THE UNIVERSITY OF TEXAS BULLETIN

No. 3125: July 1, 1931

THE GEOLOGY OF GRAYSON COUNTY, TEXAS

By

FRED M. BULLARD

Bureau of Economic Geology

J. A. Udden, Director E. H. Sellards, Associate Director

PUBLISHED BY
THE UNIVERSITY OF TEXAS
AUSTIN

Publications of The University of Texas

Publications Committees:

The University publishes bulletins four times a month, so numbered that the first two digits of the number show the year of issue and the last two the position in the yearly series. (For example, No. 3101 is the first bulletin of the year 1931.) These bulletins comprise the official publications of the University, publications on humanistic and scientific subjects, and bulletins issued from time to time by various divisions of the University. The following bureaus and divisions distribute bulletins issued by them; communications concerning bulletins in these fields should be addressed to The University of Texas, Austin, Texas, care of the bureau or division issuing the bulletin: Bureau of Business Research, Bureau of Economic Geology, Bureau of Engineering Research, Interscholastic League Bureau, and Division of Extension. Communications concerning all other publications of the University should be addressed to University Publications, The University of Texas, Austin.

Additional copies of this publication may be procured from the
Bureau of Economic Geology, The University of Texas,
Austin, Texas

THE UNIVERSITY OF TEXAS PRESS

THE UNIVERSITY OF TEXAS BULLETIN
No. 3125: July 1, 1931

THE GEOLOGY OF GRAYSON COUNTY, TEXAS

By

FRED M. BULLARD

Bureau of Economic Geology
J. A. Udden, Director E. H. Sellards, Associate Director

PUBLISHED BY THE UNIVERSITY FOUR TIMES A MONTH, AND ENTERED AS SECOND-CLASS MATTER AT THE POSTOFFICE AT AUSTIN, TEXAS, UNDER THE ACT OF AUGUST 24, 1912

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

CONTENTS

ILLUSTRATIONS

FIGURES

MAP

GEOLOGY OF GRAYSON COUNTY, TEXAS

By

FRED M. BULLARD[1]

INTRODUCTION

LOCATION

Grayson County is located in the extreme north central part of Texas. It is one of the border counties of Texas, Red River forming its northern boundary. It is bounded on the west by Cooke County, on the south by Denton and Collins counties, and on the east by Fannin County. Sherman, a city of about 15,000, is the county seat and is near the geographical center of the county. Denison, an important railroad center, is about ten miles north of Sherman.

Grayson County lies within the quadrangle formed by the thirty-third and thirty-fourth parallels and the ninety-sixth and ninety-seventh meridians. It has an area of approximately one thousand square miles. With the exception of a strip about six miles in width along the eastern border, the county is included in the United States Geological Survey Topographic Atlas, Denison sheet.

FIELD WORK

The field work upon which this report is based was done during the summer of 1926. The Department of Geology of The University of Texas offers a course in field geology beginning about the 10th of June and continuing until the 1st of September. An area is selected for study, a permanent camp established, and the advanced students in geology are given an opportunity to do actual field work. Grayson County was the area selected for study during the summer of 1926. The large number of mappable formations exposed at the surface, fourteen in all, and the fact that the beds are not complexly folded, yet sufficiently disturbed to develop various types of structures, make Grayson County well suited for student work.

---

[1]Department of Geology, The University of Texas.
Geologic map printed 1928; text, August, 1931.

There is an excellent topographic map, the Denison sheet, covering most of Grayson County. A photographic enlargement of the topographic sheet to a scale of two inches to one mile was used as a base on which to map the

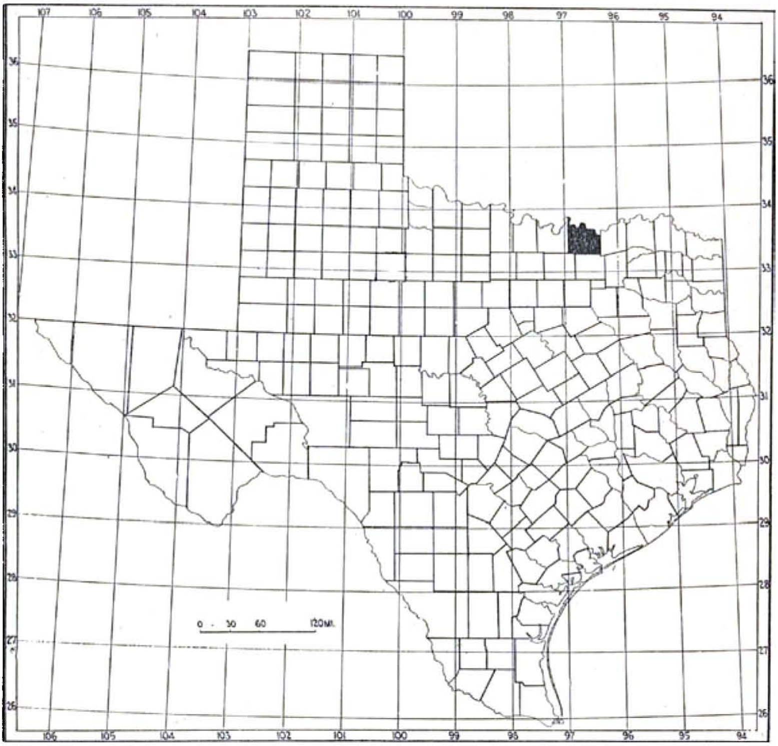

FIG. 1. Map of Texas showing location of Grayson County.

areal geology. A soil map of Grayson County, published by the United States Department of Agriculture, on a scale of one inch to the mile, was used as a base map in the areas not covered by the topographic sheet.

The work was under the direction of the writer, assisted by Mr. T. L. Allen, Instructor in the Department of Geology. Most of the field work was done by the students of The University of Texas Geology Camp, but it was carefully supervised and checked.

ACKNOWLEDGMENTS

A permanent camp was established at Denison for the summer of 1926. The writer wishes to acknowledge the many courtesies extended to the members of the Geology Camp by the citizens of Denison which made the work very satisfactory and the stay in Denison very pleasant.

The writer was ably assisted by Mr. T. L. Allen, of the Department of Geology.

The following students were members of the Geology Camp for the entire period of twelve weeks: M. B. Arick, Robert Brown, J. B. Christner, Raymond Doherty, Derwood Jolley, J. J. King, Oscar M. Longnecker, W. B. McCarter, Vaughn Maley, Robert H. Mueller, T. J. Slavik, E. R. Stiles, and E. D. Williams. The following students were members of the Geology Camp for a period of six weeks: Francis Fulk, E. M. Hawtof, Richard Mannen, W. B. Milton, J. W. Smith, F. B. Crawford, W. L. Mills, and Wray Ryan.

HISTORICAL SUMMARY

From the standpoint of Cretaceous stratigraphy, Grayson County is one of the most important areas in Texas, since much early work on the Cretaceous of North Texas was done here and the county is classic in Cretaceous stratigraphy. In this county is found the type locality of the following formations: The Duck Creek, Weno, Pawpaw, Main Street, and Grayson.

The first important work on the Cretaceous of the Texas region was by Doctor Ferdinand Roemer, a distinguished German geologist, who visited Texas from 1845 to 1847, studying the region with reference to its adaptation to German settlement. Several papers were published giving the results of his studies. They were published both in German and English as follows: Two papers[2] in the American Journal of Science and two volumes in German, the titles[3] of which may be translated as "Texas, with Especial

[2]Roemer, Ferdinand, A sketch of the geology of Texas: Am. Jour. Sci., 2nd ser. vol. 2, pp. 358–365, 1846; and Contributions to the geology of Texas: Am. Jour. Sci., 2nd ser. vol. 6, pp. 21–28, 1848.

[3]Roemer, Ferdinand, Texas. Mit besonderer Rücksicht auf deutsche Auswanderung und die physichen Verhältnisse des Landes nach eigener Beobachtung geschildert. Mit einem naturwissenschaftlichen Anhange und einer topographisch-geognostichen

Reference to German Emigration and the Physical Condition of the Country, Based Upon Personal Observations," Bonn, 1849, and "The Cretaceous Formations of Texas and Their Organic Remains, with an appendix containing a description of Paleozoic and Tertiary fossils," Bonn, 1852.

Although the geology of Texas has been alluded to previously by various writers, Roemer deserves credit for presenting the first orderly treatment of the geology of this region; for, as he said at the time of publication, he had been unable to find a "single European or American publication on the peculiar features or distribution of the geologic formations of Texas."

Roemer did not make stratigraphic sections, but mentions in sequence the "Beds at the foot of the Highlands" and the "Beds of the Highlands." In this sequence the geologic column is practically reversed from its normal order; for, due to the Balcones fault, the "Beds at the foot of the Highlands" are younger than the topographically higher "Beds of the Highlands." In later publications Roemer suggests that the topographically higher position of the latter may be due to a fault. He did not recognize the Lower Cretaceous, but in accordance with the general usage at that time, considered it all as Upper Cretaceous.

The next observation of importance on the Cretaceous of Texas was made by Doctor G. G. Shumard,[4] geologist attached to the expedition for the exploration of the Red River of Louisiana, along the northern border of the State. He used the term Fort Washita limestone for the beds which he traced from Fort Washita, Oklahoma, to Fort Belknap, Young County, Texas. A report on the fossils collected by the expedition was made by Doctor B. F. Shumard.

Two expeditions sent out by the Federal Government to locate a suitable route for a railroad to the Pacific coast crossed portions of Texas and Oklahoma. The first of these,

---

Karte von Texas: Bonn, bei Adolph Marcus, 1849; and, die Kreidebildungen von Texas und ihre organischen Einschlüsse. Mit einem die Beschreibung von Versteinerungen aus palaozoischen und tertiaren Schichten enthaltenden Anhange und mit 11 von C. Hohe nach der Natur auf Stein gezeichneten Tafeln: Bonn, bei Adolph Marcus, 1852.

[4]Expl. Red River of La. in the year 1852, by R. B. Marcy, Capt. 5th Inf., U. S. Army, assisted by Geo. B. McClellan, brevet Capt. U. S. Engineers; with report on the natural history of the country and numerous illustrations. Washington, 1854.

known as the "Thirty-fifth parallel survey,"[5] followed approximately the course of the South Canadian River across Oklahoma and the Panhandle of Texas. It was accompanied by Professor Jules Marcou as geologist. He made some very important observations, but due to a misunderstanding with Jefferson Davis, Secretary of War, his notes were turned over to Mr. W. P. Blake, who prepared the geologic section of the report. Thus the full value of the observations made by Marcou was never realized. However, many of his conclusions were incorporated in a later publication.[6]

The second expedition, known as the "Thirty-second parallel survey," crossed Texas from the vicinity of Denison to El Paso. The notes and collections made by the officers under the direction of Marcou, who did not accompany the party, were turned over to him and he wrote a brief general report.[7]

Marcou was the first to recognize the Lower Cretaceous in North America. In 1855 he identified[8] a number of fossils from Texas and western Oklahoma as Neocomian, and asserted that rocks of that age cover considerable areas in Texas and Indian Territory. Marcou maintained the validity of his conclusions in subsequent papers, but for several reasons American geologists did not accept his view, although it was essentially correct. This was due in a large measure to the fact that Marcou referred a portion of the same series, at Tucumcari Mt., New Mexico, to the Jurassic, and for nearly forty years carried on a bitter controversy with American geologists as to the age of this section. Further, Roemer's work as well as Shumard's work referred these beds to the Upper Cretaceous.

---

[5]Reports of Explorations and Surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, made under the direction of the Secretary of War, 1853–'54–'55, vol. 3, Washington, 1856.

[6]Marcou, Jules, Geology of North America: Zurich, 1858.

[7]Pope, John, Bvt. Capt., Corps of Top. Eng.: Geological notes of a survey of the country comprised between Preston, Red River, and El Paso, Rio Grande del Norte, in report of Exploration of a route for the Pacific Railroad near the thirty-second parallel of latitude, from Red River to the Rio Grande: Report of Sec. of War House Document 129, vol. 4, Chap. 13, pp. 125–128, 1855.

[8]Pacific Railroad Expedition reports: vol. 4, pp. 40–48, 1855. Republished in the 4th edition of Marcou's "Geology of North America," 1858.

In 1858 the State of Texas provided for a State Geological Survey, and in the same year Doctor B. F. Shumard was named to fill the office of State Geologist. The Shumard survey was of short duration, due to internal friction, and in 1860 Shumard was relieved of his duties as State Geologist. Nc publications of any import were issued by this survey, but Shumard[9] published elsewhere some very important observations on the Cretaceous strata of Texas which included his now famous "Shumard section." This was a composite section, compiled from the work of his brother, G. G. Shumard, whose work in connection with the expedition for the exploration of Red River has been mentioned, and from that of W. P. Riddell, Assistant State Geologist under the Shumard survey, and from his own observations. It will be noted that, like Roemer's, the Shumard section is for the most part reversed from the normal order.

The year following the publication of the Shumard section Marcou[10] published a criticism and rearranged it in accordance with his own views. Although Marcou's rearrangement of the section was not accepted, it presented the most accurate interpretation of the succession of formations published to date.

The subject remained in this state until 1887, when the publication of papers by R. T. Hill and C. A. White, based on the field work of the former, established the true succession of beds and showed that there is in Texas a great series of Cretaceous rocks underlying the generally recognized Cretaceous (Upper) of other parts of the country. This is the Comanche series made so familiar through the numerous papers by Hill.

It will be impracticable to follow in every detail the development of the Cretaceous section of Texas by Hill. It will suffice here to state that in 1887 Hill[11] published the first correct section of the Cretaceous of this region. He

---

[9]Shumard, B. F., Observations upon the Cretaceous strata of Texas: Trans. Acad. Sci., St. Louis, vol. 1 pp. 582–590, 1860.

[10]Marcou, Jules, Notes on the Cretaceous and Carboniferous rocks of Texas: Proc. Boston Soc. Nat. Hist., pp. 86–97, 1861.

[11]Hill, R. T., Texas section of the American Cretaceous: Am. Jour. Sci., 3rd ser. vol. 34, pp. 287–309, 1887.

subsequently made numerous changes, chiefly in nomenclature, and finally in 1901 published his monograph[12] which is today the standard reference on the Cretaceous of Texas. Numerous papers have appeared on this region since 1901, and while some minor changes have been made in the nomenclature, the foundation established by Hill has not been changed.

In an appendix to a paper on the "Geology of Western Texas" by George G. Shumard,[13] published in 1886, is contained "a detailed report on the Geology of Grayson County." This material was gathered by G. G. Shumard in 1855 and 1856 while acting as Assistant State Geologist to B. F. Shumard. The material was not published until thirty years later, due to the outbreak of the Civil War.

PHYSIOGRAPHY

The entire area of Grayson County forms a part of the large physiographic province of North America known as the Gulf Coastal Plain. The Gulf Coastal Plain extends almost entirely around the Gulf of Mexico as a broad belt of sands, clays, and limestones having a gentle slope toward the sea. The belt covers a large area in Mexico, the southeastern half of Texas, the southeastern tier of counties in Oklahoma, all of Louisiana and Mississippi, the southern part of Alabama and Georgia, all of Florida, and merges into the Atlantic Coastal Plain province which borders the Atlantic Ocean from Florida to New Jersey.

