Léveillé), x1, from exposure on highway 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13883.)
4. *Rhynchopora cooperensis* (Shumard), ventral view, x2, from exposure 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13889.)
5. *Avonia blairi* (Miller), ventral view, x1, from exposure on highway 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13893.)
6. *Eumetria osagensis* (Swallow), ventral view, x2, from exposure near Leon River, Mason County, Loc. 159–T–45. (Specimen P 13564.)
7. *Avonia concentrica* (Hall), ventral view, x2, from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–35. (Specimen P–13278A.)
8. *Linoproductus tenuicostus* (Hall), x2. from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–35. (Specimen P–13330B.) *a*, Ventral view; *b*, lateral view.
9. *Striatifera ovata* (Hall), ventral view, x1, from exposure about 4½ miles west of White's Crossing, Mason County, Loc. 159–T–35. (Specimen P–13314.)
10. *Acanthospira aciculifera* (Rowley), ventral view, x2, from exposure northeast of Pillar Bluff, Burnet County, Loc. 27–T–23. (Specimen P–13377B.)
11. *Delthyris novamexicana* (Miller), ventral view, x2, from exposure on east side of Jack Sloan's corral, southwest of rock house, western San Saba County, Loc. 205–T–77. (Specimen P–12060.)
12. *Rhynchopora pustulosa* (White), ventral view, x1, from highway exposure about 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13887.)
13. *Eumetria altirostris* (White), x2, from exposure on east side of Jack Sloan's corral, southwest of rock house, western San Saba County, Loc. 205–T–77. (Specimen P–12067.) *a*, Dorsal view; *b*, anterior view.
14. *Cleiothyridina incrassata* (Hall), ventral view, x2, from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–35. (Specimen P–13327.)
15. *Brachythyris suborbicularis* (Hall), ventral view, x1, from highway exposure 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13882.)
16. *Leptaena analoga* (Phillips), x2, from exposure northeast of Pillar Bluff, Burnet County, Loc. 27–T–23. (Specimen P–13373.)
17. *Rhynchopora persinuata* (Winchell), dorsal view, x1, from highway exposure 6½ miles south of Brady, McCulloch County, Loc. 153–T–110. (Specimen P–13881.)
18. *Camarotoechia elegantula* Rowley, ventral view, x2, from exposure near Leon Creek in western Mason County, Loc. 159–T–45. (Specimen P–13595.)
19. *Rhipodomella oweni* (Hall and Clark), ventral view, x1, from exposure about 4½ miles west of White's Crossing on Llano River, Mason County, Loc. 159–T–35. (Specimen P–13323.)
20. *Rhipodomella burlingtonensis* (Hall), ventral view, x2, from exposure near Leon Creek, western Mason County, Loc. 159–T–45. (Specimen P–13533.)
21. *Cleiothyridina prouti* (Swallow), x2, from exposure near Pillar Bluff, Burnet County, Loc. 27–T–23. (Specimen P–13375.) *a*, Dorsal view; *b*, anterior view.
22. *Brachythyris chouteauensis* (Weller), ventral view, x2, from exposure near Pillar Bluff, Burnet County, Loc. 27–T–23. (Specimen P–13377A.)
23. *Shumardella obsolens* (Hall), x2, from exposure on east side of Jack Sloan's corral, southwest of rock house, western San Saba County, Loc. 205–T–77. (Specimen P–13885.) *a*. Anterior view; *b*, dorsal view.
24. Typical slab of crinoidal coquina from the Chappel limestone, collected at White's Crossing on Llano River, Mason County, Loc. 159–T–2.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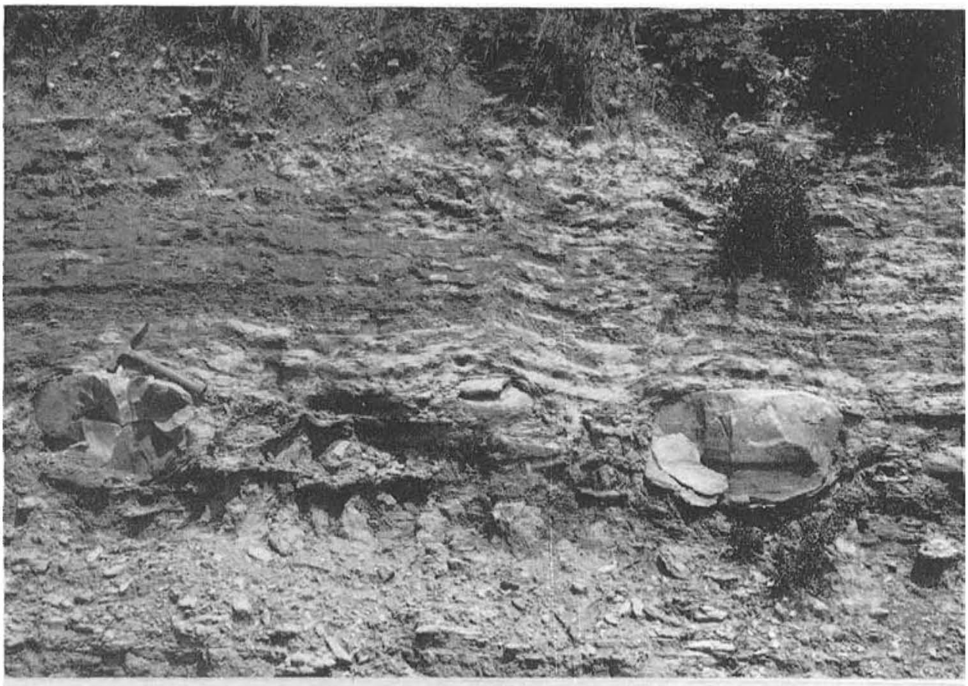

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B

Barnett formation. A, Typical view of Barnett shale showing large spherical concretions. B, Barnett shale exposed along Pillar Bluff Creek on Hallenbeck ranch, 5 miles west of Lampasas (photograph by Dana).

## PLATE 8

Barnett fossils

FIGURES—

1. *Posidonomya* cf. *P. vaughani* (Girty), x0.67, from exposure on Honey Creek, Mason County, Loc. 159–T–4. (Specimen P–8390.)
2. *Posidonomya vaughani* (Girty), x1.4, from base of bluff on Espey Creek, Lampasas County, Loc. 141–T–11. (Specimen P–12375.)
3. *Caneyella wapanuckensis* Girty, x2, from bank of creek on Leonard ranch, San Saba County, Loc. 205–T–98. (Specimen P–12752.)
4. *Deltopecten batesvillensis* (Weller), left valve, x2, from bank of Honey Creek, Mason County, Loc. 159–T–1. (Specimen P–7290A.)
5. *Camarotoechia laxa* Girty, ventral view, x2, from bank of Honey Creek, Mason County, Loc. 159–T–1. (Specimen P–13028.)
6. *Leiorhynchus carboniferum* Girty var., ventral view, x1.7, from exposure 3 miles southeast of San Saba, San Saba County, Loc. 205–T–10. (Specimen P–13817.)

7, 8. *Leiorhynchus carboniferum* Girty.
   - 7. Anterior view of a specimen (4955A) from an outcrop south of San Saba, San Saba County; x1.4.
   - 8. Dorsal view of a specimen (P–13447A) from exposure west of Honey Creek, Mason County, Loc. 159–T–3; x1.4.

9. *Composita pusilla* Girty, x2, from exposure west of Honey Creek, Mason County, Loc. 159–T–3. (Specimen P–13445.) *a*, Dorsal view; *b*, ventral view.
10. *Striatifera ovata* (Hall), ventral view, x2, from exposure 3 miles southeast of San Saba, San Saba County, Loc. 205–T–10. (Specimen 5351.)
11. *Dictyoclostus elegans* (Norwood and Pratten), ventral view, x1.7, from exposure west of Honey Creek, Mason County, Loc. 159–T–3. (Specimen P–13104.)
12. *Edmondia crassa* Girty, right valve, x1.4, from exposure west of Honey Creek, Mason County, Loc. 159–T–3. (Specimen P–8494.)
13. *Dictyoclostus inflatus* (McChesney), ventral view, x1.4, from exposure west of Honey Creek, Mason County, Loc. 159–T–3. (Specimen P–13757.)
14. *Leda vaseyana* (McChesney), x1.4, from exposure 3 miles southeast of San Saba, San Saba County, Loc. 205–T–10. (Specimen P–13830.)

