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GEOLOGY OF THE COASTAL PLAIN OF TEXAS WEST OF BRAZOS RIVER

BY

ALEXANDER DEUSSEN

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GEOLOGY OF THE COASTAL PLAIN OF TEXAS WEST OF BRAZOS RIVER.

By Alexander Deussen.

INTRODUCTION.

AREA DESCRIBED.

The region considered in this report includes that part of the Coastal Plain of Texas which is shown in figure 1. It contains about 38,900 square miles, an area about as large as the State of Kentucky.

SOURCES OF DATA.

The descriptions and the conclusions here presented are largely the results of field examinations made by the writer from 1909 to 1913, inclusive. The previous knowledge of the region is set forth almost entirely in papers by Penrose, Dumble, and Kennedy. In 1889 Penrose and Dumble studied the Tertiary formations exposed on Colorado River between Austin and La Grange, on Brazos River between Waco and Hempstead, and on the Rio Grande between Eagle Pass and Reynosa. The results of these studies are given by Penrose.[1] Dumble and Singley made a survey of Lee, Burleson, and Washington counties in the nineties, and the results of their work are given in part by Dumble.[2] In 1901 and 1902 Kennedy [3] made an incidental study of the area. Dumble [4] summarized his studies in southwest Texas in an instructive paper.

The writer has made use of such parts of the reports of these pioneer investigators as are in harmony with his observations and has given due credit.

ACKNOWLEDGMENTS.

During a part of the time that the writer was in the field he was assisted by Mr. Leon Russ and Mr. David Donoghue. Credit is due Mr. Russ for some of the information concerning Lee, Caldwell, and Gonzales counties.

This paper was prepared under the general supervision of T. Wayland Vaughan, of the United States Geological Survey, who was in charge of investigations in the Coastal Plain. In addition to supervising the work Mr. Vaughan has identified many of the invertebrate fossils and has supplied information concerning the horizons represented by the collections.

The writer has been the recipient of many courtesies from William Kennedy and E. T. Dumble, of Houston; M. M. Graves, of Somerville; D. A. Cypher, of Caldwell; Frank Graves, of Burton; J. D. Mitchell, of Victoria; Leon Brown, of Lagrange; Hugh Duval, of Bastrop; and J. C. Melcher, of O'Quinn.

DIFFICULTIES OF GEOLOGIC WORK IN THE COASTAL PLAIN.

The difficulties of geologic investigation in the Coastal Plain are numerous and formidable. Satisfactory exposures of the subsurface formations are few and occur only in widely scattered localities, and the absence of fossils makes the identification of many of these formations difficult. Few beds that have distinctive lithologic character can be traced over considerable distances. The discrimination and correlation of formations reported in well logs is often uncertain, as the repeated alternation of beds of sand and clay affords little distinctive material. The dense vegetation and the scarcity of roads and trails in places hinder the geologist greatly in making traverses. Added to all these difficulties is the lack of satisfactory contour maps. Nevertheless the major features of the region have probably been fairly well recognized despite these difficulties, and the results of the investigation are presented in the expectation that they will afford a working basis for future detailed mapping.

[1] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 5-101, 1890.

[2] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 549-567, 1894.

[3] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, 1903.

[4] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 913-987, 1903.

SURFACE FEATURES.

GENERAL FORM OF THE LAND.

The Coastal Plain of Texas west of Brazos River, like the Atlantic and Gulf Coastal Plain of North America, of which it is a part, is a plain whose original surface has been dissected by streams and in part destroyed by erosion, so that in some areas it shows diversity in relief.

The characteristic surface features of the region are a number of dip plains that slope gently seaward, so that the traveler from the coast reaches the higher lands by ascending a series of long, gentle slopes that are terminated at their inland edges by escarpments that face west or north. These escarpments are cut by many streams, which flow in wide valleys that are partly filled with alluvium and that lie from 10 to 350 feet below the adjacent uplands. The materials that form the surface of the plains consist largely of sand, clay, and limestone, which were deposited during the Cretaceous, Tertiary, and Quaternary periods.

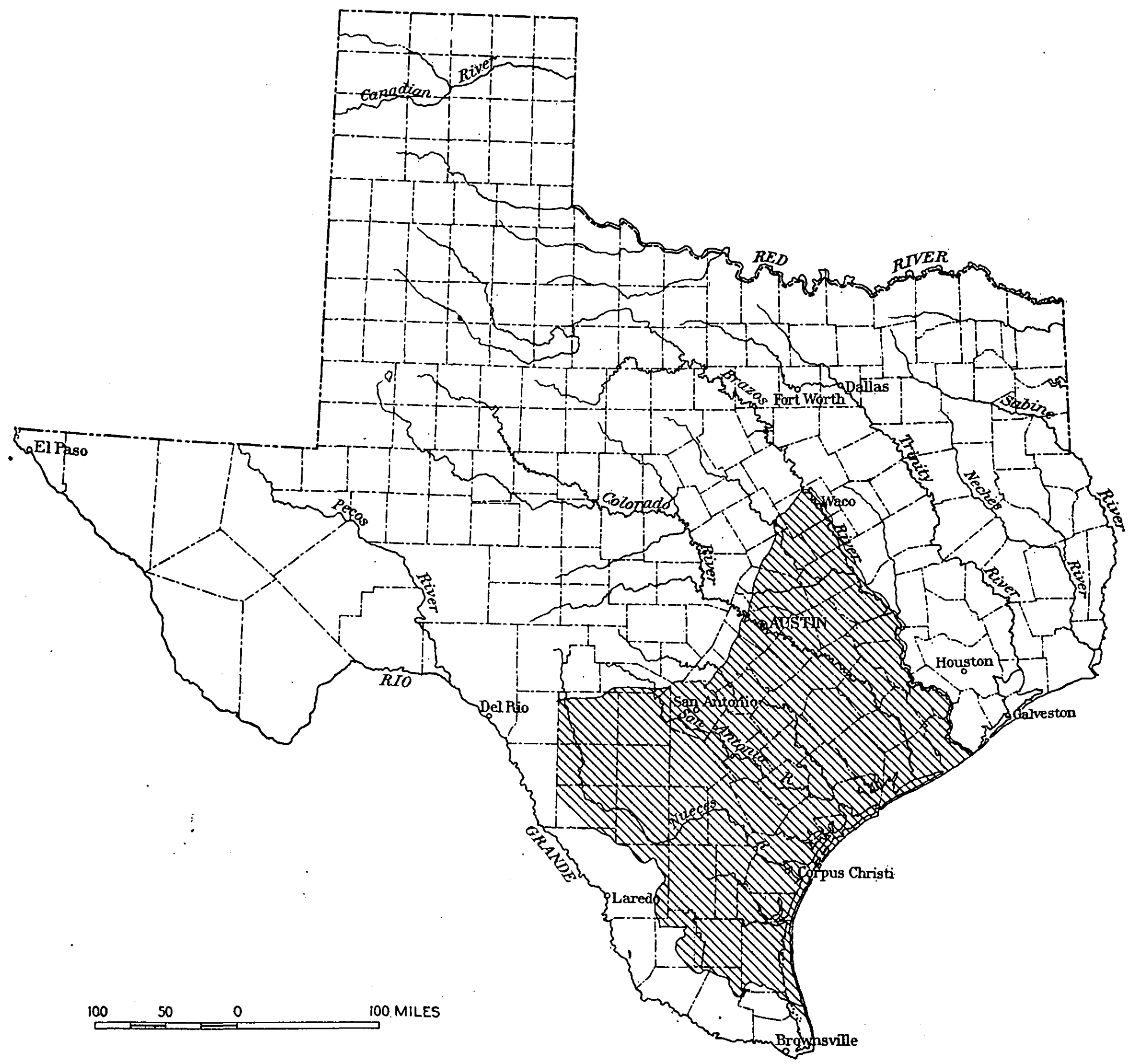


FIGURE 1.—Map of Texas showing location of the region considered in this report.

The climate of the part of the Coastal Plain that lies west of Guadalupe River is semiarid, and the soil, vegetation, and culture in that part of the region are different from those of the part that lies east of this stream.

The part of the plain that lies near the coast stands only a few feet above the sea, but its western margin ranges in height from 650 feet near Waco to 1,517 feet in Kinney County.

The slope of the land for about 50 miles back from the coast is very gentle—about 2 feet to the mile. Farther inland the slope is somewhat steeper, averaging about 4 feet to the mile.

GEOGRAPHIC SUBDIVISIONS OF THE REGION.

The Coastal Plain of Texas may be divided into a number of geographic units, which differ from one another in altitude, topography, character of soil, mineral resources, underground water supply, climate, vegetation, and culture. (See fig. 2.) Some of these differences are determined by the character of the underlying rocks.

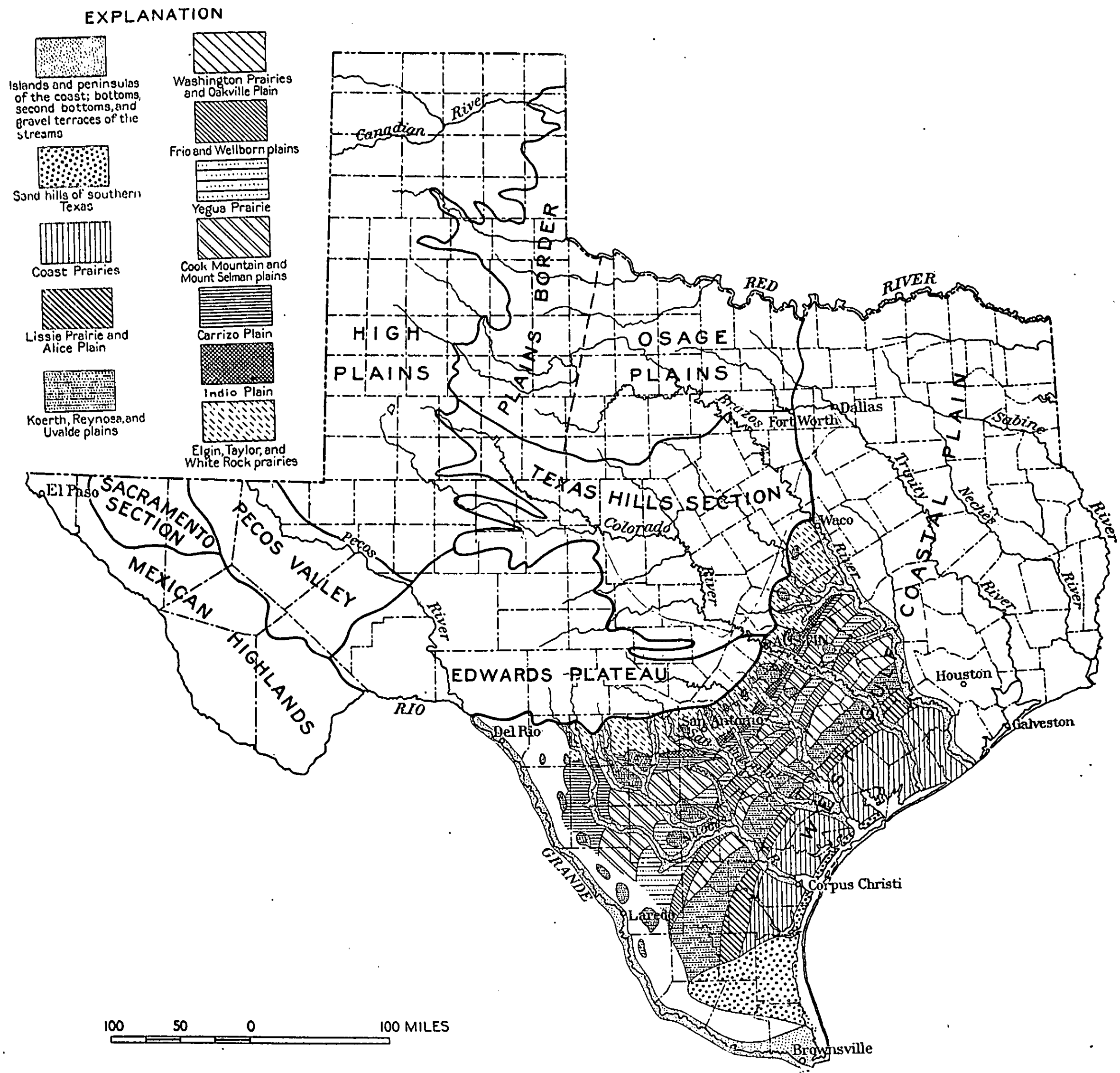


FIGURE 2.—Map of Texas, showing main geographic subdivisions.

ISLANDS AND PENINSULAS OF THE COAST.

The floor of the sea along the coast of Texas is a submerged, gently sloping, even, sand-covered shelf that extends 50 miles seaward. By the action of the tides, waves, currents, and winds, this sand is piled into ridges or barrier beaches, which form long, narrow peninsulas and islands that fringe the coast. These coastal features, which nowhere reach a height of 20 feet above the sea, include Bolivar Peninsula, Galveston Island, Matagorda Peninsula, and Matagorda, Mustang, and Padre islands. Their surface material is unconsolidated drifting sand of Recent origin, and their vegetation is scant.

Between the islands and the mainland lie a number of shallow bays and lagoons into which most of the streams of the Coastal Plain discharge.

The shore of the mainland is very irregular in outline, being indented by reentrants and shallow bays. At many places wave-cut cliffs, 5 to 40 feet in height, overlook a bay. Farther inland there are numerous lagoons.

COASTAL SAND-DUNE BELT.

In Calhoun, Aransas, San Patricio, Nueces, and Kleberg counties sand dunes practically cover a strip of country 4 to 7 miles in width on the mainland bordering the lagoons. (See fig. 2.) The dunes are nowhere more than 25 feet high. The surface material in this belt is a fine white to gray sand of Recent origin, which is thrown up by the waves and drifted inland by the wind.

A thick growth of small live oaks, 1 to 4 feet high, covers most of the surface. Groves of larger trees occupy small hills or hummocks in places, forming what are called "mottes." Grass maintains a foothold with difficulty, especially where the trees are thick. Some marshy places near the coast are covered with salt grass.

SAND-HILL BELT OF SOUTH TEXAS.

The strip of sand dunes merges into an extensive almost triangular area of sand hills in parts of Kenedy, Willacy, Brooks, Hidalgo, and Jim Hogg counties. (See fig. 2.) The base of the triangle is formed by the coast between Baffins Bay and the north line of Willacy County, and the apex extends beyond Altavista, in Jim Hogg County.

The surface of the greater part of this area is gently rolling, though in some places it is flat and in others it contains ridges that trend northwestward and that are as much as 75 feet high. Many of the dunes are covered with vegetation and no longer migrate, but others are still moving as a consequence of the drifting of the sand.

The character of the vegetation is similar to that in the coastal sand-dune belt. The large development of dunes in this part of the Coastal Plain is probably due to the comparative aridity of the climate, to the surface features of the shore, and to the prevailing direction of the wind. Little use is made of these areas except for pasture.

SEAWARD-FACING TERRACES OF THE COASTAL PLAIN.

CHARACTER AND SIGNIFICANCE OF THE TERRACES.

The part of the Coastal Plain that lies east of the Oakville and Bordas escarpments includes a number of seaward-facing terraces, which record successive stages in the uplift of the Coastal Plain and are preserved because they are comparatively young.

The lowest terrace is immediately adjacent to the coast; the highest is represented by the crests of escarpments. The lowest terrace is likewise the youngest and the highest is the oldest. The position of a terrace is therefore an index of its age, and the terraces thus constitute useful time markers in the later history of the Coastal Plain.

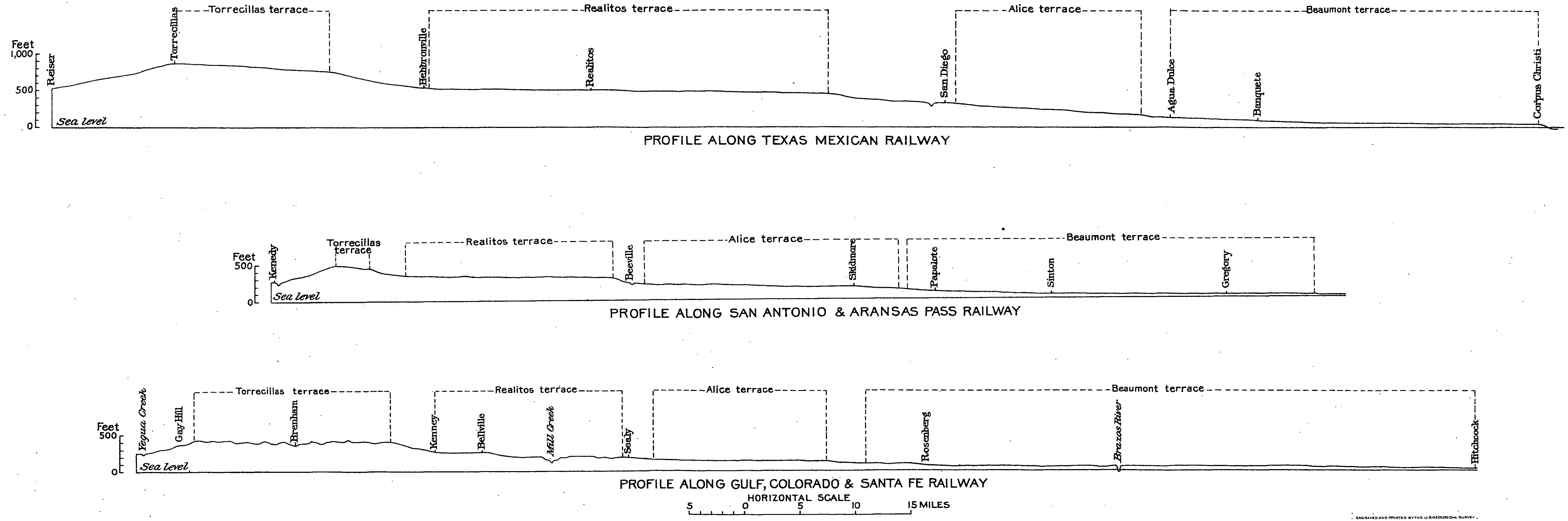
At least five terraces and possibly others can be recognized. Provisionally the terraces of the Coastal Plain are named the Recent, the Beaumont, the Alice, the Realitos, and the Torrecillas.

The Alice terrace is probably composed of several distinct terraces that can not now be discriminated.

A profile across these terraces along the lines of the Texas-Mexican, the San Antonio & Aransas Pass, and the Gulf, Colorado & Santa Fe railways is shown on Plate I. The elevations of the outer and inner margins of the terraces along these railways is shown in the following table:

Elevations of margins of terraces of the Coastal Plain of Texas along certain railways.

Terrace or plain.	Texas-Mexican Railway.		San Antonio & Aransas Pass Railway.		Gulf, Colorado & Santa Fe Railway.	
	Outer margin.	Inner margin.	Outer margin.	Inner margin.	Outer margin.	Inner margin.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Torrecillas plain	740	872	432	500	398	426
Realitos terrace	460	520	300	340	200	250
Alice terrace	150	316	125	230	122	150
Beaumont terrace	40	135	35	110	19	102
Recent plain	0	20	0	20	0	10



PROFILES SHOWING SEAWARD-FACING TERRACES OF THE COASTAL PLAIN

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

BEAUMONT TERRACE.

The Beaumont terrace is a very smooth, gently seaward-tilted plain, which is represented by the Coast Prairie and is coextensive with it. Its width in Nueces County is about 39 miles. The Texas-Mexican Railway crosses it between Agua Dulce and Corpus Christi. The elevation of its western margin is about 135 feet and that of its eastern margin is about 40 feet. Its surface slopes southeastward at the rate of about 2½ feet to the mile.

In Bee and San Patricio counties its width is about 30 miles. The San Antonio & Aransas Pass Railway crosses it between a point 3 miles northwest of Papalote and Gregory. The elevation of the western margin is 110 feet and of the eastern margin 35 feet. The surface slopes southeastward at the rate of about 2½ feet to the mile.

In Fort Bend and Brazoria counties the Beaumont terrace is about 50 miles wide. The Gulf, Colorado & Santa Fe Railway crosses it between milepost 72, which is 6 miles northwest of Rosenberg, and Hitchcock. The elevation of its inner margin is 102 feet and that of its outer margin 19 feet. The surface slopes southeastward at the rate of 1.65 feet to the mile.

ALICE TERRACE.

The Alice terrace borders the Beaumont terrace on the west and lies at a higher level. It is displayed in Duval, Jim Wells, San Patricio, Bee, Goliad, Victoria, Colorado, and Austin counties and is coterminous with the Lissie Prairie and the Alice Plain. Faint seaward-facing escarpments mark its eastern and western boundaries.

Its width in Jim Wells County is about 12 miles. The Texas-Mexican Railway crosses it between San Diego and a point 2 miles west of Agua Dulce. The elevation of the western margin is about 316 feet and of the eastern margin 150 feet. The surface slopes southeastward at the rate of about 14 feet to the mile.

Its width in San Patricio County is about 7 miles. The San Antonio & Aransas Pass Railway crosses it between Beeville and milepost 43, which is 4 miles southeast of Skidmore. The elevation of its western margin is about 230 feet; that of its eastern margin about 125 feet. Its surface slopes southeastward at the rate of about 15 feet to the mile.

The width of the Alice terrace in Austin and Fort Bend counties is about 15 miles. The Gulf, Colorado & Santa Fe Railway crosses it between a point 2 miles southeast of Sealy and milepost 76, which is 10 miles northwest of Rosenberg. The elevation of the inner margin is 150 feet and of the outer margin 122 feet. The surface slopes southeastward at the rate of about 2 feet to the mile.

REALITOS TERRACE.

The Realitos terrace borders the Alice terrace on the west in Duval, Jim Wells, Live Oak, Bee, Goliad, De Witt, Lavaca, Colorado, and Austin counties. It stands at a higher level than the Alice terrace and is marked by seaward-facing escarpments on its eastern and western margins. The flat of the terrace is represented in part by the Koerth and Reynosa plains.

In the southern part of Duval County the Realitos terrace is about 20 miles wide. The Texas-Mexican Railway crosses it between Hebbronville and milepost 65, which is 2 miles northeast of Mesquite. The elevation of its western margin is 520 feet and that of its eastern margin 460 feet. Its surface is more or less dissected, but all high points reach a common gradient of 3 feet to the mile southeastward.

In Bee County the flat part of the terrace is about 10 miles wide. The elevation of the interior margin is 340 feet and that of the outer margin 300 feet. The surface has a southeastward slope of about 4 feet to the mile.

In Washington County this terrace is about 17 miles wide. The Gulf, Colorado & Santa Fe Railway crosses it between milepost 112 and Sealy. The elevation of the inner margin is 250 feet and of the outer margin 200 feet. The surface is more or less dissected, but all high points fall into a plane which has a southeastward slope of 3 feet to the mile.

The Realitos terrace increases in elevation toward the south, and it has shared in the Torrecillas uplift.

TORRECILLAS PLAIN.

The Torrecillas Plain is an eroded, seaward-tilted, warped, elevated plain that occupies parts of Webb, Duval, Live Oak, Bee, Karnes, De Witt, Lavaca, Fayette, Austin, and Washington counties. It is represented in part by the Washington Prairies and the Reynosa Plain. (See pp. 8–9.)

The Oakville and Bordas escarpments, which face westward, mark its western margin, and a seaward-facing scarp, the edge of the Torrecillas Plain, marks its eastern margin.

The Torrecillas Plain is about 8 miles wide in the southeast corner of Webb County. The elevation at Torrecillas, at the western margin, is 872 feet, and at milepost 109, on the Texas-Mexican Railway, at the eastern margin, it is 740 feet. The eastward slope is about 8 feet to the mile.

In the northern part of Bee County the plain is about 10 miles wide and is well displayed between Monteola and a point on the Beeville-Mineral road about 11½ miles northwest of Beeville. The elevation at Monteola is about 491 feet and at the other locality 412 feet.

In Washington County the plain is about 17 miles wide and is well displayed along the Gulf, Colorado & Santa Fe Railway from a point 1½ miles south of Gay Hill to Kenney, in Austin County. (See Pl. I.) The elevation at the point south of Gay Hill is 426 feet and at Kenney 398 feet. The surface is more or less dissected by streams, but all high points reach a gradient of about 2 feet to the mile southeastward.

There is considerable discordance in the elevations of the northern and southern limits of this plain, for the western margin is about 446 feet higher in Webb County than in Washington County. This discrepancy is due to a late uplift centered in the southeast part of Webb County (described on p. 124), which has elevated the southern part of the plain much above the level occupied by it farther north.

UPLAND BELTS OF THE COASTAL PLAIN.

COAST PRAIRIE.

The level treeless area about 45 miles wide that borders the coast between Sabine River and the north line of Willacy County is called the Coast Prairie. (See fig. 2.) Foster on the Brazos, Glenflora on the Colorado, Victoria on the Guadalupe, and San Patricio on the Nueces mark approximately its interior margin.

The elevation of the seaward margin of this prairie ranges from 20 to 40 feet. The elevation of its interior margin ranges from 110 feet on the Brazos to about 135 feet on the Nueces. The seaward slope is about 2 feet to the mile.

This prairie is so very nearly flat that at some places the eye can not detect any perceptible break in its surface for miles. The rainfall makes its way to the drainage channels with difficulty, and much of it stays where it falls until it is evaporated or slowly enters the almost impervious soil.

On the Coast Prairie there are a number of low rounded, circular, or oval elevations, locally known as "mounds" or "domes," which range in size from a few acres to a square mile. They are structural features and have been produced by local uplift. Gas, oil, salt, gypsum, and sulphur are usually associated with them. The location and the features of some of these mounds are described below.

Bryan Heights, a mound in southern Brazoria County near the mouth of Brazos River, 3 miles from Velasco, is 300 acres in extent and rises 19 feet above the surrounding plain.[5] Damon, a roughly circular mound about 2 miles across, in northwestern Brazoria County, rises 75 feet above the surrounding prairie. Its diameter is about 2 miles.[6] Kiser's or West Columbia Mound, an elevation of irregular form in western Brazoria County, 3 miles northwest of Columbia, just west of Brazos River, rises 30 feet above the surrounding plain.[7] Markham Mound, in Matagorda County, 6 miles northwest of Markham station, an oblong elevation whose longer axis trends northwestward, has only a slight elevation above the surrounding plain.[8] Big Hill, in Matagorda County near the mouth of Colorado River, 5 miles northeast of Matagorda, is a rather flat-topped dome which rises 36 feet above sea level, or 20 to 24 feet above the level of the Coast Prairie.[9]

Circular elevations 10 to 50 feet in diameter and 2 to 5 feet in height, which occur singly or in groups and are known as "pimples," are also common on the Coast Prairie, notably in Brazoria and Calhoun counties. Their origin is not known. They have been ascribed to the action of escaping gas, to the work of ants, to the action of the wind, and to human agency, and they may have been produced by different causes in different localities. Those at Humble in Harris County, seem to have been produced by the action of gas. Veatch has discussed these mounds somewhat fully, and for further

[5] Harris, G. D., Oil and gas in Louisiana, with a brief summary of their occurrence in adjacent States: U. S. Geol. Survey Bull. 429, p. 14, 1910.
[6] Idem, p. 16.
[7] Idem, p. 20.
[8] Idem, pp. 20–31.
[9] Idem, p. 21.

information the reader should consult his paper.[10]

Depressions known as "hog wallows," which range from 6 to 20 inches in depth and from 3 to 10 feet in diameter, are at some places scattered somewhat regularly over the surface of the Coast Prairie. According to a tradition among the inhabitants of this region, these "wallows" were formed by buffaloes, but their real mode of origin is unknown.

The soil of the Coast Prairie is at most places a black or drab clay, derived by weathering from the underlying yellow or reddish, stiff, waxy, calcareous clay, which contains small nodules of lime, and from the decay of vegetal matter.

The vegetation consists of a rich growth of grasses and many flowering plants. Live oaks, loaded with Spanish moss, border the prairies along the stream courses or grow in scattered "mottes" over them. Around Port Lavaca, Calhoun County, huisache and salt cedar are noticeable. South of the Nueces a heavy growth of mesquite, chaparral, prickly pear, and mesquite grass appears.

Beneath the surface of the Coast Prairie lie valuable accumulations of petroleum, natural gas, salt, and sulphur. Petroleum is produced in considerable quantity at West Columbia, Damon Mound, and Markham and in smaller quantity near Matagorda. Natural gas has been used for fuel near Matagorda. Gas under strong pressure was discovered in 1914 at White Point on Nueces Bay, 12 miles south of Sinton, San Patricio County. (See Pl. II, *A*.) Sulphur is mined at Freeport, in Brazoria County, and at Big Hill, in Matagorda County. All building material except sand and clay is scarce, and the clay is too limy for making clay products. The supply of surface and ground water is abundant, but the ground water is in places too salty for use.

The chief industries in the Coast Prairie are the cultivation of rice, cotton, truck, sugar cane, and fruit, the raising of stock, the production of crude petroleum, and the mining of sulphur. In Fort Bend County a number of sugar mills are engaged in making and refining sugar. Rice is grown by irrigation with water drawn from surface streams and wells.

The principal towns in the Coast Prairie are Columbia in Brazoria County, Richmond in Fort Bend County, Wharton in Wharton County, Edna in Jackson County, Victoria in Victoria County, Port Lavaca in Calhoun County, Bay City in Matagorda County, and Corpus Christi in Nueces County. Of these towns the largest is Corpus Christi, the population of which in 1920 was 10,522.

[10] Veatch, A. C., U. S. Geol. Survey Prof. Paper 46, pp. 55-59, 1906.

LISSIE PRAIRIE.

The Lissie Prairie lies west of the Coast Prairie, and north of Guadalupe River. (See fig. 2.) It includes parts of Fort Bend, Austin, Wharton, Colorado, Lavaca, Jackson, and Victoria counties.

This prairie differs from the Coast Prairie in altitude and soil and is underlain by a different geologic formation. The elevation of its seaward margin is about 122 feet; the elevation of its interior margin is about 150 feet. Its width is about 20 miles where it is crossed by the Colorado and about 12 miles where it is crossed by the Guadalupe. Its average width is about 16 miles. Its soil is largely a gray or dark-gray sandy loam. Gravel consisting of quartz, flint, limestone, jasper, feldspar, and other pebbles is present at no great depth beneath the surface. This prairie is at some places treeless and grass-covered, but at others it is occupied by a forest of post oak, live oak, and blackjack. No valuable minerals are found in this prairie. The supply of water, both surface and ground, is large. Wells obtain large quantities of water at comparatively slight depths. The ground water is used for domestic purposes and for making steam, and also for the irrigation of rice. The chief industries are the culture of cotton, corn, rice, and sugar cane.

ALICE PLAIN.

The Alice Plain represents the continuation of the Lissie Prairie south of the Guadalupe. It occupies parts of Goliad, Bee, Live Oak, San Patricio, Jim Wells, Nueces, Duval, Brooks, and Kleberg counties. (See fig. 2.)

The elevation of this plain ranges from 125 to 316 feet. This plain differs from the Lissie Prairie, of which it is the continuation, in the nature of the underlying material, soil, and vegetation. The subsurface formation is a yellow silt and limy conglomerate or a gravel representing in part the débris of crystalline rocks cemented by lime. The soil consists of dark-drab sandy loam. The plain is in large part covered with mesquite, chaparral, and cactus.

KOERTH PLAIN.

West of the Lissie Prairie and the Alice Plain lies a belt of country which may be called the Koerth Plain north of Guadalupe and the Reynosa Plain south of the Guadalupe. The Koerth Plain occupies parts of Austin, Colorado, Lavaca, and De Witt counties. (See fig. 2.)

Its average elevation is about 250 feet. Unlike the areas lying between it and the coast this plain is more or less dissected.

The soil is a light-gray sand, a sandy loam, or a loam that contains a considerable admixture of waterworn gravel. The material beneath the surface is gravel, consisting of pebbles of quartz, feldspar, jasper, and other minerals derived by stream erosion from crystalline rocks.

The plain is heavily forested with post oak, live oak, and blackjack.

Cotton and corn are the principal crops grown, but sorghum and ribbon cane are planted to some extent. Much of the plain is used for pasture.

REYNOSA PLAIN.

South of the Guadalupe the Reynosa Plain corresponds to the Koerth Plain. It borders the Alice Plain on the west and occupies parts of De Witt, Karnes, Goliad, Bee, Live Oak, Jim Wells, Duval, Webb, and Jim Hogg counties. (See fig. 2.)

It is higher than the Alice Plain or the Koerth Plain, the elevations ranging from 300 to 872 feet above sea level. The surface is more dissected by stream erosion than that of the plain to the east.

The Reynosa Plain is underlain by limestone belonging to the Reynosa formation, which on weathering leaves a residuum that forms a red soil. Much of it is open prairie, but in places there is a scattering growth of mesquite and cactus, and in places where the soil is thin there is a thick growth of chaparral. (See Pl. III, A.)

This plain is not largely cultivated. A small part of it is devoted to the growing of cotton, but the larger part is used for pasture.

The western boundary of the Reynosa Plain consists of a westward-facing slope known as the Bordas escarpment,[11] a very prominent feature of the Coastal Plain south of Guadalupe River. (See Pl. III, *B*.)

This escarpment has been formed because of the superior resistance to erosion of the limestone of the Reynosa formation in this arid part of the Coastal Plain.

UVALDE PLAIN.

West of the Koerth and Reynosa plains, and on the high divides between the major streams there are remnants of a former extensive plain (see fig. 2) known as the Uvalde Plain, which has been largely destroyed by erosion.

In Travis County this plain stands 600 feet above sea level; in Bexar County 680 feet; in Uvalde County 970 feet; and in Webb County 728 feet. The remnants of the plain are conspicuous in Travis, Hays, Comal, Bexar, Medina, Uvalde, Zavalla, Frio, and Webb counties. The surface of the upland is generally flat. Owing to the coarse texture of the soil and subsoil the drainage is good.

The material that underlies this dissected plain in most places is a conglomerate in which pebbles and cobbles of flint, jasper, quartz, feldspar, and other minerals are cemented by lime. At some places this conglomerate is covered with a black clay soil, through which are scattered numerous flint pebbles and cobbles. At other places the conglomerate disintegrates into a coarse gravel, which remains in place and forms barren tracts of land.

The gravelly black clay soil is covered with mesquite. The coarse gravel tracts north of the Guadalupe are covered with post oak, and those south of the Guadalupe are covered with chaparral, huisache, and guajillo. At some places there are a few live oaks.

The gravelly, black-clay "hog-wallow" lands of this plain are very productive and yield good crops of cotton, corn, and sorghum in Travis, Comal, Bexar, and Medina counties. The gravel tracts are suited only for pasture.

WASHINGTON PRAIRIES.

The Washington Prairies were first recognized and named by Hill,[12] who called them the "Fayette Prairies." They form a belt of country, 10 to 30 miles wide, lying west of the Koerth Plain, in Austin, Washington, Fayette, Colorado, Lavaca, De Witt, and Karnes counties. (See Pl. III, *C*, and fig. 2.) Their maximum width is 30 miles. South of the

[11] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, p. 5, 1903.

[12] Hill, R. T., Geography and geology of the Black and Grand prairies, Tex.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 408, 1901.

Brazos the width gradually diminishes until in the region of the Guadalupe it is not more than 10 miles.

The altitude of the Washington Prairie ranges from 350 to 600 feet. The surface features consist of a succession of broad rolling ridges whose trend swings from eastward to southeastward. The slopes of these ridges are, as a rule, long and gentle. In the western and northwestern part of the prairies, however, the slopes are somewhat steeper and the tops of the ridges are not so broad. The ridges rise about 100 feet or more above the intervening troughs or valleys. The succession of ridges with green pastures and cultivated fields makes a pleasing landscape.

The escarpment that marks the western margin of these prairies can be readily traced across the country. The course of Cedar Creek, in Fayette County, is determined by it. At La Grange the escarpment forms a pronounced bluff, known as Monument Hill, which has deflected the Colorado. Buckners Creek follows it for 6 or 8 miles. Burkett Mound, in Lavaca County, is a part of it. The escarpment is very pronounced in De Witt County.

This escarpment has never been named, so far as the writer knows. Its existence in the Coastal Plain was recognized by Loughridge [13] and Dumble,[14] but it has not been discriminated from other escarpments, which in places are parallel to it. The name Oakville escarpment is therefore proposed for this feature.

The soil of the Washington Prairies is at most places a stiff black waxy clay but is at some places a black heavy loam or clay loam or a dark-brown sandy loam. The subsoil is a stiff, tenacious yellow, red, or drab clay, which in some areas contains concretions of lime. The soil and subsoil are derived by weathering from the underlying calcareous sandstones and clays of the Oakville and Lagarto formations and from decayed vegetal matter. Locally the lands are called "hog-wallow," "black waxy," or "black prairie" lands.

The prairies are generally treeless, but some of the sandy knolls are occupied by live-oak "mottes."

The mineral resources are of little value. The supply of both surface and underground water is abundant. The underground water is generally good and can be obtained at slight expense.

Cotton and corn are the staple crops grown on the Washington Prairies.

The chief towns are Brenham, in Washington County, and Hallettsville and Yoakum, in Lavaca County. The largest of these towns is Brenham, whose population in 1920 was 5,066.

OAKVILLE PLAIN.

The sandstone and clay that underlie the Washington Prairies north of the Guadalupe extend south of that stream through parts of Bee, Live Oak, McMullen, and Duval counties, but as the climate is semiarid the surface features that have been developed here are sufficiently different to warrant the application to the area of the name Oakville Plain. (See fig. 2.)

This plain lies 400 to 600 feet above the sea. Its southeastern half is rather level or gently rolling, but its northwestern half is much dissected by erosion and is rugged and hilly.

The western boundary of the plain is a westward-facing escarpment, which is continuous with the escarpment that bounds the Washington Prairies. (See Pl. IV, *A* and *B*.) This escarpment parallels for a considerable distance the Bordas escarpment and finally merges into it in the southern part of Duval County.

The more level parts of the plain are covered with residual dark-gray to dark-brown loam, which contains a large quantity of organic matter. Where the surface is uneven the soil is thin. The plain is covered by a heavy growth of black chaparral, catclaw, cactus, guajillo, and other native brush. The land is used chiefly for grazing.

FRIO PLAIN.

The Frio Plain forms a belt of country 1 to 15 miles wide which adjoins the Oakville Plain on the west. It extends through Gonzales, Karnes, Atascosa, Live Oak, McMullen, and Duval counties. (See fig. 2.)

The surface is rather level or gently rolling. The soil is residual fertile black clay north of the Guadalupe and dark-gray to dark-brown loam and black clay loam south of that stream. It is derived from the marl of the underlying Frio formation. On the black clay mesquite, cedar, and mottes of live oak abound in alternation with open prairie. The loam areas

[13] Loughridge, R. H., Physico-geographical and agricultural features of the State of Texas: Tenth Census U. S., vol. 5, p. 679, 1884.

[14] Dumble, E. T., The physical geography and geology of Texas: A comprehensive history of Texas, vol. 2, pp. 471-519, Dallas, 1898.

of Live Oak and McMullen counties are covered with a thick growth of chaparral; the clay loam areas are treeless.

WELLBORN PLAIN.

The Wellborn Plain is a sharply dissected belt of plain which occupies parts of Burleson, Fayette, Gonzales, Wilson, Atascosa, McMullen and Webb counties. (See fig. 2.) It is 7 to 15 miles wide.

The western boundary south of Colorado River is formed by a westward-facing escarpment that parallels the course of the Oakville escarpment. It extends as far south as the southern part of Duval County, where it merges into the Oakville and Bordas escarpments.

The soil of this plain north of the Guadalupe consists largely of gray sand or sandy loam and supports a growth of post oak; south of the Guadalupe it consists of dark-gray to dark-brown loam and is covered with mesquite, which is replaced in Atascosa, McMullen, and Duval counties by chaparral and cactus. On the broken lands of the western margin the soil is in many places extremely thin.

These lands are utilized largely for pasture. Stone suitable for construction occurs at a number of places and is quarried at Quarry, Washington County, and at Muldoon, Flatonia, and Ledbetter, Fayette County.

YEGUA PRAIRIE.

The Yegua Prairie extends from the Brazos to the Nueces across Burleson, Lee, Fayette, Gonzales, Wilson, Atascosa, McMullen, and Lasalle counties. (See fig. 2.)

The surface is rather level or very gently rolling; in places it is almost flat. The soil is a fertile black clay, or a dark-brown or black clay loam, derived from clay of the underlying Yegua formation, enriched by the decay of vegetal matter. The prairie is largely open and treeless. South of the Guadalupe it presents a pleasing contrast to the chaparral-covered plain on either side.

The land near the railroads is largely cultivated and produces good crops of cotton, corn, and sorghum. Where facilities for transportation are not available, it is utilized chiefly for pasture.

COOK MOUNTAIN PLAIN.

The Cook Mountain Plain lies west of the Yegua Prairie and occupies parts of Burleson, Lee, Bastrop, Caldwell, Gonzales, Wilson, Atascosa, Frio, and Lasalle counties. (See fig. 2.) It is 5 to 20 miles wide.

The name San Antonio Prairie is locally applied to this plain in Lee and Burleson counties. The prairie was so named from the old San Antonio road, which traversed it. This highway extended from San Antonio to Natchitoches in Louisiana and was the main route of overland travel in the early days of the settlement of Texas.

The elevation of the Cook Mountain Plain ranges from 400 to 600 feet. The surface is gently rolling and well drained. The soil north of the Guadalupe consists chiefly of black or red clay derived by weathering from a green glauconitic marl. In places, however, there are gray to red sands and sandy loams derived from underlying sand and sandstone. South of the Guadalupe the prevailing type of soil is a red or a brownish-red sandy loam on a bright-red sandy clay subsoil, but in places a black loam lies on a red clay subsoil.

The heavy clay lands north of the Guadalupe are covered chiefly with grass, though mesquite is gradually encroaching on the open tracts. The tracts of sand and sandy loam are covered with post oak and blackjack. The vegetation south of the Guadalupe consists of a very thick growth of mesquite, prickly pear, chaparral, tassojilla, guajillo, catclaw, and similar types.

In the vicinity of the railroads and the towns good crops of cotton, truck, and corn are grown on these lands.

MOUNT SELMAN PLAIN.

The Mount Selman Plain, which flanks the Cook Mountain Plain on the west, slopes gently seaward and is somewhat dissected and eroded. It is 4 to 20 miles wide and occupies parts of Burleson, Milam, Lee, Bastrop, Caldwell, Guadalupe, Gonzales, Wilson, Atascosa, Frio, Zavalla, and Dimmit counties. (See fig. 2.)

The elevations range from 450 to 700 feet. Porter Knob in Guadalupe County, which is 700 feet high, is one of the highest points. The surface is rolling or hilly.

The plain terminates on the west in a low escarpment formed by erosion, which east of the Brazos has been called the Nacogdoches Bajada.[15] The hills which form the escarp-

[15] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 18, 1914.

ment are capped by low-grade limonite ores or hard ferruginous sandstone, and they owe their form to this protective cover.

The soil of the Mount Selman Plain is residual and consists of deep-gray or yellow sand on a subsoil of orange, red, or mottled ferruginous sand. At some places the surface soil is red and contains some iron, but at others the iron has been leached out.

The part of the plain that lies north of Atascosa Creek, in Atascosa County, is covered with a forest of post oak and blackjack. There is an isolated forest of pine in Bastrop County near Colorado River. The vegetation south of Atascosa Creek consists of mesquite, cactus, and chaparral.

The region is not well adapted to agriculture.

CARRIZO PLAIN.

The Carrizo Plain lies west and north of the Mount Selman Plain. It occupies portions of Milam, Lee, Bastrop, Caldwell, Guadalupe, Wilson, Bexar, Atascosa, Frio, Medina, Uvalde, Zavalla, and Dimmit counties. (See fig. 2.)

The elevation ranges from 500 to 800 feet, and the surface is fairly level or hilly.

The soil of the Carrizo Plain is chiefly fine to coarse yellow sand or fine sandy loam, representing a weathered phase of the underlying Carrizo sandstone. In places there is a dark-gray loam. A forest of post oak and blackjack occupies the plain as far west as the southeast corner of Medina County. The vegetation in Frio, Zavalla, and Dimmit counties consists chiefly of mesquite, chaparral, prickly pear, guajillo, and catclaw.

Much of this land is used for pasture. Vegetables are grown under irrigation to some extent in Dimmit, Zavalla, and Frio counties.

INDIO PLAIN.

The Indio Plain lies west and northwest of the Carrizo Plain in Milam, Lee, Williamson, Bastrop, Caldwell, Guadalupe, Wilson, Bexar, and Medina counties. (See fig. 2.) Its width in the vicinity of the Brazos is 12 miles or more. It becomes narrower southward and probably does not extend west of Medina County.

The elevations range from 450 to 750 feet. The surface is greatly dissected by streams and is in places hilly.

The soil consists chiefly of gray, yellow, or orange sands, sandy loam, and loam derived by weathering from the underlying sand and clay of the Indio formation. The plain is covered with a forest of post oak and blackjack as far south as Guadalupe River. The vegetation of the area south of this stream consists chiefly of mesquite and prickly pear.

Fair crops of cotton and corn and some fruit and truck are grown on these lands. Much of the plain is used for pasture.

Lignite is mined at Rockdale, Milam County; Phelan, Bastrop County; and Lytle, Medina County.

ELGIN PRAIRIES.

The Elgin Prairies lie west of the Indio Plain and form a belt 5 to 12 miles wide which extends southwestward through Falls, Milam, Williamson, Travis, Bastrop, Caldwell, Guadalupe, and Bexar counties. They are coextensive with the outcrop of the Navarro and Midway formations. (See Pl. VIII, in pocket.)

The elevations range from 450 to 650 feet, and the surface is gently undulating or rolling. The fertile soil consists of residual black calcareous sand and clay. Much of the land is open prairie, but at some places there are thickets of mesquite.

The prairies are densely settled. The leading industry is the culture of cotton and corn.

TAYLOR PRAIRIES.

Hill has applied the name Taylor Prairies to the belt of rolling prairie land that lies west of the Elgin Prairies.[16] These prairies occupy the greater part of Falls County, the eastern part of Bell, the western part of Milam, the eastern part of Williamson, and small areas in Travis, Hays, Comal, Guadalupe, and Bexar counties. In the last five counties mentioned the Taylor Prairies in their typical form appear at only a few places.

These prairies mark the outcrop of the Taylor marl, a characteristic feature of which is a stiff black waxy calcareous clay soil, which grades into a jointed and laminated light-blue marl locally known as "soapstone" or "joint clay." The surface is gently rolling and is in places covered with a growth of mesquite. "Hog-wallow" land is common on poorly drained divides, and wide, shallow valleys lie between the low, rounded hills. The prairies are drained by many small streams, but some of them are dry most of the time.

[16] Hill, R. T., Geography and geology of the Black and Grand prairies, Tex.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 67-68, 1901.

The average elevation of these prairies is about 600 feet, and the highest ridges have an altitude of 675 to 700 feet.

These prairies are extremely fertile and form the most valuable farming lands in Texas. Before the advent of the boll weevil they produced without fertilization an average crop of a bale of cotton to the acre.

The leading industry is agriculture, and the staple products are cotton and corn. The clay that lies beneath the soil is in places used for making brick.

The important economic problem in this region is that of obtaining an adequate supply of water. No water can be obtained near the surface, and artesian water can be procured only by going to great depths at much expense. The main source of supply is surface water impounded in storage reservoirs, but during droughts this supply often fails.

WHITE ROCK PRAIRIES.

The White Rock Prairies, so named by Hill,[17] form the westernmost of those diverse belts of country that parallel the coast and make up the Coastal Plain of Texas. These prairies include parts of McLennan, Bell, Williamson, Travis, Hays, Comal, Guadalupe, Bexar, Medina, Uvalde, and Kinney counties. They are named from the white rock or chalky limestone—the Austin chalk—that here underlies the soil.

The surface of these prairies is more rugged and more sharply incised by deep stream channels than that of the Taylor Prairies, but the relief is nevertheless low, and there are no steep bluffs and scarps like those in the regions on the west. The hills are rounded and have gently sloping sides, but at some places along the stream courses there are precipitous bluffs of white limestone. The soil is easily eroded, and the underlying white limestone appears at the surface at many places.

The western boundary of these prairies north of Temple in Bell County is formed by the White Rock scarp. South of Temple the continuity of the escarpment is interrupted by faults, and at many places the prairies terminate at the foot of the Balcones scarp.

The soil of the White Rock Prairies is a dark-brown to black loam or a black clay, which becomes stiff and tenacious when wet. The subsoil is a stiff, dark-brown clay, which at comparatively slight depth becomes lighter in color, the proportion of silt increasing with the depth. The subsoil grades into a white silty material composed of soft, chalky limestone.

The character of the vegetation on the White Rock Prairies is determined largely by the depth of the soil. Where the soil is thin or where there is no soil there is a good growth of mountain cedar; where the soil is thicker there are groves of moss-covered live oak, and where the soil is rather deep there are clumps of mesquite.

The chief mineral resource of the White Rock Prairies is building stone, which is quarried in places from beds of the Austin chalk. When mixed with a proper proportion of clay, this rock can also be used in making Portland cement, for which purpose it is utilized in two mills at San Antonio.

Underground water is hard to get at slight depths. Artesian water can be procured at most places on the prairies at depths of 1,000 to 2,700 feet.

The chief industry is agriculture. Cotton and corn are the leading crops. Hill[18] has pointed out the fact that many of the chief cities of Texas, including Sherman, Dallas, Waco, Austin, and San Antonio, are built on these prairies.

WHITE ROCK SCARP.

The northern part of the western margin of the Coastal Plain terminates in a range of hills that presents a westward-facing scarp of erosion, which has been produced by the superior resistance of the harder Austin chalk as compared with the softer underlying Eagle Ford shale. This scarp has been called the White Rock scarp.[19]

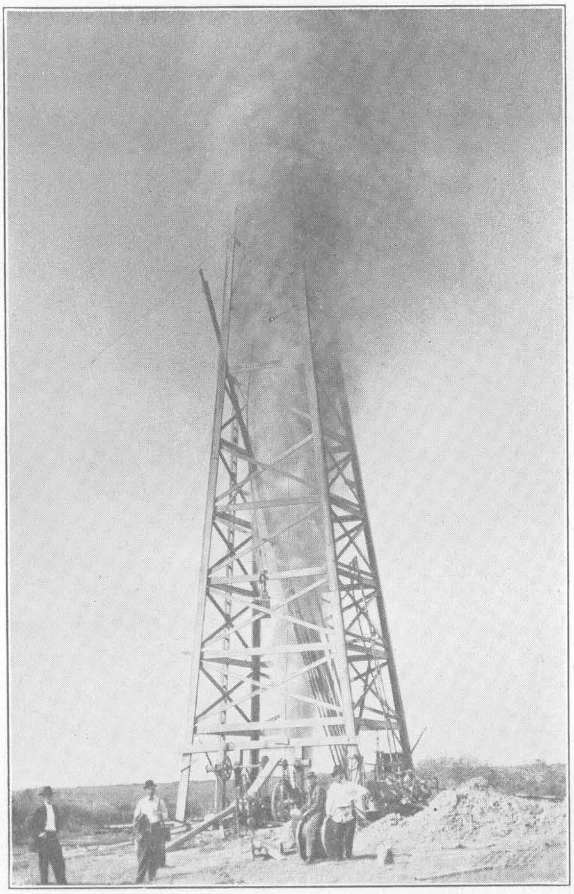
BALCONES SCARP.