The strata bordering the Gulf of Mexico all dip gently toward the Gulf. The youngest, or those most recently deposited, occur at the water's edge; the oldest, namely, the Trinity sand of Cretaceous age, is found outcropping farthest north, and all intervening formations from the youngest to the oldest may be found in their proper places farther and farther from the water's edge outcropping as concentric belts around the Gulf of Mexico.

---

[12]Hill, R. T., Geography and Geology of the Black and Grand prairies, Texas: U. S. Geol. Surv., 21st Ann. Rept., Pt. 7, 1901.

[13]Shumard, Geo. G., Partial report on the geology of western Texas, consisting of a general geological report and journal of geological observations along the route traveled by the Expedition between Indianola, Texas, and the valley of the Mimbres, New Mexico, during 1855 and 1856, with an appendix giving a detailed report on the geology of Grayson County: State Printing Office, Austin, 1886.

Grayson County lies near the northern boundary of the Gulf Coastal Plain and may be described as a dissected Coastal Plain upland. The elevation ranges from 881 feet above sea level, the elevation of a bench mark about four miles south of Pottsboro, to less than 530 feet along Red River at the eastern edge of the county. The average elevation of the county is about 750 feet.

The drainage of Grayson County is almost entirely into Red River. The principal tributaries to Red River which drain Grayson County are: (1) Mineral Creek and its tributaries in the western part of the county, (2) Little Mineral Creek in the central part of the county, and (3) Choctaw Creek and its tributaries, including Iron Ore Creek, in the eastern part of the county. A small area in the southwestern part of the county drains southward into the Trinity River. Red River forms the northern boundary of Grayson County and flows in a very sinuous course through a deep broad valley. This valley is in places two hundred feet below the general level of the surrounding country. The creeks flowing into Red River have cut deep canyon-like valleys in order to enter the main stream at grade, and as a result a very rugged topography is found near Red River.

The topography of a dissected region is determined chiefly by the character of the underlying rocks. On this basis the northern part of Texas has been separated into a number of distinct physiographic and topographic units, which are also fairly distinct geologic units. The following are represented in Grayson County: (1) The Western Cross Timbers, or the area covered by the outcrop of the Trinity sand; (2) the Grand Prairie, or the area underlain by the limestones and shaly clays of the Lower Cretaceous lying above the Trinity sand; (3) the Eastern Cross Timbers, or the area covered by the outcrop of the Woodbine sand; and (4) the Black Prairie, or the area covered by the outcrop of the Eagle Ford and Austin chalk formations of the Upper Cretaceous.

The Western Cross Timbers are represented in Grayson County by a very restricted area in Preston Bend and a narrow strip along Red River in the northwestern portion of the county. It is characterized by rolling to hilly topography, a very sandy soil, and a thick growth of scrub oak and black jack timber.

Above the Trinity sand are several hundred feet of alternating beds of limestone and shale or clay forming a rolling upland prairie called the Grand Prairie. This division includes a belt of country ranging from one to six or eight miles in width extending the full length of Grayson County, adjacent to Red River. It has a rolling to hilly surface on which the indurated layers tend to produce small escarpments and benches. The most important of the escarpment-forming ledges, in ascending order, are: (1) Goodland limestone, (2) Lower Duck Creek limestone, (3) Fort Worth limestone, (4) "Quarry" limestone, and (5) Main Street limestone.

The Eastern Cross Timbers, or the Woodbine sand outcrop, forms a belt six to eight miles in width entering the county from the east, extending in a general northwesterly direction to the vicinity of Gordonville, and then bearing to the south beyond the limits of Grayson County. The topography of the Eastern Cross Timbers, while similar to that of the Western Cross Timbers, is more rugged and hilly. The hills are due to large masses and segregations of residual iron, protecting the strata, while the unprotected areas have been worn away. The area is thickly wooded, the timber consisting chiefly of post oak and black jack.

STRATIGRAPHY

The surface rocks in Grayson County consist of sands, clays, marls, and limestones, all of Cretaceous age. The Cretaceous system has been subdivided into two major divisions, namely, the Comanche series and the Gulf series. In this area the Comanche series appears in surface exposures only in the northern part of Grayson County, along Red River, where it has been brought to the surface by the uplift that produced the Preston anticline. Were it not for this anticline the Comanche series would be buried beneath the Gulf series throughout the entire extent of Grayson County. Underlying the Cretaceous rocks in Grayson County are strata of Paleozoic age. These beds are not exposed at any point within the bounds of the county, but have been penetrated in many wells drilled in search for oil.[15] A detailed description of the formations exposed in Grayson County will be given, beginning with the oldest beds.

STRATIGRAPHIC COLUMN FOR GRAYSON COUNTY

Recent			Alluvial and Terrace deposits
CRETACEOUS	Gulf series		Austin chalk Eagle Ford shale Woodbine sand
	Comanche series	Washita group	Grayson marl Main Street limestone Pawpaw sand Weno clay Denton clay Fort Worth limestone Duck Creek formation Kiamichi clay
		Fredericksburg group	Goodland limestone
		Trinity group	Trinity sand

COMANCHE SERIES

The Comanche series is the lower or basal division of the Cretaceous. It has been commonly known as the Lower Cretaceous, and by some authors is considered the equiva-

[15]For a description of the Paleozoic formations under the Cretaceous in this county see Pre-Cretaceous Rocks Found in Wells in the Part of the Gulf Coastal Plain South of the Ouachita Mountains by Hugh D. Miser and E. H. Sellards. Bull. Amer. Assoc. Petr. Geol. (in press).

lent of a separate system, which they call Comanchean, restricting the term Cretaceous to the upper division or Gulf series, as used in this report. There seems to be little justification for this usage, and consequently the Comanche series is considered as the lower division of the Cretaceous, equivalent in rank with the upper division, or Gulf series. The basis for the division of the Cretaceous into two series is both paleontologic and depositional. In 1889 Hill[16] made the following statement in regard to the separation of these two series:

> This separate identity of the two series is shown by (1) the absolute stratigraphic break between them, as can be seen in numerous contacts in the city of Austin and elsewhere; (2) the radical change in character of sediments, as seen along the partings of the lower Cross Timbers and the Comanche series; (3) the absolute change of life in the two formations, not a single species, as far as known, passing from the Lower series into the Upper, thus indicating a lapse of time between them sufficiently long for an almost complete change of specific characters in the ocean's inhabitants.

The Comanche series is subdivided into three major groups. Beginning with the oldest, they are: The Trinity group, the Fredericksburg group, and the Washita group. Each of these groups is divided into formations, which in turn are divided into members and individual beds. As a general statement it may be said that in North Texas the Trinity is composed of sand and clay deposited in an encroaching sea on a subsiding land mass; the Fredericksburg is a pure white limestone deposited in a more or less quiet or stable sea and probably represents the maximum extent of the Comanchean submergence; the Washita is a series of alternating thin-bedded limestones and shaly marls with some sand in the upper part of the group, deposited in an oscillating and in the main a retreating sea.

The Comanche series has a thickness averaging about 1,000 feet in Grayson County.

---

[16]Hill, R. T., Annotated Check list of the Cretaceous Invertebrate Fossils, Geol. Survey of Texas, Bull. 4, 1889.

TRINITY GROUP

The Trinity group is represented in Grayson County by a single formation, the Trinity sand. Farther south, in Central Texas, the Trinity group is made up of several formations, which are mentioned later in the discussion.

TRINITY SAND

The Trinity sand was named by Hill[17] from Trinity River in Central Texas, along which the formation is typically developed. The Trinity sand in Grayson County represents the near-shore, or beach, deposit of the Comanchean sea as it transgressed upon the land from the southeast.

In its typical development the Trinity sand is a fine, white to yellow pack sand, occurring in massive beds 25 to 40 feet in thickness. Scattered throughout the formation are lentils of clay, which range in thickness from a few inches to 20 or 30 feet, and vary in color from yellow to purple and show a mixture of variegated colors. Locally the Trinity has some indurated layers, which project as massive ledges and form hills and escarpments. These ledges are more prominent in the lower part of the formation. They are usually composed of a white sand, which on weathered surface is a dull gray. The base of the Trinity is not exposed in Grayson County, but some 30 to 40 miles to the north, in the vicinity of Ardmore, Oklahoma, the base is well exposed, and a coarse, massive conglomerate varying in thickness up to 50 feet is found. This conglomerate consists chiefly of quartz pebbles, well rounded, and ranging in size from that of a pea up to several inches in diameter. Another point which seems worthy of note is that in this region the lower part of the Trinity contains some red material, which may be confused with the Permian.

The Trinity sand weathers so easily, forming a mantle of loose debris covering its outcrop, that exposures which permit a detailed section to be measured are extremely rare.

From a study of well records in this region it is estimated that the Trinity has a thickness of from 500 to 700 feet.

[17]Ark. Geol. Survey Ann. Rept. for 1888, vol. 2, pp. 116–152; 176–179.

Section of the Trinity Sand on a Tributary of Little Mineral Creek, Four Miles North of Fink, Grayson County, Texas, Where the Goodland Limestone Is Exposed on the Public Highway

	Ft.	In.
Goodland Limestone:		
Walnut Clay (?)	5	6
Trinity Sand:		
17. Covered with weathered fragments of Goodland limestone and river deposit	11	0
16. Bluish-white sandy shale	0	6
15. Fine pack sand, yellowish to pink	4	2
14. Fine pack sand, cross-bedded, massive, pink to light gray; pink sand has very fine texture; light gray sand is coarse grained and contains residual calcareous material	2	7
13. Fine pack sand, light gray to white, with veins of calcareous nodules	4	11
12. Fine pack sand, light gray to white to yellowish, with veins of calcareous nodules and flint pebbles	8	10
11. Fine pack sand, light gray to white	1	9.5
10. Fine pack sand, light gray to white, containing silicified and carbonized logs	6	1.5
9. Light gray sandy shale grading downward into sand with sharp contact with gray pack sand above	1	10
8. White pack sand with yellow iron stains	7	10
7. White sand containing small rounded pebbles (conglomeratic)	1	2
6. White pack sand with yellow iron stains	1	2
5. Black bituminous shale grading downward into sand with sharp contact on upper surface	1	8
4. Massive white pack sand with spots of yellow iron stain	9	8
3. Dark gray to black pack sand with fragments of carbonized wood	1	2
2. Gray pack sand with yellow iron stains	3	6
1. Massive white pack sand	50	0
Total	123	6

The outcrop of the Trinity sand in Grayson County is limited to a narrow belt along Red River in the northwestern part of the county.

Farther south in Texas the middle portion of the Trinity sand becomes calcareous, and south of the Brazos River is separable, according to Hill,[18] in ascending order into the Basement sands, 127 feet; the Glen Rose formation, chiefly limestone, 315 feet; and the Paluxy sand, 190 feet. Still farther south, at Austin, Texas, the Paluxy sand is apparently represented by limestone in the upper part of the Glen Rose so that the Trinity is divided into two formations; namely, the Travis Peak formation consisting of conglomerate, grit, sand, clay, and calcareous beds having a thickness of 200 or 300 feet; and the Glen Rose formation consisting chiefly of limestone having a thickness of about 450 feet. Grayson County was throughout Trinity time a near-shore, shallow zone, so that sands were accumulating, but to the south, in Central Texas, limestone deposits were being formed.

The Trinity sand weathers to form a rolling topography usually covered by a thick growth of scrub oak and black jack. Where it outcrops with the Goodland limestone overlying, steep escarpments and a very rugged topography are developed. Excellent examples of this type of topography may be seen along the public highway about a mile south of Preston, where a very steep bluff is formed by the Goodland limestone overlying the Trinity sand.

The upper portion of the Trinity contains, in some places, a marked abundance of fossilized and carbonized wood. At the location of the section of the Trinity sand given on page 17 some very fine examples of carbonized logs may be seen in the bed of the stream about 20 to 30 feet below the Goodland-Trinity contact.

At Henderson Ferry, on Red River, the upper forty feet of the Trinity is well exposed and consists of fine to coarse gray and yellow sand containing some clay and slightly indurated sand.

FREDERICKSBURG GROUP

The Trinity sand is overlain by the Fredericksburg group, which is represented in this area by the Goodland

[18]U. S. Geol. Surv. 21st Ann. Rept., pt. 7, pp. 153–154, 171, 1901.

limestone. The Goodland limestone was named by Hill[19] from the town of Goodland, Choctaw County, Oklahoma.

In 1894, and again in 1901, Hill restricted the term Goodland to the massive limestone between the underlying Walnut clay, which he regarded as forming the upper part of the "Antlers" (Trinity) sand, and the overlying Kiamichi clay. In the Atoka folio, and again in the Tishomingo folio, Taff[20] included the Walnut clay in the Goodland, and this usage has since been adopted and followed by other writers, including the United States Geological Survey. Stephenson,[21] in 1918, although following the usage of Taff, advocated that the original definition of the Goodland, as given by Hill, be followed, and that the Walnut clay or, as it is sometimes called, the Walnut shaly member, be separated from the massive limestone in accordance with Hill's original usage.

South of Grayson County the Walnut clay becomes thicker and assumes the importance of a formation rather than a member. Its maximum thickness is attained in the vicinity of Dallas, where it is approximately 150 feet in thickness. It then begins to thin, and at Austin is only about fifteen feet thick. Following is the description of the Walnut clay as given in the Austin folio:[22]

> *Walnut clay.*—At the top of the Glen Rose formation a bed of yellow calcareous clay always occurs, which is extremely rich in two species of oysters: *Exogyra texana* Roemer and *Gryphea marcoui* Hill and Vaughan. Its thickness is from 10 to 15 feet. This is an extremely persistent bed both in its lithologic and its paleontologic characters. To it the name Walnut clay has been given. Above these clays is a soft chalky limestone, the Comanche Peak limestone.

The Walnut clay member is hardly recognizable in the exposure in northern Grayson County. Careful search will usually reveal a few inches or a foot of yellow calcareous clay, but in many exposures it apparently is entirely absent,

[19]Geol. Soc. Amer. Bull., vol. 2, 502–514, 1891.

[20]Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902, and the Tishomingo folio (No. 98), 1903.

[21]Stephenson, L. W., Contributions to the geology of northeastern Texas and southern Okla., U. S. Geol. Survey Prof. Paper 120, pp. 129–163, 1918.

[22]Hill, R. T., and Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Austin folio (No. 76), 1902.

so that it has not been separated in this area and will not be further discussed.

GOODLAND LIMESTONE

The Goodland limestone consists of from 15 to 20 feet of hard, white, semi-crystalline limestone, which weathers almost a pure white. It is massively bedded, there being as a rule about four beds ranging in thickness from 4 to 6 feet each. The lower part of the Goodland is slightly chalky, while the upper part is a very hard pure white limestone. A peculiar characteristic of the upper part of the Goodland is that of breaking or scaling off in thin plates. This gives the outcrop a more or less shattered appearance. The upper part of the Goodland also weathers very characteristically; that is, rather spongy or full of holes. This is due to the unequal weathering of the limestone, which contains many spots or cavities filled with calcite which yield very readily to the agencies of weathering.