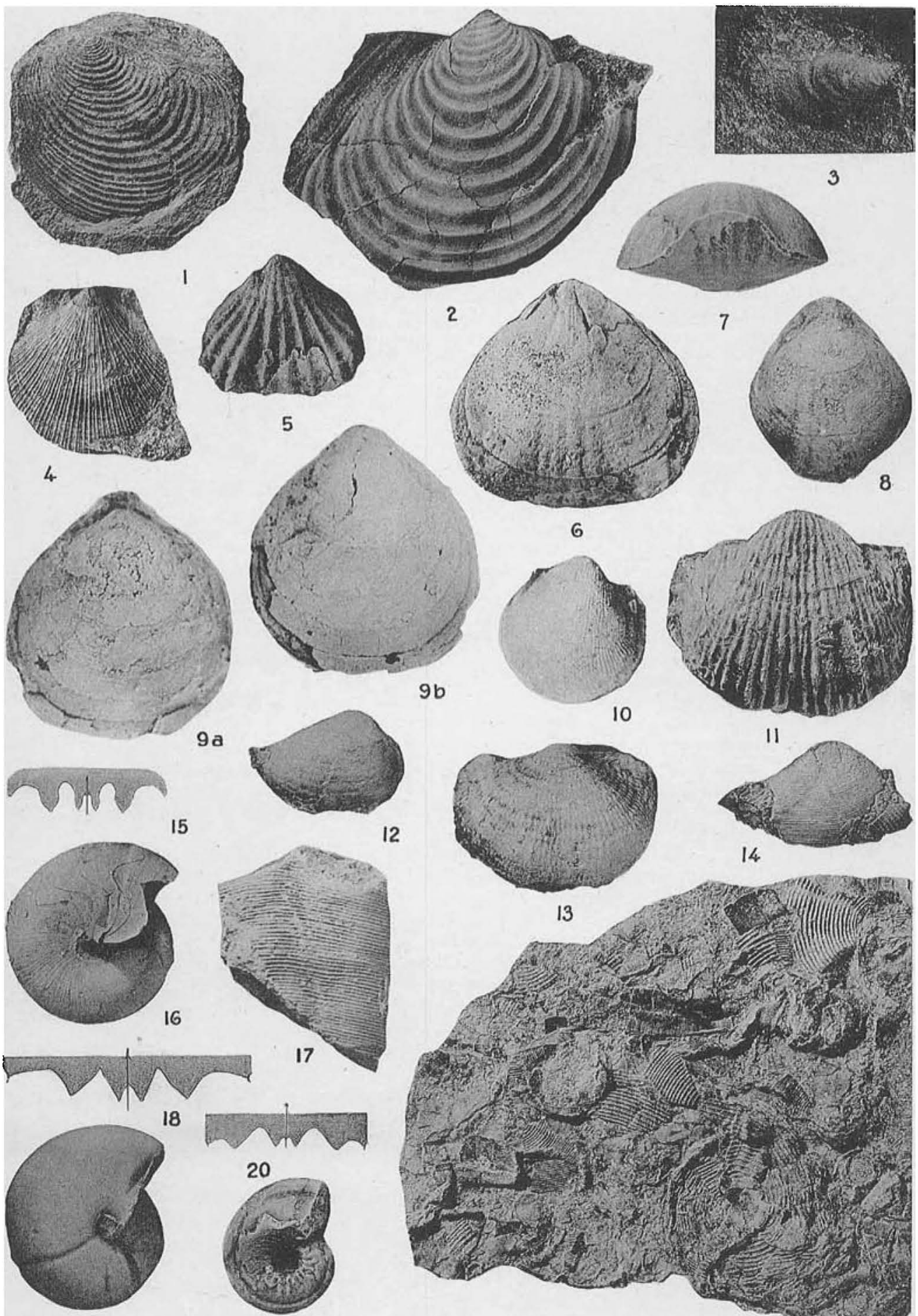
15, 16. *Nuculoceras barnettense* Plummer and Scott.
   - 15. Suture from specimen P–7589, x1.2, from exposure 3 miles southeast of San Saba, Loc. 205–T–10.
   - 16. Lateral view of specimen P–12744, x2, from bank of creek on Leonard ranch, San Saba County, Loc. 205–T–98.

17. *Plagioglypta?* cf. *P. annulistriata* (Meek and Worthen), x2, from outcrop 1.2 miles west of Chappel, San Saba County, Loc. 205–T–54. (Specimen P–11382A.)

18, 19. *Goniatites choctawensis* Shumard.
   - 18. Suture on specimen (P–7569) from bank of Espey Creek, 4 miles southwest of Lampasas, Lampasas County, Loc. 141–T–1; x1.4.
   - 19. Lateral view of a specimen from an outcrop south of Richland Springs, San Saba County (one of Hyatt's cotypes of *Glyphioceras cumminsi*); x2.

20, 21. *Eumorphoceras bisulcatum* Girty, from exposure 3 miles southeast of San Saba, San Saba County, Loc. 205–T–10. (Specimen P–7565.)
   - 20. Suture line at shell diameter of 11.5 mm., x1.7.
   - 21. Lateral view, x1.4.

22. Fossiliferous limestone from Barnett formation, excavation on San Saba-Bend road, about half a mile northeast of Barnett Springs, San Saba County, Loc. 205–T–70. Of the characteristic fossils present, the most abundant is *Lyrogoniatites newsomi* (Smith).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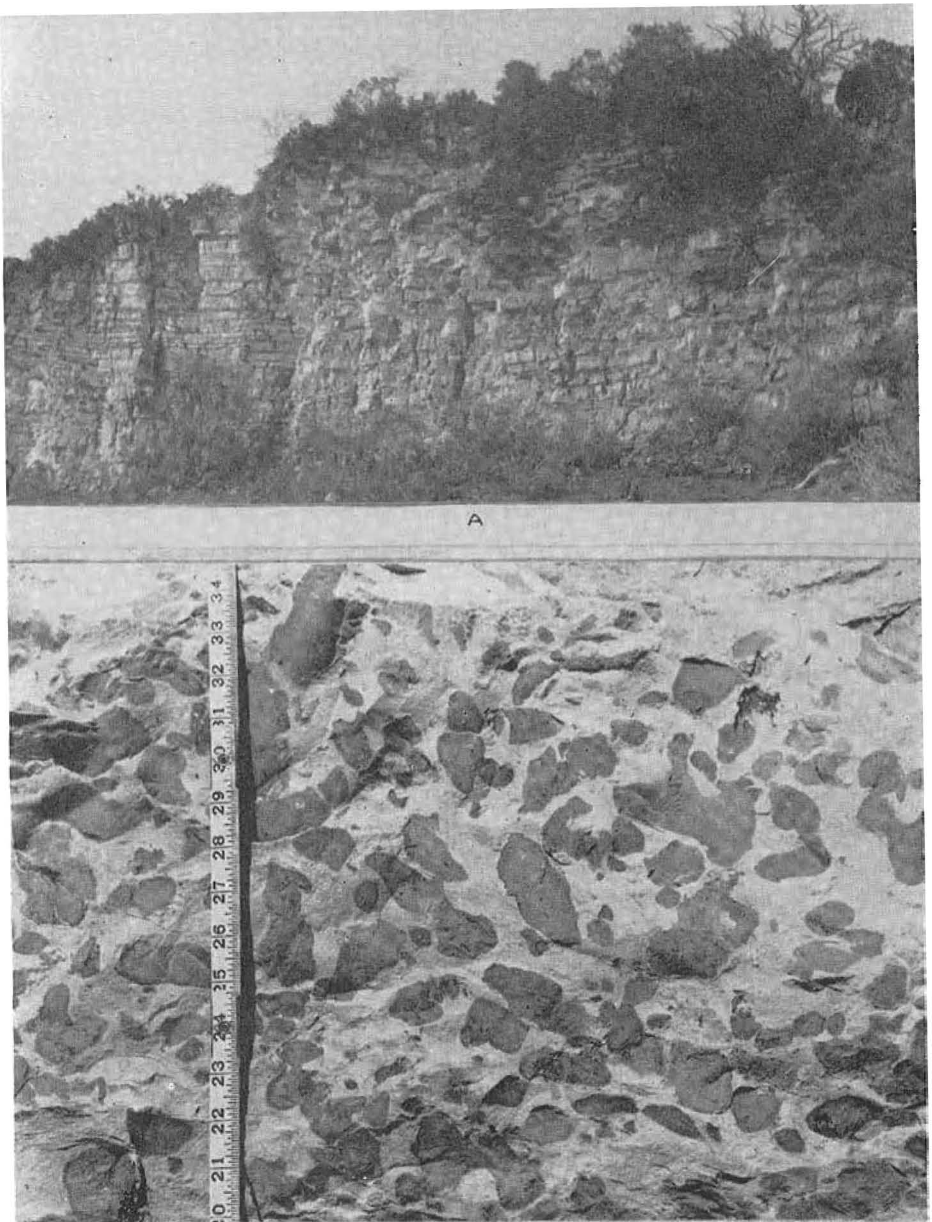



Big Saline formation. A, Thin-bedded, siliceous strata of the Lemons Bluff member exposed at mouth of Bluff Creek on the San Saba River. B, Mottled limestone of the Brister member. This distinctive layer occurs just above the Lemons Bluff member and forms an easily recognizable horizon which can be traced with a few interruptions from Brady on the west to Marble Falls, Burnet County. The dark irregular markings are thought to have been formed by algae.