A pronounced seaward-facing fault scarp, known as the Balcones scarp, forms the interior margin of the Coastal Plain south of Temple. It passes through Austin, San Marcos, New Braunfels, and San Antonio, and there turns westward and extends through Hondo and Uvalde to Del Rio. Seen from the more open and level country on the east and south the scarp appears as a sharp line of cedar-covered

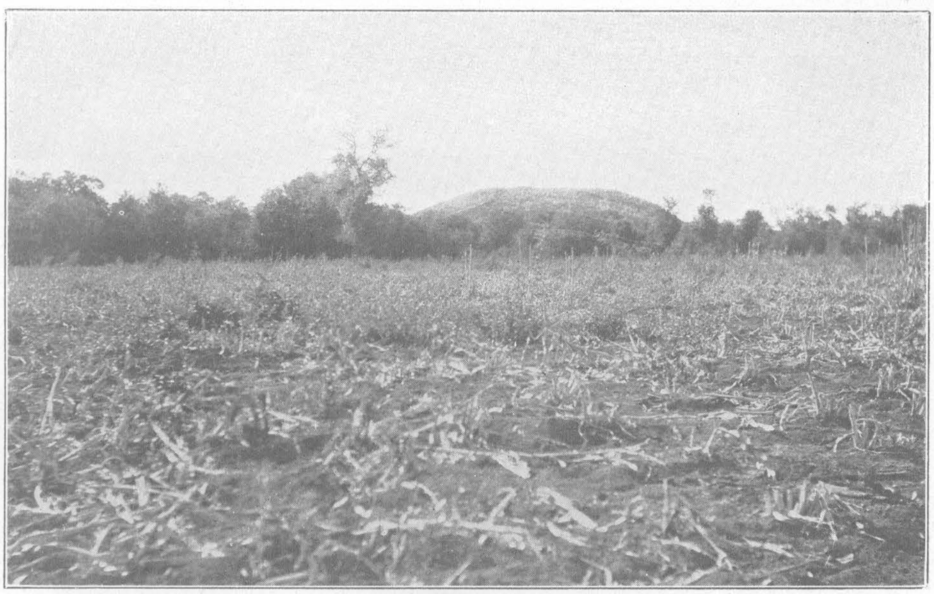
[17] Hill, R. T., Geography and geology of the Black and Grand prairies, Tex.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 68, 1901.

[18] Idem, p. 68.

[19] Idem, p. 63.



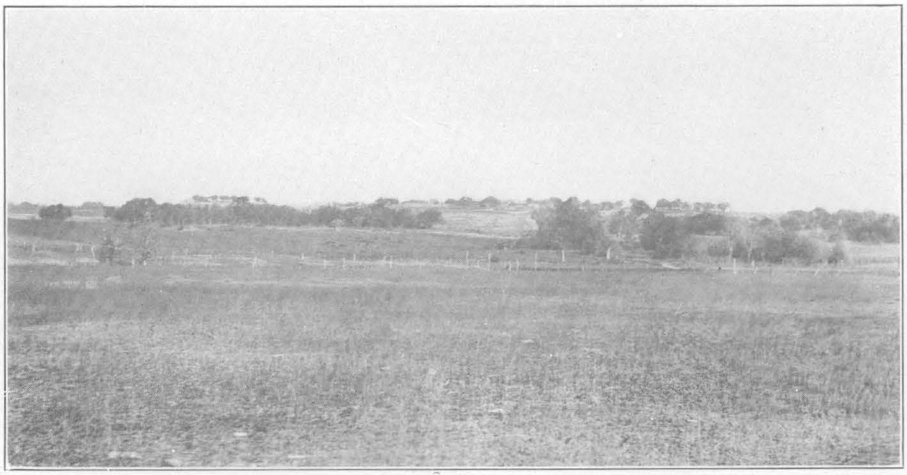
A. GAS WELL OF THE WHITE POINT OIL & GAS CO. ON NUECES BAY, SAN PATRICIO COUNTY, TEX.



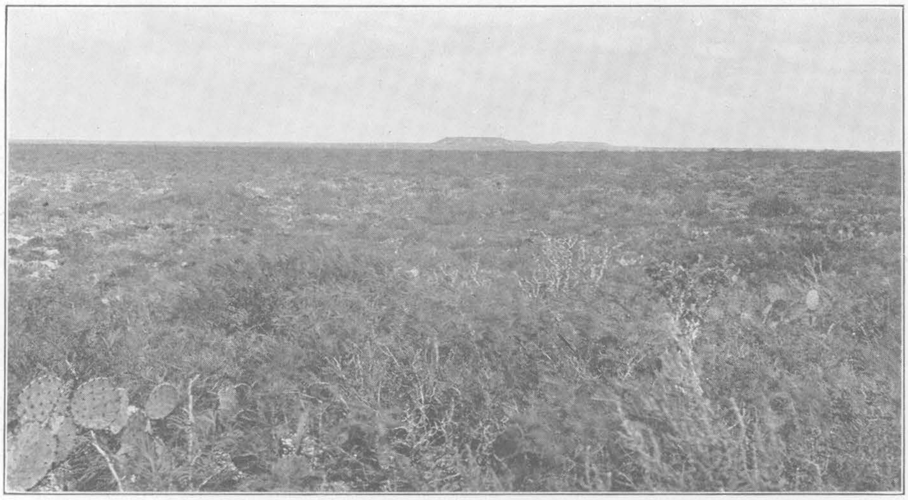
B. MOUNT INGE, A PHONOLITE KNOB ABOUT 2 MILES SOUTH OF UVALDE, UVALDE COUNTY, TEX.

A. CHAPARRAL OF THE RIO GRANDE PLAIN ABOUT 2 MILES SOUTHEAST OF TILDEN, McMULLEN COUNTY, TEX.

B. VIEW OF BORDAS ESCARPMENT LOOKING SOUTHWESTWARD FROM LOS PICACHOS HILL, IN THE NORTHERN PART OF DUVAL COUNTY, TEX.

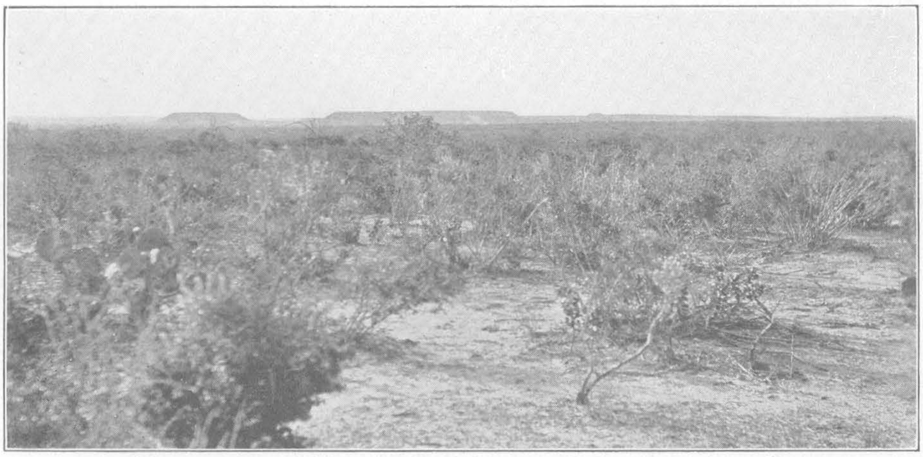


C. WASHINGTON PRAIRIES IN THE VICINITY OF BURTON, WASHINGTON COUNTY, TEX.

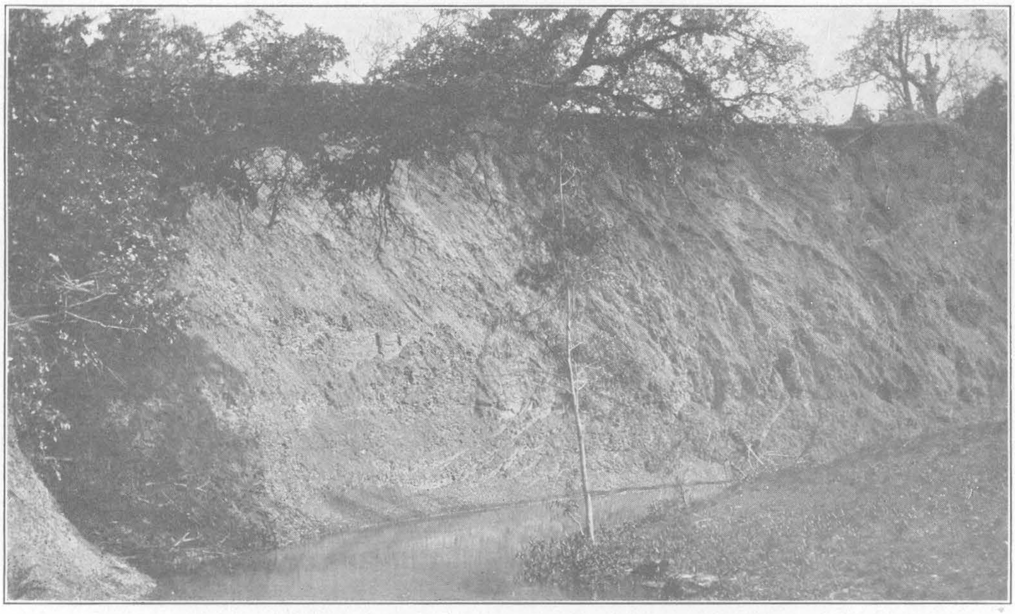


A. VIEW OF LOMO ALTO HILL LOOKING NORTHEASTWARD FROM LOS PICACHOS HILL, ABOUT 5 MILES DISTANT TO THE SOUTHWEST, IN DUVAL COUNTY, TEX.

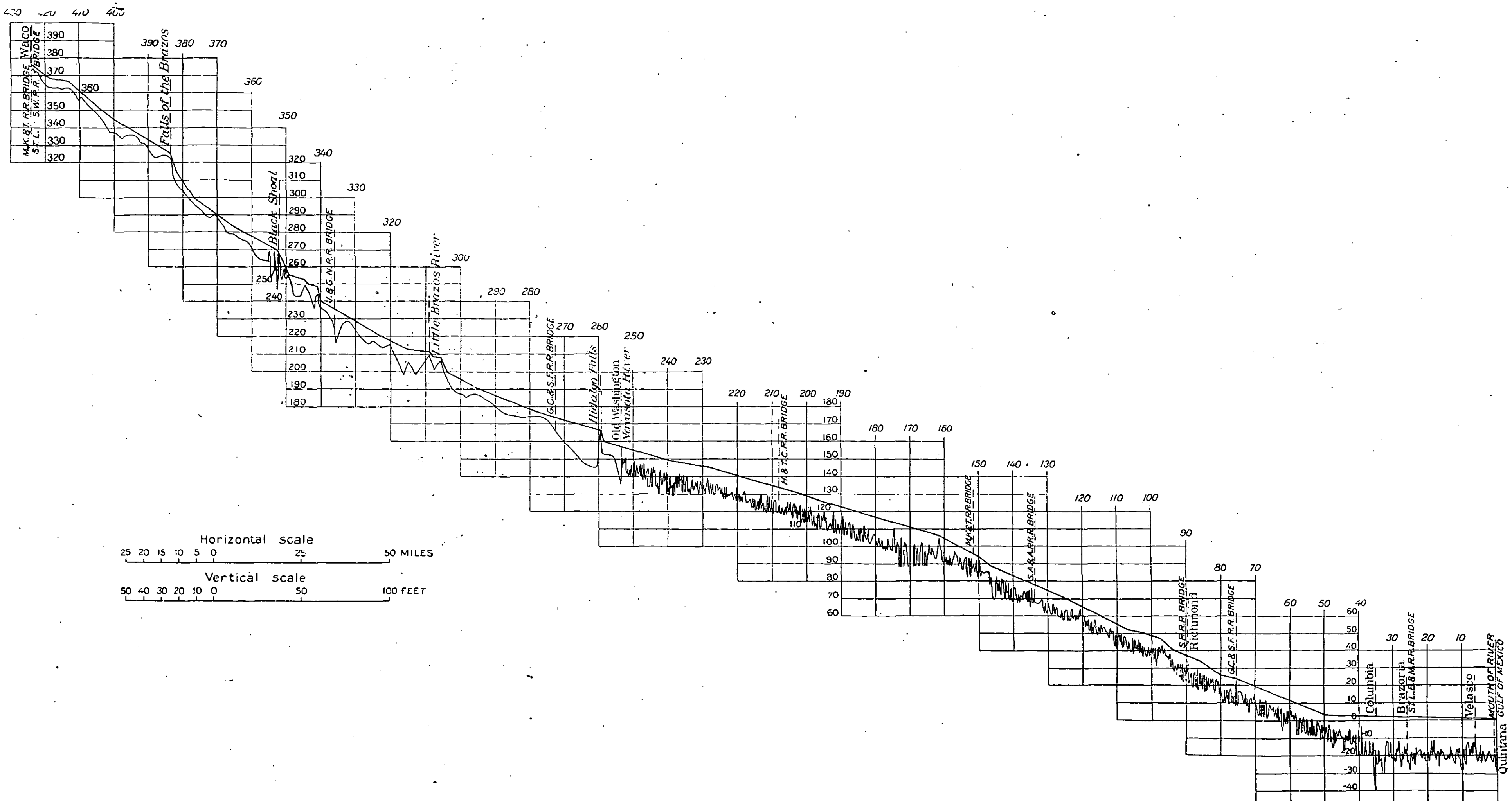
Note chaparra in foreground.



B. CHUSAS HILLS AS SEEN FROM LOMO ALTO POST OFFICE, McMULLEN COUNTY, TEX., ABOUT 2 MILES DISTANT TO THE WEST.



C. VIEW OF BLUFF EXPOSING TAYLOR MARL ON BIG WALNUT CREEK, 1½ MILES SOUTH OF SPRINKLE, TRAVIS COUNTY, TEX.



MIDSTREAM PROFILE OF BRAZOS RIVER FROM WACO, TEX., TO THE MOUTH.

The upper sloping line represents the normal water stage; the lower jagged line represents the bottom of the channel.

hills, locally called "mountains." Near Austin the highest summits are about 400 feet above the lower plain; in Uvalde County they are nearly 1,000 feet above it.

ANACACHO MOUNTAINS.

A dissected monoclinal limestone-capped plateau, which slopes southward from an abrupt scarp on the north, known as the Anacacho Mountains, lies in the southeast part of Kinney County. The highest points in this area are in these hills, and one reaches an elevation of 1,517 feet above sea level.

IGNEOUS KNOBS.

On the interior margin of the Coastal Plain there are many conspicuous hills that rise well above the level of the surrounding plains. These hills consist of knobs of igneous rock or volcanic plugs. Pilot Knob, in Travis County; Sulphur, Obi, Nueces, Inge, Taylor, Blue, and Big Mountain, in Uvalde County; and Turkey Mountain, Las Moras, and Pinto Mountain, in Kinney County, are examples of these knobs. (See Pl. II, *B*.)

VALLEYS.

GENERAL FEATURES.

The surface features thus far described constitute the uplands of the central Coastal Plain region. Extensive valley bottoms, which lie 10 to 300 feet below the uplands, flank the streams and cross the upland belts, generally at right angles. The slope of the longitudinal profiles of these valleys is less than that of the uplands, so that although the valley bottoms along the coast lie about 10 feet below the uplands, those along the interior margin of the Coastal Plain lie about 300 feet below them. Different types of surface succeed one another on the upland from the coast toward the interior, but approximately the same type prevails in the valleys at any given level above the stream bed. Several terraces usually flank the streams on both sides, at different levels, the outermost at the highest and the innermost at the lowest level.

GRAVEL-COVERED TERRACES.

In the valleys of the Brazos, Colorado, Guadalupe, Nueces, and Rio Grande the outermost and uppermost terraces are 1 to 3 miles wide and gravel-covered. Most of the gravel consists of pebbles and cobbles of quartz, feldspar, jasper, granite, flint, chert, and dark limestone.

The gravel on the Brazos occurs in irregular patches on both sides of the valley between Waco, in McLennan County, and Peters, in Austin County. It occurs in similar form in the valley of the Colorado between Austin, in Travis County, and Alleyton, in Colorado County. The soil of these terraces is invariably thin and of little agricultural value. As the land is high and the texture of the soil and rock is loose, water seeps away rapidly, and in times of drought crops suffer severely. The land is valuable mainly for its heavy growth of post oak and blackjack. The population is not dense, and most of the few farms that are worked belong to negroes. The roads in the region generally follow these terraces, for the gravel makes fairly good road beds, and the landowners generally place the roads on poor land.

The outermost terrace in the Guadalupe valley is somewhat different from the others. In Comal and Guadalupe counties the gravel consists of pebbles of limestone and flint, which are in places cemented by lime into a conglomerate. These materials, on weathering form a black clay soil which sustains a growth of mesquite where it is deep, or of live oak, where it is shallow. Where the gravel lies at the surface there is a growth of cedar.

On the Nueces the upper gravel-covered terrace appears in Dimmit, La Salle, and McMullen counties. These terraces occupy comparatively small areas at irregular intervals on both sides of the streams. The gravel is made up largely of limestone and flint. The vegetation consists mainly of chaparral, guajillo, cactus, catclaw, and prickly pear.

Gravel-covered terraces covered with chaparral, guajillo, cactus, and other plants are found on the Rio Grande in Maverick, Dimmit, Webb, and Zapata counties. The gravel is made up of granitic débris, limestone, and flint.

Gravel-covered terraces form the outer margins of the valleys of the smaller streams, including Blanco River, Cibolo River, and Little River, but the gravel consists chiefly of limestone or flint, and the surface features are similar to those on the Guadalupe.

SECOND BOTTOMS.

The second bottoms, locally called "bottom lands," are conspicuous features in the valleys of the larger streams of the Coastal Plain. They are large areas of fertile alluvial land that lie at lower levels than the gravel-covered terraces, but above the bottom or overflow lands proper, though at rare intervals, some parts of them are subject to overflow.

Bluffs 30 to 50 feet in height separate the flats of the gravel-covered terraces from the second bottoms. The surface of the second bottoms is very flat and has only a slight seaward gradient. The creeks that cross them flow in deep trenches or U-shaped valleys.

The soil of the second bottoms is variable. The prevailing type in the Colorado and Brazos valleys is a brown or red sandy loam, loam, or clay, representing weathered débris derived from the Permian rocks of northwestern Texas. A similar soil is found in the Rio Grande valley. Most of the soil in the Guadalupe Valley is a stiff black clay. The prevailing type on the Nueces and the Frio is a grayish-brown loam, which contains a large quantity of silt and a great number of recent land shells. In consequence the terraces are locally called "shell land." All the soils of the second bottoms are extremely fertile.

The native vegetation of these bottoms on the Brazos, Colorado, and Guadalupe consists of hardwoods, including elm, pecan, cottonwood, ash, hackberry, and box elder. The vegetation on the Frio, Nueces, and Rio Grande, where the climate is semiarid, consists chiefly of chaparral, mesquite, and prickly pear.

Water may generally be had on the second bottoms of the Brazos and Colorado in wells not exceeding 60 or 70 feet in depth, and the relatively low elevation of these lands as compared with the adjacent upland favors flowing wells, many of which have been obtained in the second bottom of the Brazos.

The second bottoms are extensively cultivated. The Brazos "bottom" is famous for its fertile soils, and is one of the principal farming regions of the State. In the Brazos, Colorado, and Guadalupe valleys cotton and corn are the leading crops raised. On the second bottoms of the Nueces and the Rio Grande onions, cabbages, lettuce, and cantaloupes are extensively grown by the aid of irrigation.

FLOOD PLAINS OR BOTTOMS.

The parts of the stream valleys that are subject to overflow, the flood plains or the bottoms, are narrow middle belts that lie between and below the higher valley terraces. The material of these bottoms on the Brazos and the Colorado is a red or brown loam or clay. The soils are red or brown loams, sandy loams, or loamy sands. At some places, notably in Brazoria County, the soils are stiff black or chocolate-colored waxy clays, which crack in dry weather. Locally these areas are known as "buckshot lands," because the soil will crumble under the pressure of the hand into small rounded particles resembling buckshot.

The Brazos and Colorado bottoms are still largely covered with timber, which includes elm, ash, live oak, pecan, and cottonwood. At many places there is a dense undergrowth of vines and bushes.

The soil of the bottom lands on the Guadalupe consists largely of black or dark silt or loam, which where mixed with decayed vegetable matter forms a black clay or black loam. The vegetation is similar to that on the Colorado and the Brazos.

The soil on the bottom lands on the Nueces consists largely of yellow loam or silt. The surface is level or gently undulating, but in places it is cut up more or less by so-called "bayous," which are abandoned channels of the stream or its tributaries. A soil common to all parts of the Nueces bottom is a grayish-brown or dark-brown silty clay loam, which supports a vigorous growth of mesquite, prickly pear, guajillo, tassojilla, several species of native grasses, and in places live oak, pecan, hackberry, and sycamore. Another soil is a dark-gray heavy plastic clay loam, the color of which varies somewhat with the variation in the quantity of moisture it contains. On account of its high content of lime and humus this soil, when dry, is loose and granular. At most places it is covered with mesquite, prickly pear, and native grasses, but in the southeastern part of La Salle County and the western part of McMullen County, where there is some salt in the soil, it supports a thick growth of a tall rank, coarse grass known as sacahuiste. In consequence this bottom is spoken of as the "sacahuiste flats."

The soil of the bottom of the Rio Grande consists of reddish-brown silt or loam. The weathered soil is a gray or brown sandy loam or a silt loam. The vegetation consists of a dense growth of mesquite, cottonwood, chaparral, and cactus. (See Pl. III, *A*.)

In the lower part of the Rio Grande Valley the bottom merges into the delta, which begins at Closner and occupies an extensive area in Hidalgo, Willacy, and Cameron counties. The delta forms a wide, flat region which is subject to overflow and which is cut by numerous narrow, winding sloughs or "resacas," representing old channels of the river. These "resacas" are 15 to 30 feet deep and 75 to 150 yards wide. When the river overflows, or in seasons of heavy rainfall, they become filled with water, which they retain for the greater part of the year.

The soils of the delta consist of light-brown to gray silt loam in the well-drained parts and heavy dark-brown to black sticky clay in the poorly drained parts. The well-drained parts are overgrown with mesquite, chaparral, ebony, and cactus. Groves of palm stand in spots near the river, and on lower ground there is a luxuriant growth of cane, tules, and coarse marsh grass. The poorly drained flats near the coast are occupied by marsh grass. The ancient beaches in this vicinity, which are long, narrow ridges of sand and gravel 30 feet or more high, are covered with Spanish dagger and several varieties of cactus.

Most of the valleys of the minor streams of the Coastal Plain have bottom lands similar to those of the larger stream valleys. The Yegua bottom, in Burleson and Washington counties, is a type of such lands. The upper part of this valley contains no fluviatile deposits, and the creek is eroding its channel. The lower part of the valley is filled with alluvium consisting of black or dark loam and is thickly set with timber, in which elm predominates. This alluvium forms a single bench between the upland and the water line and merges into the bottom lands of the Brazos.

DRAINAGE.

GENERAL FEATURES OF THE DRAINAGE BASINS.

The principal drainage systems of the Coastal Plain west of Brazos River, named from east to west, are those of the San Bernard, Colorado, Navidad, Guadalupe, Nueces, and Rio Grande. In addition to these rivers there are creeks and bayous on the Coast Prairies that drain territory not drained by the larger river systems.

The Coastal Plain includes only small parts of the drainage basins of these rivers. Much of the water that finds its way into them is collected outside the area here considered.

The main trunks of the several systems are consequent streams. They have a general southeasterly course determined primarily by the general southeasterly slope of the Coastal Plain. They cut the geologic formations in the line of the dip. Some of the streams flow only during periods of wet weather; others, such as the major streams, are in part spring-fed. Some of the supply springs are simple gravity springs; others are bold fissure springs. The Guadalupe derives a large part of its water from fissure springs; the Colorado is fed chiefly by gravity springs but also by fissure springs; the Brazos, so far as known, is fed entirely by gravity springs.

The streams of the Rio Grande Plain are mostly of the interrupted type. In places they contain flowing water, but in other places their beds are dry, and the water flows underground. Cibolo, Frio, and Nueces rivers are conspicuous examples.

Across that part of the Coastal Plain that lies west of the Coast Prairies the chief streams flow in narrow, sinuous channels, from 50 to 400 feet wide. One sharp bend follows another within a short distance, and at the point of each bend there is a sand bar on one side and generally a caving bank on the other. In places there are long stretches of slow-moving water, locally called "eddies." Here the banks slope gently and are covered with overhanging trees. The channel is wider than it is at the bends. The "eddies" terminate in shoals or riffles, across which the water flows with torrential velocity and enters one of the long bends. The shoals are formed at places where hard strata cross the bed of the stream.

Here and there in the course of their meandering the rivers have removed the materials of the terraces that at one time filled the valley, and in these places one bank rises directly to the upland as a high bluff without the intervention of terraces. Along the inner margin of the Coastal Plain these bluffs are in places 250 to 300 feet high, and either upstream or downstream from the bluffs there may be one or more alluvial flats. Smaller bluffs are formed by the removal of parts of lower terraces, the bank leading directly to the higher terrace.

The major streams flow across the Coast Prairies in wide, deep channels of slight gradient, in which there are no shoals. The channels are at some places cut to a depth of 40 feet below sea level. (See Pl. V.)

At Bay City, in the Coast Prairies, Colorado River has brought down driftwood that forms a dam, locally known as a raft.

The Rio Grande, Brazos, and Colorado carry large quantities of red silt. The sediment of the Brazos and Colorado is derived mainly from the Permian "Red Beds" of northwest Texas, which gives to the water its characteristic red color, from which the Colorado derives its name.

J. C. Nagle has made some measurements of the sediments carried by the Brazos, and his results are given in the following table:

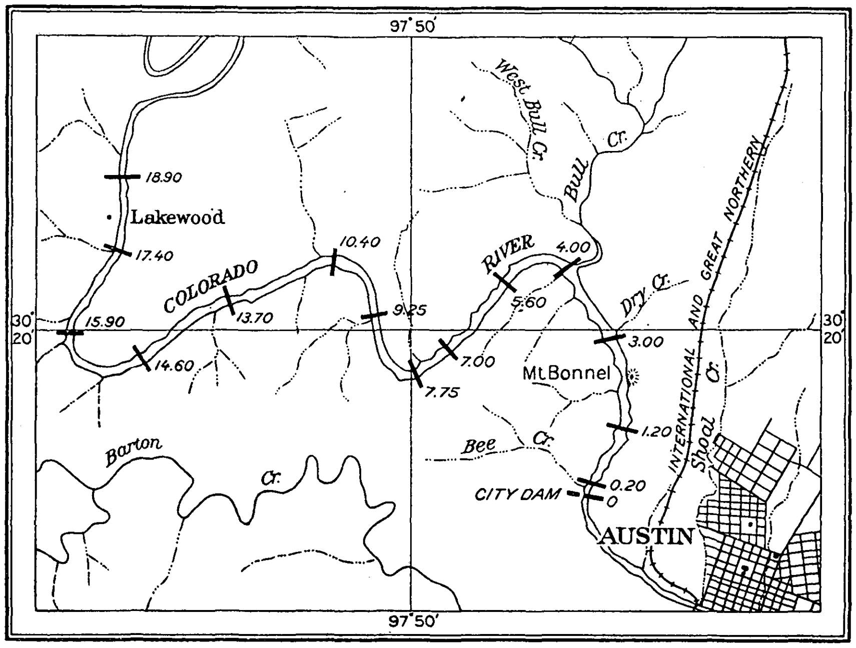


FIGURE 3.—Map of Colorado River in vicinity of Austin, Tex., showing location of sections where measurements for silt were taken. (After Taylor.)

Summary of silt measurements, Brazos River, Tex.[a]

[Collections made at Jones Bridge.]

Time.	Total discharge.	Silt.			
		One week's settlement.		One year's settlement.	
	Acre-feet.	*Acre-feet.*	*Per cent.*	*Acre-feet.*	*Per cent.*
Aug. 1 to Dec. 31, 1899	1, 165, 300	10, 090	0. 866	7, 567	0. 649
Jan. 1 to Dec. 31, 1900	8, 806, 986	115, 782	1. 315	86, 837	. 986
Jan. 1 to Dec. 31, 1901	976, 602	12, 838	1. 262	9, 246	. 947
Jan. 1 to Dec. 31, 1902	3, 362, 991	40, 190	1. 195	30, 142	. 896
Total for 41 months	14, 311, 879	178, 900	1. 246	133, 792	. 935

[a] U. S. Dept. Agr. Office Exper. Sta. Bull. 133, p. 205, 1903.

During 1902 the collections were made at much shorter intervals than for the time preceding, but the results are only a little smaller than for the entire period. Probably a mean value of 1.2 per cent by volume for one week's settlement and 0.9 per cent for one year's settlement would be not far wrong as an estimate of general conditions. The percentages of silt were determined volumetrically and are much larger than similar determinations based on weights where the weight of a given volume of the sediment has been assumed.[20]

Prof. T. U. Taylor, of the University of Texas, has measured the silt-bearing capacity of the Colorado. He has determined the amount of silt deposited on the bed of Lake Austin, formed by the dam built at Austin in 1893. This dam was washed out in 1900, and the opportunity was afforded to measure accurately the sediment deposited during the life of the reservoir. He found that 7.7 feet of silt was deposited upon an area a square mile in extent each year.[21] (See figs. 3 and 4.)

The silt carried by the rivers that head in the Edwards Plateau, including the Guadalupe, the

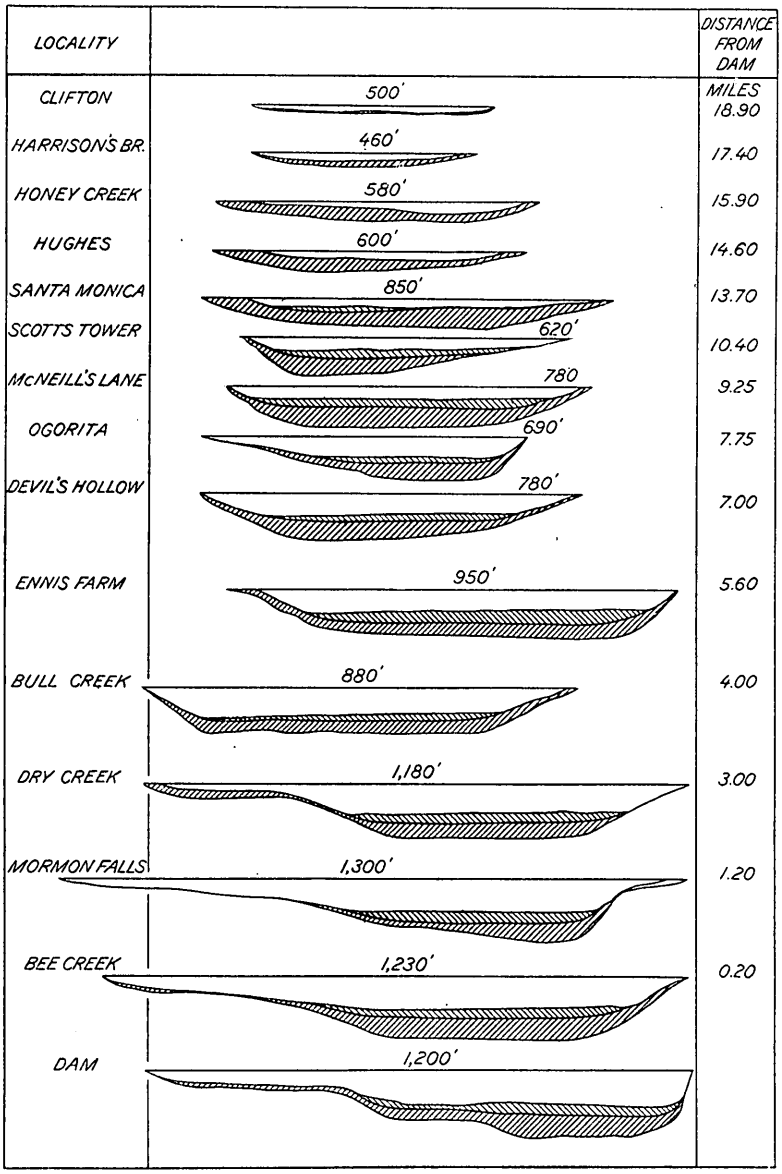


FIGURE 4.—Cross sections of Lake Austin illustrating accumulation of sediment between 1893 and 1897 (illustrated by upper shaded area). The number above each section indicates its length in feet. (After Taylor.)

[20] Nagle, J. C., Irrigation in Texas: U. S. Dept. Agr., Office Exper. Sta. Bull. 222, p. 19, 1910.

[21] Taylor, T. U., The Austin dam: Texas Univ. Bull. 164, p. 40, 1910.

San Antonio, and the Nueces, differs somewhat in quantity and character from that carried by the Rio Grande, the Brazos, and the Colorado. The water of the Guadalupe, which is typical, is remarkably clear, the color is blue, and very little silt is carried in suspension except in floods. At times of high water the color is dark.

The following table gives the chemical character of the water of these streams:

Analyses of stream waters of Texas.

[Parts per million.]

	Brazos.[a]	Colorado.[b]	Rio Grande.[c]
Turbidity	1,462	351	....
Suspended matter	1,188	....	....
Silica (SiO_2)	22	18	....
Iron (Fe)	.26	3.1	....
Calcium (Ca)	121	52	100
Magnesium (Mg)	19	17	18
Sodium and potassium (Na+K)	234	49	110
Carbonate radicle (CO_3)	0.0	0.0	....
Bicarbonate radicle (HCO_3)	158	195	240
Sulphate radicle (SO_4)	279	42	210
Nitrate radicle (NO_3)	2.2	....	.49
Chlorine (Cl)	338	59	100
Total dissolved solids	1,136	321	699

[a] Mean of a number of analyses of samples collected at Waco, Tex., Dec. 14, 1906, to Nov. 19, 1907. Dole, R. B., The quality of surface waters in the United States: U. S. Geol. Survey Water-Supply Paper 236, p. 50, 1909.
[b] Idem, p. 116. Sample collected at Austin, Tex.
[c] Mean of a number of analyses, samples collected near El Paso, Tex. Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 140, 1911.

The coefficient of fineness of the suspended matter in the water of the Brazos (ratio of turbidity to suspended matter) is 1.3.

The water of the Brazos, whose headwaters drain the salt and gypsum beds of the Permian and Triassic rocks of northwestern Texas, is a calcium-sulphate water, whereas that of the Colorado and the Rio Grande, which do not cross extensive gypsum deposits, is a calcium-carbonate water.

All the streams of the area are subject to floods, but the most destructive are those that occur along the Brazos. These floods are most pronounced on the Coastal Plain, chiefly because the bottom and second bottom lands are more extensive in this part of the drainage basin. They usually occur in the spring or early summer, when the headwater areas of the larger streams receive excessive rainfall. They are rare during the winter. One of the most disastrous of the floods that have devastated the Brazos lowlands in recent years was that of September, 1921. The flood of December, 1913, covered the entire valley from Bosque County to the coast, and caused damage to property estimated at about $3,500,000. Another disastrous flood occurred in June and July, 1899. The average duration of this overflow was about eight days. The water submerged an area of 2,000 square miles, and the damage amounted to $7,500,000. Other floods occurred in 1833, 1843, 1852, 1885, 1902, and 1908.

MAJOR STREAMS.

RIO GRANDE.

The Rio Grande is the most extensive of the river systems that cross the Coastal Plain. Its source is in the masses of snow that gather on the Continental Divide in southwestern Colorado. The main stream flows in a southerly direction to El Paso, from which its general course is southeasterly along the boundary of Texas. Its length is about 2,000 miles, and the area of its drainage basin includes about 250,000 square miles. A comparatively small part of the area drained by the Rio Grande is considered in this paper.

The discharge of the river is less at El Paso and Presidio, Tex., than it is at San Marcial, N. Mex. The stream at times ceases to flow at the surface in the district between El Paso and Presidio, notwithstanding the fact that in New Mexico and Colorado it may contain a normal quantity of water. The discharge is absorbed by the dry sand of this arid portion of Texas and Mexico.

BRAZOS RIVER.

Brazos River rises in the Staked Plains of Texas. Its length is 950 miles, and its drainage basin covers about 44,000 square miles. Its general course is southeasterly across the State.

COLORADO RIVER.

The Colorado heads in Gaines County in the Staked Plains of Texas. It receives some contributory drainage from the southeastern part of New Mexico. The drainage basin covers approximately 40,000 square miles, and its length is about 900 miles.

The principal tributaries include Concho River, Pecan Bayou, San Saba River, Llano River, Pedernales River, Onion Creek, and Walnut Creek.

GUADALUPE RIVER.

Guadalupe River heads in Kerr County in the Edwards Plateau, and follows a southeasterly course across the Coastal Plain to San Antonio Bay. The length of the main stream is about 300 miles; the drainage basin covers about 10,731 square miles.

Though the drainage basin of the Guadalupe is small as compared with those of the larger streams of Texas, it is one of the most favorable streams for the development of power in the State, owing to the large quantity of water supplied by the fissure springs at New Braunfels and San Marcos.

NUECES RIVER.

Nueces River rises in Edwards County in the Edwards Plateau. It follows a general southeasterly course to the southeast corner of La Salle County, where it turns and flows northeastward for a distance of approximately 75 miles. At Oakville, Live Oak County, it changes to a southeasterly course, which it follows until it empties into Corpus Christi Bay. The area of the drainage basin of Nueces River is approximately 16,540 square miles; the length of the main stream is approximately 450 miles.

MINOR STREAMS.

The San Bernard drains territory between the Brazos and the Colorado. It heads in Austin County and follows a southeasterly course to the Gulf. Its drainage basin includes parts of Austin, Colorado, Fort Bend, Wharton, and Brazoria counties and is about 1,048 square miles in area. The length of the stream is about 100 miles.

The Navidad drains territory between the Colorado and the Guadalupe drainage basins. Parts of Fayette, Lavaca, Wharton, and Jackson counties are included in its drainage basin. The river heads in the southern part of Fayette County and follows a southeasterly course until it discharges into Lavaca Bay.

The drainage basin includes 2,200 square miles. The length of the main stream is about 80 miles. The principal tributary is Lavaca River, which unites with the Navidad about 14 miles above its mouth.

Most of the main laterals of the major trunks are subsequent streams. In many places they follow valleys at the foot of escarpments. The direction in which they flow is at right angles to the regional slope. Yegua Creek, a branch of the Brazos, is an example of streams of this type.

The branches that feed the main laterals are of two types. The major branches are consequent streams, which drain the divides between the major trunks and flow in general southeastward. The minor branches are obsequent streams, which drain the inland-facing escarpments and flow in general northwestward. Yegua Creek, which forms the boundary between Lee and Burleson counties, is an example of the consequent streams, and Cedar Creek, which forms part of the boundary between Washington and Fayette counties, is an example of the obsequent streams.

That part of the Brazos, Colorado, and Rio Grande systems which is developed on the Cretaceous formations, including the Black and Grand prairies and the Edwards Plateau, is consequent drainage. Those parts of the main streams which appear on the Coastal Plain represent extended consequent drainage, for the streams extended their courses across the plain during its gradual reclamation from the sea. The smaller streams of the Coastal Plain that flow directly into the Gulf are chiefly of the consequent type.

GEOLOGY.

SALIENT FEATURES OF THE STRUCTURE.

When the materials that formed the beds of rock now exposed on the Coastal Plain of Texas were originally deposited in the sea they lay practically horizontal, but since their deposition the inland part of the region has been gradually elevated, and they have thus been tilted. The beds, therefore, instead of being horizontal, are now slightly inclined toward the Gulf. Since they were elevated above sea and tilted these beds have been considerably eroded, so that the surface of the Coastal Plain no longer coincides with the surface of the uppermost layer of rock, but bevels all the gently inclined layers at a slight angle. From place to place different sheets are exposed to view. The lowermost formation is exposed at the greatest distance from the coast; the uppermost at the coast. (See geologic map, Pl. VIII, in pocket.)

These inclined, superimposed sheets of rock may be likened to a pack of cards adjusted to the position indicated in figure 5.

The surface of the Coastal Plain corresponds to the area A B C D in the diagram. This surface is formed by parts of all the cards in the pack. The line B C of the card pack corresponds to the shore line, and A D corresponds to the interior margin of the Coastal Plain. If one should run his hand from B to A it would cross each of the cards successively, the lowermost last. Similarly, if one should travel inland from the coast he will cross successively the upturned edges of each of the geologic formations that form this plain.

In the following account of the geologic formations composing the Coastal Plain, these formations will be described in the order of deposition, the lowermost or oldest first.

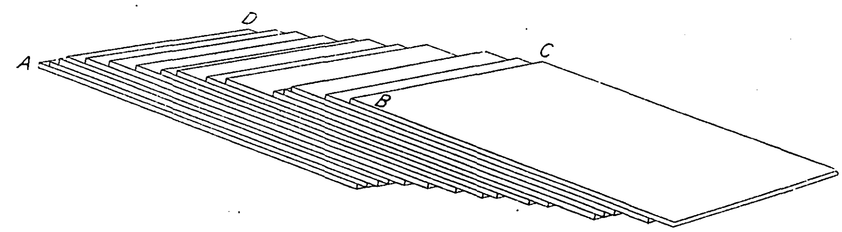


FIGURE 5.—Diagram illustrating relations and sequence of formations in the Coastal Plain. (After Hill.)

STRATIGRAPHY.

GENERAL FEATURES.

The deposits that form the Coastal Plain belong to the Cretaceous, Tertiary, and Quaternary systems, and include the formations shown in the following table:

Geologic formations exposed in the Coastal Plain of Texas west of Brazos River.

System.	Series.	Formation.	Thickness.	Lithology and characteristic fossils.	
Quaternary.	Recent.		*Feet.* 0-60	Fluviatile deposits of black, yellow, and brown silt forming low terraces of the streams; modern flood-plain materials consisting of sand and gravel; beach and dune sands of the coast and sand hills of southern Texas.	
	Pleistocene.	Beaumont clay.	300-900	Blue calcareous clay with small nodules of lime and lenses of sand and sandy clay. Specimens of *Rangia cuneata*, etc. Embedded logs common.	Farther inland the Beaumont clay is represented along the stream valleys by a number of terraces.
		Lissie gravel.	493-1, 020	Gravels derived from crystalline rocks; flint and chert pebbles and cobbles; coarse sands; pockets of red clay in places. South of the Guadalupe the gravels are cemented by a limy matrix into a limy conglomerate or adobe. The fossils include *Equus complicatus*, *Equus francisci* Hay, *Smilodon fatalis*, and *Elephas imperator*.	The Lissie gravel is represented farther inland along the stream valleys by a number of terraces occupying higher levels than those of Beaumont age.
		—Unconformity—			
Tertiary.	Pliocene. (?)	Reynosa formation.	560-1, 505	Limy conglomerates and limestones; the conglomerate consists of flint, limestone, quartz, and jasper pebbles cemented by a matrix of lime; pockets or lenses of pink limy clay in places. East of the Colorado the Reynosa formation consists of coarse red or mottled sands and beds of gravel. The gravel contains pebbles of quartz, chert, jasper, etc.	Farther inland the Reynosa formation is represented by the upstream deposits heretofore called "Uvalde" formation, consisting of cobbles of flint, and in places of quartz, chert, jasper, and of fragments of petrified wood, in some localities cemented by a limy matrix into a limy conglomerate. These gravels occupy the uplands south and east of the Balcones fault and appear as a terrace west of the fault on some of the streams. Thickness: 1 to 100 feet.
		—Unconformity—			

Geologic formations exposed in the Coastal Plain of Texas west of Brazos River—Continued.

System.	Series.	Formation.	Thickness.	Lithology and characteristic fossils.	
Tertiary.	Pliocene.	Lagarto clay.	*Feet.* 346–647	Light-colored or mottled pink and green clays, with numerous lime nodules; stained heavily with manganese in places. Strings of limestone extend downward into the clay where it is capped by limestone. Includes also sands and sandstones.	Seaward the Lagarto, Lapara, and Oakville formations are represented, east of Colorado River, by marine sands and clays, carrying *Arca carolinensis* and other upper Miocene and lower Pliocene ? forms.
		Lapara sand.	75–455	Interbedded sands and clays. The sands are coarse and sharp and include pebbles of clay and lime concretions; the clays are red, green, and pink. In places a conglomerate of clay pebbles may be seen. Contains many fragments of bone, determined as of Pliocene age.	
		Unconformity(?)			
	Miocene.	Oakville sandstone.	180–603	Gray sandstones, soft and highly calcareous in places, in other places hard and noncalcareous; some clay lenses are interstratified. The fossils include *Protohippus medius* Cope, *Protohippus perditus* Leidy, *Protohippus placidus* Leidy; and *Aceratherium*.	
		Unconformity			
	Oligocene.	Catahoula sandstone.	0–1, 200	Hard blue quartzitic sandstones; green, blue, and brown talclike clays; gray cross-bedded sandstones; lenses of white clay; green sandy clay; bedded gray sandstones; fossil wood.	
	Eocene.	Frio clay.	235–705	Green and pink compact clay with small lime nodules; greenish-gray marls; concretions of hard siliceous and aluminous limestones stained with manganese; beds of volcanic ash. In lower part are beds of brown marl with *Ostrea georgiana* Conrad.	
		Fayette sandstone.	480–800	Gray sands and sandstones, brown and chocolate-colored clays, lignitic clays, and lignite; beds of volcanic ash, white, kaolin-like clays and fuller's earth. Silicified and opalized wood very common. Clays are leaf-bearing in places and carry *Pisonia jacksoniana* Berry, *Bombacites jacksonensis* Berry, etc. The sandstones are fossiliferous in places and carry *Ostrea georgiana* Conrad, *Tellina eburniopsis* Conrad?, *Corbula wailesiana* Harris ?, etc.	
		Claiborne group. Yegua formation.	475–1, 049	Dark-green clays; brown leaf-bearing and lignitic clays; yellow and dark sands, and lenticular beds of lignite. Clays carry masses and plates of selenite. Beds of oyster shells occur in places. The fossil leaves include *Aneimia eocenica* Berry, and *Arundo pseudogoepperti* Berry. The marine fossils include *Ostrea alabamiensis* Lea, *Plejona* sp., and *Corbula* sp.	
		Claiborne group. Cook Mountain formation.	520–865	Beds of greensand, greensand marl, iron ore, lignite, lignitic clay, clay, sandstone, and sand. The glauconitic sands and clays predominate, and weather into characteristic red soils. Marine fossils very numerous and include *Corbula deusseni* Gardner, *Corbula smithvillensis* Harris, *Phos texanus* Gabb, and *Dentalium minutistriatum* Gabb.	
		Claiborne group. Mount Selman formation.	640–820	Dark-green, brown, and yellow sands, thin seams of iron ore, lenses of lignite and clay, and beds and concretions of limonite. Beds in general are highly ferruginous. Fossils are rare. They include *Venericardia planicosta* Lamarck, *Plejona petrosa* Conrad, and *Cornulina armigera* (Conrad).	
		Unconformity			

Geologic formations exposed in the Coastal Plain of Texas west of Brazos River—Continued.

System.	Series.	Formation.		Thickness.	Lithology and characteristic fossils.	
Tertiary.	Eocene.	Wilcox group.	Carrizo sandstone.	*Feet.* 300–800	Coarsely crystalline brown sandstone, cross-bedded and calcareous in places; coarse quartzitic sands; bedded, gray, fine-grained, micaceous sandstone. Plants collected from this sandstone by E. W. Berry in the summer of 1921 definitely establish its age as upper Wilcox.	
			-Unconformity-			
			Indio formation.	350–840	Lenses of sand, leaf-bearing calcareous sandstone concretions, sandstones, clays, sandy clays, lignites. Petrified wood very common. Fossil leaves include *Dillenites texensis*, *Euonymus splendens*, *Ficus spectabilis*, and *Terminalia hilgardiana*.	
		Midway formation.		260–566	Clays and limestones of marine origin. Characteristic fossils are *Enclimatoceras vaughani*, *Ostrea pulaskensis*, *Plejona limopsis*, and *Ostrea crenulimarginata*.	
		-Unconformity-				
Cretaceous.	Gulf.	Navarro formation.		400–500	Bluish-black marls and glauconitic clays; blue clays with concretions of siderite and limonite; yellow-brown sands with hard sandy limestone concretions; yellow and brown sandstones. Fossils: *Exogyra costata* Say, *Ostrea falcata* (and varieties), *Sphenodiscus lenticularis*.	West of Bexar County, the Navarro is replaced by the Escondido formation, which consists of yellow and brown sandstones, glauconitic sandstones, black and blue clays, impure limestones, and layers of oyster shells. Fossils: *Exogyra costata* Say, *Ostrea cortex*, *Sphenodiscus pleurisepta*. Thickness: 200 to 600 feet.
		Taylor marl.		475–1, 150	Blue calcareous clay marls. Fossils: *Exogyra ponderosa*, *Gryphaea vesicularis*.	West of Bexar County, the Taylor marl is replaced by the Anacacho limestone. This consists of hard yellowish limestones with interstratified beds of marl. Fossils: *Exogyra ponderosa*, *Gryphaea vesicularis*. Maximum thickness, 279 feet.
		Austin chalk.		275–600	Impure chalk with interstratified thin beds of soft marl. Fossils: *Gryphaea aucella*, *Mortoniceras texanum*, *Ostrea* aff. *O. diluviana*, *Inoceramus undulato-plicatus*, *Exogyra laeviuscula*.	
		Eagle Ford shale.		25–260	Laminated petroliferous shale and thin bands of arenaceous laminated limestone. Pyrite nodules are common. Fossils: Fish teeth, *Ostrea lugubris* Conrad, *Inoceramus labiatus*, etc.	
	Comanche (Lower Cretaceous).					

The following series of Lower Cretaceous formations underlies the oldest formation exposed in the Coastal Plain and outcrops in the hills that form its western boundary:

Formations penetrated by wells in the Coastal Plain but not exposed at the surface.

System.	Series.	Group and formation.		Thickness.	Lithology.
Cretaceous.	Comanche (Lower Cretaceous).	Washita group.	Buda limestone.	*Feet.* 0–80	Whitish or yellowish cavernous limestone; heavy bedded in upper part, thin bedded in lower part.
			Del Rio clay.	30–200	Greenish-blue laminated clay, in places gypsiferous. Contains thin slabs of shell breccia and near top thin layers of arenaceous limestone.
			Georgetown limestone.	15–150	Grayish marly limestone with intercalated marls and shales.