Section of the Goodland Limestone and Underlying Walnut Shaly Member on Little Mineral Creek About Two Miles North of Fink, Grayson County, Texas

	Ft.	In.
Goodland Limestone:		
Hard massive white limestone	5	10
Hard massive white limestone containing *Oxytropidoceras acutocarinatum* near the top	4	10
Hard, white, nodular limestone containing *Turritella sp.*, pectens, and *Grypheas*. Base of Goodland	4	2
Total	14	10
Walnut Shaly Member:		
Lenticular parting of fossiliferous blue-gray clay	0	1
Impure fossiliferous limestone	0	6
Shale parting	0	2
Hard, blue to gray shell breccia containing *Exogyras*, *Grypheas*, etc.	0	9
Blue to brown thinly laminated, irregularly bedded clay	0	1
Hard bluish shell breccia	0	3
Hard, blue to brown clay, irregularly bedded	0	6
Blue to brown shale, thinly laminated	2	2

Walnut Shaly Member:	Ft.	In.
Hard shell breccia, containing *Exogyras* and *Grypheas*	0	8
Yellow ferruginous clay containing many fossils. Base of Walnut (?)	1	0
Total	6	2

Trinity Sand:

Gray, white, and blue pack sands, containing many marcasite nodules.

Section of Goodland Limestone and Walnut Shaly Member in Creek About Five Hundred Feet West of Jackson's Elberta Peach Farm, Two Miles West of Preston, Grayson County, Texas

Goodland Limestone	Ft.	In.
Hard massive white limestone which scales off in thin plates at right angles to the bedding plane on weathering	15	0
Walnut Shaly Member		
Mottled blue and yellow sandy shale, with a thin layer of fine loose sand of half-inch thickness at the top	0	6
Soft yellow ferruginous pack sand occurring in layers two inches in thickness and separated by thin partings of clay	1	0
Blue clay which locally contains indurated lenses carrying abundant fossils	1	6
Water level of creek.		

The thickness of the Goodland limestone is fairly constant throughout Grayson County, but is rather variable over larger areas. In Cooke County the average thickness of the Goodland is about 25 feet along the northern border, but it gradually thickens to the southward. Along the southern border of Cooke County it has a thickness in excess of 30 feet and contains several clay horizons near the top. The Goodland limestone is regarded as the time equivalent of the Walnut clay, the Comanche Peak and Edwards limestone of Central Texas, which have a thickness of 300 feet or more at Austin.

The Goodland usually outcrops in a narrow, sinuous band, frequently forming the cap rock of a bluff overlooking an expanse of Trinity sand. In Grayson County the Goodland is found in the Preston Bend area and in the extreme northwestern corner of the county near Orlena. Attention is called to the small inlier of Goodland on Shawnee Creek, just below the city reservoir, northwest of Denison. This outcrop represents approximately the crest of the Preston anticline.

WASHITA GROUP

Overlying the Fredericksburg with apparent conformity is the Washita, the highest group of the Comanche series. The term Washita was applied to this group by Hill[23] from the old Fort Washita, Bryan County, Oklahoma, which has become famous in the history of Cretaceous stratigraphy through the observations made there by Marcou and Shumard.

The Washita group is composed of marine shaly clays, marls, and subordinate limestones, having a total thickness of approximately 400 feet in Northern Texas. Toward the top there is a sandy formation, the Pawpaw, which is the only marked exception to the non-sandy character of this division. The limestones, although subordinate to the clays in thickness, form several definite horizons that contain characteristic fossils and are readily traceable throughout the area, and for this reason are of the utmost importance in determining the stratigraphic sequence and structure of the region.

The Washita group has been subdivided by Hill[24] and also by Taff.[25] The classification used in this report is essentially that given by Hill, except that several of the apparently unnecessary group terms have been omitted and the members under these groups described as formations.

The Washita represents the beginning of the withdrawal of the Comanchean sea which reached its maximum expanse either during the preceding epoch or at the beginning of Washita time. This shallowing of the sea during Washita time is recorded in the increase of clay and shale toward

[23]Hill, R. T., Annotated check list of the Cretaceous invertebrate fossils of Texas; Geol. Survey of Texas Bull. 4, 1889.
[24]Hill, R. T., U. S. Geol. Survey 21st Ann. Rept., pt. 7, pp. 240–292, 1901.
[25]Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902.

the top of the group, and finally in the deposition of sand. The numerous sand layers throughout the Washita group bear evidence of shallow water deposition in the form of ripple marks and cross-bedding. Finally, at the end of Washita time, it is believed that the sea retreated entirely from the area, and a short erosional interval, indicated by a slight disconformity, intervened between the Comanche series and the Gulf series.

The following subdivisions of the Washita group have been mapped in Grayson County:

Grayson marl
Main Street limestone
Pawpaw sand
Weno clay
Denton clay
Fort Worth limestone
Duck Creek formation
Kiamichi clay

KIAMICHI CLAY

The Kiamichi clay was named for the Kiamichi River of Southeastern Oklahoma. It was in the valley of this river that Dr. Pitcher collected the now famous *Gryphea pitcheri* of Morton in 1827, the first fossil of the Comanche series to be described. The Kiamichi clay, which includes all the sediments between the Goodland limestone and the Duck Creek formation, is easily recognized due to its position between two relatively hard, resistant, limestone formations. It is composed of about thirty-five feet of dark yellow to olive-green to black shaly clay with thin platy lenses of a yellow siliceous limestone in the basal portion; at the top the formation is marked by two or three ledges of a hard yellowish shell breccia made up of *Gryphea navia* Hall and *Gryphea corrugata* Say. This *Gryphea* conglomerate is always present at the top of the Kiamichi, the individual beds ranging from a few inches up to three feet in thickness. It is confined entirely to this one horizon and is probably the most characteristic horizon in the entire Comanche series. The erosion of the soft clay underlying the hard oyster-shell breccia (*Gryphea* conglomerate) causes it to slump and break off in large slabs which frequently cover the outcrop of the Kiamichi clay. Some of the slabs may finally come to rest standing on edge or making various angles from horizontal to vertical. They are commonly referred to as "edge rock" by the layman.

The contact between the Goodland limestone and the Kiamichi clay is usually marked by a rather persistent bench or terrace, due to the erosion of the soft clay overlying the hard limestone. The contact between these two formations is not a gradation, but rather a sharp break from the pure limestone to the typical greenish-brown clay of the Kiamichi. Usually a few inches of a thinly laminated, brown, siliceous limestone occurs at the base of the Kiamichi, representing the transition from the Goodland limestone to the Kiamichi clay. It has been suggested that there is an unconformity between these two formations. The writer did not find any evidence to support this suggestion except the fact that a very sudden change occurs in the type of sediments.

The Kiamichi usually outcrops on the slopes above the Goodland escarpment or on the sides of hills capped by the lower Duck Creek limestone. Since the Kiamichi lies between two relatively hard escarpment-forming limestones, its outcrop is narrow and tortuous. Its occurrence in Grayson County is about the same as the Goodland limestone, being limited to the northwestern portion of the county along the Red River.

The following section is typical of the formation:

Section of the Kiamichi Clay on Shawnee Creek Immediately Below the City Lake Dam on the Public Highway, Four Miles Northwest of Denison, Grayson County, Texas

	Ft.	In.
Duck Creek Formation:		
Kiamichi Clay:		
Limestone, hard gray, filled with *Gryphea navia* Hall and *G. corrugata* Say	0	3
Shale, light chocolate colored	0	3
Limestone, hard gray, filled with *Gryphea navia* Hall		

Kiamichi Clay:	Ft.	In.
and *G. corrugata* Say	1	0
Shale, bituminous, light gray color, containing thin bands of ferruginous material	2	6
Shell conglomerate, light blue, containing *Ostrea* sp., *Pecten* sp., and *Grypheas*, with the latter predominating	0	9
Shale, dark blue bituminous, thinly laminated with streaks of ferruginous clay containing flakes of gypsum. Contains some thin layers of a hard blue arenaceous limestone	3	5
Limestone, hard gray, with a considerable number of *Gryphea navia* Hall. The lower 5 inches is loosely consolidated and contains few shells	0	10
Shale, dark blue bituminous, thinly laminated, with streaks of ferruginous clay containing flakes of selenite. The bituminous clay also has flakes of selenite between the laminae. Rather abundant fauna of small pelecypods	4	6
Limestone, hard bluish-gray, slightly arenaceous; weathers to a yellowish-brown	0	2
Shale, dark olive to drab colored, containing small veins of ferruginous material; grades upward into dark gray shale	22	9
Goodland Limestone		
Total	36	5

There has been more or less uncertainty as to whether the Kiamichi clay should be placed at the top of the Fredericksburg or at the base of the Washita. Hill, in his earlier publications, drew the boundary between the Fredericksburg and Washita "above the zone of *Ammonites acutocarinatus* (now *Oxytropidoceras acutocarinatum)* Shumard, which has been referred to *A. peruvianus* von Buch."[26]

Such a division would place the Kiamichi in the Fredericksburg. Later, Hill changed his opinion in regard to the boundary between these two divisions, drawing it on the occurrence of *Nerinea* and *Rudistes* forms, which places the Kiamichi in the Washita. This usage has been quite generally adopted, and in the dominantly limestone area of

[26]Hill, R. T., U. S. Geol. Survey 21st Ann. Rept., pt. 7, p. 257, 1901.

Central Texas it seems to be very satisfactory, but in the marginal areas it has given rise to much confusion.

Taff, in a statement quoted by Hill,[27] recognized that the Kiamichi clay would not fit in the adopted classification.

> In considering some of its (Kiamichi) fossil remains, like *Exogyra texana* and *Schloenbachia belknapi*, Taff has expressed doubts as to whether this formation in the areas of its marginal extension could be separated sufficiently from the Fredericksburg division to give it the status of a distinct formation.

Such difficulties as Taff suggests have been encountered in the marginal areas. Stanton and Vaughan,[28] in their study of the section at El Paso, Texas, experienced difficulty in separating the Fredericksburg and the Washita The following sentence is quoted from their report:

> The evidence of the fossils taken altogether is in favor of the view that part of the Fredericksburg is represented here and that it grades into the basal Washita so imperceptibly that no paleontologic line can be drawn between them.

Recently Adkins[29] has returned to Hill's original definition of the Fredericksburg; that is, drawing its upper limit on the occurrence of *Oxytropidoceras* sp., which places the Kiamichi in the Fredericksburg. In this report the Kiamichi clay is placed in the Washita group, although it is recognized that it may ultimately be necessary to transfer it to the Fredericksburg group. It is necessary to admit that the division finally adopted by Hill, based on the occurrence of *Rudistes,* has led to much confusion in correlation, particularly in the outlying sections.

DUCK CREEK FORMATION

The Duck Creek lies directly above the Kiamichi clay. It received its name from the excellent exposures of this formation along Duck Creek, north of Denison, Texas. The Duck Creek consists of approximately 100 feet of limestone and gray to grayish-blue calcareous shaly clay. In the lower 30 to 40 feet of the formation the limestone and shaly

[27]U. S. Geol. Survey 21st Ann. Rept., pt. 7, p. 257, 1901.

[28]Stanton, T. W., and Vaughan, T. W., Section of the Cretaceous at El Paso, Texas, Am. Jour. Sci., 4th ser., vol. 1, pp 21–27, 1896.

[29]Adkins, W. S., Geology and Mineral Resources of the Ft. Stockton Quadrangle: The Univ. of Texas Bull. 2738, 1927.

clay alternate in beds averaging from 6 to 12 inches in thickness in about equal proportions; in the upper 60 to 70 feet the clay greatly predominates, the limestone layers becoming thinner and separated by a greater thickness of clay.

The contact between the Duck Creek and the overlying Fort Worth limestone has been placed at different horizons by various writers, resulting in a great variation in the thickness assigned to these formations. There is no sharp break between these two formations, but rather a gradation from clay or marl into a marly limestone. In the upper part of the Duck Creek thin beds of limestone, varying from one-half inch up to two or three inches in thickness, are separated by several feet of clay. These limestone beds gradually become thicker and more numerous and the clay beds become thinner until the formation becomes dominantly limestone. With the shifting of the contact the thickness assigned to the Duck Creek and Fort Worth varies accordingly. However, the total thickness of the two formations is fairly constant, so that by comparing the figures given for each formation it is possible to account for the disagreement in thickness as recorded by different writers.

Taff[30] combined the Duck Creek and Fort Worth in Southern Oklahoma to form the Caddo limestone. In some cases it is difficult to determine the exact contact between these two formations, but in general they are easily identified, as each carries an abundant and a characteristic fauna.

The following section by Stephenson is typical of the formation:

Section on Duck Creek and in Cut of the St. Louis and San Francisco Railroad Two and Three-quarter Miles North of Denison, Grayson County, Texas[31]

	Feet
Fort Worth Limestone:	
Limestone, nodular, impure, argillaceous, and fossiliferous, in four or five layers interbedded with gray shaly clay	8

[30]Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902; Tishomingo folio (No. 98), 1903.
[31]Stephenson, L. W., U. S. Geol. Survey Prof. Paper 120, p. 139, 1918.

Duck Creek Formation:	Feet
Clay, gray shaly calcareous, with interbedded layers of impure non-ledge forming limestone at intervals of 2 or 3 feet	22
Concealed (probably shaly clay)	20
Clay, greenish-gray calcareous from which weather numerous specimens of *Plicatula* cf., *P. incongrua* Conrad, and small rusty ammonites, probably young of *Pachydiscus* and *Schloenbachia*, also a few specimens of *Gryphea washitaensis* Hill	15
Limestone, ledges with interbedded layers of gray shaly clay, poorly exposed; the limestone, especially one layer near top, contains numerous keeled and non-keeled ammonites, many of which are of large size (maximum 2 feet in diameter)	20
Limestone and gray shaly clay, in alternate beds, ammonite bearing, well exposed in bluff along creek	20
Kiamichi Clay	
Total	105

The lower part of the Duck Creek formation contains an abundance of well-preserved fossils. The large ammonite *(Desmoceras brazoense* Shumard) occurs at the top of the series of alternating limestone and shaly clay layers in the lower part of the Duck Creek formation. About thirty feet above the *Gryphea* breccia, at the top of the Kiamichi clay, there is a massive white limestone bed averaging two feet in thickness. This limestone ledge is a very persistent bed and one of the most prominent layers in the lower Duck Creek formation. In its unweathered appearance it resembles the Goodland limestone. The large ammonites, above referred to, occur in this limestone bed and in the shaly clay directly above and below it. They are limited to a vertical range of not more than eight or ten feet, and for this reason are valuable as a key bed in structural work. Below the "large ammonite" horizon there is an abundance of fossils, the most prominent of which are as follows: *Inoceramus comancheanus* Cragin, *Hamites fremonti* Marcou, *Hemiaster whitei* Clark, *Pervinquieria trinodosa* (Böse).