## PLATE 11

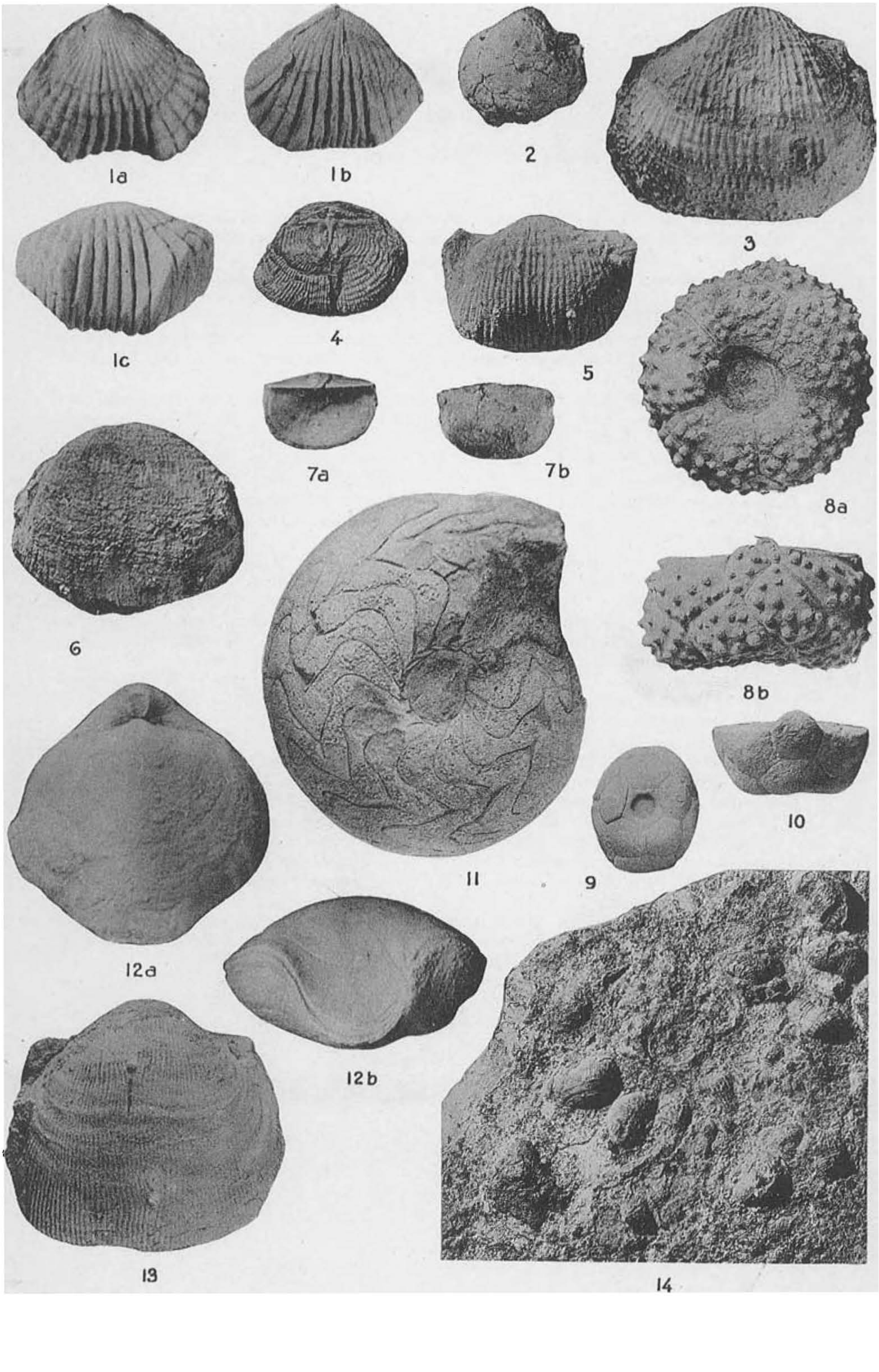
Marble Falls (Sloan) fossils

FIGURES—

1. *Rhynchopora illinoisensis* (Worthen), x2; from exposure west of Wallace Creek road about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11921.) *a*, Ventral view; *b*, dorsal view; *c*, anterior view.
2. *Horridonia globosa* (Mather), ventral view, x2; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11221.)
3. *Juresania wilberana* (McChesney), ventral view, x1.4; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11957.)
4. *Dictyoclostus morrowensis* (Mather), interior of ventral valve, x0.6; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11919.)
5. *Marginifera roemeri* Girty, ventral view, x1.7; from exposure on south side of Turkey Roost Creek, Sloan ranch, San Saba County, Loc. 205–T–110. (Specimen P–12867A.)
6. *Dictyoclostus morrowensis* (Mather), left valve, x1; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11227.)
7. *Paeckelmannia* sp., x2, from exposure in clay pit northeast of Jack Sloan's rock house, San Saba County, Loc. 205–T–92. (Specimen P–12723B.) *a*, Dorsal view; *b*, ventral view.
8. *Ethelocrinus texasensis* Moore and Plummer, holotype, x1; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11182.) *a*, Dorsal view; *b*, posterior view.

9, 10. *Cibolocrinus punctatus* Moore and Plummer, x1; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43.
  9. Dorsal view of holotype (specimen P–11183).
  10. Posterior view of paratype (specimen P–11186).

11. *Phaneroceras nolinense* (Cox), lateral view, x1.4; from Sloan's ranch, half a mile west of San Saba River, San Saba County, Loc. 205–T–65. (Specimen P–14035.)
12. *Composita ozarkana* Mather, x2; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11929.) *a*, Dorsal view; *b*, anterior view.
13. *Linoproductus nodosus* (Newberry), ventral view, x1.4; from exposure west of Wallace Creek road, about 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43. (Specimen P–11235.)
14. Slab of limestone from the Sloan member, showing usual associations of numerous specimens of *Marginifera roemeri* from outcrop west of Wallace Creek road 11 miles southwest of San Saba, San Saba County, Loc. 205–T–43.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## PLATE 12

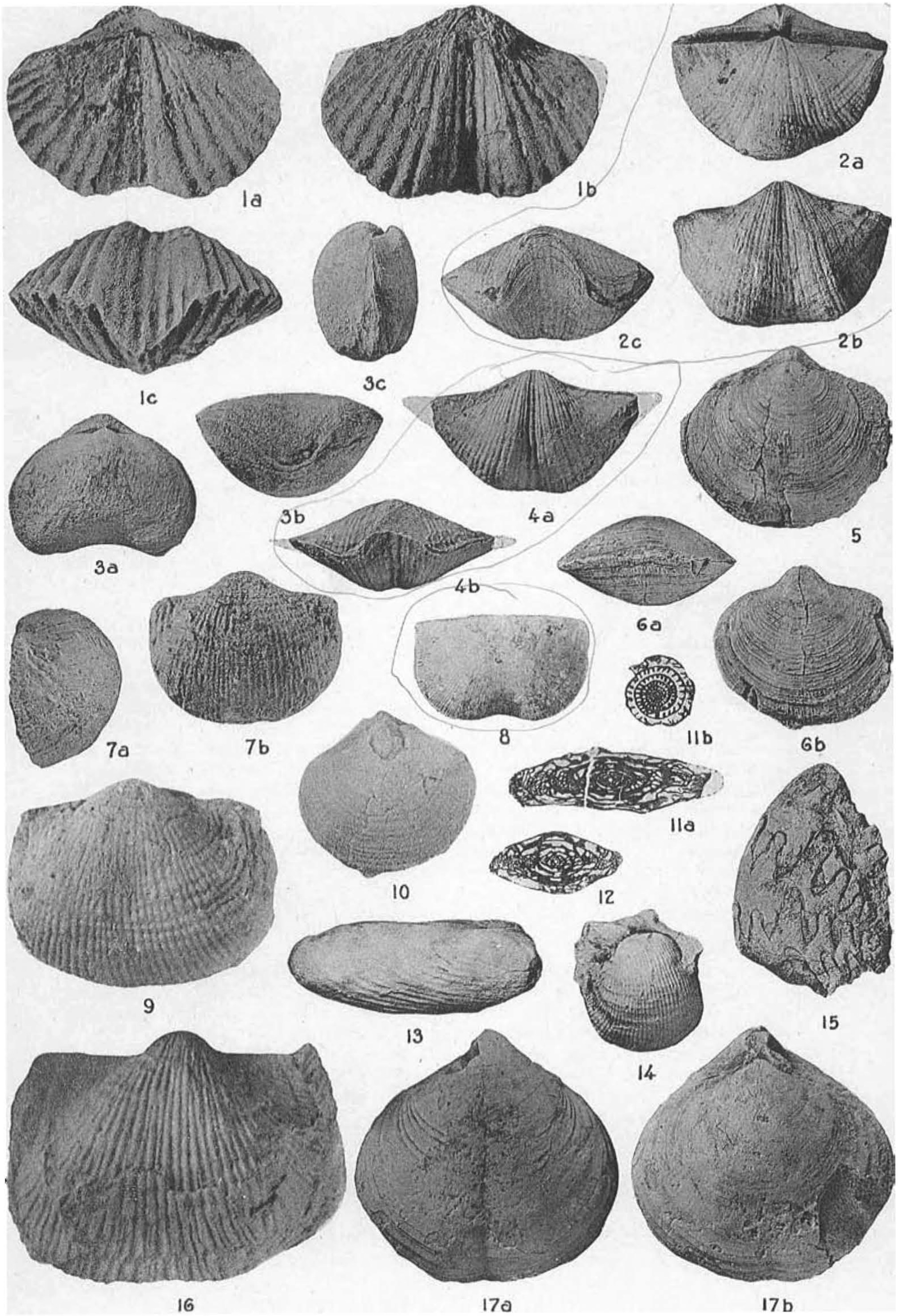
Marble Falls (Big Saline) fossils

FIGURES—

1. *Spirifer rockymontanus* Marcou, x1.7, from exposure in Williams pasture, 3½ miles south-southeast of Rochelle, McCulloch County, Loc. 153–T–48. (Specimen P–8988.) *a*, Dorsal view; *b*, ventral view; *c*, anterior view.
2. *Neospirifer cameratus* (Morton), x0.7, from bluff on Llano River near mouth of Big Saline Creek, Kimble County, Loc. 134–T–2. (Specimen P–3800.) *a*, Dorsal view; *b*, ventral view; *c*, anterior view.
3. *Schizophoria resupinoides* (Cox), x0.67, from bluff on Llano River near mouth of Big Saline Creek, Kimble County, Loc. 134–T–2. (Specimen P–3801B.) *a*, Ventral view; *b*, anterior view; *c*, lateral view.
4. *Neospirifer goreii* (Mather), x0.67, from outcrop at road fork west of Chappel School, San Saba County, Loc. 205–T–117. (Specimen 12988.) *a*, Ventral view; *b*, anterior view.

