A CONTRIBUTION TO THE GEOLOGY OF NORTHEASTERN TEXAS AND SOUTHERN OKLAHOMA.

By Lloyd William Stephenson.

PURPOSE AND SCOPE OF THE PAPER.

The region in central and northeastern Texas and southern Oklahoma known as the Black and Grand prairies abounds in features of interest to physiographers, geologists, and paleontologists, and the pioneer investigators of this region must have experienced renewed satisfaction in each day's exploration. The reports of Joseph A. Taff, Robert T. Hill, and others, published chiefly under the auspices of State and Federal surveys, represent with approximate accuracy at most places the general distribution of the outcrops of the formations in this region, and contain detailed descriptions of many sections that constitute a mine of useful information. The reader of the present paper is urged, therefore, to hold as most important the general excellence of the earlier reports of these authors and to relegate the inaccuracies and mistakes to which his attention will be called to the relatively unimportant place in which they belong, remembering at the same time that a future generation of investigators may find our own shortcomings as great as those we now criticize.

The present report treats of the area shown in Plate XVII, which includes Grayson, Fannin, Lamar, Delta, Hunt, and Collin counties, Tex., and the southern parts of Marshall and Bryan counties, Okla. It is based on the results of studies carried on during several brief field seasons between the years 1911 and 1917, inclusive. The results are by no means final, but enough facts have been obtained to justify their presentation to those who may be interested in the geology of the region. The purpose of the paper is therefore to set forth the present state of knowledge in the areal mapping, in the interpretation of structure, and in correlation, and to indicate certain mappable units and structural features that have not heretofore been recognized.

A comparison of Hill's geologic map published in 1901 [1] with the map accompanying the present paper reveals at once certain inaccuracies in his representation of the areal distribution of the Cretaceous formations which require no further comment. Another striking feature of his map consists of the two great parallel faults, the Cook Springs and Red River (or Preston) faults, which are shown as extending from Love and Marshall counties, southern Oklahoma, far to the southeast through Grayson, Fannin, and other counties in Texas. Between the faults is an uplifted block represented as bringing to the surface formations that ought normally to be far below the surface. The reported existence of these faults, although unverified, has been cited in explanation of certain structural phenomena even as far east as northern Louisiana and Vicksburg, Miss.[2] The Cook Springs fault was first described by Taff [3] in 1893. In the light of the facts presented on subsequent pages the basis for the postulation of these faults in Texas disappears.

In 1902 Taff [4] indicated the geographic continuity of the Austin chalk and Annona chalk, which Hill failed to recognize, but he did not realize the magnitude of the upward transgression of the chalk across the geologic column from south to north and east. Gordon [5] in 1911 mapped with approximate accuracy the distribution east of the ninety-sixth meridian of the major lithologic units below the Eocene, to

[1] Hill, R. T., Geography and geology of the Black and Grand prairies, Tex., with detailed descriptions of the Cretaceous formations and special reference to artesian waters: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pl. 66, 1901.

[2] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 68, 1906.

[3] Taff, J. A., Texas Geol. Survey Fourth Ann. Rept., pp. 297–298, 1893.

[4] Taff, J. A., Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 698–700, 1902.

[5] Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, pp. 21–25, pl. 1, 1911.

and including the Blossom sand, but he erred in correlating the Blossom sand with the Eagle Ford clay, and although he noted the geographic connection of the Annona chalk with the Austin he also failed to recognize the upward transgression of the chalk in its northeastward extension.

ACKNOWLEDGMENTS.

In 1911 the writer was accompanied by T. W. Stanton in a brief examination of parts of northeastern Texas, including the area in the longitude of Paris between the North Fork of Sulphur River and Red River, the vicinity of Cooper, Delta County, and the vicinity of Sherman, Grayson County. Subsequently he frequently conferred with Mr. Stanton in regard to the interpretation of the physical and paleontologic facts and has greatly benefited by his many helpful suggestions.

O. B. Hopkins, during a brief visit in 1915, determined the stratigraphic succession and attitude of the Upper Cretaceous rocks that appear at the surface in the vicinity of Wolfe City, Hunt County, and Gober, Fannin County, Tex. He stated his conclusions to the writer and indicated certain favorable localities for examining outcrops. The area was subsequently visited by the writer, who traced the several lithologic divisions both to the northeast and southwest of Wolfe City, as shown on Plate XVII. Mr. Hopkins also obtained by correspondence the logs of several wells in northeastern Texas and southern Oklahoma, which he generously placed at the writer's disposal.

In December, 1917, O. B. Hopkins and Sidney Powers accompanied the writer in a supplementary field study of the areas in Grayson, Fannin, and Hunt counties where the Cretaceous formations are involved in the Preston anticline and in the Leonard-Celeste monoclinal nose. The outcrops of key rocks were traced, and altitudes were determined at numerous points on them by means of aneroid readings. Messrs. Hopkins and Powers continued the determination of altitudes during the later part of December and the first half of January, 1918. H. M. Robinson had in 1917 made a series of similar altitude determinations on a part of the Preston uplift in southern Marshall County, Okla., locally known as the Enos anticline. The general results obtained by these three men are embodied in the structure contours shown as an overprint in red on the geologic map (Pl. XVII). A more detailed report of their results, with particular reference to the occurrence of oil and gas, will be published later as an economic bulletin.

Indebtedness is gratefully acknowledged to Mr. J. T. Bryant, of Pottsboro, Tex., for information and personal assistance that enabled the writer and his associates quickly and advantageously to find and study numerous important exposures in northern Grayson County, Tex., and southern Marshall County, Okla. Mr. Bryant also kindly contributed the logs of several wells on the Preston anticline.

Courtesies were also extended to the writer and to his associates by Messrs. R. H. Cook, of Denison; M. L. Wilson, of Wolfe City; and J. Balch Moor, of Bonham, who furnished well logs and placed facilities for field study at their disposal.

LITERATURE.

The principal publications relating to the area treated in the present paper are listed below in chronologic order:

Shumard, B. F., Notes upon the Cretaceous strata of Texas: St. Louis Acad. Sci. Trans., vol. 1, pp. 582–610, 1860.

Taff, J. A., and Leverett, S., Report on the Cretaceous area north of the Colorado River: Texas Geol. Survey Fourth Ann. Rept., pp. 239–354, 2 maps, 1 plate, 1893.

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Hill, R. T., Geology of parts of Texas, Indian Territory, and Arkansas adjacent to Red River: Geol. Soc. America Bull., vol. 5, pp. 297–338, pls. 12, 13, 1894.

Hill, R. T., and Vaughan, T. W., The Lower Cretaceous Gryphaeas of the Texas region: U. S. Geol. Survey Bull. 151, 139 pp., 35 pls., 1898.

Hill, R. T., Physical geography of the Texas region: U. S. Geol. Survey Top. Atlas, folio 3, 12 pp., 11 pls., 1900.

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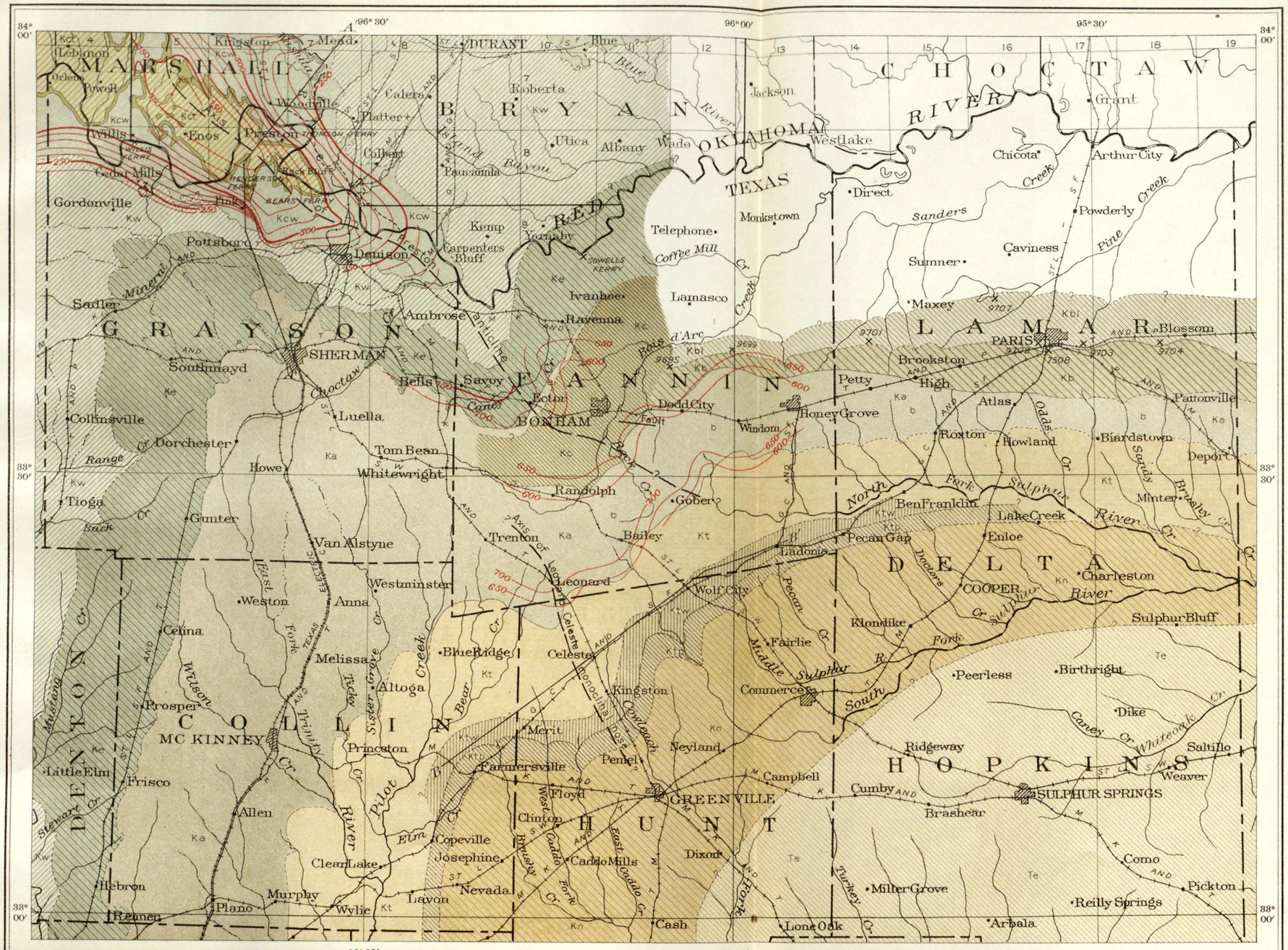
Taff, J. A., Chalk of southwestern Arkansas: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 687–742, pls. 47–53, 1902.

Taff, J. A., U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 8 pp., 4 maps, 2 columnar-section sheets, 1902.

Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tishomingo folio (No. 98), 8 pp., 3 maps, 1 columnar-section sheet, 1903.



GEOLOGIC MAP OF PARTS OF NORTHEASTERN TEXAS AND SOUTHERN OKLAHOMA

Scale 1/500,000

5 0 5 10 15 20 25 Miles

1918

Areal geology by L. W. Stephenson, supplemented by data published by Hill, Taff, and Gordon, and by data furnished by O. B. Hopkins, S. Powers, and H. M. Robinson

Structure contours showing the altitude above sea level of the top of the Goodland limestone, by O. B. Hopkins, S. Powers, and H. M. Robinson

Structure contours showing the altitude of the base of the Ector tongue of the Austin chalk and the base and top of the Annona tongue of the Austin chalk, by O. B. Hopkins and S. Powers

EXPLANATION

TERTIARY

Eocene series

Te — Midway formation and part of the Wilcox formation (*Sand and clay*)

UNCONFORMITY

CRETACEOUS

Gulf series

Kn — Navarro formation (*Calcareous clay and sand*)

Ktp / Ktw / Kt — Taylor marl (*Calcareous shaly clay*)
Pecan Gap chalk member, Ktp
Wolfe City sand member, Ktw

Ka — Austin chalk (*Includes Ector tongue (a on map) and Annona tongue (b on map). Includes also, for convenience of mapping, 10 to 35 feet of unnamed nonchalky clay and sand, down to and including the "fish-bed conglomerate"*)

Kc — Clay eqvivalent to part of Austin chalk on the west, and in part to the Blossom sand and Brownstown marl on the east

Kb — Brownstown marl (*Calcareous clay*)

Kbl — Blossom sand (*Calcareous glauconitic sand*)

Ke — Eagle Ford clay (*Dark shaly clay*)

Kw — Woodbine sand (*Fine to coarse sand and clay*)

UNCONFORMITY?

Comanche series

Kcw / e — Washita group (*Includes in ascending order Kiamichi clay, Duck Creek formation, Fort Worth limestone, and Denison formation.*
e, *approximate outcrop of top of Fort Worth limestone*)

Kcf — Fredericksburg group, which in this area is represented by the Goodland limestone

Kct — Trinity sand (*Fine sand and clay*)

600 / 500 / 400 — Contours showing altitude of key rocks above sea level. Interval 50 feet

The altitude of the top of the Goodland limestone where it is involved in the Preston anticline is represented by the contours in northern Grayson County, Tex., and southern Marshall and Bryan counties, Okla.
The altitude of the base of the Ector tongue of the Austin chalk is represented by the contours in the vicinity of Ector and Ravenna, Fannin County, Tex.
The altitude of the base of the Annona tongue of the Austin chalk is represented by the contours within a few miles south, east, and northeast of Bonham, Fannin County, Tex.
The altitude of the top of the Annona tongue of the Austin chalk is represented by the contours in the vicinity of Leonard, Bailey, Gober, and Honey Grove, Fannin County, Tex.

× 9707 — Locality at which fossils have been obtained from the Blossom sand. The figures indicate U. S. G. S. collection number

Veatch, A. C., Geology and underground-water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, 422 pp., 51 pls., 1906.

Gordon, C. H., The chalk formations of northern Texas: Am. Jour. Sci., 4th ser., vol. 27, pp. 369–373, 1909.

Taff, J. A., and Reed, W. J., The Madill oil pool, Okla.: U. S. Geol. Survey Bull. 381, pp. 504–513, 1910.

Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, 78 pp., 2 pls., 1911.

Shannon, C. W., and others, Petroleum and natural gas in Oklahoma: Oklahoma Geol. Survey Bull. 19, pt. 2, pp. 316–321, 1917.

TOPOGRAPHY AND DRAINAGE.

The area shown on Plate XVII lies near the northwestern border of the Gulf Coastal Plain in northeastern Texas and southern Oklahoma, and is a dissected coastal-plain upland ranging in altitude from about 530 feet in the southeast to 850 feet in places in the northwest. The highest points in the area are between Denison and Pottsboro, Grayson County, Tex., where several hills rise slightly more than 900 feet above sea level. Red River, which crosses the area from west to east in a sinuous course near the northern margin, has cut a broad valley 200 to 300 feet below the general upland, the altitude of low-water level where the river enters the area being approximately 590 feet and where it leaves the area not quite 400 feet. A little less than the northern half of the area is drained by tributaries of Red River. In the east, south of the Red River valley, the drainage is carried by tributaries of Sulphur River, which flows eastward and joins Red River in Louisiana. The southern and southwestern parts of the area are drained by numerous southward-flowing creeks belonging to the Trinity River system.

The drainageways of the area present many good examples of consequent, subsequent, obsequent, and perhaps other classes of streams, a detailed description of which is outside the scope of this paper. Attention may be called, however, to the conspicuous development of small tributaries of South Sulphur River, itself a subsequent stream, which flow down the gentle southward-facing slope of the cuesta formed by the Pecan Gap chalk in Delta County and the northeastern part of Hunt County, and the similar tributaries of North Sulphur River, also a subsequent stream, which flow southward on the corresponding slope of the cuesta formed by the Annona tongue of the Austin chalk in southern Lamar and Fannin counties. (See p. 132 and Pl. XVII.) These are not consequent streams, as that term was originally defined, in that their courses are not determined in consequence of the original slope produced by the uplift of the area from beneath the sea, but rather in consequence of the southward slope of the chalk and clay formations down whose eroded surfaces they flow. With the exception of some of the smaller streams in the terraced area along Red River the drainage is almost completely adjusted to the structure of the underlying Cretaceous formations, and in general the area affords an excellent example of maturely adjusted drainage on only partly consolidated, unequally resistant rocks of gentle monoclinal attitude.

The area falls chiefly within the four physiographic divisions [1] commonly known as the Black Prairies, the Eastern Cross Timbers, the Grand Prairies, and the Western Cross Timbers. The boundaries separating these divisions are approximately coincident with the boundaries of underlying formations composed of unequally resistant rocks, but these boundaries are not everywhere sharply defined. Along Red River is a belt of alluvial terrace plains of Pleistocene age (see p. 132), which ranges in width from 2 or 3 miles where the river enters the area, at the west, to 15 miles or more in the northeastern part of the area and which may well be classed as a physiographic division distinct from each of the four just enumerated.

The Black Prairies embrace chiefly the areas in Collin, Hunt, Delta, Lamar, Fannin, and Grayson counties underlain by the marine chalks, clays, and marls of the Gulf series. (See geologic map, Pl. XVII.) Topographically these areas are characterized in the main by nearly level to gently rolling surfaces, merging near Red River and the larger creeks into hills of moderate relief and smoothly rounded slopes. Cuestas of low relief have been produced by the relatively resistant chalk members of the series as described on a subsequent page.

The Eastern Cross Timbers include the relatively narrow belt underlain by the Woodbine sand of the Gulf series (see Pl. XVII), which extends from the northwestern part of

[1] Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 65–75, pl. 10, 1901.

Fannin County west by north through Grayson County to the vicinity of Gordonville and thence south along the western border of the area mapped. The belt is characterized by sandy hills of pronounced relief, supporting a growth of blackjack and post oak trees; a good example is afforded by the hills within several miles southwest and west of Denison, Grayson County. (See Pl. XXVI.) As shown elsewhere in this report, however, the Woodbine formation is irregularly bedded, and locally considerable parts of it are composed of clay which has produced a gently rolling surface similar to that of the Black Prairies; such an area occurs along the central and southern parts of the belt of outcrop of this formation for a distance of several miles west-northwest from Pottsboro, Grayson County.

The Grand Prairies include the area along the south limb of the Preston anticline in northern Grayson County, Tex., and small areas along the north limb of the anticline in Marshall County, Okla., underlain by the limestones and shaly clays and marls of the Comanche series down to but not including the Trinity sand. (See geologic map, Pl. XVII.) This belt resembles the Black Prairies in its gently rolling to moderately hilly aspect, but the indurated layers of the Comanche series, including in ascending order those of the Goodland, Duck Creek, Fort Worth, "Quarry," and Main Street limestones, tend to produce numerous small benches and low cuestas in the otherwise smooth to moderately rolling surface; these features are well exhibited in Grayson County in the northward-facing slope of the Red River valley, north of the belt of outcrop of the Woodbine sand. The belt of outcrop of the sandy strata of the Pawpaw member locally produces a narrow belt of timbered, sandy soil within the Grand Prairies, which resembles the Eastern Cross Timbers.

The Western Cross Timbers are represented in this area chiefly by a narrow belt that marks the crest of the Preston anticline in southern Marshall County, Okla., west of Preston Bend of Red River, where the sandy strata of the Trinity sand come to the surface. Topographically the area is hilly and similar to that of the Eastern Cross Timbers.

The belt of alluvial terrace plains bordering Red River includes plains at several levels: (1) The present flood plain of Red River is narrow along that part of the river bordering Grayson County, Tex., but broadens out to 3 or 4 miles in places along the northern border of Fannin and Lamar counties, Tex., and the southern border of Bryan County, Okla. (2) A well-defined river terrace 45 to 75 feet above low-water level of Red River is moderately extensive in places along the river valley; the village of Preston, in Preston Bend, in the northern part of Grayson County, is situated on an exceedingly flat portion of this plain, 4 or 5 square miles in extent, and Woodville, about 2½ miles north of Preston, in Marshall County, Okla., stands on a somewhat larger portion of the plain. (3) A terrace plain 140 to 160 feet above water level is represented here and there in that part of the valley above the mouth of Washita River but occupies extensive areas in the valley below that river; in the southwestern part of Bryan County, Okla., the alluvial deposits of this terrace form a flat sandy plain 8 miles or more in width from north to south, and large areas of the plain occur in the northern parts of Fannin and Lamar counties, Tex. (4) Remnants of surficial deposits were observed at still higher altitudes at several places in the area and may represent one or more additional terraces. The alluvial deposits on these terrace plains effectually obscure the Cretaceous formations over many square miles in the Red River valley, rendering it difficult to determine the areal extent and structure of the formations.

Minor features of the topography that have an important bearing on the areal mapping and the determination of the stratigraphy and structure are the ridges, benches, and stream bluffs produced by the more resistant strata of both the Comanche and Gulf series. Many of these features take the form of cuestas—that is, broad, low ridges of great linear extent that trend parallel to the strike of the rocks and present long, gentle slopes to the east, southeast, or south in the direction of the dip and short, steep slopes on the inland side, which marks the western edge of the outcrop of the harder ridge-forming strata. An example is the white rock escarpment of Hill,[1] which marks the western and northern edge of the Austin chalk in Grayson and Collin counties and which makes a relatively steep descent

[1] Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 68, 1901.

from a portion of the Coastal Plain upland that is underlain by the Austin chalk to a belt of the upland that lies 75 to 100 feet or more lower and is underlain by the softer Eagle Ford clay. Similar examples are the relatively steep slopes that mark the northern edges of the Annona tongue of the Austin chalk in Fannin and Lamar counties and of the Pecan Gap chalk in Delta, Fannin, Hunt, and Collin counties. (See geologic map, Pl. XVII.)

GENERAL GEOLOGIC FEATURES.

The area shown on the geologic map (Pl. XVII) is underlain throughout its extent by strata of Cretaceous age, which rest upon a buried, moderately smooth basement composed of ancient rocks. Just to the north, in the Atoka and Tishomingo quadrangles, Okla., where the basement comes to the surface, it includes Paleozoic sedimentary rocks of Cambrian, Silurian, Devonian, and Carboniferous age and pre-Paleozoic granites. The upper surface of the basement rocks is believed to be a peneplain formed by erosion prior to the deposition of the Cretaceous sediments upon it and subsequently tilted slightly coastward.

The northern boundary of the Cretaceous deposits trends about due west 10 to 30 miles north of Red River, and the western boundary trends south by west through Montague, Wise, and Parker counties, Tex. Both these boundaries are outside the area shown on Plate XVII. The tilted peneplained surface of the basement rocks dips to the south from the northern boundary at rates estimated to range in different places from 50 to 70 feet or more to the mile, and to the southeast from the western boundary at rates probably ranging from 40 to 50 feet to the mile. Within the area mapped the basement rocks lie nearest to the surface beneath the crest of the Preston anticline, in the southern part of Marshall County, Okla., and the northern part of Grayson County, Tex., where their depth ranges from 350 to 700 feet; they lie deepest in the southeastern part of the area, where their depth is estimated as between 4,000 and 5,000 feet.

The basement rocks are separated from the overlying Cretaceous deposits by an unconformity representing a long interval of geologic time, including at least the Triassic and Jurassic periods and probably a considerable part of the Lower Cretaceous epoch.

The Cretaceous deposits are divisible into two great series, a lower, the Comanche series, which appears at the surface about the flanks of the Preston anticline in the northwestern part of the area and has an estimated thickness of 800 to 1,000 feet, and an upper, the Gulf series, which has an estimated thickness of at least 3,000 feet and the outcrop of which covers considerably more than half the area. Each of these series is separable into subordinate divisions, which are discussed on subsequent pages. The Gulf series is unconformably overlain by strata of Eocene age which appear at the southeast in a relatively small part of the area under discussion. (See Pl. XVII.) In general the strike of the strata is parallel to the inner margin of the Coastal Plain, and the dip is coastward from this margin at rates ranging from 30 feet or less to 80 feet or more to the mile. A considerable departure from the prevailing regularity in strike and dip occurs in the northwestern and central parts of the area, in connection with the Preston anticline, described on pages 159, 160. A less pronounced departure from the common monoclinal structure is occasioned by the fold which produced the Leonard-Celeste monoclinal nose, described on page 161.