Formations penetrated by wells in the Coastal Plain but not exposed at the surface—Continued.

System.	Series.	Group and formation.		Thickness.	Lithology.
				Feet.	
Cretaceous.	Comanche (Lower Cretaceous).	Fredericksburg group.	Edwards limestone.	250–835 (?)	Hard white limestone, cavernous at some horizons. Contains many dark, irregular flint nodules in certain layers.
			Comanche Peak limestone.	60±	Heavy-bedded white marly limestone.
			Walnut clay.	25–200	Marly laminated yellow clays and thin limestones.
		Trinity group.	Glen Rose limestone.	300–600	Limestone with three or more notably sandy or cavernous horizons.
			Travis Peak sand.	250–300	Chiefly sand or sandstone, with bands of arenaceous limestone and conglomerate.

CRETACEOUS SYSTEM.

GULF SERIES (UPPER CRETACEOUS).

EAGLE FORD SHALE.

Name.—The Eagle Ford shale, named after Eagle Ford, in Dallas County, Tex., was first differentiated and described by Hill[22] in 1887.

Stratigraphic position.—In the region north of the Brazos the Eagle Ford formation rests conformably on beds called the Woodbine sand. In the region south of the Brazos the Woodbine is not known, and neither has its paleontologic or time equivalent been recognized. In this region the Eagle Ford shale rests directly on the Buda limestone. The formation is stratigraphically and conformably overlain by the Austin chalk.

Lithology.—The Eagle Ford formation consists largely of laminated petroliferous shale, which when first exposed is dark blue but on weathering changes to light yellow. It includes at some places thin layers of laminated sandy limestone. The beds are more calcareous south of the Brazos. Nodules of pyrite half an inch to 2 inches in diameter are common.

The well drillers in Bexar, Comal, and Guadalupe counties call this hard dark shale "lignite."

Thickness and dip.—On Red River, at the northern boundary of the State, the Eagle Ford shale is 600 feet thick; at Dallas, 450 to 500 feet; at Waco, 200 feet; at Taylor, 260 feet; at Austin, 30 feet; in Bexar County, from 25 to 40 feet; and on the Nueces, 30 feet.

[22] Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.

The beds dip to the south and southeast at a rate ranging from 40 to 70 feet to the mile, and averaging probably about 40 to 45 feet.

Paleontology.—This shale carries such characteristic fossils as *Metoicoceras whitei* Hyatt, *Metoicoceras swallovi* Shumard, *Ostrea lugubris* Conrad, *Inoceramus fragilis, Inoceramus labiatus,* and *Ostrea congesta.*

An especially noteworthy feature is the occurrence of the remains of fishes, some of the more flaggy layers containing numerous fish teeth.

Areal extent and underground distribution.—The outcrops of the formation appear in Kinney, Uvalde, Medina, Bexar, Comal, Hays, and Travis counties, in an irregular belt, lying south and east of the Balcones fault and paralleling its course. North of the Colorado the outcrop forms a belt of country that trends northward through Travis, Williamson, Bell, McLennan, Hill, Johnson, Tarrant, Dallas, Denton, and Grayson counties, ranging in width from half a mile to 10 miles. East of this belt it is concealed by the Austin chalk and overlying Upper Cretaceous and Tertiary formations.

Correlation.—The time equivalent of the Eagle Ford shale in the eastern Gulf region (Alabama and Mississippi) is believed by Stephenson to be an undetermined lower part of the Eutaw formation. In the western interior area of the United States the Benton shale is regarded as approximately representing the Eagle Ford.[23]

[23] Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, pp. 19, 48, 1893.

Detailed sections.—The following section, which indicates the character of the upper beds of the Eagle Ford in that vicinity, is exposed at Sherman, in Grayson County.

Section of Eagle Ford shale 2 miles west of Binkley house, at Sherman, Grayson County, Tex.[24]

	Feet.
Sandy clay shale with *Ostrea lugubris*	10±
Thin layers of brown sandstone with conglomerate of small rounded jasper pebbles, *Ostrea lugubris*, and fish teeth	5
Blue laminated clay, weathering into limonitic colors	10
Massive agglomerate of *Ostrea lugubris*	2
Sandy clay shale in thin alternations of clay and sand; clay efflorescent and drab on drying; *Ostrea lugubris*	40+
Blue clay with gigantic septaria	67±

Bluish and bluish-gray clays and arenaceous shale containing fish remains are exposed in the bluffs of the Bosque northwest of Waco and at Prather's tank.

In a bluff on Big Walnut Creek half a mile east of Watters station, Travis County, 15 feet of the Eagle Ford shale is exposed. At this place the formation is a dark-blue fine-grained, hard, laminated bituminous shale, carrying nodules of marcasite half an inch to 2 inches in diameter and is overlain by 10 feet of limestone gravel of Pleistocene age. (See Pl. VI, *A*.)

On Shoal Creek, about 200 yards north of the crossing of the Mount Bonnel road at Austin, the lowermost beds of the formation, consisting of yellow calcareous laminated shale, 10 feet thick, interstratified with yellow arenaceous limestone flags from 1 inch to 3 inches thick, is exposed in a low bluff 50 to 60 feet east of a bluff formed by the underlying Buda limestone.

Calcareous, arenaceous flags, 10 feet thick, are exposed in the bank of a creek about an eighth of a mile north of the Bandera road and 3½ miles southeast of Helotes, Bexar County. The flags carry shark and fish teeth.

Whitish calcareous clay is exposed in a roadside cut at the crossing of the Bandera road on Leon Creek, 10 miles northwest of the courthouse at San Antonio. An undetermined brachiopod was taken from the clay.

[24] 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, p. 326, 1901.

AUSTIN CHALK.[25]

Name.—The limestone now known as the Austin chalk was first described by Roemer [26] in 1852 and was correctly assigned by him to the Upper Cretaceous.

The name Austin limestone was first applied to this formation in 1860 by Shumard,[27] who included in it the upper part of the Eagle Ford shale, which he called the "Fish bed."

Shumard correctly assigned the Austin limestone to the Upper Cretaceous, but his stratigraphic column was erroneous, as he placed the so-called "Comanche Peak group" directly on the Austin limestone.

Hill [28] in 1887 was the first to determine correctly the stratigraphic position of the unit here described, which he called the "Dallas limestone," discarding Shumard's name Austin.

In 1890, however, Dumble [29] went back to Shumard's name, calling the unit recognized by Hill the Austin chalk. Since then the name Austin chalk or Austin formation has been generally applied by authors to this formation.

Stratigraphic position.—The Austin chalk lies conformably upon the Eagle Ford shale and below the Taylor marl.

Lithology.—The formation consists of beds of impure chalk, carrying 85 per cent or more of calcium carbonate, interstratified with softer beds of marl. The chalk is usually of an earthy texture, free from grit, and when freshly exposed is easily cut with a handsaw.

[25] Partial synonymy of the Austin chalk:
Dallas limestone: Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.
Austin-Dallas chalk: Hill, R. T., A preliminary annotated check list of the Cretaceous invertebrate fossils of Texas, accompanied by a short description of the lithology and stratigraphy of the system: Texas Geol. Survey Bull. 4, pp. 13, 28, 29, 1889.
White Rock: Idem.
Austin chalk: Dumble, E. T., A review of Texas geology as developed by the work of the survey: Texas Geol. Survey First Ann. Rept., p. 47, 1890.
Austin limestone formation: Taff, J. A., Reports on the Cretaceous area north of Colorado River: Texas Geol. Survey Third Ann. Rept., pp. 305-308, 1892.

[26] Roemer, Ferdinand, Die Kreidebildungen von Texas und ihre organischen Einschlüsse, pp. 11-15, 1852.

[27] Shumard, B. F., Observations on the Cretaceous strata of Texas: Acad. Sci. St. Louis Trans., vol. 1, pp. 583, 585-586, 1860.

[28] Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.

[29] Dumble, E. T., Texas Geol. Survey First Ann. Rept., p. 47, 1890.

Under the microscope the rock shows oolitic granules, crystals of calcite, particles of amorphous calcite, and the shells of Foraminifera, molluscs, and echinoids—materials common to chalk formations. The water-saturated beds underground are bluish, but the air-dried indurated surfaces are glaring white. Small nodules of marcasite are common in the fresh chalk. On exposed surfaces streaks of rust radiate from these nodules and locally discolor the face of the rock. The beds differ but little in hardness, although some that lie at the surface are in places rather hard.

The formation is compact, and the streams that cross it flow in canyons in the walls of which the lines of stratification and the effects of weathering are well shown (Pl. VI, *B*). The marly and softer bands readily disintegrate, leaving the harder layers projecting in rounded or subangular shelves.

Chemical composition.—The chemical composition of the Austin chalk is indicated by the following analyses:

Analyses of Austin chalk.

	1	2	3	4	5	6	7	8
Silica (SiO_2)	5.94	10.32	11.31	6.17	5.34	5.24	5.46	21.79
Alumina (Al_2O_3)	1.41	5.41	5.78	2.17	2.15	2.24	2.04	5.88
Ferric oxide (Fe_2O_3)	1.31	1.15	1.72	.88	1.33	1.13	.94	1.44
Manganese oxide (MnO)	....	....	....	.09	....	....	....	.02
Lime (CaO)	48.73	45.31	42.61	48.66	50.46	50.85	50.32	37.49
Magnesia (MgO)	....	....	....	.90	.73	.85	.85	.64
Sulphuric anhydride (SO_3)	.42	1.04	1.13	.30	....	....	....	Trace.
Soda (Na_2O)	2.60	2.07	2.36	.50	....	....	....	.30
Potash (K_2O)	.20	.17	.33	.21	....	....	....	.81
Water at 100° C	.82	.51	1.27	.60	....	....	....	.72
Ignition loss	....	....	....	39.39	....	....	....	31.55
Carbon dioxide (CO_2)	37.84	34.44	33.86	....	....	....	....	....
Phosphoric acid (P_2O_5)	.142	.218	.131	....	....	....	....	....
	99.412	100.638	100.501	99.87	....	....	....	....

1. Sample from basal part of Austin chalk on Brushy Creek, 6½ miles below Round Rock, Williamson County, Tex. Analysis by G. H. Wooten. Taff, J. A., Reports on the Cretaceous area north of Colorado River: Texas Geol. Survey Third Ann. Rept., p. 351, 1892.
2. Sample from central part of Austin chalk on Brushy Creek, about 3 miles southeast of Hutto. Analysis by G. H. Wooten. Taff, J. A., op. cit., p. 352.
3. Sample from upper part of Austin chalk on San Gabriel River 1 to 2 miles below Jonah post office. Analysis by G. H. Wooten. Taff, J. A., op. cit., p. 354.
4. Sample from Big Walnut Creek, 9 miles northeast of Austin and about 1 mile below the Fiskville crossing. Burchard, E. F., Structural materials available in the vicinity of Austin, Tex.: U. S. Geol. Survey Bull. 430, p. 315, 1910.
5. White chalky limestone that forms topmost layer in quarry adjacent to International & Great Northern Railway, about three-quarters of a mile southwest of railroad bridge at Austin, Tex. Analysis by L. Gabrecht and W. E. Thomas.
6. Blue limestone in same quarry as that from which sample 5 was taken. Analysis by L. Gabrecht and W. E. Thomas.
7. White limestone in same quarry as that from which samples 5 and 6 were taken and below bed from which sample 6 was taken. Analysis by L. Gabrecht and W. E. Thomas.
8. Sample from bluff on Salado Creek, 6½ miles northeast of courthouse at San Antonio, Tex. Sample collected by E. F. Burchard.

Thickness and dip.—The Austin chalk is 625 feet thick southeast of McKinney, Collin County; 600 feet (estimated) near Sherman; about 600 feet at Dallas; 550 feet at Waxahachie; about 600 feet at Waco; about 300 feet at Taylor; 410 feet at Manor, Travis County; 285 feet in Guadalupe County; 275 to 430 feet in Bexar County; and 350 to 400 feet in Uvalde County.

The dip is to the south and southeast and ranges from 40 to 90 feet to the mile but averages probably between 40 and 50 feet.

Paleontology.—The Austin chalk carries many fossils. In the Austin section there is a lower zone, which is characterized by *Inoceramus undulato-plicatus;* a middle zone, which is characterized by *Mortoniceras texanum;* and an upper zone, which is characterized by *Exogyra ponderosa*, *Exogyra laeviuscula*, and *Gryphaea aucella*. In addition to these fossils *Radiolites austinensis*, *Eutrephoceras* sp., and *Ostrea* aff. *O. diluviana* also occur in the chalk. (See Pls, VII and X.)

Areal extent and underground distribution.—South of the Colorado the outcrop of the formation lies at the foot of the Balcones fault in Kinney, Uvalde, Medina, Bexar, Comal, Guadalupe, Hays, and Travis counties. North of the Colorado the outcrop passes through Travis, Williamson, Bell, McLennan, Hill, Ellis, Dallas, Collin, and Grayson counties.

The formation has been recognized in the area east of the outcrop in wells that have been drilled deep enough to penetrate it. Where the Cook Mountain formation is exposed the dip of the Austin chalk has carried it below the reach of the drill (see geologic map, Pl. VIII, in pocket), and it has not been found farther southeast. The inference, however, is that the chalk underlies much of the Coastal Plain.

Correlation.—Hill[30] in 1901 perceived that the Annona chalk occupied a stratigraphic position higher than the type Austin chalk, and he included it in the Navarro formation.

Taff[31] in 1902 showed that the Austin chalk is continuous with the much thinner Annona chalk of north Texas, and his conclusions were confirmed by the subsequent work of Gordon.[32]

Veatch[33] in 1906 represented the formation as corresponding in age to the upper part of the Taylor and the lower part of the Navarro. Neither Hill nor Veatch, however, recognized the continuity of the Annona with the Austin, nor did any of the authors cited recognize the true stratigraphic and age relations of the Annona and the formations adjacent to it in northeastern Texas and southwestern Arkansas.

The results of L. W. Stephenson's stratigraphic and paleontologic studies[34] have not only confirmed the conclusion that the Austin and Annona are continuous but have shown that the Annona in its entirety in southwestern Arkansas occupies a stratigraphic position well above the top of the Austin in its type area, so that the Austin chalk trends diagonally across the geologic column in its extension from the Rio Grande to Arkansas, at the same time becoming much thinner in northeast Texas. He finds that the typical Annona corresponds in age to the upper part of the typical Taylor, though the top of the Annona is not quite so high as the top of the Taylor. The chalk at Austin therefore corresponds in age to nonchalky marls and sands that lie beneath the type Annona.

The Austin chalk epoch is represented in the eastern Gulf region in Alabama and Mississippi by the Tombigbee sand member of the Eutaw formation, perhaps also including some of the typical Eutaw deposits below this member.[35] In the Western Interior the Niobrara limestone occupies approximately the time interval of the Austin.[36]

Section on Brazos River.—Numerous exposures of the Austin chalk may be seen in the vicinity of Waco. The lowermost beds are found in the bluff on the east side of North Bosque River 4 miles northwest of Waco. Here 50 to 75 feet of the chalk is exposed, showing the interstratification of glaring white soft, amorphous chalky layers, 2 to 5 feet thick, with the softer, more argillaceous, blue marly layers, 2 to 6 inches thick. Species of *Inoceramus* sp.? are found in the chalky layers.

A similar succession of blue and white beds may be seen in the bluff known as "Lover's Leap," which flanks the Bosque about 3 miles northwest of the city hall at Waco. This section is 150 feet thick, and the beds lie almost horizontal.

Beds that lie stratigraphically above the preceding can be seen in a small canyon between the Missouri, Kansas & Texas and the St. Louis Southwestern railways, about 1½ miles southwest of the city hall at Waco. Here 15 to 20 feet of chalk, occurring in layers with a maximum thickness of 4 feet, interstratified with blue marly layers, 2 to 6 inches in thickness, are exposed.

The upper beds of the chalk showing the same alternations in color can also be seen in the ravines at the head of Cottonwood Creek where it is crossed by the Missouri, Kansas & Texas Railway, about 4 miles southwest of Waco.

Section on Big Walnut Creek.—The lowest beds of the chalk may be seen about half a mile below the railroad bridge at Watters station, and about 2 miles above the bridge on the

[30] Hill, R. T., Geography and geology of the Black and Grand prairies Tex.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, pp. 340–341, 1901.

[31] Taff, J. A., Chalk of southwestern Arkansas: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 698–700, 1902.

[32] Gordon, C. H., Geology and underground waters of northeastern Texas: U. S. Geol. Survey Water-Supply Paper 276, pp. 21–22, 1911.

[33] Veatch, A. C., Underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, p. 19, 1906.

[34] Stephenson, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma: U. S. Geol. Survey Prof. Paper 120, pp. 129–163, 1918.

[35] Stephenson, L. W., Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, p. 32, 1914.

[36] Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, pp. 19, 48, 1893.

Fiskville road. These beds, together with some of the underlying beds of the Eagle Ford shale, have been brought to the surface by faulting and folding. (See Pl. VI, *A*.) The chalk consists of alternate layers of chalk and marl. The layers of chalk do not exceed 3 feet in thickness; the marly layers 1 foot. The beds contain species of *Inoceramus*.

Bluffs of chalk that are similar in lithology and stratification to the one below Watters appear on both sides of the creek between the bridge on the Fiskville road and a point 1 mile in a straight line below. (See Pl. VI, *B*.) This part of the formation, which is about in the middle part of it, contains specimens of *Radiolites austinensis* (Roemer), *Mortoniceras dentato-carinatus* (Roemer), and *Mortoniceras texanum* (Roemer).

At a locality 1 mile in a straight line below the bridge at the Fiskville crossing precipitous bluffs of chalk, about 50 feet high, form the right wall of the canyon. The strata range in thickness from 2 to 6 feet, but the thicker ones predominate.

Three-fourths of a mile along the meanders above the bridge at the Dessau road crossing the bluff on the left side of the canyon shows 19½ feet of white, soft, fossiliferous chalk, overlying 1 foot of softer argillaceous chalk. (See Pl. VI, *C*.)

In a collection made at this place Stephenson identified *Cucullaea* sp., *Gryphaea aucella* Roemer, *Spondylus guadalupae* Roemer, *Lima crenulicostata* Roemer, *Anomia anomiaeformis* (Roemer), *Liopistha elegantula* (Roemer), *Gyrodes* sp., and *Baculites* sp.

Section three-fourths of a mile above bridge at Sprinkle crossing, Big Walnut Creek, Travis County, Tex.

	Ft.	in.
Flint gravel, embedded in black clay soil	1	5
Austin chalk:		
White chalk, same stratum as base of the following section, with *Gryphaea aucella*	5	
White homogeneous chalk	9	10
White arenaceous chalk	5	6
Clay parting		7
White homogeneous chalk	9	6
Clay parting	2	
White arenaceous chalk	5	6
Clay parting		5
White homogeneous chalk	7	6
Limy clay parting		10
White chalk	8	
Clay parting		3
White chalk	4	2
Clay parting		10
White chalk exposed	10	
	71	4

Section 674 feet below bridge at Sprinkle crossing, Big Walnut Creek, Travis County, Tex.

	Feet.
Austin chalk:	
White soft homogeneous chalk	4
White soft homogeneous chalk with *Exogyra ponderosa* and *Inoceramus*	6
White soft homogeneous chalk	6
Bluish-white soft chalk with *Gryphaea aucella*, and *Exogyra ponderosa*	2
Bluish marly chalk	1
Blue chalk	1
White soft chalk with *Exogyra ponderosa*, and numerous *Gryphaea aucella*, same as top chalk stratum of preceding section	3
	23

The highest beds of the chalk, which are very close to the top of the formation, are exposed in the bed of the creek about three-fourths of a mile by the meanders below the bridge on the road from Sprinkle to Austin.

Section on Colorado River.—Along Colorado River the chalk is exposed from a point about one-fourth of a mile east of the International & Great Northern Railway to Montopolis bridge, a distance of 4 miles, measured in a straight line. In the bluff flanking the creek adjacent to the International & Great Northern Railway, three-fourths of a mile southwest of the railroad bridge at Austin, 25 feet of the base of the Austin chalk rests conformably on the Eagle Ford shale.

Exposures of chalk occur from a point about one-fourth of a mile east of the International & Great Northern Railway to the west end of a bluff at the water's edge three-fourths of a mile below the Congress Avenue bridge, flanking the valley of the Colorado.

The chalk in this section exhibits the same general lithologic and faunal characteristics that were observed in its lower half, on Big Walnut Creek. Species of *Inoceramus* are of common occurrence.

Fine bluffs of chalk are exposed on the south side of Colorado River, from a point about three-fourths of a mile below the Congress Avenue bridge to a point one-fourth of a mile above Stones ford. (See fig. 6, 200, 202.) These bluffs are from 50 to 100 feet high and show the characteristic alternation of the white chalky and blue marly strata.

The chalk is here gently folded into a monoclinal fold. At the upper end of the bluff the beds lie very nearly horizontal; at a point about three-fourths of a mile above Stones ford (see fig. 6) they dip about 270 feet to the mile in a direction S. 85° E.; at a point one-half mile above Stones ford (201) they dip about 112 feet to the mile in the same direction.

A fault crosses the river one-eighth to one-fourth mile above Stones ford, and the chalk, represents the topmost part of the Austin chalk, for 75 feet above the level of the river the Taylor marl forms the prairie.

The uppermost beds of the chalk occur also at Montopolis bridge (204), where they underlie the Taylor marl. The dip of the beds between

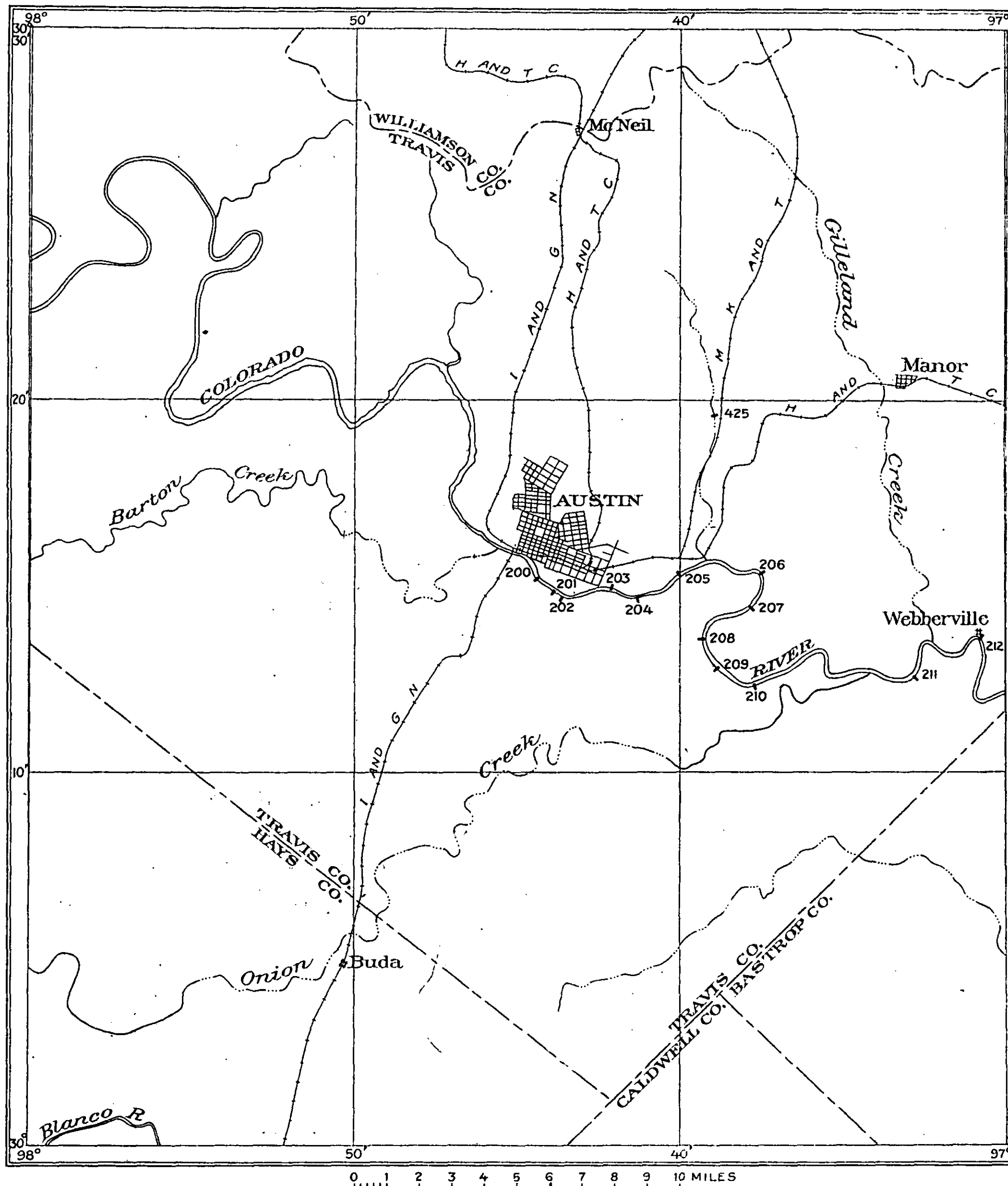
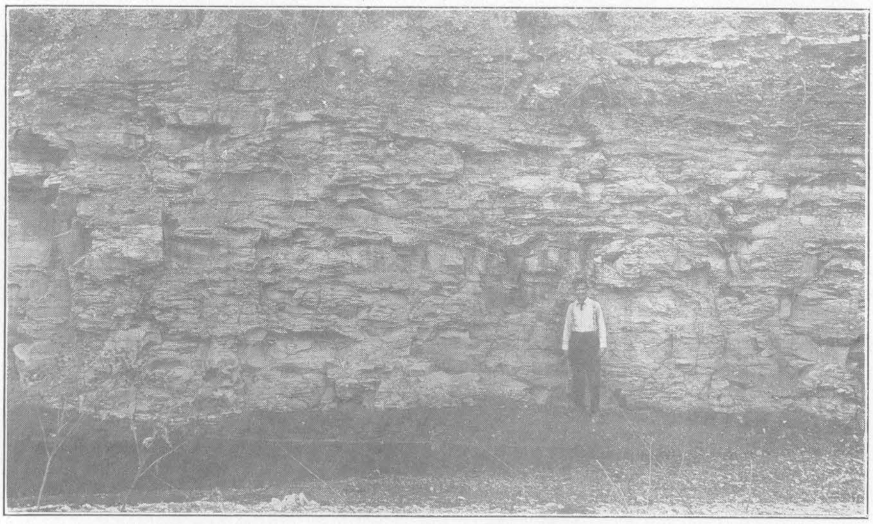


FIGURE 6.—Sketch map of the Austin quadrangle, showing location of the sections described.

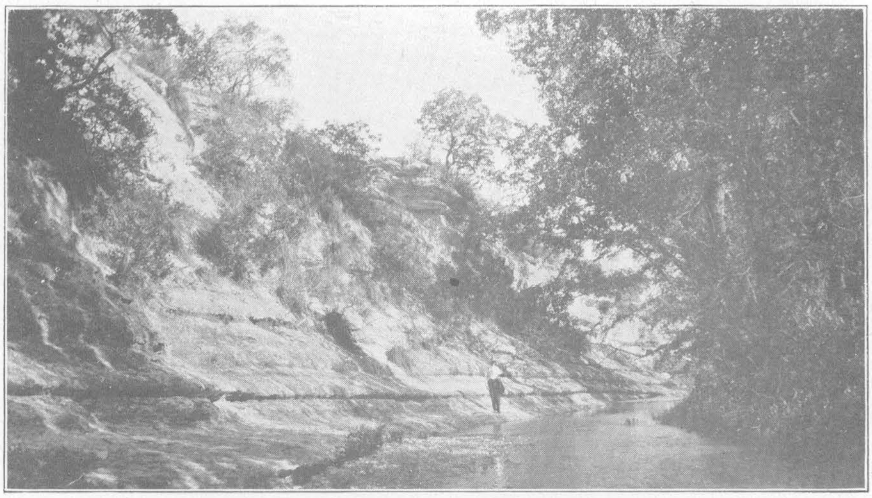
seen to the east of the fault, is a part of the downthrown block. By reason of this faulting the upper half of this formation, its topmost part, is not exposed on Colorado River.

A small outcrop of chalk occurs just above the water line at Stones ford. This outcrop Stones ford and Montopolis bridge is very slight, being hardly more than 10 feet to the mile. The stratigraphic relations of the exposures on Colorado River are indicated graphically on Plate IX (in pocket).

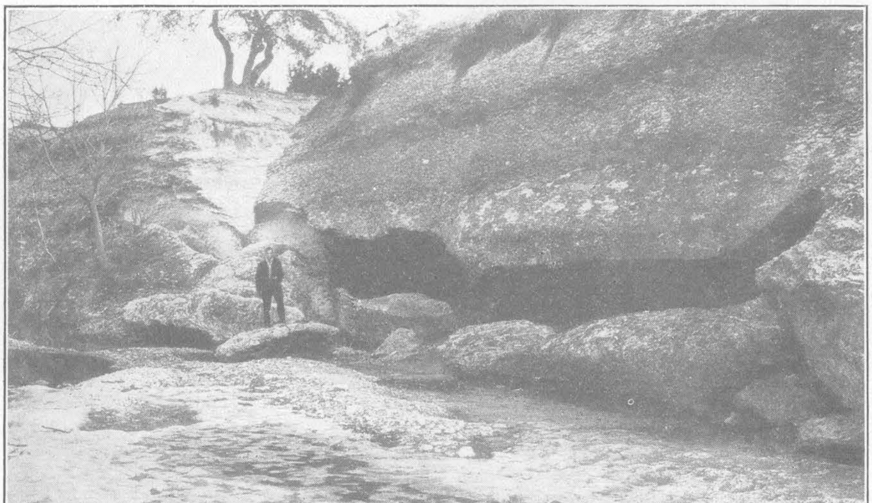
Section on Cibolo Creek.—The Austin chalk is exposed on Cibolo Creek from a point about



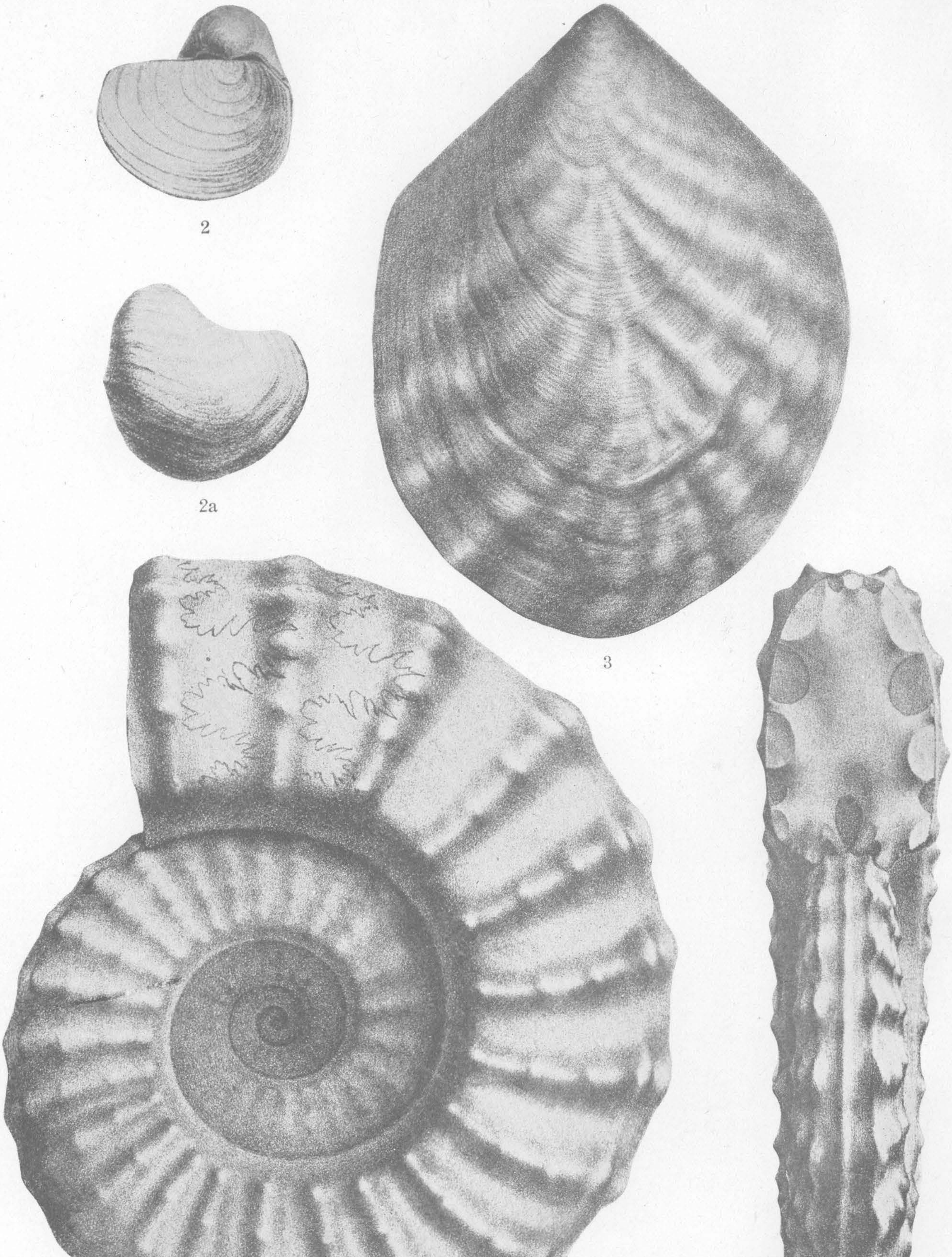
A. EAGLE FORD SHALE ON BIG WALNUT CREEK, HALF A MILE EAST OF WATTERS, TRAVIS COUNTY, TEX.



B. AUSTIN CHALK ON BIG WALNUT CREEK IN TRAVIS COUNTY, TEX., 200 YARDS BELOW BRIDGE ON FISKVILLE ROAD.



C. AUSTIN CHALK ON BIG WALNUT CREEK BETWEEN SPRINKLE AND DESSAU ROADS, TRAVIS COUNTY, TEX.



CHARACTERISTIC FOSSILS OF THE AUSTIN CHALK.

1, 1a. *Mortoniceras texanum* (Roemer). **2, 2a.** *Gryphaea aucella* Roemer. **3.** *Inoceramus undulatoplicatus* Roemer.

2 miles above Bracken, Comal County, to a point near Schertz, Guadalupe County, a distance of 5 miles in a straight line in a southeast direction. (See fig. 7.)

A description of the exposures follows in stratigraphic order. At the International & Great Northern Railway bridge in Bexar County 15 feet of white massive soft chalky limestone, carrying *Exogyra laeviuscula* Roemer and beds 4 to 5 feet thick. These beds dip N. 30° W. at the rate of 360 feet to the mile.

At Selma, in Bexar County, 13 feet of the chalk is exposed, which shows the customary alternation of white chalk and blue marl. It is overlain by limestone gravel of Pleistocene age. The beds dip N. 10° E. at the rate of 22 feet to the mile, or in opposition to the normal dip in this region.

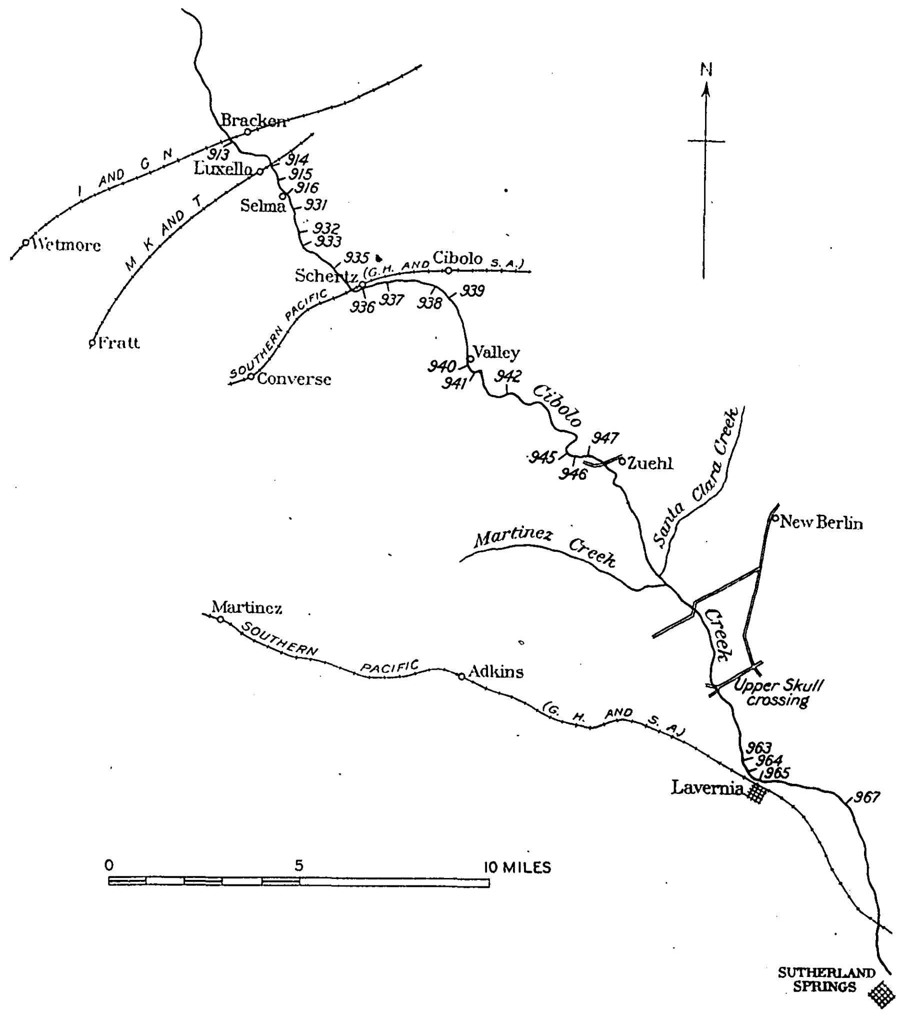


FIGURE 7.—Map of Cibolo Creek between Bracken and Sutherland Springs, Tex., showing location of sections described.

dipping N. 30° W. 270 feet to the mile, underlies Pleistocene clay and gravel.

At Landa station (Luxello), in Comal County, there is an exposure of white chalk with stratigraphic and structural relations similar to those noted above.

About midway between Selma and Landa (Luxello), or about three-fourths of a mile north-northwest of Selma, there is a bluff of Austin chalk, composed of very fossiliferous

On the opposite side of the creek the same beds of chalk are exposed, and here they contain numerous rusted nodules of marcasite (iron disulphide, FeS_2). Limonite stains occur along the joint planes, showing that the water circulated along these planes.

Roemer collected at this locality[37] *Exogyra laeviuscula*, *Spondylus guadalupae*, *Inoceramus cripsii*, *Baculites anceps*(?), and *Micraster* sp.

[37] Roemer, Ferdinand, Die Kreidebildungen von Texas und ihre organischen Einschlüsse, p. 14, 1852.

Section on Cibolo Creek three-fourths of a mile south of Selma, in Guadalupe County, Tex.

	Feet.
Pleistocene:	
Yellow calcareous loam grading into the gravel below	15
Limestone gravel	5
Unconformity.	
Austin chalk:	
Fossiliferous chalky limestone with *Gryphaea aucella*	2
Yellow water-bearing sand	2
Yellow sand in beds 6 inches thick, alternating with argillaceous limestone flags 2 inches thick, with *Gryphaea aucella*	3
	27

The beds of the chalk dip N. 15° W. at the rate of about 45 feet to the mile, in opposition to the normal dip in the Coastal Plain. This reversal of dip is probably due to movements associated with the Balcones fault, which crosses this creek some 7 or 8 miles upstream.

The occurrence of the sand in the lower part of the section is also worth noting.

One and a half miles south of Selma the Austin chalk is finely exposed. On the right bank of the stream is a bluff of thick-bedded fossiliferous limestone about 50 feet high. The beds near the base are "honeycombed," similar to the pitting in the Edwards limestone. This "honeycombing" is favorable for the circulation of water, and the honeycombed layers may constitute an underground water-bearing zone in this vicinity. The occurrence of the fossils *Exogyra laeviuscula* and *Inoceramus* sp. indicate that only the upper part of the formation is represented by the outcrop. The dip at this locality is downstream.

Beds of chalk may be seen on this creek about three-fourths of a mile above Schertz station. The outcrop, however, is rather small. The boundary line between the Austin chalk and the overlying Taylor marl crosses somewhere between a point three-fourths of a mile above and a point one-fourth of a mile below Schertz, for at the former locality the outcrop of chalk already described may be observed and at the latter the lower part of the Taylor marl.

Only the upper beds of the chalk are exposed on this creek between the International & Great Northern Railway bridge and Schertz station. The dip of the beds from this bridge to a point 1½ miles south of Selma is the reverse of the normal dip of the region, being in a northwesterly direction and ranging from 360 feet to 22 feet to the mile. South of the locality last mentioned the dip is normal, or to the southeast. The most pronounced northwesterly dips occur between a point halfway between Selma and Landa and the International & Great Northern Railway bridge. These disturbances of the dip are produced by faulting, and it is therefore not possible to get a continuous section of the chalk on this creek. Fortunately, however, the Southern Pacific Co. has drilled a well at Schertz that has afforded some accurate data on the thickness of the formation in this vicinity. According to the well record the chalk is 304 feet thick. After penetrating the Pleistocene deposits the well passes through some 32 feet of the overlying Taylor marl and enters the chalk. The record follows:

Log of well at Schertz water station, Galveston, Harrisburg & San Antonio Railway, Guadalupe County, Tex.

[Drilled in 1904.]

	Feet.
Recent:	
Black soil	4
Pleistocene, late:	
Brown clay	8
Cement gravel	20
Taylor marl:	
Yellow clay	32
Austin chalk:	
"Blue clay"	234
"Magnesium limestone"	20
Blue limestone	50
Eagle Ford shale:	
"Lignite"; blue shale	21
Buda limestone:	
Gray limestone	37
Del Rio clay:	
"Mud hole and rotten blue clay"	53
Georgetown and Edwards limestones:	
Yellow limestone	57
Water cavity or upper reservoir of the Edwards limestone	7
Yellow limestone	20
	563

Section on Salado Creek.—The Austin chalk is exposed on Salado Creek in Bexar County, one-eighth mile southeast of the crossing of the Valverde-San Antonio road, about 7 miles northeast of the courthouse at San Antonio. Here it consists of stratified white soft chalky limestone, with nodules of pyrite and specimens of *Gryphaea aucella* Roemer, and is exposed in a bluff 75 feet high. The dip here is ¾° S. 25° W.

Twelve feet of white chalky limestone is exposed in a bluff on Salado Creek at the crossing of the Austin-San Antonio road about 6½ miles northeast of the courthouse at San Antonio.

Section in northern part of San Antonio.—A triangular faulted block of Austin chalk is exposed in the northern part of the city of San Antonio. The apex of this block is at San Pedro Springs. From this point a fault, which forms the southeastern boundary of the block, trends northeastward toward Fratt station on the Missouri, Kansas & Texas Railway. (See Pl. VIII.) Between the springs and a point a mile northeast of the Academy of the Incarnate Word the course of the fault is marked by a decided scarp 10 to 40 feet in height and by bold fissure springs. The western boundary of this block is a second fault that trends in a direction approximately N. 22° E. to a point beyond Olmos Creek. (See Pl. VIII.)

The block of chalk has been uplifted with respect to the surrounding country. The Taylor marl, which lies stratigraphically above the chalk, bounds it on the south and west and lies at the present time on lower ground than the chalk.

Excellent exposures of soft white chalky limestone of the Austin chalk occur in bluffs 40 to 50 feet in height at Alamo Heights northeast of San Antonio on the north side of Olmos Creek Canyon.

Good exposures of the chalk are also to be seen in the quarries belonging to the city and the Alamo Portland Cement Co. west of Brackenridge Park, about 3 miles north by east of the courthouse at San Antonio. The elevated position of the chalk relative to the country on the downthrown side of the fault in this vicinity is favorable for quarrying, and a number of quarries have been opened in which 30 to 40 feet of chalk is exposed. The strata are from 3 to 10 feet thick, and carry in places many nodules of pyrite from one-half inch to 2 inches in diameter. In fresh openings the rock is light blue, but this color gradually changes to white when exposed.

Immediately north of San Pedro Springs Park, at San Antonio, the city operated a quarry in which 10 to 20 feet of Austin chalk is exposed. The beds are white in color, and from 1 to 5 feet in thickness. The rock is fairly soft. Specimens of *Gryphaea aucella* Roemer occur.

Section on Leon Creek.—Austin chalk is exposed in the bed of Leon Creek at the crossing of the Culebra road 8¾ miles west of the courthouse at San Antonio. Soft blue limestone with specimens of *Inoceramus* sp. crops out beneath the bridge.

Section on Medina River.—Thirty feet of white chalky fossiliferous limestone is exposed at a creek crossing on a road from Rio Medina to the dam of the Medina Irrigation Co., about 4.8 miles north of Rio Medina, in Medina County. In the bed of the creek is a ledge of oyster agglomerate 1½ feet in thickness containing a great number of *Gryphaea aucella* Roemer. *Exogyra ponderosa* Roemer (young individuals) and *Exogyra laeviuscula* Roemer (variety that has fine costae) also occur in the chalk at this locality. These beds correspond with the top of the Austin chalk of the Walnut Creek section of Travis County.

TAYLOR MARL.[38]

Name.—The unit here recognized was first defined by Hill,[39] who called it the *Exogyra ponderosa* marl because it contained the fossil so named. Later he abandoned that name and called it the Taylor marl,[40] after Taylor, Williamson County.

Stratigraphic position.—The Taylor marl lies conformably above the Austin chalk and below the Navarro formation.

Lithology.—The formation consists of calcareous clay marl, which is locally known as "joint clay." It contains a small quantity of sand, which is not apparent to the eye. The unweathered marl is blue-black, is of fine consistency, compact, and is apparently massive until its laminae are developed by exposure.

[38] Partial synonymy of the Taylor marl:

Exogyra ponderosa marl: Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.

Exogyra ponderosa marls or Blue Bluffs division: Hill, R. T., A preliminary annotated check list of the Cretaceous invertebrate fossils of Texas, accompanied by a short description of the lithology and stratigraphy of the system: Texas Geol. Survey Bull. 4, pp. 13, 29–31, 1889.

Taylor marls: Hill, R. T., On the occurrence of artesian and other underground waters in Texas, eastern New Mexico, and Indian Territory, west of the ninety-seventh meridian, 52d Cong., 1st sess., S. Ex. Doc., vol. 4, p. 97, 1892.

[39] Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.

[40] 52d Cong., 1st sess., S. Ex. Doc., vol. 4, p. 97, 1892.

It weathers to a dense black soil, forming the well-known "black waxy" soil of the Black Prairie. The subsoil is usually whitish yellow.

Chemical composition.—The chemical composition of the Taylor marl is indicated by the following analyses:

Analyses of Taylor marl.

	1	2	3	4	5	6	7
Silica (SiO_2)	22.18	45.02	48.72	28.34	30.01	36.08	13.21
Alumina (Al_2O_3)	10.17	16.17	16.10	7.50	10.57	18.64	5.49
Ferric oxide (Fe_2O_3)	2.97	4.78	4.87	3.92	1.19	4.14	.88
Manganese oxide (MnO)						.01	Trace.
Lime (CaO)		14.26	11.79	29.76	25.44	17.39	42.11
Magnesia (MgO)			Trace.		2.52	1.74	.46
Sulphuric anhydride (SO_3)		.97	2.21	1.04		1.59	Trace.
Soda (Na_2O)		3.22	3.07	2.04	.60	.19	.05
Potash (K_2O)		.975	1.14	.29	1.41	1.49	.21
Water at 100° C.		4.36	3.68	3.77		3.09	1.88
Ignition loss					28.38	15.77	35.50
Carbon dioxide (CO_2)		10.36	8.30	22.80			
Phosphoric acid (P_2O_5)		.113	.109	.118	.36		
		100.22	99.99	99.57	100.48	100.13	99.79

1. Sample from basal part of formation on Little Cottonwood Creek, near Hewitt, south of Waco, Tex.
2. Sample of basal part from fresh exposure in bank of creek one-half mile southeast of Taylor, Tex. Analysis by G. H. Wooten. Taff, J. A., Reports on the Cretaceous area north of Colorado River: Texas Geol. Survey Third Ann. Rept., p. 356, 1892.
3. Sample of central part from face of high bluff at Rice's Crossing on Brushy Creek, Williamson County, Tex. Analysis by G. H. Wooten, op. cit., p. 356.
4. Sample of upper part 1 mile above Missouri, Kansas & Texas Railway bridge on Brushy Creek, Williamson County, Tex. Analysis by G. H. Wooten, op. cit., p. 357.
5. Sample from middle part in bluff on Colorado River 1½ miles north of Delvalle, Travis County, Tex. Analysis by T. B. Tucker.
6. Sample from lower part in east bank of Big Walnut Creek 6½ miles northeast of Austin, Tex. Burchard, E. F., Structural materials available in the vicinity of Austin, Tex.: U. S. Geol. Survey Bull. 430, p. 315, 1910.
7. Sample from upper part in test pit 5 miles north of courthouse at San Antonio, Tex.

Thickness and dip.—Along the Brazos the Taylor marl is probably 1,150 feet thick. In Travis County, as shown by the record of the Manor well, it is about 650 feet thick. In Bexar County it is about 475 feet thick.

The dip is to the southeast, at a rate ranging from 40 to 90 feet to the mile. On the Brazos it is 58 feet to the mile.

Paleontology.—The lower part of the Taylor marl contains the fossil oyster *Exogyra ponderosa* Roemer. In the Austin section, at a higher horizon, above the *Exogyra ponderosa* zone, there are numerous specimens of *Inoceramus,* and near the top is *Gryphaea vesicularis* Lamarck. (See Pl. X.)

Areal extent and underground distribution.—South of Colorado River, the Taylor marl outcrops in a belt of country 2 to 6 miles wide that roughly parallels the Balcones fault and lies 2 to 8 miles distant from it. North of the Colorado the belt is from 3 to 15 miles wide and trends northeastward. The outcrop appears in Bexar, Guadalupe, Caldwell, Comal, Hays, Travis, Williamson, Milam, Bell, Falls, McLennan, Limestone, Hill, Navarro, Ellis, Kaufman, Dallas, Rockwall, and Collin counties.

Wells drilled in a strip of country 5 to 20 miles wide lying east of and adjacent to the outcrop penetrate the formation. How far the marl extends underground toward the coast is a matter of conjecture, but it evidently continues eastward for a considerable distance.