5, 6. *Cleiothyridina orbicularis* (McChesney), x1.7, from slope of small hill south of Brady Creek, about 3½ miles southeast of Brady, McCulloch County, Loc. 153–T–77.
   5. Specimen P–9863B; dorsal view.
   6. Specimen P–9863A; *a*, anterior view; *b*, ventral view.

7. *Linoproductus welleri* (Mather), x1.7, from bluff on Llano River near mouth of Big Saline Creek, Kimble County, Loc. 134–T–2. (Specimen P–4020.) *a*, Lateral view; *b*, ventral view.
8. *Chonetina chouteauensis* (Mather), ventral view, x2, from bottom of Brady Creek, 3 miles southeast of Rochelle on Smith farm, McCulloch County, Loc. 153–T–40. (Specimen P–8731.)
9. *Dictyoclostus inflatus* var. *coloradoensis* (Girty), ventral view, x2, from exposure at old road crossing on Brady Creek, southeast of Brady, McCulloch County, Loc. 153–T–81. (Specimen P–9928.)
10. *Squamularia perplexa* (McChesney), dorsal view, x2, from exposure about 1 mile east-southeast of Nelin, McCulloch County, Loc. 153–T–47. (Specimen P–8984.)
11. *Fusulina llanoensis* Thomas, from top of bluff on Llano River, near mouth of Big Saline Creek, Loc. 134–T–2. (Preparations and photographs by C. O. Dunbar.) *a*, Longitudinal section; *b*, transverse section.
12. *Fusulinella primaeva* Skinner, longitudinal section, from base of bluff on Llano River near mouth of Big Saline Creek, Kimble County, Loc. 134–T–2. (Preparation and photograph by C. O. Dunbar.)
13. *Allorisma costatum* Meek and Worthen, x0.35, from caliche pit on Brady-Mason highway, 4 miles southeast of Brady, McCulloch County, Loc. 153–T–82. (Specimen P–9818.)
14. *Cancrinella sampsoni* (Weller), x2, from exposure about three-fourths mile east of Shropshire Lake and about 4¼ miles east-southeast of Brady, McCulloch County, Loc. 153–T–56. (Specimen P–9192A.) This species differs from *C. boonensis*, the common Pennsylvanian form, in lacking all traces of spines.
15. *Pronorites llanoensis* Plummer and Scott, x0.7, from bluff on Llano River, near mouth of Big Saline Creek, Kimble County, Loc. 134–T–2. (Specimen P–3791.)
16. *Buxtonia* sp., x2, from exposure on branch of Pecan Creek, Mason County, Loc. 159–T–63. (Specimen P–13811.)
17. *Composita ovata* Mather, x1.7, from exposure 3 miles south of Brady, McCulloch County, Loc. 153–T–1. (Specimen 12309.) *a*, Ventral view; *b*, dorsal view.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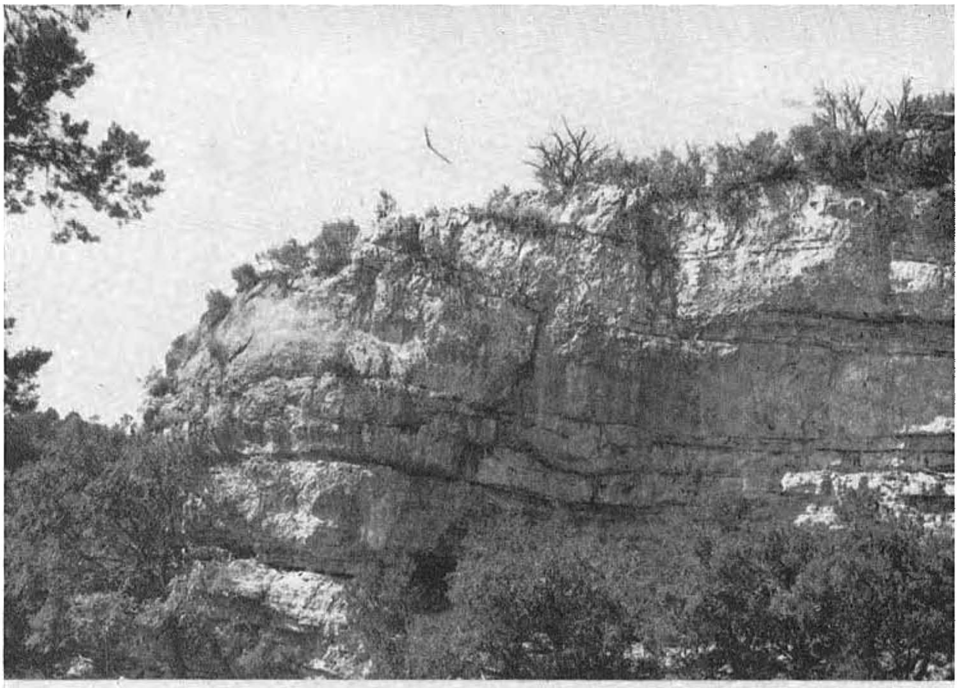

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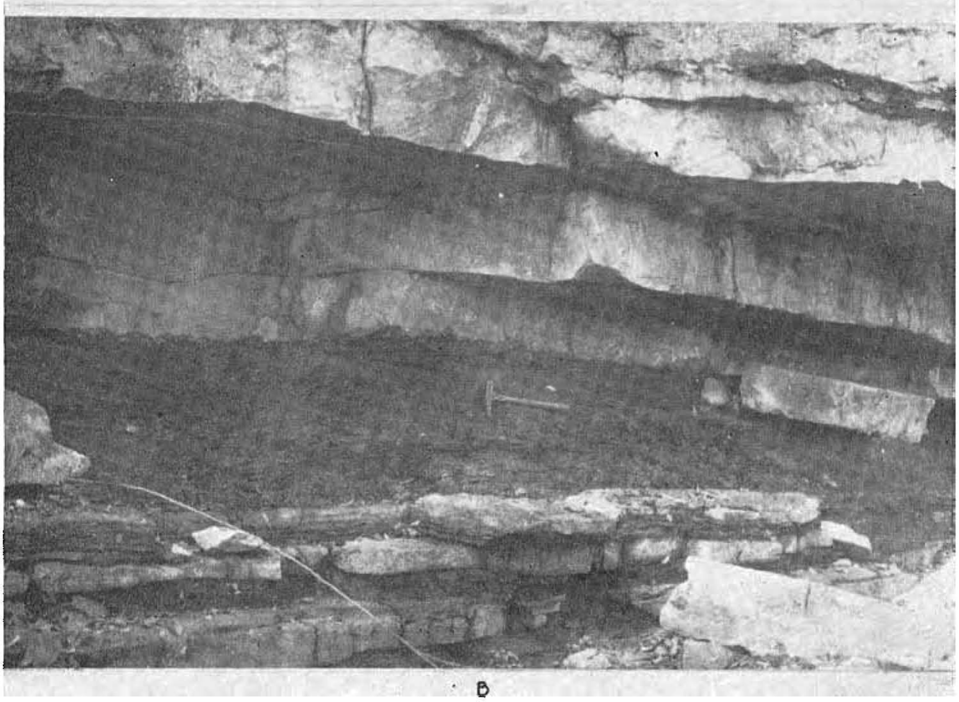

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Marble Falls group. A, Massively bedded, reef-like, crinoidal limestone of the Soldiers Hole member of the Big Saline formation, on Big Saline Creek, Kimble County. B, Lower member of Sloan formation on Wallace Creek, 13 miles by road southwest of San Saba (Loc. 205-T-43).

## PLATE 14

Marble Falls (Lemons Bluff) fossils

FIGURES—

1. *Neospirifer goreii* (Mather), ventral view, x1, from shaly limestone in bed of Cherokee Creek, 1 mile northeast of Bend, San Saba County; Loc. 205–T–6. (Specimen 4948.)
2. *Chonetes dominus* R. H. King, x2, from type locality for the species in the steep road bank, 2.7 miles south of San Saba on Llano road, San Saba County; Loc. 205–T–2. (Specimen K–267C.) *a*, Dorsal view; *b*, ventral view.
3. *Spirifer opimus* Hall, x0.7, from exposure 7 miles southwest of Mason near Honey Creek, Mason County; Loc. 159–T–1. (Specimen 9208.) *a*, Anterior view; *b*, view halfway between ventral and posterior.
4. *Punctospirifer transversa* (McChesney), x1.7, from roadside bank, 2.7 miles south of San Saba on Llano highway, San Saba County; Loc. 205–T–2. (Specimen P–9991.) *a*, Ventral view; *b*, dorsal view; *c*, posterior view.
5. *Orthotetes kaskaskiensis* (McChesney), dorsal valve, x1; from roadside bank, 2.7 miles south of San Saba on Llano road, San Saba County; Loc. 205–T–2. (Specimen 6884.)
6. *Wellerella utah* (Marcou), x1.7, from exposure 6 miles south of Algerita and west of Wallace Creek. (Walker Museum 12425.) *a*, Dorsal view; *b*, ventral view.
7. *Spirifer matheri* Dunbar and Condra, x1, from roadside bank, 2.7 miles south of San Saba on Llano highway, San Saba County; Loc. 205–T–2. (Specimen P–9979.) *a*, Halfway between dorsal and posterior views; *b*, ventral view; *c*, anterior view.