The Cretaceous deposits consist of sand, shaly clay, calcareous shaly clay, limestone, and chalk. With the exception of the Trinity sand (p. 134) and the Woodbine sand (p. 145), both of which were laid down in deltas and in marginal marine waters, all these deposits are of typical marine origin.

The boundaries of the formations as indicated on Plate XVII are in part very much generalized. Where they are established with approximate accuracy for the scale of the map by the personal observations of the writer and his associates or by published evidence regarded as sufficiently reliable, the boundaries are drawn as full lines. Elsewhere the boundaries have been determined by general considerations or by using the unverified boundaries indicated on maps of Hill, Taff, and Gordon and are drawn as broken lines. The geologic formations of the northeastern part of Fannin County and the northern part of Lamar County are little known, owing in part to an extensive covering of Pleistocene alluvial terrace deposits which largely conceal the Cretaceous formations in a broad area bordering

Red River on the south, and in part to the inadequacy of the field work that has been done in the area. The writer has not examined the boundary between the Woodbine and Eagle Ford formations anywhere in western Grayson and eastern Denton counties, nor the boundary between the Eagle Ford and Austin south of the Texas Pacific Railroad in Grayson and Collin counties. The position assigned to the Cretaceous-Eocene contact in Hunt and Hopkins counties is based chiefly on the maps of Hill and Gordon.

CRETACEOUS SYSTEM.

COMANCHE SERIES.

GENERAL CHARACTER.

The Comanche series consists of sands, shaly clays, marls, and limestones having an estimated thickness in northeastern Texas of 800 to 1,000 feet. The series has been subdivided in Texas in ascending order into the Trinity, Fredericksburg, and Washita groups, all of which are represented in the area treated in this paper. (See Pl. XVII.) In this area the series appears in surface exposures only in the northern part of Grayson County, Tex., and in an adjacent area north of Red River in the southern parts of Marshall and Bryan counties, Okla., where it has been brought to the surface by the uplift that produced the Preston anticline. (See p. 159.) Were it not for this anticline the series would lie buried beneath the Gulf series in the area mapped, with the possible exception of its extreme northwestern corner. Hill's classification of the Comanche series in Grayson County is given in column C in Plate XVIII.

The Comanche series is of Cretaceous age. Until recently the series has been regarded by American geologists as belonging to the Lower Cretaceous, but for a number of years certain European geologists, notably Douvillé,[1] have regarded the series as in part Upper Cretaceous. Berry and Knowlton[2] now correlate the Washita, the uppermost group of the series, unquestionably with the Cenomanian (Upper Cretaceous). Whatever may be the position of this series with respect to the standard European section, it is reasonably certain that the Comanche constitutes a closely related lithologic and paleontologic series.

TRINITY SAND.

The Trinity group, which is represented in northeastern Texas chiefly by sand (the "Antlers sand" of Hill), is the basal division of the Comanche series. According to well records this sand is 400 to 700 feet thick in the vicinity of Red River in Grayson County, Tex., and Marshall County, Okla. Taff, who studied it in the Tishomingo quadrangle, Okla., a few miles north of Grayson County, states that the formation consists of fine, compact incoherent sand and scattered lentils of sandy clay, with a basal conglomerate a few feet to 50 feet thick, which in the western half of the quadrangle is cemented with chalky white lime.[3] Pebbly lenses occur in the sand in places.

In the area under consideration the sand is at the surface in the axial portion of the Preston anticline, in an irregular belt having a maximum width of 7 or 8 miles, extending from a point several miles southeast of Rock Bluff, on Red River, to the northwest corner of the area in Oklahoma, as shown on the geologic map (Pl. XVII). Localities where the sand was examined are mentioned or briefly described below.

At Rock Bluff, Red River, 2½ miles south of Preston or 8½ miles northwest of Denison, Grayson County, Tex. (see Pl. XIX, *A*), near the axis of the Preston anticline, the upper 150 feet of the Trinity is well exposed, as described in the following section:

Section at Rock Bluff, Red River, Grayson County, Tex.

[Altitude at top of section estimated to be 690 feet above sea level.]

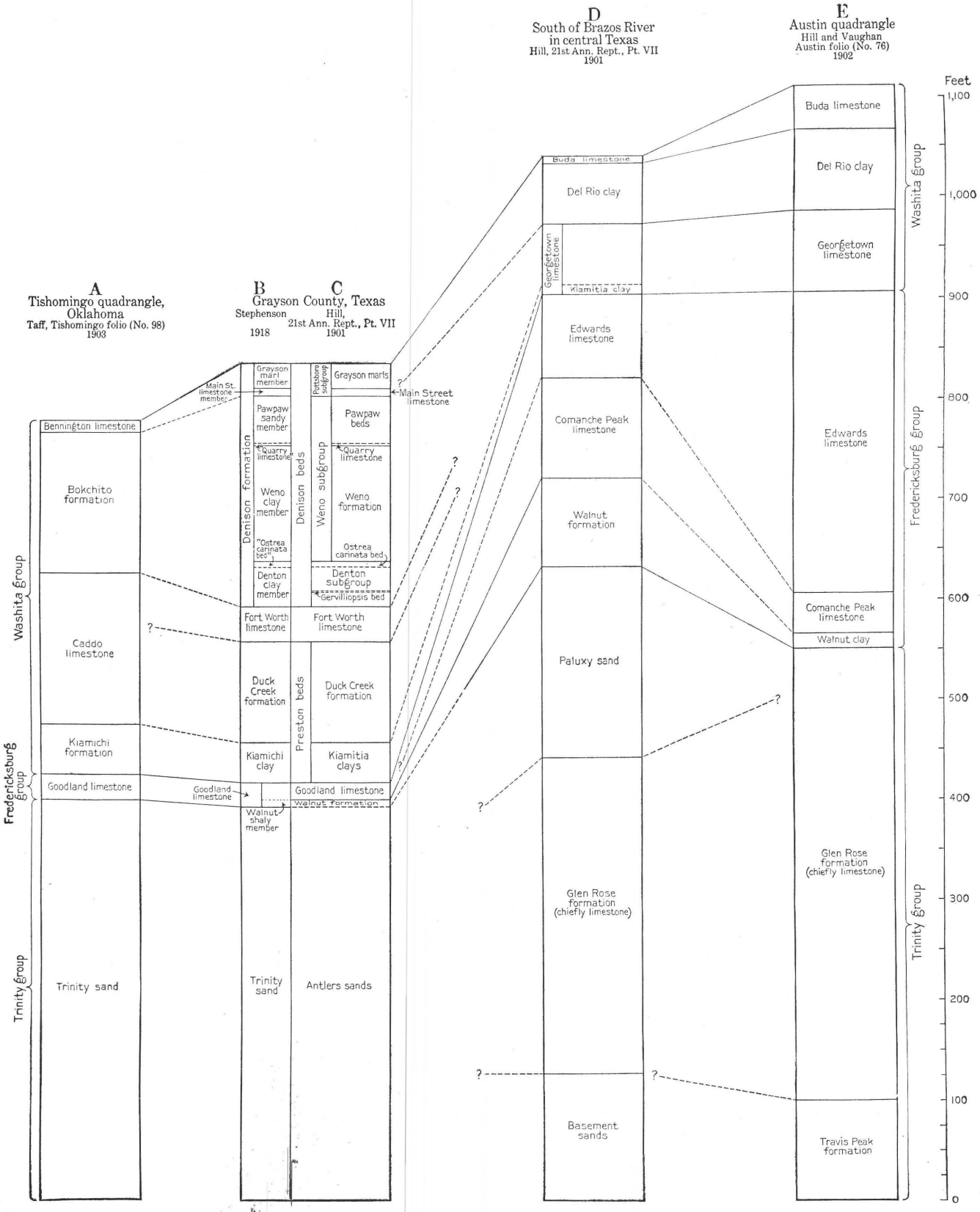
	Feet.
Fredericksburg group (Goodland limestone):	
Hard massive limestone	10
Shaly clay, poorly exposed (Walnut shaly member)	1
Limestone (Walnut shaly member)	2
Trinity sand ("Antlers sand" of Hill):	
Light-gray, mostly fine argillaceous irregularly bedded compact sand, with subordinate lenses of fine sandy clay and some pebbly lenses; in the lower 30 feet are interbedded lenses of purplish clay having a maximum observed thickness of 6 feet	150
	163

In a bluff of Red River 1½ miles above Rock Bluff, 1¼ miles south by east of Preston, 30 feet

[1] Douvillé, H., Sur quelques rudistes américains: Soc. géol. France Bull., 3d ser., vol. 28, p. 218, 1900.

[2] Berry, E. W., The Upper Cretaceous floras of the world: Maryland Geol. Survey, Upper Cretaceous, pp. 222, 223, 1916.

[3] Taff, J. A., U. S. Geol. Survey Geol. Atlas, Tishomingo folio (No. 98), p. 6, 1903.



CORRELATION TABLE SHOWING THE RELATION OF THE SUBDIVISIONS OF THE COMANCHE SERIES IN GRAYSON COUNTY, TEX., TO THE FORMATIONS OF THE SAME SERIES IN OTHER PARTS OF TEXAS AND OKLAHOMA.

of Trinity sand essentially like that just described is exposed beneath 30 feet of Pleistocene terrace alluvium.

In the public road 1½ miles west of Preston 30 or 35 feet of Trinity sand outcrops in the steep westward-facing slope of the Red River valley, and the Goodland limestone forms a ledge at the crest of the hill, about 650 feet above sea level. Pebbly lenses were noted in the Trinity at this locality.

At Henderson Ferry on Red River, 4 miles west by south of Rock Bluff, the upper 40 feet of the Trinity is moderately well exposed and consists of fine to coarse gray and yellow sand with small mechanically included fragments of clay and slightly indurated sand. The sand is overlain by the Goodland limestone, including the Walnut member at its base, which is poorly exposed.

Good exposures of the Trinity occur in the southern part of Marshall County, Okla., on the headwater branches of Sand Creek, 6 miles south by west of Kingston; in the valley of Buncombe Creek, 2½ to 8 miles north by east of Willis Ferry; and in the valleys of Brier and House creeks, 3 to 8 miles north and northwest of Willis Ferry.

The northwesternmost locality where the Trinity was examined by the writer is on the northeastward-facing slope of the Red River valley about a mile southeast of Orlena, in the extreme northwestern part of Grayson County, Tex. Here the Goodland limestone caps the hill, forming a rocky ledge at its crest at an altitude of about 750 feet, and 75 feet or more of the Trinity appears in the steep slope below the Goodland.

South of the Red River region in Texas the middle portion of the Trinity becomes calcareous, and south of Brazos River is separable according to Hill [1] 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, the Paluxy sand is apparently represented by limestone in the upper part of the Glen Rose, so that the Trinity is separable in ascending order into only two parts—the Travis Peak formation, consisting of conglomerate, grit, sand, clay, and calcareous beds, 100 feet; and the Glen Rose formation, chiefly limestone, 450 feet. (See Pl. XVIII.)

[1] Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 153-154, 171, 1901.

FREDERICKSBURG GROUP.

GOODLAND LIMESTONE (INCLUDING WALNUT SHALY MEMBER).

The Trinity sand is overlain by the Fredericksburg group, which in northeastern Texas is represented by the Goodland limestone, only 13 to 20 feet thick. The Goodland outcrops in a narrow area on the flanks of the Preston anticline, surrounding the area of outcrop of the Trinity sand (see Pl. XVII), in northern Grayson County, Tex., and in southern Marshall and Bryan counties, Okla. Along the south side of the anticline the Goodland dips south by west at rates ranging from 40 to 300 feet or more to the mile. The steepest known dip occurs about a mile and a half northeast of Pottsboro. (See structure contours, Pl. XVII.)

The basal 3 to 6 feet of the Goodland limestone consists of layers of persistent hard thin-bedded coquina-like limestone with interbedded thin layers of dark marly shale, which are in this paper called the Walnut shaly member. These beds were not recognized by Hill [2] in the type section at Goodland, in Choctaw County, Okla. He says:

> Proceeding westward along the ancient Ouachita shore line from Arkansas into Texas, the *Exogyra texana* beds (the Walnut clays and *Gryphaea* breccia) are missing until the escarpment is reached north of Marietta, in the Chickasaw Nation [Love County, Okla.], where they first appear, thinly represented beneath the Goodland limestone.

In 1894 [3] and again in 1901 [4] 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 [5] and again in the Tishomingo folio,[6] Taff included the Walnut clay in the Goodland, and this usage has subsequently been followed by Taff and other authors. Although the United States Geological Survey has adopted Taff's usage of Goodland, the present writer is of the opinion that future investigations will demonstrate the appropriateness of restricting the application of the name to the massive limestone above the interbedded shaly clay and coquina-like limestone, here called Walnut shaly member, in accordance with Hill's original usage.

[2] Geol. Soc. America Bull., vol. 2, pp. 502-514, 1891.
[3] Geol. Soc. America Bull., vol. 5, pp. 303, 304, 1894.
[4] U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 216-222, 1901.
[5] U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902.
[6] Idem, Tishomingo folio (No. 98), 1903.

Southward from Grayson and Cooke counties in Texas the Walnut member becomes thicker, and in Tarrant and Johnson counties it assumes the importance of a formation rather than a member; here it consists of alternating hard and soft thin-bedded limestone and marl and reaches a maximum thickness of 140 or 150 feet. Still farther south, in Hood and Somervell counties, the thickness again decreases to approximately 90 feet, and in the vicinity of Austin, Travis County, it is only 15 feet. (See Pl. XVIII.) The type locality of the Walnut member is at Walnut (or Walnut Springs), in Bosque County.

Above the Walnut member the Goodland consists of 10 to 15 feet of hard massive persistent limestone, which weathers white. This limestone forms conspicuous outcrops and is therefore a valuable key rock in determining structure from surface exposures. It is easily recognizable in well borings, its position so closely above the Trinity sand preventing its confusion with other limestones in the overlying Washita group. As a rule, the drillers do not differentiate the few feet of limestone and marl of the Walnut member at the base of the Goodland limestone. Characteristic fossils of the Goodland limestone are *Gryphaea marcoui* Hill and Vaughan, *Exogyra texana* Roemer, *Remondia robbinsi* (White), *Cerithium bosquense* Shumard, and *Schloenbachia acutocarinata* (Shumard). The importance of the Goodland as a key rock warrants a fairly full description of its occurrence about the flanks of the Preston anticline.

One of the easternmost outcrops of the Goodland near the crest of the Preston anticline is in the banks of a small creek entering Shawnee Creek just below the pumping station at the city lake, 4 miles northwest of Denison. The creek near its mouth is intrenched in the limestone to a depth of 6 to 7 feet, and the limestone is overlain by a few feet of alluvium. Upstream the top of the limestone gradually becomes lower with respect to water level, and within a few hundred yards it passes beneath the bed of the creek. At Bears Ferry, Red River, 1½ miles north by east of the city lake, the top of the Kiamichi formation is about 25 feet above water level, showing that the Goodland is here 15 or 20 feet below water level. Within a mile west of Bears Ferry the Goodland rises above water level and forms a gradually rising ledge in the northward-facing slope of the Red River valley westward to Rock Bluff, where the base of the limestone lies a little more than 150 feet above the river. The section at Rock Bluff is described on page 134.

West of Rock Bluff the Goodland appears in both slopes of the Little Mineral Creek valley, but its southward dip carries it below the surface in the bed of the creek at a point approximately 4¼ miles north of Pottsboro. A fine exposure of the limestone is afforded by a bluff on this creek 4½ miles north of Pottsboro. (See Pl. XIX, *B*.)

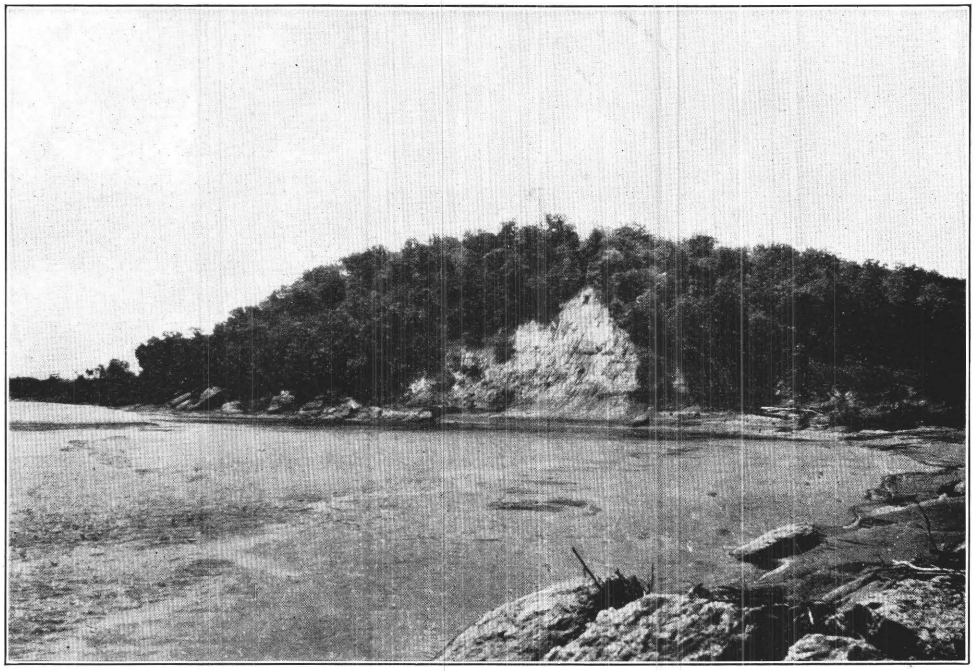
Section on Little Mineral Creek 4½ miles north of Pottsboro, Grayson County, Tex.

[Altitude at top of section estimated to be 615 feet above sea level.]

	Feet.
Soil	2
Fredericksburg group (Goodland limestone):	
Massive limestone	13
Walnut shaly member: Hard thin-bedded coquina-like limestone containing *Ostrea subovata* Shumard, *Gryphaea marcoui* Hill and Vaughan, *Trigonia* sp., and *Anomia* sp., with interbedded thin layers of dark marly shale	6
	21

Both the massive limestone and the underlying Walnut shaly member are well exposed in a branch in the eastward-facing slope of Little Mineral Creek, 6 miles north of Pottsboro (3 miles north of Fink), where a thin earthy calcareous layer in which cone-in-cone structure was well developed was noted about a foot below the top of the Walnut member. On the divide between Little Mineral Creek and Red River the Goodland extends northward to a point 7 miles north of Pottsboro, where the altitude of its top is about 720 feet above sea level. The limestone here lacks less than 2 miles of closing to the north over the crest of the Preston anticline, its absence in this interval being due to erosion which has removed the Goodland from the underlying Trinity. (See p. 137 and Pl. XVII.)

At Henderson Ferry, Red River, 6¾ miles north by west of Pottsboro, the base of the Goodland is only 35 or 40 feet above water level, and upstream from the ferry, within an estimated distance of 1 or 2 miles, it finally comes down to water level and crosses into Oklahoma beneath the Pleistocene and Recent alluvial deposits of the Red River valley.



A. TRINITY SAND AND LOOSE SLABS OF GOODLAND LIMESTONE AT ROCK BLUFF (OLD MARSHALL BLUFF) ON RED RIVER, 8½ MILES NORTHWEST OF DENISON, GRAYSON COUNTY, TEX.

The upper 150 feet of the Trinity is exposed in the bluff. The Goodland limestone, which immediately overlies the Trinity, forms a ledge along the crest of the bluff, and large masses of rocks broken from it have fallen down the slope, giving rise to the name Rock Bluff.

B. GOODLAND LIMESTONE ON LITTLE MINERAL CREEK IN NORTHERN GRAYSON COUNTY, TEX.

The massive Goodland limestone is underlain by the Walnut shaly member (the undermined portion).

Northwest of Henderson Ferry, in Marshall County, the southward-dipping limestone appears in the valley slopes of the southward-flowing creeks tributary to Red River and was especially noted along two small creeks respectively 3 and 3½ miles east of Willis Ferry. North of Willis Ferry the Goodland crops out in both the east and west slopes of the ridge separating Buncombe and Brier creeks, and its continuity is interrupted at only one place on the crest of the ridge, where it has been eroded away. At a point estimated to be about 3½ miles west by north of Willis Ferry the Goodland again crosses Red River into Grayson County, Tex., where, gradually rising to the northwest in the northeastward-facing slope of the river valley, it finally forms the crest of the hill overlooking the valley about a mile southeast of Orlena. The Trinity sand appears in the slopes of this hill below the Goodland.

On the north limb of the Preston anticline the Goodland crops out in the valley of Rock Creek south of Kingston, in Marshall County, Okla., and is especially well exposed in a branch about 3¾ miles south by west of Kingston. The section here shows the upper massive limestone, underlain by the Walnut shaly member, and this in turn by the Trinity sand. Down the valley of Rock Creek from this locality the limestone appears in the southwestward-facing slope, gradually descending toward water level until, in the vicinity of the big bend a mile or two west of Woodville, it crosses the Red River valley beneath the Pleistocene and Recent alluvial deposits and reappears on the Texas side of the river in the hills in the northern part of Preston Bend, Grayson County. A good exposure of the limestone was noted in the public road on the westward-facing slope of the Red River valley 1½ miles west of Preston, where it is underlain by 30 or 35 feet of Trinity sand that outcrops in the slope below the limestone. This locality is less than 2 miles north of the northernmost occurrence of the limestone in the south limb of the anticline on the divide between Little Mineral Creek and Red River. (See p. 136.) The limestone here and in other outcrops in this vicinity dips to the northeast at an angle sufficient to carry it 40 or 50 feet below water level at Thomson Ferry, a mile north of Preston, Tex.

East of Preston the Goodland again crosses the Red River valley beneath alluvial deposits, and although not traced in detail it was examined in an outcrop at the foot of a terrace scarp at the edge of the Red River bottom about half a mile north of Bears Ferry, in Bryan County, Okla. Here the top of the limestone is 30 or 35 feet above water level.

South of Red River in Cooke County, Tex., the Goodland gradually increases in thickness. It is regarded as the time equivalent of the Walnut clay, and of the Comanche Peak and Edwards limestones of central Texas, which south of the Brazos River valley have a combined thickness of over 250 feet; still farther south the Edwards continues to thicken, being 300 feet thick in the vicinity of Austin, Travis County (see Pl. XVIII), and 520 feet thick in Uvalde County, whereas the Walnut and Comanche Peak become thinner, the former being only 15 feet and the latter 40 feet thick in the vicinity of Austin.

WASHITA GROUP.

LITHOLOGY AND SUBDIVISIONS.

The Washita group consis s chiefly of marine shaly clay, marl, and interbedded subordinate limestone, having a total estimated thickness in northern Grayson County of 415 feet; toward the top there is a sandy member, the Pawpaw (see p. 142), which is the only conspicuous exception to the nonsandy character of the group in this area. The limestone, though subordinate in thickness to the clay and marl, forms several definite bands that have individual physical characteristics and contain index fossils which render them readily traceable throughout the area; they have also been approximately correlated by means of the fossils with beds of corresponding age in central and southwestern Texas. The limestones are therefore valuable key beds in determining the geologic structure of the deposits.