The upper part of the Duck Creek formation, composed principally of shaly clay, contains very few fossils.

The Duck Creek outcrops in a belt along Red River, where it has been brought to the surface by the Preston anticlinal uplift.

FORT WORTH FORMATION

Overlying the Duck Creek formation is the Fort Worth limestone, named from the city of Fort Worth, Texas, where it is typically exposed along the streets. The Fort Worth limestone is readily separated into three members. The lower member consists of from 10 to 15 feet of yellowish-white limestone and grayish to blue shaly clay. The middle member is chiefly shale and also ranges from 10 to 15 feet in thickness. The upper member is predominately limestone, separated by thin layers of shaly clay. The limestone is a hard, cream-colored limestone, very similar to the more massive beds of the lower Duck Creek. The resemblance in lithologic character between the Duck Creek and Fort Worth makes it difficult to distinguish between the two formations except on the basis of the fossils. Each formation contains an abundance of easily recognized and characteristic fossils, and a few minutes' search is usually sufficient to establish the identity of the formation on the basis of the fossils. The most outstanding fossils used in identifying the Fort Worth are as follows: *Holaster simplex* Shumard, *Hemiaster elegans* Shumard, *Pervinquieria leonensis* (Conrad), and a large oyster, *Exogyra americana* Marcou.

The thickness of the Fort Worth averages between forty-five and fifty feet in Grayson County. Following is Hill's[32] description of the Fort Worth at the type locality:

> The Fort Worth formation, as exposed in the railway cuts north of the Union Station at Fort Worth, and underlying all the business portion of that city, consists of a group of impure white limestones, very slightly arenaceous, regularly banded in persistent layers averaging nearly a foot in thickness, and alternating very regularly with similar layers of marly clay.

[32]Hill, R. T., U. S. Geol. Survey 21st Ann. Rept., pt. 7, p. 259, 1901.

The limestones and marls occur in strata 4 or 5 inches to 2 or more feet in thickness. The marly layers alternate with the hard limestones in bands ranging from thin laminae to beds 6 inches or more thick. The gradation from hard marly lime bands to firm limestone is apparently sharp, but on close examination it is found to be very gradual so that well-defined lines cannot always be clearly drawn between them. Upon weathering in vertical bluffs the hard ledges become projecting shelves and the marls form recessions between them. Before exposure the rocks are dull blue, but when weathered they are glaring white, sometimes with a slightly yellowish tinge.

Following is a typical section of the formation:

Section of the Fort Worth Limestone on Branch of Duck Creek One Mile North of Denison, Texas. Base of Section Just Below Tank on Tobin's Stock Farm

	Ft.	In.
Denton Clay		
Fort Worth Limestone:		
Alternating layers of massive white limestone and thin beds of clay. The limestone layers are much thicker than those lower in the section, and contain iron stains. There are numerous fossils including *Gryphea washitaensis* Hill, *Pervinquieria leonensis* (Conrad), *Holaster simplex* Shumard, *Hemiaster elegans* Shumard, *Exogyra americana* Marcou, and some *Sphenodiscus*-like forms. At the top there is a thin bed of fossiliferous marl which grades into the Denton	19	0
Thick beds of clay shale with thin alternating beds of impure limestone containing the following fossils: *Pervinquieria leonensis* (Conrad), *Holaster simplex* Shumard, *Gryphea washitaensis* Hill, and *Pecten* sp.	19	0
White limestone containing *Pervinquieria* sp. and *Hemiaster* sp.	0	6
Light gray shaly clay containing iron stains; also some small specimens of *Gryphea washitaensis* Hill	3	9
Impure yellowish limestone containing fucoids	1	0
Clay shale, blue	2	6
Light blue shaly limestone	0	5
Blue clay shale	1	2
Impure chalky limestone	0	9
Blue clay shale	0	10
Hard blue impure limestone containing traces of ferruginous material which gives the ledge a rusty color. The bed contains many large fucoids on its under surface	1	0

	Ft.	In.
Fort Worth Limestone:		
Blue clay shale with several thin ferruginous bands; contains several specimens of a small *Gryphea washitaensis* Hill	1	4
White, impure, chalky limestone, slightly arenaceous	1	2
Duck Creek Formation		
Total	52	5

The top of the Fort Worth is usually characterized by a marked abundance of *Gryphea washitaensis* Hill. This is the lowest horizon where this particular *Gryphea* has been noted in abundance, although it ranges throughout the Washita division. *Exogyra americana* Marcou is easily identified due to its size and is a valuable marker for the top of the Fort Worth. The two echinoids, *Holaster simplex* Shumard and *Hemiaster elegans* Shumard, begin in the upper part of the Duck Creek, but their zone of abundance is in the Fort Worth, usually near the middle of the formation.

The Fort Worth limestone, like the other Comanchean formations, outcrops in northern Grayson County in a belt along Red River, on the south flank of the Preston anticline.

DENISON FORMATION

The Fort Worth limestone passes upward into a group of sediments of various aspects laid down in shallower water and characterized by certain well marked paleontologic zones. They are for the most part near shore, littoral deposits, some of which have no traceable representative farther south than North-Central Texas, and arenaceous and argillaceous formations in Grayson County grade into marls and limestones in Central Texas. The effect of this gradation may be seen by comparing the thickness of the Washita division in Grayson County and Central Texas. In Northern Texas the Washita division, as previously stated, is composed chiefly of shaly clays, marls, and subordinate amounts of thin limestones, with an average thickness of about 400 feet, while in the vicinity of Austin, Texas, it is represented by three formations, the Georgetown limestone, the Del Rio clay, and the Buda limestone, having a total combined thickness of approximately 160 feet.[33]

Hill's description of the beds which make up the Denison formation in the Denison area, which he states may be considered the type locality for North Texas and Indian Territory, is as follows:[34]

> In this region it consists of laminated ferruginous clays, sandy clays, impure limestones (littoral breccias), and sand. These beds are all characterized by the strong ferruginous colors peculiar to near shore deposits, which appear only faintly, if at all, in the lower lying Comanche series, or the extension of the Denison beds south of the Brazos, while the white chalky element is entirely absent.
>
> In the Denison section the Denison beds consist of about 300 feet of ferruginous dark-colored clays and sands, free from the lighter-colored calcareous (chalky) element of the underlying beds, with occasional conspicuous indurated layers of impure limestone, ferruginous sandstone, iron ore, and clays, which lie between the top of the Fort Worth limestone and the Grayson marl.

Hill applied the term Denison beds to a portion of this series and then divided it into a number of members. In this regard he says:[35]

> In a general manner the Denison beds may be subdivided into three conspicuous subgroups; the lower, middle, and upper.
>
> The lower subgroup of the Denison beds, including all that portion below the top of the *O. carinata* horizon, will be generally alluded to as the Denton beds.
>
> The medial or Weno subgroup of the Denison beds, including all that portion above the *O. carinata* horizon and beneath the Main Street limestone, for convenience may be divided into the Weno and Pawpaw formations. For the upper subgroup consisting of the Main Street limestone and Grayson marl, the term Pottsboro may be used.

Stephenson[36] in his work accepted Hill's subdivision of the beds, but simplified his nomenclature somewhat by dis-

---

[33]Hill, R. T., and Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Austin folio (No. 76), 1902.

[34]Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 266, 1901.

[35]Hill, R. T., *Idem.*, p. 267.

[36]Stephenson, L. W., U. S. Geol. Survey Prof. Paper 120, 1918.

carding all the subgroup names, calling the whole series the Denison formation, with the following members:

Grayson marl member
Main Street limestone member
Pawpaw sandy member
Weno clay member
Denton clay member

Taff[37] grouped all the beds in Southern Oklahoma lying below the Main Street limestone (which he called Bennington) and above the Fort Worth limestone under the name Bokchito formation. In recent reports[38] the Bokchito has been separated into the three subdivisions recognized in Texas; namely, the Denton, Weno, and Pawpaw members, respectively. The Main Street and Grayson are described as separate formations. In order to further simplify the already complicated nomenclature of these beds, all unnecessary terms have been dropped and the following formations described:

Grayson marl
Main Street limestone
Pawpaw sand
Weno clay
Denton clay

While it is recognized that these beds have a certain unity or similarity both in lithologic and paleontologic characteristics, it is believed that the dropping of all unessential terms is justified.

DENTON CLAY

The Denton clay immediately overlies the Fort Worth limestone. In Grayson County the Denton consists of from thirty to forty feet of brownish-yellow clay with numerous sandstone beds and lenses ranging throughout the formation. The top of the Denton is marked by a brownish-yellow arenaceous shell limestone, made up frequently of countless numbers of *Gryphea washitaensis* Hill and *Ostrea*

[37]Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902; Tishomingo folio (No. 98), 1903.

[38]Bullard, Fred M., Geology of Marshall County, Oklahoma: Oklahoma Geol. Survey Bull. 39, 1926.

carinata Lamarck. This zone rarely exceeds one or two feet in thickness.

Hill[39] makes the following statement in regard to the Denton:

> The lower part of the Denton subgroup consists of beds of blue marly clays, terminating above by conspicuous indurations of oyster breccia made up largely of *Gryphea washitaensis* accompanied by *Ostrea carinata*.

The lower five to ten feet of the Denton is decidedly a calcareous clay. The first horizon that stands out prominently in the Denton is a sandstone bed, ranging from one to two feet in thickness. This sandstone is thinly laminated, a yellowish-brown on weathered surfaces, and frequently contains well preserved "ripple marks." This ripple-marked sandstone lies, as a rule, near the middle of the Denton, varying from twenty to thirty feet above the base. However, the Denton is somewhat variable, and frequently the sandstone is much nearer the top than the middle of the formation. This sandstone is usually the only indurated layer in the Denton, and for this reason is very useful in mapping, since it is very easy to locate, as large slabs frequently cover the slope of a small escarpment or bench which it forms. The top of the Denton, as previously stated, is marked by an impure, fossiliferous limestone, the *Ostrea carinata* horizon of Hill.

Section of the Denton Clay on the Riverside Park Road About Two Miles Northeast of Denison, Grayson County, Texas

Denton Clay:	Ft.	In.
Shell breccia	5	5
Thinly laminated, brown sandstone	0	9
Brown clay	25	0
Total	31	2

[39] *Op. Cit.*, p. 268.

Section of the Denton-Weno Contact in Cut of St. Louis and San Francisco Railroad, Just West of the Riverside Park Road, About One and One-Half Miles Northeast of Denison, at the 633.1+ Mile Post

	Ft.	In.
(a) Denton-Weno contact: alternating layers of breccia and brown clay marl. Contains *Gryphea washitaensis* Hill, *Ostrea carinata* Lamarck, and *Leiocidaris* plates and spines	3	8
(b) Hard, brown sandstone occurs approximately three feet below base of shell breccia. A thin clay parting occurs in the middle of the sandstone bed	0	10
(c) Dark bituminous stratum, 8 inches below sandstone, which alternates with a yellow, ferruginous shale. Many small shells were observed throughout the dark-colored clay	1	13

The thickness of the Denton is quite variable. In Cooke County the average thickness is approximately sixty feet, while in Grayson County it ranges under forty feet. However, the nature of the material indicates deposition in a shallow, littoral zone, which would be favorable to marked variations of thickness in short distances. For comparison, a section of the Denton clay in Cooke County, Texas, is here given:

Section of the Denton Clay on Hampton Hollow About Two Miles Down Stream From the Toll Bridge on Red River, North of Gainesville, Cooke County, Texas

Denton Clay:	Ft.	In.
Yellowish-brown clay marl with scattered individuals of *Gryphea washitaensis* Hill	35	4
Yellowish-brown, thinly laminated, ripple marked sandstone	1	6
Brown to yellow marly clay with a few iron nodules	30	2
Total	67	0

It is notable that practically all the variations in thickness of the Denton occur above the sandstone bed, as its position with respect to the Fort Worth limestone is fairly constant over the entire region. Excellent exposures of the Denton may be seen in Munson Park, one mile north of Denison, and, as above stated, along the road to Riverside Park, northeast of Denison.

WENO CLAY

The Denton clay is overlain by a dark gray to yellow shaly clay with subordinate thin partings, lenses, and layers of fine gray to yellow sand, some of which are indurated and form ledges of sandstone. To this material Hill gave the name Weno, from the small village of Weno, on Red River five miles northeast of Denison. The postoffice of Weno has been abandoned for many years and does not appear on recent maps.

Following is Hill's[40] description of this formation:

> This subgroup attains its maximum development in the Denison section, where it includes all the beds between the top of the *G. washitaensis* agglomerate and the top of the Quarry limestone. It is well developed in the Red River region, where its several beds are important stratigraphic units, but these lose individuality southward across the State.
>
> The Weno formation is characterized by a littoral fauna of many small species occurring in great quantities in certain horizons, notably *O. quadriplicata* and certain ammonitic forms of the *Engonoceras* type, which are now being studied by paleontologists.
>
> *Character of beds at Denison.*—In the Denison section these beds embrace several well-defined members consisting of very ferruginous brownish marls, with occasional presistent harder beds, such as large lens-shaped segregations, beds of ferruginous sandstone, impure limestone, etc., all of which are locally persistent and some very conspicuous. The indurated beds of the Denison section are interesting. One of these indurated layers, 80 feet below the summit, is especially noticeable, in as much as it consists of large lenticular indurations of a clay ironstone which are thinly laminated and break into sheets along the line of laminae. These concretions are blue interiorly and brown exteriorly, and are often 4 or 5 feet in diameter. About 22 feet below the indurations, or 104 feet below the Quarry limestone, there is another indurated bed consisting of sandstone, as exposed near the cemetery gate north of Denison. Below this, extending down to the

[40]*Op. Cit.*, p. 274.

> *O. carinata* beds, there are brown clay marls to a depth of about 22 feet. In the Denison section the strata of the Weno subgroup are clearly defined and easily recognizable. Southward toward Fort Worth they lose their individuality, after the disappearance of the Quarry limestone in Denton County, which to the northward separates the Weno from the Pawpaw formation. . . . Furthermore, the limestone element increases proportionately until the lithologic character so changes that along the banks of the Trinity the beds somewhat resemble the underlying Fort Worth beds.

The Weno is very similar to the Denton in lithologic character, the principal differences being that the Weno contains more thin, soft sandy layers and also contains many clay ironstone concretions.

The thickness of the Weno is somewhat variable, although it is fairly constant for Grayson County. The average thickness in Grayson County is from 85 to 95 feet. To the west of Grayson County, in Cooke County, the Weno is usually about 100 feet in thickness. To the north of Grayson County, in Marshall County, Oklahoma, sections of the Weno have been measured which total 135 feet. A marked variation in the thickness of the Weno is noted on opposite sides of the Preston anticline, the thicker sections being on the north side of the anticline, or the shoreward side. No clear explanation of this fact is offered, but it is thought that underlying the Preston anticline is a pre-Cretaceous ridge, which probably influenced sedimentation in this area. A more detailed discussion of this phase of the subject will be found under the heading of "Structure."