8, 9. *Rhipodomella*, n. sp., x1.7, from exposure 5.7 miles southwest of Bend and 0.7 mile southeast of Chappel, San Saba County; Loc. 205–T–28.
   8. Ventral view of specimen 11356D.
   9. Interior of ventral valve, specimen 11356A.

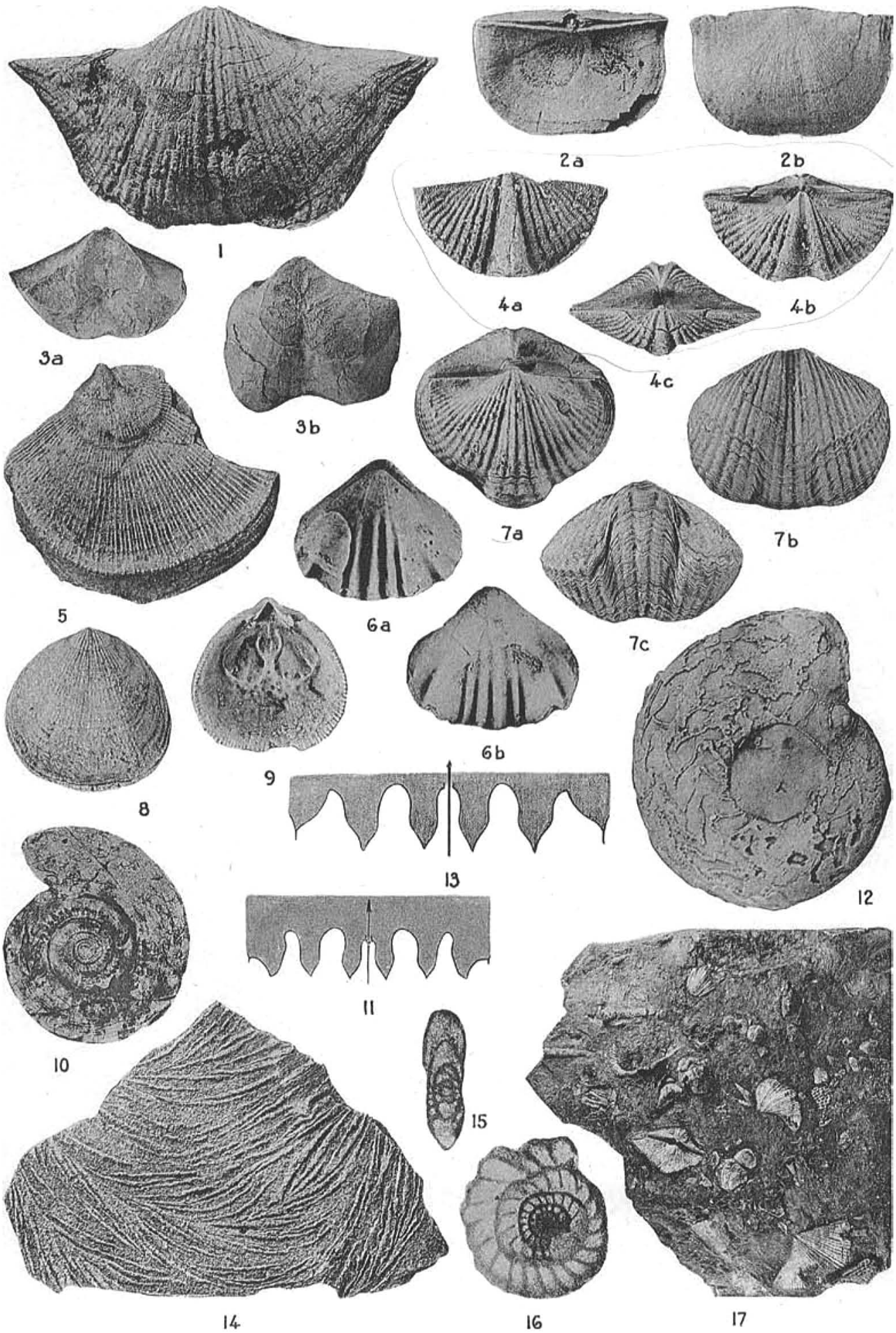
10, 11. *Paralegoceras texanum* (Shumard), from Colorado River bluff about three-fourths of a mile southwest of Bend, San Saba County; Loc. 205–T–1.
   10. Lateral view of Walker Museum specimen 25582, x0.2.
   11. Suture from Walker Museum specimen 31803, x0.5.

12, 13. *Phaneroceras compressum* (Hyatt)
   12. Lateral view of specimen P–8507, x0.5, collected near Mill Creek, Mason County; Loc. 159–T–11.
   13. Suture taken from Hyatt's holotype of *Gastrioceras compressum*, collected near Bend, San Saba County; Loc. 205–T–1.

14. *Taonurus caudagalli* (Vanuxem), x1, from exposure on east side of Cherokee Creek on Yates ranch, San Saba County; Loc. 205–T–116.

15, 16. *Millerella marblensis* Thompson, from north bank of Colorado River, near bridge at Marble Falls, Burnet County.
   15. Tangential section, x35 (after Thompson).
   16. Sagittal section, x35 (after Thompson).

17. Slab of limestone carrying *Neospirifer goreii* (Mather) and other typical fossils of upper Marble Falls age; from exposure near Richland Springs, San Saba County.



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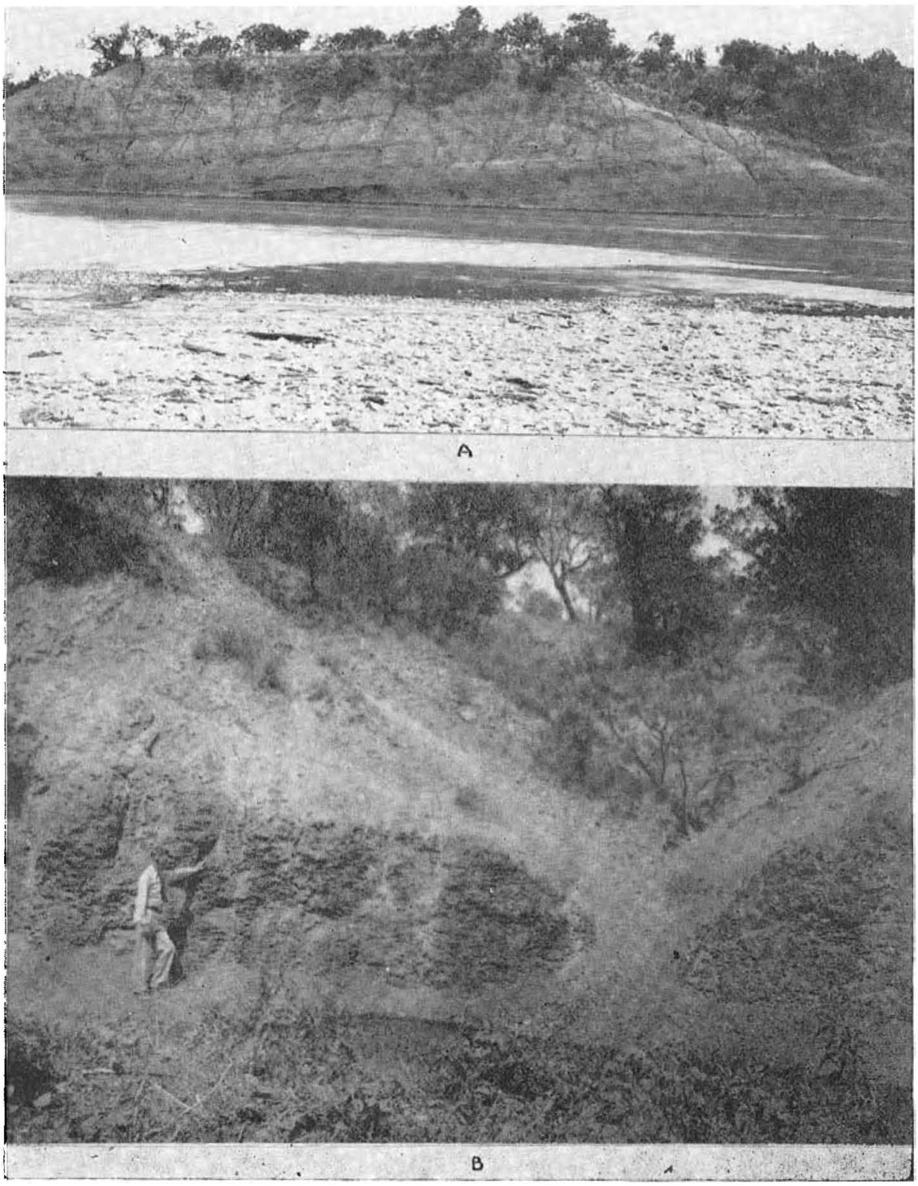
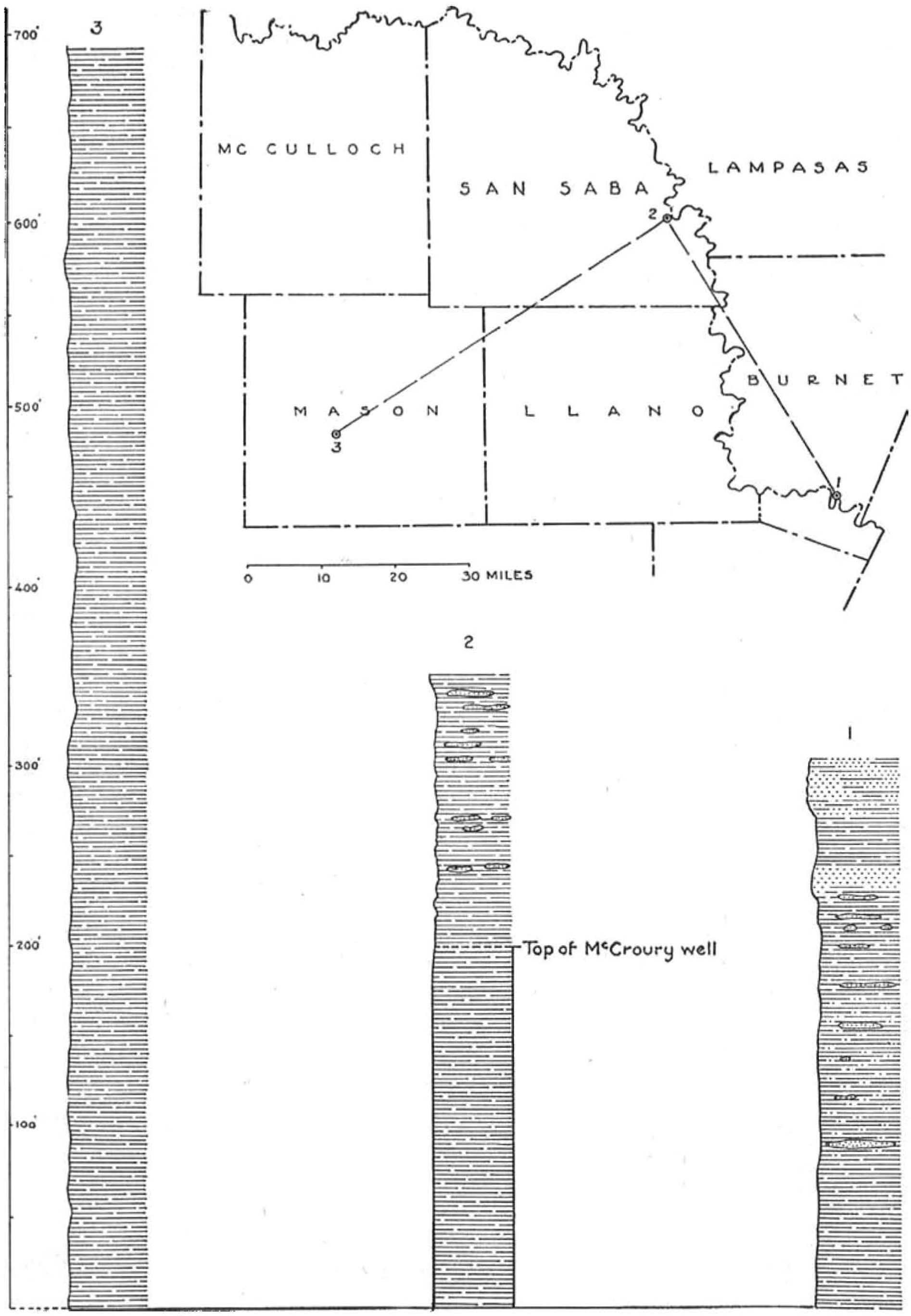