The group has been subdivided by Hill[1] and Taff.[2] Although Hill's nomenclatural treatment is not in all respects precise and consistent, the succession of beds described by him has been substantially verified. He recognized the following divisions, named in ascending order (see Pl. XVIII): (*a*) The Preston beds, sub-

[1] U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 240–292, 1901.
[2] U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902; Tishomingo folio (No. 98), 1903.

divided into the Kiamitia clay, thickness 40 feet, which rests upon the Goodland limestone, and the Duck Creek formation (clay, marl, and limestone), thickness 100 feet; (*b*) the Fort Worth limestone, thickness 35 feet; (*c*) the Denison beds, subdivided into (1) the Denton subgroup, thickness 45 feet; (2) the Weno subgroup, including the Marietta or Weno formation, thickness 115 feet; the Quarry limestone, thickness 2 feet; and the Pawpaw beds, thickness 45 feet; and (3) the Pottsboro subgroup, including the Main Street limestone, thickness 8 feet; and the Grayson marl, thickness 25 feet.

The divisions recognized by Taff in the Tishomingo and Atoka quadrangles, Okla., which correspond to the Denison beds of Hill, include in ascending order the Kiamichi formation, equivalent to the "Kiamitia" clay of Hill; the Caddo limestone, equivalent to the Duck Creek formation and the Fort Worth limestone; the Bokchito formation, equivalent to the Denton subgroup and the Weno subgroup (Marietta or Weno formation and Pawpaw beds) of Hill; and the Bennington limestone, equivalent to Hill's Pottsboro subgroup (Main Street limestone and Grayson marl). (See Pl. XVIII.)

South of Grayson and Cooke counties, Tex., the Washita group, as a whole, becomes thinner, at the same time gradually assuming a different lithologic character. In the Austin quadrangle (see Pl. XVIII) the Georgetown limestone, which is only 80 feet thick, appears to represent all of the Washita group of Grayson County up to and including the basal part of the Main Street limestone, a total thickness of at least 385 feet. However, the upper part of the Main Street limestone and the Grayson marl, which, together have a thickness of about 30 feet, become thicker toward the south and are represented in the Austin quadrangle by the Del Rio clay and Buda limestone, which have a combined thickness of about 125 feet.

Hill's classification of the group is given in Plate XVIII (p. 134), which also includes columns showing the correlation with the subdivisions of the group recognized by Taff in the Tishomingo quadrangle, Okla., by Hill in the region south of the Brazos River valley, and by Hill and Vaughan in the Austin quadrangle, Tex. In the present report Hill's classification of the group, modified somewhat for the sake of simplicity and greater clearness, is adopted, as shown in Plate XVIII, column B. The changes include the dropping of the apparently unnecessary terms Preston beds, Weno subgroup, and Pottsboro subgroup.

KIAMICHI CLAY.

The Kiamichi clay is named for Kiamichi River, on which it is typically exposed in Choctaw County, Okla. In Grayson County the Kiamichi clay, which includes all the beds between the Goodland and Duck Creek formations, is 40 or 50 feet thick and consists chiefly of dark carbonaceous shaly clay, with thin platy layers of siliceous limestone interbedded with the clay in the lower few feet and with thin layers of gray impure fossiliferous limestone in the upper 10 or 15 feet. The writer has not seen the full thickness of the formation, and the description is based partly on the statements of Taff and Hill. The section at Thomson Ferry, given below, which includes the upper part of the formation, was examined by the writer. (See Pl. XX.) This locality is on the north limb of the Denison anticline.

Section at Thomson Ferry, on the right bank of Red River, in Grayson County, Tex., 2 miles south of Woodville, Okla.

	Feet.
Duck Creek formation:	
Layers of limestone interbedded with subordinate layers of dark shaly calcareous clay, the limestone hard and nodular in the upper part, softer and less nodular below, especially in the lower 2 feet. Fossils recognized: *Kingena* sp., *Exogyra plexa* Cragin, *Plicatula* sp., *Gryphaea washitaensis* Hill, *Hamites fremonti* Marcou (?), *Schloenbachia* (two or three species)	15
Kiamichi clay:	
Layers of gray impure, very fossiliferous limestone with thin interbedded layers of dark calcareous shaly clay; the limestone layers contain vast numbers of *Gryphaea*, chiefly *G. navia* Hall	3½
Dark shale with layers of *Gryphaea*-bearing limestone resembling the limestone in the overlying division but more widely spaced. Fossils recognized: *Gryphaea navia* Hall, *Trigonia* sp., and *Plicatula* sp	7

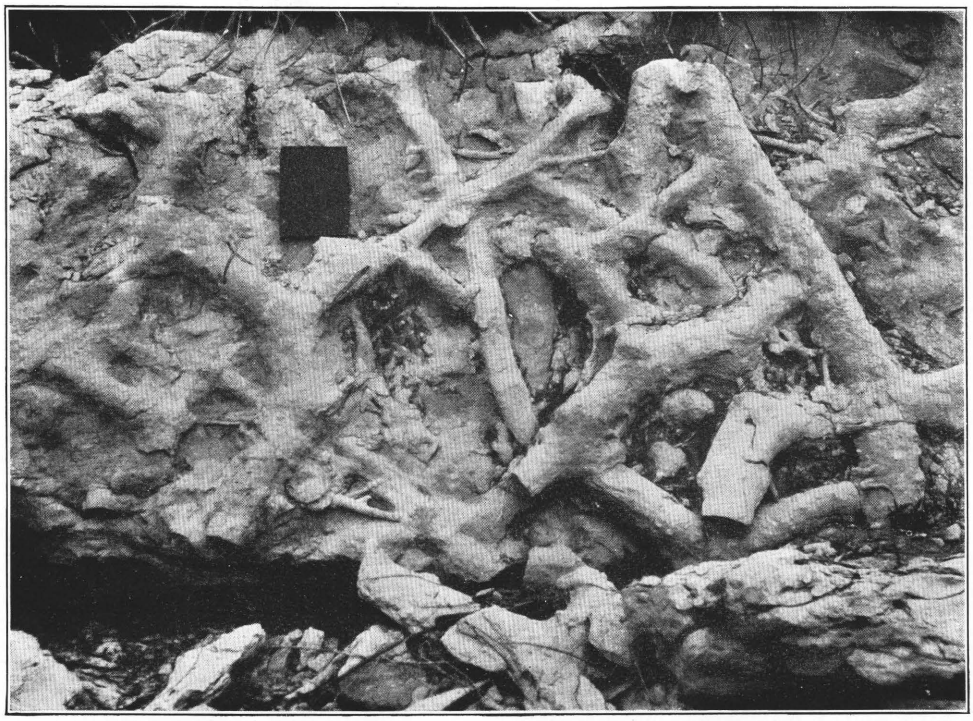
The *Gryphaea*-bearing limestones in the upper part of the Kiamichi clay are characteristic and persistent and form excellent key beds in determining the structure of the rocks in this area. They were noted also on the north

A. TOP OF KIAMICHI CLAY, OVERLAIN BY LIMESTONE MEMBER OF DUCK CREEK FORMATION, IN BLUFF ABOVE THOMSON FERRY, RED RIVER, 11 MILES NORTHWEST OF DENISON, GRAYSON COUNTY, TEX.

B. SLABS OF GRYPHAEA-BEARING IMPURE LIMESTONE FROM THE UPPER PART OF THE KIAMICHI CLAY AT THE LOCALITY SHOWN IN *A*.

The shells belong chiefly to the species Gryphaea navia Hall.

A. EARTHY FACIES OF THE LOWER PART OF THE FORT WORTH LIMESTONE ON THE OKLAHOMA SIDE OF RED RIVER AT THE MISSOURI, KANSAS & TEXAS RAILWAY BRIDGE 5 MILES NORTH OF DENISON, GRAYSON COUNTY, TEX.



B. FOSSIL FUCOIDS (?) ON THE UNDER SIDE OF A SLAB OF FORT WORTH LIMESTONE, AT THE LOCALITY SHOWN IN *A*.

limb of the Preston anticline in a branch of Rock Creek at a public road crossing 3 miles south by west of Kingston, Marshall County, Okla. On the south limb of the anticline they were examined along the Preston road a short distance south of Rock Bluff (see p. 134); along the road leading down to Henderson Ferry, 5½ miles north by west of Pottsboro; and in the bed of Little Mineral Creek, 3½ miles north of Pottsboro.

DUCK CREEK FORMATION.

The Duck Creek formation, which is typically exposed on Duck Creek north of Denison, in Grayson County, consists of approximately 100 feet of limestone and gray to greenish-gray shaly calcareous clay, which intervene between the Kiamichi clay below and the Fort Worth limestone above. In the lower 35 or 40 feet the limestone alternates with the clay in layers 6 to 12 inches thick, in about equal proportions; in the upper part of the section the clay predominates, the limestone layers being rather soft and separated by intervals of 2 to 3 feet or more of clay. The limestones in the lower 35 or 40 feet are characterized by keeled and nonkeeled ammonites, many of which reach a diameter of 2 feet or more. One layer of white, chalky limestone 3 or 4 feet thick 35 or 40 feet above the base of the formation and 2 or 3 feet of gray calcareous clay that immediately underlies it contain great numbers of large ammonites and form a zone that has been recognized in outcrops over a large area in Texas and Oklahoma and was used by Messrs. Hopkins, Powers, and Robinson as a key in the determination of structure. The keeled ammonites belong chiefly to the genus *Schloenbachia*, several species of which have been differentiated. The nonkeeled forms belong chiefly to the species *Pachydiscus brazoensis* (Shumard). The limestones also contain some of the remains of the problematic organisms (fucoids?), such as occur in great numbers and of larger size in the Fort Worth limestone. (See p. 140 and Pl. XXI, *B*.) The most complete section of the Duck Creek formation examined by the writer is on Duck Creek and in a cut of the St. Louis & San Francisco Railroad where it comes close to Duck Creek, 2¾ miles north of Denison.

Section on Duck Creek and in a cut of the St. Louis & San Francisco Railroad 2¾ miles north of Denison, Grayson County, Tex.

	Feet.
Fort Worth limestone:	
Four or five layers of nodular impure argillaceous fossiliferous limestone interbedded with gray shaly clay	8
Duck Creek formation:	
Gray shaly calcareous clay with interbedded layers of impure non ledge-forming limestone at intervals of 2 or 3 feet	22
Concealed	20
Greenish-gray calcareous clay from which weather numerous specimens of *Plicatula* cf. *P. incongrua* Conrad and small rusty ammonites, probably the young of *Pachydiscus* and *Schloenbachia*, also a few specimens of *Gryphaea washitaensis* Hill	15
Ledges of limestone with interbedded layers of gray shaly clay, poorly exposed; the limestone, especially one layer near the top, contains numerous keeled and nonkeeled ammonites, many of which are of large size (maximum, 2 feet in diameter)	20
Alternating beds of ammonite-bearing limestone and gray shaly clay, about half and half, well exposed in bluff along the creek	20

Other exposures of the limestones forming the lower part of the Duck Creek formation were observed by the writer in a small branch of Little Mineral Creek at the crossing of the road leading to Henderson Ferry, 4¾ miles north of Pottsboro; in the road leading down to Henderson Ferry about a mile west by north of the locality just mentioned; and at Willis Ferry (Oklahoma side), 13 miles northwest of Pottsboro, Tex. The upper part of the Duck Creek, consisting of calcareous clay, which lacks conspicuous layers of limestone, is well exposed in a bluff on the north side of Red River, about half a mile above Willis Ferry. These localities are on the south limb of the Preston anticline; the section at Thomson Ferry, on the north limb of the anticline described on page 138, reveals the basal 15 feet of the limestone.

FORT WORTH LIMESTONE.

The Fort Worth limestone, named from the city of Fort Worth, Tarrant County, Tex., consists in the vicinity of Red River north of Denison, Grayson County, of about 25 feet of gray nodular earthy limestone interbedded with layers of dark shaly clay, followed above by 8 to 10 feet of heavy-bedded hard cream-

colored chalky limestone. This limestone resembles the limestone portion of the underlying Duck Creek formation, from which it may be distinguished by slight lithologic differences, by the more common occurrence of pectens, by the presence of echinoids in greater number and of larger size, and by the greater abundance and larger size of the problematic fucoid-like remains described below. The Fort Worth is immediately overlain by the Denison formation. A good exposure of the lower 25 feet of the formation is afforded by the bluff of Red River at the north end of the bridge of the Missouri, Kansas & Texas Railway 5 miles north of Denison, on the north limb of the Preston anticline. (See Pl. XXI, *A*.) Here the impure nodular limestone layers range in thickness from a few inches to 2 feet, and the interbedded shaly clay composes half or more of the bulk of the material. The limestone layers are fossiliferous and the most numerous and conspicuous forms are keeled ammonites, some of which have a maximum diameter of 18 inches, and echinoids. An interesting and characteristic feature of these limestones is the problematic fucoid (?) remains or casts of borings (?) which line the underside of some of the limestone layers. Good examples are shown in Plate XXI, *B*. The upper part of the formation is well exposed in the bank of a small branch about a third of a mile northeast of the Missouri, Kansas & Texas Railway bridge just east of the railway track; here the Fort Worth is overlain by 15 feet of reddish terrace sand.

The upper heavy-bedded cream-colored limestone of the Fort Worth is exposed at many places on the south limb of the Preston anticline in Grayson County and was observed in a cut of the Missouri, Kansas & Texas Railway 2 miles north by east of Denison; on the Bears Ferry road 1¾ miles in an air line northwest of the post office at Denison; on the Preston (Rock Bluff) road 3¼ miles north of the Missouri, Kansas & Texas Railway, near the head of a branch of Little Mineral Creek; on the public road 2⅓ miles in an air line northeast of Pottsboro; and on the Henderson Ferry road 3¼ miles north of Pottsboro, an eighth of a mile north of Fink. This upper massive part of the Fort Worth limestone constitutes a good key bed, owing to its ledge-forming character and its characteristic fossils, among which are *Hemiaster elegans* Shumard, *Exogyra walkeri* White (a large smooth species), *Nautilus texanus* Shumard, and *Schloenbachia leonensis* Conrad.

DENISON FORMATION.

DENTON CLAY MEMBER (INCLUDING "OSTREA CARINATA BED").

Hill[1] originally applied the name Marietta to beds, chiefly shaly clays, 160 feet thick, between the Fort Worth limestone below and imperfectly defined so-called North Denison sands above. Later he reclassified the Denison formation, as shown in Plate XVIII, column C, introducing the name Denton subgroup, from Denton Creek, Denton County, for the lower 45 feet of the original Marietta, including the "*Ostrea carinata* bed" at its top, and applying the name Weno formation to the beds which lie between the Denton and the "Quarry" limestone and include most of the upper part of the original Marietta. In one of his tables in the same paper[2] he somewhat loosely applied the name Marietta to the beds between the Denton and Pawpaw divisions. As the name Marietta is preoccupied for sandstone in the Dunkard group of Pennsylvania, West Virginia, and Ohio, its use in the Denison section seems undesirable.

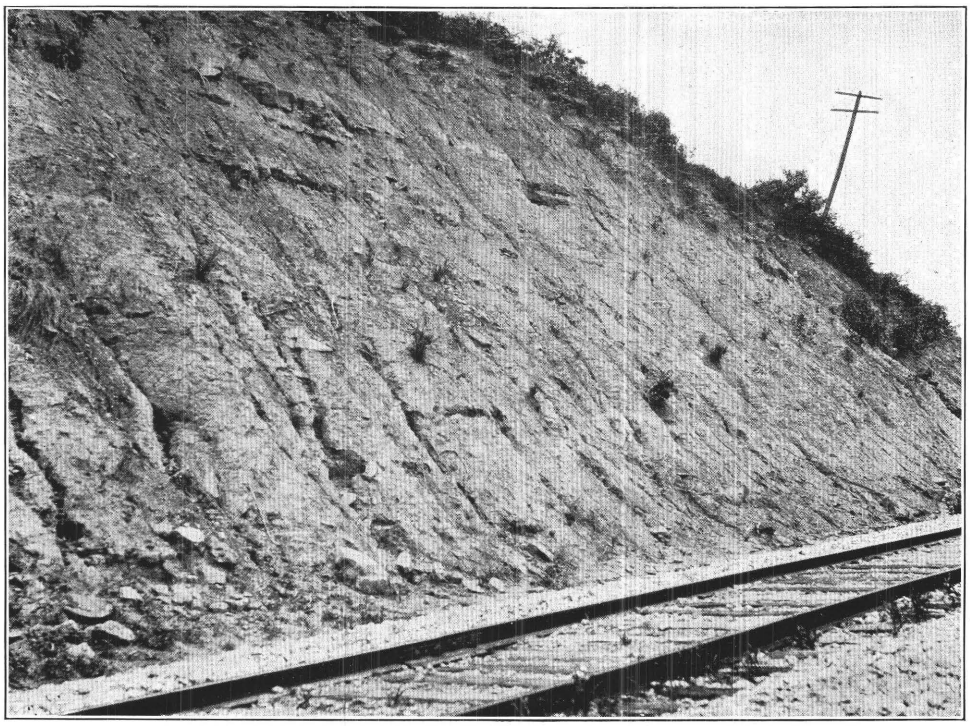
The lower 5 feet of the Denton is a strongly calcareous clay of a decided marly character. This is followed by 35 feet of shaly, less calcareous clay, which in turn is followed by 3 to 5 feet of highly fossiliferous impure limestone, composed largely of the shells of *Gryphaea washitaensis* Hill but containing also a few large echinoid spines and other fossils, among which are considerable numbers of *Ostrea carinata* Lamarck, a fossil which suggested the name "*Ostrea carinata* bed." The Denton member appears in imperfect exposures along the St. Louis & San Francisco Railroad 1½ to 2 miles north of Denison.

The "*Ostrea carinata* bed" appears in many small exposures along the south limb of the Preston anticline and is an excellent key rock, chiefly because of the presence of *O. carinata* Lamarck, a peculiar and easily recognizable fossil. This stratum is exposed on the St.

[1] Hill, R. T., Geol. Soc. America Bull., vol. 5, p. 303, 1894.
[2] Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 115, 1901.

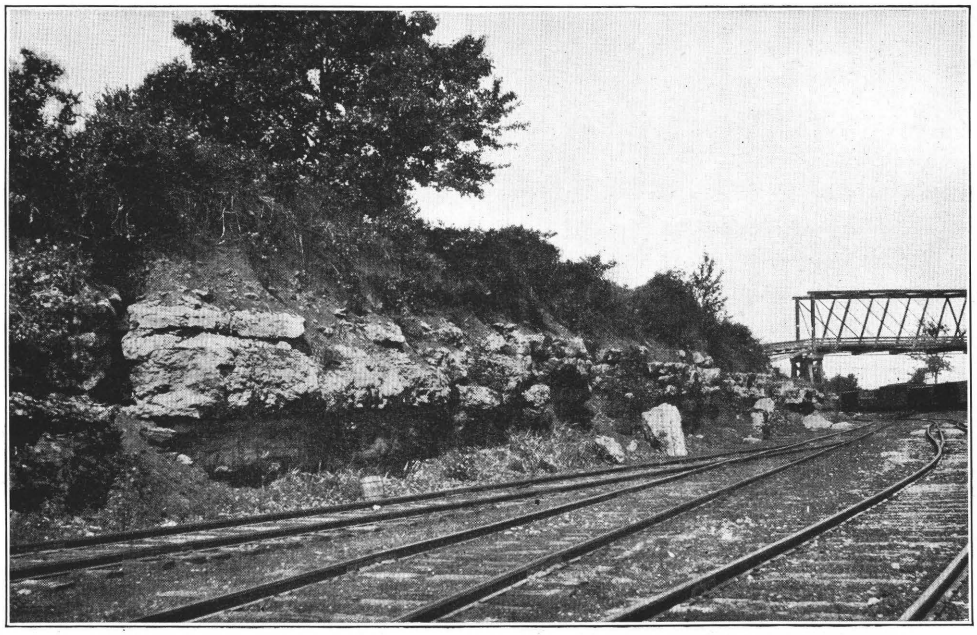
A. UPPER PART OF THE WENO CLAY IN THE EAST BANK OF WASHITA RIVER AT THE FRISCO RAILROAD BRIDGE 2¼ MILES WEST OF PLATTER, BRYAN COUNTY, OKLA.

The material exposed in the bank comprises shaly clay and subordinate interbedded layers of sandstone.

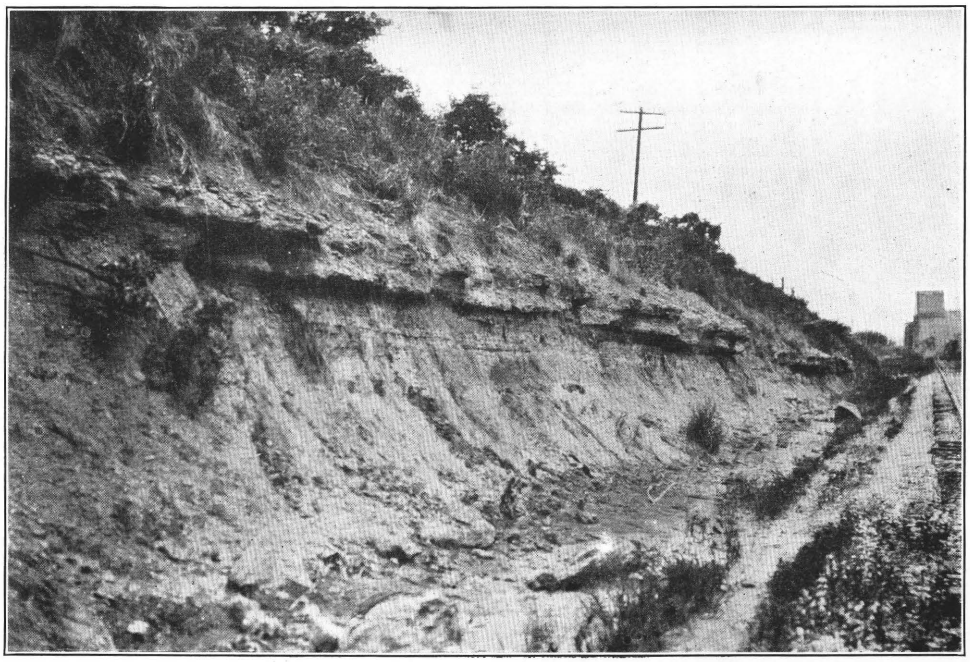


B. UPPER PART OF THE WENO CLAY IN A CUT OF THE FRISCO RAILROAD A MILE NORTH OF THE STATION AT DENISON, GRAYSON COUNTY, TEX.

A ledge of the "Quarry" limestone, which overlies the Weno, appears at the extreme top of the section.



A. MAIN STREET LIMESTONE IN A CUT OF THE MISSOURI, KANSAS & TEXAS RAILWAY 3 MILES WEST OF THE STATION AT DENISON, GRAYSON COUNTY, TEX.



B. "QUARRY" LIMESTONE, UNDERLAIN BY THE WENO CLAY, IN A CUT OF THE FRISCO RAILROAD THREE-QUARTERS OF A MILE NORTH OF DENISON, GRAYSON COUNTY, TEX.

Louis & San Francisco Railroad 1½ miles north of Denison and was seen also on the Missouri, Kansas & Texas Railway 1¼ miles north of Denison; on the Bears Ferry road about 1½ miles in an air line northwest of the post office at Denison; in the headwater branches of Shawnee Creek, 3½ miles west by north of the post office at Denison; and at Fink post office, 3 miles north of Pottsboro. Messrs. Hopkins and Powers noted outcrops of a stratum that carries *O. carinata* Lamarck and apparently represents the "*Ostrea carinata* bed" stratigraphically 55 feet above the Fort Worth limestone, at two localities on the north limb of the anticline in Marshall County, Okla., namely, 3¼ miles southeast of Kingston, in the NE. ¼ sec. 3, T. 7 S., R. 6 E.; and 2½ miles east of Kingston, in the SE. ¼ sec. 28, T. 6 S., R. 6 E.

WENO CLAY MEMBER.