Section of the Weno Clay One Mile North of the City of Denison. Base of Section in Bed of Ditch One-third Mile N. 12° E. of City Stand Pipe. Section Measured Approximately N. 70° E.

Weno Clay:	Ft.	In.
12. Loose yellowish-brown arenaceous clay	7	0
11. Clay ironstone bed filled with *Turritella* sp., numerous gastropods, pelecypods, and other fossils	0	4
10. Yellowish-brown arenaceous clay containing iron concretions. Layer of soft yellow sand 7 feet from base	9	5

Weno Clay:	Ft.	In.
9. Fine, soft, yellow sandstone	0	8
8. Series of soft yellow sandstone ledges, 1 to 2 inches in thickness, containing iron concretions, separated by yellowish-brown clay 1 to 4 inches in thickness	15	8
7. Thinly laminated soft yellowish-brown sandstone	0	8
6. Argillaceous sand, cream-colored with slight yellowish tinge filled with clay ironstone concretions. Also contains some selenite	16	8
5. Yellowish-brown compact sandstone, apparently concretionary, 4 inches in thickness, and a layer of clay, ironstone, and sandstone concretions interstratified with yellowish-brown arenaceous clay	1	2
4. Blue clay, lenticular	6	0
3. Covered by stream fill	10	2
2. Fine yellowish-brown arenaceous clay with bed of *Ostrea quadriplicata* Shumard two feet above top of underlying shell breccia. Lenses of blue clay 10 inches above *O. quadriplicata* horizon followed by one foot of yellowish-brown clay	5	1
1. Shell breccia composed of *Gryphea washitaensis* Hill and *Ostrea carinata* Lamarck cemented in an argillaceous limestone	2	11
Total measured thickness	75	9
Correction for measuring down a dip of 1° 30′ for a distance of 760 feet from base of section to station four	17	3
Total thickness	93 feet	

The above section stops at the base of the "Quarry limestone," remnants of which may be seen on top of the hill.

Section of the Weno Clay on Armstrong Avenue Road One-half Mile North of Stand Pipe, Denison, Grayson County, Texas

Weno Clay:	Ft.	In.
Light yellow clay alternating with thin layers of ferruginous sandstone	24	9
Light chocolate-colored pack sand	0	10
Clay, dark brown	0	7

Weno Clay:	Ft.	In.
Light, chocolate-colored pack sand, containing large sand concretions, which are thinly laminated and break in large round slabs, resembling table tops	8	9
Pack sand, light brown, ferruginous, cross bedded	0	10
Light brown clay containing calcareous nodules and thin layers of ferruginous sand in the clay	3	8
Red, sandy, ferruginous clay	14	7
Chocolate-brown clay containing calcareous concretions	6	4
Hard, yellow, slightly calcareous clay containg clay ironstone concretions	0	10
Arenaceous clay with fucoid-like calcareous concretions	1	0
Alternating layers of thin brown shale and shell breccia composed principally of *Gryphea washitaensis* Hill and *Ostrea carinata* Lamarck	5	2
Total	67	4

A good section of the Weno clay is exposed about one mile northeast of the city of Denison, just north of the Denison-Carpenters' Bluff Road. The thickness of the Weno, measured at this point, is ninety-five feet.

The Weno can usually be recognized by the large amount of clay ironstone concretions which it contains. This will ordinarily help to distinguish it from the Denton. The top of the Weno is marked by the so-called "Quarry limestone." The name limestone is somewhat of a misnomer, for the typical Quarry is more of a sandstone than a limestone. The bed was called Quarry by Hill because it was commonly quarried for local use as a building stone. The type area of the Quarry is about a mile east of Denison, where rather extensive local quarries were formerly operated. Hill's[41] description of the "Quarry limestone" is as follows:

Quarry limestone.—This is a persistent band of siliceous limestone, which is notable in the series of otherwise unconsolidated beds and is the chief building stone in the country underlain by the Denison beds. Its interior portion is steel-blue in color, but it is oxidized for a depth of 2 or 3 inches from the surface into a chrome yellow. Its thickness at Denison is about 1.7 feet. This is an especially conspicuous formation within the relatively limited area of its occurrence, although at no place over 2 or 3 feet

[41]*Op. Cit.*, p. 275.

in thickness. It is very arenaceous and might as well be considered a sandstone as a limestone. It is accompanied above by great quantities of the peculiar *Ostrea quadriplicata*.

Much confusion has resulted as to the thickness of the Weno, due to the fact that in the lower portion of the Pawpaw there are several beds which resemble the Quarry, and it is sometimes very difficult to be sure the bed in question is the Quarry and not one of the other horizons. At Carpenters' Bluff, on the eastern edge of Grayson County, good exposures of the Quarry may be seen near the water's edge.

Fossil pelecypods and gastropods in a good state of preservation are numerous in the ferruginous lenses and concretions in the upper part of the Weno. Stephenson[42] noted the following: *Nucula* sp., *Ostrea quadriplicata* Shumard, *Protocardia texana* (Conrad), *Cyprimeria* sp., *Corbula* (three species), *Cymbophora* sp., *Turritella* sp., *Anchura mudgeana* White, *Engonoceras serpentinum* (Cragin).

A point which seems worthy of note is that the ferruginous layers in the upper Weno are to a very large extent made up of *Turritella* sp., while similar beds in the Pawpaw are composed principally of small pelecypods.

The Weno clay weathers very readily and as a rule is poorly exposed on the upland and valley slopes. For this reason sections which will permit of detailed study are exceedingly rare. The Weno is best exposed in the area to the north and east of Denison, but is present, like the other formations, in a narrow belt bordering Red River across the entire north side of Grayson County.

PAWPAW SAND

The Weno clay is overlain by about fifty feet of irregularly bedded sandy clays and sands extending from the Quarry limestone at the base to the Main Street limestone at the top. The Pawpaw is here restricted to those sediments lying between the two limestones above named. Stephenson included the Quarry limestone with the Paw-

[42]U. S. Geol. Survey Prof. Paper 120, 1918.

paw, but in this paper Hill's original usage—that is, considering the Quarry as the top of the Weno—is followed.

Following is Hill's description of these beds in the Denison area:[43]

> *Pawpaw beds.*—These include the strata between the "Quarry" and the Main Street limestones. In the Denison section these are very impure laminated sandy clays and sands, dark blue and bituminous in places, oxidizing surficially into brown ferruginous colors, very much like the Woodbine (Dakota) formation. They are very sandy in the upper 5 feet at the crossing of Pawpaw Creek and the Texas Central Railway. This aspect is local, however. There are also small fragments of lignite in the sands and the character of the sediments appears to be favorable to the preservation of leaf impressions, but careful search up to date has failed to discover these.
>
> The Pawpaw is the most impure of all the Denison beds, and was apparently laid down near the shore, being accompanied by beds of ferruginous sand, which are not elsewhere found in the Washita division. The total thickness at Denison is 45 feet.
>
> At the base of the Pawpaw, just above the Quarry limestone, are lead-colored clay shales with sandy alternations containing innumerable well-preserved nacreous shells, which in some places are replaced by pseudomorphs of iron ore. One band, just above the Quarry limestone, consists of one foot or more of impure, friable ferruginous material, containing beautifully preserved fossils. These fossils are especially abundant in the lower 12 feet and consist of littoral Mollusca of many species.
>
> In certain clay layers the nacreous shells are preserved with all their pearly luster. In sandy layers where ferruginous percolation has taken place the shell substance is dissolved and they are preserved as casts and moulds in an arenaceous matrix of limonitic ironstone.

While the Pawpaw is called a sand, it should be noted that it contains, especially in the lower part, many clay beds which may be easily confused with the Weno. The upper part of the Pawpaw is usually dominantly sand, highly ferruginous, and cross-bedded. The iron usually occurs as a thin sheet between the bedding planes, or filling fissures which cut the sand at every angle. This portion of the Pawpaw is very similar to the Woodbine, with which it is frequently confused.

[43]U. S. Geol. Survey, 21st Ann. Rept., pt. 7, p. 276, 1901.

Section of the Pawpaw Sand on Pawpaw Creek in the Eastern Edge of the City of Denison, Between the Bridge on East Main Street and the Outcrop of Main Street Limestone to the South

	Ft.	In.
Main Street Limestone:		
Pawpaw Sand:		
Covered by soil and fragments of Main Street limestone	21	0
Light yellowish-brown pack sand	24	0
Alternating layers of blue shale and pack sand in beds varying from 6 to 18 inches	2	10
Blue shale containing a thin layer of ferruginous limestone about 2 inches thick 8 feet from base	13	2
Total	61	0

The above section may be in excess of the actual thickness of the Pawpaw, as the upper contact, the Main Street-Pawpaw contact, is not clear cut and could not be definitely located, due to debris which covered the outcrop.

The following section gives in detail the upper portion of the Pawpaw sand:

Section of Pawpaw Sand (in part) on the Bank of Little Mineral Creek About 500 Feet South of the Bridge on the Locust Road, One Mile South of Fink, Grayson County, Texas

	Ft.	In.
Main Street Limestone (detailed section on page 44)	13	9
Pawpaw Sand:		
Blue to brown, loose, argillaceous sand containing iron nodules	3	0
Coarse brown sandstone, highly colored by iron	0	6
Light blue pack sand	1	0
Coarse, brown sandstone highly colored by iron	0	8
Massive, gray to yellow sandstone which breaks off in large blocks on weathering	1	4
Alternating beds of fine yellow sand and blue shale	0	8
Massive, gray to yellow sandstone which breaks off in large blocks on weathering. Contained in this bed are two thin layers of reddish-brown ironstone	2	10
Brown sandy shale containing an abundance of small fossils	0	4
Blue shale stained on surface to brown by iron	1	10
Level of water in creek		
Total	25	11

The upper part of the Pawpaw is highly ferruginous and also very cross-bedded. A good example of the cross-bedding may be seen near the subway south of the Missouri, Kansas, and Texas Railway Station at Denison, Texas. At this outcrop the Main Street forms the top of the cut and, underneath, the thinly laminated sands and clay of the upper Pawpaw make high angles with the true bedding planes.

The ferruginous layers in the Pawpaw frequently contain well preserved fossils similar to those found in the Weno. Stephenson[44] lists the following fossils from the thin lenses of ferruginous, oxidized, soft sandstone: *Nucula* sp., *Protocardia texana* (Conrad), *Cymbophora* sp., *Corbula* sp., *Anchura mudgeana* White, and *Engonoceras se pentium* (Cragin). It will be noted that the above list is practically identical with the one given for the Weno, except that *Turritellas* are absent.

The Pawpaw is more likely to be confused with the Woodbine than any of the other formations of the Cretaceous. It is very similar to the Woodbine, both in type of topography produced and in the soil and vegetation that it supports.

Excellent exposures of the Pawpaw are found at many places in Grayson County. The Pawpaw outcrops in the northern part of the city of Denison, and it is also well exposed along Pawpaw Creek in the eastern part of the city. In general it forms a belt extending along the northern boundary of Grayson County, adjacent to Red River.

MAIN STREET LIMESTONE

The Main Street limestone, so named by Hill because it outcrops on the main street of the city of Denison, Texas, immediately overlies the Pawpaw sand. It consists of from ten to twenty feet of massive, hard, brown, semi-crystalline limestone, with thin subordinate layers of calcareous clay or marl. As a rule the limestone beds are more massive near the base and become thinner toward the top, with the marly layers becoming more prominent. The Main Street

[44]*Op. Cit.*, p. 143.

is the only limestone of any consequence in a thick series of clay and sand, and for this reason is a very important marker for stratigraphic and structural work. It differs from the other limestones of the Washita division in that it contains more ferruginous material which gives it a distinctly brownish color. Taff[45] applied the name Bennington to this limestone in Southern Oklahoma.

Following is Hill's[46] description of the Main Street limestone in the Denison area:

> *Main Street limestone.*—In the Red River section the Main Street limestone constitutes a very conspicuous formation, not only on account of the hardness of the strata, but because of its effect as a topographic factor. It consists of a coarsely crystalline, bedded, brecciated, white limestone, which, on oxidation, turns a deep yellow, showing much more ferruginous coloring than any of the other limestones of the Comanche series. It occurs in strata of various thicknesses. Usually there are more massive beds at the base and thinner strata at the top, with occasional sandy marl layers. The formation nowhere aggregates more than 25 feet. Taff notes a thickness of 23 feet at Rock Creek, Grayson County. At Denison 15 feet have been noted.

The Main Street is characterized by two easily recognized fossils, *Exogyra arietina* Roemer, which occurs throughout the formation but is more abundant in the upper part, and *Kingena wacoensis* Roemer, the only brachiopod of common occurrence in the Comanche series, which is found more abundantly in the lower portion.

The following sections give in detail the character of this formation:

Section of Main Street Limestone on Rock Creek, Northwestern Grayson County, Texas (from Hill)[47]

	Ft.	In.
Grayson Marl:		
Marl light yellow with bands of limestone and great numbers of *Gryphea mucronata* Gabb, the upper portion concealed	15	0

[45] U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902.
[46] U. S. Geol. Survey, 21st Ann. Rept., pt. 7, p. 280, 1901.
[47] U. S. Geol. Survey 21st Ann. Rept., pt. 7, p. 281, 1901.