Correlation.—The Taylor marl of central Texas is believed to be geographically continuous with the Marlbrook marl of southern Arkansas. The paleontologic studies of L. W. Stephenson indicate, however, that the Marlbrook occupies a somewhat higher stratigraphic position than the Taylor in its type area north of Austin.[41] His opinion is that the basal part of the Marlbrook corresponds in age to the uppermost part of the Taylor and that the upper part of the Marlbrook is younger than the top of the Taylor; in other words the Taylor transgresses to higher levels in its northward extension in a manner similar to the transgression of the underlying Austin chalk. (See

[41] Stephenson, L. W., U. S. Geol. Survey Prof. Paper 120, p. 154, 1918.

p. 26.) The top of the Taylor in the type locality, however, has been somewhat arbitrarily regarded as corresponding to the top of the *Exogyra ponderosa* zone, the exact position of which has not been definitely determined.

The Taylor marl does not extend southward very far beyond Medina River, in Medina County, but in western Medina, Uvalde, and eastern Kinney counties it is represented by the Anacacho limestone,[42] and Vaughan[43] states that in Maverick and southern Kinney counties this limestone is in turn represented by the Upson clay.[44] Subsequent work of Stephenson has shown that the San Miguel beds of Dumble, which overlie the Upson, correspond to the upper part of both the Anacacho and the Taylor.

In the eastern Gulf region, according to Stephenson, the Taylor is represented by the lower part of the Selma chalk—that is, by the part of the chalk within the *Exogyra ponderosa* zone. In the western interior area of the United States the Pierre shale of the Montana group is considered the approximate time equivalent of the Taylor.[45]

Section on Brazos River.—In the region of the Brazos the lowermost beds of the Taylor marl consisting of 5 to 15 feet of weathered plastic yellow calcareous clay may be seen in the banks of Little Cottonwood Creek near Hewitt, south of Waco. An analysis of this marl is given on page 32.

Section at Taylor.—The following beds were penetrated in the well of the Taylor Water Co., Taylor, Tex.:

Log of the Taylor Water Co's. artesian well at Taylor, Tex.

	Feet.
Recent:	
Black soil	1
Taylor marl:	
Yellow clay	39
Blue clay	460
Austin chalk:	
White clay	200
Soft white limerock; about 40 barrels of water a day	100
Soft blue limerock?	200
Eagle Ford shale:	
Dark-blue clay	60
Buda limestone:	
Hard white limerock	30
Del Rio clay:	
Blue clay	90
Georgetown, Edwards, and Comanche Peak limestones, Walnut clay, and Glen Rose limestone:	
Hard limerock	135
Stratified hard limerock and soft sandrock containing sulphur water. First or upper Edwards water horizon	160
Hard white limerock	81
Blue clay	1
Hard limerock	813
Blue shale and mud	70
Gray limerock	30
Blue shale and mud	45
Dark-gray limerock	65
Travis Peak sand:	
Water-bearing sand	142
Hard dark sandrock	40
Soft sand, water-bearing	50
Green shale	15
Soft white sand, water-bearing	60
Water-bearing sand	77
Hard sandrock	10
Water-bearing sand producing a flow of about 2,500,000 gallons of water a day	286
	3,260

Well started February 4, 1913; completed November 24, 1913. 10-inch casing set on limestone at 1,180 feet; 8-inch casing set on limestone at 2,515 feet; 499 feet of 6⅝-inch perforated pipe set in sand at 2,974 feet.

Section on Big Walnut Creek.—On Big Walnut Creek, in Travis County, 1½ miles south of Sprinkle the lower part of the Taylor marl is well exposed.

About half a mile above the Pecan Springs road a bluff 40 feet high forms the left bank of the creek. Here massive blue calcareous shale carrying specimens of *Exogyra ponderosa* Roemer is exposed. From the top of the bluff a steep slope leads to the divide, the elevation increasing about 150 feet in a quarter of a mile. The slope is underlain by the Taylor marl, which here shows a thickness of about 150 feet. (See Pl. IV, *C*, p. 12.)

An analysis of the marl from this locality is given on page 32.

Section on Colorado River.—Near Colorado River in Travis County there are many excellent exposures of the Taylor marl. At Montopolis a few feet of the weathered marl overlies the Austin chalk. The marl is massive and compact and carries the following fossils (identified by L. W. Stephenson): *Nucula* sp.,

[42] Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 240, 1898.

[43] Vaughan, T. W., Eagle Pass and Eocene coal fields of the middle Rio Grande region of Texas: U. S. Geol. Survey Bull. 164, pp. 20, 21, 1900.

[44] Dumble, E. T., Notes on the valley of the middle Rio Grande: Geol. Soc. America Bull., vol. 3, pp. 219, 224, 1892.

[45] Vaughan, T. W. (quoted from T. W. Stanton), The San Carlos coal field of trans-Pecos Texas and adjacent portions of the Vieja Mountains: U. S. Geol. Survey Bull. 164, p. 82, 1900.

Pteria sp., *Inoceramus* sp. (numerous and large), *Ostrea plumosa* Morton ?, *Lucina* sp., *Ancyloceras* cf. *A. tricostatus* (Whitfield), and *Scaphites* sp. It dips S. 42° E. 45 feet to the mile.

Two miles by river below Montopolis (station 205, fig. 6) is an exposure of blue marl 10 feet in thickness.

On the banks of Colorado River 1¾ miles southwest of Hornsby, Travis County, 10 feet of light-blue calcareous shale or marl is exposed below gravel of granitic materials. Also on the same river 1½ miles north of Delvalle, Travis County, 30 feet of light-gray calcareous shale dipping S. 20° E. at a rate of 90 feet to the mile is exposed. An analysis of this shale is given on page 32. An exposure similar to that described above occurs in a bluff of the river 1 mile northeast of Delvalle, where 50 feet of calcareous shale may be seen.

Light-gray calcareous shale, containing *Gryphaea vesicularis* and lying within 30 to 60 feet of the top of the Taylor marl, is found in a bluff on Colorado River 1¾ miles east of Delvalle (station 210, fig. 6). No *Exogyra ponderosa* were found in the gray shale, and the fossils are not plentiful. The bluff extends upstream for a distance of 3 miles.

The relative stratigraphic position of the exposures on Colorado River is given on Plate IX (in pocket).

Section on Cibolo Creek.—The lithologic and faunal characters of the Taylor marl in the southern part of the area under consideration may be best indicated by describing in stratigraphic order the exposures on Cibolo Creek, in Bexar and Guadalupe counties. After leaving the Austin chalk one traversing the creek sees the first outcrop of the marl a quarter of a mile south of Schertz (station 936, fig. 7). This outcrop consists of 10 feet of blue calcareous shale or marl, which lies beneath gravel composed of limestone pebbles.

Three-fourths of a mile east of Schertz, Bexar County, there is exposed 20 feet of massive yellow calcareous shale or marl, underlying limestone gravel.

Two miles east of Schertz 10 feet of the same yellow marl, containing *Exogyra ponderosa* Roemer and *Inoceramus* sp., is exposed. The specimens of *Exogyra* at this locality have a coating of limonite.

Three and a half miles southeast of Schertz and about an eighth of a mile below the crossing of Schaffer road on Cibolo Creek (station 939 on the map, fig. 7) 10 feet of the yellow marl is also exposed.

In the vicinity of Zuehl, Guadalupe County, there are two exposures of the Taylor marl. One 5 miles northwest of the town shows 2 feet of blue argillaceous sand and the other 4 miles north-northwest of the town 15 feet of blue calcareous massive shale or marl.

The boundary line between the Taylor marl and overlying Navarro formation crosses Cibolo Creek at a point about midway between Zuehl and Schertz, or about 5 miles southeast of Schertz. The contact is not exposed, but a short distance below the point referred to the Navarro formation is exposed, and half a mile above it the Taylor marl appears.

Section on Salado Creek.—About 4 feet of yellow fine-grained sand, which overlies about 15 feet of brown joint clay containing fragments of gypsum and some iron nodules, is exposed in a bluff on Salado Creek, about half a mile west of the Missouri, Kansas & Texas Railway and about 3¾ miles northeast of Fort Sam Houston at San Antonio. About 5 feet of weathered yellow clay, evidently belonging to the Taylor marl, is exposed in the bluff on the same creek, flanking Salado Creek bottom at the pump house on the Brackenridge place, about 2 miles northeast of Fort Sam Houston.

Yellow clay of the Taylor formation is exposed on the road about half a mile west of the well of the Salado Water Supply Co., on Salado Creek, about 1½ miles northeast of Fort Sam Houston, at San Antonio.

Blue shale of the Taylor marl is exposed in a bluff on Salado Creek at the crossing of the Galveston, Harrisburg & San Antonio Railway, from San Antonio to Victoria, 4 miles east of the courthouse at San Antonio.

Section near San Antonio.—The marls of the Taylor formation are exposed near the International & Great Northern Railway about 5 miles north of the courthouse at San Antonio. An analysis of the marl from a test pit 10 feet in depth at this place is given on page 32.

Yellow clay of the Taylor formation is exposed in the banks of Olmos Creek at the crossing of the International & Great Northern Railway about 4 miles north of the courthouse at San Antonio.

Blue limy shale weathering yellow is exposed on the Alamo Heights road, about 200 yards east of the Academy of the Incarnate Word, about 3½ miles north-northeast of the courthouse at San Antonio.

Yellow calcareous clay of the Taylor formation was exposed in excavations made for a subway at the Nolan Street crossing of the Galveston, Harrisburg & San Antonio Railway at San Antonio.

Excavations at Fort Sam Houston, in the northeastern part of San Antonio, reached blue clay which weathers yellow. The clay, which is a part of the Taylor formation, is covered by a black clay soil in which are embedded subangular to rounded flint cobbles bearing a brown coating of iron.

The following section is exposed 2 miles east-southeast of San Antonio:

Section at quarry near the cemeteries, about 2 miles east-southeast of the courthouse at San Antonio, Tex.

	Feet.
Black clay soil with embedded flint cobbles....	2±
Unconformity.	
White marl (clayey lime); a kind of adobe similar to that used in buildings in San Antonio in the early days. A few flint cobbles are scattered through the adobe..........................	3–4
Unconformity.	
Reynosa formation (upstream facies):	
Flint and limestone gravel in a matrix of yellow clay.......................................	3–6
Unconformity.	
Taylor marl:	
Blue shale; exposed	1

Section on Leon Creek.—Yellow shale 80 feet thick, containing specimens of *Exogyra ponderosa* Roemer and *Exogyra ponderosa* var. *erraticostata* Stephenson, is exposed in bluffs bordering the valley of Leon Creek at the crossing of the Culebra road 8¾ miles west of the courthouse at San Antonio.

Washes 50 feet north of the San Antonio-Castroville road, 200 feet west of the crossing on Leon Creek and 6¾ miles west of the courthouse at San Antonio, expose 10 to 20 feet of whitish-yellow calcareous clay.

ANACACHO LIMESTONE.

Name.—The Anacacho limestone was first described in 1898 by Hill and Vaughan,[46] who named it from the Anacacho Mountains, in Kinney County, Tex., where it is well exposed.

Stratigraphic position.—The Anacacho limestone lies conformably above the Austin chalk and below the Escondido formation in Medina, Uvalde, and Kinney counties, Tex. The "Coal series" of Maverick County, which should fall in the Anacacho, is apparently represented by marine beds, which may be included in the lower part of the Escondido formation.

Lithology.—The formation consists of hard yellowish limestones, which occur in thick ledges or slabs, and beds of yellow marl, some of them 15 to 20 feet thick. Most of the marly beds are thinly laminated. The limestones are not pure but in places contain large quantities of clay or sand. Their yellow color is due to their content of iron. Their texture is generally coarse. They are evidently of organic origin and at many places are made up of fragments of shells. The coarse shell rock in places contains asphaltic matter.

Thickness and dip.—In the western part of Uvalde County the formation is about 300 feet thick.[47] It becomes thicker toward the east, and in the eastern part of Uvalde County it is not less than 400 feet thick. From this point it gradually becomes thinner toward the east, and it finally disappears in the western part of Bexar County. It dips to the southeast at the rate of 160 feet to the mile.

Paleontology.—The formation contains *Exogyra ponderosa* Roemer, and *Gryphaea vesicularis* Lamarck.

Areal extent and underground distribution.—The Anacacho limestone crops out in a belt of country that roughly parallels the Balcones fault at a distance of 5 to 10 miles from it, in Kinney, Uvalde, and Medina counties, Tex.

Correlation.—The correlation of the Anacacho limestone is discussed in connection with the Taylor marl, on page 33.

Section on Medina River.—Exposures of the Anacacho limestone have been noted on Medina River as indicated below.

A bed of semicrystalline gray limestone 6 inches thick is exposed in the bank of a creek about two-fifths of a mile south of Rio Medina post office, in Medina County.

An exposure of brown bedded limestone was seen in the bed of a creek that crosses the Castroville-Rio Medina road about a mile south of Rio Medina post office, and another exposure of similar rock was seen on the same road about a mile north of the post office of Castroville.

[46] Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 240-241, 1898.

[47] Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), p. 2, 1900.

NAVARRO FORMATION.[48]

Name.—The Navarro formation was first described in 1862 by Shumard, who named it from Navarro County, in northern Texas, where the beds are typically exposed.[49]

Stratigraphic position.—The Navarro formation lies conformably above the Taylor marl, and in the area between Brazos and San Antonio rivers it lies unconformably below the Midway formation of the Tertiary system.

Lithology.—The formation consists of bluish-black calcareous marl, bluish-black glauconitic clay, blue clay containing concretions of siderite and limonite, yellow-brown sandstone containing concretions of hard blue siliceous limestone that range from 2 to 10 feet in diameter, and yellow and brown sandstone. The beds show little lateral continuity but appear to be lenticular, a lens of clay being succeeded laterally by a lens of sandstone and so on.

The features that distinguish the Navarro formation from the underlying Taylor marl are the presence of glauconite; a higher content of iron, probably altered glauconite, which is in the form of large ferruginous concretions 1 to 2 feet in diameter; the red color of the burned clay; the presence of large hard calcareous concretions; the presence of sand; and the general lack of lithologic homogeneity.

Thickness and dip.—Along the Brazos the Navarro beds are about 500 feet thick; on the Colorado they are probably nearly 500 feet thick; in Bexar County they are from 405 to 470 feet thick.

The beds dip to the southeast at a rate ranging from 40 to 90 feet to the mile.

[48] Partial synonymy of the Navarro formation:
Navarro beds: Shumard, B. F., Descriptions of new Cretaceous fossils from Texas: Boston Soc. Nat. Hist. Proc., vol. 8, p. 189, 1862.
Ripley group: Idem, pp. 190–205.
Ripley group: Loughridge, R. H., Physico-geographical and agricultural features of the State of Texas: Tenth Census U. S., vol. 5, pt. 1, p. 676, 1884.
Navarro beds: Hill, R. T., The topography and geology of the Cross Timbers and surrounding regions in northern Texas: Am. Jour. Sci., 3d ser., vol. 33, p. 298, 1887.
Glauconitic division: Hill, R. T., A preliminary annotated check list of the Cretaceous invertebrate fossils of Texas, accompanied by a short description of the lithology and stratigraphy of the system: Texas Geol. Survey Bull. 4, pp. 13, 30, 1889.
Webberville formation: Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 241–243, 1898.

[49] Shumard, B. F., Descriptions of new Cretaceous fossils from Texas: Boston Soc. Nat. Hist. Proc., vol. 8, p. 189, 1862.

Paleontology.—Among the fossils found in this formation are *Exogyra costata* Say, *Gryphaea vesicularis* Lamarck, *Ostrea larva* Lamarck, and *Sphenodiscus lenticularis* (Owen). (See Pl. XI.)

Areal extent and underground distribution.—Between Trinity and San Antonio rivers the Navarro formation crops out in a belt 3 to 10 miles wide that extends through Bexar, Guadalupe, Caldwell, Hays, Travis, Williamson, Milam, Falls, Limestone, and Navarro counties. (See map, Pl. VIII, in pocket.) In the region farther east the formation underlies Tertiary rocks, as is shown by the records of wells.

Correlation.—The results of L. W. Stephenson's paleontologic studies indicate that the time equivalents of the Navarro formation in Arkansas include the Nacatoch sand, the Arkadelphia clay, and all but the basal portion of the Marlbrook marl. The Escondido formation [50] of southwest Texas represents the southwestern extension of the Navarro.

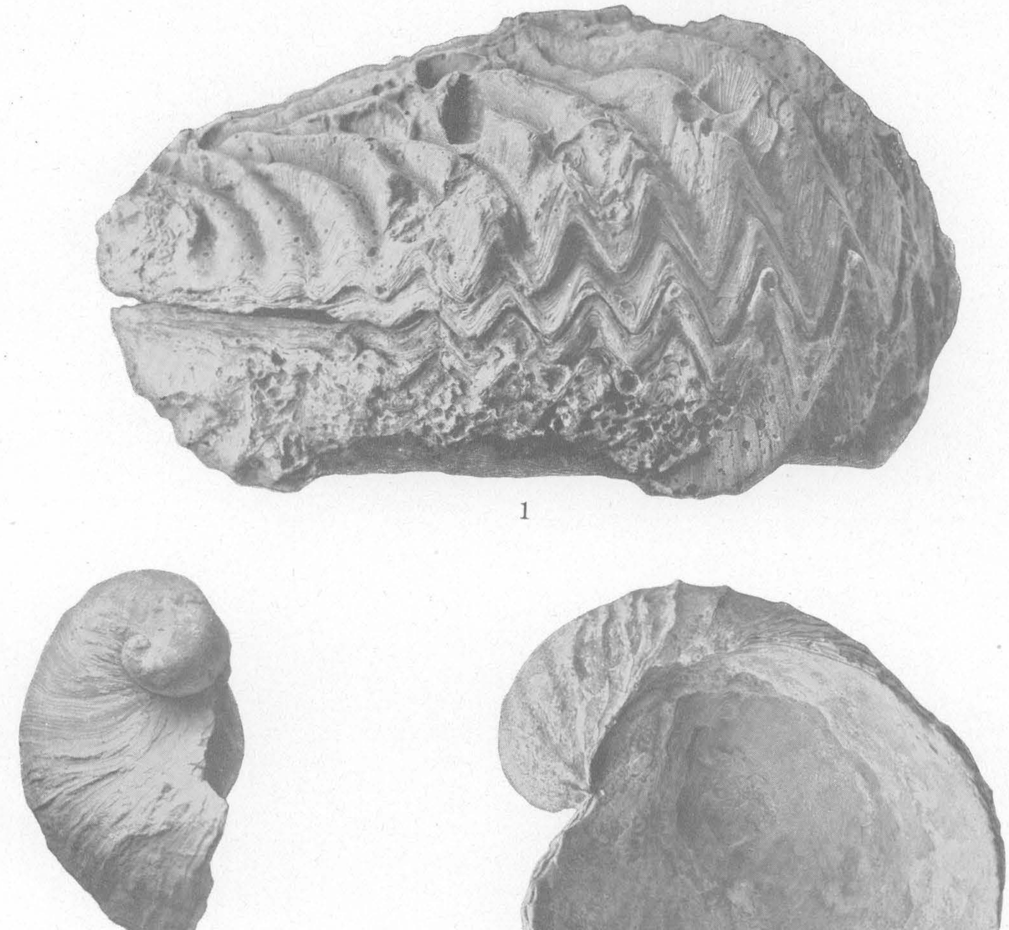
In the region east of Mississippi River the Navarro is represented approximately by the rocks embraced within the *Exogyra costata* zone of Stephenson,[51] which includes the type Ripley formation of northern Mississippi, the upper part of the Selma chalk of Mississippi and Alabama, the Peedee formation of the Carolinas, and the Monmouth formation of Maryland, Delaware, and New Jersey. The Ripley and its time equivalents have long been recognized by Stanton, Hill, and other paleontologists as approximately representing the time interval of the Navarro. In the Western Interior region the Navarro is approximately represented by the Fox Hills sandstone of the Montana group.[52]

Section on Brazos River.—The Navarro formation is exposed along the Brazos for a distance of 7 miles in a direct line above the northern corner of Milam County. About 1½ miles by river above this corner there is a bluff that shows the uppermost beds of the formation in contact with the overlying Eocene. The Navarro formation here consists of massive blue clay containing *Baculites.*

[50] Dumble, E. T., Notes on the geology of the valley of the middle Rio Grande: Geol. Soc. America Bull., vol. 3, pp. 227–229, 1892.

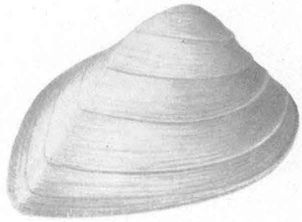
[51] Stephenson, L. W., The Cretaceous deposits of the eastern Gulf region: U. S. Geol. Survey Prof. Paper 81, pp. 37–39, pl. 10, 1914.

[52] Vaughan, T. W., Eagle Pass and Eocene coal fields of the middle Rio Grande region of Texas: U. S. Geol. Survey Bull. 164, p. 12, 1900.

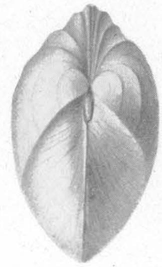


FOSSILS OF THE TAYLOR MARL.

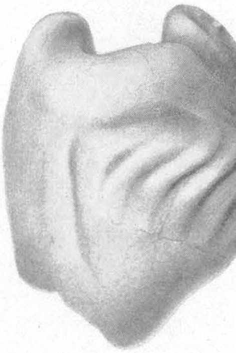
1. *Ostrea* sp. aff. *O. diluviana* Linnaeus. 2. *Exogyra laeviuscula* Roemer. 3. *Exogyra ponderosa* Roemer.



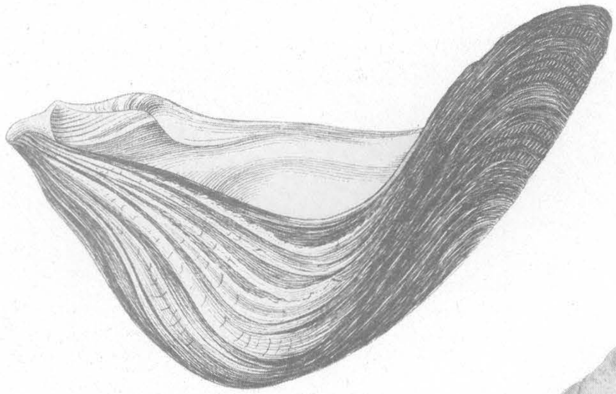
2



2a

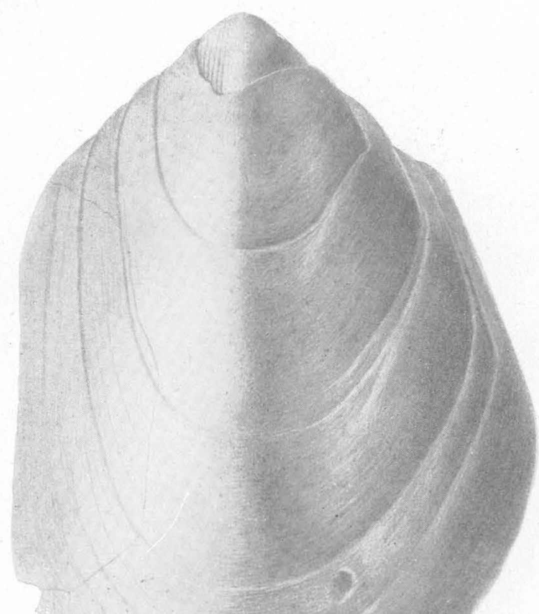


1



3

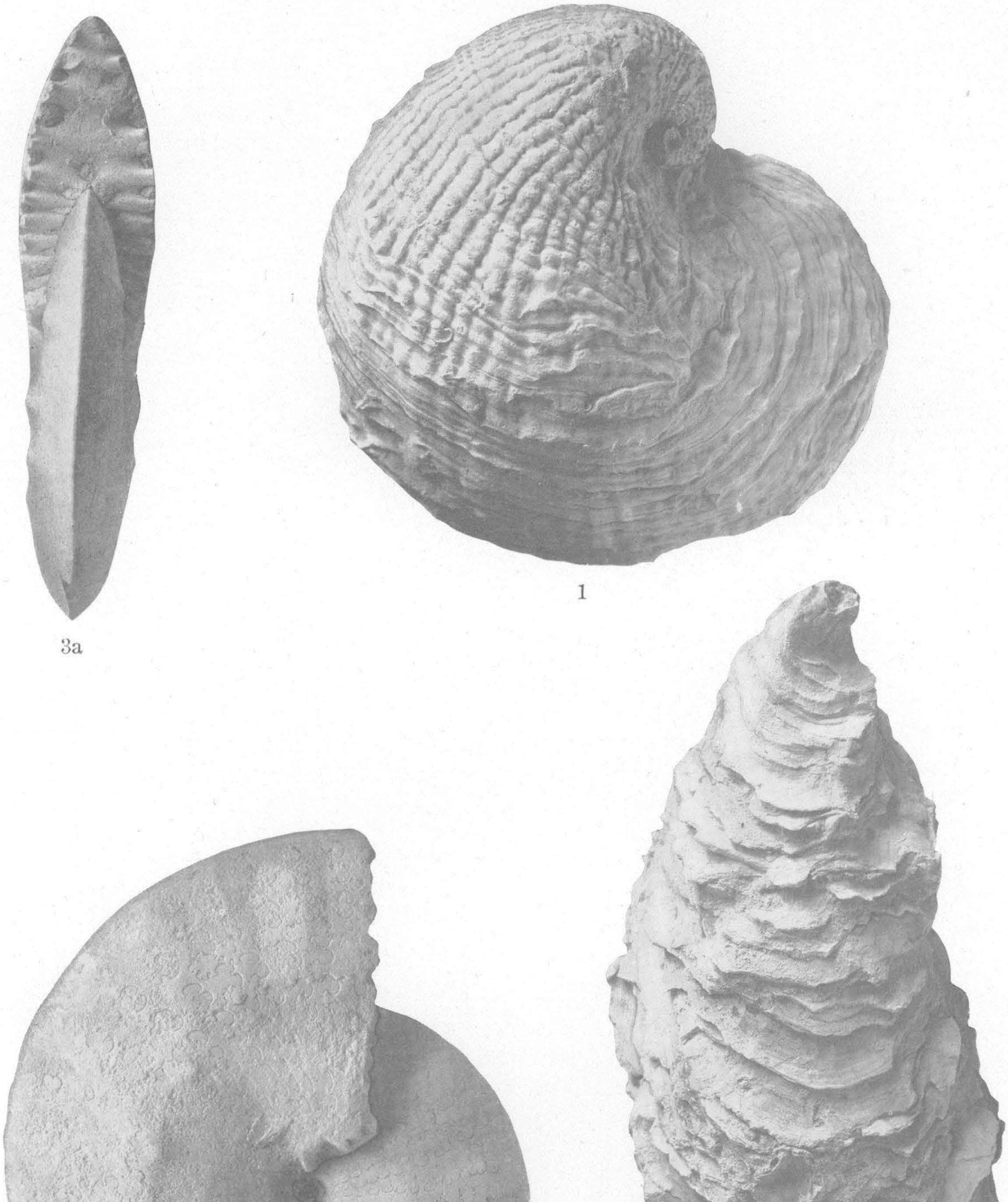
3a



4

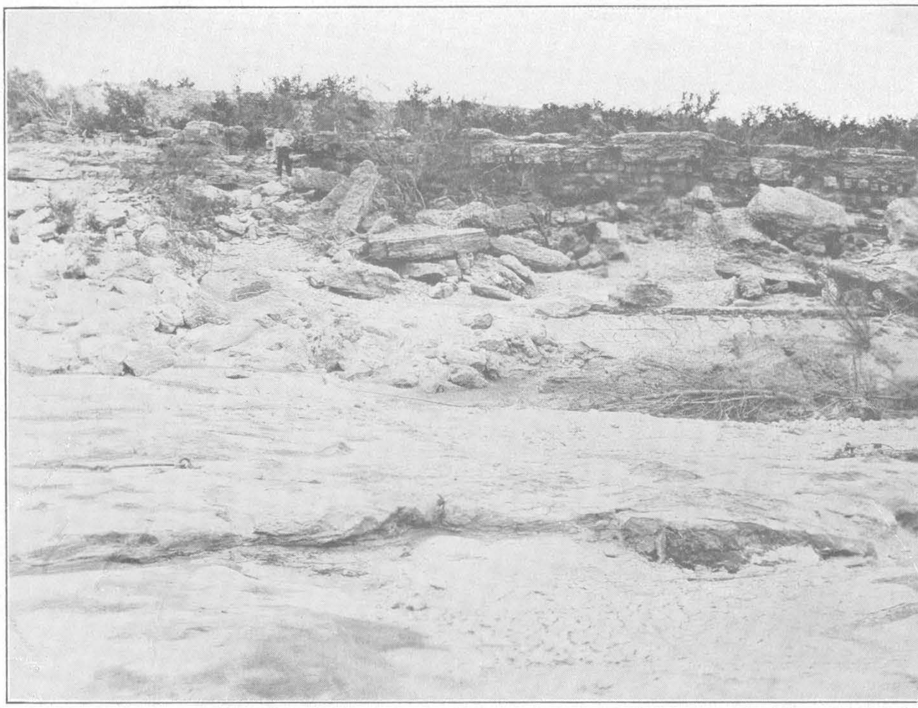
CHARACTERISTIC FOSSILS OF THE NAVARRO FORMATION.

1. *Pugnellus densatus* Conrad.
2, 2a. *Veniella lineata* (Shumard).
3, 3a. *Ostrea owenana* Shumard.
4. *Cardium* (*Pachycardium*) *spillmani* Conrad (variety).

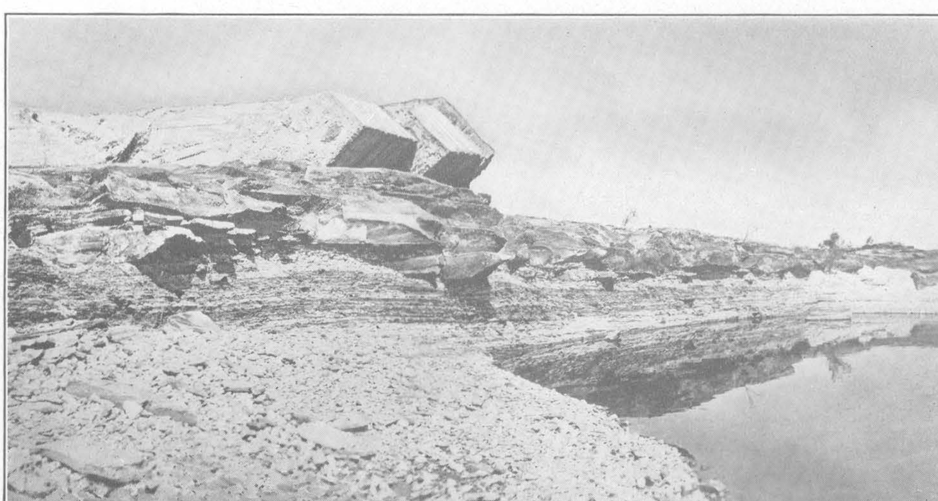


CHARACTERISTIC FOSSILS OF THE ESCONDIDO FORMATION.

1. *Exogyra costata* Say. 2. *Ostrea cortex* Conrad. 3, 3a. *Sphenodiscus pleurisepta* (Conrad).

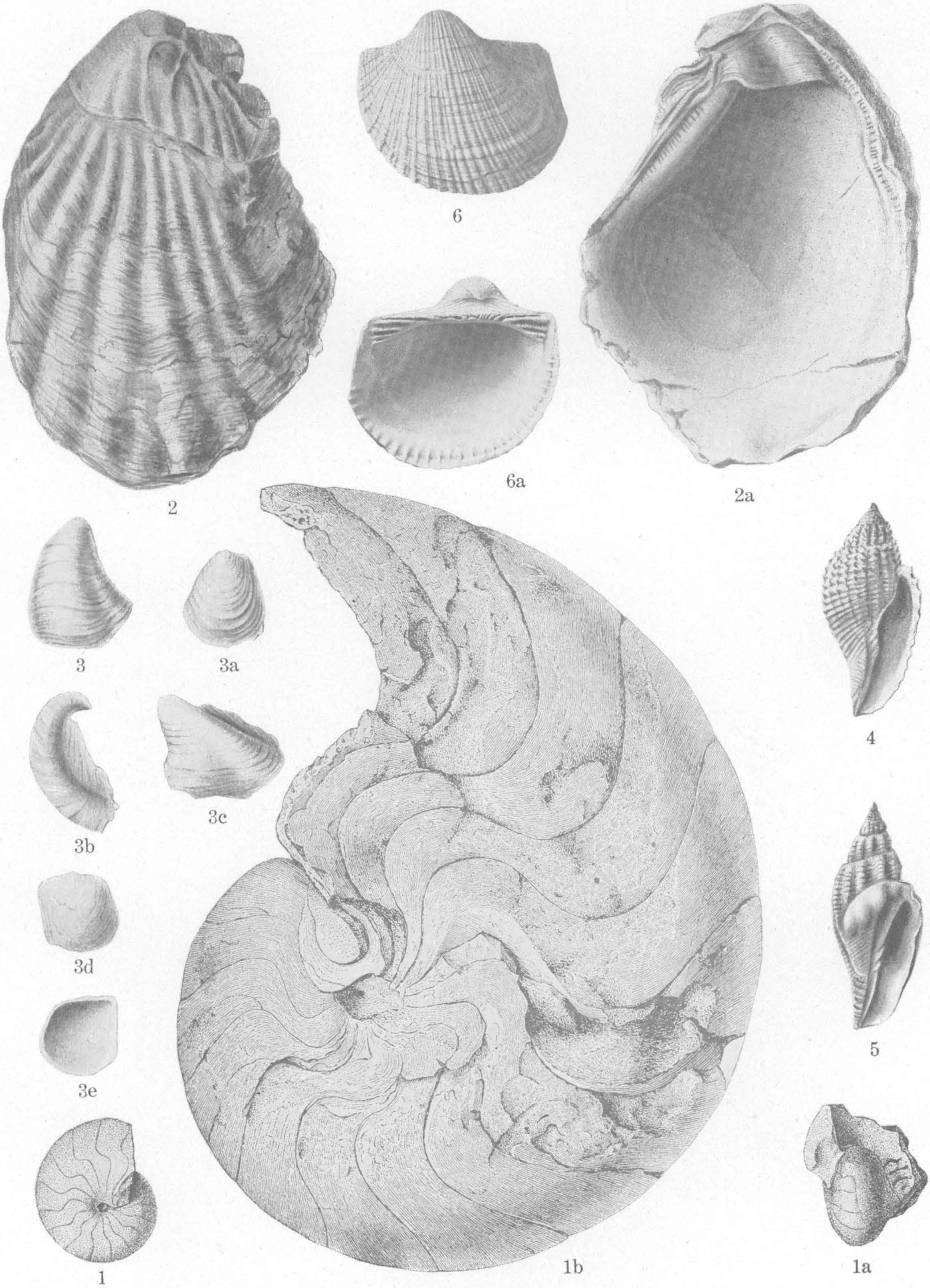


A. FOSSILIFEROUS LIMESTONES, BEDS 2 TO 5 OF THE SECTION ON PAGE 40.



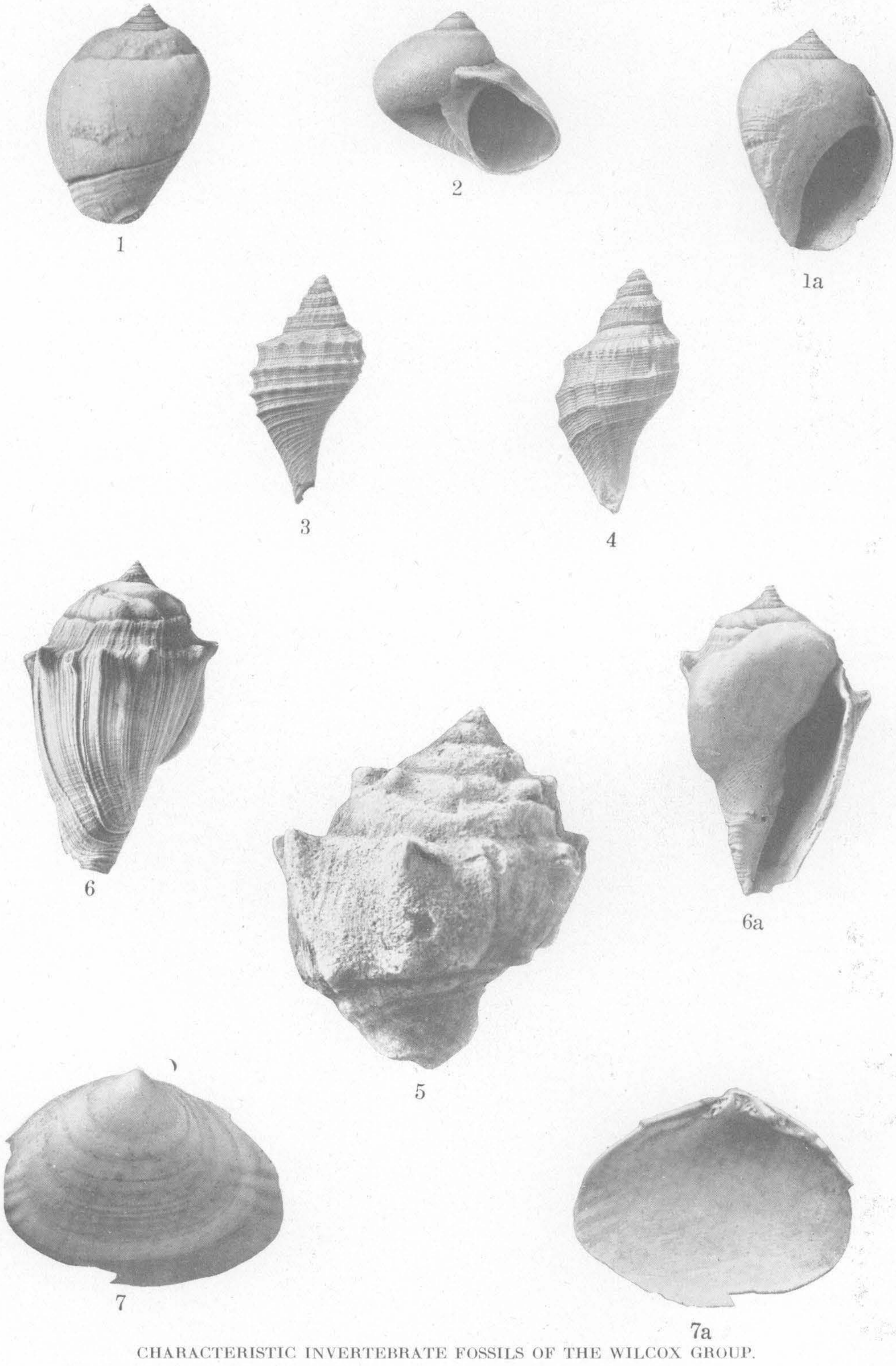
B. ASPHALTIC SANDSTONE OVERLYING SLATE-COLORED SHALE.

ESCONDIDO FORMATION EXPOSED IN BLUFF ON NUECES RIVER AT RAILROAD BRIDGE AT PULLIAM, ZAVALLA COUNTY, TEX.



CHARACTERISTIC FOSSILS OF THE MIDWAY FORMATION.

1, 1a–b. *Enclimatoceras ulrichi* White. (The Texas analogue of this species from Arkansas is *Enclimatoceras vaughani* Gardner, a species that has been discriminated since this plate was made up. See U. S. Geol. Survey Prof. Paper 131, p. 115, pl. 32, 1923.)
2, 2a. *Ostrea crenulimarginata* Gabb.
3, 3a–e. *Ostrea pulaskensis* Harris.
4. *Plejona limopsis* (Conrad).
5. *Plejona rugata* Conrad.
6, 6a. *Cucullaea macrodonta* Whitfield.



CHARACTERISTIC INVERTEBRATE FOSSILS OF THE WILCOX GROUP.

1, 1a. *Pseudoliva vetusta* Conrad.
2. *Natica aperta* Whitfield.
3, 4. *Pyrula juvenis* Whitfield.
5. *Cornulina armigera* Conrad.
6, 6a. *Plejona petrosa* Conrad subsp. *tuomeyi* (Conrad).
7, 7a. *Kellia prima* Aldrich.

Section on Colorado River.—The lowermost beds of the Navarro in the Colorado drainage basin can be seen in a bluff about 60 feet high on Onion Creek, about 500 to 700 feet below the crossing of the Delvalle-Garfield road. The lower 50 feet of the exposure is stratified blue shale containing a few layers of harder calcareous shale, each a foot thick. The upper 10 feet is brown to yellow clay, which represents the weathered phase of the underlying shale.

The shale contains great numbers of the fossil *Exogyra costata* Say and some specimens of *Ostrea larva* Lamarck.

In a ravine that cuts back into the upland close to Garfield, Travis County, which stands on a gravel terrace of Colorado River, the Navarro formation is well exposed. Here it includes 40 feet of yellow sand, alternating with blue clay. Associated with the sand are hard brown fossiliferous limestone concretions, 2 to 4 feet in diameter, which are firmly embedded in the rock. The fossils found here are *Lunatia* sp., and poorly preserved pelecypods and gastropods.

In a bluff about a mile and a half below the mouth of Onion Creek 30 feet of bluish-black clay is seen above the water line. The beds have a slight dip upstream. The clay weathers dark brown. A large number of calcareous concretions, 5 to 10 feet in diameter, derived from this formation lie on the bank of the river.

From 3 to 4 feet of dark-blue fossiliferous clay containing concretions is exposed above the water line on the left bank at the ferry across Colorado River at Webberville, Travis County. These are the uppermost beds of the Navarro formation. The following fossils (collections 7601–7602) were collected by L. W. Stephenson and Alexander Deussen and were identified by Mr. Stephenson:

- Nucula sp.
- Leda (2 species).
- Striarca sp. (same as in well near Groesbeck, Tex., depth 675–800 feet).
- Pteria sp.
- Lucina n. sp.
- Venericardia n. sp. (same as in well near Groesbeck, Tex., depth 675–800 feet).
- Corbula sp.
- Cadulus obnutus (Conrad).
- Dentalium sp.
- Eulima sp.
- Lunatia sp.
- Turritella sp. (same as in well near Groesbeck, Tex., depth 675–800 feet).
- Pyramidella n. sp.
- Olivella sp.
- Tornatellaea sp.
- Ringicula pulchella Shumard (?) (same as in well near Groesbeck, Tex., depth 675–800 feet).

This fauna, according to Stephenson, contains new elements, which have been recognized also in a well owned by the Robinson Oil & Gas Co., 2 miles west of Groesbeck, Limestone County, Tex., at a depth of 675–800 feet, where the containing beds immediately overlie the Nacatoch sand.

The relative positions of the exposures on Colorado River in Travis County are indicated graphically on Plate IX.

Section at Maxwell, Caldwell County.—The character of the beds at Maxwell, Caldwell County, is shown by the following well log:

Log of well of C. T. Schawe at Maxwell, Tex., drilled by Gulf Coast Drilling Co. in 1914.

	Feet.
Reynosa formation:	
White rock	10
Gravel	4
Rock	1
Navarro and Taylor formations:	
Yellow clay	39
Black soapstone	36
Blue gumbo	20
Soapstone	10
Blue gumbo	44
Black shale	70
Black gumbo	140
Shale	25
White gumbo	260
Shale	40
White gumbo	70
Austin chalk:	
White rock (show of oil)	276
Eagle Ford shale:	
Gumbo	35
Buda limestone and Del Rio clay:	
White limerock	42
White rock	29
Georgetown, Edwards, and Comanche Peak limestones:	
Brown porous rock	328
Brown rock with hard white layers	46
White rock, very hard	8
Brown porous rock, sulphur water	51
Gray hard rock	48
Porous rock, sulphur water	14
Hard gray rock	23
White limerock	134
Hard gray rock	22
White limerock	35

	Feet.
Georgetown, Edwards, and Comanche Peak limestones—Continued.	
Brown rock, white layers	79
Hard white rock	7
Brown rock, white layers	32
Hard white rock	7
Brown rock, white layers	32
Brown rock	77
Walnut clay:	
Gumbo mud hole	8
Glen Rose limestone:	
Brown rock, very hard	8
Brown porous rock; show of water	107
Gray rock	123
Gumbo mud hole	6
White limerock	87
Soft brown rock, show of water	85
Brown rock, white layers	36
Hard brown rock	27
Gray sandrock	15
Soft brown rock	137
Hard white lime	40
Travis Peak sand:	
Soft yellow sandrock	40
White limerock	10
Yellow sandrock; water	134
Hard blue rock	11
Hard gray rock	19
Yellow sandrock	49
White sandrock	39
Gumbo mud hole	11
Rock with gumbo mixed	25
Yellow rock with gumbo mixed	13
Red and blue gumbo mixed	34
Hard white sandrock	13
White sandrock; soft and hard streaks	195
Sand	93
Blue shale	40
	3,499

Section on Cibolo Creek.—On Cibolo Creek, about 1¾ miles northwest of Zuehl, in Bexar County, the Navarro formation consists of 5 feet of alternating layers of yellow sandstone and calcareous shale and 10 feet below, in the bed of the creek, a blue shale containing hard calcareous sandstone concretions 2 to 5 feet in diameter. A quarter of a mile downstream there is a bed of yellow, calcareous clay about 6 feet thick. A bed of yellow calcareous shale of the Navarro formation is exposed 1½ miles northwest of Zuehl, Bexar County.

A mile northwest of Zuehl (station 947 on map, fig. 7) 4 feet of yellow fossiliferous sandstone containing *Exogyra costata* Say and *Ostrea larva* Lamarck is exposed.

About 20 feet of Navarro sand is exposed a short distance below this point from which specimens of *Nucula* cf. *N. percrassa* Conrad and *Crassatella* sp.? were collected.

ESCONDIDO FORMATION.[53]

Name.—White in 1891 applied to the group of strata above the "Ponderosa marls" or Upson clay in the Rio Grande region the name Eagle Pass beds.[54]

Dumble in 1892 extended the name Eagle Pass "division" to include all the Cretaceous beds overlying the "Pinto limestone" or Austin chalk. He established four subdivisions. The lower yellow clays he called the Upson clays; the overlying sandstones with interbedded bands of clay he called the San Miguel beds; the shales, clays, and coal above the San Miguel he called the Coal series; the upper sandstones and clays he called the Escondido beds.[55]

The name Escondido formation as used in this report is applied to the beds that Dumble originally so designated.

Stratigraphic position.—The Escondido formation lies conformably above the Anacacho limestone of Medina, Uvalde, and Kinney counties and above the so-called "Coal series" of Maverick County. It lies unconformably below the Midway formation of the Eocene series.

Lithology.—The formation consists of yellow and brown sandstones, glauconitic sandstone, yellow, black, and blue clays, yellow sandy clay, impure ferruginous limestone, and layers of oyster shells. The beds are lenticular and have slight lateral continuity, a bed of clay being succeeded laterally by a bed of sandstone and so on. The terranes in general weather yellow, though in places the fossiliferous limestones are more nearly white.

Thickness and dip.—The thickness of the Escondido formation in Medina County is about 600 feet; in Uvalde County 200 feet; in Frio County 455 to 489 feet.

[53] Partial synonymy of the Escondido formation:
Eagle Pass beds (part): White, C. A., Correlation papers — Cretaceous: U. S. Geol. Survey Bull. 82, p. 117, 1891.
Escondido beds: Dumble, E. T., Notes on the valley of the middle Rio Grande: Geol. Soc. America Bull., vol. 3, pp. 227-229, 1892.
Eagle Pass: Hill, R. T., Notes on Texas-New Mexican region: Geol. Soc. America Bull., vol. 3, p. 94, 1892.
Eagle Pass formation (part): Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of under ground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 241, 1898.
Eagle Pass formation (part): Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, p. 21, 1900.
Escondido beds (part): Vaughan, T. W., idem, p. 26.
Pulliam formation: Vaughan, T. W., U. S. Geol. Survey Geol. Atlas Uvalde folio (No. 64), p. 2, 1900.

[54] White, C. A., Correlation papers—Cretaceous: U. S. Geol. Survey Bull. 82, p. 117, 1891.

[55] Dumble, E. T., Notes on the valley of the middle Rio Grande: Geol. Soc. America Bull. vol. 3, pp. 224-229, 1892.

The dip south of Uvalde County is S. 70° E., and east of the west line of Uvalde County it is S. 18° E. The formation therefore dips beneath the Tertiary formations.

Paleontology.—The characteristic fossils include *Exogyra costata* Say, *Ostrea cortex* Conrad, and *Sphenodiscus pleurisepta* Conrad. (See Pl. XII.)

Areal extent.—The formation outcrops in a belt of country 2 to 15 miles wide, lying in the eastern part of Maverick County, the extreme northwest corner of Zavalla County, and the southern parts of Uvalde and Medina counties. (See map, Pl. VIII.)

Correlation.—The Escondido formation represents the extension of the Navarro formation into southwest Texas. The "Pulliam formation" of Vaughan represents the Escondido formation in Uvalde County.

The equivalents of the Escondido in the eastern Gulf region and in the Western Interior region have already been indicated in the statements pertaining to the age of the Navarro formation (p. 36).

Section on Leon Creek.—Yellow shale 12 feet thick, containing calcareous sandstone concretions, is exposed on the slopes of the valley of Leon Creek at the crossing of the Frio City road, 7½ miles southwest of the courthouse at San Antonio.

Fossils occur in the shale on Leon Creek, but none of those collected could be determined.

The following analysis shows the composition of the shale from the Escondido formation on Leon Creek:

Analysis of shale from the Escondido formation from valley of Leon Creek, at crossing of the Frio City road.

[Sample collected by E. F. Burchard.]

Silica (SiO_2)	51.34
Alumina (Al_2O_3)	10.42
Ferric oxide (Fe_2O_3)	4.09
Manganese oxide (MnO)	.07
Lime (CaO)	14.91
Magnesia (MgO)	.93
Sulphuric anhydride (SO_3)	Trace.
Soda (Na_2O)	.89
Potash (K_2O)	.69
Water at 100° C	1.54
Ignition loss	14.93
	99.81

Brown sand with a large admixture of grains of green glauconite is exposed in a bluff on Leon Creek about a tenth of a mile above the International & Great Northern Railway bridge 8 miles southwest of the courthouse at San Antonio.

Section on Medina River.—About 2 feet of hard yellow calcareous sandstone is exposed at a crossing of Medina River, three-quarters of a mile southeast of the post office at Castroville. The sandstone carries *Inoceramus* sp., *Exogyra costata* Say, *Gryphaea* sp. (large), *Lima* sp., *Plicatula* sp., *Trigonia* sp., and *Crassatellites* sp. The largest exposure of the Escondido formation in the drainage basin of Medina River consists of 140 feet of yellowish-brown shale containing lenses of sand 2 to 3 feet in diameter. This exposure is about three-quarters of a mile southwest of the post office at Castroville.