Smithwick formation. A, Exposure of shale at type section near Old Smithwick on the Colorado River (photograph by Haring). B, Outcrop on Wallace Creek southwest of San Saba, San Saba County (photograph by Fisher).




Typical graphic sections of the Smithwick formation. 1, North side of Colorado River at Old Smithwick, Burnet County. 2, Composite section of outcropping strata and the McCroury well northwest of Bend, San Saba County. 3, Honey Creek, Mason County.

## PLATE 17

Smithwick fossils

FIGURES—

1, 2. ***Straparolus savagei* Knight, x1.5.**

1. Side view of specimen from Marble Canyon,[13] Sierra Diablo, Culberson County, Loc. 55–T–43. (Specimen 11127.)
2. View looking down on spire; specimen from Gibbons ranch, Loc. 205–T–71, San Saba County. (Specimen P–11805A.)

3. *Nuculopsis ventricosa* (Hall), x2, from outcrop 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–6. (Specimen K–370A.) *a*, Left valve: *b*, cardinal view.

4–6. *Ambocoelia planoconvexa* (Shumard), x1½, from outcrop 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–6. (Specimens P–10108A, B, and C.)

4, 5. Ventral views of two different specimens.
6. Ventral view of an internal mold.

7. *Nuculopsis ventricosa* (Hall), x2, internal mold from outcrop 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–6. (Specimen P–7806.) *a*, Left valve; *b*, cardinal view.

8, 9. *Daraelites (Boesites) scotti* A. K. Miller and Furnish, from outcrop 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–6.

8. Lateral view of specimen P–1336B; x2.2.
9. External suture on specimen P–1336A; x5.

10, 11. *Nuculoceras smithwickense* Plummer and Scott.

10. Typical specimen (P–10120) from 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–6; x1.8. *a*, Ventral view; *b*, lateral view.
11. Suture line on a specimen (P–7567) from Marble Canyon, Culberson County, Loc. 55–T–43; x1.5.

12. *Leda arata* (Hall), x1.5, from a gully south of a cattle tank on Leonard ranch, San Saba County, Loc. 205–T–79. (Specimen P–12653C.)

13. *Leda*, n. sp., x1.7, from Marble Canyon, Sierra Diablo, Culberson County, Loc. 55–T–43. (Specimen 11161.)

14, 15. *Paeckelmannia derelicta* R. H. King, from gully on Bend-Chappel road, 1.3 miles west of Bend, San Saba County, Loc. 205–T–13.

14. External view of a ventral valve, x2.5. (Specimen 12281.)
15. Interior of a dorsal valve, x2. (Specimen K–218.)

16. *Cumminsia aplata* (Cummins), x2, from a gully on Leonard ranch, San Saba County, Loc. 205–T–79. (Specimen P–12650E.) *a*, Upper view of the corallite; *b*, side view of same.

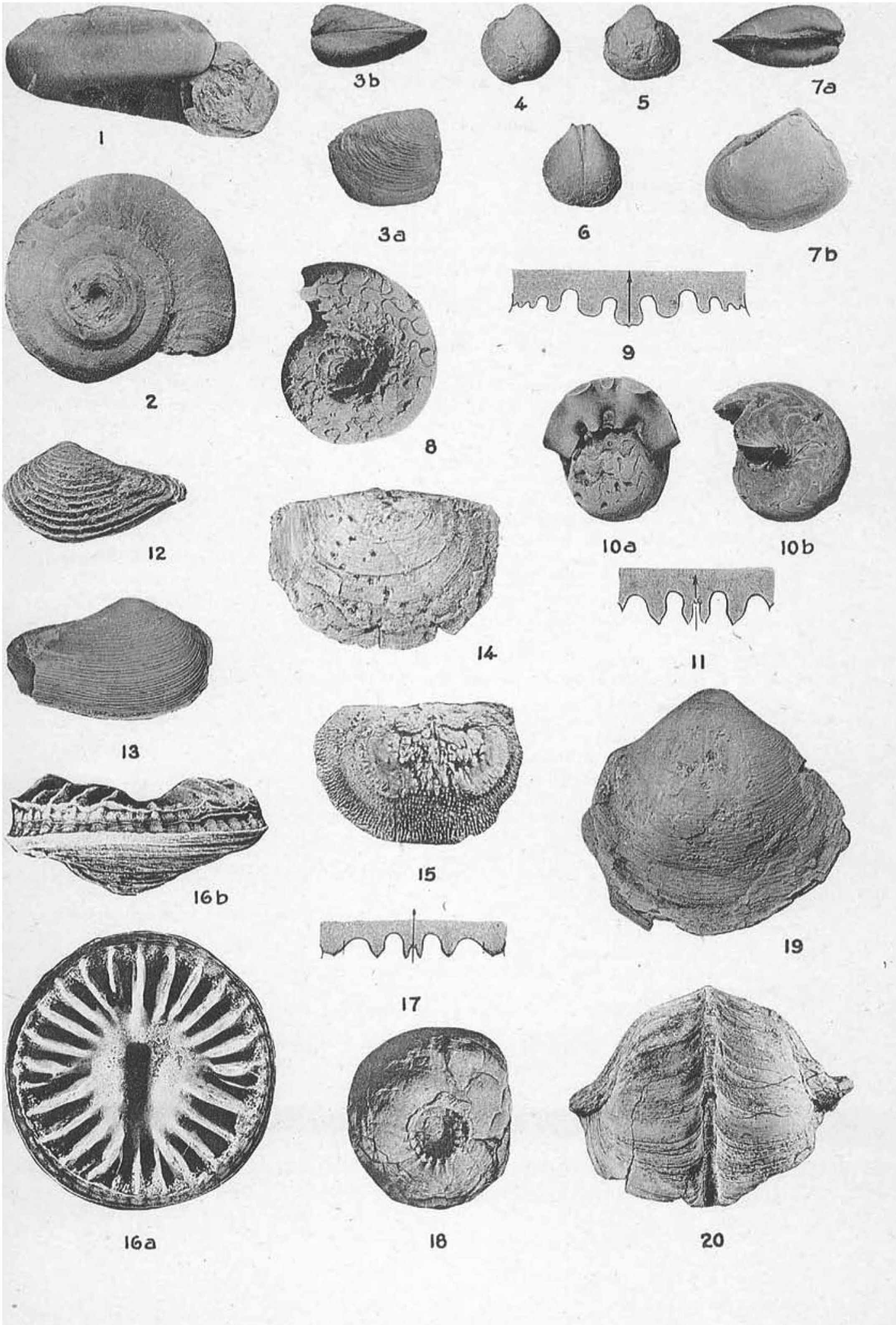
17, 18. *Gastrioceras occidentale* (Miller and Faber).