Main Street Limestone:	Ft.	In.
Limestone, beginning at the base with compact yellow shell and grading upward into friable marl. *Kingena wacoensis* occurs in the upper portion, while *Exogyra arietina* ranges throughout	18	0
Arenaceous shell limestone, with *Ostrea quadriplicata* and *O. subovata* at the base, and *Exogyra arietina* and *Kingena wacoensis* succeeding	5	0
	38 feet	

Section of Main Street Limestone in Railroad Cut on Pottsboro Cut-Off of Missouri, Kansas, and Texas Railroad, About Four Miles West of Denison, Grayson County, Texas

Woodbine Sand
Grayson Marl

Main Street Limestone:	Ft.	In.
Marl, containing nodules of lime	2	9
Limestone, somewhat arenaceous, containing many fossils, including *Exogyra arietina* Roemer, *Exogyra plexa* Cragin, *Kingena wacoensis* Roemer	0	8
Marl, containing *Kingena wacoensis* Roemer	0	7
Limestone, turns yellow on exposure, contains *Kingena wacoensis* Roemer	1	6
Marl, yellowish-white, containing *Kingena wacoensis* Roemer, *Exogyra plexa* Cragin	0	3
Limestone, ferruginous, arenaceous, white, coarse grained, turns yellow on weathered surface. Contains: *Exogyra plexa* Cragin, *Exogyra arietina* Roemer, *Ostrea quadriplicata* Shumard, and *Pecten* sp.	0	9
Marl, containing fossils similar to limestone above	0	2
Limestone, similar to above	0	8
Marl, sandy, ferruginous, contains *Exogyra plexa* Cragin	1	0
Limestone, ferruginous, coarse grained, white, yellow on weathered surface. Contains: *Kingena wacoensis* Roemer, *Exogyra arietina* Roemer, *Exogyra plexa* Cragin	1	4
Marl, containing *Exogyra plexa* Cragin and *Exogyra arietina* Roemer	0	6
Limestone, impure bluish semi-crystalline, containing irregular veins of calcite	1	1
Pawpaw Sand		
Total	11	3

Section of Main Street Limestone and Grayson Marl at Bridge on Choctaw Creek, Near Denison, on Denison and Bonham Road (by Hill)[48]

	Ft.
Grayson Marl:	
Yellow marl and limestone in alternating strata, containing *Turrilites brazoensis* (?), *Gryphea mucronata*, *O. subovata*, *Cyprimeria* sp. (?), echinoids, *Cardium hillanum*, *Ostrea* sp. (?), and *Nautilus* sp. (?)	5
Main Street Limestone:	
Limestone with *Exogyra arietina*, which grades upward into white limestone and marl	12
Limestone with *Terebratula wacoensis*	4 or 5
Pawpaw Beds	

Section of the Main Street on Little Mineral Creek, 500 Feet South of the Bridge on the Locust Road, One Mile South of Fink, Grayson County, Texas

	Ft.	In.
Main Street Limestone:		
Alternating beds of hard, massive, yellowish limestone, 4 to 6 inches thick, and brownish shaly limestone, 3 to 8 inches thick, containing *E. arietina* and *E. plexa* and *Pectens*	4	5
Hard, blue, slightly argillaceous limestone approaching a shell breccia and containing *E. arietina* and *E. plexa*	1	6
Massive, yellow limestone containing an abundance of *K. wacoensis*	2	2
Limestone, yellow, argillaceous, containing fucoids, *K. wacoensis*, *E. plexa*, *E. arietina*, and *Pectens*	0	6
Limestone, blue, massive	0	8
Limestone, bluish-brown, argillaceous, containing *E. arietina*, *E. plexa*, *O. quadriplicata*	0	3
Alternating beds of laminated yellow limy shale and yellow limestone, containing *E. plexa*, *E. arietina*, *O. quadriplicata*	1	10
Limestone, highly fossiliferous, approaching a shell breccia, containing fossils similar to ones listed above, poorly preserved	0	9
Marl, soft, bluish-yellow, fossiliferous	0	5
Limestone, massive, yellow, containing iron stains, breaks in plates perpendicular to the bedding on weathering	1	3
Total	13	9

[48]*Op. Cit.*, p. 281.

Section of the Main Street Limestone on a Tributary of Little Mineral Creek, About One Mile South of Fink on Public Highway

	Ft.	In.
Grayson Marl		
Main Street Limestone:		
Massive limestone, containing iron stains	0	11
Marl, yellow	0	4
Limestone	0	5
Marl, yellow	0	5
Limestone, light brown	0	11
Limestone, hard, brown, coarse grained, surface honeycombed by weathering. Contains *E. plexa*, *E. arietina*, well preserved	0	8
Marl, brown, highly fossiliferous, containing same fossils as limestone bed below	0	4
Limestone, containing red, ferruginous stains on top, highly fossiliferous, containing *E. arietina* and *O. quadriplicata*	0	10
White limestone	1	4
Covered by water in creek	1	6
Total	7	10

The above sections show the variation in thickness of the Main Street, even in comparatively short distances. A very interesting section of the Main Street occurs on the public road just to the east of Cedar Mills, on the west bank of Sandy Creek, a tributary to Mineral Creek. At this location the Main Street does not exceed five feet in thickness and is overlain directly by the Woodbine sand. This will be further discussed in connection with the Grayson marl. Excellent exposures of the Main Street may be seen in the western edge of the city of Denison; on the bluff on the east bank of Pawpaw Creek, one mile east of Denison; and for several miles along the public highway west of Fink, where the road follows the outcrop.

The Main Street forms a well-defined band, easily traced, trending in a general northwesterly direction across the northern side of Grayson County. It is an excellent horizon for structural work.

GRAYSON MARL

The Grayson marl is the uppermost formation of the Comanche series in this region. The type exposure of the Grayson is in an abandoned cut of an old unused railroad grade in the southeastern portion of Denison, Texas, discovered by Cragin, who named the formation. The Grayson marl consists of light-colored fossiliferous clays or marls with many small lumps and thin bands of lime and limestone nodules, having a total thickness of approximately twenty-five feet.

The Grayson rests immediately upon the Main Street, and in fact its contact with the Main Street is sometimes rather difficult to establish definitely, as the contact is rather a gradation from the limestone into a marl. The upper contact of the Grayson, or the Grayson-Woodbine contact, is usually covered by ferruginous sandstone and other debris from the overlying Woodbine sand. Indeed, in very few places can a clear-cut Grayson-Woodbine sand contact be seen, and for this reason the question of the conformity of the Grayson and Woodbine has long been a matter of dispute. In many places the outcrop of the Grayson is entirely covered by debris from the Woodbine.

The lower part of the Grayson contains an abundance of *Exogyra arietina* Roemer. Other fossils characteristic of the Grayson and found in abundance are: *Gryphea mucronata* Gabb and *Turrilites brazoensis* Roemer.

The contact of the Grayson-Woodbine is exceptionally well shown in the following complete section of the Grayson marl as exposed on Pawpaw Creek in the northwestern portion of Grayson County. This is the best exposure of Grayson known to the writer in the county.

Section of the Grayson Marl and Basal Woodbine Sand on Pawpaw Branch, Three Miles East of Stillhouse Ferry, Northwestern Grayson County, Texas

	Ft.	In.
Woodbine Sand:		
Soil		
Sandstone, reddish-yellow	3	0
Sandstone, yellowish	3	0

	Ft.	In.
Woodbine Sand:		
Sand, pack, fine grayish-white	2	0
Clay, bluish-gray arenaceous	11	3
Sand, fine white pack	7	10
Blue-gray marly clay, grading into black bituminous clay, then into yellow sandy clay (this zone represents a gradation from Grayson into Woodbine)	8	5
Grayson Marl:		
Limestone, white, soft	0	4
Clay, marly, bluish-gray	6	8
Limestone, nodular	0	10
Marl, bluish-gray	3	10
Limestone, nodular	0	8
Marl, bluish-gray, limy, nodular	7	8
Two beds of marly clay separated by a bed of bluish clay	3	10
Blue to gray clay marl filled with limestone nodules containing two rather prominent six-inch beds of impure nodular limestone containing *Turrilites* sp., *Sphenodiscus* sp., *Holectypus* sp., *Nautilus* sp.	3	0
Total Woodbine	35	6
Total Grayson	26	10

In the above section there seems to be rather perfect gradation from the typical Grayson marl into the Woodbine sand. Evidence of a sudden break or change is, however, contained in the rather abrupt change from limestone to a bituminous clay and the gradation of this clay into typical Woodbine sand, all in a very few feet. The question of the relation of the Comanche series and Gulf series has long been discussed. Most writers have agreed that the relation is probably one of unconformity, but the word unconformity is usually written with a question-mark following. The contact between the Grayson marl and the Woodbine sand is, of course, the contact in question. Possibly a reason for uncertainty on this point is the absence of clear-cut contacts between these formations, due to the debris from the Woodbine covering the contact zone. A very interesting area which throws some light on this problem is in the vicinity of Cedar Mills. Sandy Creek, a small tributary to Mineral Creek, flows just to the north and east of Cedar Mills, and is crossed by the public highway a short distance north and also a short distance east of Cedar Mills. At the point to the north of Cedar Mills where the highway crosses the creek there is a good exposure of Main Street limestone, and immediately overlying is the Woodbine sand, with the Grayson marl entirely missing. Furthermore, the Main Street limestone is less than seven feet in thickness. At the crossing of the same creek on the public highway east of Cedar Mills another outcrop of Main Street, followed by the Woodbine with the Grayson missing, was noted. At this latter place several feet of coarse conglomeratic ferruginous sand and sandy clay occur at the base of the Woodbine.

About one-half mile upstream from Cedar Mills on Sandy Creek excellent exposures of the Grayson are found, and here it appears to have its normal thickness. However, the upper contact of the Grayson is somewhat irregular, and its contact with the Woodbine, instead of being a straight sharp line, is a wavy surface.

There is without doubt excellent evidence in favor of a nonconformity between the Grayson and Woodbine at the Cedar Mills locality. However, at the Pawpaw Creek locality, section of which is given above, there is no evidence, which, however, does not preclude the possibility of a break between these formations. It is believed that a widespread nonconformity separates the Grayson and Woodbine, or the Comanche series and the Gulf series. Abundant evidence supporting this view is found in the general region to the east of Grayson County, as illustrated by the condition in Southwestern Arkansas, where the Gulf series rests on the basal portion of the Comanche series or on the Trinity sand. It is believed that a nonconformity separates the Grayson marl and the Woodbine sand in Grayson County, but the area was not distinctly above sea level, or for only short periods, and the break is not clearly recorded.

Section of the Grayson Marl and Basal Woodbine Sand on the Public Highway at the Crossing of a Tributary of Little Mineral Creek About One Mile South of Fink, Grayson County, Texas

	Ft.	In.
Woodbine Sand		
Sandstone, massive fine grained, light gray at base grading into yellow sand at the top	11	3
Clay, sandy, light gray grading upward into a purple clay	1	6
Sandstone, fine grained, white	2	7
Clay, yellowish-brown grading into a sandy clay	4	6
Sandy clay, hard, fine grained white	3	10
Yellow sandy clay containing beds of alternating red and yellow sandstone about 2 inches in thickness. The lower of these beds is made up principally of steel-gray limonite	4	1
Grayson Marl:		
Marl, light gray, grading into thinly laminated beds of gray clay and thin veins of red and yellow iron oxide. Very few fossils	8	2
Clay marl, blue-gray, containing thin beds of nodular limestone and an abundance of *Gryphea mucronata* Gabb	7	0
Marl, containing thin beds of nodular limestone	5	5
Limestone, chalky, shaly, nodular, containing *Turrilites brazoensis* Roemer, *Pecten* sp.	1	0
Clay marl, gray	4	1
Clay marl grading into shaly limestone at the top	2	2
Clay marl, light yellow to white, containing *Turrilites brazoensis* and *Exogyra arietina*	1	3
Total Woodbine	27	9
Total Grayson	29	1

A section of the Grayson was measured at the railroad cut on the Missouri, Kansas, and Texas Railroad freight cut-off about two miles east of Pottsboro and a thickness of a little over eighteen feet noted.

The Grayson is easily recognized by the lime nodules and characteristic fossils which it contains in abundance.

GULF SERIES

As has been stated in the Introduction, the Cretaceous rocks are divided into two great divisions, the Comanche series forming the lower part and the Gulf series the upper part of the system. The relation of these major divisions has been discussed in connection with the Grayson marl and it was shown that the Gulf series overlies the Comanche series disconformably. The disconformity is only slightly developed in Grayson county, but becomes more marked to the eastward.

The Gulf series in North Texas is divided into the following formations:

Gulf series	Navarro formation
	Taylor marl
	Austin chalk
	Eagle Ford shale
	Woodbine sand

Only the three basal formations listed above are present in Grayson County. Following is a brief description of the formations exposed in Grayson County:

WOODBINE SAND

The Woodbine sand, named from the village of Woodbine, in eastern Cooke County, Texas, is the basal formation of the Gulf series in North Texas. It is a highly variable formation consisting of strongly cross-bedded, more or less ferruginous sands, and laminated shaly clays, with some interbedded layers of lignite and bituminous clay. On account of the highly cross-bedded nature of the formation, it is extremely difficult to estimate the thickness from surface outcrops, but according to Stephenson[49] "it is reasonably certain that in Grayson County the thickness is not less than 300 to 400 feet and may be as great as 500 feet."

Hill recognized two subdivisions of the Woodbine—a lower member called by him the Dexter sands, consisting "of brown and yellow ferruginous sandstone heavily laden with siliceous ironstone" with an estimated thickness of 160 feet, and an upper member, called by him the Lewisville beds, consisting of 150 feet or more of "laminated, lignitic sands and sandy clays, interstratified with brown sands,

[49]U. S. Geol. Survey, Prof. Paper 120, p. 145, 1918.

ferruginous reddish-brown sandstone, shell sandstone, and argillaceous shelly sandstone which contains large lens-like calcareous concretions and laminated argillaceous sandstone at the top." Hill's[50] description of the Woodbine sand is as follows:

> The rocks of the Woodbine formation are largely made up of ferruginous, argillaceous sands, characterized by intense brownish discoloration in places, which are accompanied by bituminous laminated clays. These sands, like those of the Trinity division (Western Cross Timbers), are unconsolidated in places, but differ from them by containing a greater proportion of iron and other mineral salts, which materially influence the character of the waters derived from them. The sands, which in the unoxidized substructure are usually white and friable, contain particles of iron occurring as glauconite and pyrite. These minerals oxidize toward the superfacies, and their solutions consolidate the more porus beds of sand into dark brown siliceous iron ore, occurring in immense quantities in certain localities. Other beds of sand break down into deep, loose soils. These support a vigorous timber growth and are especially adapted to fruit culture. The clays are usually sandy and sometime bituminous, although in some places, as near Denton, of sufficient purity for making stoneware. They occur either as extensive beds or as laminae and thin strata interbedded in the sands.
>
> The presence of fossil vegetation, such as leaf impressions and lignite, distinguishes the beds of this division from the other formations of the upper Cretaceous and attests its shallow-water littoral origin.

Sand seems to predominate throughout the Woodbine, and it weathers in a typical sand-hill type of topography which is well illustrated in the area adjacent to Denison. However, locally it appears that clay predominates, and on weathering it produces a rolling prairie topography as illustrated in the vicinity of Pottsboro. The iron veins and segregations mentioned as occurring especially in the lower half of the Woodbine concentrate on the hill tops, due to the removal of the soft friable sand. Many of the hills are protected by a capping of this siliceous iron material.

Due to the variable character of the Woodbine, it would be impossible to give a section which would apply to a very

[50]U. S. Geol. Survey 21st Ann. Rept., pt. 7, p. 294, 1901.

large area. The following section, however, will give a good idea as to the character of the individual beds in the lower part of the Woodbine. Due to the extreme cross-bedding at the locality where the following section was taken, there is danger that the thicknesses are slightly in error. However, it is the most complete section available, and for that reason is given.