In Medina County the Escondido is exposed in a cut of the Southern Pacific Railroad, about 300 yards east of milepost 237 and 2 miles west of Lacoste. The exposure here consists, in descending order, of yellow flaggy fossiliferous limestone, containing fossils in a 2-inch layer, 2 feet thick; yellow shale, 5 feet thick; yellow argillaceous sandstone, 4 inches thick; and yellow-brown shale, 3 feet exposed. The yellow argillaceous sandstone has a dip of 1° S. 45° W.

The fossiliferous limestone contains *Leda* sp., *Striarca* sp., *Ostrea cortex* Conrad?, *Anomia* sp., and a shark tooth.

Section on Frio River.—A thickness of 5 feet of hard blue bedded fossiliferous sandstone, in beds ranging from 6 inches to 1½ feet thick and containing *Ostrea cortex* Conrad, is exposed on Frio River about 1 mile above Myrick's lower apiary and 1¾ miles southeast of the Englemann Ranch, in Uvalde County. The beds dip 2° ± NE.

About 200 feet downstream from the point where this section was taken 20 feet of yellow sandstone forms the upper part of the bluff on the left bank and overlies the fossiliferous Escondido beds described above. This yellow sandstone probably represents the basal beds of the Midway formation, which are more clearly exposed in the bluffs a short distance downstream.

Limestone boulders or lenses in a matrix of blue clay are exposed on Frio River about three-quarters of a mile above Myrick's lower apiary and about 9 miles east-southeast of Uvalde.

Section on Nueces River.—The Escondido formation is exposed on Nueces River in the southern part of Uvalde County, between Pulliam and a point 3½ miles (by direct line) above Pulliam. Only the lower 160 feet of the formation is exposed, the upper portion being overlapped by the Indio formation of the Eocene.

The topmost beds on this river can be seen in a bluff at the bridge of the San Antonio, Uvalde & Gulf Railroad, at Pulliam station. The following section is exposed:

Section of bluff on west side of Nueces River at Pulliam, Zavalla County, Tex.

[See Pl. XIII.]

	Ft.	in.
Pleistocene terrace of Nueces River:		
1. Gravel in gray silt matrix; limestone and flint pebbles and cobbles	17±	
Unconformity.		
Escondido formation:		
2. Hard fossiliferous yellow limestone	3	
3. Laminated blue shale		8
4. Cavernous fossiliferous yellow limestone	2–3	
5. Shell marl		6
6. Concealed	6–8	
7. Hard fossiliferous limestone, with a layer of shell breccia at top; specimens of *Ostrea cortex* Conrad	3	
8. Hard red limestone; weathers gray	1	
9. Blue laminated sandy shale	2	6
10. Concealed	4±	
11. Laminated black, oil-bearing or asphaltic sandstone; bed is irregular	4–5	
12. Compact gritless slate-colored shale, coarsely laminated, breaking with a conchoidal fracture; slightly calcareous; exposed above water line	15	
	62±	

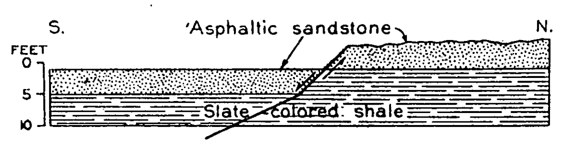


FIGURE 8.—Plat of small fault cutting beds of the Escondido formation at railroad bridge at Pulliam, Zavalla County, Tex. Strike of fault is N. 50° E.

A small fault cuts the beds at the south end of the falls. The vertical displacement is 4 feet. The fault plane strikes S. 50° W. and dips 45° S. at a point about 11 feet above water level and changes to 25° S. below this level. The surface of asphaltic sandstone along the fault plane is slickensided and striated. (See fig. 8.)

The shale (No. 12) lies horizontal at the fault. Beds 2 to 5 dip N. 50° W. at an angle of 1° from the railroad bridge to a point 100 feet north. From 100 to 300 feet north of the bridge the dip increases to 2°.

It is the upstream or northwest dip of the beds which forms the falls in the river. One hundred feet below the bridge the beds, as indicated by the dip of the shale (No. 12), lie horizontal; from this point they dip downstream to the southeast and upstream to the northwest. The structure is therefore an anticline, and it is in the crest of this anticline that the oil, now represented by the asphalt in the sandstone (bed No. 11), has accumulated. The axis of the anticline trends N. 45° ± E. A plat of the structure is shown in figure 9.

TERTIARY SYSTEM.

EOCENE SERIES.

MIDWAY FORMATION.

Name.—Smith and Johnson [56] originally used the term Midway in 1887 to designate the beds exposed at Midway landing, on Alabama River, in Alabama. These beds represent the lowermost part of what is here considered the Midway formation.

Penrose in 1889 described the formation in Texas under the name "Wills Point or Basal clays," from the exposure at Wills Point, in Van Zandt County.[57]

Harris in 1892 pointed out the fact that the calcareous beds lying above the Cretaceous and below the Wilcox in Alabama extend eastward into Georgia and westward into Texas, retaining throughout these States essentially the same lithologic and paleontologic character. This stratigraphic unit, which is the one recognized in this report, he called the Midway.[58]

Stratigraphic position.—The Midway formation lies unconformably above the Cretaceous and conformably below the Wilcox.[59] Contacts are exposed in Mississippi, Alabama,

[56] Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, p. 62, 1887.

[57] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 19–22, 1890.

[58] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept., 1892, vol. 2, pp. 8, 9, 22, 1894; The Midway stage: Bull. Am. Paleontology, vol. 1, pp. 11–13, 1896.

[59] Harris, G. D., The Midway stage: Bull. Am. Paleontology, vol. 1, pp. 38–39, 1896. Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, pp. 51–52, 1900. Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 90, pp. 157, 169–181, 1915.

Arkansas, and on Frio River and the Rio Grande in Texas.

Lithology.—The formation consists of clay and limestone of marine origin. At its base are generally found bluish micaceous clay or clayey sand and in some places light-yellowish beds of fossiliferous limestone of marine origin. These beds are succeeded above by sandy beds upon which generally rests black selenitic clay.

Thickness and dip.—The thickness of the formation on the Brazos is about 500 feet, in Wilson County about 566 feet, and in Bexar County about 505 feet. The dip along the Brazos is 66 feet to the mile. The average dip for the area is about 50 feet to the mile.

Paleontology.—The Midway formation contains *Enclimatoceras ulrichi* White, *Ostrea pulaskensis* Harris, *Cucullaea macrodonta* Whitfield, *Plejona limopsis* (Conrad), *Ostrea crenulimarginata* Gabb. (See Pl. XIV.)

Areal extent.—The formation crops out in a narrow belt of rolling country that extends southwestward through Falls, Milam, Lee, Williamson, Bastrop, Travis, Caldwell, Guadalupe, and Bexar counties, and from Bexar County westward through Medina and Uvalde counties. (See Pl. VIII, in pocket.) Much of it is obscured by materials of later age.

Correlation and history of investigation.—The Midway formation extends from Georgia west to Mexico. Its exposures in Arkansas and Louisiana have been described by Harris;[60] those in Mississippi by Crider;[61] those in Alabama by Smith;[62] and those in Georgia by Harris.[63] The lower part of Vaughan's "Myrick formation" includes the Midway beds of Uvalde county.[64] Stephenson has described the Midway formation of Medina, Uvalde, and Maverick counties.[65]

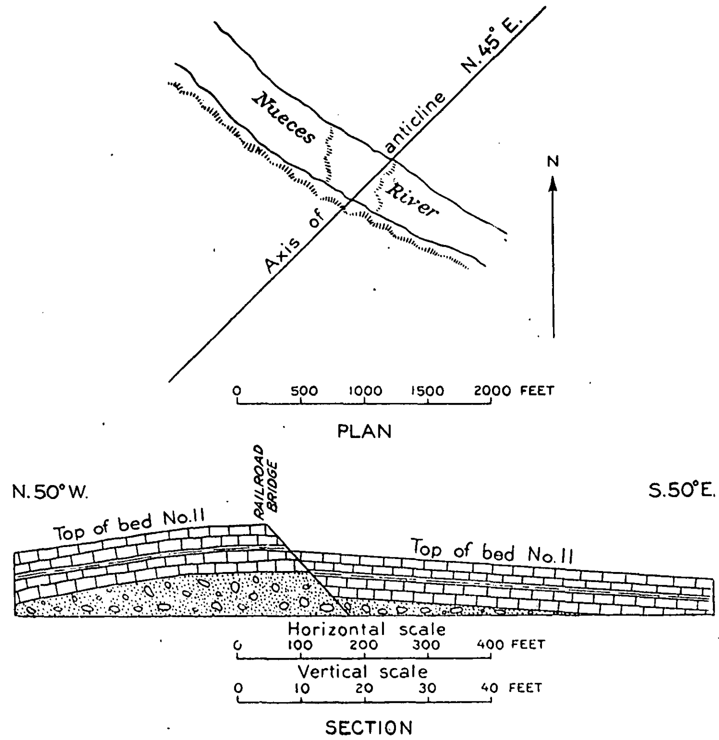


FIGURE 9.—Anticline at the railroad bridge at Pulliam, Zavalla County, Tex. Plan, showing strike of the anticline, and section across the anticline in the direction N. 50° W. on right bank of Nueces River, showing deformation of bed No. 2.

Section on Brazos River.—Beds belonging to the Midway formation are exposed along Brazos River from a point about 1½ miles by

[60] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept., 1892, vol. 2, p. 33, 1894.

[61] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 22-25, 1906.

[62] Smith, E. A., The underground water resources of Alabama: Alabama Geol. Survey, pp. 5, 15, 1907.

[63] Harris, G. D., The Midway stage: Bull. Am. Paleontology, vol. 1, pp. 36-37, 1896.

[64] Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, pp. 51-52, 1900. Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), pp. 2-3, 1900.

[65] Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 90, pp. 169-181, 1915.

river north of the Milam-Falls county line to a point about 2 miles north of the mouth of Pond Creek in Milam County. The contact with the underlying Cretaceous is seen about 1½ miles north of the Milam-Falls county line. The section follows:

Section exposed in bluff on west bank of Brazos River on the southeast line of the Josiah Hogan League, Falls County, Tex.[66]

	Feet.
Eocene (Midway formation):	
Blue clay and sand breaking into nodules and conchoidal pieces, weathering into a grayish-yellow clay and containing *Calyptraphorus velatus* var. *compressus* Aldrich; *Aporrhais gracilis* Aldrich; *Turritella alabamiensis* Whitfield; *Yoldia eborea* (Conrad); *Cucullaea macrodonta* Whitfield; *Ostrea pulaskensis* Harris; *Crassatellites gabbi* (Safford)	5
Transitional blue clay	1
Cretaceous: Massive blue clay with *Baculites* and other Cretaceous fossils	14
	20

Half a mile below the Cretaceous-Tertiary contact just described a bluff at Blue Shoals shows 5 feet of blue indurated clay with concretions of limestone, containing *Enclimatoceras vaughani* Gardner, *Calyptraphorus velatus* Conrad var. *compressus* Aldrich, *Turritella alabamiensis* Whitfield, *Yoldia eborea* (Conrad), *Cucullaea macrodonta* Whitfield var., *Ostrea pulaskensis* Harris, *Crassatellites gabbi* (Safford), *Venericardia alticostata* Conrad var., and 4 feet of laminated blue, almost black fossiliferous clay.[67]

The lower part of Black or Milam Bluff, which is on the west bank of the river at the northern limit of Milam County, a mile below the section just described, is composed of almost black clay containing fragments of shells and of yellowish and greenish clay toward the top. The upper part contains highly calcareous indurated strata showing a nodular structure and containing many fossils.

The beds dip southeastward 276 feet to the mile. They have yielded[68] *Enclimatoceras ulrichi* White, *Plejona rugata* (Conrad), *Calyptraphorus velatus* Conrad var. *compressus* Aldrich, *Turritella mortoni* Conrad var., *T. nerinexa* Harris, *Nucula magnifica* Conrad, *Yoldia eborea* (Conrad), *Cucullaea macrodonta* Whitfield, *Crassatellites gabbi* (Safford), and *Venericardia alticostata* Conrad var.

About three-fourths of a mile below Milam or Black Bluff, in Cribbs League Bluff, the following section is exposed:[69]

Section of Midway formation exposed at Cribbs League Bluff, Milam County, Tex.

	Feet
Yellow clay	4
Ledge of fossiliferous siliceous limestone	2
Yellow clay; similar to that at the top	5
Ledge of fossiliferous siliceous limestone	2
Dark-blue laminated jointed clay	30–35
	43–48

The fossils collected at this locality include *Plejona rugata* (Conrad), *Fusus ostrarupis* Harris, *Calyptraphorus velatus* Aldrich var. *compressus*, *Turritella mortoni* Conrad, *Yoldia eborea* (Conrad), *Cucullaea macrodonta* Whitfield; *Ostrea pulaskensis* Harris, *Venericardia alticostata* Conrad var., and *Crassatellites gabbi* (Safford).

In Oyster Bluff or Smileys Bluff on the west side of Brazos River, 3 miles by river below Cribbs League Bluff and 2 miles above the mouth of Pond Creek, the beds exposed represent the uppermost portion of the Midway formation and are the equivalent of the Naheola ("Matthews Landing") formation of the Alabama section.[70]

Section of Midway formation exposed at Smileys Bluff, west bank of Brazos River and northeast corner of Byrum Wickson League, Milam County, Tex.

	Feet.
Blue laminated clay, fossiliferous	4
Thin bed of concretions and hard fossiliferous limestone	1
Thinly laminated gray clay and sand	3
Bluish-gray sand	1
Thinly laminated dark-blue clay and sand	3
Dark-blue laminated fossiliferous sand	2
	14

The fossiliferous beds of the Midway carry *Pleurotoma* (*Pleurotomella*) *anacona* Harris, *P.* (*Surcula*) *ostrarupis* Harris, *Plejona precursor* Dall, *Fusus ostrarupis* Harris, *Pseudoliva ostrarupis* Harris, *Cerithium penrosei* Harris, *C. whitfieldi* Heilprin, *Leda milamensis* Harris and *L. milamensis* Harris, large var.[71]

[66] Kennedy, William, The Eocene Tertiary east of the Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, p. 145. The fossils were determined by Harris; the list has been partly revised.

[67] Idem, p. 148. The fossils were determined by Harris; the list has been partly revised.

[68] Harris, G. D., The Midway stage: Bull. Am. Paleontology, vol. 1, p. 128, 1896.

[69] Kennedy, William, The Eocene Tertiary of Texas east of the Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, p. 147. The list of fossils has been partly revised.

[70] Harris, G. D., New and otherwise interesting Tertiary Mollusca from Texas: Acad. Nat. Sci. Philadelphia Proc., 1895, p. 45.

[71] Kennedy, William, op. cit., p. 147. The list of fossils has been partly revised.

These isolated outcrops represent different zones in the Midway formation on the Brazos. The relative positions are indicated in the columnar section shown in figure 10. The topmost beds are those exposed farthest downstream; the lowermost are those exposed farthest upstream.

Section near Elgin, Bastrop County.—A dug well at Elgin shows about 30 feet of blue shale. Clay pits a few yards west of the railroad station expose about 30 feet of red-burning blue shale containing a few blue sandy layers. From another shallow well at Elgin the fossil *Plejona limopsis* was taken.

On the farm of Lawrence Solomon, on a branch of Wilbarger Creek about 8 miles southwest of Elgin (see station 245 on the map, fig. 11), 14 feet of loose yellow sand with laminae of lignitic shale 2 to 3 inches thick overlying 6 feet of blue laminated sandy shale is exposed. The sand is cross-bedded on a large scale and contains large sandstone concretions 5 to 10 feet in diameter and 2 to 3 feet thick. One of the concretions is highly fossiliferous, but the fossils are poorly preserved. Among the recognizable forms is *Fusus ostrarupis* Harris.

Section on Colorado River.—On the Colorado the contact of the Midway with the Cretaceous is not exposed. Cretaceous beds are exposed at Webberville (see p. 37), and the next exposure downstream is at a point 4 miles by river below Webberville or about 2½ miles north of Caldwell village, in Bastrop County. (See station 213 on the map, fig. 11.) At this place there is an exposure of the Midway formation consisting of dark-brown fossiliferous shale carrying *Tornatina leai* Aldrich, *Scaphander ligniticus* Aldrich, *Plejona limopsis* Conrad, *Dentalium medianense* Harris, *Cucullaea macrodonta* Whitfield, *Corbula aldrichi* Meyer. The Midway lies horizontal on a line trending S. 75° E. This shale is probably the same as the Naheola formation of the Alabama section.

Half a mile downstream the dark-brown clay is exposed to a thickness of 4 feet above the water line. (See station 214 on the map, fig. 11.) Here a ledge of indurated fossiliferous sandstone, dipping downstream, has weathered into knobs or boulders. The beds are highly fossiliferous and carry great numbers of *Venericardia bulla* Dall, a species characteristic of the Midway. From this point to Miller Riffles, where the base of the Indio formation is exposed, no other outcrops occur.

A composite section of the formation as exposed on the Colorado, showing the relative stratigraphic positions of the exposures described, is given on Plate IX.

Section on Cibolo Creek.—Beds of the Midway formation may be seen on Cibolo Creek from Zuehl to a point about 4½ miles southeast of this village.

About 15 feet of massive blue fossiliferous shale is exposed in a ravine by the roadside 100 to 300 feet west of the crossing of Cibolo Creek at Zuehl.

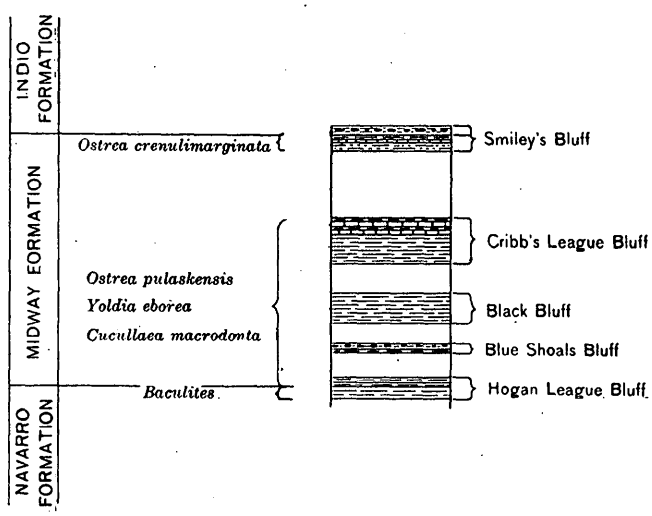


FIGURE 10.—Columnar section of Midway formation exposed on Brazos River in Milam, Falls, and Robertson counties, Tex. Vertical scale, 1 inch=350 feet.

A number of clay ironstone concretions, 6 inches to 2 feet in diameter, occur in the clay. Among the fossils found is *Cucullaea macrodonta* Whitfield, an Eocene species.

About three-fourths of a mile below Zuehl, on Cibolo Creek, there is an exposure of 15 feet of dark-brown shale overlain by Pleistocene gravel and loam.

About 1½ miles below Zuehl there is an exposure of 20 feet of brown shale, carrying limestone concretions 2 to 3 feet in diameter.

About 3 feet of black fossiliferous shale crops out in the bed of the creek 2 miles below Zuehl. The fossils found include *Pleurotoma*, *Mesalia alabamiensis* Whitfield, and *Corbula aldrichi* Meyer. A quarter of a mile southeast of this locality there is another exposure of the same shale.

A fault is exposed a short distance above the mouth of Martinez Creek. The upthrow is on the north side, and in consequence the Midway beds occur in juxtaposition with the Indio on the upland east of Cibolo Creek.

A number of hard calcareous, fossiliferous sandstone concretions, containing numerous specimens of *Ostrea crenulimarginata* Gabb, are exposed just north of the fault, on the upland overlooking the valley of Cibolo Creek, about 3 miles southwest of New Berlin.

Section on Salado Creek.—Beds belonging to the Midway formation may be seen in the clay pit of the Bem Brick Co. on the Gonzales road, 3 miles N. 80° E. of Concеption Mission, in Bexar County. About 25 feet of blue shale, breaking with a conchoidal fracture and carrying concretions of limonite and siliceous iron ore 2 feet in diameter, is exposed. The shale weathers yellow and burns red. It contains a few undeterminable fossils.

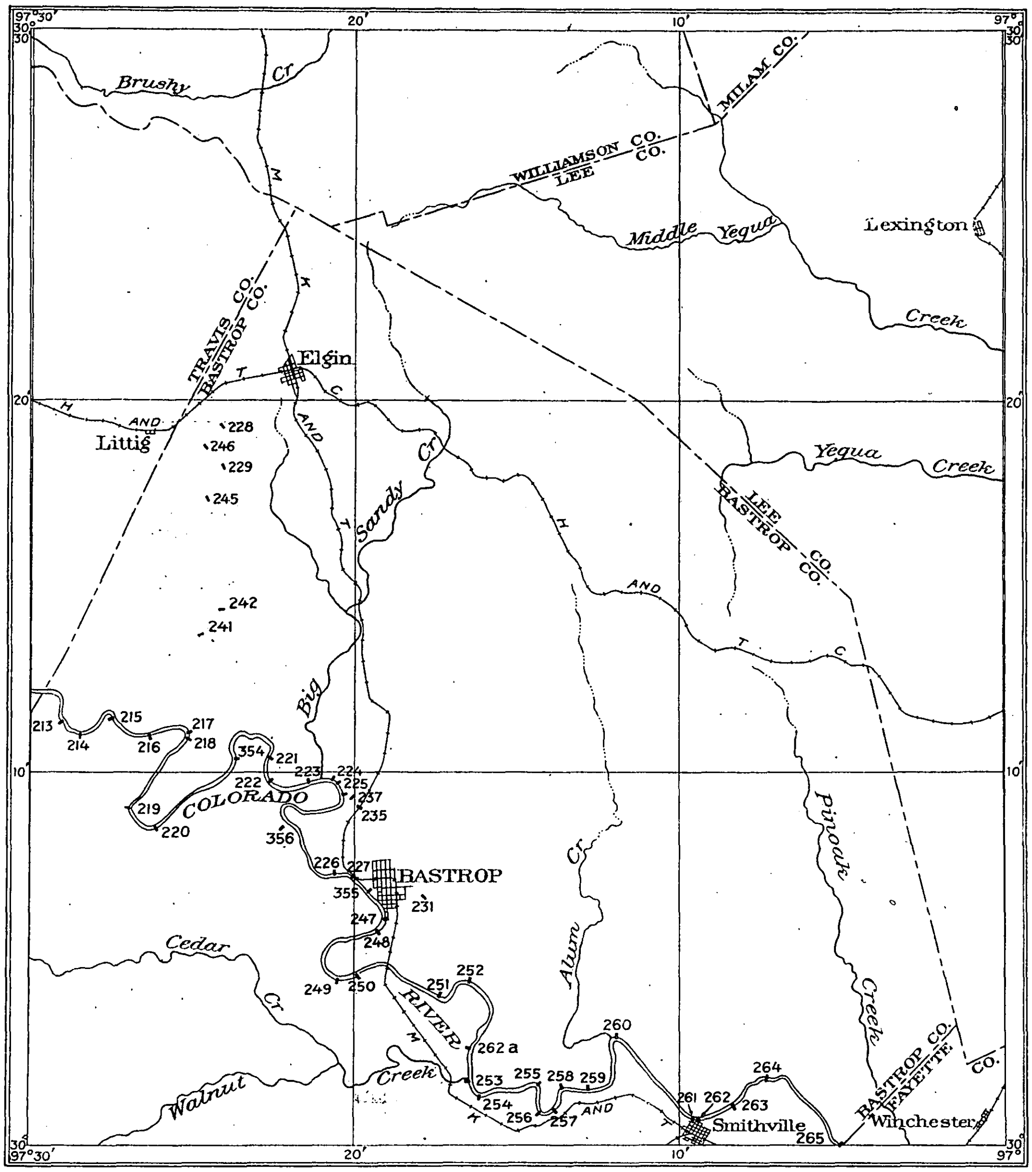


FIGURE 11.—Map of the Bastrop quadrangle, Tex., showing location of sections described.

An analysis of the clay shows the following composition:

Analysis of clay and concretions from clay pit of the Bem Brick Co. on Gonzales road east of San Antonio, Tex.

[Samples collected by E. F. Burchard. Analysis by P. H. Bates, U. S. Geological Survey.]

	Clay.	Concretions.	
		1	2
Silica (SiO_2)	56.04	14.31	15.06
Alumina (Al_2O_3)	18.77	5.43	5.82
Ferric oxide (Fe_2O_3)	6.41	5.67	52.07
Manganese oxide (MnO)	Trace.	.03	.59
Lime (CaO)	1.88	38.21	8.17
Magnesia (MgO)	2.40	.80	.79
Sulphuric anhydride (SO_3)	.70	.14	.08
Phosphoric oxide (P_2O_5)			.29
Soda (Na_2O)	.17	.53	.02
Potash (K_2O)	.50	Trace.	.73
Water at 100° C	3.21	.70	1.33
Ignition loss	10.25	33.99	15.52
	100.33	99.81	100.47

1. An irregular mass uniform throughout.
2. A rounded mass, which on breaking was shown to be a broken rock surrounded by concentric layers of ferric oxide at the interior and layers of clay of decreasing iron content toward the exterior. The inner layers are cracked, and the cracks are filled with calcite.

Blue shale of the Midway formation is exposed on new Sulphur Springs road about a quarter of a mile east of the crossing on Salado Creek and about 5¼ miles southeast of the courthouse at San Antonio.

In a dug well, 12 feet deep, on the north side of Salado Creek and 5½ miles southeast of the courthouse at San Antonio, there is a bluish-gray compact, homogeneous fossiliferous shale, carrying concretions of iron ore and sandstone about 2 feet in diameter, which contains *Cadulus* sp., *Ringicula* sp., *Fusus* sp., *Cardium* sp., *Dentalium* sp., *Lunatia* sp., Ostracoda, and Foraminifera.

About 1 foot of blue clay of the Midway formation is exposed in a gravel pit about half a mile north of Hot Wells and about 4¼ miles south-southeast of the courthouse at San Antonio.

Sections on Leon Creek and Medina River, Bexar County.—About 20 feet of weathered yellow clay is exposed in washes at the crossing of the Palo Alto road on Leon Creek, about 4½ miles west-northwest of Earle, Bexar County. This clay is a weathered phase of a blue shale that probably belongs to the Midway formation.

Section of Midway formation at Jett crossing, on Medina River, 5¼ miles west of Earle, Bexar County, Tex.

	Ft.	in.
Reddish-brown fossiliferous concretions consisting of indurated greensand with a coating or shell of fossiliferous hematite; contains *Plejona limopsis* (Conrad), *Turritella* sp., *Venericardia complexicosta* Meyer and Aldrich, and *Venericardia planicosta* Lamarck	1	
Blue sandy shale, the sand occupying discontinuous laminae	15	
Medium hard brown sandstone		10
Blue sandy shale similar to that above the sandstone	10	
Lenses and boulders of brown sandstone, medium hard, 2 feet thick and 4 to 6 feet in diameter	3	6
Concealed	15	
Blue plastic shale to water line	2	
	47	4

Section on Hondo Creek.—Stephenson records the occurrence of a fossiliferous boulder detached from a ledge of rock a quarter of a mile above the crossing due east of Elstone, Medina County. The boulder contains *Leda elongatoidea* Aldrich var. Harris, *Glycymeris* sp., *Ostrea* sp., *Modiolus saffordi* Gabb, *Venericardia planicosta* Lamarck, *Venericardia* sp., *Meretrix* (?) sp., *Corbula* sp., and *Turritella* sp.[72]

Section on Seco Creek.—Stephenson reports the occurrence of a fossiliferous limestone on the D'Hanis-Yancey road about 7½ miles east of south from D'Hanis, Medina County, from which he collected *Cucullaea macrodonta* Whitfield (?), *Ostrea crenulimarginata* Gabb (?), *Venericardia* sp., *Lucina* sp., and fragments of gastropods.[73]

Section on Sabinal River.—On Elm Creek near the Schuddemagen ranch house, 11 miles south of Sabinal,[74] 10 feet of the Midway formation is exposed, overlain by 50 feet of strata of the Indio formation, poorly exposed. The Midway is massive sandy limestone containing poorly preserved fossils, prominently exposed on the hill slope. Vaughan, Cooke, and Gardner have identified the following species from this limestone: *Glycymeris* sp., *Ostrea* sp., *Venericardia alticostata* var. *whitei* Gardner, *Callocardia ripleyana* Gabb, *Natica* sp., *Turritella mortoni* (Conrad), *Turritella* sp., *Calyptraphorus velatus* Conrad var., *Pseudoliva* cf. *P. unilineata* Aldrich, *Phos* (?), sp., *Pleurotoma* sp.

[72] Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 90, p. 179, 1915.
[73] Idem, p. 178.
[74] Idem, p. 177.

Section on Frio River.—On Frio River about half a mile above Myrick's lower apiary and about 9½ miles east-southeast of Uvalde, 20 feet of yellow sandstone of the Midway formation overlies the fucoidal sandstone of the Escondido formation. The upper sandstone has a dip of about 2° E. The lower sandstone has a more pronounced dip in the same direction.

The yellow sandstone composing the upper 20 feet of the section just described extends downstream and is exposed in the right wall of the canyon for about 300 yards. It carries concretions measuring 1 to 2 feet in diameter and 6 inches to 1 foot in thickness, standing on edge.

About 300 yards downstream from the preceding locality there is exposed, on the left side of Frio River, about 30 feet of yellow sandstone. The upper 6 feet is made up of beds 1 to 1½ feet thick; the lower 24 feet consists of beds 1 to 4 feet thick.

Vaughan has collected from this exposure *Cucullaea texana* Gardner, *Ostrea crenulimarginata* Gabb, *Ostrea pulaskensis* Harris, *Venericardia alticostata* var. *whitei* Gardner (?), *Venericardia alticostata* var. *hesperia* Gardner, *Phacoides* sp., *Callocardia* sp., *Natica* sp., *Turritella humerosa* Conrad, *Turritella mortoni* Conrad, *Levifusus trabeatus* (Conrad) var. (?), and *Enclimatoceras vaughani* Gardner.

About an eighth of a mile east of Myrick's lower apiary is a bluff which consists, in descending order, of yellow sandstone, 10 feet thick; yellow thin-bedded and semicross-bedded sandstone stained red in places, 10 to 20 feet thick; and yellow sandstone 20 feet thick, containing in places hard concretions or boulders about 2 feet in diameter and 1 foot thick. The lower sandstone with concretions is Midway; the sandstones above are Indio. At the upper and of the bluff, which is about 1,000 feet in length, the beds have a slight dip downstream; at the lower end they have a slight dip upstream. Apparently there is a shallow syncline between these two points.

WILCOX GROUP.

ESSENTIAL FEATURES.

Name.—The Wilcox formation was named by Crider [75] from Wilcox County, Ala., where it is characteristically exposed. It was first differentiated by Harris in 1894, who called i the "Lignitic."[76] The same group of beds was called "Chickasaw" by Dall in 1896,[77] "Sabine" by Veatch in 1906,[78] and Wilcox by Crider,[79] in 1906. Of these, Wilcox is the only name to which there are no objections. The term "Lignitic" is a lithologic and not a geographic name, and it therefore does not conform to the rules of geologic nomenclature. The term "Chickasaw" was originally proposed by Hilgard as an equivalent for the beds he called the "Northern Lignitic," which included beds belonging to the Wilcox, Claiborne, and Jackson formations. Dall used the same term later to apply to beds here recognized as belonging to the Wilcox. Penrose, in 1890, applied the term "Sabine River beds" to deposits including the Claiborne and the Wilcox, and his use of the term "Sabine" would have precedence over Veatch's use. In the region described in this report the Wilcox deposits have been divided into two unconformable formations, the Carrizo sandstone above and the Indio formation below.

Stratigraphic position.—The Wilcox deposits lie conformably above the Midway and unconformably beneath the Mount Selman formation of the Claiborne group.

Correlation and history.—The Wilcox formation occurs in Texas, Arkansas, [80] Louisiana, [81] Mississippi, [82] Alabama, [83] and Georgia.[84]

The first authentic account of the Texas representatives of the Wilcox was given by Dr. R. A. F. Penrose in 1890 in the First Annual Report of the Geological Survey of Texas, in which he described what are here called the Indio, Carrizo, Mount Selman, and Cook Mountain formations under the name of the "Timber Belt or Sabine River beds." He fixed their stratigraphic position correctly as lower Tertiary, overlying the Midway, but made no

[75] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 25–28, 1906.

[76] Harris, G. D., The Tertiary geology of southern Arkansas: Arkansas Geol. Survey Ann. Rept. for 1892, vol. 2, p. 55, 1894.

[77] Dall, W. H., A table of North American Tertiary horizons correlated with one another and with those of western Europe, with annotations: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 344–345, 1898.

[78] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46 pp. 34-36, 1906.

[79] Crider, A. F., op. cit., pp. 25-28.

[80] Harris, G. D., op. cit.

[81] Harris, G. D., The geology of the Mississippi embayment with special reference to the State of Louisiana, Louisiana Geol. Survey, pp. 11-17 1922.

[82] Crider, A. F., op. cit.

[83] Smith, E. A., The underground water resources of Alabama, Alabama Geol. Survey, pp. 15-16, 1907.

[84] McCallie, S. W., A preliminary report on the underground waters of Georgia: Georgia Geol. Survey Bull. 15, pp. 34-35, 1908.

attempt to correlate them with the divisions of the Tertiary established by Hilgard in Mississippi in 1860,[85] and by Smith and Johnson in Alabama in 1887.[86] In an earlier paper, however, he had correlated the Texas beds with Hilgard's "Lignitic" of Mississippi. He writes:[87]

> Lignites occur in very many places in eastern Texas. * * * They belong to the lowest division of the Eocene formation, known as the *Lignitic* (Hilgard). This formation is exposed in various places between the Cretaceous formation as its western boundary and the Claiborne and Mansfield formations on the south and east.

Vaughan in 1895 referred the beds exposed at Port Caddo landing, in Harrison County, Tex., to the "Lignitic stage" as defined by Harris (Wilcox formation).[88] The strata in southwestern Texas that Vaughan has described as the "Myrick formation" include the Wilcox [89] and Midway formations.

INDIO FORMATION.

Name.—The lower formation of the Wilcox group in this part of Texas has been named Indio formation by Trowbridge.[89a] It rests conformably on the Midway formation and is overlain unconformably by the Carrizo sandstone, the upper formation of the Wilcox group.

Lithology.—The Indio formation consists almost entirely of deposits of shallow-water origin, including lenticular beds of sand, large leaf-bearing calcareous sandstone concretions, sandstones, clays, sandy clays, lignites, and cross-bedded sands and sandstones. Petrified wood is associated with the sand. Along Sabine River, in Sabine County, there are fossiliferous beds of marine origin. In the deeper parts, toward the Gulf coast, the formation probably consists wholly of deposits of marine origin, including beds of glauconitic marl.

The shallow-water origin of the exposed parts of the formation is proved not only by the character of the materials of which it is composed, such as the lignite and the cross-bedded sand, but by the occurrence in them of fossil leaves and plants.

[85] Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, 1860.

[86] Smith, E. A., and Johnson, L. C., Tertiary and Cretaceous strata of the Tuscaloosa, Tombigbee, and Alabama rivers: U. S. Geol. Survey Bull. 43, 1887.

[87] Penrose, R. A. F., Report of geologist for eastern Texas: Texas Geol. Survey First Rept. of Progress, p. 59, 1888.

[88] Vaughan, T. W., The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, p. 209, 1895.

[89] Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), pp. 2-3, 1900.

[89a] Trowbridge, A. C., A geologic reconnaissance in the Gulf Coastal Plain of Texas near the Rio Grande: U. S. Geol. Survey Prof. Paper 131, pp. 89-91, 1923.

Thickness.—Along the Brazos the Indio deposits are about 840 feet thick. In Wilson County, according to the record of a well at Sutherland Springs, they are about 657 feet thick. On the Nueces the exposed part of the formation is not more than 350 feet thick, but this represents only its lower part. The dip along the Brazos is about 66 feet to the mile. The average dip is about 50 feet.

Paleontology.—*Ostrea tasex* Gardner, a marine fossil, has been found in abundance in the Indio formation west of Brazos River, 4 miles north of Rockdale, in Milam County; 11 miles south of Sabinal in Uvalde County; and in several localities in Maverick and Dimmit counties. In corresponding beds of Wilcox age on Sabine River *Kellia prima* Aldrich, *Pleurotoma silicata* Aldrich, *Levifusus indentus* Harris, *Levifusus supraplanus* Harris, *Fusoficula juvenis* Harris, and *Natica aperta* Whitfield are characteristic fossils. (See Pl. XV.) The fossil leaves, which are common, include *Dillenites texensis*, *Euonymus splendens*, *Ficus spectabilis* Lesquereux, and *Terminalia hilgardiana* (Lesquereux). (See Pl. XVI.)

Areal extent.—The formation outcrops in a belt of country that includes parts of Milam, Burleson, Lee, Bastrop, Caldwell, Guadalupe, Wilson, Bexar, Atascosa, Medina, and Uvalde counties. (See Pl. VIII.)

Economic character.—This formation is of great economic value. The soil derived from the sandstone favors the growth of trees suitable for lumber and fuel. The thicker lenses of lignite are mined at many places. Some of the harder sand and sandstone is used locally as building stone. At many places the formation includes beds of clay suitable for making building brick, paving brick, and pottery.

Section on Brazos River.—The beds exposed on Brazos River between Smileys Bluff, in northern Milam County, and a point 2 miles northwest of the railroad bridge at Valley Junction, in northern Robertson County, are referred to the Indio formation.

At Smileys Bluff, 2 miles above the mouth of Pond Creek (see p. 42), the lower beds carry fossils characteristic of the Midway. The upper 10 feet is nonfossiliferous yellowish-gray clay, sand, and blue clay containing concretions of calcareous sandstone. These concretions probably represent the basal part of the Indio on Brazos River.

About 1½ miles below the mouth of Pond Creek, in Milam County, there are deposits of sand that contains black specks and that is rendered plastic by a white clay. Large calcareous concretions (locally called "kettle bottoms"), 1 to 8 feet in diameter, are embedded in the sand.

About 3 miles below the mouth of Pond Creek the sand just described is close to the water's edge and is overlain by gray clay carrying beds of lignite.[90]

About 4 miles below Pond Creek the gray clay dips beneath the water and is overlain by gray sand carrying calcareous concretions.

At Cannon Ball Shoals, 8 miles by river below this point, gray sand 5 to 15 feet thick, interstratified with thin calcareous sandstones 6 inches to a foot thick,[91] is exposed. At Black Shoals,[92] half a mile below Cannon Ball Shoals, not far below Black Bridge, on the Calvert-Cameron road, the following section is exposed:

Section of Indio formation at Black Shoals on Brazos River, Tex.

	Ft.	in.
Gray sand	5	
Black or dark-blue clay, jointed and broken into cuboidal blocks	1	
Broken seams of lignite, running out 300 feet from foot of shoals		6
Black clay similar to black clay above	5	
Sandstone	1–6	
Black clay	4	
Gray calcareous sandstone		6±
Gray sand, laminated, and containing thin layers of dark clay	10	
Bed of rounded waterworn boulders, containing streaks of calcite	1	
Gray sand with pyrites	5	

The beds dip to the southeast 91 to 276 feet to the mile.[93]

One mile below Black Shoals the Indio is exposed on the west side of the river, in Milam County. The section in descending order includes 8 feet of pale-blue sandy clay with limy concretions, 3 feet of lignite, 1 foot of iron ore, 2 feet of dark-blue clay, and a bed of lignite.

[90] Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, p. 135, 1892.

[91] Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., p. 71, 1893.

[92] Kennedy called these shoals "Bee Shoals." On the War Department map of Brazos River, survey of 1900, these rapids are marked "Black Shoals," which is probably the correct designation.

[93] Kennedy, William, op. cit., p. 71.

At Herndon Shoals, 1½ miles below Black Shoals, at Calvert Bluff,[94] the following section is exposed:

Section of Indio formation in Calvert Bluff on Jesse Webb League, Robertson County, Tex.

	Ft.	in.
Gray sand	3	
Lignite	12	
Dark-blue clay	3	
Lignite	3	
Dark-blue clay	6	
Lignite	3	6
Dark grayish-blue sand	15	
Calcareous sandstone		6
Dark-gray sand	2	
Lignite, poor quality		6
Dark-gray sand	8	
Gray calcareous sandstone	1	
Dark bluish-gray sand, with iron pyrites	8	
Boulders of clay ironstone and gray calcareous sandstone, with nodules of iron ore and thin seams of ferruginous sandstones with fossil leaves	2	
Gray sandstone	1	6
Laminated bluish-gray sand to water line	2	
	71	

The beds have been warped into a gentle anticline, the crest of which crosses the river at Herndon's landing.

The stratigraphic relations of the different outcrops are shown in figure 12.

Section at Rockdale, Milam County.—A dug well not far from the station at the Rockdale power plant shows the following section:

Section of Indio formation in a well at the Rockdale power plant, Rockdale, Tex.

	Feet.
Yellow clay	7
Blue clay	25
Blue fossiliferous clay, containing fossil leaves and a fossil tooth of a crocodile, *Crocodilus* cf. *grypus* Cope, a Wasatch Eocene species	18
Soft quicksand, yielding a plentiful supply of potable water	4
Blue clay	1
Coarse water-bearing sand, not entirely penetrated	40
	95

Possibly 30 to 50 feet higher in the stratigraphic column occur the lignite-bearing beds at the mines a mile or so northeast of Rockdale.

[94] Johnson, L. C., The iron regions of northern Louisiana and eastern Texas: 50th Cong., 1st sess., H. Ex. Doc., vol. 26, No. 195, p. 21, 1889.

A section of the Rockdale Mining Co.'s shaft follows:

Section of the Indio formation at Rockdale Mining Co.'s shaft at Vogel, near Rockdale, Tex.[95]

	Ft.	in.
Brownish-gray sand	1	6
Red clay	4	
Black waxy clay	4	
Thinly laminated dark-gray sand and clay laminae from one-eighth to 1 inch; the clay generally thicker	15	
Gray clay (soapstone)	12	
Gray sand	1	6
Clay (same as soapstone above)	8	
Lignite	5	
Clay or soapstone	8	
Gray sand and clay	6	
Clay or soapstone	8	
Gray sand	1	6
Lignite	9	10
Sand	30	
Lignite	4	
	118	4

In the northeast corner of the William Isaacs tract, out of the James Reese survey, about 4 miles south of Rockdale, and immediately adjacent to the Rockdale-Tanglewood road, there is an outcrop of a fossiliferous limestone concretion containing *Ostrea tasex* Gardner.

[95] Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, p. 178, 1892.

Section on Colorado River.—On Colorado River, in Bastrop County, the Indio is exposed between Miller Riffles, about 5 miles east of Webberville, and Red Bluff, about 2 miles south of Bastrop.

At Miller Riffles (see station 215 on the map, fig. 11) sandstones are exposed that probably represent the basal part of the Indio.

The next exposure is about 1½ miles above Pope Bend (station 216 on the map, fig. 11). At this place sandstone 39 feet thick is exposed.

About 1,000 yards below or south of Pope Bend (station 218 on the map, fig. 11) there is exposed 15 feet of laminated blue sandy clay containing streaks of sand and leaf-bearing lignitic shale in which occur leaves of *Dillenites texensis* and *Euonymus splendens* (?), as determined by Prof. E. W. Berry. The layers of sand are cross-bedded and apparently dip slightly upstream.

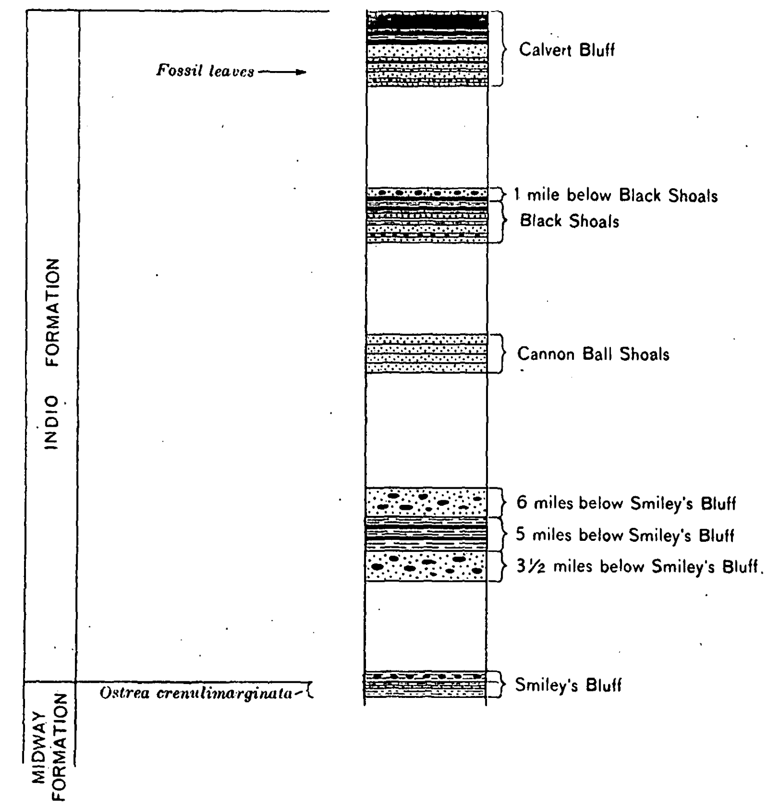


FIGURE 12.—Columnar section of Indio formation on Brazos River, Tex. Vertical scale, 1 inch=250 feet.

About 1½ miles east of Caldwell Knob, Bastrop County (station 219 on the map, fig. 11) three members of the Indio formation are exposed. These are, in descending order, gray sandy shale 40 feet, with a seam of lignite 6 inches thick; friable porous, slightly glauconitic sands, 6 feet; and gray sandy shale 20 feet, with sandstone concretions 1 to 3 feet in diameter and 6 to 12 inches thick. The Indio beds dip S. 65° E., at the rate of 270 feet to the mile. They occupy about the same stratigraphic position as those 1,000 yards south of Pope Bend.

At a place 1½ miles downstream from this locality (station 220 on the map, fig. 11), there is exposed, in the right bank of the stream, 6 feet of blue clay overlain by 1 foot of sandstone. These beds overlie those seen 1½ miles east of Caldwell Knob.

About 1¼ miles north-northeast of Nash's Ferry and about 300 to 400 yards back from the river a low bluff of indurated gray sandstone overlooks one of the later Pleistocene terraces of the river.

Blue sandy shale in which occur large concretions of calcareous sandstone 5 to 15 feet in diameter is exposed on the left bank of Colorado River about 1¼ miles in a direction a little south of west from Washington farm.

On Colorado River three-quarters of a mile northeast of Goodman 15 feet of soft yellow friable, porous sand with large concretions is exposed.

At a place 1¼ miles south by east of Washington farm (station 223 on the map, fig. 11) there is a similar exposure of sand 10 feet thick.

Ten feet of indurated nonfossiliferous brown sandstone is exposed at a point where the road leading from Bastrop to Nash's Ferry, crosses a small creek, about 1¾ miles southeast of Goodman.

The following section is exposed at the north end of Powell Bend on Colorado River, 1½ miles southeast of Washington farm (station 224 on the map, fig. 11):

Section of Indio formation on Colorado River 1½ miles southeast of Washington farm, Bastrop County, Tex.

	Feet.
Blue laminated and lignitic sand containing concretions of calcareous sandstone 6 inches thick	18
Sand containing laminae of ferruginous sand	1
Blue laminated and lignitic sand containing concretions of calcareous sandstone 6 inches thick	2
Gray porous, friable water-bearing sand	3
Blue laminated and lignitic sand containing calcareous concretions	5

The beds dip S. 45° E., 250 feet to the mile.

Section of Indio formation on Colorado River, at center of Powell Bend, 2½ miles east of Goodman, Bastrop County, Tex.

	Ft.	in
Blue clay	3	
Laminated sandy clay	2	
Coarse sand	1	
Clay		6
Sand	1	
Hard ferruginous sandstone		3
Blue clay	5	
Lignite	5	5
Blue clay	1	6
Lignite		6
Bituminous shale		10
Lignite	6	4
Covered to water line	25±	
	52±	

Below the lowest bed of lignite noted in the section there is another bed of lignite 4 feet or more thick. The beds dip S. 15° E., at the rate of 90 feet to the mile.

The beds mined by the Independence Mining Co. three-fourths of a mile S. 60° ± E. of this bluff, near the Missouri, Kansas & Texas Railway, are continuous with those exposed on the river at the center of Powell Bend.

A bed of lignite lies above the water 100 yards downstream from the middle of Powell Bend. The dip is slightly upstream, indicating apparently a small syncline or possibly a fault in this vicinity.

The road from Bastrop to Colorado Chapel crosses a small ravine, known as Hoppe Hollow, a quarter of a mile southeast of the center of Powell Bend (station 237, fig. 11). The bank of the ravine at the crossing shows 20 feet of loose, porous white and yellow sand, with interstratified beds of clay 2 to 3 inches thick. The dip is eastward at the rate of 270 feet to the mile. The sand represents the continuation of the sand overlying the lignite 100 yards below the middle of Powell Bend.

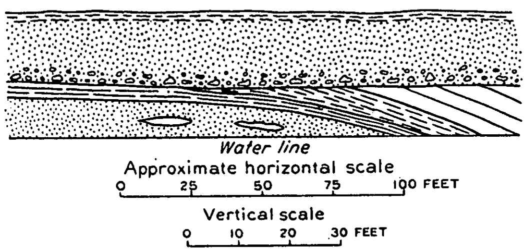


FIGURE 13.—Sketch of bluff on Colorado River, 1¼ miles northwest of wagon bridge at Bastrop, Tex., showing relative positions of the constituent beds.

About 1½ miles northwest of the wagon bridge at Bastrop (station 226) there is 4 feet of lignite underlain by sand and shale, of which 10 feet is exposed above water level.

About 1¼ miles northwest of the wagon bridge at Bastrop (station 227 on the map, fig. 11) 18 feet of the Indio formation is exposed, which consists of alternating shale and sand.

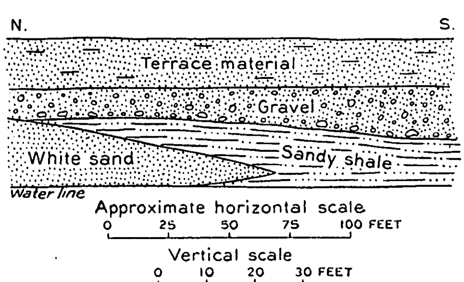


FIGURE 14.—Sketch of bluff on Colorado River three-fourths of a mile below wagon bridge at Bastrop, Tex., showing the relative positions of the beds.

A sketch of the bluff showing the relative positions of the several beds is given in figure 13.