17. Suture from a specimen (P–5692) from Marble Canyon, Culberson County, Loc. 55–T–43; x1.
18. Lateral view of a typical specimen (Dept. Geol., Univ. Texas) from near Bend, San Saba County; x1.

19. *Cleiothyridina sublamellosa* (Hall), x1.5, from gully on Bend-Chappel road, 1.3 miles southwest of Bend, San Saba County, Loc. 205–T–13. (Specimen K–223.)

20. *Pharkidonotus* cf. *P. percarinatus* (Conrad), x1, from gully on Bend-Chappel road, 1.3 miles southwest of Bend, San Saba County, Loc. 205–T–13. (Specimen 12252.)

[13]In Univ. Texas Bull. 3701, p. 406, this exposure was listed as 114–T–46 in Hudspeth County, but it is now known to lie in Culberson County.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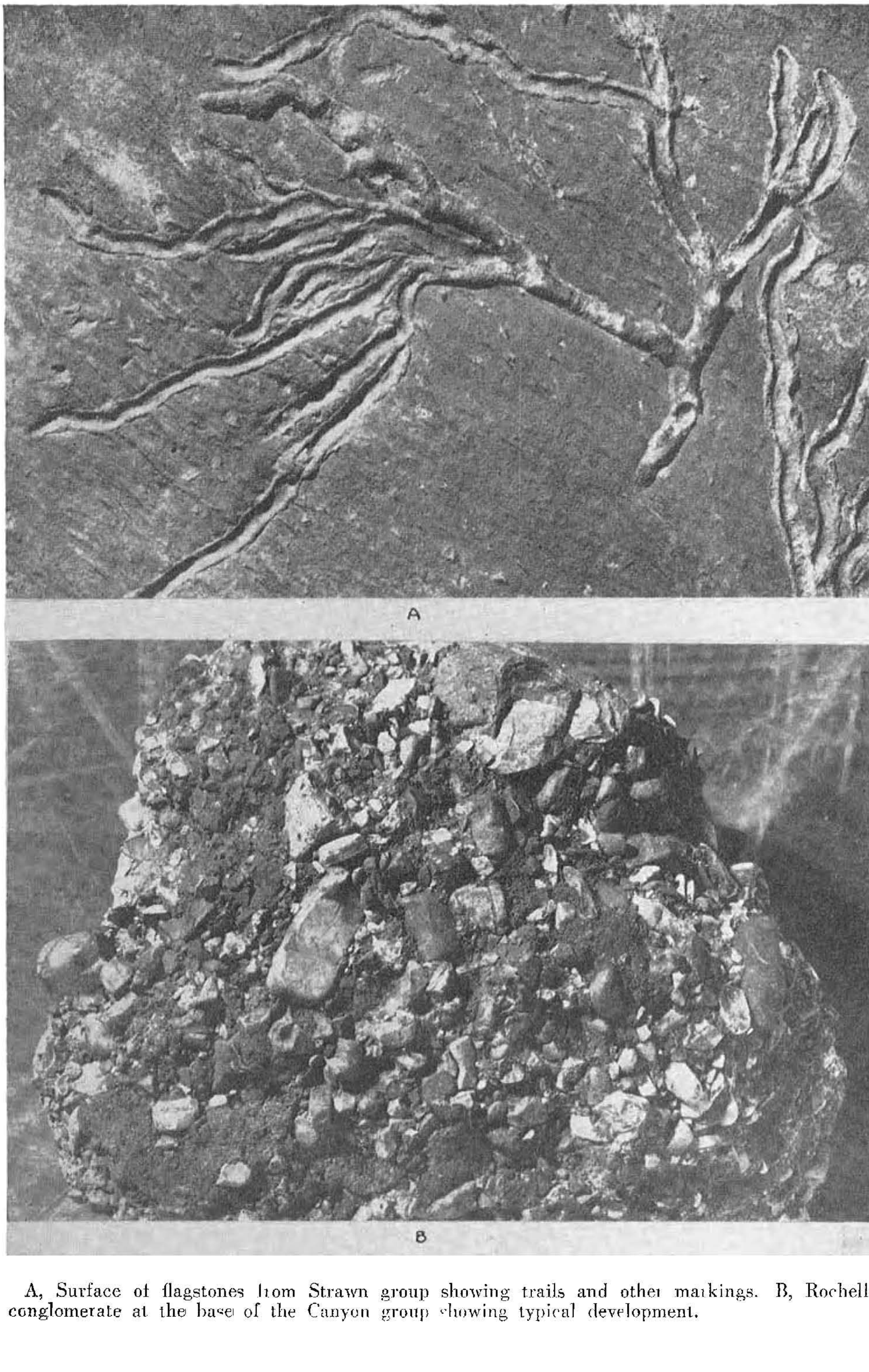



A, Surface of flagstones from Strawn group showing trails and other markings. B, Rochelle conglomerate at the base of the Canyon group showing typical development.

## PLATE 19

Strawn fossils

FIGURES—

1. *Rhipodomella carbonaria* (Swallaw), x3; from exposure along creek bank, 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–7. (Specimen P–9743B.) *a*, Ventral view; *b*, dorsal view.
2. *Punctospirifer kentuckyensis* (Shumard), dorsal view, x3; from exposure along creek bank, 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–22. (Specimen K–136.)

3–5. *Chonetina*, n. sp., x1.5; from base of shale bluff on Llano River, Bierschwale ranch, Kimble County, Loc. 134–T–5.
  3. Specimen P–13411A. *a*, Ventral view; *b*, dorsal view.
  4. Specimen P–13411E, interior of dorsal valve.
  5. Specimen P–13411G, ventral view.
  6. Specimen P–13411B, interior of ventral valve.

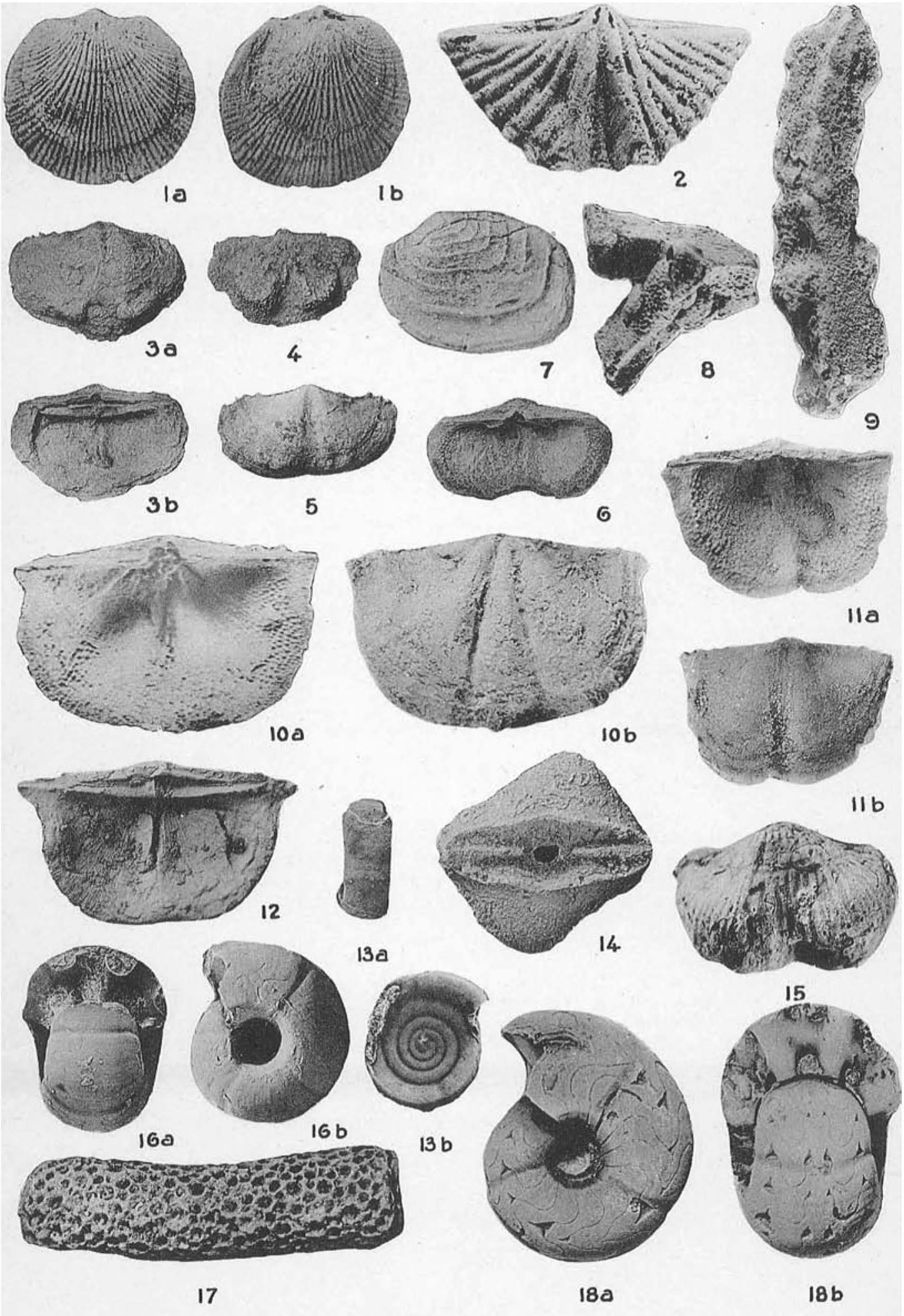
7. *Astartella varica* McChesney, x3; from creek bank 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–22. (Specimen K–133.)