Section of the Lower Portion of the Woodbine Sand in Railroad Cut of Missouri, Kansas, and Texas Freight Cut-Off Near Pottsboro, About Four Miles West of Denison, Grayson County, Texas

Woodbine Sand:	Ft.	In.
Yellowish-brown, mottled arenaceous clay	10	0
Yellowish-blue-gray sandy clay somewhat more arenaceous than the lower bed, grading upward into a soft yellowish-brown sandstone above which is a fine, soft, yellowish sand containing numerous iron concretions	41	7
Yellowish-blue-gray sandy clay containing masses and concretions of limonite which form several well defined layers near the top. The top of the bed is marked by a ferruginous shell bed 4 inches in thickness containing numerous pelecypods and gastropods	62	3
Sandy clay containing beds of soft ferruginous sandstones ranging in thickness from 2 to 4 inches	12	6
Soft red to brown sandstone	2	0
Series of alternating beds of red sandstone ranging from 2 inches to 18 inches in thickness separated by thin beds of sandy gray shale averaging about 2 inches in thickness. The sandstone beds are prominent in the lower part, while in the upper part the shale beds become thicker. Contains throughout veins and masses of impure limonite	22	8
Sandstone, cross-bedded, lenticular, white to red, containing thin veins, bands, and segregations of impure limonite	8	5
Sandy clay, light buff alternating with a gray sandy clay	7	10
Sandstone, cross-bedded, massive, yellowish-brown at base grading into a light yellow at top. Contains thin beds of ferruginous sand in the basal portion	14	5
Massive grayish-white sandstone with more or less irregular contact on upper surface	3	4

Woodbine Sand:	Ft.	In.
Clay, yellowish-brown at base grading upward into a light yellow	13	10
Clay, yellow at base grading upward through blue to a somewhat impure mottled reddish-brown at top	15	1
Massive gray sandstone, irregularly bedded containing at the base a thin bed of ferruginous sandy clay	11	6
Sandy clay, ferruginous, with thin layers of dark black to blue impure limonite with metallic luster	1	3
Lead-colored clay containing bands of light yellow and red clay grading upward into a series of alternating beds of brown and light gray sandy clay	5	5
Yellow to brown clay grading upward into thinly laminated blue to gray clay shale containing bands of black carbonaceous material and red iron oxide	10	11
Grayson Marl		
Total	243	0

No definite horizons have been recognized in the Woodbine, but as a general rule the base contains a bed of black bituminous clay or shale ranging from a few inches to several feet in thickness. However, this is not always present, as several sections have been noted where the basal Woodbine consists of massive pack sand. It has also been noted that as a general rule the zone which contains the segregations of iron in greatest abundance, and which is the one usually recognized, occurs approximately 140 feet above the base of the Woodbine. This cannot be checked at all localities, but was noted at several places to be approximately correct.

The relation of the Woodbine to the underlying Comanche series has been discussed in connection with the Grayson marl. The Woodbine apparently rests unconformably on the underlying Grayson marl. In this connection Stephenson[51] says:

> The nature of the contact separating the Gulf series from the underlying Comanche series has not been satisfactorily determined in northeastern Texas. Probably it is that of unconformity, the basal member of the upper series, the Woodbine sand, having been deposited in shallow waters of the trans-

[51]*Op. Cit.*, p. 144.

gressing sea, in the deeper waters of which the succeeding truly marine sediments of the series were laid down.

Fossil leaves were obtained from the lower portion of the Woodbine on the public highway, about five miles south of Denison, near Iron Ore Creek. A rather extensive collection of plants has been made from Arthur's Bluff, on Red River fifteen miles north of Paris, Lamar County, Texas, which has been described by Berry.[52] The upper portion of the Woodbine yields a peculiar shallow-water marine fauna best known from exposures on Timber Creek, near Lewisville, Denton County, Texas. This fossiliferous horizon can be recognized in Grayson County, but is very poorly developed as compared with the exposures near Lewisville.

The Woodbine outcrop covers a much more extensive area in Grayson County than any of the formations of the Comanche series. Its outcrop forms a broad belt ranging from two to five miles in width extending along the northern side of Grayson County, and then as it nears the western border swinging southward and forming a belt from four to five miles in width along the western boundary of the county. The big bend in the outcrop is caused by a broad shallow syncline, the Sherman syncline, which is described under Structure.

Several beds of a very impure and poor grade of lignite outcrop in the vicinity of Redbranch, in the western part of Grayson County. The lignite at these outcrops is of such an inferior quality as to be of no value as a fuel supply.

EAGLE FORD SHALE

The Woodbine sand is overlain by the Eagle Ford shale named by Hill from Eagle Ford, a small village six miles west of Dallas. The writer has not studied this formation in as much detail as the preceding formations, but in order to make this report as complete as possible a summary of the work of Stephenson and Hill is given, supplemented by

---

[52]Berry, E. W., U. S. Geol. Survey Prof. Paper 129, pp. 153–181, 1922.

the data obtained by the writer. The following information is taken chiefly from Stephenson's[53] work.

The Eagle Ford consists chiefly of dark bluish-gray to nearly black shaly clay, which is as a rule gypsiferous and more or less bituminous; in places crystals of selenite weather from the clay in great numbers. In Grayson County the formation has an estimated thickness of 300 to 400 feet. Thin platy layers of sandstone and sandy limestone, some bearing the imprints of small costate and keeled ammonites, occur in the formation, particularly in the central portion. Flattish calcareous nodules occur in the lower part of the formation, and oval to spherical hard limestone septaria are characteristic of the upper part. In the upper twenty to twenty-five feet of the formation in the vicinity of Sherman the dark clays are interstratified with beds of sand, one of which, fifteen to twenty feet below the base of the Austin chalk, carries vast numbers of a small fluted oyster, *Ostrea lugubris* Conrad. Ten feet below the base of the Austin chalk, in Grayson County, is a conglomeratic layer of gray sandstone, carrying numerous more or less rounded phosphatic pebbles, shells of *Ostrea alifera* Cragin, and fish teeth, of which shark teeth are common. This is the "fish-bed conglomerate" of Taff, which, according to Stephenson, should be regarded as the base of the Austin chalk, rather than part of the Eagle Ford shale.

Section of the Upper Part of Eagle Ford Shale Between the Base of "Fish-Bed Conglomerate" and Base of Austin Chalk on the West Sherman-Denison Highway About Five Miles North of Sherman

	Ft.	In.
Austin Chalk—Exposed on top of hill		
Eagle Ford Shale:		
Light blue to yellow clay with thin veins of ferruginous clay, grading into light yellow marl containing veins of chalk in upper 5 feet	18	3
Sand, dark, ferruginous and argillaceous, containing concretions of calcite with small pebbles forming the nucleus of the concretions. Weathers to a dark greenish color	3	3

[53]U. S. Geol. Survey Prof. Paper 120, 1918.

Eagle Ford Shale:	Ft.	In.
Shell breccia, arenaceous, and cemented with calcium carbonate, containing fucoids throughout and *Ostrea lugubris*, *Ostrea* sp.	1	0
Sand, soft, argillaceous and ferruginous, interstratified with thin layers of ferruginous clay. The color of this bed ranges from light yellow to brown, and on weathering assumes a dark greenish color	2	6
Shell breccia, slightly arenaceous, cemented with calcium carbonate, containing *Ostrea lugubris* and *Ostrea* sp.	2	0
Total	27	0

Hill[54] gives the following section of the upper part of the Eagle Ford shale:

Section at Sherman, Grayson County, Texas, Two Miles West of Binkley House

Austin Chalk		
Eagle Ford Shale:	Ft.	In.
Sandy clay shales with *O. lugubris*	10	0
Thin slabs of brown sandstone with small rounded conglomerate of jasper pebbles, *O. lugubris*, and fish teeth	5	0
Blue laminated clay weathering into limonitic colors	10	0
Massive agglomerate of *O. lugubris*	2	0
Sandy clay shale in thin alternations of clay and sand; clay efflorescent and drab colored on drying	40	0
Blue clays with gigantic septaria		
Total	67	0

Hill's[55] general description of the Eagle Ford in this area is as follows:

In the counties of Dallas, Collin, and Grayson, where the beds have their greatest development, near Sherman, they show the following sequence: The lower portion is made up of very thin laminations of deep blue or black clays with occasional laminae of sand, passing upward into purer clays locally containing irregular bands of thin calcareous matter and ferruginous clay nodules. This clay is usually highly indurated and of a laminated

[54] *Op. Cit.*, p. 326.
[55] *Op. Cit.*, p. 324–325.

character. It is generally largely intermixed with selenite which is disseminated through it in the form of minute lenticular crystals. Sometimes the gypsum is so abundant as to constitute a fourth or fifth of its bulk, and consequently the water flowing through this formation is generally bitter and disagreeable. In a few instances thin seams of selenite have been detected traversing the clay horizontally, and in others the clay appears reticulated with the selenite. Small septaria composed of hard, compact, blue argillaceous limestone are also sometimes met with in the lower bed. The only limestone element of the lower part of the formation occurs in the nodules or segregations embedded in the clay. These are generally flattened, from 1 to 2 inches thick, and vary in width from a few inches to 1 to 2 feet. They are unusually hard, compact, and of an earthy texture. Externally they are of an iron rust color, but when broken exhibit various shades of blue and brown. These nodules usually occur in the clay in the form of distinct bands or layers, which are nearly horizontal. Sometimes several of these bands are seen in the same section.

In the central portion of the formation are a few persistent flaggy layers of a laminated arenaceous-argillaceous limestone, seldom over an inch in thickness and aggregating 10 feet, which weather into buff colors. Although in themselves not very durable, these are of sufficient relative hardness to produce a distinct escarpment and dip plain, which makes a conspicuous topographic feature, as seen west of Dallas, between that city and Eagle Ford. These layers are also exposed in Grayson County, near the source of Mustang Creek, in northern Denton County, and west of Hillsboro in Hill County, and are apparently the base of the beds which in the southward extension constitute the prevalent material of the Eagle Ford formation.

Succeeding these medial arenaceous layers are considerable thicknesses of the blue-black clays in which are numerous spherical septaria, some of which attain a diameter of three feet. These are composed interiorly of a dense blue limestone and are cracked in numerous directions by cross fissures which are filled with crystals of calcite and selenite. This portion of the section contains beautifully preserved fossils with a nacreous coating, including many ammonites, such as *Buchiceras swallovi, Placenticeras,* etc.

In the upper portions of these clays and about 50 feet below the summit of the formation in the Dallas-Sherman sections there are other calcareous and flaggy sheets containing numerous remains of fish teeth, *Inoceramus* sp., and *Ostrea lugubris* Conrad. These flaggy, arenaceous layers increase in general thickness and in percentage of sand in their northward extension, having a thickness of 10 or 15 feet in Grayson County, as seen in the western portion of the city of Sherman. Above this there are 10 or 20 feet more of the blue laminated shale.

According to Stephenson, the fossils most useful in the identification of the Eagle Ford are: *Ostrea lugubris* Conrad, *O. alifera* Cragin, fish teeth belonging to the species *Ptychodus whipplei* Marcou, *Inoceramus labiatus* Schlotheim, *I. fragilis* Hall and Meek, and small-keeled ammonites belonging to *Prionotropis* or *Prionocyclus,* or to both. Of these the first three occur only in the upper forty or fifty feet of the formation.

Excellent outcrops of the Eagle Ford occur in the vicinity of Bells, eastern Grayson County. Near Cook Springs, between Denison and Sherman, the lower part is particularly well exposed and was formerly used in the manufacture of brick at that place. The upper part of the Eagle Ford is well exposed in the western edge of the city of Sherman along the banks of Sand Creek.

The outcrop of the Eagle Ford shale forms a rolling prairie, and only locally, as near Bells, do the sandy layers become prominent enough to produce a sand-hill topography. The Eagle Ford weathers very readily, forming a black waxy soil.

AUSTIN CHALK

With the exception of recent stream deposits, the Austin chalk represents the youngest formation exposed in Grayson County. It immediately overlies the Eagle Ford shale and according to Stephenson reaches a thickness of approximately 1,000 feet in this region. The type area of the Austin chalk is at Austin, Travis County, Texas, where, according to Hill, it has a thickness of 410 feet. It consists of white chalky limestone in beds of varying thickness, with interbedded marly layers especially in the upper part. However, in Grayson County the Austin chalk, while possessing many of the characteristics of the Austin chalk of Travis County, has in many respects assumed new features. It is much thicker and contains, in addition to the typical chalky limestone, interbedded layers of marl and argillaceous clay.

Some of the fossils commonly found and characteristic of the Austin chalk are:

Inoceramus undulato-plicatus Roemer
Ostrea aff. diluviana Lamarck (uppermost part)
Gryphea aucella Roemer
Exogyra ponderosa Roemer (upper half)
Radiolites austinensis Roemer
Mortoniceras texanus Roemer

The Austin chalk usually outcrops in a bluff or escarpment overlooking a broad plain or prairie formed by the Eagle Ford shale. The outcrop of the Austin chalk was referred to by Hill as the "white rock escarpment." The Austin chalk weathers readily, forming a black sticky soil very similar to that formed by the Eagle Ford shale. The outcrop of the Austin chalk is confined to the southeastern portion of Grayson County.

STRUCTURE

The Cretaceous formations of Grayson County were deposited on the eroded surface of Paleozoic rocks,[56] with depositional slope or initial dip of from thirty to eighty feet per mile to the south and east. The general monoclinal dip of the Cretaceous strata is interrupted in Grayson County by two rather prominent folds, the Preston anticline and the Sherman syncline.

THE PRESTON ANTICLINE

This large anticlinal fold is one of the most important structural features of North Texas. A structural contour map of the Preston anticline was published[57] in 1922. The fold begins in northern Marshall County, Oklahoma, and extends in a southeasterly direction, passing near Preston and just to the north of Denison. As outlined on Figure 4, it is a broad plunging arch representing an upthrust of

[56]Pre-Cretaceous Rocks Found in Wells in the Part of the Gulf Coastal Plain South of the Ouachita Mountains by Hugh D. Miser and E. H. Sellards. Bull. Amer. Assoc. Petr. Geol. (in press).

[57]Hopkins, O. B., Powers, Sidney, Robinson, H. M., Structure of the Madill-Denison area, Okla. and Texas, with notes on Oil and Gas development: U. S. Geol. Sur. Bull. 736, pp. 1–34, 1922.

some 700 or 800 feet, the crest of the fold being located in southern Marshall County, Oklahoma, about eight miles northwest of Fink. From the crest the anticline plunges rather rapidly to the southeast until it finally disappears in the vicinity of Gober, Fannin County, Texas. The Preston anticline has a total length of approximately forty miles and an average width of about ten miles.

The axis of the Preston anticline enters Grayson County from the northwest, crossing Preston Bend, passing near Rock Bluff, continues on to the southeast, past the city waterworks plant on Shawnee Creek, and then becomes rather indistinct a few miles to the east of Denison. In the Preston Bend area the axis of the fold is marked by a belt of Trinity sand between outcrops of the Goodland limestone. At the city waterworks plant of the city of Denison, on Shawnee Creek, an inlier of Goodland limestone, just below the bridge on the public highway, marks the crest of the anticline at that place.

The dip of the formations away from the axis of the Preston anticline varies from a few feet per mile to more than 300 feet per mile. In general, the south limb of the fold is steeper than the north limb. The steepest part of the fold is on the south limb just to the northeast of Pottsboro. The steep dip is first noticed in the railroad cut of the Missouri, Kansas, and Texas freight cut-off near Pottsboro. Here the beds, particularly the Main Street limestone, are dipping at an angle of approximately 14 degrees. Traced northwestward from this point, the Main Street forms a well-defined ridge, or a semi-hogback, extending for a distance of approximately two miles, the dip becoming much less in the vicinity of Fink. The pronounced narrowing of the width of the outcrop of the Woodbine sand in this area, due to the steep dip, is perhaps the basis for the so-called Cook Springs fault postulated by Taff and Leverett, and also by Hill.