The Denton clay member is overlain by 115 feet of dark-gray shaly clay with subordinate thin partings, lenses, and layers of fine gray to yellow sand, some of which are indurated to ledge-forming sandstone. To this material Hill[1] gave the name Weno formation, from the small village of Weno, on Red River 5 miles northeast of Denison, Grayson County, which does not appear on recent maps and is apparently abandoned. Hill in the same paper also used the name Weno in a broader ("subgroup") sense, to include both the Weno clay member and the overlying Pawpaw sandy member, a usage not followed in the present paper. Sand layers are numerous, though subordinate to the clay, in the upper 35 feet of the division in cuts of the St. Louis & San Francisco Railroad about a mile north of the station at Denison (see Pl. XXII, *B*), where one lens has a maximum thickness of 1½ feet. At the same locality the clays contain many small flattish ferruginous concretions, probably derived by oxidation from concretions of iron carbonate, and some small concretions of marcasite. Fossil pelecypods and gastropods in a good state of preservation are numerous in the clays, sands, and ferruginous concretions in these upper beds, among which were recognized *Nucula* sp., *Ostrea quadriplicata* Shumard, *Protocardia texana* (Conrad), *Cyprimeria* sp., *Corbula* (three species), *Cymbophora* sp., *Turritella* sp., *Auchura mudgeana* White, *Engonoceras serpentinum* (Cragin).

The Weno clay weathers down to smooth surfaces and is as a rule poorly exposed on the uplands and valley slopes. In addition to the section in the railroad cut just described, a good exposure of strata believed to represent a portion of the Weno clay and certainly representing either this clay or the Pawpaw member is afforded by Carpenters Bluff, on Red River below the bridge of the Missouri, Oklahoma & Gulf Railway, 7 miles in an air line due east of Denison. Hill mapped the area in which this bluff is included as belonging to the Woodbine formation, though Taff had at an earlier date recognized that the outcrop at the bluff belonged to the Washita group. This exposure is about on the southeastward-plunging axis of the Preston anticline.

According to Messrs. Hopkins and Powers the Weno clay in the north limb of the Preston anticline in Marshall County, Okla., is about 135 feet thick, or 20 feet thicker than in the south limb in Grayson County, Tex. A fine exposure of the upper 50 feet of the Weno, overlain by the "Quarry" limestone, is afforded by a bluff on the left bank of Washita River at the crossing of the St. Louis & San Francisco Railroad 2¾ miles west of Platter, Bryan County, Okla. A view of this bluff, taken at a low stage of water, is shown in Pl. XXII, *A*. The beds here consist predominantly of greenish shaly calcareous clay, with an interstratified layer of sandstone 5 or 6 feet below the "Quarry" limestone and several layers of thin flaggy sandstone 25 to 40 feet below the "Quarry." Well-preserved fossil shells, many species of which are identical with those collected in a cut of the St. Louis & San Francisco Railroad a mile north of Denison in Grayson County, Tex., are abundant in some layers of the clay and in some of the indurated layers. Several well-preserved fragments of crustaceans were found in the talus.

About 20 feet of dark shaly clay of the Weno member, containing poorly preserved fossils, is well exposed in the left bank of a branch just east of the Missouri, Kansas & Texas Railway, 1½ miles south of Colbert, Bryan County, Okla.; this locality also is on the north limb of the Preston anticline.

[1] Hill, R. T., U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 121, 274, 1901.

PAWPAW SANDY MEMBER (INCLUDING "QUARRY" LIMESTONE).

The Weno clay member is overlain by approximately 50 feet of more or less irregularly bedded clays and sands, including at the base a persistent layer of sandy limestone 1 to 4 feet thick, known as the "Quarry" limestone. Calcareous clay predominates in the lower half of the division above the "Quarry" limestone, and sand and interbedded laminated sand and clay predominate in the upper half. Good exposures, particularly of the upper part of the member, occur in the headwater branches of Pawpaw Creek within the corporate limits of the eastern part of Denison.

The "Quarry" limestone is a sandy bluish-gray limestone that weathers yellow and purple and contains considerable numbers of *Ostrea quadriplicata* Shumard. *Ostrea subovata* Shumard is rather sparingly represented. A good exposure is afforded by a cut of the St. Louis & San Francisco Railway three-quarters of a mile north of the station at Denison (see Pl. XXII, *B*), where it is 2 feet thick and the lower 3 to 12 inches is conglomeratic. The somewhat scattered pebbles in the conglomeratic portion consist of waterworn calcareous sandstone, sandy limestone, and calcareous and ferruginous concretions, the largest 3 inches or more in length. A few borings into the top of the underlying Weno clay, filled with material characteristic of the limestone, were noted. As the base of the limestone is sharply separated from the underlying clay and is somewhat undulating, the contact appears to mark an unconformity, though the time represented by it was probably short. The limestone in this section is overlain by 4 feet of clay, above which is another layer of similar limestone 6 inches to 1 foot thick, which shows the lenticular character of the rock and which apparently connects the "Quarry" limestone more closely with the overlying Pawpaw member than with the underlying Weno clay. In this connection it may be mentioned that Messrs. Hopkins and Powers have noted in Marshall County, Okla., several layers of sandy limestone in the Pawpaw member that resemble the "Quarry."

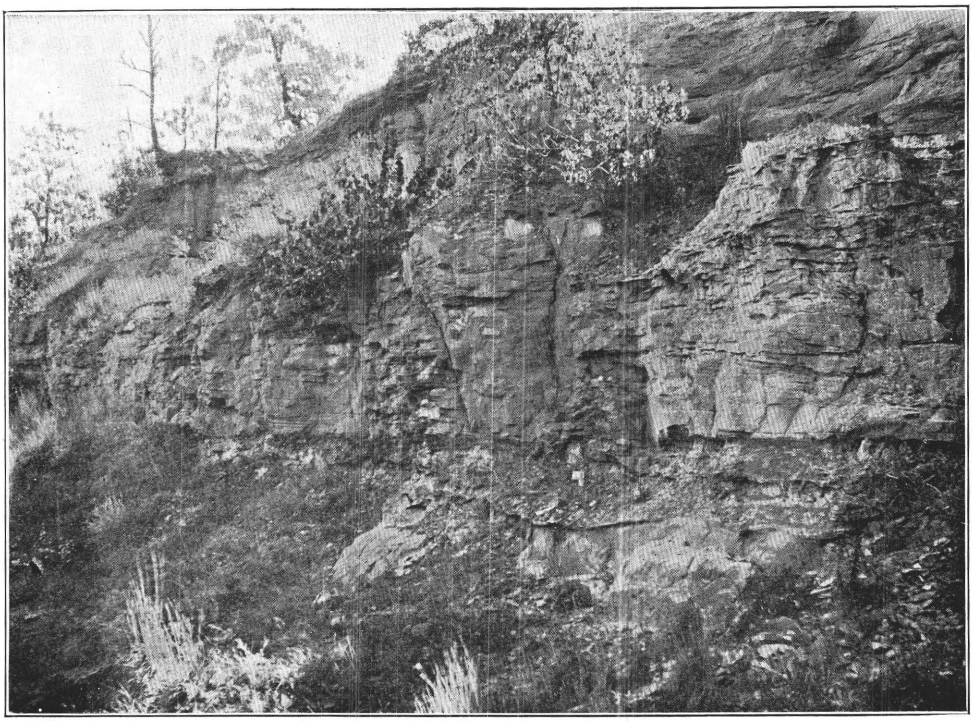
Other outcrops of the limestone were examined in Grayson County in the bed of a small branch of Smith Creek just south of the Missouri, Oklahoma & Gulf Railway, 4¾ to 5½ miles east of Denison; in a ditch and in a field south of the Missouri, Oklahoma & Gulf Railway about 2½ miles east of Denison; at a culvert of the Missouri, Oklahoma & Gulf Railway about 2 miles east of Denison; in a north-south public road 1½ miles east by north of Pottsboro; in an east-west road at two creek crossings 2 miles north of Pottsboro; in the Henderson Ferry road 2¾ miles north of Pottsboro, a quarter of a mile south of Fink; and in the public road a quarter of a mile west of Fink.

On the north limb of the Preston anticline the "Quarry" limestone outcrops at the crest of the steep part of the bluff on Washita River at the crossing of the St. Louis & San Francisco Railway in Bryan County, Okla. (see p. 141), where it overlies the Weno clay and is overlain in turn by clays and sands of the Pawpaw member. Poor exposures were also noted near the public road leading to Kingston, about 3 miles northwest of Woodville, in Marshall County, Okla. Messrs. Hopkins and Powers state that in the latitude of Kingston and farther north there is no definitely recognizable "Quarry" limestone, but several beds resembling it; 3 miles east of Kingston they examined a section which included four distinct layers of sandy limestone each resembling the "Quarry" and each containing *Ostrea quadriplicata* Shumard. Mr. Hopkins noted an outcrop of a sandy glauconitic limestone resembling the "Quarry" 4 miles east of Kingston, Marshall County, in the center of the west line of sec. 35, T. 6 S., R. 6 E., from which he obtained a specimen of a bryozoan which R. S. Bassler refers to the genus *Domopora*.

The section described below shows the relation of the Pawpaw member to the overlying Main Street limestone member. (See Pl. XXIV, *B*.)

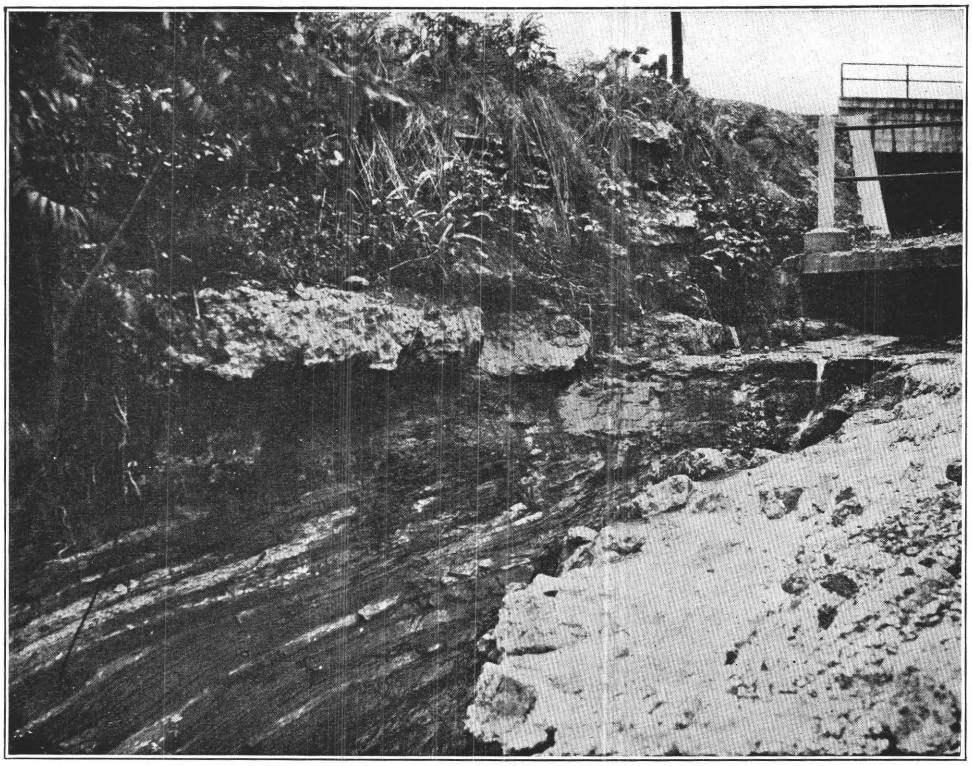
Section in a small headwater branch of Pawpaw Creek just east of the subway under the Missouri, Kansas & Texas Railway south of the station at Denison, Tex.

	Feet.
Main Street limestone member:	
Irregular nodular layers of hard limestone 6 to 18 inches thick, interbedded with soft yellow marl a few inches to 6 inches thick; the under side of the lowest limestone layer is roughly nodular. *Exogyra arietina* Roemer occurs abundantly in the upper 2 or 3 feet.....	8
Gray, faintly laminated sandy and calcareous (marly) clay, coarsely sandy in the basal few inches; in the basal 6 inches are numerous small ferruginous concretions and a few flattish, partly oxidized iron carbonate concretions; one apparently water-worn quartzitic sandstone pebble was noted.....	1½–2



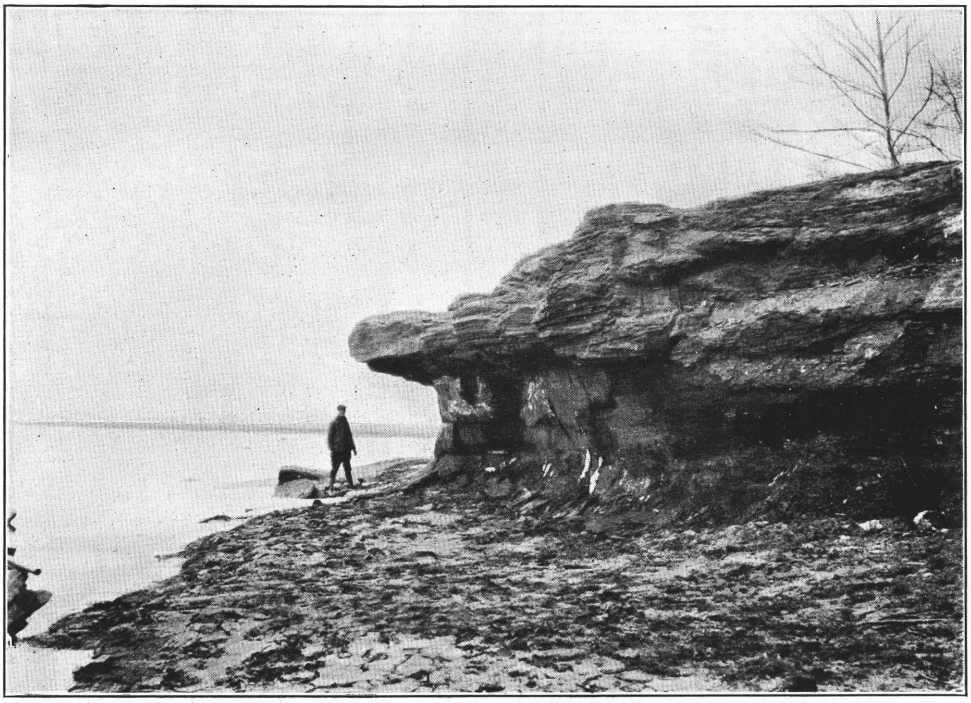
A. WOODBINE SAND IN A CUT OF THE MISSOURI, KANSAS & TEXAS RAILWAY 1½ MILES WEST BY SOUTH OF THE STATION AT DENISON, GRAYSON COUNTY, TEX.

The Woodbine here is a partly indurated ferruginous sand, containing irregularly distributed thin ironstone plates.

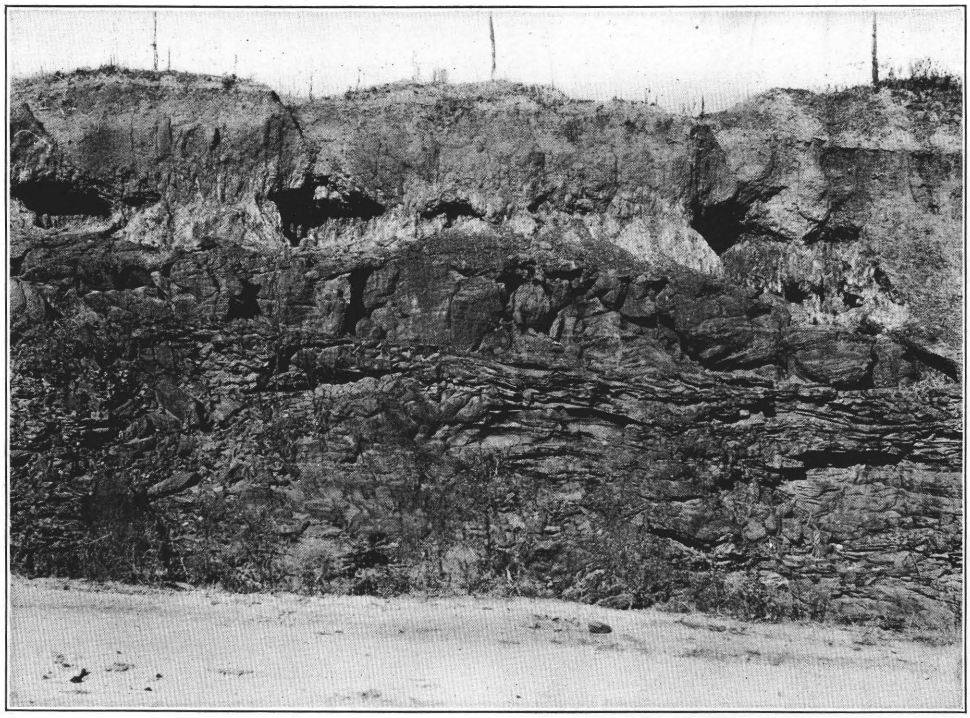


B. MAIN STREET LIMESTONE UNDERLAIN BY THE PAWPAW SANDY MEMBER OF THE DENISON FORMATION NEAR THE SUBWAY SOUTH OF THE MISSOURI, KANSAS & TEXAS RAILWAY STATION AT DENISON, GRAYSON COUNTY, TEX.

The Pawpaw member, as exposed at this locality in a headwater branch of Pawpaw Creek, comprises laminated cross-bedded sand and clay.



A. SAND AND CLAY OF THE WOODBINE FORMATION AT HYATTS BLUFF, ON RED RIVER 5 MILES NORTHWEST OF RAVENNA, FANNIN COUNTY, TEX.



B. FERRUGINOUS SAND OF THE WOODBINE FORMATION IN THE SHERMAN ROAD, 2 MILES SOUTHWEST OF DENISON, GRAYSON COUNTY, TEX.

	Feet.
Unconformity (?).	
Pawpaw sandy member:	
Thinly laminated, strongly cross-bedded gray clay and sandy clay with thin sand partings and some larger lenses of fine yellow sand; numerous thin iron crusts occur in the partings; some comminuted plant fragments were noted	6

The upper 6 feet of the Pawpaw is also well exposed beneath the Main Street limestone on the Missouri, Kansas & Texas Railway at the iron overhead bridge 3 miles west of the station at Denison. (See below and Pl. XXIII, *A*.) Here the Pawpaw consists of current-bedded, laminated sand and clay with highly fossiliferous thin lenses of ferruginous oxidized soft sandstone. Among the fossils recognized were *Nucula* sp., *Protocardia texana* (Conrad), *Cymbophora* sp., *Corbula* sp., *Anchura mudgeana* White, and *Engonoceras serpentinum* (Cragin).

The Pawpaw member produces a narrow belt of sandy soil between the clay soils of the Weno and those of the overlying Main Street limestone and the Grayson marl. The topography produced by the sandy beds of the Pawpaw is similar to that characteristic of the outcrop of the Woodbine formation of the Gulf series.

MAIN STREET LIMESTONE MEMBER.

The Main Street limestone, named from exposures on Main Street in Denison, consists, in Grayson County, of 8 to 20 feet or more of heavy-bedded hard limestone, with subordinate interbedded layers of unconsolidated calcareous marl, and is characterized by the presence of *Exogyra arietina* Roemer, particularly in the upper part, and of *Kingena wacoensis* (Roemer) in the lower part. One of the best exposures of the limestone is afforded by a cut of the Missouri, Kansas & Texas Railway 3 miles west of the station at Denison. (See Pl. XXIII, *A*.)

Section in cut of Missouri, Kansas & Texas Railway 3 miles west of the station at Denison, Grayson County, Tex.

	Feet.
Residuum and creep:	
Brownish loam containing in places along its base a great number of ferruginous sandstone fragments and boulders derived from the Woodbine sand	2–6
Main Street limestone member:	
Irregular layers of limestone 3 to 4 feet thick, with discontinuous interbedded lenses of soft marl, underlain by 3 to 4½ feet of massive hard limestone having an undulating nodular base; *Exogyra arietina* Roemer is common in the upper layers	7½
Main Street limestone member—Continued.	Feet.
Greenish-gray sandy calcareous clay marl with scattered white clay pebbles and ferruginous concretionary clay nodules along the base, some of which suggest having been mechanically included	1¼–1½
Unconformity (?).	
Pawpaw sandy member:	
Current-bedded greenish-gray fine sand, with fine clay laminae and subordinate lenses of laminated clay. Highly fossiliferous thin discontinuous lenses of ferruginous oxidized soft sandstone with many molds and internal casts of fossil mollusks; soft molds and internal casts occur also in the soft sands. (See list, above.) Maximum exposed thickness	6

The limestone is poorly exposed on Main Street east of the railroad tracks in the eastern part of Denison and is well exposed in some of the branches and on the slopes about the headwaters of Pawpaw Creek in the same vicinity. One section is described on page 122. (See also Pl. XXIV, *B*.)

Other exposures of the limestone were noted along the south limb of the Preston anticline in Grayson County, in the bed of a headwater branch of Iron Ore Creek just north of the Missouri, Kansas & Texas Railway, 5¼ miles west of the station at Denison and a quarter of a mile east of a north-south public road; poor exposures showing dips of 20° or more in a low strike ridge extending from a point 2 miles east of Pottsboro northwestward for a distance of 2 miles; in the bed of a headwater branch of Little Mineral Creek on the Henderson Ferry road 2½ miles north of Pottsboro, seven-eighths of a mile south of Fink; poor exposures along the east-west public road three-fourths of a mile to 1½ miles west of Fink; on the same road near the heads of ravines 2¼, 2½, 2¾, and 3⅛ miles west of Fink, overlain by the Grayson marl, which appears in several poor exposures; in the bed of a small southward-flowing branch of Mill Creek about 4 miles west by north of Fink; along a north-south public road 2 miles east by south of Cedar Mills; on a public road on the westward-facing slope of the Mineral Creek valley 1½ miles east by south of Cedar Mills; in a small branch at the turn of the road just south of Cedar Mills; on the northward-facing slope of the Sandy Creek valley just north of Cedar Mills; at the crossing of a public road over a headwater branch of Brier Creek 5 miles northwest of Gordonville; and on the southeast

crest of Brushy Mound, 9 miles northwest of Gordonville.

The Main Street limestone was not seen in place by the present writer on the north limb of the Preston anticline, but Messrs. Hopkins and Powers state that they have seen it well exposed at the following localities in Oklahoma: In Bryan County on the south bank of Rock Creek along the public road, 2 miles northwest of Platter; and in Marshall County a mile west of Washita River; on the south bluff of Washita River at the southeast corner of sec. 7, T. 7 S., R. 7 E.; 2 miles northeast of Woodville, in the center of the east line of sec. 19, T. 7 S., R. 7 E.; and 4 miles north of Woodville, in the NW. ¼ sec. 1, T. 7 S., R. 6 E. According to the geologic map of the Tishomingo quadrangle, which joins the Denison quadrangle on the north, the Bennington limestone of Taff, which includes the Main Street limestone, enters the Denison quadrangle 2 or 3 miles west of its northeast corner.

GRAYSON MARL MEMBER.

The topmost division of the Denison formation and of the Washita group, known as the Grayson marl, consists of 15 to 25 feet of light greenish-gray calcareous clay or marl with lumps of white lime and several nodular thin layers of limestone. The fossils carried by the marl include species of *Gryphaea*, *Pecten*, *Trigonia*, *Plicatula*, *Protocardia*, *Turrilites*, and *Hoplites*, of which *Gryphaea mucronata* Gabb is perhaps the most common.

The marl is poorly exposed above the Main Street limestone about the headwater branches of Pawpaw Creek, in the eastern part of Denison. The best exposure examined was in a pit south of the Missouri, Oklahoma & Gulf Railway about a quarter of a mile east of the station at Denison, where a thickness of 16 feet of the marl was noted.