8, 9. *Prismopora serrata* (Meek), x3; from creek bank 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–22.
  8. Specimen K–1633B, showing branching habit.
  9. Specimen K–1633A, showing characteristic angulation and scalloped margins.

10. *Mesolobus rochellensis* R. H. King, x3; from creek bank 3½ miles east of Rochelle, McCulloch County Loc. 153–T–7. (Specimen P–1008[illegible]B.) *a*, Interior of ventral valve; *b*, ventral view.

11, 12. *Chonetina robusta* R. H. King, x2; from creek bank 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–7.
  11. Specimen P–10064B. *a*, Interior of ventral valve; *b*, ventral view.
  12. Specimen P–10064A, dorsal view.

13. *Pronoceras prone* (A. K. Miller and Owen), x4; from base of shale bluff on Llano River, Bierschwale ranch, Kimble County, Loc. 134–T–5. (Specimen P–8563.) *a*, Ventral view; *b*, lateral view.
14. *Platycrinus* sp., x3, segment of stem; from creek bank 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–22.
15. *Marginifera splendens* (Norwood and Pratten), ventral view, x2; from creek bank 3½ miles east of Rochelle, McCulloch County, Loc. 153–T–22. (Specimen K–140.)
16. *Glaphyrites clinei* (A. K. Miller and Owen), x2; from base of shale bluff on Llano River, Bierschwale ranch, Kimble County, Loc. 134–T–5. (Specimen P–14157.) *a*, Apertural view; *b*, lateral view.
17. *Striatopora moorei* Wells, x1½; from type locality for species, at base of shale bluff on Llano River, Bierschwale ranch, Kimble County, Loc. 134–T–5. (Specimen P–13798.)
18. *Glaphyrites raymondi* Plummer and Scott, x2.5; from base of shale bluff on Llano River, Bierschwale ranch, Kimble County, Loc. 134–T–5. (Specimen P–13408.) *a*, Lateral view; *b*, apertural view.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## PLATE 21

Canyon fossils

FIGURES—

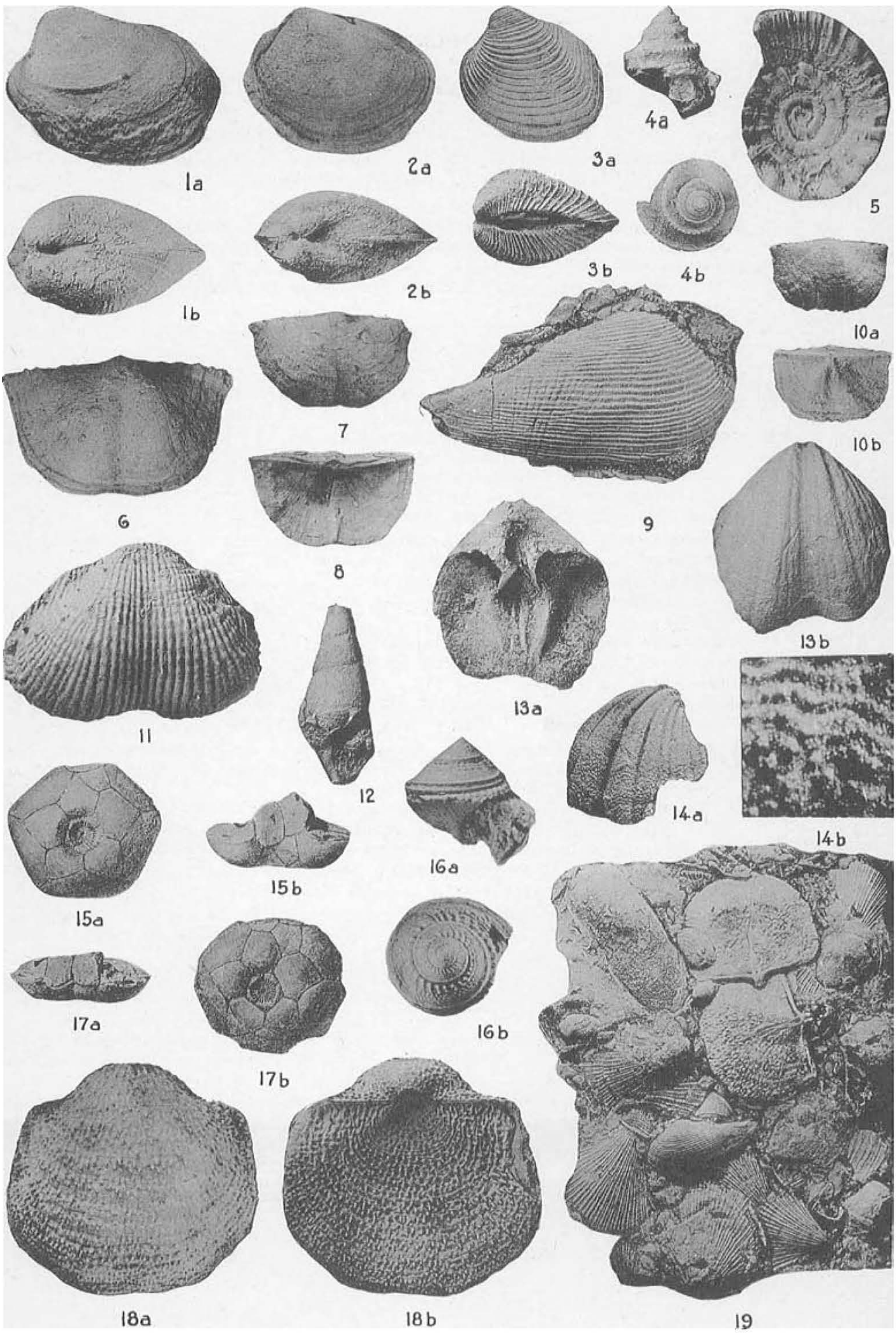
1. *Nuculopsis ventricosa* (Hall), x2; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12625A.) *a*, Left valve; *b*, cardinal view.
2. *Nucula anodontoides* Meek, x2; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12635B.) *a*, Left valve; *b*, cardinal view.
3. *Astartella concentrica* (Conrad), x1.4; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12626.) *a*, Left valve; *b*, cardinal view.
4. *Worthenia tabulata* (Conrad), x1.4; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12622C.) *a*, Side view; *b*, view from above.
5. *Amphiscapha catilloides* (Conrad), upper view, x2; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12616.)

6–8. *Chonetina flemingi* var. *plebeia* Dunbar and Condra, x2; from exposure 2 miles north-northeast of Nelin, McCulloch County, Loc. 153–T–112.
   6. Specimen P–13163C, ventral view.
   7. Specimen P–13163G, ventral view.
   8. Specimen P–13163E, dorsal view.

9. *Leda arata* Hall, right valve, x2; from exposure along creek 4 miles southeast of Placid, McCulloch County, Loc. 153–T–98. (Specimen P–12579.)
10. *Chonetina rostrata* Dunbar and Condra, x1.4; from exposure along creek 4 miles southeast of Placid, McCulloch County, Loc. 153–T–98. (Specimen P–12580B.) *a*, Ventral view; *b*, dorsal view.
11. *Marginifera lasallensis* (Worthen), ventral view, x1.4; from shale below Adams Branch limestone, 0.5 mile east of Price's ranch house, or 2.4 miles northeast of Rochelle, McCulloch County, Loc. 153–T–113. (Specimen P–13168A.)
12. *Meekospira peracuta* (Meek and Worthen), side view, x1.4; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12610.)

13, 14. *Neospirifer texanus* (Meek), from top of Brownwood shale just below Adams Branch limestone ledge, 0.5 mile east of Price's ranch house, or 2.4 miles northeast of Rochelle, McCulloch County, Loc. 153–T–113.
   13. Specimen P–1317B, x1.4. *a*, Interior of ventral valve; *b*, ventral view.
   14. Specimen P–13171C showing pustulation of surface. *a*, x1.4; *b*, x10.

15. *Plaxocrinus omphaloides* Moore and Plummer, holotype, x1.4; from exposure along road on east slope of Rugged Mountain, McCulloch County, Loc. 153–T–23. (Specimen P–11189.) *a*, Dorsal view; *b*, posterior view.
16. *Glabrocingulum grayvillense* (Norwood and Pratten), x2; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–12619A.) *a*, Side view; *b*, view from above.
17. *Plaxocrinus lobatus* Moore and Plummer, holotype, x1.4; from exposure 3 miles southeast of Placid, McCulloch County, Loc. 153–T–100. (Specimen P–11188.) *a*, Posterior view; *b*, dorsal view.
18. *Juresania symmetrica* (McChesney), x1; from exposure 4 miles southeast of Placid along creek, McCulloch County, Loc. 153–T–98. (Specimen P–12589.) *a*, Ventral view; *b*, dorsal view.
19. Slab of limestone from exposure along creek 4 miles southeast of Placid, McCulloch County, Loc. 153–T–98.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# INDEX