The south limb of the Preston anticline is not a smooth regular dip to the southeast, but, on the contrary, it contains many irregularities, such as flattening, terraces,

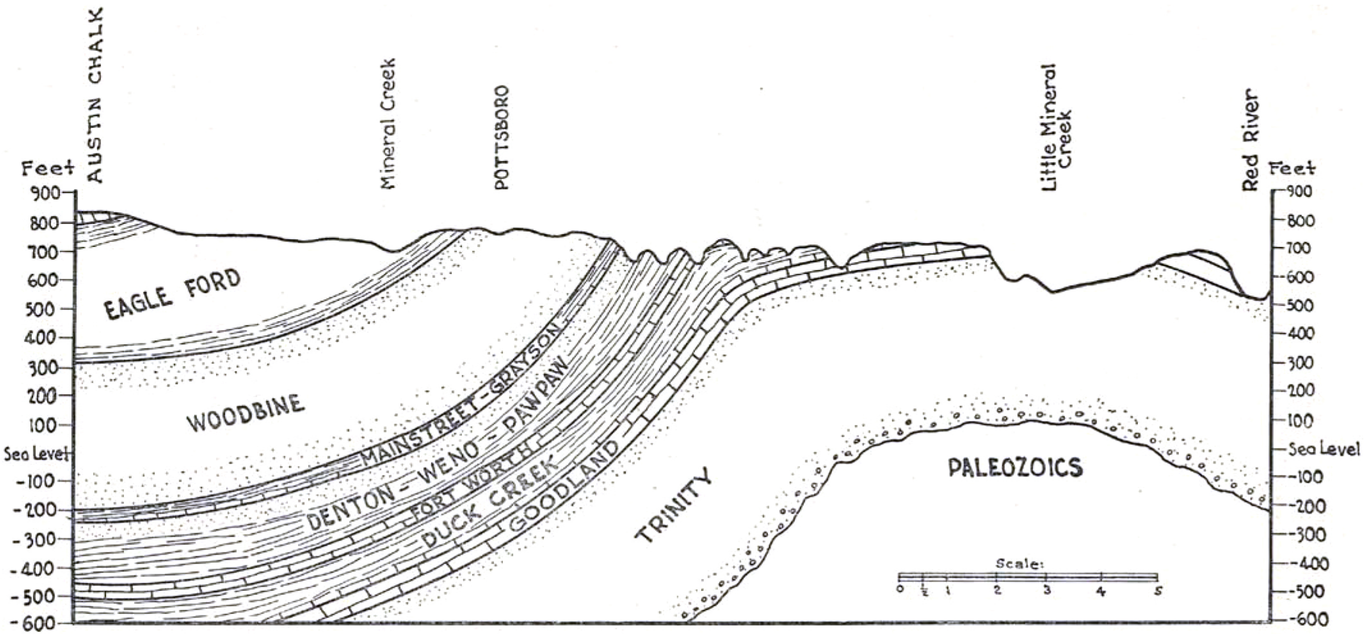

FIG. 2. Structure section across the Preston Anticline from a point on Red River, one mile northeast of Preston, southward through Pottsboro.

noses, and on the whole, is most irregular. No attempt has been made to include these small irregularities on the structural contour map, but in detailing this structure it was noted that many such features are present. One of the most prominent of these variations is found northeast of Pottsboro, where a rather distinct nose occurs. A detailed map of this nose shows a small amount of closure. It is on this structure that the Pottsboro gas field, the only oil and gas-producing area in Grayson County, is located.

Traced northwestward into Oklahoma, the axis of the Preston anticline is observed to coincide with that of the Criner Hills. It is believed that the Criner Hills represent a portion of the Preston anticline in which the Cretaceous covering has been removed by erosion, exposing the core of ancient Paleozoic rocks.

The Preston anticline has brought to the surface the Comanche series of formations, which normally would be buried beneath the overlapping Gulf series. However, the uplift of approximately 800 feet has caused erosion to remove not only the Gulf series but the underlying Comanche series from a considerable area along the axis of the uplift. The outcrop of the formations of the Comanche series parallel the sides of the anticline and wrap about its eastward plunging nose in a typical fashion. The strike of all the Comanchean formations in Grayson County has been deflected considerably to the southeast, due to this broad uplift. The axis of the Preston anticline conforms in direction to that of the Criner Hills and the Arbuckle Mountains, and it is very probable that the folding of the Cretaceous beds was merely incident to later movement along this previous line of folding.

THE SHERMAN SYNCLINE

To the south of the Preston anticline, and with its general trend parallel to it, is the Sherman syncline, a broad shallow trough with a steep slope on the north side and a very broad open slope on the south. This asymmetrical syncline was named the Sherman syncline because the

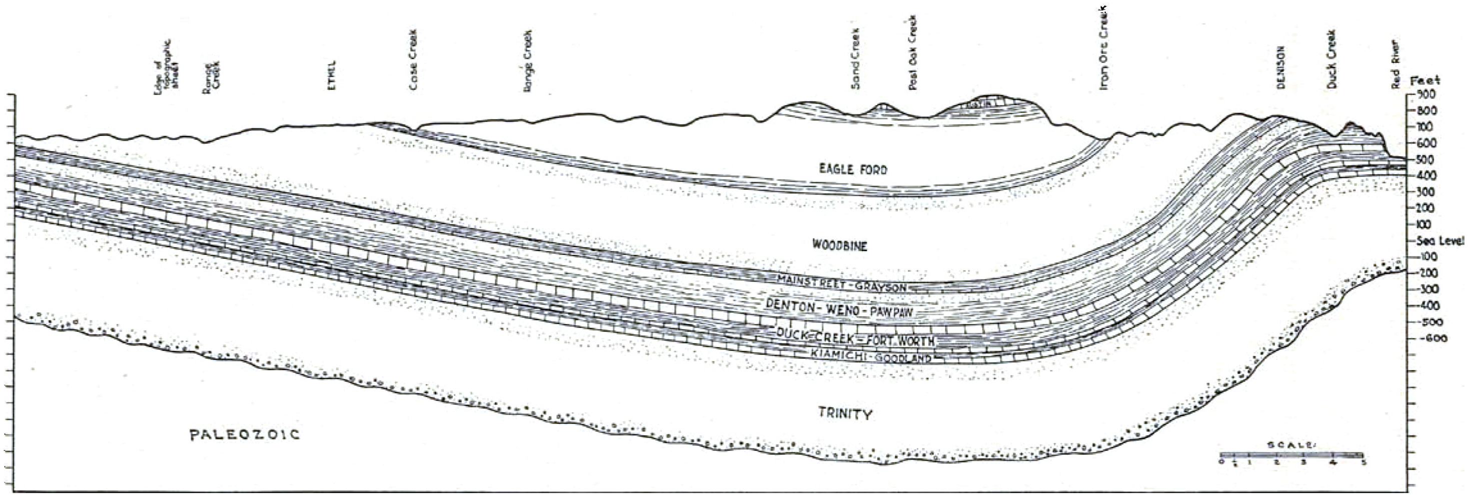

FIG. 3. Structure section across Grayson County on a line through Denison and Ethel.

trough of the syncline passes through the city of Sherman. It is believed that the Sherman syncline is continuous with the Marietta syncline in Love County, Oklahoma.

It would be expected that other anticlines and synclines would be present to the south of the Sherman syncline, but the character of the surface rocks makes their detection very difficult. The surface is covered by the outcrop of the Austin chalk and the difficulty in locating horizons in this formation makes detailed structural work very difficult. To the north of the Preston anticline, in Marshall County, Oklahoma, there is a series of anticlines and synclines which are located on the general structural map (Fig. 4).

No faulting of any magnitude was observed in Grayson County. Some small faults having a throw of six inches to one foot were observed in the Eagle Ford shale north of Gordonville, but these were probably due to a settling of the sediments.

THE POTTSBORO GAS FIELD

This field is located about six miles west of Denison and about two miles northeast of Pottsboro, and, as previously stated, is on a structural nose on the south limb of the Preston anticline.[58] The gas-producing horizon occurs at depths ranging from 880 to 900 feet and is at or near the base of the Trinity sand, which makes an unconformable contact with the underlying Paleozoic rocks. At the present time (January, 1931) there are two wells producing oil in this field; namely, the Sherman Oil Company Nos. 1 and 2 R. C. Dalton, on the James Ingram Survey. The production is obtained from a depth of 921 to 933 feet and the oil has a gravity of 25 degrees Baumé. The producing horizon is highly clastic, erratic, and lenticular, and is believed to represent approximately the unconformable contact at the base of the Trinity sand.

---

[58]The writer is indebted to Mr. J. B. Lovejoy, of the Gulf Production Company, for the information on the Pottsboro field and the statement in regard to the test near Tioga.

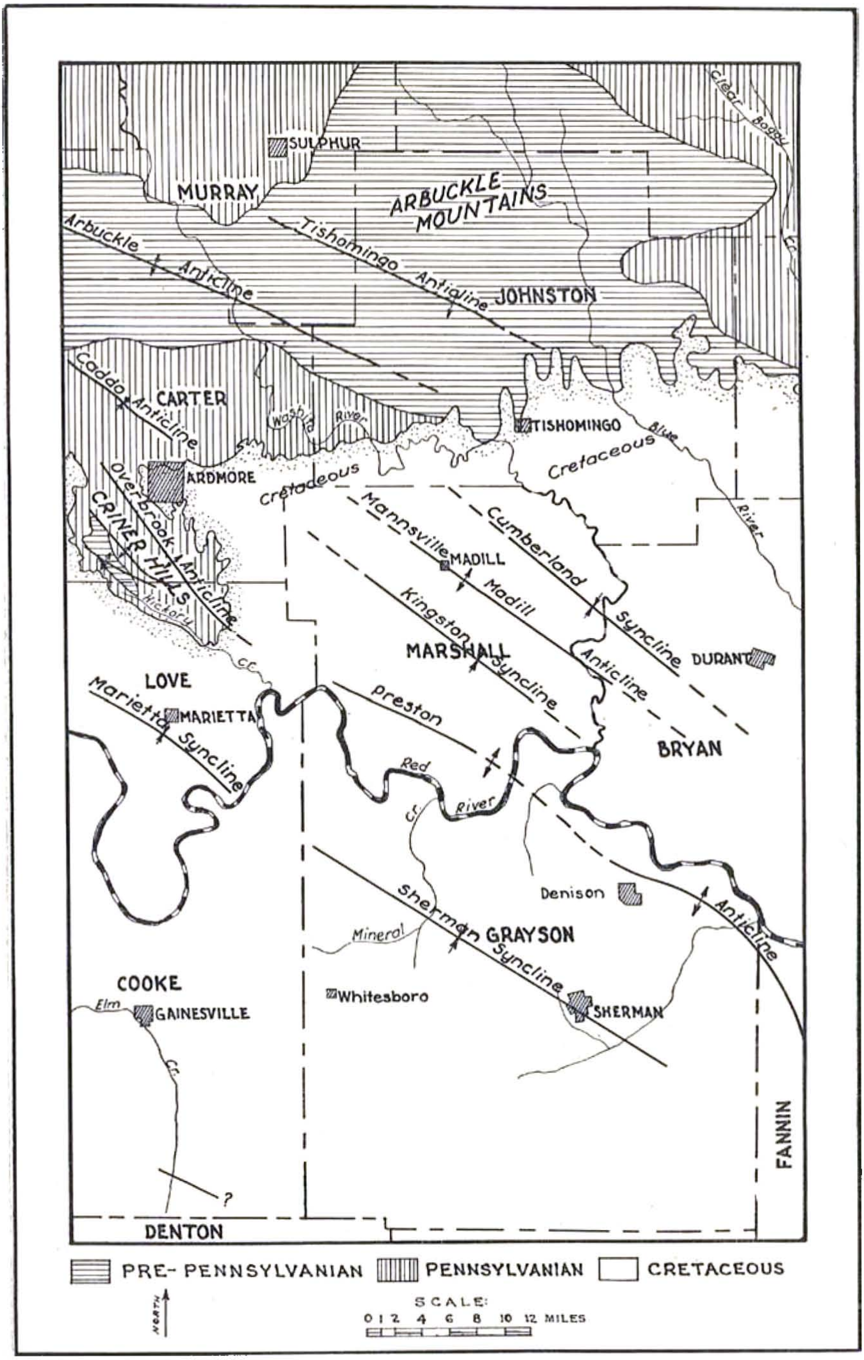

FIG. 4. Map showing axes of principal folds in Grayson County and adjacent areas.

The following table shows the several wells in the field, the depth, amount of production, and other information:

Company		Farm	Depth	Initial Prod	Pay	Survey
Sherman Oil No.	1	R. C. Dalton	892′	9 MCFG	882–92′	Jas. Ingram
			DD– 924½′	27 bbls. oil	921–24½′	
	2	"	899′	3 MCFG	897–99′	"
			DD– 933′	33 bbls. oil	931–33′	
Simpson-Fell	1	H. Guilloud, Sr...	900′	11,200,000 CFG (305# RP)	887–900′	"
Murchison Oil	1	G. W. Wall.... ..	903′	6–1/5 MCFG (305# RP)	880–903′	"
	3	"	897′	2 MCFG (est)	891–97′	G. R. Greeves
Simpson-Fell	1	G. W. Wall..	2515′ PB–1294′	2 MCFG	849–50′ 887–88′ 919–21′ 1160–62′ 1191–94′	"
	3	"	881′	4,207,000 CFG	870–81′	"

The subsurface conditions in the Pottsboro field are not well known. Most of the wells have not been drilled deep enough to give satisfactory control on the older formations. Between two wells drilled by Simpson and Fell, Nos. 1 and 2 G. C. Wall, located due east and west of each other and 500 feet apart, a west dip of 470 feet is noted. Whether this is due to faulting or to sharp folding is not known.

It is interesting to compare the gravity of the oil found at Pottsboro with that of the Madill pool in Marshall County, Oklahoma. The Madill pool is approximately thirty miles north of the Pottsboro field and produces from approximately the same stratigraphic horizon. The gravity of the Madill oil is 47.5 degrees Baumé while that at Pottsboro is 25.3 degrees Baumé. It seems likely that the oil of the Pottsboro field, as well as that of the Madill pool, is not indigenous to the Cretaceous, but has migrated from some of the underlying formations.

No attempt is made to list the various tests which have been drilled in Grayson County. However, a test drilled by the Texas Company, No. 1 G. W. Cannon, S. A. & M. G. Survey, A-1142, near Tioga, southwestern Grayson County, encountered a slight showing of oil near the base of the Cretaceous at a depth of 1,100 feet. Several showings of oil were reported at the following depths in the Paleozoic: 2,556–2,601 feet, 2,602–06 feet, 2,666–73 feet, and 2,793–2,800 feet. No surface folds are in evidence in this area and the subsurface control is too limited for definite mapping.

INDEX