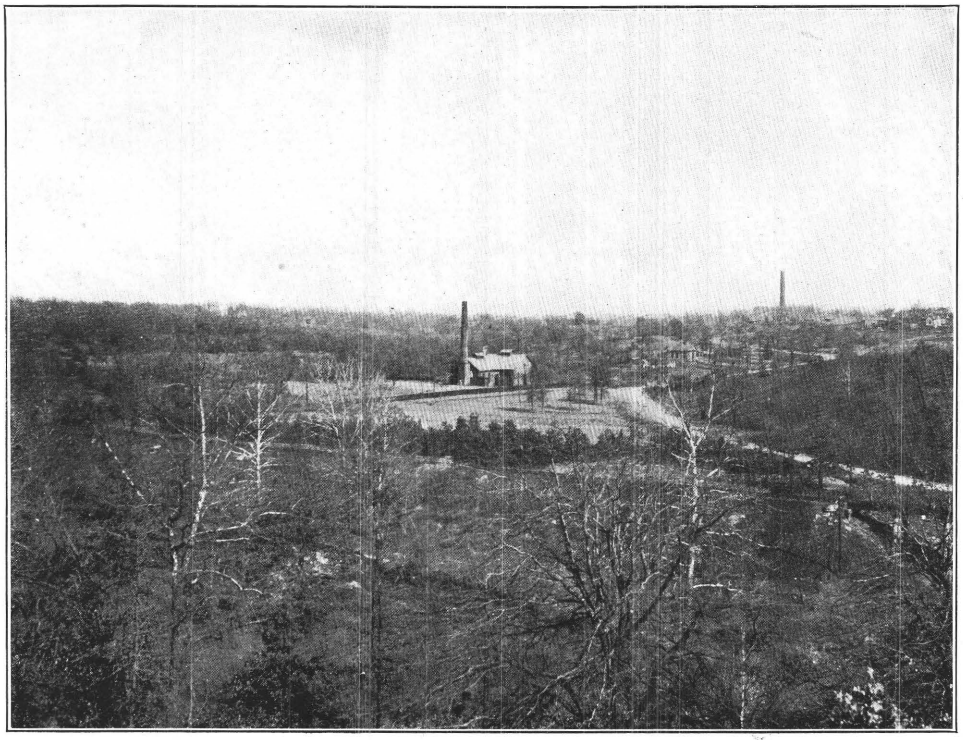
Other exposures in Grayson County occur in the banks of headwater branches of Iron Ore Creek near the Missouri, Kansas & Texas Railway 5¼ to 5½ miles west of Denison; in the bank of a headwater branch of Little Mineral Creek near the crossing of the Henderson Ferry road, 2½ miles north of Pottsboro and seven-eighths of a mile south of Fink; and at intervals on and near the public road leading west from Fink for a distance of about 4 miles.

GULF SERIES.

GENERAL CHARACTER.

The Gulf series is composed of sands, shaly clays, chalks, and calcareous clays and sands (marls), which have an estimated thickness of approximately 3,000 feet in the area under consideration. In the southwestern part of the area the succession of formations in the series is, in ascending order, as follows: Woodbine sand, Eagle Ford clay, Austin chalk, Taylor marl (including the Wolfe City and Pecan Gap members; see pp. 155–156), and Navarro formation. Toward the north the lower part of the Austin chalk merges, with some intertonguing, into contemporaneous nonchalky sands and clays, and the upper part of the Austin transgresses to a higher position in the geologic column, so that in Fannin and Hunt counties the following succession of mappable units is recognizable: Woodbine sand, Eagle Ford clay, unnamed clays and sands beneath the Austin chalk, Ector tongue of Austin chalk, unnamed clay in the vicinity of Bonham, Annona tongue of Austin chalk, Taylor marl (including Wolfe City and Pecan Gap members), and Navarro formation. Still farther to the northeast, in Lamar, Delta, and Hopkins counties, the succession of units is as follows: Woodbine sand (exposed at Arthurs Bluff, on Red River), Eagle Ford formation (largely concealed by terrace deposits), unnamed sands and clays (also largely concealed), Blossom sand, Brownstown marl, Annona tongue of Austin chalk, Taylor marl, and Navarro formation. The age relations of the units just named in different parts of the area are diagrammatically represented in the correlation section given in Plate XXX, *C* (p. 155).

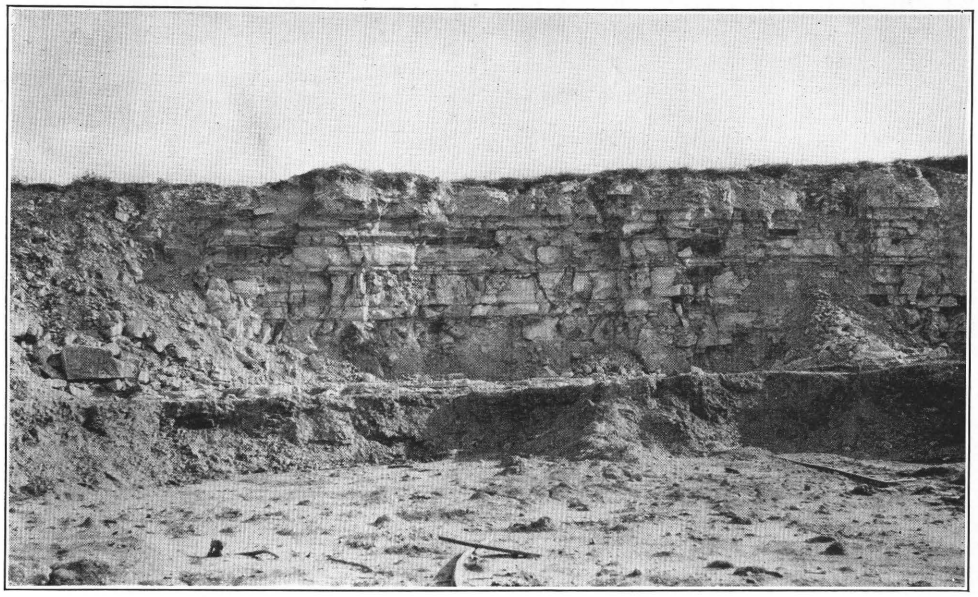
The Gulf series is referable in its entirety to the Upper Cretaceous, though, as indicated on page 134, it may not include representatives of the lowermost part of the Upper Cretaceous. The nature of the contact separating the Gulf series from the underlying Comanche series has not been satisfactorily determined in northeastern Texas. Probably it is that of unconformity, the basal formation of the upper series, the Woodbine sand, having been deposited in the shallow waters of the transgressing sea, in the deeper waters of which the succeeding truly marine sediments of the series were



A. TOPOGRAPHY IN THE HILLY AREA UNDERLAIN BY THE WOODBINE SAND 1¾ MILES SOUTHWEST OF DENISON, GRAYSON COUNTY, TEX.

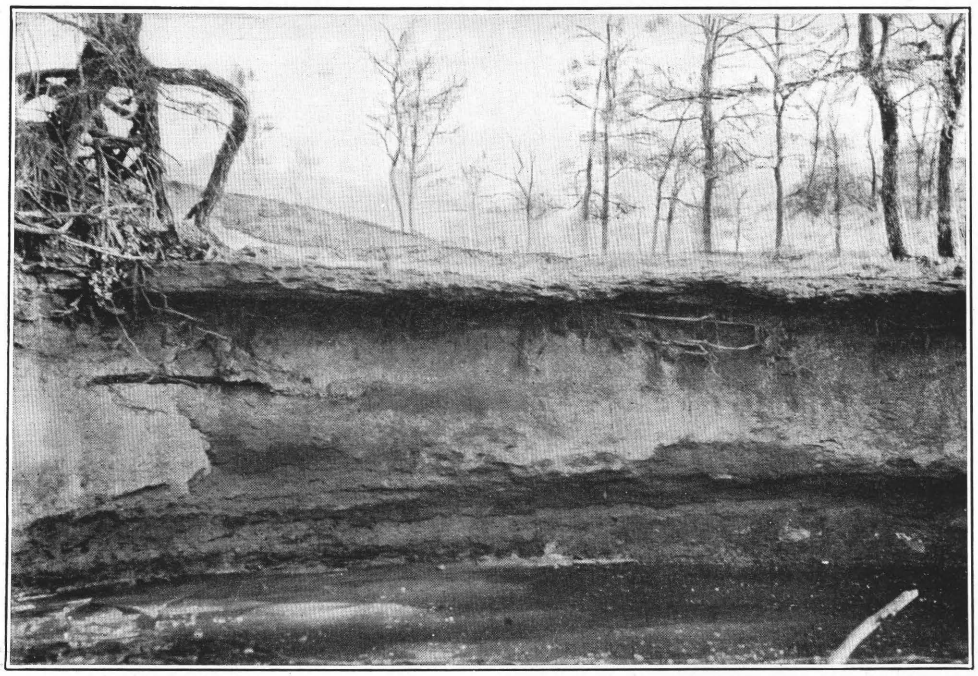
View looking northeast toward the old waterworks plant.

B. A DETAIL OF TOPOGRAPHY IN A SMALL BRANCH VALLEY UNDERLAIN BY THE WOODBINE SAND 1½ MILES SOUTHWEST OF DENISON, GRAYSON COUNTY, TEX.



A. CONTACT BETWEEN THE EAGLE FORD CLAY AND THE AUSTIN CHALK IN A QUARRY OF THE TEXAS PORTLAND CEMENT CO. 3 MILES WEST OF DALLAS, TEX.

The contact between the Eagle Ford clay and the Austin chalk is approximately marked by the crest of the prominent bench in the foreground.



B. "FISH-BED CONGLOMERATE" (?) IN THE BED OF A BRANCH 3 MILES SOUTH OF RAVENNA, FANNIN COUNTY, TEX.

The indurated conglomeratic layer is immediately underlain by somewhat argillaceous fine marine sand, which here forms the topmost stratum of the Eagle Ford clay.

laid down. Toward the south the Woodbine sand becomes progressively thinner, finally disappearing in McLennan County, south of which the Eagle Ford clay rests directly upon the Buda limestone of the Comanche series. The absence of the Woodbine in central and southwestern Texas would therefore seem to indicate unconformity, unless the age equivalent of the Woodbine lies in the relatively thin sediments that compose the Buda limestone, a supposition which seems highly improbable and which has no basis of known fact.

WOODBINE SAND.

The Woodbine sand, named from the village of Woodbine, in Cooke County, is the basal division of the Gulf series in northeastern Texas. It is a highly variable formation, consisting of strongly current-bedded, more or less ferruginous sand and laminated shaly clay, with some interbedded layers of lignite and lignitic clay. On account of the irregularity of the bedding it is scarcely possible to determine the thickness of the formation from surface outcrops, but it is reasonably certain that in Grayson County the thickness is not less than 300 or 400 feet and may be as great as 500 feet. A well at Ladonia, in the southeast corner of Fannin County, penetrated between depths of 1,800 and 2,425 feet about 625 feet of sand and clay which are interpreted as belonging to the Woodbine. As stated above, the Woodbine becomes progressively thinner toward the south, finally disappearing in McLennan County. The formation is traceable eastward from Grayson County through Texas and into Arkansas, where it is believed to be represented by a part at least of the Bingen sand.

The scope of this paper will not permit a detailed account of the many different lithologic aspects of the formation, for which the reader is referred to the sections described by Hill and Taff in the papers listed on pages 130–131. Hill recognized two subdivisions of the Woodbine—a lower member, called by him the Dexter sands, consisting of an estimated thickness of 160 feet of "brown and yellow ferruginous sandstone heavily laden with siliceous ironstone," 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, ferruginous reddish-brown sandstone, shell sandstone, and argillaceous shelly sandstone which contains large lenslike calcareous concretions and laminated argillaceous sandstones at the top." Sand seems to predominate over clay, producing a pronounced sand-hill type of topography, as in the country immediately southwest and west of Denison; but locally clay makes up the bulk of the formation, producing a smoothly rolling surface, as in the belt of country northwest of Pottsboro. (See p. 132.)

Fossil leaves have been obtained from the lower member (Hill's Dexter sands) of the Woodbine near Denison. The upper member (Hill's Lewisville beds) yields a peculiar shallow marine fauna that differs markedly from the Cretaceous faunas either below or above it in Texas. This fauna is best known from exposures on Timber Creek, 3 or 4 miles west, southwest, and south of Lewisville, Denton County, Tex., and though it includes a relatively small number of species is rich in individuals, which largely make up certain lenses and layers of the formation. The following are some of the species that have been described:

Arca (Barbatia) micronema (Meek), numerous.
Ostrea soleniscus Meek, very numerous.
Modiolus filisculptus Cragin.
Cytherea leveretti Cragin.
Cerithium tramatensis Cragin.
Cerithium interlineatum Cragin

The fossiliferous strata of the upper member are represented in Grayson County, though they are not so conspicuously exposed as they are on Timber Creek in Denton County.

Fossil plants have also been collected from beds regarded as representing the Woodbine formation at Arthurs Bluff, on Red River 15 miles north of Paris, in Lamar County, Tex.

The Woodbine sand outcrops in a belt a few miles wide along the south limb of the Preston anticline (see geologic map, Pl. XVII) and in a north-south belt along the western border of the area mapped. The belt of outcrop wraps around the southeastward-plunging nose of the Preston anticline in northwestern Fannin County, Tex., and passes northward into Oklahoma, where it extends in a broad belt to the northwest and north, and to the east down the Red River valley. Exposures of the Woodbine at three localities are shown in Plates XXIV, *A*, and XXV, *A* and *B*.

The formation may be studied to advantage on sandy hills along the northern margin of the belt of outcrop between Pottsboro and Cedar Mills, in Grayson County; in road and railroad cuts and creek beds between Denison and Pottsboro, and for several miles southwest of Denison; in cuts of the Missouri, Kansas & Texas Railway in the western outskirts of Denison, Grayson County (see Pl. XXIV, *A*); in roads and stream banks and beds in the hilly country within 6 or 7 miles east-southeast of Denison; on sandy hills in the northwestern part of Fannin County; and at Hyatts Bluff, on Red River just above the mouth of Caney Creek, 6 miles northwest of Ravenna, Fannin County (Pl. XXV, *A*).

Hyatts Bluff, not heretofore described, is half a mile long and 45 feet high and trends N. 28° E. Reddish terrace sand forms the upper 20 feet of the section, beneath which are 25 feet of Woodbine strata consisting of soft cross-bedded glauconitic sandstone; dark-greenish, more massive soft glauconitic sandstone; small lenses of pebbly sand; and dark shaly clay. The main bedding planes are fairly persistent and dip perceptibly downstream. One persistent sandstone stratum 2½ feet thick, overlain by a lignitic band a foot thick, was traced from a point where it is 20 feet above water level for 1,800 feet along the face of the bluff to a point where it passes beneath water level. The dark shaly clay forming the portion of the section that is stratigraphically highest in the Woodbine contains concretions of iron carbonate, some of which are fossiliferous, and there is one layer of dark-greenish glauconitic soft sandstone containing the abundant remains of a poorly preserved molluscan fauna that inhabited a shallow sea. The photograph reproduced in Plate XXV, *A*, was taken where the lignitic band lies at water level and is overlain by 4 or 5 feet of shaly, easily eroded clay. The conspicuous projecting ledge is highly cross-bedded sandstone along the base of which are discontinuous small lenses of conglomerate.

EAGLE FORD CLAY.

The Woodbine sand is overlain by the Eagle Ford clay, a formation named from Eagle Ford, a village 6 miles west of Dallas, where it is typically exposed. The formation 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 and Fannin counties the formation has an estimated thickness between 300 and 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 20 or 25 feet of the formation in the vicinity of Sherman the dark clays are interstratified with beds of sand, one of which, 15 to 20 feet below the base of the Austin chalk, carries vast numbers of the small fluted oyster, *Ostrea lugubris* Conrad. Ten feet below the base of the Austin chalk, which in Grayson County overlies the Eagle Ford, 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,[1] which in the opinion of the present writer (see p. 149) should not be included in the Eagle Ford but should be regarded as the base of the sediments that have their typical expression in the Austin chalk.

The formation outcrops in an east-west belt through the northern part of Grayson County and the northwestern part of Fannin County, but the belt is sharply deflected to the south in northwestern Fannin County, where it passes around the southeast end of the Preston anticline. In the northern part of Fannin County the formation passes under the Pleistocene terrace deposits of the Red River valley; east of Fannin County the only place where it has been certainly recognized in surface outcrops is Garretts Bluff, in the northwestern part of Lamar County. Two localities where the formation can be advantageously studied in northern Fannin County are at Sowells Bluff, on Red River 5 miles northwest of Ivanhoe, and in deep ravines in the westward-facing slope of the Red River valley 6 miles north of Ivanhoe. At the last-named locality, where approximately 140 feet of strata are exposed, the upper part of the section exhibits a larger

[1] Texas Geol. Survey Fourth Ann. Rept., for 1892, pp. 299–304, 1893.

proportion of sandstone than is typical of the formation, and some beds of the sandstone are cross-bedded, simulating the Woodbine sand. Below this dominantly sandy portion, 40 or 50 feet below the top of the section, is a gravel layer generally less than a foot thick, composed chiefly of dark, smooth pebbles which have not yet been critically studied. This may represent the "fish-bed conglomerate," in which case both the pebble layer and the beds above it, including the dominantly sandy strata, should, in the writer's opinion, be excluded from the Eagle Ford formation. Characteristic Eagle Ford fossils have been obtained from wells in northeastern Louisiana.[1]

West of Sherman and Denison the belt of outcrop bends nearly due south and is traceable through Texas to the Rio Grande, which it intercepts in Kinney and Valverde counties. Well records show the formation to be 535 feet thick in the western part of Collin County, Tex., and 460 to 485 feet in the vicinity of Dallas; south of Dallas it becomes thinner, reaching a minimum of about 30 feet at Austin; southwestward and westward from Austin the thickness again increases, being 75 feet or more in the Uvalde quadrangle and about 250 feet in the Brackett quadrangle.

The sandy beds at the top of the Eagle Ford have been traced from the vicinity of Sherman eastward through Grayson County and northeastward to about the north-central part of Fannin County. Good exposures of the sandy beds occur in the vicinity of Bells in eastern Grayson County. A mile west of Bells the east-west public road that runs about a quarter of a mile south of the Texas & Pacific Railway crosses a layer of ferruginous sandstone at the head of a northward-flowing branch of Mill Creek, which probably represents the "fish-bed conglomerate." (See p. 146.) The sandstone is underlain by 4 or 5 feet of dark greenish-gray massive sand, and in succession down the ravine follow 35 or 40 feet of more or less argillaceous fine sand, with layers of soft yellow sandstone at intervals, and about 40 feet of dark shaly gypsiferous septaria-bearing clay, typical of the Eagle Ford clay.

Another good exposure of the sandstone layer ("fish-bed conglomerate") occurs in an east-west public road on the westward-facing slope of the Mill Creek valley 2 miles in an air line southwest of Bells, where it is underlain by 15 or 20 feet of fine gray massive marine sand. The base of the Austin chalk appears at a higher level in the same road a short distance east of the outcropping ledge of sandstone, from which it is separated by 10 or 15 feet of poorly exposed strata, apparently clay.

From the vicinity of Bells eastward these upper sandy beds of the Eagle Ford have produced a narrow belt of country characterized by sandy soil and rougher topography than that exhibited by the adjacent land either to the north or to the south. Outcrops of the persistent "fish-bed conglomerate" occur here and there just above the sand and serve as a check to the correlation of this sandy member of the Eagle Ford, which crosses the headwaters of Caney Creek 2½ miles southeast of Bells and, approximately paralleling this creek, swings around the plunging nose of the Preston anticline and extends to the northeast past Lesleys schoolhouse, Ector, and Ravenna, in Fannin County. The "fish-bed conglomerate" is more fully described on pages 148–149.

The upper part of the Eagle Ford formation is exposed in a branch west of a north-south road and south of an east-west portion of the same road 3 miles south of Ravenna. Immediately below the conglomerate at the locality shown in Plate XXVII, *B*, is 5 feet of fine argillaceous marine sand, near the top of which was observed a large piece of lignite. Within about a quarter of a mile farther down the branch occur good exposures of typical dark shaly gypsiferous clay of the Eagle Ford formation; interbedded with this clay are subordinate layers of fine-grained sandstone and a few layers and lenses of gray calcareous earthy rock that exhibits finely developed cone-in-cone structure. In places thick layers of this earthy rock surround apparently concretionary masses of limestone. Several specimens of *Ostrea lugubris* Conrad were found loose in the bed of the creek below the outcrop of the conglomerate and probably came from some bed in the upper part of the Eagle Ford.

Some of the common fossils of use in recognizing the Eagle Ford formation 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 ammo-

[1] Matson, G. C., The De Soto-Red River oil and gas field, La.: U. S. Geol. Survey Bull. 661, p. 115, 1917.

nites belonging to *Prionotropis* or *Prionocyclus*, or to both. Of these the first three occur only in the upper 40 or 50 feet of the formation.

AUSTIN CHALK.

TYPICAL AREA.

The Austin chalk is typically exposed in the vicinity of Austin, Travis County, Tex., where it rests upon the Eagle Ford clay, is approximately 410 feet thick, and consists of white chalky limestone in beds of varying thickness, with interbedded marly layers in its upper two-fifths. Some of the common fossils that are especially characteristic of the formation are the following:

Inoceramus undulato-plicatus Roemer.
Ostrea aff. O. diluviana Lamarck (uppermost part).
Gryphaea aucella Roemer.
Exogyra ponderosa Roemer (upper half).
Exogyra laeviuscula Roemer (upper half).
Radiolites austiniensis Roemer.
Mortoniceras texanus (Roemer).

The Austin chalk extends from the Rio Grande in Maverick County, Tex., eastward by way of Uvalde to San Antonio, thence northeastward to Austin, and thence northward by way of Waco and Austin to Grayson County. From Austin northward the chalk thickens, and its upper surface appears gradually to transgress upward across the geologic column, or, in other words, to become younger, until in the latitude of Sherman the uppermost bed of chalk is considerably younger than the top of the chalk at Austin and occupies a position stratigraphically 400 or 500 feet higher. The exact manner in which this upward transgression takes place, whether by a gradual rise or by minor tongues of chalk at successively higher positions, has not been determined, very little detailed field work having been done in the intervening area.

DEVELOPMENT IN NORTHEASTERN TEXAS.

SALIENT FEATURES.

In the Sherman-Greenville section the Austin chalk is probably not less than 1,000 feet thick. In the eastern part of Grayson County and the western part of Fannin County, however, the lower two-fifths or more of the chalk becomes impure and gradually passes laterally into nonchalky sands and clays and only slightly chalky clay marls. In a section drawn through Bonham, Fannin County, and Commerce, Hunt County, the succession of recognizable and mappable lithologic units is decidedly different from that in the latitude of Austin. In Collin, Hunt, and Delta counties other lithologic changes have taken place in beds above the chalk, representing the upper part of the Taylor marl, and these changes add further contrast to the section in northeastern Texas as compared to that in the Austin region. These relations are diagrammatically shown in Plate XXX, *C*.