Three-fourths of a mile below the wagon bridge at Bastrop (station 247, fig. 11) stands a bluff (see fig. 14) at the north end of which there is exposed a lens of loose white sand. This sand is replaced on the south by a lens of laminated sandy shale, containing layers of lignitic shale 2 inches thick, the whole having a banded appearance. The sandy shale has a maximum vertical thickness of 15 feet and dips downstream.

Half a mile by the river below this place (station 248 on the map, fig. 11), on the left bank of the river, there is a bluff, in which is exposed about 20 feet of laminated sandy corrugated-looking shale, belonging to the Indio formation. It contains concretions of calcareous sandstone. (See fig. 15.)

About 2½ miles nearly S. 30° W. of the wagon bridge at Bastrop, on the right bank of Colorado River, there is 20 feet of laminated sandy shale, which dips downstream.

A mile east of this locality (station 250, fig. 11) 6 feet of lignite is exposed just above water level on the right bank. The lignite is overlain by sandy shale.

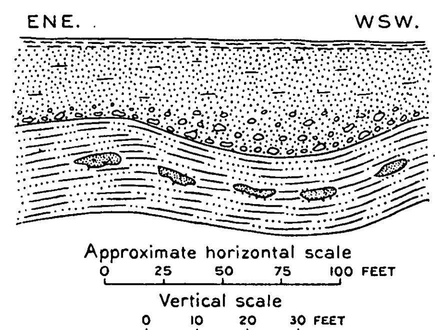


FIGURE 15.—Sketch of bluff on Colorado River, about 1½ miles south o wagon bridge at Bastrop, Tex.

The next exposure of the Indio is at Red Bluff, about 2¼ miles southeast of the Missouri, Kansas & Texas Railway bridge near Bastrop (station 251, fig. 11). This consists of 65 feet of blue sandy shale containing concretions of sandstone 4 to 5 inches thick and 3 or 4 feet in diameter, overlain by the Carrizo sandstone, consisting of 40 feet of loose yellow sand. (See Pl. XVII.)

The lignite that occurs 2 miles south of the wagon bridge at Bastrop (station 250) and 1½ miles northwest of it is the downstream continuation of the beds that are exposed in the middle of Powell Bend. The same beds are worked at Phelan by the Independence Mining Co., in the coal mines 3 miles northwest of

McDade, at Rockdale, at Calvert Bluff on the Brazos, and at Bear Grass in Leon County, and they are exposed on Yegua Creek, 2 miles northeast of Blue, Lee County. Three beds are usually present, but they thicken and thin along the strike. This is the uppermost zone of the Indio formation.

The relative stratigraphic positions of the exposures on Colorado River are given on Plate IX.

Section on Cibolo Creek.—The section on Cibolo Creek, in Wilson County, indicates the character of the Indio formation toward the south.

Large concretions of cross-bedded yellow nonfossiliferous sandstone occur at the mouth of Santa Clara Creek, about 3 miles southwest of New Berlin. (See fig. 7, p. 29.) One mile below the mouth, in the left bank, is a loose yellow sand 40 feet thick, in which are embedded large sandstone concretions 5 to 20 feet in diameter.

One-fourth of a mile southeast of this locality, where the road from New Berlin to St. Hedwig crosses Cibolo Creek (see fig. 7), there is 30 feet of cross-bedded sandstone without fossils. The sandstone overlies a blue shale, which is exposed about 100 yards farther up on the creek. This shale may belong to the Midway, which has been elevated to this position by the fault described on page 44.

The next conspicuous exposure on the creek is found at Upper Skull Crossing (see fig. 7), about 3 miles north-northwest of Lavernia. The Indio is here represented by 25 feet of blue calcareous clay, containing large lenses of sand, which carry concretions of calcareous sandstone 3 to 5 feet in diameter. The clay crops out in the bed of the creek and in a bluff that extends about one-eighth of a mile downstream.

Two miles southeast of Upper Skull Crossing and about a mile north-northwest of Lavernia (station 963 on the map, fig. 7) there is a bluff that shows 15 feet of yellow calcareous clay, containing lenticular masses of yellow sand. The clay contains small calcareous concretions and specks and stains of limonite. In general the beds look like those at Upper Skull Crossing. They contain no fossils.

A bed of yellow sandy clay, interstratified with blue shale, the whole lenticular in shape, is exposed on Cibolo Creek, about three-fourths of a mile north of Lavernia (station 964 on the map, fig. 7). Concretions of calcareous sandstone, 15 to 30 feet in diameter, occur in the bed of the creek. The total thickness of the section is 15 to 20 feet.

Similar beds are found at a place on the creek about one-eighth of a mile above the bridge at Lavernia (station 965 on the map, fig. 7).

A cut on the Galveston, Harrisburg & San Antonio Railway about half a mile east of the railroad station at Lavernia shows, in descending order, blue calcareous shale 2 feet thick, laminated ferruginous sandstone 2 feet thick, and yellow laminated argillaceous sand 4 feet thick. The beds dip 1° S. 60° E.

At the place where the road crosses Cibolo Creek, about 2 miles east of Lavernia and three-fourths of a mile east of the mouth of Blue Creek (station 967 on the map, fig. 7), there is exposed 3 feet of hard sandstone flags. These beds are underlain by 10 feet of interlaminated sand and clay, covered at this point but exposed farther up the creek, and by 2 feet of black lignitic shale, with efflorescence of sulphur.

Section on Salado Creek.—A bluff 100 feet high on Salado Creek about 1¾ miles north of Dullnig's well, in Bexar County, is made up of blue shale containing great numbers of hard brown sandstone concretions, 2 to 7 feet thick.

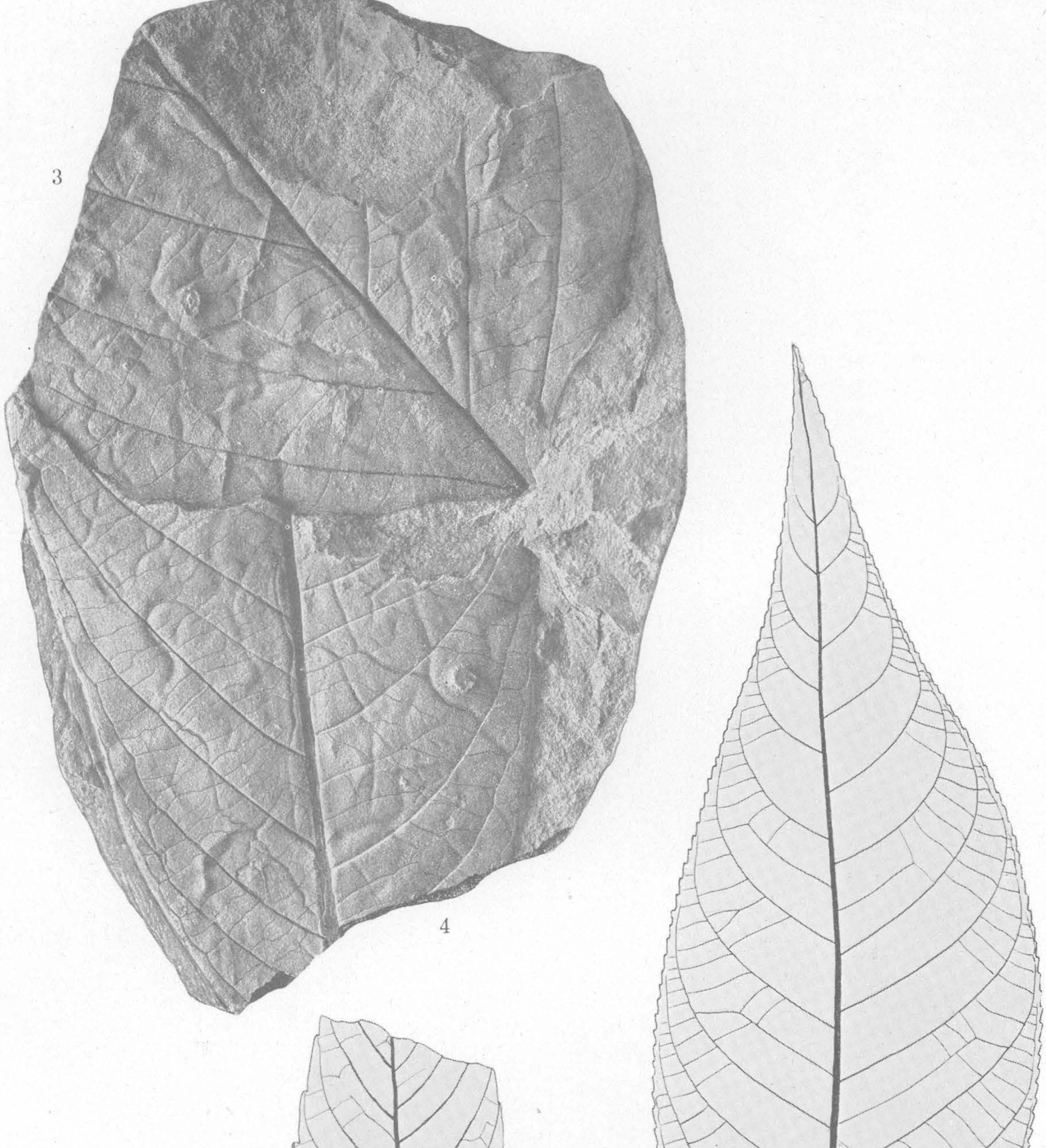
About 15 feet of similar shale is seen in a bluff on Salado Creek, about 1 mile north-northeast of Dullnig's well and about 3 miles northeast of Berg station, in Bexar County.

In a well close to the San Antonio & Aransas Pass Railway bridge across Salado Creek lignite was struck at a depth of 30 feet.

Where the railroad crosses Salado Creek there is an exposure of 35 feet of material containing numerous large blue calcareous sandstone concretions (weathering brown), 2 to 4 feet thick and 3 to 10 feet in diameter.

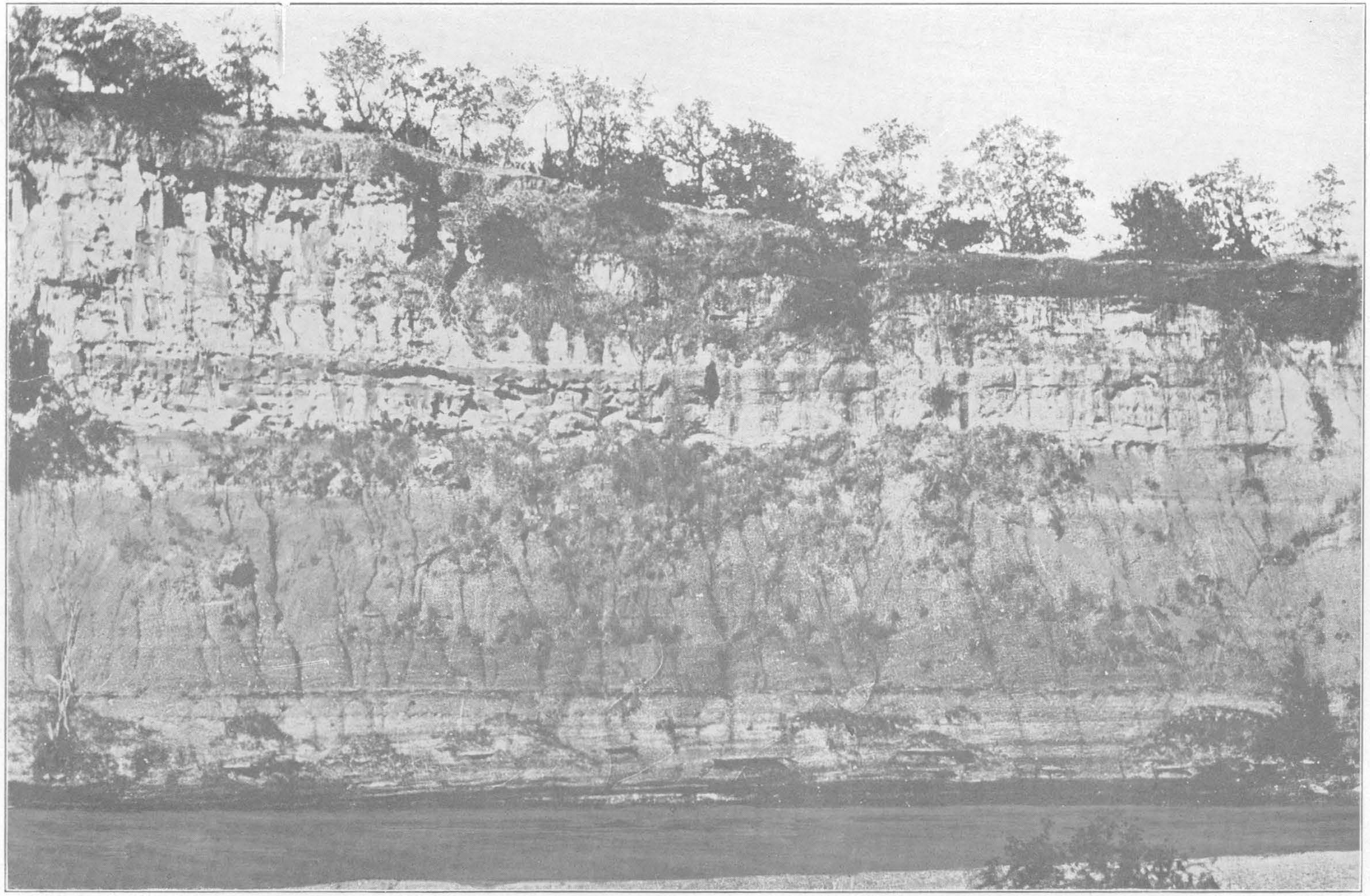
Section on San Antonio River.—Hard brown sandstone boulders or concretions of the Indio formation, 2 to 4 feet in diameter, outcrop on Goliad road, 2½ miles east-southeast of Conception Mission, in Bexar County, in the drainage basin of San Antonio River.

A ravine along the roadside and a cut on the railroad a few yards south of the road,



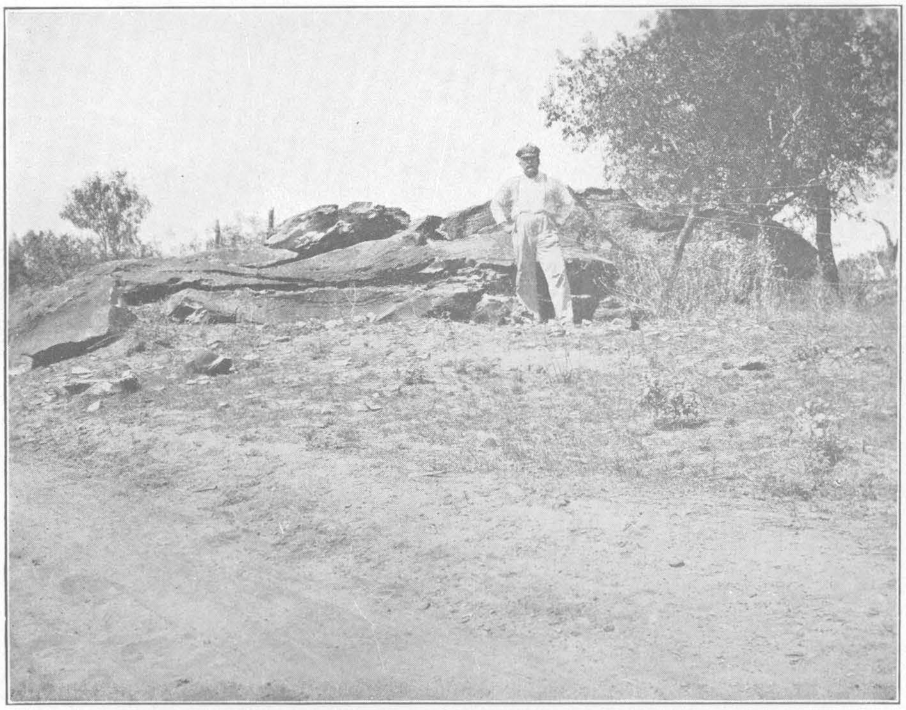
FOSSIL LEAVES COMMON IN THE WILCOX GROUP.

1. *Dillenites texensis* Berry. Locality near Pope Bend, on Colorado River, Bastrop County, Tex.
2. *Euonymus splendens* Berry. Locality near Pope Bend, on Colorado River, Bastrop County, Tex.
3. *Ficus vaughani* Berry. Little Cypress Bayou, Harrison County, Tex.
4. *Terminalia hilgardiana* (Lesquereux) Berry. Little Cypress Bayou, Harrison, County Tex.

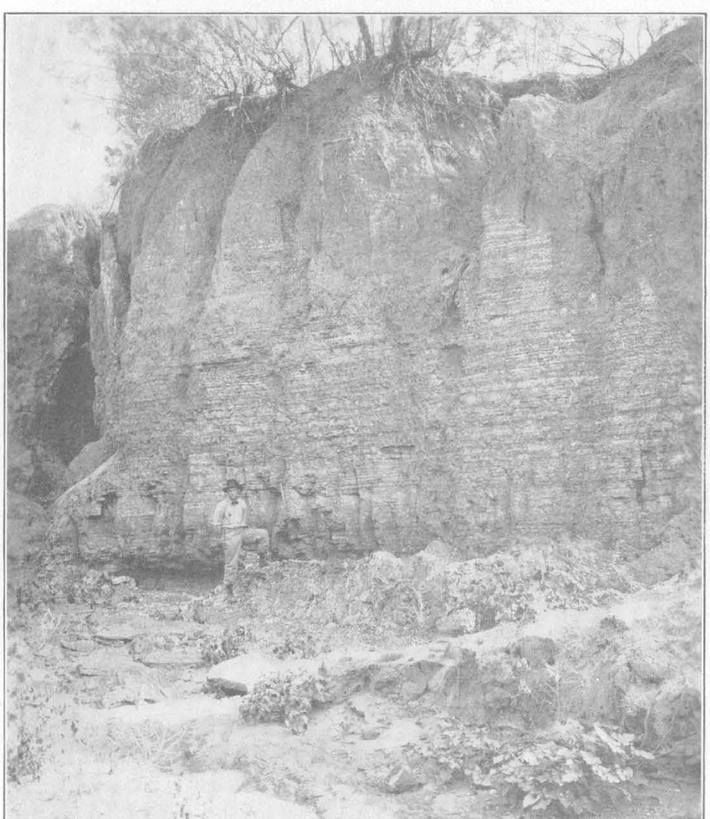


CARRIZO SANDSTONE AND UNDERLYING BEDS OF INDIO FORMATION.

Exposure at Red Bluff, on Colorado River, 2¼ miles southeast of Missouri, Kansas & Texas Railway bridge near Bastrop, Bastrop County, Tex.

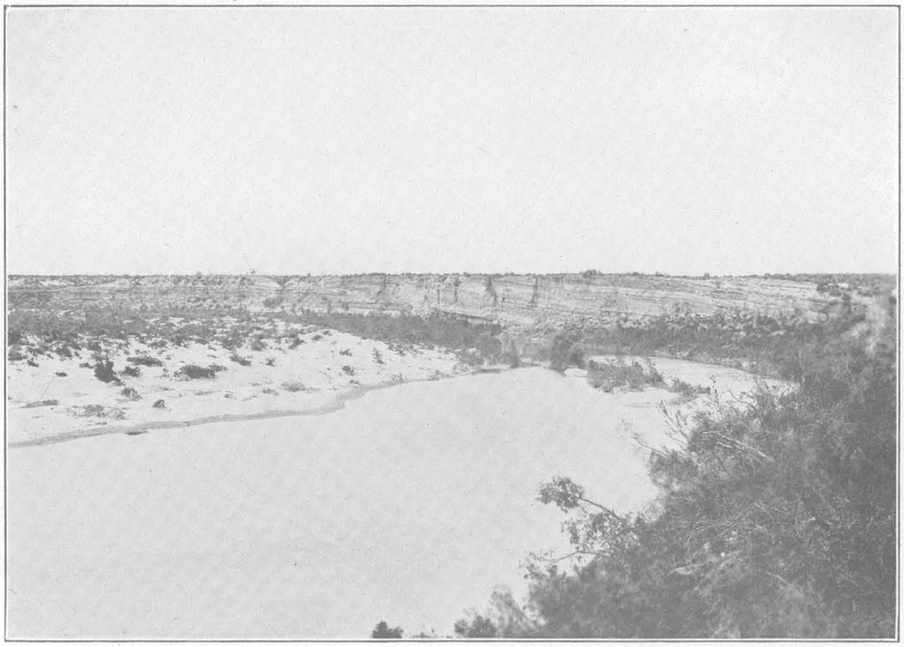


A. HARD BLUE SANDSTONE BOULDERS IN THE INDIO FORMATION THREE-FOURTHS OF A MILE NORTH-NORTHEAST OF LYTLE, ATASCOSA COUNTY.



B. SHALES AND SANDSTONES OF INDIO FORMATION IN SMALL GORGE ABOUT 1,000 FEET SOUTHWEST OF POST OFFICE AT LOSOYA, BEXAR COUNTY.

EXPOSURES OF THE INDIO FORMATION IN BEXAR AND ATASCOSA COUNTIES, TEX.

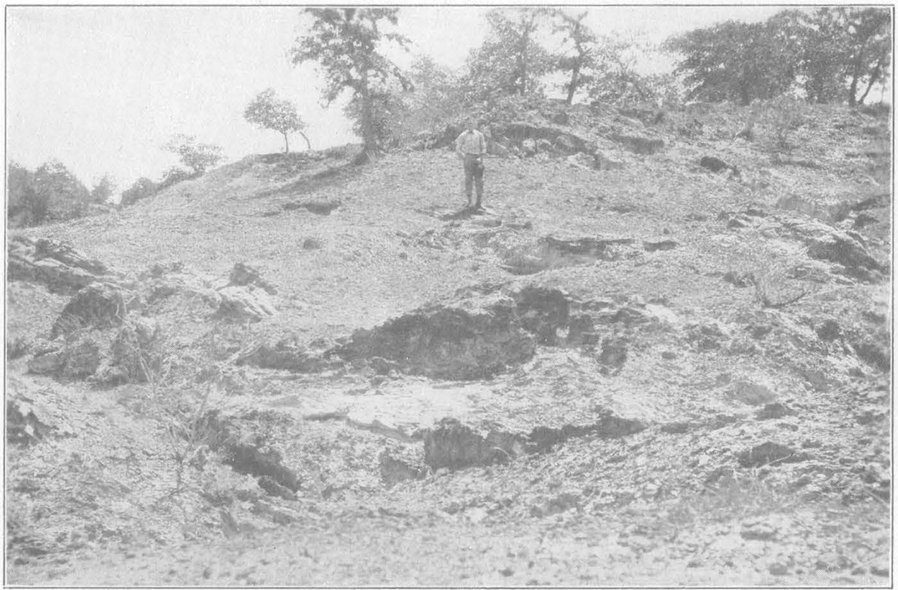


A. BLUFF $2\frac{3}{4}$ MILES SOUTHEAST OF PULLIAM, ZAVALLA COUNTY, TEX.

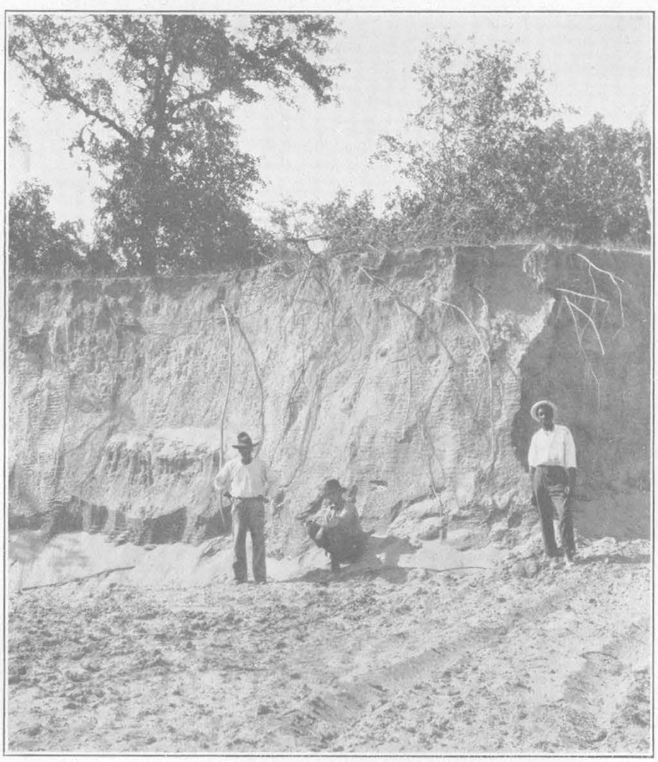
View looking north.

B. BLUFF 3 MILES N. 26° E. OF CRYSTAL CITY, ZAVALLA COUNTY, TEX.

EXPOSURES OF THE INDIO FORMATION ON NUECES RIVER.



A. BLUFF 1 MILE SOUTH OF GRAYTOWN AND HALF A MILE EAST OF THE GRAYTOWN-FAIRVIEW ROAD.

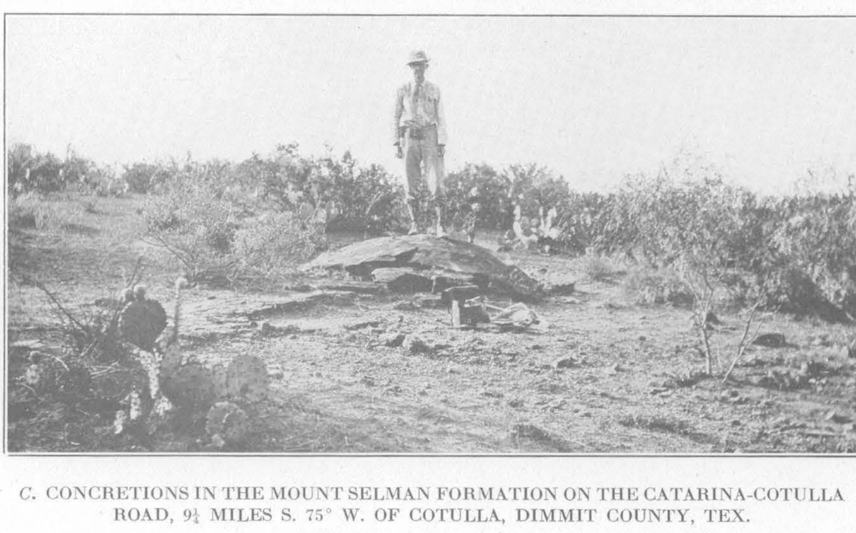


B. SAND PIT 1½ MILES NORTHWEST OF CALAVERAS.

EXPOSURES OF THE CARRIZO SANDSTONE IN WILSON COUNTY, TEX.

A. LEAF-BEARING MICACEOUS CARRIZO SANDSTONE IN THE SOUTHWEST PART OF ASHERTON, DIMMIT COUNTY, TEX.

B. FAULT CUTTING MOUNT SELMAN FORMATION 600 TO 1,000 FEET NORTH OF DEPOT AT MILANO, MILAM COUNTY, TEX.



C. CONCRETIONS IN THE MOUNT SELMAN FORMATION ON THE CATARINA-COTULLA ROAD, 9¼ MILES S. 75° W. OF COTULLA, DIMMIT COUNTY, TEX.

about three-fourths of a mile south of the State Insane Asylum, and 1½ miles north-northwest of Berg station, in Bexar County, expose 3 to 10 feet of blue shale, in which are embedded large hard brown sandstone concretions 1½ to 3 feet in diameter.

On the road about 1¼ miles west of Dullnig's well, and about 5½ miles southeast of the courthouse at San Antonio, blue shale of the Navarro formation underlies a calcareous conglomerate probably belonging to the Reynosa formation. In a bluff on Sixmile Creek, three-quarters of a mile west of Berg station, Bexar County, 18 feet of the Indio formation is exposed. The upper 10 feet consists of loose, porous yellow sandstone containing concretions of hard brown sandstone 2 to 10 feet in diameter. The lower 8 feet is purple laminated shale.

On Rosillo Creek, near its junction with Salado Creek, in Bexar County, 3 feet of blue shale with small limestone concretions is exposed.

In drilling a well on the C. A. Goeth farm, about a quarter of a mile south of Southton, Bexar County, a bed of impure lignite 1 foot thick was found at a depth of 60 feet, another 2 feet thick at a depth of 70 feet, and the drill was stopped at a depth of 150 feet after having passed 20 feet into a sand bearing highly mineralized water. These beds belong to the Indio formation.

In a well adjacent to San Antonio River, 1¾ miles southwest of Southton, lignite was found at a depth of 30 feet.

Near the farmhouse of C. A. Goeth, 10½ miles south-southeast of the courthouse at San Antonio, there is an exposure of yellow sand, about 20 to 30 feet thick, in which are embedded a considerable number of hard blue calcareous sandstone concretions, 2 to 3 feet thick and 2 to 10 feet in diameter.

On San Antonio River about 5¼ miles east of Losoya, Bexar County, there is exposed a lens of hard blue sandstone a foot thick, overlying 15 feet of bluish-black lignitic shale. At the base of the bluff there are large concretions, which have weathered out of the shale.

About 4 feet of blue sandy shale and alternating layers of yellow sandstone 2 inches thick are exposed in the north pit of the San Antonio Sewer Pipe Manufacturing Co., about 1¼ miles east of Elmendorf, in Bexar County. The dip of the shale is 7° N. 84° E.

About 1,400 feet S. 15° E. of the north pit there is a lens of gray shale, which is used in making sewer pipe. This lens is 15 feet thick at its north end. This shale is overlain by 15 feet of red sandstone supposed to belong to the Carrizo sandstone.

Fifteen feet of reddish to gray sandy shale and gray shale is exposed in the old pit of the San Antonio Sewer Pipe Manufacturing Co., about 200 yards north of the plant and about a mile north of the railroad station at Saspamco.

Near the bridge across Calaveras Creek on the Saspamco-Calaveras road, about three-fourths of a mile northwest of Calaveras, 5 feet of yellow stratified sand inclosing a lens of gray leaf-bearing shale is exposed. Fossil leaves collected at this place have been identified by Berry as *Bumelia* sp., *Cassia* cf. *bentonensis* Berry, *Diospyros brachysepala* Alexander Braun(?), *Ficus vaughani* Berry(?), *Gleditsiophyllum eocenicum* Berry, *Mespilodaphne eolignitica* (Hollick) Berry, *Rhamnites berchemiaformis* Berry, *Sapindus bentonensis* Berry, *Sapindus linearifolius* Berry, *Sabalites* sp., and *Terminalia lesleyana* (Lesquereux) Berry. This flora, according to Berry, is of Wilcox age.

Section on Medina River.—Lignite was struck at a depth of 30 feet in a well at the south end of Mitchell Lake, three-fourths of a mile north-northwest of Earle, Bexar County.

Large lenses of hard blue leaf-bearing sandstone occur at Earle, Bexar County. These lenses are 50 to 100 feet long and 5 to 20 feet thick. Leaves of the Wilcox flora collected from the sandstone have been identified by Berry as *Pourouma* n. sp., *Ficus spectabilis* Lesquereux, *Ficus occidentalis* Lesquereux, *Ficus* sp., *Platanus aceroides latifolia* Knowlton, *Cinnamomum affine* Lesquereux, *Laurus wardiana* Knowlton, *Asimina eocenica* Lesquereux, *Dolichites* n. sp., and *Terminalia hilgardiana* (Lesquereux). Two of these species are new; three occur in the Wilcox deposits at other localities; five occur in the Denver formation of eastern Colorado, of Eocene age; and three occur in the Raton formation of the Grand Mesa coal field of Colorado and New Mexico, also of Eocene age.

Section of Indio formation exposed in ravine leading to Medina River one-fourth mile southeast of Earle, Bexar County, Tex.

	Feet.
Blue shale; interlaminated with yellow and brown sand	5
Laminated blue shaly sandstone	$\frac{1}{2}$
Blue leaf-bearing laminated sandy shale	8
Medium hard gray leaf-bearing laminated shaly sandstone	$\frac{1}{3}$
Yellow ferruginous sand interlaminated with blue shale; laminae are from one-sixteenth to one-eighth inch in thickness; bed is leaf-bearing	6
Laminated blue shaly sandstone	$\frac{1}{3}$
Yellow ferruginous sand interlaminated with blue shale	3
Bluish brown laminated shale	8
Yellow porous sand	1
Mostly covered	10
Sandstone mass 2 feet thick and 5 feet in diameter	2

Hard brown sandstone lenses embedded in a blue shale matrix are exposed on the San Antonio-Pleasanton road about 1¼ miles south of Earle, Bexar County.

About 1,000 feet below the bridge on Medina River, at Losoya, Bexar County, there is an exposure of 60 feet of blue shale, near the middle of which is a lenticular mass of sandstone 50 feet wide and 10 feet thick.

In a ravine about 1,000 feet southwest of the post office at Losoya there is exposed 15 feet of blue laminated shale with some thin beds of sandstone overlying 2 feet of hard brown and blue sandstone. (See Pl. XVIII, *B.*)

Section on Atascosa Creek.—In the drainage basin of Atascosa Creek the Indio formation is exposed from a point half a mile north of Atascosa, Bexar County, to Somerset, Atascosa County.

Section of Indio formation in shaft at Carr's mine, about 1½ miles west of Lytle, Medina County, Tex.[96]

	Feet.
Brown sand with concretions of sandstone	10
Yellow laminated clay with small boulders	10
Laminated yellow gray sand with black clay or lignitic partings; micaceous and very friable	12
Lignite	6
Gray clay; floor of mine.	

On the International & Great Northern Railway about three-fourths of a mile north-northeast of Lytle, Atascosa County, there is 20 feet of false-bedded sand containing calcareous sandstone concretions from 4 to 15 feet in diameter and 1 to 6 feet thick. (See Pl. XVIII, *A.*) Higher beds are exposed in a cut on the railroad about 200 feet to the southwest.

On the Lytle-Devine road, about one-half mile west-southwest of Lytle, yellow limestone in beds 4 inches thick is exposed below red sand of the overlying Carrizo sandstone. Some lenses or concretions of hard blue sandstone 4 feet in diameter and 2 feet thick also crop out on the road at this place.

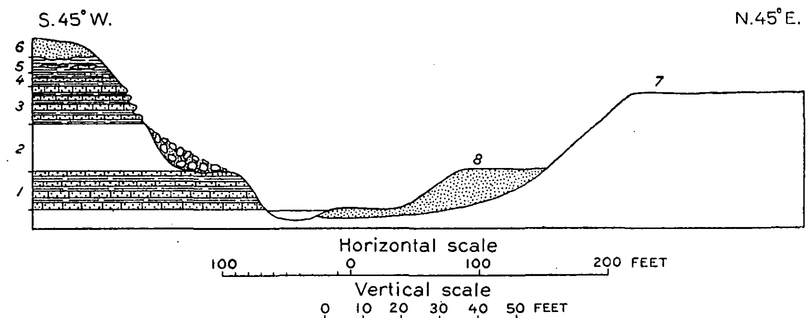


FIGURE 16.—Profile across valley of Nueces River 1 mile below railroad bridge at Pulliam, Zavalla County, Tex., showing the stream terraces and the strata composing the bluff on the west bank (Indio formation). 1, Bands of dark-yellow sandy limestone, 6 to 10 inches thick, with interbedded bands of laminated blue sandy shale, irregularly bedded. 2, Covered. 3, Same as No. 1. 4, Blue laminated shale, slightly sandy and calcareous, with yellow bands of laminated leaf-bearing sandstone 6 inches thick. 5, Large concretions of brown sandy limestone. 6, Gravel in gray silt matrix; limestone and flint pebbles and cobbles. 7, Pleistocene terrace of Nueces River. 8, Recent gravel bar.

At Benton, Atascosa County, the beds in descending order include: 10 feet of hard blue flaggy sandstone; 6 feet of blue laminated sand with lime nodules 1 inch in thickness; 3 feet of interlaminated blue sandy clay and red siliceous iron ore, the ore 1 inch thick; and 1 foot of blue sand with concretions of hard blue sandstone.

Sections on Sabinal and Frio rivers.—In the drainage areas of Sabinal and Frio rivers occur the exposures of the Indio formation that are described below.

[96] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, p. 925, 1903.

The upper 50 feet of the section exposed on Elm creek, near the Schuddemagen ranch house, 11 miles south of Sabinal, resting on the Midway, belongs to the Indio formation. The beds consist of fine greenish-gray, slightly calcareous sand, containing numerous interbedded thin layers of sandstone. At one place the basal 2 or 3 feet of the deposits contains abundant *Ostrea tasex* Gardner.

On the west side of Frio River, about 15¾ miles southeast of Uvalde,[97] the Wilcox deposits, in descending order, consist of 20 feet of coarse-grained brown ferruginous sandstone (Carrizo sandstone?), 8 feet of soft white or yellowish sand (Carrizo?), 7 feet of clay with a thin streak of lignite, 20 feet of soft white sand with sandy clay at base, 2 feet of sandy shale, and 3 feet of white sandy clay. The lower four beds of this section belong to the Indio formation.

On Sabinal River at the old Huyler ranch, 14 miles south of Sabinal, Uvalde County, there is 30 feet of thinly stratified yellow, red, and pink sandstone containing lenses of hard blue sandstone 2 feet thick and 12 feet in diameter, which is supposed to belong to the Indio formation.

About 15 feet of bedded yellow sandstone is exposed on Frio River a quarter of a mile above the crossing on the Frio Town-Sabinal road, in the southwest corner of Medina County. The sandstones dip downstream.

Section on Nueces River.—On Nueces River, the Indio formation is exposed from a point a mile below the railroad bridge at Pulliam, Zavalla County, to a point half a mile above the mouth of Live Oak Creek.

A mile below the railroad bridge at Pulliam there is an exposure of this formation on the west bank of Nueces River, which shows the following section:

Section of Indio formation on west bank of Nueces River, 1 mile below railroad bridge at Pulliam, Zavalla County, Tex.

[See fig. 16.]

	Feet.
Large concretions of brown sandy limestone	3
Blue laminated shale, slightly sandy and calcareous, with yellow bands of laminated leaf-bearing sandstone 6 inches thick; specimens of *Sabalites vicksburgensis* Berry (?)	3½
Bands of dark-yellow sandy limestone, 6 to 10 inches thick, with interbedded bands of laminated blue sandy shale, irregularly bedded	9
Covered	20 ±
	35½ ±

Half a mile downstream, on the opposite or east side of the river, there is another bluff, about 40 feet high, which shows brown sandstone. The beds dip downstream at an angle of about 1°.

About 2¾ miles southeast of Pulliam there is exposed, in the center of a large bend of Nueces River, on the left bank, in a bluff about 90 feet high and about three-fourths of a mile long, the following section:

Section on Nueces River, 2¾ miles southeast of Pulliam, Zavalla County, Tex.

[See Pl. XIX, *A*.]

	Ft.	in.
Very hard blue highly calcareous sandstone, forming cap rock of bluff	2	
White limestone (?) in beds 1 foot in thickness	4	
Brown sandstone; beds 1 foot thick; lower bed ferruginous	6	
Blue shale, slightly calcareous	10	
Ferruginous hard laminated red sandstone		10
Blue shale	10	
Massive soft gray calcareous, subflaggy sandstone	5	
Hard calcareous brown sandstone	4	2
Blue shale with interlaminated layers of gray sand about one-sixteenth of an inch thick which carry fossil leaves	6	
Blue shale, with layers of plant-bearing sand; not completely exposed	6	
Hard ferruginous brown sandstone		6
Blue shale, slightly calcareous	8	6
Covered to water line	30	
	93	

The upper two members of this section belong to the Carrizo sandstone; the lower eleven members belong to the Indio.

The beds dip S. 20° E. at an angle of about 2°.

Vaughan states that the lowest member of this section contains three small beds of lignite interbedded with chocolate-colored clay.[98]

The dip 2¾ miles southeast of Pulliam is 2° S. 20° E. The dip half a mile above the mouth of Live Oak Creek is 4° N. 50° W. These dips indicate a syncline (see fig. 33, p. 125) the axis of which probably parallels that of the anticline noted at Pulliam. The strike is probably N. 45° E.

[97] Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, p. 53, 1900.

[98] Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), p. 5, 1900.

Section of Indio (?) formation on the Cross S Ranch, 7 miles N. 8° E. of Crystal City, Zavalla County, Tex.

	Ft.	in.
Blue sandy joint clay with rounded red-brown iron concretions averaging 10 inches in diameter	14±	
Purple shale		5
Brown sandy shale	3	
Blue calcareous shale	3	
Impure lignite		10
Green shale; slightly calcareous		6 (?)
Lignite		½
Purplish-brown shale		11½
Green shale	6	
Purple, probably manganic, slightly calcareous sandstone		2
Green shale	3	
Purple, slightly calcareous sandstone		2
Green shale	2	11
	35±	

The dip is ½° to 1° S. 40° E.

Section shown by log of Hemphill well No. 2 on farm 6, Section 208, Cross S Ranch, about 4¾ miles northeast of Crystal City, Zavalla County, Tex.

	Feet.
Carrizo sandstone(?):	
Light-yellow sand	26
Fine water sand and gravel (the gravel probably caved from Pleistocene beds)	27
Indio formation(?):	
Soft blue shale	17
Hard light-blue shale	39
Rock	1
Shale	3
Rock	1
Hard light-blue shale	8
Soft light-blue shale	36
Gray sand	1
Soft blue shale	5
Soft gray sand	12
Hard sand	6
Hard blue shale	8
Soft sand and shale	21
Hard and soft layers of sand streaked with lignite	91
Blue gumbo	6
Blue shale and concretions	15
Blue gumbo	12
Blue shale and concretions	10
Blue gumbo and concretions	5
Rock	1
Hard blue gumbo	7
Rock	2
Shale	2
	364

Section of Indio formation on Cross S Ranch, on west bank of Nueces River 3 miles N. 26° E. of railroad station at Crystal City, Zavalla County, Tex.

[See Pl. XIX, *B*.]

	Feet.
Green joint clay with rounded red-brown iron concretions 4 to 8 inches in diameter and rounded yellow limestone concretions varying from 8 by 14 inches up to 4 feet in diameter	15±
Medium coarse-grained yellow-gray calcareous sandstone	1
Yellow sandy calcareous shale	1
Red ferruginous calcareous sandstone	6
Yellow sandy calcareous shale	8
Covered to water line	4
	35±

The uppermost sandstone has an archlike appearance, spreading over a horizontal distance of about 40 feet and rising 5 feet above a horizontal plane. The structure is probably related to the Zavalla anticline, described on page 128.

Section of Indio formation 100 feet below Chalk Bluff crossing on Nueces River, 5¼ miles S. 36° E. of Crystal City, Zavalla County, Tex.

	Ft.	in.
Carrizo sandstone(?):		
Cross-bedded coarse-grained calcareous brown sandstones; only isolated boulders capping bluff	2±	
Indio formation:		
Light-green shale with masses of gypsum averaging in size 6 by 1 by 4 inches	12±	
Indurated calcareous light-green shale		6
Light-green shale	3	
Indurated calcareous light-green shale		5
Green joint clay	9±	
Blue shale, calcareous; seams of limonite one-eighth to one-fourth inch in thickness form a network at the top	4	6
Blue shale with green limestone concretions and seams of gypsum one-eighth inch in thickness	7	
Impure lignite		5
Blue shale	3	
	41±	

At the south end of the bluff the dip changes to 2° upstream, or N. 20° W. The lignitic zone, which lies in the lower part of the formation, is probably the same as that which occurs in the Hemphill well and other sections.

CARRIZO SANDSTONE.

Name.—The following is Owen's original description of the Carrizo sandstone:[99]

A line drawn from a point on the Nueces River south of the town of Uvalde to a point 10 miles west of Carrizo Springs, thence south to the Rio Grande, will represent the outcrop of a sand bed nearly 200 feet thick. This sandstone has a monoclinal dip to the southeast. It is a very loose, coarse friable sand and free from any deleterious salts and is an inexhaustible reservoir capable of furnishing water sufficient for irrigating purposes. This sand stratum supplies the numerous wells at Carrizo Springs.

[99] Owen, J., Texas Geol. Survey First Rept. of Progress, p. 70, 1889.

In 1900 Vaughan[1] gave the following section of the Eocene in southwestern Texas:

Résumé of section of Eocene in southwestern Texas.

	Feet.
The coal beds and the clays and sandstone immediately overlying them were the highest beds seen; between the two coal seams is a bed of fossils not yet determined	190
Below the coal beds is a series of alternations of clay, shales, and sandstones, at least	400
A series of fine-grained micaceous sandstone	300
The coarsely crystalline Carrizo sandstone, at least	150
Bluish clays, ascertained by a well boring, below which are more sandstones and clays.	

Vaughan stated further:

From Indio ranch to San Ambrosia Creek the road to Laredo passes over numerous exposures of ripple-marked brown sandstone, which disintegrates rapidly and forms very poor roads. Between San Ambrosia and San Lorenzo creeks, as there is no covering of more recent deposits, loose sands, derived from the disintegration of the sandstone constitute the surface. * * * When unweathered the sandstone is gray, but upon disintegration it forms coarse, loose brown crystalline sand. Its thickness, so far as ascertained, is 150 feet. * * * It is underlain by clays and is a well-defined lithologic horizon, apparently what Owen designated the Carrizo sands. * * *

The coarse-grained Carrizo sandstone seems a fairly persistent member. It outcrops around the Chupadero ranch, between Indio ranch and San Lorenzo Creek, and extends northward on the west side of Carrizo Springs. A very similar sandstone outcrops in the hills around the Turk ranch in the northwestern corner of Zavalla County and near the Habey ranch on the Nueces. It is seen 12½ miles south of Uvalde, between the Leona and Nueces rivers, along the road to Batesville, and apparently extends southward to Loma Vista. It occurs on the divide in southern Uvalde County, between the Leona and Frio rivers.[2]

Dumble in a paper published in 1903 wrote as follows:[3]

The Carrizo sands were first described by Owen in the first report of progress of the Geological Survey of Texas and are the stratigraphical equivalent of the Queen City beds of Kennedy. They comprise interbedded sands and sandy clays, white or yellow in color, containing ferruginous matter as nodules, strings of concretions, and laminae. Pyrites is also found. The sands are somewhat calcareous and are indurated in places to a buff sandstone excellently adapted for building purposes. The courthouse and jail at Carrizo Springs are built of this sandstone, quarried a short distance from the town.

Dumble included the Carrizo sandstone in his "Lignitic stage," which is the equivalent of the Wilcox group.

In 1911 Dumble published the following:[4]

In a recent study of the Rio Grande region, Mr. W. Kennedy finds that in this section, instead of being somewhat similar in composition to the top of the Lignitic beds and lying in apparent conformity with them, as in eastern Texas, the Carrizo sands are here materially different from the underlying lignitic, and that while the Lignitic shows a rather strong dip for the Tertiary the Carrizo sandstones lie at a very gentle inclination. Indeed, these sandstones not only lie unconformably on the Lignitic, but overlap both it and the underlying Midway and are found resting upon the Escondido or upper Cretaceous sediments in many places. * * *

From these facts it will be seen that the Carrizo sands are not a part of the Lignitic, as formerly supposed, but that in reality they correspond both in position and composition with the Buhrstone of the Alabama section, of which we therefore consider them the equivalent, and form the base of the Claiborne series or the Middle Eocene.

These quotations show some discrepancy in the use of the term Carrizo sands by the different authors. As used by Dumble it is more inclusive than as used by Vaughan, for Dumble's unit included not only the beds exposed west of Carrizo Springs but those at the town and also those 8 miles east. This would embrace Nos. 2 and 3 of Vaughan's section.

The name is used in this report with the significance given it by Dumble. The upper Wilcox age of the Carrizo sandstone has been definitely established by Berry's paleobotanical studies in the summer of 1921, and it is therefore here treated as a formation of the Wilcox group.

Stratigraphic position.—The Carrizo sandstone lies stratigraphically and in places unconformably above the underlying beds of the Indio formation. In southwest Texas there is a considerable overlap, which has almost obliterated the exposure of the underlying Indio formation in certain localities. The Carrizo is overlain by the Mount Selman formation, and in some districts there is an erosional unconformity between these two. (See p. 58.)

Lithology.—The lower part of the Carrizo is a coarsely crystalline brown sandstone, cross-bedded and calcareous in places. The upper part, which appears only in southwest Texas, is a gray bedded, fine-grained micaceous sandstone, in places incrusted with a coating of lime.

Thickness and dip.—On the Colorado the thickness of the Carrizo sandstone is approx-

[1] Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, p. 45, 1900.

[2] Idem, pp. 37-51.

[3] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 929, 930, 1903.

[4] Dumble, E. T., The Carrizo sands: Texas Acad. Sci. Trans., vol. 11, pp. 52-53, 1911.

imately 200 feet, and the dip is southeastward, 50 to 70 feet to the mile. In the Nueces drainage the thickness is approximately 450 feet, and the beds have only a very gentle dip to the east and southeast.

Paleontology.—Fossil plants collected from the Carrizo sandstone by E. W. Berry during the summer of 1921 definitely establish its upper Wilcox age.[5]

Areal extent.—The Carrizo sandstone outcrops in a belt of country extending through Dimmit, Zavalla, Uvalde, Frio, Medina, Bexar, Atascosa, Wilson, Guadalupe, Caldwell, Bastrop, Lee, and Milam counties. (See Pl. VIII, in pocket.)

Economic value.—The Carrizo sandstone is a valuable water-bearing stratum. Where streams cross its outcrop there are bold springs, as, for example, at Sutherland Springs, Wilson County.

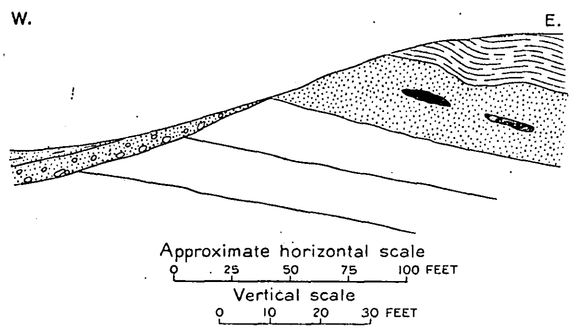


FIGURE 17.—Sketch section of beds exposed on Bastrop-Giddings road, 1 mile east of wagon bridge at Bastrop, Tex.

Correlation.—The Carrizo sandstone has been regarded by Dumble and other writers as the stratigraphic equivalent of the Queen City sand of east Texas, which is now classified as the upper member of the Wilcox formation.[6]

As already indicated, the Carrizo beds were originally regarded as of Wilcox age, but Dumble in 1911 placed them in the Claiborne and correlated them with the "Buhrstone" (Tallahatta buhrstone) of Alabama. Their age has therefore been in doubt, but the plants recently collected by Berry establish their upper Wilcox age.

Section on Colorado River.—In White Bluff near Bastrop (252 on map, fig. 11) on the left side of Colorado River, there is an exposure of Carrizo sandstone, 30 feet thick, whose base is 20 feet above water level. The Carrizo is a white cross-bedded coarse-grained sand, at the top of which, in small erosion hollows, there are lenses of white clay, reaching at some places a thickness of 2½ inches, which separate the white sandstone below from the red sandstone of the Mount Selman formation above.