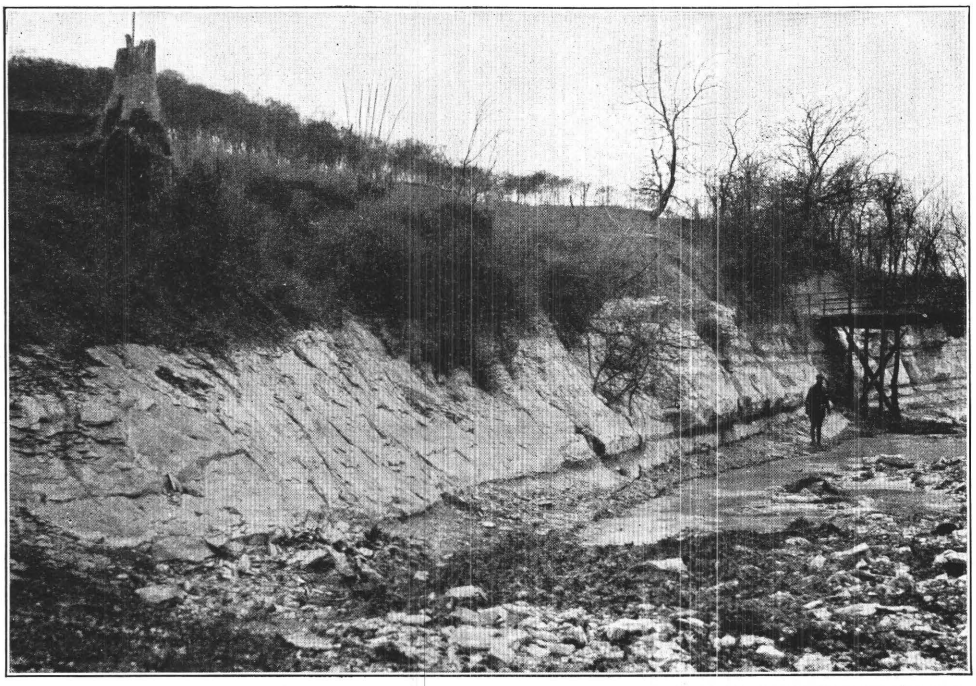
In the Bonham-Commerce section the following divisions, named in ascending order, together represent the chalk and its equivalents in this area: A band of basal nonchalky clay and sand 10 to 35 feet thick, with the "fish-bed conglomerate" described below, at its base, all mapped with the Ector tongue; the Ector tongue of the Austin chalk; an unnamed transitional clay in the vicinity of Bonham (p. 150); and the Annona tongue of the Austin chalk. (See Pl. XXX, *C*.)

In the longitude of Paris, Lamar County, the chalk and its equivalents include imperfectly known beds, probably clay, sand, and marl, representing the eastward extension of the Ector tongue and part of the clay in the vicinity of Bonham; the Blossom sand; the Brownstown marl; and the Annona tongue of the Austin chalk. (See Pl. XXX, *C*.)

UNNAMED CLAYS AND SANDS CONTEMPORANEOUS WITH BASAL PART OF TYPICAL AUSTIN CHALK.

Phosphatic pebbles occur in the base of the Austin chalk, immediately above its contact with the underlying Eagle Ford formation, in a quarry of the Texas Portland Cement Co., 3 miles west of Dallas, Tex. (See Pl. XXVII, *A*.) In Grayson County, Tex., a conglomeratic layer, a few inches to 30 inches thick, called by Taff [1] the "fish-bed conglomerate," occurs 10 feet below the base of the chalk, with beds of shaly clay and sand intervening. From Grayson County the conglomerate extends eastward into Fannin County, where from west to east the interval between the conglomerate and the base of the overlying chalk, which is here the Ector tongue of the Austin, gradually increases until in the vicinity of Ector and Ravenna it is not less than 35 feet. Between Ector and Ravenna, in Fannin County, the material in this interval is mostly greenish cal-

[1] Texas Geol. Survey Fourth Ann. Rept., pp. 303, 304, 1893.



A. ANNONA TONGUE OF AUSTIN CHALK IN THE BANK OF A CREEK 5½ MILES WEST OF LEONARD, FANNIN COUNTY, TEX.

The beds, which dip perceptibly downstream, comprise massive layers of chalk interbedded with shaly layers 6 inches to 2 feet thick.

B. BUILDING-STONE FACIES AT TOP OF ANNONA TONGUE OF AUSTIN CHALK IN AN ABANDONED QUARRY 3 MILES SOUTH OF HONEY GROVE, FANNIN COUNTY, TEX.

careous shaly clay becoming more or less sandy, with lenses of sand and sandstone in the lower 10 feet. Lithologically the clay is of lighter color than the typical clay of the Eagle Ford.

The "fish-bed conglomerate" is well exposed in a branch west of a north-south public road 3 miles south of Ravenna, where it forms a ledge across the bed of the stream. (See Pl. XXVII, *B*.) At this place it consists of a conglomeratic layer about 10 inches thick composed of coarse calcareous sand, grayish and brownish phosphatic pebbles, a few pebbles of quartz and chert, and scattered shark teeth. One specimen of *Ostrea alifera* Cragin was obtained from the conglomerate at another outcrop in an east-west road about a quarter of a mile northwest of this locality, where also a thin interbedded layer of earthy limestone exhibiting cone-in-cone structure was noted. One pebble from the conglomerate was examined qualitatively by W. B. Hicks in the chemical laboratory of the United States Geological Survey and found to be composed chiefly of calcium phosphate. The conglomerate is here about 35 feet below the base of the Ector tongue of the Austin chalk (see Pl. XXX, *C*), and apparently the intervening strata are chiefly greenish shaly clay.

A gravel bed that may represent the northeastward continuation from the preceding locality of the "fish-bed conglomerate" is described on pages 146–147.

The significance of the "fish-bed conglomerate" in the geologic history of this part of Texas has not been definitely determined. Heretofore the conglomerate, together with the 10 to 35 feet of clay and sand that intervene between it and the overlying chalk, have been regarded as forming the uppermost part of the Eagle Ford. The conglomerate, lying immediately above sandy beds that are obviously of shallow-water marine origin, strongly suggests a temporary uplift of the sea bottom of this area above sea level, followed soon after by a readvance of the sea and the formation of the pebble bed as a basal conglomerate marking the beginning of the cycle of deposition that has its typical expression in the Austin chalk. This interpretation, if found to be correct, would seem to necessitate the exclusion of the conglomerate and the overlying clay and sand from the Eagle Ford. Such Eagle Ford fossils as the conglomerate may be found to contain can be explained as having been mechanically introduced from underlying Eagle Ford strata in place.

ECTOR TONGUE.

The Ector tongue of the Austin chalk, a thin tonguelike projection of chalk from the basal beds of the main body of the Austin, has been traced, by means of a few outcrops and the black soils to which the chalk weathers, from western Fannin County northeastward to a point about a mile and a half southeast of Ravenna. (See Pl. XVII.) Ector, from which the tongue is named, is a few hundred yards west of the belt of outcrop, which is rather strongly deflected where it passes around the southeastern nose of the Preston anticline. Only 10 or 15 feet of the chalk was seen in the best exposures, and it probably does not exceed 50 feet in thickness in the vicinity of Ector. The Ector tongue is underlain by shaly clay, which apparently grades into the chalk through a thickness of only a foot or two of material. This clay, together with thin beds of sand and a basal conglomerate ("fish-bed conglomerate") associated with it, are regarded as distinct from the Eagle Ford formation and as more closely related in origin to the overlying Austin chalk and its equivalents. (See above.) These basal beds are mapped with the Austin chalk and its extension, the Ector tongue. No exposures of the Ector tongue showing clearly its relation to the clay of Austin age that overlies it were seen.

The chalk is poorly exposed in the public road north of the Texas & Pacific Railway about a quarter of a mile east of Ector.

Another exposure appears in an east-west public road about 3 miles north by east of Ector, or 5¼ miles northwest of Bonham; here several feet of the chalk is underlain by clay, the passage from the clay to the chalk apparently being transitional through a thickness of a foot or more of material.

In other exposures revealed by a small branch and gullies west of a north-south public road 3 miles south of Ravenna the weathered rock has the appearance of typical chalk of the Austin and yielded the characteristic fossils *Gryphaea aucella* Roemer and *Radiolites austinensis* Roemer. As noted above, the "fish-bed conglomerate" crops out in the bed of the branch and in an east-west public road less

than a quarter of a mile west of this locality, in a position about 35 feet stratigraphically lower than the base of the chalk.

The belt of chalk of the Ector tongue crosses the old Bonham-Ravenna road about 1½ miles southeast of Ravenna, where the chalk was seen in a small, poor exposure in the road ditch. This is the easternmost locality at which this chalk has been recognized, and its identification farther east would probably be accomplished with difficulty, owing to the extensive covering of Pleistocene alluvial deposits in a broad belt south of Red River in Fannin and Lamar counties. It is assumed for the present that the chalk loses its identity toward the east by merging into contemporaneous nonchalky clays or sands.

The structure contours in the vicinity of Savoy, Ector, and Ravenna shown in Plate XVII indicate the altitude above sea level of the base of the Ector tongue.

TRANSITIONAL CLAYS NEAR BONHAM.

The Ector tongue of the Austin chalk is overlain in the west-central part of Fannin County by greenish-gray waxy clay, weathering yellowish green, which in the Bonham region appears to occupy the entire interval of approximately 400 feet above the Ector tongue and below the Annona tongue of the Austin. Exposures of the clay appear in roads and streets both north and south of Bonham and in the ditches of the roads leading to the north, northwest, west, and southwest. As considerable areas bordering Bois d'Arc Creek are covered by terrace clay derived chiefly from the underlying Cretaceous clay, it is in places difficult to determine whether the more or less weathered materials are residual from the undisturbed older clay or from the reworked terrace deposits.

A little above the middle of this body of clay is a band of glauconitic clay, of undetermined thickness, that is lithologically identical with pockets or lenses of glauconitic clay in the Blossom sand near Paris, Lamar County. This band has been recognized in poor exposures in street ditches south of the railroad in Bonham, and in somewhat better exposures on the Randolph road 5 and 6½ miles by the road southwest of Bonham. At the last-mentioned locality the clay is calcareous and strongly glauconitic and contains fragments of a large species of *Inoceramus*, *Ostrea congesta* Conrad, and *Ostrea plumosa* Morton. These fossils, though in themselves not conclusive evidence, combined with the lithologic evidence mentioned above indicate that the glauconitic clay represents the Blossom sand. A layer of impure sandy limestone exposed in a small branch at the crossing of the road to Prospect Church, 3 miles northwest of Dodd City, Fannin County, yielded *Aguilaria?*, *Inoceramus* sp., *Ostrea plumosa* Morton, *Gryphaea aucella* Roemer, *Baculites asper* Morton, and *Prionotropis?*. These fossils indicate that this locality also lies within the belt of clay representing the Blossom sand.

The upper part of the clay in the vicinity of Bonham above the glauconitic band is greenish and waxy and contains a few calcareous septaria; it represents the Brownstown marl, which, in the vicinity of Paris, lies above the Blossom sand and below the Annona tongue of the Austin chalk. (See Pl. XXX, *C*.)

In Plate XXX, *C*, the clay in the vicinity of Bonham is represented as merging toward the west through calcareous clay into the Austin chalk. That this interpretation is correct, and that the merging takes place gradually through a considerable linear distance, appears to be confirmed by all the observations that have been made in the area. On the strike of the clay in the area between Bells and Whitewright, in eastern Grayson County, the rock underlying the surface is composed largely of impure argillaceous chalk and chalky clay that appear to be transitional, and even as far west as the vicinity of Luella, in the east-central part of Grayson County, a considerable thickness of the Austin is a highly argillaceous, slightly bituminous shaly chalk or chalky clay. This facies of the Austin is exposed in gullies in the small branches of Cedar Creek near Luella and in the northward-flowing branches and northward-facing slopes of Choctaw Creek north of Luella.

The lower part of the clay in the vicinity of Bonham has not been traced farther east than the central part of Fannin County, beyond which in northeastern Fannin and northern Lamar counties the strata are largely obscured by an extensive covering of Pleistocene alluvial terrace deposits and are therefore imperfectly known. However, the distribution and relations of the clay seem to indicate that either it or equivalent material that is litho-

logically different, such as sand or marl, extends eastward stratigraphically beneath the Blossom sand. (See Pl. XXX, *C*.)

ANNONA TONGUE.

The division to which the name Annona is now applied was originally called the "White Cliffs chalk" by Hill,[1] from White Cliffs village and bluff, on Little River, Little River County, Ark. Because "White Cliffs" was preoccupied as a formation name, Hill, in 1901,[2] renamed the chalk Annona, from the town of Annona, in Red River County, Tex. The new name was inappropriate, for Annona is several miles south of the belt of outcrop of the chalk, but the name has become so commonly used that it should be retained, with the understanding, however, that the chalk does not outcrop at Annona—in fact, the section at White Cliffs, Ark., should continue to be regarded as the type locality of the division.

Hill[3] regarded the Annona as stratigraphically higher than the Austin as developed in its type area, for he says:

> It is not known what has become of the Austin chalk in this section [Paris, Tex.], but my hypothesis, backed by some evidence, is that to the southward it has been faulted down. The Anona (White Cliffs) is an entirely distinct and higher bed, for it is underlain by the Taylor (*Exogyra ponderosa*) marls, which overlie the Austin chalk.

In a later report[2] he says:

> The chalky (Anona) beds (the White Cliffs chalk of the writer's Arkansas section) outcrop at Clarksville and thence via Paxton [Roxton] and Honey Grove nearly to Bonham but are not known south of these points. The writer has considered this chalk to represent a higher horizon than the Austin chalk, but its exact relationship is subject to future determination.

Outcrops of chalk north of Windom and Honey Grove, in Fannin County, which in reality lie within the belt of outcrop of the Annona, were regarded by Hill[4] as belonging to the Austin.

Taff[5] recognized the geographic continuity of the Austin and Annona and also the fact that the lower part of the Austin is represented in northeastern Texas by beds that are not typical chalk. He says:

> The lower part of the thick chalk formation of north Texas changes to marl in the vicinity of Sherman, and still farther east higher beds successively become chalky marl, so that within a comparatively short distance only the upper part of the chalk formation as it occurs farther south is true chalk. In other words, the white chalk transgresses upward in the series of Cretaceous rocks from the vicinity of Sherman, Tex., eastward into Arkansas.

It is not quite clear from this quotation whether Taff regarded the Annona as actually younger than the upper part of the type Austin, or whether the last sentence of the quotation refers only to an upward transgression of the base of the chalk.

Gordon[6] also recognized the continuity of the Austin and Annona but did not detect the upward transgression of the top of the chalk across the geologic column from Austin northward. He therefore combined the Annona chalk and underlying Brownstown marl under the name Austin group, which he represented as occupying the time interval of the typical Austin of central Texas.

The Annona tongue in northeastern Texas consists of 400 or 450 feet of bluish-gray brittle, more or less argillaceous chalk, which breaks with a conchoidal fracture and weathers to white bald spots such as are typical of the area farther south in Texas underlain by the main body of the Austin chalk. The chalk is slightly bituminous, fresh samples from practically any part of it having a decided bituminous odor when struck with the hammer and yielding small quantities of oil by destructive distillation. The Annona has been traced almost continuously from a point north of Annona, in Red River County, through Lamar and Fannin counties to the southwestern part of Fannin County, where it is found to be continuous with the upper part of the main body of the Austin chalk (see Pl. XVII and Pl. XXX, *C*), and for that reason it is here regarded as a tongue of the Austin formation. No good exposure was found showing the relation of the Annona tongue to the underlying Brownstown marl, into which, however, the chalk probably merges through a vertical transition zone.

The upper 5 to 10 feet of the Annona in parts of northeast Texas consists of soft, tough, uniform chalk, which weathers to a soft cream color and is capable of being readily sawed into building blocks. It has been used locally in the construction of foundations, chimneys, dwellings, stores, churches, and courthouses.

[1] Arkansas Geol. Survey Ann. Rept. for 1888, vol. 2, pp. 87–89, 1888.
[2] U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 341, 1901.
[3] Geol. Soc. America Bull., vol. 5, p, 308, 1894.
[4] U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pl. 66, 1901.
[5] U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 698–699, fig. 58, 1902.
[6] Gordon, C. H., U. S. Geol. Survey Water-Supply Paper 276 pp. 21–25, 1911.

As a building stone, this rock appears to be durable and is of pleasing appearance; in its toughness and lack of brittleness the rock is in strong contrast to the chalk immediately underlying it and to the ordinary chalks of the Cretaceous formations of the Gulf Coastal Plain. The building-stone facies appears to be rather sharply separated from the overlying Taylor marl and forms a persistent stratum that has been traced from a point south of Atlas, in Lamar County, to Bailey, in Fannin County. It was not seen in the vicinity of Leonard, Fannin County, but rock of apparently identical physical character crops out on the hills 4 miles east of McKinney, in Collin County, where it has been quarried for building stone, and similar rock has also been quarried about 4 miles east of Allen, Collin County.

About 13 miles east of Clarksville the Annona passes under the alluvium of Red River, beneath which it is concealed to the Arkansas boundary, but the chalk reappears at Rocky Comfort, in the southwestern part of Little River County, Ark., and again at White Cliffs, on Little River in the same county. It passes as a narrow belt through the southeastern part of Howard County and thins and disappears in the western part of Hempstead County.

The set of structure contours on the geologic map (Pl. XVII), extending from the area north of Honey Grove southwest by west to Randolph, Fannin County, indicates the altitude above sea level of the sloping base of the Annona tongue of the Austin chalk; the broad eastward deflection of these lines south of Bonham marks the eastward extension of the plunging nose of the Preston anticline. The set of contours extending from the area south of Honey Grove, southwest by west past Gober and Bailey to Leonard, Collin County, indicates the altitude of the top of the Annona tongue; the slight eastward deflection of these lines northeast of Gober probably approximately marks the dying out of the uplift that produced the Preston anticline. The somewhat more pronounced southward deflection of these same contour lines at Leonard marks another structural feature that is described on page 161 as the Leonard-Celeste monoclinal fold.

BLOSSOM SAND.

The sand to which the name Blossom is applied was first recognized by Veatch [1] in wells at Clarksville, Red River County, where it constitutes an important water-bearing formation; he called it the "sub-Clarksville sand." Gordon [2] renamed the sand the Blossom sand member of the Eagle Ford clay, correlating it especially with the sandy beds that form the upper part of the Eagle Ford in the vicinity of Sherman, in Grayson County, an interpretation which, as shown by the abundant evidence presented in this paper, is incorrect.

The Blossom sand, which Gordon described as "brown sandy ferruginous glauconitic beds interlaminated with thin beds of clay, is overlain by the Brownstown marl and forms a belt of sandy country several miles wide extending westward through Red River County north of Clarksville; thence westward through Lamar County, where Blossom and Paris are on the outcrop; thence westward into Fannin County, where north of Dodd City it merges into clay (see Pl. XXX, *C*), changing its topographic and much of its lithologic character. However, the clay into which it merges toward the west retains its characteristic glauconitic content and is traceable past the south side of Bonham to a point about halfway between Ector and Randolph. Some facies of the sand are strongly calcareous and are chalky in appearance.

Fossil evidence indicates that the Blossom sand corresponds in age to the upper part, perhaps the upper half, of the Austin chalk as developed in the type area in Travis County. The fossils listed in the table below have been collected at a sufficient number of localities between Blossom, in Lamar County, and a point southwest of Bonham, in Fannin County, to amount to a virtual tracing of the beds throughout this distance of about 50 miles. At least eleven of the species are common to the Austin chalk of the type area, whereas no Eagle Ford species appear in the list. Synchroneity with the upper part of the type Austin is espe-

[1] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 25, 1906.

[2] Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, p. 19, 1911.

cially indicated by the following forms: *Inoceramus* aff. *I. deformis* Meek, *Ostrea congesta* Conrad, *Ostrea* aff. *O. diluviana* Linné, *Gryphaea aucella* Roemer, *Exogyra ponderosa* Roemer, *Liopistha elegantula* (Roemer)? and *Baculites asper* Morton.

The paleontologic evidence that the Blossom sand is younger than the Eagle Ford is supplemented by the lithologic evidence, for hand specimens of glauconitic clay collected on the Randolph road 5 to 6½ miles southwest of Bonham, Fannin County, in a bed that is stratigraphically well above the top of the Eagle Ford, are identical in physical aspect with specimens from undoubted Blossom sand near Paris, Lamar County.

Fossil species from the Blossom sand in Fannin, Lamar, and Red River counties, Tex.

Species.	Blossom sand.									Sandy limestone of Blossom age.	Clay of Blossom age.	Species common to the Austin chalk of the type area.
	U. S. Geological Survey collection 7496; 5 miles north by west of Clarksville, Red River County.	U. S. Geological Survey collection 9704; 2¼ miles west by south of Blossom.	U. S. Geological Survey collection 9703; 2¾ miles east by south of Paris.	U. S. Geological Survey collection 9702; 1½ miles west by south of public square, Paris.	U. S. Geological Survey collection 7508; 1¾ miles south by west of public square, Paris.	U. S. Geological Survey collection 9707; near Hopewell, 6 miles northwest of Paris.	U. S. Geological Survey collection 9701; Forest Hill Church, 7 miles northeast of Honey Grove.	U. S. Geological Survey collection 9699; Lone Elm Church, 7 miles northwest of Honey Grove.	U. S. Geological Survey collection 9695; 3 miles north by west of Dodd City.	U. S. Geological Survey collection 9693; 5¼ miles southwest of Bonham.	
Vermes:												
Serpula sp			×		×		×					
Mollusca:												
Nucula sp					×							
Cucullaea sp				×			×	×				?
Arca?								×				
Glycymeris?	×			×								
Aguileria?				×					×			
Pteria?					×							
Inoceramus aff. I. deformis Meek					×			×				×
Inoceramus sp. (1)									×			×
Inoceramus sp. (2)	×					×				×		
Ostrea congesta Conrad			×		×	×		×		×	×	×
Ostrea plumosa Morton			×		×				×	×	×	×
Ostrea aff. O. diluviana Linné					×							×
Gryphaea aucella Roemer					×	×		×	×			×
Exogyra ponderosa Roemer		×	×	×	×							×
Trigonia sp					×		×					
Pecten quinquecostatus Sowerby				×	×			×				×
Pecten sp					×							
Lima sp				×	×			×				
Spondylus sp								×				
Clavagella sp					×							
Liopistha elegantula (Roemer)?				×								×
Veniella sp					×							
Cardium spillmani Conrad	×											×
Cardium (Criocardium) sp	×				×							
Cardium sp			×	×	×		×					
Cyclorisma sp	×											
Xenophora sp					×		×					
Gyrodes sp								×				
Volutoderma sp			×		×		×	×				
Anisomyon sp					×							
Nautilus sp				×								
Hamites sp				×	×							
Baculites asper Morton			?	×	×		?	×	×			×
Placenticeras sp				×								
Prionotropis?									×			
Vertebrata (fish):												
Corax falcatus Agassiz				×								?
Otodus sp			×									

BROWNSTOWN MARL.

The Brownstown marl in its type area in Arkansas[1] consists of about 600 feet (?) of blue or gray calcareous clay or marl lying above the Bingen sand and below the Annona tongue of the Austin chalk. In northeastern Texas the Brownstown overlies the Blossom sand and underlies the Annona tongue, but its thickness probably does not exceed 300 or 350 feet. In Texas the marl resembles in a general way that of the type area, though some of it consists of gray waxy clay that is only slightly calcareous. Calcareous septaria have been observed in the clay in places in Lamar and Fannin counties. In general the soils produced by the Brownstown are of gray aspect and are in fairly strong contrast to the deep black soils of the Annona chalk on the south. The Brownstown marl extends westward, merging into the upper part of the clay in the vicinity of Bonham, Fannin County, and this clay in turn merges toward the west into the Austin chalk, as described on page 150.

The paleontologic character of the Brownstown marl has been only superficially studied. Probably the most common fossil species other than those of microscopic size is *Exogyra ponderosa* Roemer, which is very abundant in places in Texas and Arkansas. The following species have been recognized in the formation in Arkansas:

Hamulus major Gabb.
Hamulus onyx Morton.
Ostrea plumosa Morton.
Exogyra ponderosa Roemer.
Anomia argentaria Morton.
Paranomia scabra (Morton).
Liopistha (Cymella) bella (Conrad)?
Crassatellites conradi (Whitfield)?
Cyprimeria depressa (Conrad).
Corbula crassiplica Gabb.
Turritella quadrilira Johnson.
Baculites asper Morton.

When the Upper Cretaceous section of northeastern Texas is compared with that of Colorado River in Travis County near Austin it appears that the Brownstown marl is the equivalent in age of the lower part of the Taylor marl. This relation is indicated by red line *c* in Plate XXX, *C*.

[1] U. S. Geol. Survey Prof. Paper 46, p. 25, 1906.

TAYLOR MARL.

TYPICAL AREA.

The Taylor marl is typically developed in the vicinity of Taylor, Williamson County, and in Travis County, Tex., where it consists of 540 feet or more of "bluish unctuous marly clay which weathers into yellow laminated subsoil and black surface soil."[2] The formation conformably overlies the Austin chalk and is in turn conformably overlain by the Navarro formation. The most common and conspicuous fossil in the Taylor is *Exogyra ponderosa* Roemer, which is particularly abundant in the lower part of the formation but which is also common in places in the upper part of the formation.

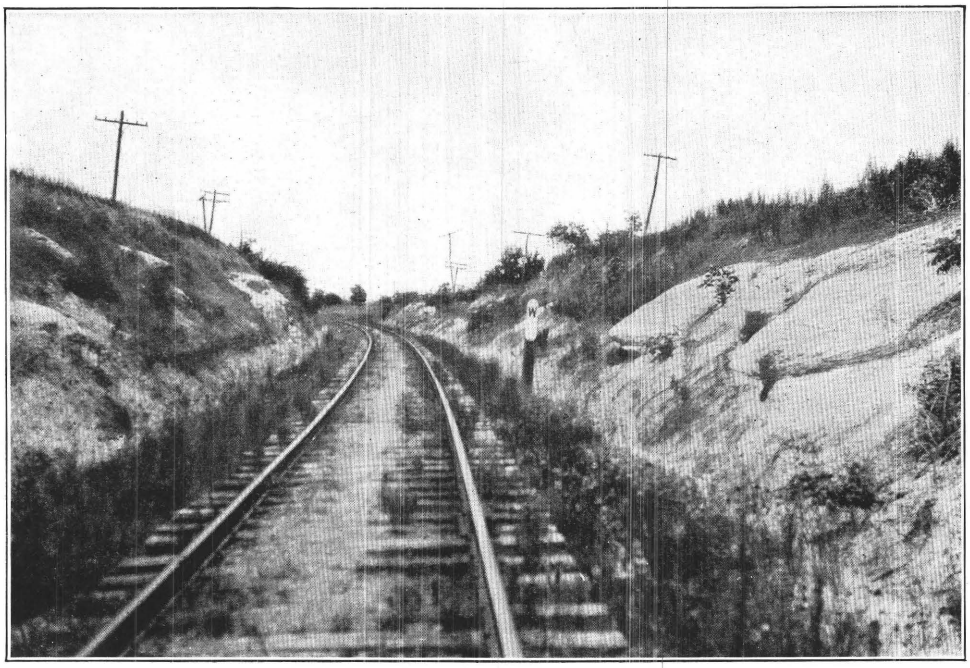
DEVELOPMENT IN NORTHEASTERN TEXAS.

SALIENT FEATURES.

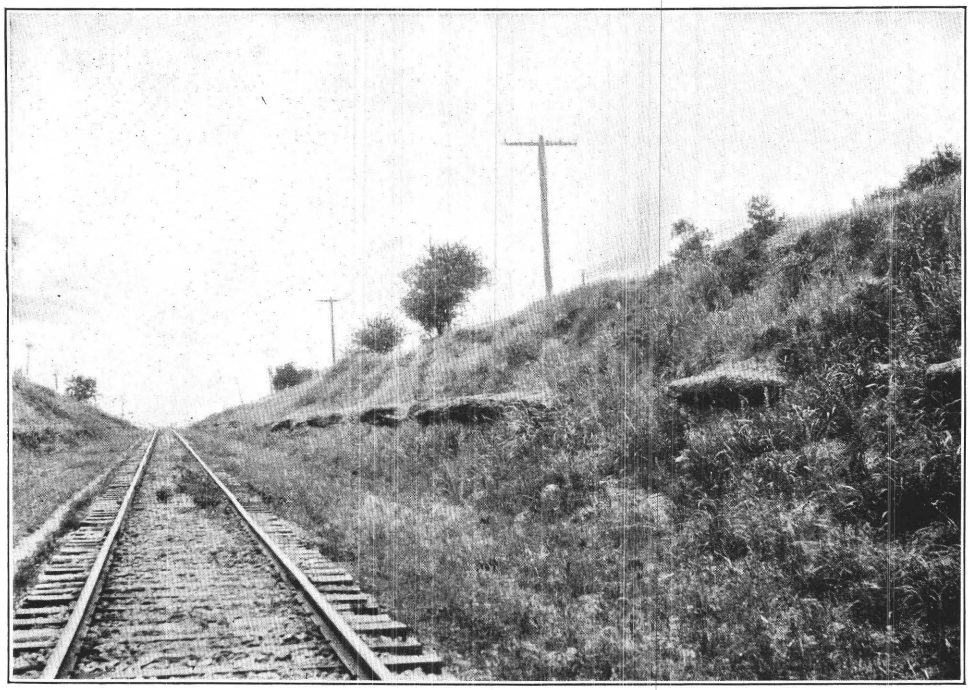
The Taylor marl of northeastern Texas occupies the interval between the underlying Annona tongue of the Austin chalk and the overlying Navarro formation and has an estimated thickness of 500 to 600 feet of strata. The correlation diagram (Pl. XXX, *C*) shows that the Taylor of this area represents only the upper part, perhaps not more than the upper half, of the formation as developed in its type area in Williamson and Travis counties. This difference in the time limits of the formation is due to the upward transgression of the top of the Austin from Travis County northward. Approximately the lower 475 feet of the Taylor as developed in Fannin and Hunt counties consists mainly of gray or bluish-gray calcareous shaly clay or marl, some portions of which are finely sandy; these deposits are of similar lithologic character to the typical Taylor marl of central Texas.

The basal part of the Marlbrook marl of southwestern Arkansas, which rests upon the Annona chalk and contains *Exogyra ponderosa* Roemer, probably corresponds to at least a part of the Taylor marl of northeastern Texas. The upper part of the Marlbrook, which carries *Exogyra cancellata* Stephenson, though perhaps continuous with the Taylor, is younger than the Taylor and corresponds in age with

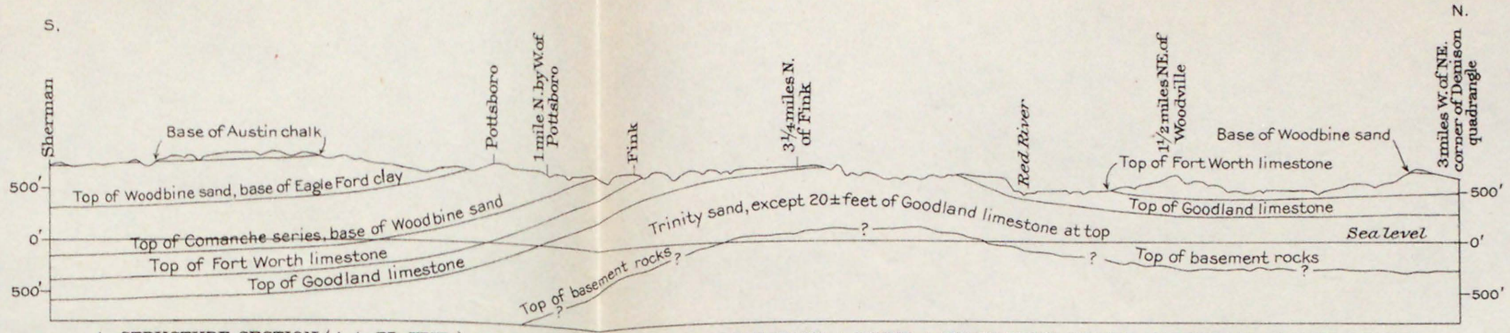
[2] U. S. Geol. Survey Geol. Atlas, Austin folio (No. 76), columnar section 1, 1902.



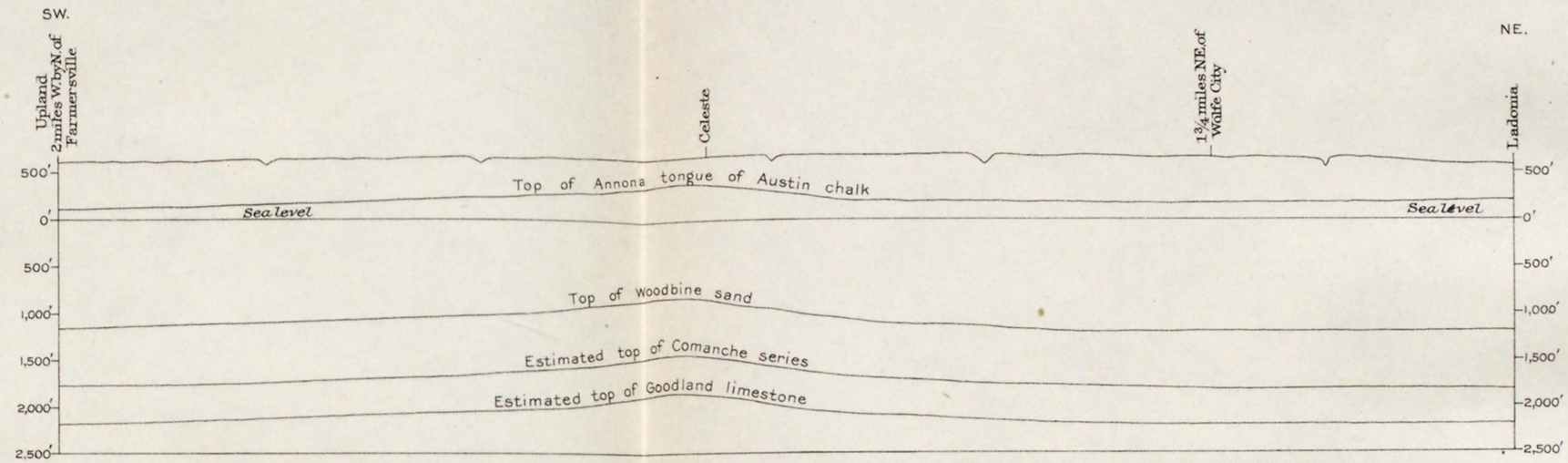
A. BASAL BEDS OF THE PECAN GAP CHALK IN A CUT OF THE GULF, COLORADO & SANTA FE RAILWAY HALF A MILE EAST OF THE STATION AT PECAN GAP, DELTA COUNTY, TEX.



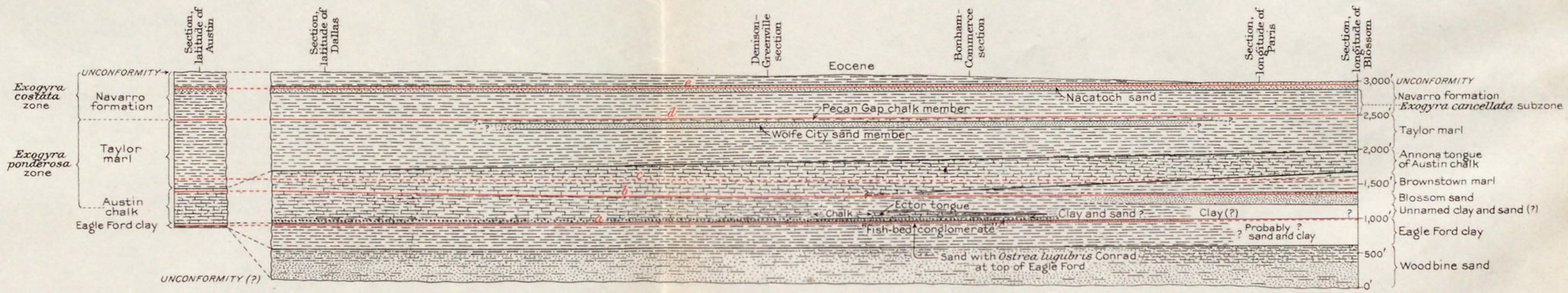
B. FOSSILIFEROUS CONCRETIONARY LAYERS OF CALCAREOUS SANDSTONE IN THE WOLFE CITY SAND IN A CUT OF THE GULF, COLORADO & SANTA FE RAILWAY 1½ MILES EAST BY NORTH OF WOLFE CITY, HUNT COUNTY, TEX.



A. STRUCTURE SECTION (A-A, PL. XVII) ACROSS THE PRESTON ANTICLINE FROM A POINT 3 MILES WEST OF THE NORTHEAST CORNER OF THE DENISON QUADRANGLE, BRYAN COUNTY, OKLA., VIA WOODVILLE, FINK, AND POTTSBORO, TO SHERMAN, GRAYSON COUNTY, TEX.



B. STRUCTURE SECTION (B-B, PL. XVII) ACROSS THE LEONARD–CELESTE MONOCLINAL NOSE FROM LADONIA, FANNIN COUNTY, VIA WOLFE CITY AND CELESTE, HUNT COUNTY, TO A POINT 2 MILES WEST BY NORTH OF FARMERSVILLE, COLLIN COUNTY, TEX.



C. GENERALIZED DIAGRAMMATIC SECTION SHOWING THE PHYSICAL AND AGE RELATIONS OF THE FORMATIONS OF THE GULF SERIES IN NORTHEASTERN AND CENTRAL TEXAS

The red lines *a*, *b*, *c*, *d*, and *e* connect beds of equal age. The formations are all more or less variable in composition both horizontally and vertically, and the symbols represent only the dominant lithologic character Structural deformations are disregarded

1 ½ 0 1 2 3 4 5 6 7 8 9 10 Miles

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the base of the Navarro—that is, with the beds containing *Exogyra cancellata*—that lie above the Pecan Gap chalk member of the Taylor. This age relation is explained by an assumed transgression of the Taylor marl upward in the geologic column from Hunt and Fannin counties, Tex., eastward toward Arkansas.

The clay is overlain by the Wolfe City sand member, described in greater detail below, and this in turn is followed by the Pecan Gap chalk member of the Taylor, also described below, the estimated thickness of which is between 25 and 50 feet.

WOLFE CITY SAND MEMBER.

The Wolfe City sand member of the Taylor marl consists of 75 to 100 feet of fine calcareous gray sand or sandy marl with a few round, oval, or irregular concretions of calcareous sandstone. The sand weathers to greenish yellow. Near the middle of the member is a more or less persistent layer of highly fossiliferous calcareous sandstone of varying thickness, which contains a moderately large but as yet only superficially studied molluscan fauna. (See Pl. XXIX, *B*.) Some beds of calcareous clay occur in the upper part of the member, between the indurated layer and the overlying Pecan Gap chalk member. Several incomplete sections of the sand are described below.

Wolfe City, Hunt County, is situated on the sand, but only small, poor exposures were seen within the town limits. The following section, representing about the middle portion of the member, is afforded by a cut of the Gulf, Colorado & Santa Fe Railway, 1½ miles east by north of Wolfe City. (See Pl. XXIX, B.)

Section in cut of Gulf, Colorado & Santa Fe Railway, 1½ miles east by north of Wolfe City, Tex.

	Feet.
Wolfe City sand member of Taylor marl:	
Poorly exposed yellowish, highly calcareous sand from which weather many small irregular gray sandy concretions of calcium carbonate. Contains *Exogyra ponderosa* Roemer, *Anomia argentaria* Morton, and *Ostrea plumosa* Morton	8
Irregular concretionary layer of yellowish-green fine highly fossiliferous sandstone. See list of fossils below	1–2½
Fine yellowish-green calcareous sand with poorly preserved fossil prints	6

Among the fossils recognized in the indurated layer in the preceding section were the following:

Inoceramus sp.
Pecten sp.
Liopistha (Cymella) bella (Conrad).
Cardium (Criocardium) sp.
Leptosolen biplicatus Conrad.
Corbula crassiplica Gabb.
Cymbophora sp.
Panope sp.
Gastrochaena sp.
Turritella trilira Conrad.
Anchura?
Pugnellus sp.
Morea sp.
Schizobasis sp.
Baculites asper Morton.
Scaphites (two or more species).

The sand and characteristic included concretions are exposed in shallow cuts of the railroad for the next 2 or 3 miles to the east.

Good exposures of the sand occur in ditches paralleling the Gulf, Colorado & Santa Fe Railway four-fifths of a mile to 1 mile east of Pecan Gap, Delta County, where the aggregate thickness revealed is probably 25 or 30 feet. The Pecan Gap chalk is exposed stratigraphically above the sands in a cut about half a mile east of Pecan Gap.

In the public road at Webb Hill, on the northward-facing slope of the South Fork of Sulphur Creek, 4½ or 5 miles southwest of Wolfe City, the indurated layer exposed in the section 1½ miles east by north of Wolf City caps the hill and is underlain by about 30 feet of well-exposed yellowish-green calcareous sand, followed below by 40 or 50 feet of similar material poorly exposed.

Exposures of the Wolfe City sand and the characteristic calcareous concretions were observed in and near the public road 1 to 2 miles south of Kingston, Hunt County, in a public-road ditch, 4½ or 5 miles north by east of Floyd, Hunt County, and in hill slopes south of the Missouri, Kansas & Texas Railway, about 2⅞ miles west of Farmersville, Collin County.

The Wolfe City sand member has thus been definitely traced from a point east of Pecan Gap, in Delta County, to a point southwest of Farmersville, in Collin County, though its boundaries have been only approximately determined.

PECAN GAP CHALK MEMBER.

The uppermost member of the Taylor marl in northeastern Texas consists of about 50 feet of bluish-gray, slightly bituminous, more or less argillaceous and sandy chalk, weathering to light gray and white, to which the name Pecan Gap chalk member is here applied. The chalk contains a moderately large fauna, most species of which are poorly preserved. The lower 10 feet of the chalk is typically exposed in a cut of the Gulf, Colorado & Santa Fe Railway half a mile east of Pecan Gap, Delta County, where the section is as follows:

Section in cut of Gulf, Colorado & Santa Fe Railway, half a mile east of Pecan Gap, Tex.

	Feet.
Pecan Gap chalk member of Taylor marl:	
Blue massive chalk, weathering to light gray and white, becoming sandy, and containing many phosphatic casts of mollusks in the lower 2 or 3 feet (see list below)	10
Wolfe City sand member of Taylor marl:	
Fine yellow argillaceous sand with numerous borings filled with chalky material from above	2
Dark to almost black fine sandy clay, poorly exposed	2

The fossils obtained from the Pecan Gap chalk at this locality are listed below:

Cucullaea sp.
Ostrea plumosa Morton.
Exogyra ponderosa Roemer.
Anomia argentaria Morton.
Crassatellites sp.
Cardium sp.
Gastrochaena sp.
Gyrodes sp.
Anchura sp.
Volutoderma sp.
Actaeon sp.
Nautilus sp.
Baculites asper Morton?
Baculites sp.

Another good exposure of the chalk is in the bed and banks of a small stream on the Cox place, 3 miles east by south of Wolfe City. Here the fresh chalk is bluish gray and slightly bituminous, and weathers light gray and white. The maximum thickness observed at any one place along the branch is 6 feet. Fossils were recognized as follows:

Cucullaea sp.
Inoceramus sp.
Ostrea plumosa Morton.
Gryphaea vesicularis Lamarck, var.
Exogyra ponderosa Roemer.
Lima sp.
Paranomia sp.
Pholadomya sp.
Veniella sp.
Crassatellites sp.
Cardium spillmani Conrad.
Gastrochaena sp.
Xenophora leprosa Morton?
Gyrodes sp.
Anchura sp.
Pyropsis sp.
Volutoderma sp.
Actaeon?
Nautilus sp.
Turrilites?
Baculites asper Morton?
Baculites sp.

A thickness of 5 feet of the chalk was examined in the bed of the south fork of Sulphur Creek near Wilsons Crossing, 4½ or 5 miles due south of Wolfe City, and poor exposures were noted in public roads 1 to 3 miles west of Wilsons Crossing in Hunt County. The chalk outcrops in the vicinity of Whiterock, a village 4 miles northeast of Kingston, Hunt County, where it is overlain by yellowish, somewhat sandy clay marl, and poor exposures of argillaceous chalk were seen in places along the public road for 4 or 5 miles south by west of Whiterock. The chalk also extends at least 2 miles north of Whiterock, where cisterns have been dug into a sandy facies of the member at several farmhouses. The chalk belt is crossed by the Missouri, Kansas & Texas Railway (McKinney branch) at Farmersville, Collin County, small exposures appearing on and near the railway for a mile or more both east and west of the station. The belt is also crossed by the St. Louis & Southwestern Railroad about midway between Nevada and Lavon, Collin County, where an outcrop of the chalk was seen in the bank of a small creek.

The largest collection of fossils yet obtained from the Pecan Gap chalk was made by Mr. and Mrs. D. A. Saunders, of Greenville, Tex., on the Jim Burnett farm, 6 miles northwest of Greenville, 1 mile west of Kellog, Hunt County. This collection was sent to the National Museum for identification and was studied, though not critically, by the writer, who recognized the following forms, many of which were too poorly preserved for specific identification:

Hemiaster aff. H. lacunosus Slocum.
Hemiaster sp.
Serpula (two or more species).

Cucullaea (two or more species).
Pteria sp.
Inoceramus sp.
Ostrea sp.
Gryphaea vesicularis Lamarck, var.
Exogyra ponderosa Roemer.
Exogyra ponderosa var. erraticostata Stephenson.
Exogyra costata Say (a small, nontypical form).
Pecten quinquecostatus Sowerby.
Pecten sp.
Anomia argentaria Morton.
Lima sp.
Trigonia sp.
Pholadomya sp.
Modiolus sp.
Clavagella armata Morton?
Liopistha (Cymella) sp.
Liopistha protexta Conrad?
Cuspidaria aff. C. jerseyensis Weller.
Crassatellites sp.
Radiolites austinensis Roemer.
Tenea sp.
Cardium sp.
Cyprimeria alta Conrad?
Legumen ellipticus Conrad.
Martesia sp.
Pleurotomaria sp.
Gyrodes petrosa (Morton).
Gyrodes sp.
Turritella sp.
Anchura (two species).
Pugnellus sp.
Pyropsis (two species).
Liopeplum sp.
Volutoderma sp.
Actaeon?
Nautilus sp.
Baculites (two or three species).
Turrilites (two species).
Scaphites (three or four species).
Corax falcatus Agassiz (shark teeth).
Lamna sp. (shark teeth).

Gordon[1] recognized the chalk member to which the name Pecan Gap is here applied, but he regarded it as a part of the Navarro formation and correlated it with the "Saratoga" chalk member of the Marlbrook marl of southwestern Arkansas. The Pecan Gap fauna, however, belongs to the upper part of the *Exogyra ponderosa* zone, whereas that of the "Saratoga" is referable to the upper part of the *E. cancellata* subzone of the *Exogyra costata* zone, which is definitely younger and higher. The possibility is recognized that the Pecan Gap chalk may transgress upward in the geologic column from Delta County, Tex., eastward toward Arkansas, being continuous with the "Saratoga" chalk in Arkansas; however, it has not been traced across the interval, although an attempt was made to find it south of Clarksville in Red River County. In view of the adverse evidence afforded by the faunas, therefore, the assumption that the two chalks are identical and continuous is not justified by the present known facts.

[1] U. S Geol. Survey Water-Supply Paper 276, p. 26, 1911.

NAVARRO FORMATION.

The Navarro formation in northeastern Texas consists of marine calcareous shaly clays, sandy clays, fine gray sands, and argillaceous sands with local indurated portions in the form of calcareous septaria or concretionary sandstone layers. These deposits are estimated to attain a thickness of not less than 800 feet. The formation is probably susceptible of separation into at least three members but has not yet been studied in this area in sufficient detail, either stratigraphically or paleontologically, to admit of mapping the subdivisions, even approximately.