The erosional unconformity between the Carrizo sandstone and the Mount Selman beds is worthy of note. That erosion took place prior to the deposition of the Mount Selman is further indicated by the lumps of the white sandy clay found in the red sandstone.

The contact of the Mount Selman and Carrizo is also shown at a point about a mile east of the wagon bridge at Bastrop and about 3½ miles N. 20° ± W. from White Bluff. The exposure at this locality, shown in figure 17, also indicates an erosional unconformity.

Section on Cibolo Creek.—The following section is exposed in a terrace scarp 3 miles east of Lavernia, on the left side of the Sutherland Springs road and adjacent to it.

Section of Carrizo (?) sandstone on Sutherland Springs road, 3 miles east of Lavernia, Wilson County, Tex.

	Feet.
Red ferruginous soft sandstone	20
Red ferruginous shale and argillaceous sand	2
Red pack sand	4
Whitish sandy shale	1
Red pack sand	2
Concealed	8
Red ferruginous sand	10
Concealed	15
Gray laminated argillaceous sand	3
Red ferruginous pack sand	2
Reddish-gray laminated argillaceous sand	20
	87

On Cibolo Creek, 200 yards above the wagon bridge at Sutherland Springs, the Carrizo, consisting of 8 feet of gray sandstone interstratified with yellow sand, overlying 1 foot of black lignitic shale, is exposed. The sandstone supplies water to chalybeate springs and dips ¼° S. 10° E.

On the Lavernia-Sutherland Springs road, about three-fourths of a mile west of old Sutherland Springs, Wilson County, 15 feet of brown, indurated micaceous sandstone, with layers and concretions of limonite, is exposed, overlying 4 feet of gray calcareous and argillaceous sandstone.

Section on San Antonio River.—On San Antonio River north of the square at Gray-

[5] Berry, E. W., Additions to the flora of the Wilcox group: U. S. Geol. Survey Prof. Paper 131, pp. 1-21, pls. 1-18, 1923.

[6] Kennedy, William, The Eocene Tertiary east of Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, pp. 135-136. Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 29, 1914.

town, Wilson County, 20 feet of massive yellow to gray water-bearing sand belonging to the Carrizo formation is exposed.

One mile south of Graytown a small hill, which stands 40 feet above San Antonio River, is capped by 10 feet of intricately cross-bedded red or orange-colored soft ferruginous sandstone, which weathers into a deep yellow sandy soil and which belongs to the Mount Selman formation. Below this sandstone, 500 feet to the south, there is red, orange-yellow, and bluish-white sandstone and sandy clay, 50 feet thick, containing thin, irregular seams of limonite, which belongs to the Carrizo. (See Pl. XX, *A*.)

Forty feet of lenticular and laminated gray sandstone, containing concretions of hard blue sandstone, is exposed on the Fairview-Graytown road 2 miles south of Graytown.

In a sand pit about 1½ miles northwest of Calaveras there is exposed 10 feet of coarse yellow sand, consisting largely of grains of quartz admixed with limonite. The sand is shipped to San Antonio, where it is used as building sand. (See Pl. XX, *B*.)

On Calaveras Creek, about three-fourths of a mile northwest of Calaveras, 4 feet of laminated gray sandstone or sandy clay overlying 10 feet of massive coarse yellow sandstone is exposed.

Section in Atascosa County.—From Somerset to a place half a mile north of Rossville, in Atascosa County, the outcrop of the Carrizo sandstone is exposed. At a number of places the characteristic section includes gray sandy soil 1 foot thick, grading downward into a red or pink or orange-colored sandy clay.

Sections on Sabinal and Frio rivers.—In the drainage basin of Sabinal and Frio rivers exposures of gray to reddish-brown sandstone of the Carrizo formation may be seen on Frio River at the crossing at the Kincaid ranch, about 13 miles southeast of Uvalde; about a mile farther down the river;[7] in a gorge about an eighth of a mile south of the Black Valley ranch, 3½ miles north of Frio Town; and at the crossing at Frio Town.

Section on Leona River.—The following section of the Carrizo sandstone is exposed on Leona River about 1.4 miles north of the bridge at Batesville:

[7] Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: U. S. Geol. Survey Bull. 164, p. 52, 1900.

Section of Carrizo sandstone on Leona River near Batesville, Tex.

	Feet.
Large yellow calcareous sandstone concretions	5±
Covered	5
Loose yellow sand; the lower 18 inches are cross-bedded; large limestone concretions at south end of exposure; at the base is a thin layer of bog ore	4–5
Erosional unconformity.	
Light-blue laminated sandy clay; large round yellow limestone concretions; exposed to water line	15±

Section on Nueces River.—In the drainage basin of the Nueces the Carrizo sandstone is exposed from a point a short distance north of La Pryor, Zavalla County, to Asherton, Dimmit County. Nearly all the outcrops are on the higher lands, for on low ground underlying beds of Indio (?) age are exposed. At the old Byrd crossing, however, near La Pryor, beds that closely resemble the Carrizo sandstone are exposed a short distance above water level. These beds are provisionally referred to that formation. If this reference is correct it would indicate the existence of a shallow syncline in this vicinity.

In a bluff bordering the valley of a creek 3,400 feet S. 50° W. from the railroad station in Asherton, Dimmit County, the following section is exposed:

Section of Carrizo sandstone in southwest part of Asherton, Dimmit County, Tex.

[See Pl. XXI, *A*.]

	Feet.
Soft flaggy yellow sandstone. The beds range in thickness from half an inch to 3 inches. The sandstones are noncalcareous, but there is a white incrustation of lime at the surface. The sandstone is micaceous in places and carries fragments of fossil palm rays	10
Blue shale; slightly calcareous in places	4
	14

The beds dip ½° N. 50° E.

Section of Carrizo sandstone on Nueces River 150 feet below Taylor's dam at Bermuda, Dimmit County, Tex.

	Feet.
Soft gray sandstone in layers 2 to 6 inches in thickness, interbedded with bluish-gray calcareous shale half an inch to 1 inch thick. Sandstones are porous and water-bearing	8±
Blue shale with white lime nodules 2 inches thick. Becomes thinner at downstream or east end of bluff.	2
Brown sandy shale, weathering blue. Laminae average three-eighths inch in thickness. Some layers of red to brown ferruginous sandstone near the top are 2 inches thick. Laminae of lignitic shale. Exposed to water line	13
	23±

CLAIBORNE GROUP.

The deposits of Claiborne age in this area are divided into three formations, named in descending order Yegua formation, Cook Mountain formation, and Mount Selman formation.

MOUNT SELMAN FORMATION.

Name.—The Mount Selman formation was named by Kennedy in 1892 after Mount Selman, in Cherokee County.[8]

Stratigraphic position.—The Mount Selman formation lies unconformably above the Carrizo sandstone and conformably below the Cook Mountain formation.

Lithology.—The formation consists of dark-green, brown, and yellow sandstone, lenses of lignite and clay, and beds and concretions of limonite. The formation as a whole is notably ferruginous.

Thickness.—The thickness of the beds on the Brazos is about 600 feet; on the Colorado about 600 feet; and on the Nueces about 700 feet. The dip is to the southeast, approximately 30 to 60 feet to the mile.

Paleontology.—The invertebrate fossils in the formation include *Venericardia planicosta* Lamarck, *Plejona petrosa* Conrad, *Cornulina armigera* (Conrad). None of these, however, are numerous, nor are they especially characteristic, for they occur in other formations of the Eocene.

Areal extent.—The Mount Selman formation outcrops in a belt of country that includes parts of Milam, Burleson, Lee, Bastrop, Caldwell, Guadalupe, Gonzales, Wilson, Atascosa, Frio, Zavalla, Dimmit, and La Salle counties. (See Pl. VIII.)

Correlation and history of investigation.—The Mount Selman formation has been discriminated only in Texas. Together with the overlying Cook Mountain, it represents the time equivalent in Texas of the "Lower Claiborne,"[9] or the St. Maurice formation[10] of Louisiana, as these have been defined and described by Harris. The Cook Mountain and Mount Selman formations are together the time equivalent of the Tallahatta buhrstone plus the Lisbon marl of Mississippi as these have been described by Crider[11] and of the Tallahatta plus the Lisbon of Alabama as these have been described by Smith.[12]

The beds included in this formation were first described by Mr. L. C. Johnson in a report on the iron regions of northern Louisiana and eastern Texas in 1888,[13] but the first adequate account of them was given by Kennedy in 1895, who described them in conjunction with the overlying formation under the name "Marine beds."[14]

Section on Brazos River.—The beds exposed on Brazos River between Burleson Bluff or Colliers Ferry, in the northern corner of Burleson County, and the International & Great Northern Railway bridge near Valley Junction, in Robertson County, are referred to the Mount Selman formation.

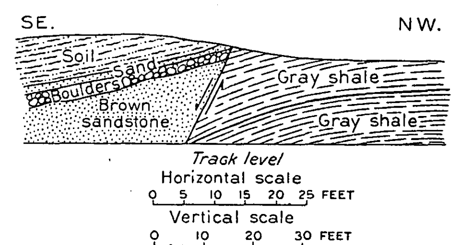


FIGURE 18.—Sketch of fault which cuts the Mount Selman formation 600 to 1,000 feet north of the depot at Milano, Tex.

At the International & Great Northern Railway bridge in Robertson County the Mount Selman formation appears to be represented by 6 feet of nonfossiliferous greensand marl and 10 feet of underlying black clay to the water line. From this point to one 2½ miles below the Burleson County line, a distance of about 12 miles by the river, interbedded clays and sands and local beds of lignite and some few small gray calcareous concretions are exposed in the bluffs.

In the vicinity of Milano, Milam County, the basal beds of the Mount Selman formation are exposed, but the stratigraphic succession is interrupted by a fault which crosses the Gulf, Colorado & Santa Fe Railway 600 to 1,000 feet north of the railroad station at Milano. (See Pl. XXI, *B*, and fig. 18.) On the upthrown side of the fault and in the east part of the cut

[8] Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 52–54, 1892.

[9] Harris, G. D., and Veatch, A. C., A preliminary report on the geology of Louisiana: Louisiana Geol. Survey Rept., pp. 73–89, 1899.

[10] Harris, G. D., The lower Tertiaries of Louisiana: Science, new ser., vol. 31, p. 502, 1910.

[11] Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. 283, pp. 28–33, 1906.

[12] Smith, E. A., The underground water resources of Alabama, Alabama Geol. Survey, pp. 17–18, 1907.

[13] Johnson, L. C., The iron regions of northern Louisiana and eastern Texas: 50th Cong., 1st sess., H. Ex. Doc. 195, pp. 19–21, 1889.

[14] Kennedy, William, The Eocene Tertiary east of the Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, pp. 108–134.

2 feet of lignite and 6 to 8 feet of overlying gray shale are exposed. These beds probably represent the topmost members of the Indio. Apparently the Carrizo sandstone is obliterated by the faulting, and the Mount Selman, represented by 4 to 5 feet of sandstone, is brought into juxtaposition to the Indio. In this event the displacement is in excess of 100 feet.

Section on Colorado River.—On Colorado River the Mount Selman formation is exposed in places from White Bluff, 3½ miles southeast of Bastrop, to a point 2 miles northeast of Upton.

The basal part as exposed at White Bluff, showing the basal beds and the contact with the underlying Carrizo sandstone, is given on page 58. It consists of red ferruginous sandstone made up of coarse grains of quartz and grains of glauconite.

At the mouth of Cedar Creek, about 1½ miles northwest of Upton, there is exposed 30 feet of yellow sand with sandstone concretions.

The next exposure of the Mount Selman on the river is 2 miles northeast of Upton (station 255 on the map, fig. 11, p. 44), where 10 feet of brown sandy shale is interstratified with beds of sandstone. The dip is downstream at a small angle.

The stratigraphic positions of these several exposures on the Colorado are indicated graphically on Plate IX (in pocket).

Section on Cibolo Creek.—The Mount Selman formation is represented by 5 feet of cross-bedded ferruginous sandstone in a gully an eighth of a mile south of the wagon bridge at Sutherland Springs and by 16 feet of sandstone and 8 feet of underlying lignitic shale in a bluff an eighth of a mile farther downstream.

At the water tank of the Galveston, Harrisburg & San Antonio Railway, in the left bank of the creek, there is a bed of black laminated sand 2 feet thick, overlying a lens of greensand or glauconite 3 feet thick.

Section of Mount Selman formation, on the Wyatt place, 1¼ miles east of Sutherland Springs, Tex.

	Ft.	in.
Yellow laminated sandstone and purple lignitic shale	14	
Yellow ferruginous sandstone		4
Blue sandstone		2
Blue shale, with lens of sand 2 feet thick in the middle	4	
Blue water-bearing sandstone	2	
Lignite, exposed above water line; total thickness not known		2
	20	8

A quarter of a mile below the bluff on the Wyatt place a bold spring in the bed of the creek emerges from a coarse white quartzitic sand. A well bored near the spring passed through 4 feet 4 inches of coarse angular white quartzitic sand and 15 feet 8 inches of blue clay.

Section at crossing of Cibolo Creek, 2 miles east of old Sutherland Springs, Tex.

	Ft.	in.
Formation doubtful:		
Yellow sandy clay, covered with black clay soil	7	
Mount Selman formation:		
Yellow calcareous clay	2	
Ferruginous sandstone	1	
Yellow calcareous clay	2	
Brown ferruginous sandstone	1	4
Fossiliferous greensand marl		5
Black laminated lignitic shale	2	
Clay ironstone		3
Green fossiliferous marl		2
Black lignitic shale to water line	2	
	18	2

The marl beds contain numerous specimens of *Plejona petrosa* Conrad, *Glycymeris* sp., and *Venericardia planicosta* Lamarck, indicating the probable Claiborne age of the inclosing material.

Section of Mount Selman formation on Cibolo Creek, at the Hankerson crossing, 4 miles west of Stockdale, Wilson County, Tex.

	Ft.	in.
Yellow calcareous shale	4	
Covered	3	
Laminated yellow sand, grading into red laminated sand at base	4	
Gray sand with interstratified beds of limonite and lignitic shale 1 inch thick	4	
Brown lignitic shale	1	6
Yellow water-saturated sand	1	6
Lignitic shale, exposed to water line		6
	18	6

Section of Mount Selman formation on Cibolo Creek, 1¼ miles below Hankerson crossing, and about 3½ miles S. 75° ± W. of Stockdale, Wilson County, Tex.

	Ft.	in.
Hard indurated sandy shale	2	
Black lignitic shale, with crystals of gypsum	2	6
Yellow sand	3	
Lignitic shale		8
Yellow sand		6
	8	8

On the Butler farm, near the bridge on the Stockdale-Floresville road, about 3½ miles southwest of Stockdale, Wilson County, a shaft has been sunk to a bed of lignite having a thickness of 2 feet. As the overlying formation is of Quaternary age some of the lignite has probably been eroded away.

Section near Stockdale, Wilson County.—Where the Floresville-Stockdale road crosses a small branch about 1½ miles west of Stockdale a 3-inch bed of limonite overlies 2 feet of gray calcareous shale. About 200 yards farther up the branch 4 feet of red ferruginous sand, probably altered greensand, overlies the bed of limonite. Twenty yards farther north the red ferruginous sand grades upward into yellow-mottled laminated sand, and about half a mile north of this place there is exposed 5 feet of yellow indurated sand which lies above the yellow-mottled sand.

On the road about three-fourths of a mile west of Stockdale 3 feet of red ferruginous clay with thin laminae of limonite overlying 1 foot of gray calcareous shale, with lime nodules, is exposed. These beds overlie those in the creek.

In a well 88 feet deep, 4 miles north-northeast of Stockdale, there is exposed at the surface a bed of red sandstone 2 feet thick, below which lies 15 to 20 feet of yellow and red laminated sands and sandy clays. Water issues from a blue sand at a depth of about 77 feet.

Section on Ecleto Creek, Wilson County.—On Ecleto Creek, 4 miles west-northwest of Pandora, the following beds of the Mount Selman formation are exposed:

Section of Mount Selman formation on Ecleto Creek 4 miles west-northwest of Pandora, Wilson County, Tex.

	Feet.
Hard yellow ferruginous sandstone	4
Covered; probably sandy clay	20
Sandy clay, with laminae of limonite	10
Grayish-yellow sandstone	1
Red sandy ferruginous clay with laminae and concretions of limonite	10
	45

The beds dip about 1° SE.

Section on San Antonio River.—Hard blue laminated shale bearing impressions of fragments of leaves is exposed in the bed of San Antonio River a mile northwest of Labatt, Wilson County. Ten feet of similar shale is exposed one-eighth of a mile below this place, and just below this point a shoal is formed by loose concretions 2 to 5 feet in diameter and 6 inches to 2 feet thick. These concretions probably occur in place not far above. They are made up in part of greensand and contain *Pleurotoma* sp., *Arca* sp., *Corbula smithvillensis* Harris (?), and *Venericardia* sp.

Section of Mount Selman formation at a point where the Calaveras-Floresville road crosses Kicester (?) Creek about 1⅞ miles northwest of Floresville, Tex.

	Feet.
Greenish-gray calcareous shale	3
Covered	12
Gray sand and sandy shale with some layers of ferruginous clay; strata range from 2 to 4 inches in thickness	17
Covered	10
Brown shale	12
Gray sand	3
	57

About 1,000 feet northeast of the railroad station at Floresville the Mount Selman formation shows, in descending order, red ferruginous sandstone, 8 inches; red clay, probably originally blue clay, 4 feet; and red ferruginous sandstone, 8 inches.

Section of Mount Selman formation about a quarter of a mile south of crossing of Mariana Creek and about 2¾ miles south-southwest of railroad station at Floresville, Tex.

	Ft.	in.
Red siliceous limonite capping hill	1	
Yellowish-brown sandy clay; bluish white where unweathered	3	
Red ferruginous sandstone	3	
Limonite		2
Blue and red mottled sandy clay	2	
Blue sand		6
Covered	4	
Reddish-brown sandstone	4	
Brown laminated siliceous limonite	1	
Gray sandy clay	1	
Brown laminated siliceous limonite		6
Bluish-white laminated sand with thin laminae of limonite	2	
Yellowish-white cross-bedded sands; water-bearing	3	
	25	2

The beds composing this section are very irregular in shape and are generally lenticular. Fragments of limonite measuring 2 by 3 by 2 inches have weathered from the strata and veneer the slope.

Section of Mount Selman formation (?) on road 2 miles south of courthouse at Floresville, Tex.

	Ft.	in.
Red clay subsoil with yellow limestone concretions averaging 1 foot in diameter	2	
Red siliceous limonite		6
Red weathered sandy clay	1	
Siliceous red limonite		6
Red sandy clay	1	
Red ferruginous sandstone; altered greensand	1	
Red ferruginous clay with limestone concretions and septaria 1 to 2 feet in diameter	3	
Covered	8	
Brown shale with limestone concretions 1 to 2 feet in diameter	15	
Reddish sandy clay; exposed in creek bed	3	
	35	

Section on Atascosa Creek.—In a small gorge tributary to the valley of Atascosa Creek, about three-fourths of a mile northeast of Anchorage, the Mount Selman formation consists, in descending order, of 2 to 3 feet of bluish-white laminated sand with numerous concretions of limonite, 6 inches of ferruginous sand (lens), 8 feet of brown laminated sand in beds 2 to 6 inches thick, 5 feet of hard blue concretionary sandstone, and 6 inches of brown ferruginous sand.

On Atascosa Creek, a quarter of a mile south of Amphion, Atascosa County, the Mount Selman formation shows, in descending order, 4 inches of flaggy sandstone, 3 to 5 feet of greenish-brown shale with limy concretions half an inch in diameter; 4 to 5 feet concealed, and 1 foot of yellow sandstone.

Section in Frio County.—Yellow laminated sand with brown sandy concretions 6 inches in thickness and 2 to 3 feet in diameter are exposed in a knoll that projects through a cover of Pleistocene material on Frio River 2½ miles north of Frio Town.

In a quarry on the Sabinal road about 1½ miles due north of Frio Town, 5 feet of irregularly bedded hard brown sandstone, with interstratified thin seams of limonite, is exposed. The dip is about 1° SE.

About 3 feet of red ferruginous loamy sand is exposed at the crossing on Buck Creek of the Pearsall-Frio Town road, 4½ miles northwest of Pearsall, and similar material is exposed in a cut, 3 feet deep, on the Pearsall-Frio Town road, about 3 miles northwest of Pearsall and about 500 yards southeast of the crossing on the creek.

One foot of dark-brown ferruginous sand with small fragments of limonite, overlying 3 feet of pink and gray laminated sand, is exposed in a cut on the International & Great Northern Railway 200 yards south of the station at Pearsall.

Section on Leona River.—Very hard fossiliferous greensand concretions from 1 to 2½ feet in diameter, embedded in blue sandy shale, is exposed on the Loma Vista-Batesville road, about three-quarters of a mile north of Loma Vista. The fossils, which are poorly preserved, include *Meretrix* sp. and *Cornulina armigera* Conrad.

Section on Nueces River.—The Mount Selman formation is exposed in the drainage area of Nueces River from a point about 6 miles southeast of Bermuda to a point about 1½ miles east of the La Salle-Dimmit county line.

About 1¼ miles south-southwest of the bridge across Nueces River, on the Asherton-Bermuda road, the Mount Selman formation shows, in descending order, 2 feet of calcareous, flaggy blue, fairly soft sandstone which weathers red; 6 feet of blue shale; 4 inches of gray sandstone; and 5 feet of blue plastic shale.

At Perkins crossing on Nueces River, 6 miles south of Big Wells, Dimmit County, the Mount Selman formation contains 3 feet of yellow argillaceous sand, overlying 5 feet of blue plastic sandy shale which weathers brown. The dip of the beds is 1° S. 20° E.

On the Big Wells-Catarina road, in Dimmit County, 1.35 miles south of Big Wells, 15 feet of gray medium soft sandstone is exposed in a roadside gully, and a similar exposure may be seen in a cut on the railroad 500 feet east of the station at Big Wells.

Hard brown calcareous concretions, 2 to 3 feet in diameter, are exposed near the Catarina-Cotulla road, 2.9 miles west of the La Salle County line and also on the Cotulla-Carrizo Springs road, about half a mile west of the La Salle County line. One badly weathered concretion carries large oyster shells.

Section of Mount Selman formation on Catarina-Cotulla road, 9¼ miles S. 75° W. of Cotulla, in Dimmit County, Tex.

	Ft.	in.
Large, subglobular brown sandy limestone concretions with concentric structure; 6 feet in diameter, 2 feet thick at the center (see Pl. XXI, *C*)	2±	
Brown sandy limestone with fossil oysters		6
Covered	5	
Brown sandy limestone		6
Brown argillaceous sand, weathered	6±	
Brown sandy limestone concretions		6
	14+	

About 10 feet of red-brown altered greensand, weathering into red pack sand and occupying nearly the same stratigraphic position as the concretions just described, crops out on the Cotulla-Carrizo Springs road, about 1,000 feet west of the crossing of Spear Creek, about 8½ miles west of Cotulla. About 500 feet west of this outcrop there are some detached masses of brown lime-incrusted sandstone. Between 300 and 500 feet farther west is a ferruginous red pack sand containing fragments of brown limonite. It forms the cap rock of the upland.

Two miles northeast of Pudding schoolhouse, in the eastern part of Dimmit County, half a mile south of the Cotulla-Carrizo Springs road, the upland is occupied by brown ferruginous sandstone concretions about 3 feet thick, in places carrying poorly preserved fossil oysters. The concretions overlie 5 or 6 feet of blue shale.

COOK MOUNTAIN FORMATION.

Name.—The Cook Mountain formation was named by Kennedy in 1892 after Cook Mountain in Houston County.[15]

Stratigraphic position.—The Cook Mountain formation lies conformably above the Mount Selman formation and beneath the Yegua formation.

Lithology.—It consists of beds of greensand, greensand marl, iron ore, lignite, lignitic clay, clay, sandstone, and sand. The glauconitic sand and marl, which are the predominant members, are marine; the lignite, lignitic clay, and sand are palustrine—they originated in marshes.

Thickness and dip.—The thickness of the beds on the Brazos is about 800 feet; on the Colorado, about 700 feet; and on the Nueces about 800 feet. The dip is to the southeast and ranges from 40 to 100 feet to the mile.

Paleontology.—Invertebrate fossils are common in the formation. The more characteristic forms include *Corbula deusseni* Gardner, *Corbula smithvillensis* Harris, *Phos texanus* Gabb, *Dentalium minutistriatum* Gabb, *Turritella nasuta* Gabb, *Latirus moorei* (Gabb), *Mesalia claibornensis* Harris, and *Anomia ephippioides* Gabb. (See Pl. XXII.)

List of fossils obtained from the Cook Mountain formation in this field.

[Letters indicate localities mentioned in descriptions below.]

Platytrochus stokesi (Lea), N, P.
Discotrochus orbignianus Milne-Edwards and Haime, B, K, N.
Turbinolia pharetra Lea, A, B, E, F, I, K, N, O, P.
Paracyathus alternatus Vaughan, A, N.
Oculina singleyi Vaughan, B, I, N.
Madracis ganei Vaughan, L, M.
Madracis johnsoni Vaughan, N.
Balanophyllia desmophyllum Milne-Edwards and Haime, L.
Balanophyllia irrorata var. mortoni (Gabb and Horn), B, N.
Balanophyllia irrorata var. coniformis Vaughan, B, E, N.
Endopachys maclurei (Lea) var. tenue Vaughan, B, O.
Actaeon pomilius Conrad, B, O.
Cylichna kelloggi Gabb, B, G, N, O.
Volvula smithvillensis Harris, B.
Ringicula trapaquara Harris, B, L.
Terebra houstonia Harris, B, C, N.
Conus sauridens Conrad, B, F, J, K.
Conus smithvillensis Harris, B, N.
Surcula gabbi Conrad, A, I, J, L, M.
Turris nodocarinata (Gabb), B, D, F, I, J, K, N, O.
Turris enstricina (Harris), B.
Turris huppertzi (Harris), N.
Turris moorei (Gabb), B, E, N, O.
Drillia texacona Harris, B, E, O.
Drillia texanopsis Harris, B, N.
Microdrillia infans Meyer, B. N.
Cochlespira bella Conrad, E, N.
Borsonia plenta Harris, B, O.
Eucheilodon reticulatoides Harris, N.
Cancellaria bastropensis Harris, B, E, N.
Cancellaria panones Harris, N.
Olivula staminea Conrad, B.
Plejona petrosa (Conrad), A, B, E, F, I, J, K, L, M, N, Q.
Lapparia dumosa Conrad, B, F, I, N.
Turricula polita Gabb, B, N, O.
Pyramitra costata (Lea), N.
Pseudoliva carinata Gabb, B.
Pseudoliva vetusta Conrad, A, B, C, E, F, I, K, N, O.
Levifusus trabeatoides Harris, B, C, K, N, O.
Fusus bastropensis Harris, N.
Fusus mortoniopsis Gabb, B, N, O.
Latirus moorei Gabb, B, C, D, J, N, O.
Phos texanus Gabb, B, C, L, O.
Alectrion scalata (Heilprin), N.
Astyris bastropensis (Heilprin), B, N.
Neptunea enterogramma Gabb, B.
Murex vanuxemi Conrad, N.
Distortrix septemdentata Gabb, B, F, K.
Pyrula penita Conrad, N.
Rimella texana Harris, A.
Turritella nasuta Gabb, B, D, G, K, N, O, P.
Turritella houstonia Harris.
Mesalia claibornensis Conrad, B, D, J, O.
Tuba antiquata Conrad, B, E, N.
Architectonica alveata (Conrad), N.
Liotia tricostata Conrad, B, N.
Natica semilunata Lea, A, B, I, K, N, O.
Neverita arata Gabb, A, B, E, I, N, O.
Sigaretus arctatus Conrad, N.
Sigaretus bilix Conrad, B, N.
Dentalium minutistriatum Gabb, B, D, N, O, P.
Cadulus abruptus Meyer & Aldrich, B, E, N.
Nucula mauricensis Harris, B.
Leda compsa Gabb, B.
Leda houstonia Harris, B.
Adrana aldrichiana Harris, B.
Trinacria pulchra Gabb, B, D, E, N, P.
Arca ludoviciana Harris, B.
Glycymeris trigonella Conrad B.
Ostrea sellaeformis Conrad, N.
Ostrea alabamiensis Conrad, N.
Pecten scintillatus Conrad, B.
Pecten burlesonensis Harris, A.

[15] Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 54-57, 1892.

Anomia ephippoides Gabb, B, P, Q.
Crassatellites antestriatus Gabb, B, N.
Astarte smithvillensis Harris, E, I, N.
Venericardia planicosta Conrad, C, D, H, I, J, K.
Venericardia rotunda Lea, B, D, H, N, O.
Lutetia texana Harris, B.
Sphaerella anteproducta Harris, N.
Callocardia texacola Harris, N.
Callocardia bastropensis Harris, C.
Tellina mooreana Gabb, B.
Tellina tallicheti Harris, N.
Pteropsis lapidosa Conrad.
Corbula smithvillensis Harris, E, F, I, L, M, N, P.
Corbula texana Gabb, B.
Corbula conradi Dall, E.
Corbula deusseni Gardner n. sp., N.
Tubulostium leptostoma (Gabb), B.

A. Burleson Bluff, Brazos River, 3 miles below the Milam-Burleson county line.

B. Moseley's Ferry, Brazos River, opposite Stone City post office, Burleson County.

C. Five hundred yards south of mouth of Little Brazos River, on Brazos River, Brazos County.

D. The A. & M. well, 900 to 1,000 feet, College station, Brazos County.

E. Cedar Creek, Burleson County.

F. Three hundred yards east of courthouse at Caldwell, Burleson County.

G. In well No. 1 of the Brenham Oil Co., at a depth of 1,275 to 1,360 feet, 7¾ miles southwest of Brenham, Washington County.

H. In well on Brenham dome, 7¾ miles southwest of Brenham, Washington County.

I. Shaw's branch, 1½ miles southwest of Lexington, Lee County.

J. In shallow well, at a depth of 30 to 44 feet, 2 miles northeast of Fedor, Lee County.

K. Pin Oak Creek, 1 mile above Bastrop-Fayette county line, Bastrop County.

L. Two miles above Burleson Ferry, Colorado River, Bastrop County.

M. Two and a half miles above Burleson Ferry, Colorado River, Bastrop County.

N. Smithville, Bastrop County.

O. Three and a half miles S. 22° E. of Floresville, Wilson County.

P. One and a half miles southwest of Pleasanton, Atascosa County.

Q. One mile south of Jourdanton, Atascosa County.

Julia Gardner describes the new species of *Corbula* listed above as follows:

Corbula (Cuneocorbula) deusseni Gardner, n. sp.

Plate XXII, Figures 8, 8a.

Shell rather small and rather delicate, inequivalve, the right valve strongly overlapping the left; transversely ovate-trigonal in outline; both valves moderately inflated, the right more strongly than the left. Posterior keel subacute, produced at its extremity, the area behind it moderately wide, feebly concave. Umbones not very prominent, well rounded, prosogyrate, subcentral in position. Lunule not defined. Escutcheon sharply differentiated, the margin in the right valve less sharply raised than that of the left, which it overlaps. Dorsal margins gently declining. Anterior extremity quite strongly rounded. Posterior extremity obliquely truncate, produced along the keel particularly in the right valve. Ventral margins strongly incurved; base line asymmetrically arcuate. External surface sculptured with concentric wrinkles, irregular and incremental in character, strengthening toward the ventral margin; microscopically fine radial threadlets usually developed on the medial and posterior portions of the shell, less faint in the left valve than the right, most crowded in the keel; more or less fortuitous in their development and disposition. Ligament very short, inset. Right cardinal moderately stout, conical, received in a correspondingly deep subumbonal pit in the left valve. Muscle scars very distinct, the posterior the stronger of the two, and, in the adult forms, seated upon a slightly overhanging ledge; interior excavated. Pallial line simple, somewhat truncate posteriorly; inner surface of the right valve grooved near the ventral margin for the reception of the edge of the left valve.

Dimensions: Altitude, 7.0 millimeters; latitude, 11.3 millimeters; diameter, 6.6 millimeters.

Type locality: Smithville, Bastrop County, Tex.

As in many of the Corbulas, there is a bewildering amount of variation in details of sculpture and, to a less marked degree, in size and outline. The figured specimen is decidedly larger than the average. The concentric sculpture is generally undeveloped upon the umbonal area, but in some specimens it is quite fine and close over the entire shell. The fine radial threading is to a certain extent fortuitous, though it is generally discernible upon the left valve and behind the keel.

In this species are included many of the forms appearing under the name of *Corbula gregorioi* Cossmann in the Texas check lists and collections. Individuals in the Aldrich collection, identified by Mr. Cossmann, indicate a species about half as large as the form in question, relatively higher and more compressed, with a relatively coarser concentric sculpture, and an apparent absence of radial threading. Cossmann's species seems to be restricted to the upper Claiborne, *C. deusseni* to the lower Claiborne. The differences between *C. conradi* and *C. deusseni* may not prove to be of specific rank, but in the material under observation *C. deusseni* is quite constantly lower and more finely sculptured concentrically.

Distribution: Cook Mountain formation, Smithville, Bastrop County; one-fourth of a mile west of Jourdanton, Atascosa County.

Areal extent.—The outcrop of the formation occupies a belt of country extending through Burleson, Lee, Bastrop, Fayette, Gonzales, Wilson, Atascosa, Frio, and La Salle counties. (See Pl. VIII.)

Correlation.—The Cook Mountain formation extends eastward into Louisiana, Mississippi, and Alabama, where it, together with the Mount Selman formation, is represented by the St. Maurice formation ("Lower Claiborne") of Louisiana and by the Tallahatta buhrstone plus the Lisbon formation of Mississippi and Alabama.

The similarity of the fossils from Texas to those from Claiborne, Ala., was announced in 1852 by Dr. Ferdinand Roemer.[16] Penrose,[17] in 1890, described the beds in connection with his so-called "Timber belt beds." Kennedy,[18] in 1892, recognized and described for the first time the unit here considered.

Section on Brazos River.—The Cook Mountain formation is exposed on the Brazos from a point 2½ miles by the river below the Burleson-Milam county line to Wellborn shoals, 500 yards south of the mouth of the Little Brazos. The details of the sections follow in stratigraphic order.

Section of Cook Mountain formation at Burleson Bluff, near old Colliers Ferry, about 3 miles below the Milam-Burleson county line, Burleson County, Tex.

	Ft.	in.
Fossiliferous limonite		8
Fossiliferous brown marl	3	
Fossiliferous green marl	1	
Fossiliferous sandstone, ferruginous, indurated	1	
Fossiliferous blue marl	6	
Covered to water line	23	4
	35	

[16] Roemer, Ferdinand, Die Kreidebildungen von Texas und ihre organischen Einschlüsse, pp. 4–5, 1852.

[17] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 22–47, 1890.

[18] Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 54–57, 1892.

About 10 feet of lignitic shale, which overlies 4 feet of lignite, provisionally referred to the Mount Selman formation, underlies the Cook Mountain beds about 100 feet upstream. The Cook Mountain beds dip 2° S. 72° E.; the Mount Selman beds dip S. 72° E. at an angle of less than 1°.

The fossils collected here and identified by T. W. Vaughan are listed under A on page 64.

Five miles south of Burleson Bluff, on the O. Astin place, in Brazos County, there is an exposure of 2 feet of lignite and 2 feet of overlying blue sand. Kennedy[19] reports that the lignite here is 12 to 14 feet thick. Not more than a quarter of a mile below this point, on the right bank of the river, there is an exposure of blue shale overlain by sand. The dip is ½° W. A similar exposure is seen 1½ miles above Moseleys Ferry, in Burleson County. A sketch of the bedding as seen from the opposite side of the river is shown in figure 19.

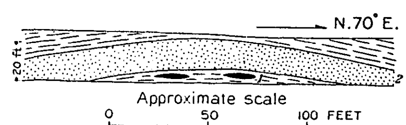


FIGURE 19.—Sketch of bluff on Brazos River, 1½ miles above Moseleys Ferry, in Burleson County, Tex.

Section of Cook Mountain formation at Moseleys Ferry on Brazos River, at Stone City post office, in Burleson County, Tex.

	Feet.
Blue fossiliferous shale	2
Iron concretions	½
Blue marl	4
Blue fossiliferous marl	4
Fossiliferous iron concretions	½
Blue fossiliferous marl	2
Fossiliferous iron ore	1
Blue fossiliferous greensand marl	3
Fossiliferous iron ore (dips under water 100 yards below ferry)	3
Blue impervious fossiliferous marl	1
Lignitic shale	1
Blue fossiliferous marl	4
Fossiliferous iron ore	1
Greensand marl to water line	6
	33

The dip is 2° S. 80° E. The fossils collected from the beds here, according to the identification of T. W. Vaughan, are listed under B on pages 64–65.

The uppermost beds of the Cook Mountain formation are exposed 500 yards south of the

[19] Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., p. 56, 1893.

mouth of the Little Brazos. In descending order these beds include 5 feet of pale-blue clay; 3½ feet of dark greensand, fossiliferous in lower part; dark fossiliferous sandy clay; ferruginous sandstone; and dark fossiliferous sandy clay. Fossils collected at this point are listed under C, pages 64–65. The list is taken from a register of Tertiary fossils collected by the Geological Survey of Texas, now in possession of the University of Texas. The species were determined by Harris.

The dips in the Cook Mountain formation on Brazos River indicate that an anticline crosses the river between Burleson Bluff and Moseleys Ferry. The structural relations are shown in figure 20. Gas issues from a number of wells

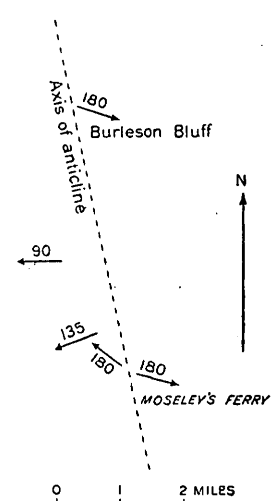


FIGURE 20.—Plat of dips of the beds of the Cook Mountain formation on Brazos River between Burleson Bluff and Moseleys Ferry, Tex. Arrows show direction and figures show amount of dip in feet per mile.

in Brazos Valley between Hearne and Navasota, and it may be derived from this anticline.

Section at College station, Brazos County.—At College station, Brazos County, two deep wells have been drilled, one by the Houston & Texas Central Railroad, the other by the Agricultural & Mechanical College of Texas in 1892. In the railroad well lignite was struck at a depth of 105 feet. Sandstone and shale were the principal materials encountered in the college well down to 900 feet. Between 900 and 1,000 feet a dark-blue clay was penetrated, which yielded the fossils listed under D, pages 64–65. The list is given in a catalogue of Tertiary fossils collected by the Geological Survey of Texas (1889–1892), now in the possession of the University of Texas. The species were determined by G. D. Harris.

Section at Bryan.—The following well log shows the character of the beds at Bryan:

Log of well at Bryan, Tex.

[Drilled for city of Bryan, by Fred M. Allison; completed May 12, 1915.]

	Feet.
Recent:	
Soil	5
Yegua formation:	
Clay	5
Sand and clay	8
Water sand	4
Red clay	4
Yellow clay	54
Light shale	85
Sandrock	3
Shale and sand	72
Cook Mountain and Mount Selman formations:	
Gumbo	30
Shale	210
Rock	4
Shale	116
Gumbo	30
Sand	15
Shale	135
Sand	20
Shale	200
Rock	20
Shale	160
Sand	35
Shale	95
Rock	2
Shale	48
Gumbo	25
Shale	98
Shells and lignite	8
Shale	24
Gumbo	13
Sand	20
Shale	18
Rock	3
Sand, water-bearing	10
Rock	2
Shale	55
Rock	4
Shale	26
Rock	3
Shale	99
Carrizo sandstone(?):	
Water-bearing sand	78
Shale	130
Indio formation:	
Water-bearing sand	20
Shale	68
Gumbo	35
	2,099

Cooke makes the following correlation of the section on the basis of the fossils:

Cook Mountain and Mount Selman formations down to 1,400 feet; below 1,400 feet the aspect of the fauna changes somewhat, but appears to be Claiborne to 1,735 feet.

Section between Hix and Caldwell, Burleson County.—Exposures of the Cook Mountain formation at creek crossings, washes, and other places between Hix, near the north corner of Burleson County, and Caldwell show a fairly complete section of the formation from bottom to top. At Hix the soil and topography indicate that the underlying bed from which the soil is derived is glauconitic clay. This represents probably the western extension of the beds seen at Burleson Bluff.

On Cedar Creek, at the crossing of the Caldwell-Hix road, the beds of the Cook Mountain formation include, in descending order, 4 inches of ferruginous sandstone, 4 feet of green clay, 4 inches of fossiliferous calcareous sandstone, 4 feet of fossiliferous green clay, and 1 foot of fossiliferous sandstone. The beds dip 1° N. 75° E.

From the fossiliferous bed the species listed under E, pages 64–65, as identified by C. W. Cooke and T. W. Vaughan, were obtained.

Three miles north of Caldwell 30 feet of the Cook Mountain formation is exposed, consisting, in descending order, of red ferruginous sandstone, 5 feet of gray fossiliferous shale, 15 feet of yellow quartzose sand, and 10 feet of brown shale.

Two miles northeast of Caldwell, on the road from Caldwell to Moseleys Ferry, there are beds of low-grade iron ore 1 foot thick, alternating with beds of clay and marl 2 feet thick. The strata carry specimens of *Ostrea sellaeformis* Conrad. The dip is approximately 1½° SW.

On the Caldwell-Moseleys Ferry road, about 1 mile north of the courthouse at Caldwell, the Cook Mountain formation consists of 2 feet of yellow calcareous clay, 6 inches of iron concretions, and 2 feet of green calcareous clay.

On Davidsons Creek, about three-fourths of a mile north of the courthouse at Caldwell, the exposed part of the Cook Mountain formation consists of 3 feet of laminated yellow ferruginous sand, 1½ feet of brown argillaceous sand, and 4 feet of unconsolidated siliceous sand. The apparent dip is 1½° N. 80° W.

A well at the cotton gin near the Gulf, Colorado & Santa Fe Railway station at Caldwell shows 4 feet of sand bearing potable water at 27 feet, 6 feet of similar sand at 60 feet, 9 feet of fossiliferous green marl at 85 feet, 8 feet of sand bearing potable water at 94 feet, and water-bearing sand with a bed of dark-green shale at a depth of 185 feet.

A fossiliferous green marl is exposed in the bed of a creek about 300 yards due east of the courthouse at Caldwell, from which the species identified by Cooke and Vaughan and listed under F on pages 64–65 were obtained.

Section on Yegua Creek.—Fossiliferous green marls, characteristic of the Cook Mountain formation, outcrop in the immediate vicinity of Brymer, about 10 miles west of Caldwell. The marls contain *Ostrea*, apparently *sellaeformis* Conrad, and *Corbula*, apparently *smithvillensis* Harris.

On Copperas Creek, about a mile north of Gus, in the western part of Burleson County, the section includes 2 feet of brown sand, 3 inches of limonite, 2 feet of brown lignitic clay, 3 inches of lignite, and 18 inches of cross-bedded laminated argillaceous sand. These beds dip ½° S. 5° E.

At a creek crossing on the Caldwell-Gus road in Burleson County, about 2½ miles east of Gus, the beds of the Cook Mountain formation, in descending order, include 4 feet of clay in beds 1 foot thick, alternating with seams of limonitic sandstone 3 inches thick; 2 feet of brown shale; and 2 feet of white unconsolidated sand, made up largely of quartz grains. The dip of these beds is ½° S. 30° E.

Fossiliferous ferruginous sandstone crops out in the banks of a small creek on the farm of Joe Blaha, about 1½ miles west of East Yegua Creek, near the Dime Box-Caldwell road, in Lee County. The sandstone dips ½° S. 35° E.

Yellow sand with concretions of limonite underlying the fossiliferous beds exposed on the farm of Joe Blaha crop out in the banks of a small branch about 1 mile northeast of the Blaha farm, and about 1½ miles west of Yegua Creek in the eastern part of Lee County.

Section in Washington County.—Fossils obtained from a depth of 1,275 to 1,360 feet in well No. 1 of the Brenham Oil Co., drilled in 1915, about 7¾ miles southwest of Brenham, Washington County, as identified by C. W. Cooke, are listed under G on page 64.

Fossils identified by C. L. Baker from the same horizon are listed under H on page 65. The collections indicate a Cook Mountain horizon.

Section near Lexington, Lee County, and vicinity.—Porous yellow-gray sand, 10 feet thick, is exposed about 3 miles north of Lexington, where the San Antonio & Aransas Pass Railway crosses Brushy Creek.

About 2 miles northeast of Lexington, at the edge of the prairie, beds of the Cook Mountain formation, in descending order, include 10 feet of bluish-yellow clay, 2 feet of hard red sandstone, 10 feet of blue clay balls in stratified yellow sand, and 10 feet of hard yellow sand and sandstone.

Near the San Antonio & Aransas Pass Railway, about 1 mile northeast of Lexington, beds of the Cook Mountain formation, in descending order, show 3 feet of calcareous, ferruginous fossiliferous sandstone; 2 feet of yellow calcareous marl with *Ostrea divaricata* Lea and *Pecten* sp.; 6 inches of concretionary iron sandstone; 6 inches of yellow calcareous marl; 6 inches of concretionary limestone; and 6 inches of fossiliferous greensand marl.

On Shaws Branch, 1¼ miles southwest of Lexington, the Cook Mountain formation shows, in descending order, 2 feet of sandy gray shale, 2 feet of porous yellow sand, 6 feet of fossiliferous yellow clay, 1 foot of ferruginous fossiliferous marl, 2 feet of fossiliferous sandy greensand marl, and 1 foot of ferruginous sandstone. The fossils in the greensand marl, as identified by Cooke and Vaughan, are listed under I on pages 64–65.

Section at Fedor, Lee County, and vicinity.—Laminated yellow sands, 10 feet thick, outcrop 2 miles northeast of Fedor. The fossils occurring in a bed of greensand from 30 to 44 feet deep in a well belonging to Charles Tatzlau at Fedor, as identified by Cooke and Vaughan, are listed under J on pages 64–65.

Section in eastern part of Bastrop County.—On Pin Oak Creek, about 1 mile above the Bastrop-Fayette county line, the Cook Mountain formation contains, in descending order, 10 feet of blue clay, ferruginous sandstone (?), 2 inches of fossiliferous blue clay, ferruginous sandstone, 20 inches of fossiliferous blue clay, fossiliferous sandstone, 20 inches of fossiliferous blue clay, and 18 inches of white sand. The fossils from the fossiliferous beds, as identified by Cooke and Vaughan, are listed under K on pages 64–65.

Section on Colorado River.—The Cook Mountain formation is exposed on Colorado River from a point 5 miles west of Smithville to the Bastrop-Fayette county line, 4½ miles east of Smithville.

In a bend of Colorado River, 3 miles above Burleson Ferry and about 5 miles west of Smithville, the Cook Mountain formation, in descending order, shows 2 feet of porous gray sand with white efflorescence on surface; 2½ feet of hard ferruginous fossiliferous sandstone; 5 feet of gray shale, fossiliferous at top; 1 foot of ferruginous brown concretion-bearing fossiliferous greensand; 4 feet of greensand; 6 inches of black sand, which at upstream end of bluff overlies a small lens of sand; and 10 feet of greensand to the water line.

The beds dip 1° E. The fossiliferous beds carry such typical Cook Mountain forms as *Madracis johnsoni* Vaughan and *Corbula smithvillensis* Harris.

On Colorado River, 2 miles above Burleson Ferry and about 4½ miles west-northwest of Smithville, the beds of the Cook Mountain formation contain, in descending order, 6 inches of iron ore, 6 inches of brown clay, 2 feet of fossiliferous greensand marl, 6 inches of fossiliferous ferruginous sandstone, 18 inches of fossiliferous greensand marl, 9 inches of fossiliferous ferruginous sandstone, 4 feet of fossiliferous greensand marl, 9 inches of indurated clay in the form of concretions 2 to 3 feet in diameter and 6 to 8 inches in thickness, and 3 feet of fossiliferous greensand marl to the water line.

The beds dip ½° N. 56° E. The fossils collected at this locality, as identified by Cooke and Vaughan, are listed under L on pages 64–65.

On Colorado River, about 2½ miles above Burleson Ferry and about 4½ miles west of Smithville, fossiliferous beds occur and have furnished the fossils identified by Cooke and Vaughan and listed under M on pages 64–65.

Nonmarine beds of the Cook Mountain formation are exposed at a point on Colorado River three-fourths of a mile above Burleson Ferry and about 3½ miles northwest of Smithville. The section shows at the base 10 feet of unconsolidated yellow sand containing concretions of limestone. Above the sand lies lignitic clay containing concretions of sandstone.

Lenticular and interstratified beds of yellow sand and black shale of nonmarine origin, about 17 feet thick, are seen at Kennedy

Bluff, on Colorado River 3¾ miles above and northwest of Smithville. (See fig. 21.)

Lenticular sand and clay of shallow-water origin extend downstream from this bluff for about 2 miles.

Section of Cook Mountain formation on south side of Colorado River, about 1,000 feet west of wagon bridge at Smithville, Tex.

	Feet.
Fossiliferous glauconitic marl, containing geodes of limonite	2
Indurated fossiliferous greensand	1
Brownish-black fossiliferous glauconitic marl	1½
Fossiliferous limonite or indurated greensand	¼
Brown laminated fossiliferous glauconitic marl	4
Fossiliferous limonite, very hard	2
Green calcareous fossiliferous glauconitic marl	5
Fossiliferous limonite or indurated greensand	1
Laminated green fossiliferous glauconitic marl	1
Concealed	10
	27¾

nonfossiliferous sulphurous clay, 1 foot of green sandy shale, 3 inches of lignitic clay, 1 foot of porous blue water-bearing sand, and 2 feet of blue sandy shale to the water line. A small synclinal fold occurs here.

The relative stratigraphic position of the several exposures on Colorado River is indicated graphically on Plate IX.

Section in Gonzales County.—In Gonzales County brown ferruginous fossiliferous sandy clay of the Cook Mountain formation is exposed near the railroad station at Harwood. The material is altered greensand marl containing fossils too poorly preserved to admit of identification.

Yellow and brown clays, interstratified with red fossiliferous beds of altered greensand 6 inches to 1 foot thick, are exposed in the scarp overlooking the valley of San Marcos River, 3 miles southwest of Ottine.