The lower 300 or 400 feet of the formation consists of gray calcareous shaly clay or marl that produces a dark-gray or black soil and carries a distinctive fauna, the most significant species of which are *Exogyra cancellata* Stephenson, found at several localities near Cooper and Greenville, and *Anomia tellinoides* Morton, found at one locality near the Texas & Midland Railroad 2 miles west of Cooper. This is the *Exogyra cancellata* subzone, which forms the basal part of the *E. costata* zone and which has been traced throughout the Atlantic and Gulf Coastal Plain from New Jersey to Kaufman County, Tex., and has been recognized at Ciudad del Maiz, San Luis Potosi, Mexico, about 440 miles south of Eagle Pass, Tex. This subzone is represented in southwestern Arkansas by the upper half or more of the Marlbrook marl with the exception of approximately the upper half of the "Saratoga" chalk member, which forms the upper 20 to 25 feet of the Marlbrook.

The basal clays of the Navarro are overlain by fine gray sands and more or less sandy clays, 100 feet or more in thickness, which have been only superficially studied in northeastern Texas, where they have yielded only a few poorly preserved fossils. These beds correspond approximately to the Nacatoch sand of southwestern Arkansas, which carries a moderately large

fauna, and to the sandy beds in the vicinity of Kaufman County and near Chatfield and Corsicana, Navarro County, Tex., which have yielded a large and incompletely described fauna. The sandy beds are therefore to be correlated approximately with the middle portion of the *Exogyra costata* zone of the Atlantic and Gulf Coastal Plain.

Farther south in Texas, from the vicinity of Corsicana, Navarro County,[1] to Mexia and Groesbeck, Limestone County,[2] sand that has been correlated with the Nacatoch sand of Arkansas is overlain by over 500 feet of shaly clay that probably represents the Arkadelphia clay of Arkansas. This higher clay has not been recognized within the area shown on the map accompanying the present report, and there is some evidence that it has been cut out by a northwestward overlap of Eocene strata. The boundary between the Navarro formation and the Eocene has, however, not been traced in detail in this area.

TERTIARY SYSTEM.

EOCENE SERIES.

The southeastern part of the area under consideration, including most of Hopkins County and the southeastern part of Hunt County, is underlain by deposits of sand and clay of Eocene age, belonging in part to the Midway formation and in part to the Wilcox formation, which overlies the Midway. The Midway rests upon the Navarro formation of the Upper Cretaceous, from which it is separated by an erosion unconformity representing a long interval of geologic time. This statement is based not upon observations made in this particular area, where the contact has not been accurately determined and traced, but upon the known fact that throughout the Atlantic and Gulf Coastal Plain the unconformity separating Upper Cretaceous deposits from the overlying Eocene represents a very long time, during which this vast region was above sea level undergoing erosion, prior to the later marine submergence and deposition of Eocene strata.

[1] Matson, G. C., and Hopkins, O. B., The Corsicana oil and gas field, Tex.: U. S. Geol. Survey Bull. 661, pp. 218–221, pls. 19 and 20, 1917.

[2] Matson, G. C., Gas prospects south and southeast of Dallas: U. S. Geol. Survey Bull. 629, pp. 21, 22, pl. 7, 1916.

STRUCTURE.

GENERAL RELATIONS AND ATTITUDE OF THE DEPOSITS.

An examination of a generalized geologic map of the south-central United States would show that the vast stretch of the Coastal Plain bordering the Gulf of Mexico is underlain by a series of sediments of Cretaceous, Tertiary, and Quaternary age, and that north and west of the Coastal Plain in Arkansas, Oklahoma, and central Texas rocks of much greater age, formed during Paleozoic and pre-Paleozoic time, appear at the surface. In reality the ancient rocks underlie the entire Gulf region, forming a supporting basement for the younger rocks, which overlap and conceal them as far northward and westward as would be indicated on the generalized geologic map. Along this boundary the upper peneplaned surface of the ancient basement rocks dips beneath the younger deposits, becoming deeper gulfward until along the coast it probably lies too deep to be reached by modern well-drilling methods.

In the area in northeastern Texas now under consideration the basement rocks do not appear at the surface, but they outcrop farther north, 10 to 30 miles north of Red River, in the southeastern part of Oklahoma, and farther west, in Montague and Wise counties, Tex. In the northwestern part of the area shown on the geologic map (Pl. XVII) the basement rocks lie in places within 350 feet of the surface, and in the southeast corner of the area, where their depth is greatest, they are estimated to lie between 4,000 and 5,000 feet below the surface.

The dip of the upper surface of the basement rocks ranges from 40 feet or less to the mile in the western part of the area to 70 feet or more to the mile in places in the east-central part. At Bowie, Montague County, Tex., near the western edge of the outcrop of Cretaceous rocks, the altitude of the surface of the basement rocks is approximately 1,100 feet above sea level; at Farmersville, Collin County, 90 miles east by south of Bowie, the basement is estimated to lie about 2,800 feet below sea level, making a general dip of 43 feet to the mile in the intervening area. Near Boggy

Depot, in Atoka County, Okla., the contact between the basement rocks and the overlying Cretaceous strata is about 550 feet above sea level; near Wolfe City, Hunt County, Tex., 64 miles south by east of Boggy Depot, the basement rocks are estimated to be 2,800 feet below sea level, indicating a general dip of 52+ feet to the mile. Locally, however, the dip of the basement surface is probably much greater than 52 feet and may reach several hundred feet to the mile. These figures are based partly on assumed thicknesses, particularly of the formations composing the Comanche series, and are subject to correction when the facts are known.

The geologic map (Pl. XVII) shows that the strike of the beds composing the Cretaceous formations of northeastern Texas is approximately east in the eastern parts of Lamar and Delta counties; it swings around toward the south, farther west and southwest, in Fannin and Hunt counties; and becomes south by a few degrees west in the southern parts of Hunt and Collin counties. The dip is gulfward at right angles to the strike except locally, where the normal attitude of the beds has been disturbed by earth movements. The general dip is probably somewhat less than the inclination of the surface of the basement rocks on which the Cretaceous beds rest. The general range of dip is believed to be from 30 feet or less to the mile to 80 feet or more to the mile, but there is evidence that locally, as along the southern limb of the Preston anticline near Pottsboro, the beds may dip as much as 300 feet to the mile.

The uniform monoclinal attitude which so generally characterizes the Cretaceous formations of the Gulf Coastal Plain is interrupted in this area by at least two pronounced deformations, the Preston anticline and the Leonard-Celeste monoclinal nose, which are described below. Other similar deformations, though probably much smaller, may be discovered as a result of future more detailed investigations.

Faulting of small magnitude occurred in places in the area, probably as a result of the movements which produced the folds; positive evidence of small faults was obtained at several localities. The building-stone facies of the Annona tongue of the Austin chalk exposed in the quarries and small branch streams at and within a few hundred yards southeast of Gober, in the southern part of Fannin County, is considerably disturbed by faults of small displacement; one fault running approximately northeast exhibits a displacement of 15 feet. At the crossing of a public road over Choctaw Creek 3¼ miles north by east of Luella, Grayson County, a fault trending N. 55° E. exhibits a displacement of 8 inches. Messrs. Hopkins and Powers indicate on their structure map a fault of relatively small displacement southeast of Bonham, Fannin County, which involves the basal strata of the Annona tongue and the clay that immediately underlies the chalk. (See Pl. XVII.)

PRESTON ANTICLINE.

The Preston anticline is a plunging upfold of Cretaceous strata that is most conspicuous in the southern parts of Marshall and Bryan counties, Okla., and the northern part of Grayson County, Tex., but is measurably manifested in the direction of its southeastward-trending axis as far as the vicinity of Gober in Fannin County, Tex. The approximate position of the axis of the anticline is indicated on Plate XVII by a dashed line.

Where the anticline is best developed in the Red River valley, northwest of Denison, the Comanche series of formations, which would normally be buried beneath the overlapping younger strata of the Gulf series, have been warped upward approximately 800 feet, and the beds of the overlying Gulf series have thus been subjected to erosion, which has entirely removed not only the Gulf series but also much of the underlying Comanche series from a considerable area along the axis of the uplift. Here the outcrops of the formations of the Comanche series parallel the sides of the anticline and wrap about its southeastward-plunging nose in typical fashion; the strike of the formations of the area, which would normally range from west to southwest, is distinctly bowed to the southeast where the formations cross the axis of the anticline, and this deflection of the strike is manifested at least as far to the southeast as Gober, Fannin County.

From the vicinity of Preston Bend in northern Grayson County, where the maximum uplift of the Cretaceous strata above the position they would have occupied had there been no folding is approximately 800 feet, the amount of deformation gradually decreases to the south-

east along the axis of the fold, and near Gober, Fannin County, the uplift is very slight.

Section A in Plate XXX is drawn approximately at right angles to the axis of the anticline from a point near the northeast corner of the Denison quadrangle, in Bryan County, Okla., southwest to a point 3¼ miles north of Fink, Grayson County, Tex., thence south to a point 1 mile north by west of Pottsboro, thence south-southeast to Sherman. The surface profile is based on the data recorded on the Denison topographic map, and the structure lines are based partly on outcrops and partly on data afforded by wells. This section is believed to be approximately accurate where it crosses the main part of the anticline north of Pottsboro, the position of the lines there having been checked against the structure contours established by Messrs. Hopkins and Powers. (See Pl. XVII.)

The structure contours shown on Plate XVII are generalized from larger-scale maps prepared by Messrs. Hopkins, Powers, and Robinson, as elsewhere explained. Their method was to determine the altitude of key rocks at as many points as possible, by means of aneroid readings corrected for changes of atmospheric pressure by barograph records obtained simultaneously at the bases from which the field work was done, and to supplement these surface observations with data afforded by all available well records.

The contours on the main part of the Preston anticline in the northern part of Grayson County, Tex., and the southern parts of Marshall and Bryan counties, Okla., show the altitude above sea level of the top of the Goodland limestone. The extension of the anticline into Fannin County is indicated by the southeastward deflection of the contours showing the altitude of the base of the Ector tongue of the Austin chalk in the vicinity of Ector, by a less pronounced deflection of the contours showing the base of the Annona tongue of the Austin chalk between Dodd City and Randolph, and by only a faint bending of the contours showing the top of the Annona tongue northeast of Gober. The last-mentioned place is approximately at the point where the anticline dies out toward the southeast. A shallow syncline parallels the anticline along its northeast side in Fannin County, as indicated by a deflection to the northwest of the several sets of contours. A structural terrace on and slightly south of the plunging nose of the anticline is indicated by the spacing of the contours 2 to 6 miles northeast of Pottsboro, Grayson County.

The dip of the strata of the Comanche series away from the axis of the Preston anticline ranges from a few feet to a little more than 300 feet to the mile. In general, the south limb is a little steeper than the north limb. The steepest part of the anticline is on the south limb in a northwest-southeast stretch about 3 miles long northeast of Pottsboro (see Pl. XVII), where, as indicated by the contours, the maximum dip of slightly more than 300 feet to the mile is attained by the Goodland limestone. This relatively strong dip is also clearly manifested in outcrops of the Main Street limestone, the next to the highest member of the Denison formation, whose strata in conjunction with the "Quarry" limestone form a low strike ridge beginning about 2 miles east of Pottsboro and extending in a northwesterly direction for about 2 miles. Along this ridge the Main Street limestone, though poorly exposed, obviously dips strongly to the southwest, in places as much as 20° or even more. The pronounced narrowing in the belt of outcrop of the Woodbine formation resulting from the unusually steep inclination of the strata in this belt was perhaps the chief basis for the postulation of the so-called Cook Spring fault by Taff [1] and Leverett and by Hill.[2]

The nature of the earth movements that produced the Preston anticline is imperfectly known, though the assumption is warranted that the movements had their origin in the basement rocks that underlie the overlapping Cretaceous sediments. As the axis of the anticline trends approximately parallel to most of the major faults and folds in the Arbuckle Mountains in Oklahoma, the assumption also seems warranted that this uplift is directly related to the Arbuckle uplift, and that the folding of the Cretaceous strata was merely incidental to the upbowing of these older basement rocks.

[1] Texas Geol. Survey, Fourth Ann. Rept. for 1892, pp. 297, 298, 1893.
[2] U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 384, 385, pl 66, 1901.

LEONARD-CELESTE MONOCLINAL NOSE.

The structure contours showing the altitude above sea level of the top of the Annona tongue in the vicinity of Leonard in southwestern Fannin County, Tex., are deflected rather sharply to the south. (See Pl. XVII.) This deflection is also clearly manifested in the outcrop of the Annona, the strike of whose uppermost beds in the vicinity of Leonard shows a distinct bulge to the south. A similar and even stronger southward or southeastward deflection is exhibited by the belts of outcrop of the Wolfe City sand and Pecan Gap chalk members of the Taylor marl between Celeste and Greenville, in Hunt County. (See Pl. XVII.) These are the surface manifestations of a fold in the underlying Cretaceous strata of the kind described by F. G. Clapp [1] as a monoclinal nose. For convenience this fold is called the Leonard-Celeste monoclinal nose. The areal distribution of the formations of the Gulf series in Fannin, Collin, and Hunt counties strongly suggests that this fold is the deflected southward extension of the Preston anticline, and this was the interpretation at first placed upon the structure. However, the structure contours on the base of the Annona tongue established by Messrs. Hopkins and Powers (see Pl. XVII) indicate that this relationship is only apparent, the Leonard-Celeste fold being separate from the Preston anticline, though doubtless closely related to it both physically and in manner and time of origin. The axis of the fold appears to trend south by east through Leonard and a mile or so west of Celeste and Kingston, Tex.

The surface evidence of the existence of this fold appears to be corroborated by the records of two wells nearly in line with the general strike of the formations—one near Wolfe City, where the top of the Annona tongue of the Austin chalk was struck at a depth of about 510 feet (160 feet above sea level), and the other at Celeste, where the Annona was reached at a depth of only 300 feet (360 feet above sea level). Section B, in Plate XXX, drawn approximately at right angles to the axis of the fold, from Ladonia, Fannin County, west by south to a point $1\frac{3}{4}$ miles northeast of Wolfe City, in Fannin County, thence southwest by way of Celeste to a point 2 miles west by north of Farmersville, Collin County, shows this upbowing of the strata in the vicinity of Celeste. The surface profile in this section is based in part on railroad elevations and in part on aneroid barometer readings, and the structure lines are based on surface outcrops and on data afforded by the wells at Celeste and Wolfe City previously mentioned and by one well at Ladonia. The depth to the Woodbine in these three wells, if their logs are properly interpreted, apparently confirms the evidence afforded by the chalk. At the southwest end of the section near Farmersville the Annona, as estimated from surface outcrops and assumed thicknesses, has again sunk back to a level approximately the same as near Wolfe City, or a little deeper.

[1] Geol. Soc. America Bull., vol. 28, p. 572, fig. 8, 1917.

OIL AND GAS PROSPECTS.

Oil and gas have frequently been found in the upbowed or anticlinal portions of strata that have been subjected to warping or folding by earth forces, and although these substances are not confined exclusively to such structural features, no argument is needed to convince the practical operator that his best chance of success in untested territory lies where folded strata are known to exist. The Preston anticline and the Leonard-Celeste monoclinal nose, described above, will therefore not fail to attract the attention of persons interested in the discovery of reservoirs of oil and gas.

In this paper only the more obvious conclusions in regard to the occurrence of oil and gas, which might be readily deduced by any oil geologist or practical oil operator from the facts already presented, will be briefly discussed. A more detailed discussion of the structural features of this area and an adjoining area on the northwest in Oklahoma, with particular reference to the occurrence of oil and gas in both the Cretaceous and underlying basement rocks, will be given by Messrs. Hopkins, Powers, and Robinson in an economic paper to be published later.

The most conspicuous part of the Preston anticline, in Grayson County, Tex., and Marshall and Bryan counties, Okla., has already been recognized by oil prospectors, and test wells have been drilled on different parts of the uplift. Gas reported to come from the lower part of the Trinity sand at depths of less than 700 feet has already been discovered near the axis of the anticline in the southern

part of Marshall County, where at least a dozen test wells have been drilled. Of these wells six, located in a group in the southeast corner of T. 6 S., R. 5 E., and the northeast corner of T. 7 S., R. 5 E., are classed as producing gas wells, and each of three of them is reported to yield from 1,500,000 to 2,500,000 cubic feet of gas daily. This pool is known as the Enos gas field. In June, 1918, an oil well near the crest of the anticline in sec. 23, T. 7 S., R. 5 E., was completed in the Trinity sand at a depth of 260 feet and was reported to produce 20 barrels of oil daily. Showings of oil or gas, or both, have been reported from the Trinity sand in some of the other wells penetrating the strata involved in the anticline. The Madill oil field,[1] farther north in Marshall County, in the southeast corner of T. 5 S., R. 5 E., which yields small commercial quantities of an exceptionally light grade oil from the Trinity sand,[2] is not connected with the Preston anticline but with another distinct though approximately parallel fold, as shown by an unpublished structure contour map prepared by Messrs. Hopkins, Powers, and Robinson.

Of the geologic subdivisions involved in the Preston anticline and its extension to the southeast in Fannin County, four are composed in part of sandy strata, which exhibit a sufficient degree of porosity, at least in their outcropping portions, to fit them to serve as reservoirs for the storage of oil or gas. They are, in ascending order, the Trinity sand, the Pawpaw sandy member of the Denison formation, the Woodbine sand, and sandy beds in the upper part of the Eagle Ford clay.

The occurrence of gas and some oil in the Trinity sand along the axis of the fold in the southern part of Marshall County, Okla., has already been demonstrated. The amount of gas and the volatile products of oil that may once have been contained in the sand and have since escaped where the formation is exposed in the crest of the fold can, of course, only be conjectured. The Trinity dips below the surface on the plunging nose of the anticline in the Red River valley, about 5½ miles north by west of Denison.

A traveler passing to the southeast along the axis of the anticline would cross successively the outcropping strata of the sandy formations mentioned above, with intervening bands of nonsandy clay and chalk, each in turn dipping below the surface down the nose of the anticline. After crossing the limestones and clays of the Comanche series above the Trinity he would come first to the narrow belt of sand of the Pawpaw sandy member of the Denison formation near the northeast corner of Grayson County, the wider sandy belt of the Woodbine in the northwest corner of Fannin County, and the narrow strip of sand forming the uppermost part of the Eagle Ford formation at Ector, in Fannin County.

A well on the axis of the anticline near the northwestern part of Fannin County would start in the Woodbine sand, below which it would encounter two of the possible oil or gas bearing sands, the Pawpaw and the Trinity. The top of the Pawpaw would probably be reached at depths of 50 to 500 feet and the top of the Trinity at depths of 500 to 1,000 feet, the depth depending on the exact location of the well.

A well at Ector would start in the sand at the top of the Eagle Ford and would penetrate the Woodbine sand at an estimated depth of 400 to 900 feet, the sandy beds of the Pawpaw at an estimated depth of 925 to 975 feet, and the Trinity sand at an estimated depth of 1,300 to 1,800 feet.

A well starting at the top of the Annona chalk northeast of Gober would penetrate the sandy beds at the top of the Eagle Ford at an estimated depth of 800 to 900 feet, the Woodbine sand at an estimated depth of 1,300 to 1,850 feet, the sandy beds of the Pawpaw at an estimated depth of 1,900 to 1,950 feet, and the Trinity sand at an estimated depth of 2,300 to 2,800 feet.

So far as known to the writer no wells have been drilled that would serve as an adequate test of the occurrence of oil or gas in the Leonard-Celeste monoclinal fold. The deepest well concerning which information has been obtained is the 1,554-foot water well at Celeste, perhaps a mile or a mile and a half east of the axis of the fold. This well is believed to have reached the uppermost sandy stratum of the

[1] Taff, J. A., and Reed, W. J., The Madill oil pool, Okla.: U. S. Geol. Survey Bull. 381, pp. 504–513, 1910

[2] Oklahoma Geol. Survey Bull. 19, pt. 2, pp. 316–320, 1917.

Woodbine formation at a depth of 1,535 feet. The sandy beds at the top of the Eagle Ford were not recognized in the well and may here be represented by nonsandy clay. The sandy beds of the Pawpaw would be reached here at an estimated depth of 2,200 feet, and the top of the Trinity sand at an estimated depth of 2,600 feet.

At Greenville, which is probably near the axis of this fold, all the possible oil sands of the Cretaceous, except the Nacatoch, would be penetrated by a well probably less than 3,500 feet deep. These would include, in descending order, the Wolfe City sand member of the Taylor marl, the sandy member at the top of the Eagle Ford, which would probably be very thin and might be represented entirely by clay; the sands of the Woodbine formation; the Pawpaw sandy member of the Denison; and, finally, the Trinity sand.

In pointing out the existence of the folds described above the writer does not wish to be understood as urging the probability of the occurrence of oil and gas in association with the folds, though he feels that the facts warrant an optimistic attitude on the subject.

Four factors are generally regarded as essential to the occurrence of oil and gas—an adequate source of hydrocarbons, such as petroliferous shales or clays; porous beds intimately connected with the source to serve as reservoirs; suitable structure for the concentration of the oil and gas; and suitable hydrostatic conditions. Two of these factors appear to be favorable in this area; porous formations for the retention of the oil are present, and structural folds exist similar to those in which oil and gas are known to have accumulated elsewhere. The factor of source, although less completely known, also appears to be favorable, for the chalks and some of the clays that intervene between the sandy formations are distinctly bituminous. In regard to the fourth factor, there is no known reason why the ground-water conditions in the Cretaceous beds of this area should be essentially different from those of the other oil and gas fields of the Gulf Coastal Plain.

SUMMARY.

1. *Areal geology.*—Important revisions in the areal distribution of the formations of both the Comanche and Gulf series, as previously mapped in this area, are indicated in Plate XVII, and three new mappable units are recognized, including the Ector tongue of the Austin chalk and the Wolfe City sand member and Pecan Gap chalk member of the Taylor marl.

2. *Stratigraphy.*—A new interpretation of the stratigraphic and age relations of the formations of the Gulf series based on the following facts is presented (see Pl. XXX, *C*): (*a*) The recognition of the so-called "fish-bed conglomerate" of Taff (see p. 149) as the probable base of the cycle of sedimentation which has its typical expression in the Austin chalk; (*b*) The recognition of a relatively thin tongue of chalk, the Ector tongue, extending northeastward from the base of the main body of the Austin chalk in the vicinity of Ector, Fannin County; (*c*) the eastward merging of approximately the basal half of the Austin chalk, with the exception of the Ector tongue, into equivalent nonchalky clay in Fannin County; (*d*) the correlation of the Blossom sand with the upper part of the typical Austin chalk of Travis County, Tex., instead of with the upper part of the Eagle Ford formation, as previously correlated (see pp. 152–153 and Pl. XXX, *C*); (*e*) the upward transgression in the geologic column of the upper part of the Austin chalk from Travis County northward; (*f*) the recognition of the Annona ("White Cliffs") chalk of Hill as a large tongue connected with the main body of the Austin chalk; (*g*) the discrimination of the Wolfe City sand and Pecan Gap chalk as upper mappable members of the Taylor marl.

3. *Structure.*—The structural feature in the northern part of Grayson County, Tex., and the southern parts of Marshall and Bryan counties, Okla., heretofore regarded as an uplifted fault block which brought the formations of the Comanche series to the surface, where normally they would lie deeply buried, is shown to be instead an anticlinal uplift, the Preston anticline, with which, so far as known, no major faults are directly associated. A newly recognized structural feature, called the Leonard-Celeste monoclinal fold, in southwestern Fannin and northwestern Hunt counties, is described. Structure contours have been established by Messrs. Hopkins, Powers, and Robinson, showing the altitude above sea level of the top of the Goodland limestone about the flanks of the Preston anticline, and Messrs. Hopkins and Powers have established contours showing the altitude of the base of the Ector tongue and the base and top of the Annona tongue of the Austin chalk in certain areas in Fannin, Grayson, and Hunt counties. (See Pl. XVII.)

4. *Oil and gas.*—A brief statement of the factors controlling the occurrence of oil and gas with particular reference to this area is given, and the hope is expressed that future prospecting may result in the discovery of these substances in commercial quantities somewhere in association with the Preston anticline or with the Leonard-Celeste monoclinal fold.