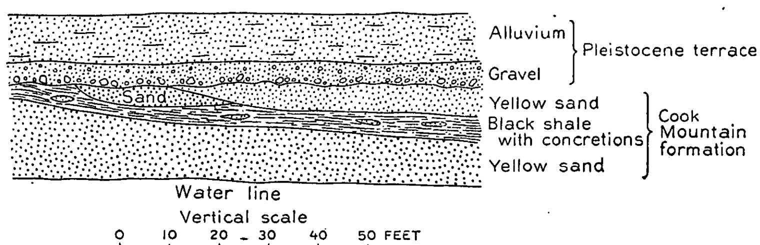


FIGURE 21.—Sketch of Kennedy Bluff, on Colorado River 3¾ miles northwest of Smithville, Tex., showing the relations of the strata.

The beds dip 6° N. 40° E.

On the south side of Colorado River, about 800 feet west of the wagon bridge at Smithville, the beds of the Cook Mountain formation, in descending order, include 2 feet of laminated nonfossiliferous sandy clay, 1 foot of fine yellow sand, 1 foot of brownish-red nonfossiliferous lignitic clay, 6 feet of green fossiliferous glauconitic marl, and 2 feet of fossiliferous glauconitic marl containing geodes of limonite (same as the uppermost bed in section above). The beds dip downstream 6° N. 40° E. The fossils collected at this locality, which were identified by Cooke and Vaughan, are listed under N on pages 64–65.

On Colorado River on the Bastrop-Fayette county line, about 4½ miles east of Smithville, the beds of the Cook Mountain formation, in descending order, show 1 foot of fossiliferous greensand marl with small concretions of iron ore, 18 inches of blue fossiliferous shale with concretions of ferruginous sandstone, 2 feet of fossiliferous greensand marl, 1 foot of blue

Section between Pandora and Nixon, in Wilson and Gonzales counties.—About 4 feet of brown calcareous shale overlies 5 feet of green calcareous shale, with irregularly distributed lenses of calcareous sandstone and concretions of silicified fossiliferous greensand, 3 miles north of Pandora.

About 100 yards north of this locality 2 feet of green calcareous shale with lime concretions overlies 1 foot of silicified greensand with fossiliferous concretions 1 to 2 feet in diameter, and this in turn overlies 3 feet of green calcareous shale weathering yellow to brown.

Section on San Antonio River.—The Cook Mountain formation is exposed in the drainage area of San Antonio River in Wilson County from a point about 4 miles south of Floresville to a point 1 mile southwest of Poth.

On San Antonio River opposite the O. C. Burkett farm, about 4 miles south-southeast of Floresville, the beds of the Cook Mountain formation, in descending order, show 21 inches of brown shale, 4 inches of reddish-brown friable sand, 5 feet 7 inches of brown shale, and 1 foot 2 inches of green fossiliferous shale. The beds dip 1° S. 15° W.

Four feet of brownish-black shale with flakes of gypsum or selenite is exposed on a neighborhood road about 5 miles south-southeast of Floresville and about three-fourths of a mile west of San Antonio River.

Limestone concretions 2 to 3 feet in diameter, embedded in blue clay, crop out on the road 3½ miles S. 22° E. of Floresville. The concretions carry fossils, which, as identified by Cooke and Vaughan, are listed under O on pages 64–65.

About 200 feet above the bridge at Dewees crossing, on San Antonio River, 3 miles south-southwest of Poth, the beds of the Cook Mountain formation, in descending order, contain a lens of laminated yellowish-gray sand (see fig. 22), 10 feet thick; a lens of bluish-gray, brown-weathering shale with small lime concretions (see fig. 22), 8 feet thick; hard greensand concretions 2 by 5 feet in dimension, protruding through cover 5 feet thick; yellow ferruginous sand, 6 inches thick; and blue argillaceous sand to the water line.

Lenticular beds of red ferruginous clay, bluish laminated sands, weathering red, and small fragments of limonite form the country rock 1¾ miles southwest of Poth. These materials weather into red clay and red loamy soils upon which grow mesquite and in places post oak.

Section in Atascosa County.—On the Jourdanton-Pearsall road, about 1 mile west of the railroad station at Jourdanton, Atascosa County, the Cook Mountain formation shows 2 feet of hard blue sandstone concretions averaging 2 by 4 feet in size, overlying 3 feet of red ferruginous clay with nodules of lime averaging half an inch in diameter.

On Stantel Creek, on the Henry Hiner league, about 7 miles west-southwest of Jourdanton, the Cook Mountain formation shows 10 feet of grayish-brown shale with small nodules of gypsum, overlying 6 inches of yellowish sand, and this in turn overlying 5 feet of brown argillaceous sand with lime nodules half an inch in diameter.

On Bonita Creek 25 feet above the bridge on the Jourdanton-Pleasanton road, 1½ miles southwest of Pleasanton, the Cook Mountain formation consists of 1 foot of brown clay, overlying 5 feet of light brown and green speckled argillaceous sand. About 200 feet below the bridge the sand is underlain by 1 foot of brown fossiliferous marl, which in turn overlies 1 foot of greenish-blue slightly sandy shale. Fossils identified by Cooke and Vaughan and listed under P on pages 64–65 were found in the fossiliferous marl.

In a cut on the Artesian Belt Railroad, about 1 mile south of Jourdanton, 3 feet of blue shale containing small lime concretions averaging an inch in diameter is exposed. At irregular intervals there are very hard, large fossiliferous limestone concretions, from 1 to 6 feet in diameter and from 6 inches to 2 feet thick. Fossils from these concretions are listed under Q on pages 64–65.

Section on Nueces River.—Beds of the Cook Mountain formation are exposed on Nueces River from a point 1½ miles east of the La Salle-Dimmit county line to a point about a quarter of a mile above the Holland dam, 10½ miles southeast of Cotulla.

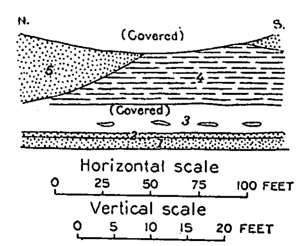


FIGURE 22.—Sketch showing relations of beds making up the bluff 200 feet above bridge at Dewees crossing on San Antonio River, 3 miles south-southwest of Poth, Wilson County, Tex.

On the Catarina-Cotulla road, 9 miles S. 79° W. of Cotulla, the beds of the Cook Mountain formation, in descending order, include 3½ feet of red ferruginous indurated sand, probably altered greensand, which weathers into red sandy loam soil; and blue sandy limestone concretions, 2 to 3 inches thick, in a matrix of red ferruginous indurated sand.

At a dam on Nueces River on the White farm, 5¾ miles west of Cotulla, a bed of the Cook Mountain formation, exposed in the north bank, consists of a bed of limestone concretions 2 feet thick, brown on exterior, blue on interior, and below this about 10 feet of blue indurated sand in layers 2 to 3 inches thick, with interbedded bands of white limy clay half an inch to an inch thick. The dip of the layers of sand is ½° S. 70° E.

At a creek crossing on the road from Cotulla to the E. A. Keck farm, 3 miles northwest of Cotulla, the Cook Mountain formation consists, in descending order, of 6 feet of brownish-yellow calcareous shell marl containing numerous fossil oyster shells and some indurated concretions of brown limestone 2 to 3 feet in diameter, 1 foot concealed, 10 feet of brown laminated ferruginous sand, and 1 foot of indurated calcareous sandstone concretions measuring about 6 inches by 4 feet. The brown sandstone dips ½° S. 20° W.

At the creek crossing on the road from Maltsberger ranch to Cotulla, 5 miles southwest of Cotulla, the Cook Mountain formation consists, in descending order, of 12 feet of massive indurated greensand which weathers into a dense red sand highly charged with iron; 25 feet of red ferruginous sandstone (altered glauconite; on fresh exposures near the top the sand is blue); and 6 feet of soft, red, poorly bedded ferruginous sandstone; altered greensand.

On the slope leading down to Harris Creek, 1¾ miles S. 20° W. from the Maltsberger ranch house, 8 miles southwest of Cotulla, the beds of the Cook Mountain formation, in descending order, include 18 inches of brown indurated sand; 6 inches of oyster shells in a matrix of brown marl; 7 feet of brown ferruginous indurated sand (probably altered greensand); and 1 foot of indurated brown irregularly bedded ferruginous sandstone in beds about 4 inches in thickness. These beds are about the same as those at the creek crossing 5 miles southwest of Cotulla.

The following section is exposed at the wagon bridge across Nueces River at Cotulla:

Section of Cook Mountain formation in north bluff on Nueces River at wagon bridge at Cotulla, Tex.

	Feet.
Brown limestone concretions, averaging 2 by 5 by 6 feet, in a matrix of red sand	4±
Hard blue limestone concretions with a band of fossils 4 inches thick, including specimens of *Turritella?* sp., *Ostrea* sp., and *Meretrix?* sp. These concretions lie in a matrix of red sand, and the largest measure 10 feet in diameter	4±
Red ferruginous sand (altered greensand)	2±
Hard limestone concretions, brown on outside, blue on inside, 1½ feet in thickness and 5 to 7 feet in diameter	1½
Brown ferruginous laminated to flaggy sand	13±
Hard sandy limestone concretions, blue on interior, brown on exterior, 1 foot in thickness and 3 to 4 feet in diameter	1±
Covered	3
Brown sand	1
Covered	4
Interlaminated shale and brown ferruginous sandstone; sandstone layers are half an inch to an inch thick	5±
Ferruginous brown sandstone	¼
Laminated porous yellow, slightly argillaceous sand.	4
	42¾±

These beds dip ½° S. 40° E.

On the old Cotulla-Laredo road, near the southeast corner of the J. M. Talbot tract (section 1676), 2 miles southwest of the wagon bridge at Cotulla, a thin lens of shell breccia containing *Ostrea* sp. crops out. This breccia overlies a foot of blue laminated sandy shale.

Hard blue calcareous sandstone concretions, encrusted with lime, in a matrix of red sand, form the cap rock of the hill on which the Cotulla courthouse stands. The stratigraphic position is about 16 feet higher than the topmost concretion in the section at the wagon bridge.

Fifteen feet of yellow-brown flaggy, irregularly bedded, soft sandstone is exposed on the Cotulla-Tilden road three-fourths of a mile east of the courthouse at Cotulla.

About 3½ miles S. 30° E. of Cotulla, on the W. J. Coleman tract, where an arroyo crosses the road to the Holland dam, hard blue sandy limestone concretions 1 foot thick and 5 to 8 feet in diameter, encrusted with a thick coating of lime, are exposed. These concretions weather brown on the exterior and are embedded in a matrix of weathered yellow sand. The entire section is about 15 feet thick.

Section of Cook Mountain formation exposed in terrace scarp on H. A. Beckwith tract 3¾ miles S. 25° E. from Cotulla, Tex.

	Feet.
Brown calcareous sandstone concretions, averaging 1 by 3 by 3 feet in size	1
Brown laminated sand	5
Gray sandstone	½
Bluish-white sandy shale	4
Soft yellow laminated sand	4
Ferruginous sand, alternate bands of red and yellow.	8
Gray sandstone	½
Dark-blue shale	4
	27

Hard brown fossiliferous rounded calcareous concretions, 1 to 2 feet in diameter, crop out on the Cotulla-Tilden road 1½ miles east of the courthouse at Cotulla. These concretions overlie 15 feet of ferruginous irregularly bedded sandstone exposed in a bluff on a creek about 500 feet to the west.

Section of Cook Mountain formation on slope to a creek 3½ miles S. 70° E. of Cotulla, Tex., on the Cotulla-Tilden road.

	Feet.
Yellow-brown, thinly stratified sandstone (altered greensand)	6
Laminated yellow sandy shale	2
Yellow-brown sandstone	6
Blue laminated sandy shale; weathers red	2
Brown indurated fossiliferous greensand containing specimens of *Meretrix* sp	6
	22

On the road from Cotulla to the Holland dam, on the J. H. Lieber tract, in a high bluff facing Poteet Lake, 4½ miles south-southeast of Cotulla, the component strata of the Cook Mountain formation are as follows:

Section of Cook Mountain formation in bluff facing Poteet Lake, 4½ miles south-southeast of Cotulla, Tex.

	Feet.
Brown sandy limestone concretions measuring 1 by 3 by 3 feet	1
Covered	4
Brown ferruginous laminated sand	½
Soft brown laminated ferruginous sand; blue on fresh surfaces	6
Very hard, highly fossiliferous limestone containing specimens of *Meretrix* sp	1
Soft yellow laminated calcareous sand containing a lens of hard brown fossiliferous limestone (altered glauconite) 2 feet thick and 15 feet long	9
	21½

The dip of the beds is about ½° S. 60° E.

On the Cotulla-Tilden road, 3 miles S. 70° E. of Cotulla, the Cook Mountain formation includes, in descending order, 6 feet of brown ferruginous fossiliferous sandstone, 7 feet of blue compact shale, 1 foot of brown hard sandstone concretions, and 2 feet of blue shale to creek flat.

At the junction of the Cotulla-Fort Ewell and the Cotulla-Tilden roads, about 4½ miles S. 70° E. of Cotulla, there is an outcrop of weathered red-brown sandy clay containing yellow manganese-stained limestone and fossiliferous limestone concretions. The fossils in the concretions include *Neverita arata* Gabb?, *Corbula deusseni* Gardner, and *Crassatellites antestriata* (Gabb)?, indicating a Claiborne horizon. Six feet of blue sandy shale, the topmost bed of the Cook Mountain formation in this section, is seen on the Cotulla-Tilden road 5½ miles S. 70° E. of Cotulla.

Section at Fowlerton.—In well No. 7 of Fowler Bros. Co., 1½ miles northwest of the post office at Fowlerton, the Cook Mountain formation was completely penetrated. The beds consist largely of fossiliferous clay and marl containing such characteristic Lower Claiborne Eocene species as *Phos texanus* Gabb, *Dentalium minutistriatum* Gabb, *Turritella nasuta* Gabb, *Corbula smithvillensis* Harris, *Corbula deusseni* Gardner, *Latirus moorei* (Gabb), and *Mesalia claibornensis* (Conrad) Harris. A detailed log of the well follows:

Log of Fowler Bros. Co.'s well No. 7 on section 16, tract 22, of the Naylor & Jones ranch, 1½ miles west-northwest of the post office at Fowlerton, La Salle County, Tex.

[Beds determined by J. M. Byers from the samples. Fossils identified by Cooke and Vaughan.]

	Thickness.	Depth.
Pleistocene terrace of Frio River:	*Feet.*	*Feet.*
Black sandy loam	20	20
Yellow sandy clay	20	40
Yegua formation:		
Variegated arenaceous blue, red, and yellow clay	20	60
Very stiff blue, red, and yellow clay	20	80
Very stiff blue, red, and yellow clay and shale containing lime concretions	20	100
Same as above, together with soft black shale	24	124
Fine-grained greenish-black water-bearing sand	10	134
Friable red, blue, yellow, black, and brown arenaceous shale and clay	96	230
Soft blue arenaceous limestone	6	236
Cook Mountain and Mount Selman formations:		
Soft blue arenaceous clay	10	246
Stiff blue slightly arenaceous clay	14	260
Soft blue arenaceous limestone	10	270
Soft friable variegated shale	23	293
Soft bluish-black clay, shale, and gravel	48	341
Dark-blue calcareous sandstone	1	342
Fine-grained greenish-black water-bearing sand; flows about 5 gallons a minute; water impotable and hard	31	373
Soft greenish-black arenaceous clay	25	398
Soft dark-blue fine-grained calcareous sandstone	2	400
Soft, friable black calcareous shale	5	405
Hard blue fine-grained calcareous sandstone	4	409
Friable black arenaceous, calcareous pyritiferous shale	35	444
Compact stiff blue fossiliferous arenaceous clay seamed with marl	23	467
Argillaceous, calcareous sand	13	480
Stiff blue clay containing many boulders; carries pyrites and flint	12	492
Calcareous sand	3	495
Fine-grained bluish-black water-bearing sand; flows about 10 gallons a minute; water salty and impotable; temperature of water 80° F	28	523
Stiff dark-blue clay	5	528
Greenish-black fossiliferous arenaceous clay	12	540
Layers of oyster shells at intervals of 2 feet	10	550
Greenish-black arenaceous pyritiferous clay	13	563

Log of Fowler Bros. Co.'s well No. 7 on section 16, tract 22, of the Naylor & Jones ranch, 1½ miles west-northwest of the post office at Fowlerton, La Salle County, Tex.—Continued.

	Thickness.	Depth.
Cook Mountain and Mount Selman formations—Continued.	*Feet.*	*Feet.*
Pyritic nodules and boulders	7	570
Greenish-black arenaceous pyritiferous clay	8	578
Soft compact black pyritiferous shale	7	585
Hard sandstone	1	586
Soft compact black fossiliferous shale and clay	25	611
Hard sandstone	2	613
Soft brittle black fossiliferous shale	21	634
Hard sandstone	2	636
Tough black fossiliferous clay and friable shale; 6 inches of hard rock at 700 feet	82	718
Tough black fossiliferous, slightly arenaceous clay and friable shale	21	739
Tough black fossiliferous, slightly arenaceous clay and friable shale containing *Terebra houstonia* Harris and *Phos texanus* Gabb	22	761
Tough black fossiliferous, slightly arenaceous clay and friable shale	21	782
Soft black fossiliferous calcareous, arenaceous clay and brittle shale containing *Terebra houstonia* Harris, *Terebra* sp., *Pleurotoma (Asthenotoma) terebriformis* Meyer, *Pleurotoma enstricrina* Harris, *Turricula (Conomitra)* sp., *Plejona petrosa* (Conrad), *Phos texanus* Gabb, *Mesalia claibornensis* (Conrad) Harris, *Neverita arata* Gabb, *Natica semilunata* Lea, *Dentalium minutistriatum* Gabb, *Corbula* sp., *Venericardia* sp	21	803
Soft black fossiliferous calcareous, arenaceous clay and brittle shale containing *Terebra texagyra* Harris, *Terebra houstonia* Harris, *Pleurotoma* (2 sp.), *Plejona petrosa* (Conrad), *Phos texanus* Gabb, *Natica semilunata* Lea, *Dentalium minutistriatum* Gabb, *Nucula* sp., *Corbula* sp., *Venericardia* sp., *Endopachys* sp., *Turritella nasuta* Gabb, *Natica* sp. (probably *N. semilunata* Lea), *Corbula smithvillensis* Harris, *Corbula deusseni* Gardner	20	823
Stiff black fossiliferous calcareous plastic clay, containing lumps of dark-green sand, pyrites, and lime nodules	66	889
Stiff black fossiliferous calcareous plastic clay, containing lumps of dark-green sand, pyrites, and lime nodules, with specimens of *Turritella* sp	21	910
Greenish-black stiff fossiliferous calcareous, arenaceous plastic clay containing lumps of marl, pyrites, and lime nodules	21	931
Bluish-black brittle fossiliferous calcareous, arenaceous shale, containing *Pleurotoma nodocarinata* Gabb, *P. (Drillia) texacona* Harris, *Plejona petrosa* (Conrad), *Pseudoliva vetusta* (Conrad), *Phos texanus*, *Turritella nasuta* Gabb, *Neverita arata* Gabb, *Sinum* sp., *Dentalium minutistriatum* Gabb, *Trinacria?* sp., *Corbula deusseni* Gardner, *Venericardia* sp	25	956
Greenish-black fossiliferous calcareous, arenaceous clay	4	960
Boulders	13	973
Greenish-black fossiliferous calcareous, slightly arenaceous stiff plastic clay	27	1,000
Brownish-black fossiliferous calcareous stiff plastic clay and several layers of arenaceous shale	20	1,020
Soft friable brownish-black fossiliferous calcareous shale containing *Pleurotoma nodocarinata* Gabb, *Pleurotoma enstricrina* Harris, *Cancellaria bastropensis* Harris var.? (occurs also at Moseleys Ferry), *Pyrula (Fusoficula) texana* Harris, *Turritella nasuta* Gabb, *Neverita arata* Gabb, *Dentalium minutistriatum* Gabb, *Trinacria?* sp., *Corbula smithvillensis* Harris, *Corbula deusseni* Gardner, *Venericardia* sp	15	1,035
Soft friable brownish-black calcareous fossiliferous shale	8	1,043
Hard brown very fine grained noncalcareous, slightly bituminous (?), fossiliferous, slightly glauconitic (?) sandstone concretions	7	1,050
Water-bearing friable brownish-black calcareous, fossiliferous, glauconitic, argillaceous sand containing *Balanophyllia* sp., *Terebra houstonia* Harris, *Pleurotoma* aff. *P. enstricrina* Harris, *Pleurotoma* cf. *P. nupera* Conrad, *Latirus moorei* (Gabb), *Mesalia claibornensis* (Conrad) Harris, *Sinum bilix* Conrad, *Nucula ovula* Lea?	68	1,118
Friable brownish-black calcareous, fossiliferous, glauconitic, argillaceous water-bearing sand containing *Terebra* sp. (young), *Pleurotoma* sp. (young), *Phos?* (young); *Pyramidella* sp. (young); *Turritella* sp. (young); *Neverita arata* Gabb (young); *Solariella?* sp. (young); *Cadulus* sp.; *Trinacria?* sp. (young); *Venericardia* sp. (young); the sand at 1,050–1,142 feet gives a 20-gallon flow of impotable salty water	24	1,142
Soft friable brown calcareous, arenaceous shale, with alternate layers of very tough compact blue shale	17	1,159
Tough blue calcareous, arenaceous clay with lumps of greensand and concretions of argillaceous limestone	24	1,183
Dark-brown calcareous, arenaceous shale; casing set on rock 1 foot thick	39	1,222
Tough black calcareous fossiliferous shale and green argillaceous sand	25	1,247
Stiff green calcareous, arenaceous clay and concretions of marcasite	13	1,260
Stiff green arenaceous clay	10	1,270
Green arenaceous shale; concretions of marcasite	24	1,294
Stiff blue arenaceous clay	16	1,310
Stiff green arenaceous glauconitic clay; sand occurs in seams and increases gradually in quantity toward water bed	90	1,400
Fine-grained glauconitic dark water-bearing sand; water salty and impotable; flow 40 gallons a minute in 1914; in January, 1914, static head was 65 feet and temperature 94° F	27	1,427

Log of Fowler Bros. Co.'s well No. 7 on section 16, tract 22, of the Naylor & Jones ranch, 1½ miles west-northwest of the post office at Fowlerton, La Salle County, Tex—Contd.

	Thickness.	Depth.
Cook Mountain and Mount Selman formations—Continued.	*Feet.*	*Feet.*
Stiff green arenaceous, glauconitic clay	5	1,432
Alternate layers of hard packed sand and brittle brown arenaceous shale	32	1,464
Stiff brown arenaceous clay; 2 inches of hard rock at 1,500 feet	68	1,532
Stiff brown shale and clay	14	1,546
Bluish-gray clay with seams of marl; concretions	14	1,560
Very tough shale	6	1,566
Friable black shale	20	1,586
Bluish-gray clay with seams of marl	23	1,609
Tough black lignitic shale; concretions	17	1,626
Friable black shale; concretions; 6 inches of rock at 1,643 feet	19	1,645
Friable black arenaceous, lignitic shale	25	1,670
Largely sand; water-bearing?	20	1,690
Blue, brown, and black lignitic shale	6	1,696
Black pyritiferous, arenaceous shale	11	1,707
Blue and black shale with pyrite and gravel	26	1,733
Blue and black shale; hard rock 2 inches thick at 1,750 feet	16	1,749
Blue and brown lignitiferous arenaceous shale	20	1,769
Tough brown clay seamed with marl	37	1,806
Very sandy, loose shale and concretions	9	1,815
Soft black arenaceous clay and marl	20	1,835
Medium hard rock	3	1,838
Soft black arenaceous clay and marl	14	1,852
Very tough brown shale	6	1,858
Friable black arenaceous shale	11	1,869
Soft rock	3	1,872
Carrizo sandstone:		
Fine-grained water-bearing gray sand; flow 217 gallons a minute; temperature 106.4° in March, 1914; water potable and soft	87	1,959

YEGUA FORMATION.[20]

Name.—In 1890 Penrose described a series of strata in the Coastal Plain of Texas that he called the "Fayette beds,"[21] a composite group that included lignite, clay, and sand at the base, sandstone in the center, and calcareous clay at the top. In 1892 Dumble differentiated the lower group of lignites, sands, and clays here considered and applied to it the name Yegua.[22]

Stratigraphic position.—The Yegua formation lies conformably above the Cook Mountain formation and beneath the Fayette sandstone.

Lithology.—The formation consists largely of dark-green clay, brown leaf-bearing and lignitic clay, yellow and dark sand, and lenticular beds of lignite. The clay contains masses, plates, and veins of selenite. Between the Brazos and the Guadalupe there are some beds of marine origin. South of the Guadalupe the palustrine strata are confined to the upper part of the formation, the lower part consisting largely of green selenite-bearing clays, dark sands, and beds of oyster shells, largely of marine origin.

Thickness and dip.—The thickness of the formation on the Brazos is 475 feet; on the Nueces, 1,049 feet. The dip on the Brazos is 54 feet to the mile; on the Nueces 48 feet to the mile.

Paleontology.—Marine fossils are not common in the formation. In southwest Texas the lower beds carry specimens of *Plejona* sp., *Corbula* sp., and *Ostrea alabamiensis* Lea. Fossil leaves are more or less common in the palustrine members of the formation. The species represented include *Anemia eocenica* Berry, *Arundo pseudogoepperti* Berry, *Coccolobis claibornensis* Berry, *Coccolobis columbianus* Berry, *Citrophyllum eocenicum* Berry, and *Thrinax eocenica* Berry. (See Pl. XXIII.)

Areal extent.—The formation outcrops in a belt of country that includes parts of Burleson, Lee, Fayette, Gonzales, Wilson, Atascosa, La Salle, and McMullen counties. (See map, Pl. VIII.)

Correlation.—The formation extends through eastern Texas into Louisiana. Its beds in Louisiana have been described as the "Cocksfield Ferry beds" by Vaughan and the "Cockfield member" by Veatch.[23]

The formation is approximately the time equivalent of the "Upper Claiborne," or the Gosport sand of Alabama.

[20] Partial synonymy of the Yegua formation:
Lufkin or Angelina County deposits, considered to be of Miocene age: Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 58-60, 1892.
Yegua division: Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, pp. 148-154, 1892.
Upper Lignitic (included the Yegua): Lerch, Otto, A preliminary report upon the hills of Louisiana: Louisiana Experiment Station Bull., 1893, pt. 2.
Cocksfield Ferry beds: Vaughan, T. W., The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, pp. 209-229, 1895.
Yegua clays: The Eocene Tertiary east of the Brazos River: Acad. Nat. Sci. Philadelphia Proc., pp. 99-108, 1895.
Cockfield member: Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 37-38, 1906.

[21] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47-58, 1890.

[22] Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, pp. 148-154, 1892.

[23] Vaughan, T. W., The stratigraphy of northwestern Louisiana: Am. Geologist, vol. 15, pp. 209-229, 1895. Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 37-38, 1906.

Section on Brazos River.—Beds belonging to the Yegua formation are exposed on the Brazos between the mouth of the Little Brazos and a point southwest of Wellborn, in Brazos County. The formation consists entirely, so far as is known, of palustrine and lignite-bearing deposits that contain no marine fossils.

Section in Burleson County.—In a shaft on the John Burch farm, about three-fourths of a mile west of Davidson switch and 6½ miles south-southeast of Caldwell, the Yegua formation, in descending order, consists of 10 feet of blue sulphurous shale, 8 feet of brown lignitic shale, 15 feet of blue sulphurous shale, and 3 feet of lignite, penetrated at the bottom of the shaft. A drill hole 18 feet deep was driven below the lignite and is said to have encountered other beds of lignite. The material passed through in the drill hole, aside from the lignite, is largely an even-textured clay.

The same succession of lignitic beds is said to have been struck in another shaft on Davidson Creek close to the Burch shaft. The lignite was reported to be 5 feet thick. A third shaft, on the opposite side of Davidson Creek, is said to have passed through 3 feet of lignite.

Greenish-gray clay, overlain by a few feet of yellow sand, is exposed on the Caldwell-Lyons road about 5 miles north-northwest of Lyons. The dip is ½° S. 60° E.

Section in Lee County.—The following exposures of the Yegua formation were noted in Lee County: At bluff crossing on West Yegua Creek about half a mile north of Loebau the Yegua formation, in descending order, is composed of 6 feet of blue clay with a few thin beds of sand, 8 feet of lignitic blue clay, 3 feet of porous gray sand, and 6 feet of lignitic shale.

Beds of sandy lignitic shale, dark-gray sandy lignitic clay, and sand containing leaf impressions are exposed on Nails Creek about 3 miles north of Giddings.

Red sand and sandstone, 10 feet thick, is exposed on a branch of Nails Creek, about 3 miles northeast of Giddings. On the opposite (north) side of the branch sandy lignitic shale, which underlies the red sands and sandstones, is exposed.

The section of the Yegua formation in the clay pit at the brick plant a quarter of a mile northwest of Giddings, in descending order, shows 3 feet of sandy clay, slightly lignitic, 1 foot of soft porous sand, 2 feet of yellow clay, 1 foot of white sandy clay, 2 feet of lignitic shale, and 2 feet of sandy clay.

On the west side of the San Antonio & Aransas Pass Railway about 1½ miles south of Giddings the Yegua formation, in descending order, includes 4 feet of sandy gray shale, 6 inches of hard ferruginous sandstone, 6 feet of porous gray sand, 6 inches of hard ferruginous sandstone, 8 feet of gray sandy shale, and 15 feet of lignitic shale. The upper hard ferruginous sandstone dips 2° S. 30° E.

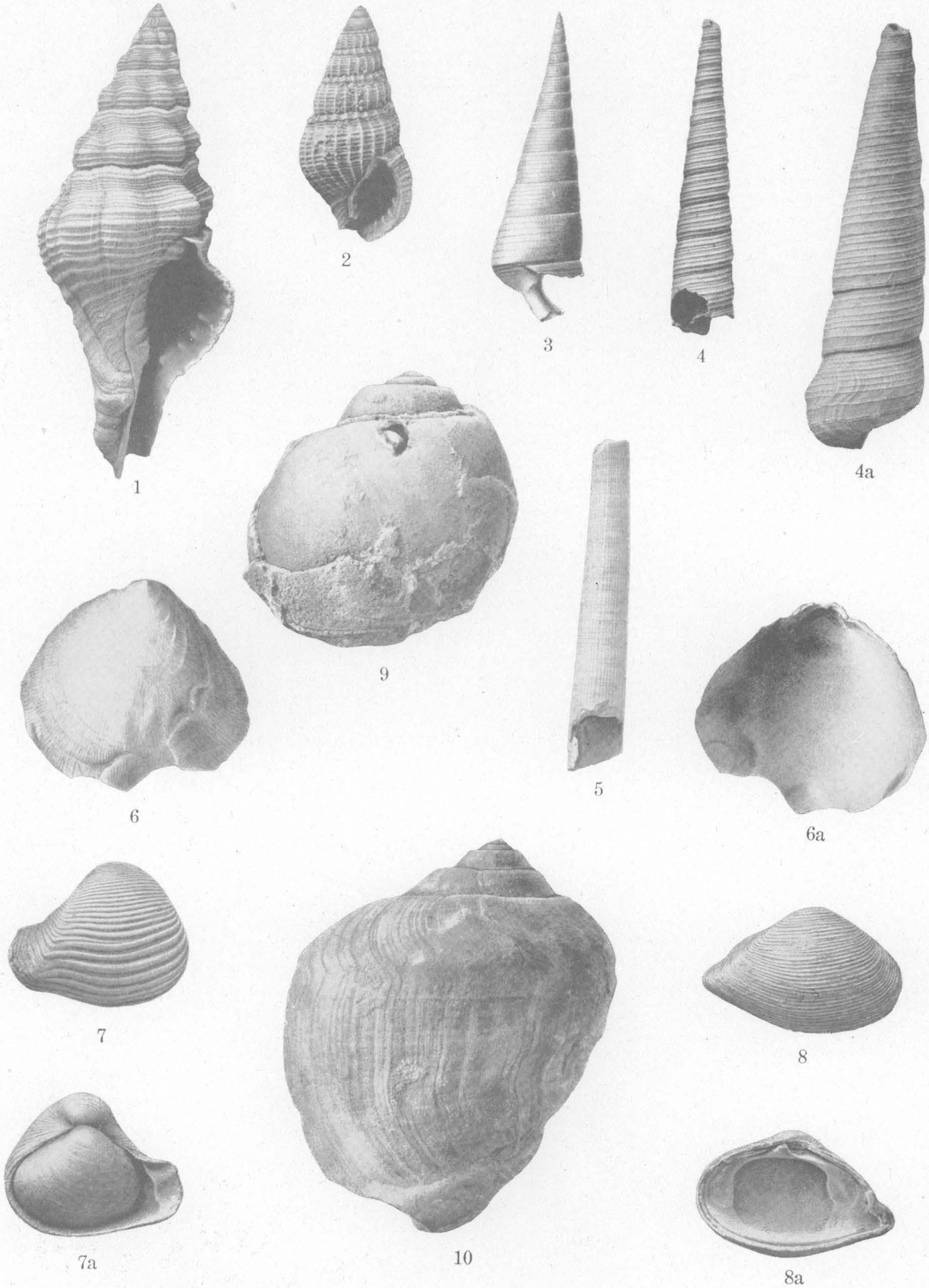
Lignitic shale dipping 2° SE. is exposed where the Giddings-Serbin road crosses Rabbs Creek, 3 miles south-southwest of Giddings. A quarter of a mile downstream, at the bridge of the San Antonio & Aransas Pass Railway, lignitic shale containing flakes of selenite is exposed. Lignite interbedded with lignitic shale is exposed 100 yards below the San Antonio & Aransas Pass Railway bridge.

Forty feet of brown lignitic shale with flakes of selenite is exposed on Rabbs Creek 5 miles south of Giddings.

Twelve feet of white sand is exposed on a branch of Rabbs Creek, about 4 miles south of Giddings and 1 mile above the mouth of the creek.

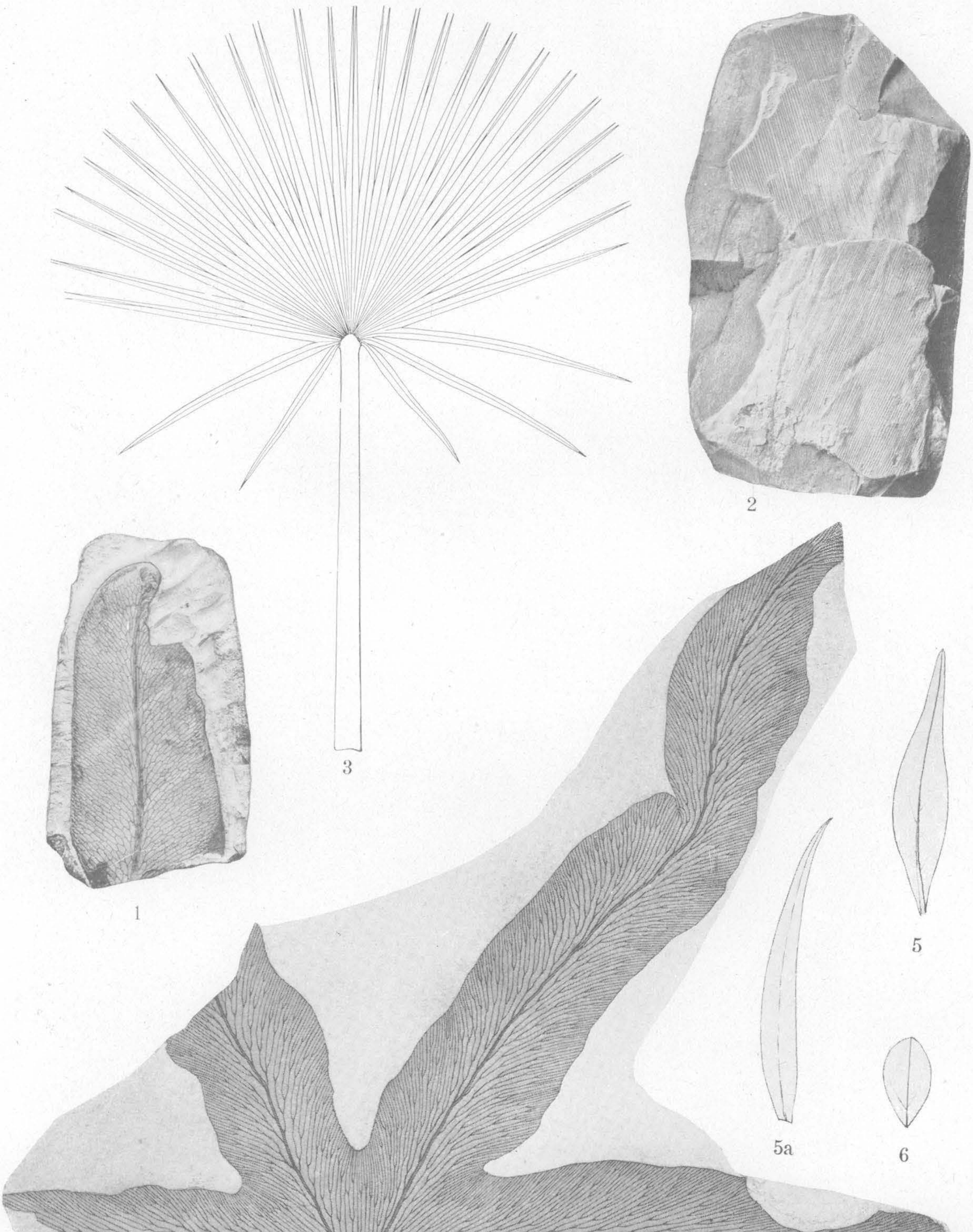
Eight feet of lignitic sand is exposed on Rabbs Creek about 1 mile above the Lee-Fayette county line. Fifteen feet of dark sandy lignitic clay is exposed on Rabbs Creek a quarter of a mile above the Lee-Fayette county line. Fifteen feet of porous yellow sand is exposed on Rabbs Creek at the La Grange-Giddings road crossing, about a mile below the Fayette-Lee county line, in Fayette County. Porous yellow sand with thin yellow partings of iron is exposed half a mile below this crossing.

Section in Fayette County.—On Rabbs Creek, 1½ miles below the La Grange-Giddings road crossing and about 1¼ miles east of Warda, Fayette County, the Yegua formation includes 10 feet of dark sandy clay, 6 inches of red ferruginous sandstone, 8 feet of dark sandy clay with gypsum, and 10 feet of bluish-yellow porous sandstone.



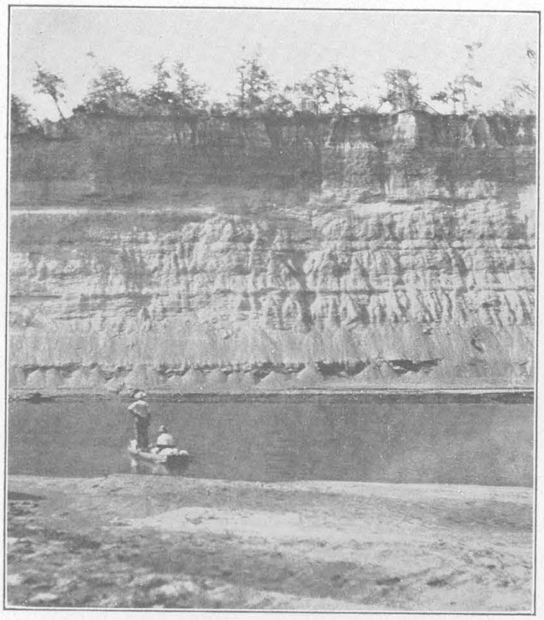
CHARACTERISTIC FOSSILS OF THE COOK MOUNTAIN FORMATION.

1. *Latirus moorei* (Gabb).
2. *Phos texanus* Gabb.
3. *Mesalia claibornensis* Conrad.
4. *Turritella nasuta* Gabb.
4a. *Turritella nasuta* subsp. *houstonia* Harris.
5. *Dentalium minutistriatum* Gabb.
6, 6a. *Anomia ephippioides* Gabb.
7, 7a. *Corbula smithvillensis* Harris.
8, 8a. *Corbula deusseni* Gardner n. sp. (For description see p. 65.)
9. *Natica dumblei* Heilprin.
10. *Lacinia alveata* Conrad.



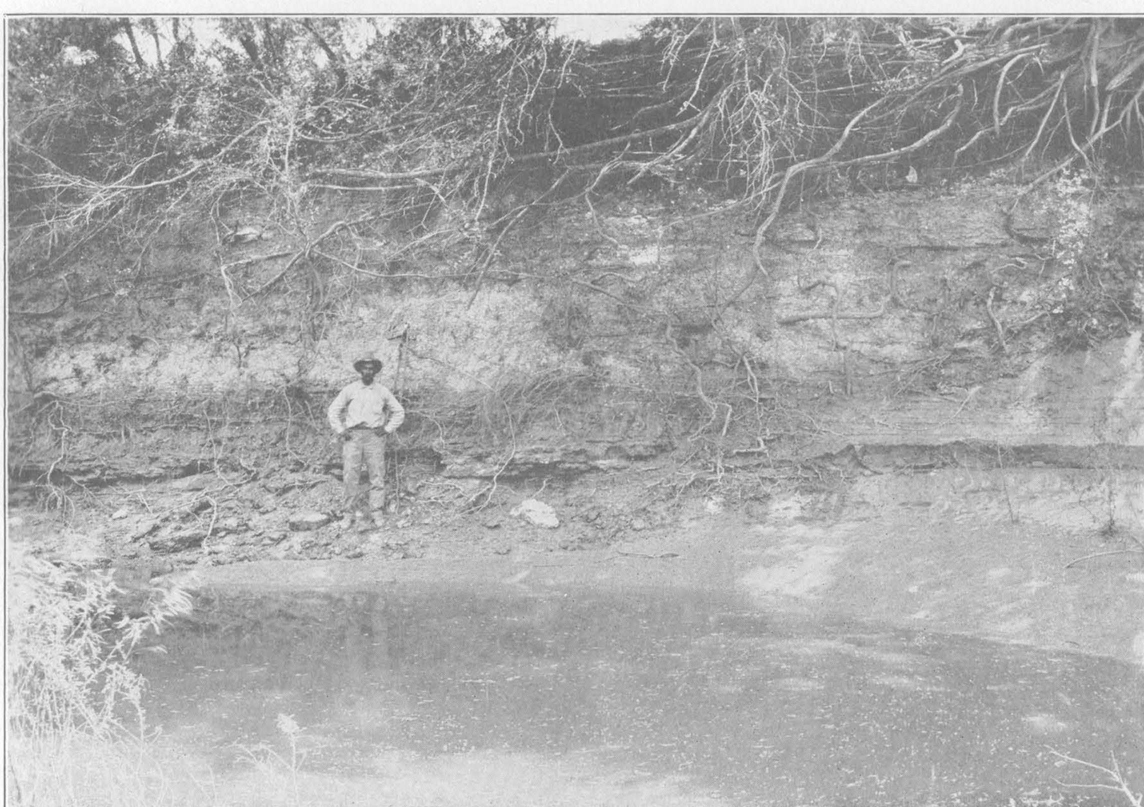
FOSSIL LEAVES OF THE YEGUA FORMATION.

1. *Acrostichum georgianum* Berry.
2. *Arundo pseudogoepperti* Berry.
3. *Thrinax eocenica* Berry.
4. *Lygodium kaulfussi* Heer.
5, 5a. *Sapindus georgiana* Berry.
6. *Pisonia claibornensis* Berry.



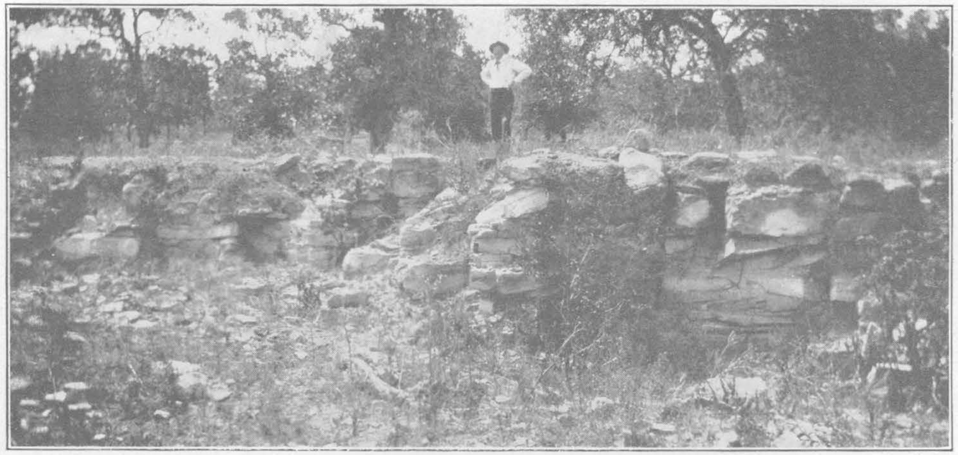
A. BLUFF ON COLORADO RIVER, 2½ MILES WEST OF WEST POINT, FAYETTE COUNTY, TEX.

B. MIDDLE FALLS IN ABANDONED GORGE OF SAN ANTONIO RIVER, ABOUT 2 MILES ABOVE WAGON BRIDGE AT FALLS CITY, KARNES COUNTY, TEX.

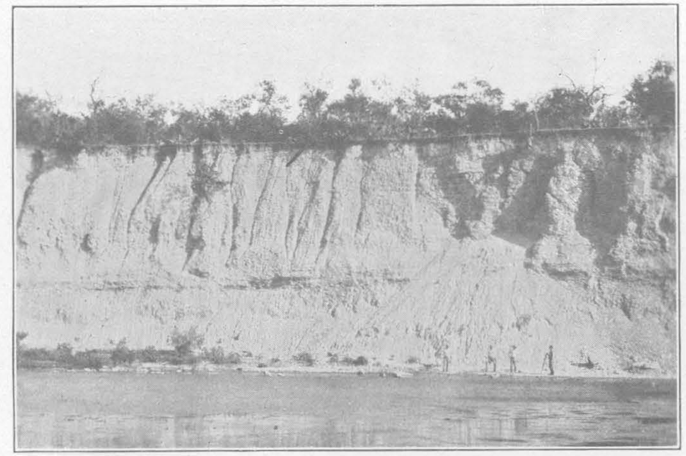


C. HOLLAND DAM ON NUECES RIVER, 10½ MILES SOUTHEAST OF COTULLA LA SALLE COUNTY, TEX.

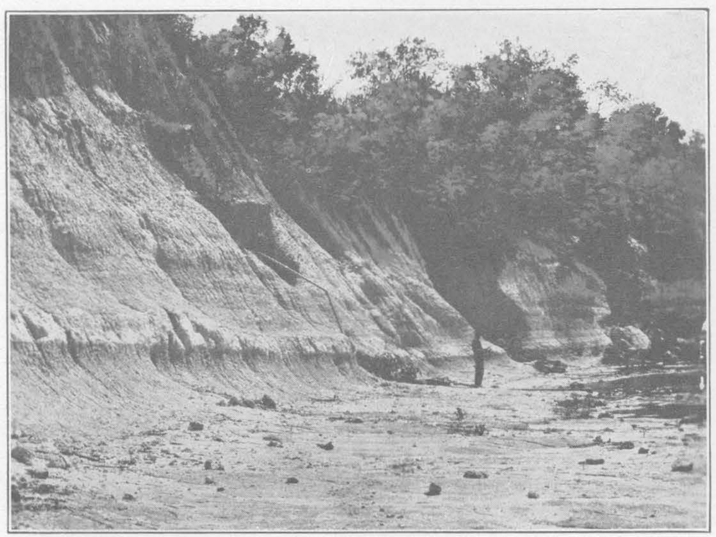
CHARACTERISTIC EXPOSURES OF THE YEGUA FORMATION.



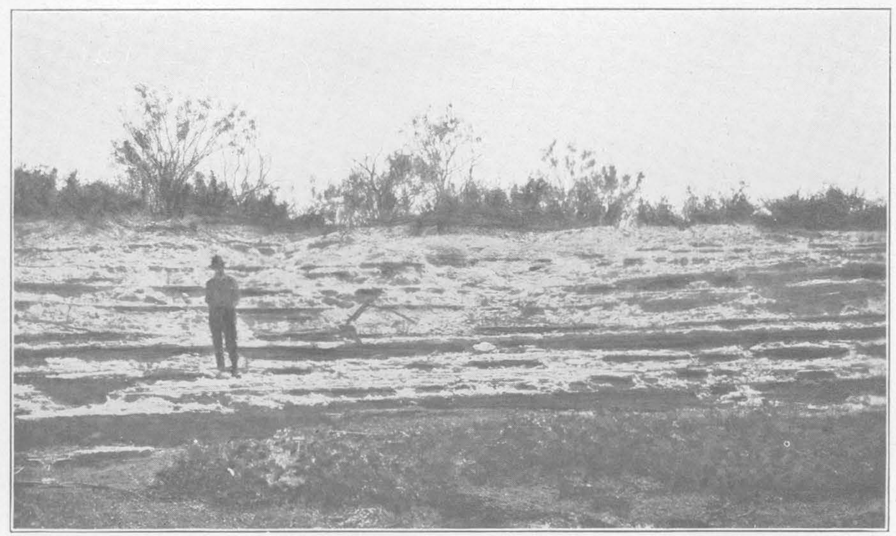
A. QUARRY IN HARD BLUE SEMIQUARTZITIC SANDSTONE OF THE FAYETTE SANDSTONE ABOUT 3½ MILES SOUTH OF WEST POINT, FAYETTE COUNTY, TEX.



B. BROWN SHALE OR FULLER'S EARTH (?) IN THE FAYETTE SANDSTONE EXPOSED AT CONQUIESTA CROSSING, ON SAN ANTONIO RIVER, ABOUT 4 MILES WEST OF FALLS CITY, KARNES COUNTY, TEX.



C. FRIO CLAY EXPOSED ON SAN ANTONIO RIVER ABOUT THREE-FOURTHS OF A MILE ABOVE BRIDGE ON ROAD BETWEEN PANNA MARIA AND KARNES CITY, KARNES COUNTY, TEX.



D. FRIO CLAY EXPOSED ON SAN CRISTOBAL CREEK, ABOUT 11 MILES NORTH-NORTHWEST OF OAKVILLE, LIVE OAK COUNTY, TEX.

Section of Yegua formation on Owl (?) Creek, 1½ miles east of Warda, Tex.

	Ft.	in.
Lignitic brown clay	10	
Hard dark clay	6	
Porous gray sand		6
Light-colored clay	5	
Gypsum		½
Brown sandy clay	3	6
Soft lignitic sand	6	
Lignite		6
Hard dark lignitic sand	6	
	37	6½

The beds dip 2° S. 20° E.

The upper beds of the Yegua formation, corresponding with those just given, also appear on Greens Creek, about half a mile north of the Fayette-Lee county line and about 7 miles south-southeast of Giddings.

Section on Colorado River.—On Colorado River the Yegua formation is exposed from a point 2 miles below the Fayette-Bastrop county line to a point 3 miles northwest of La Grange.

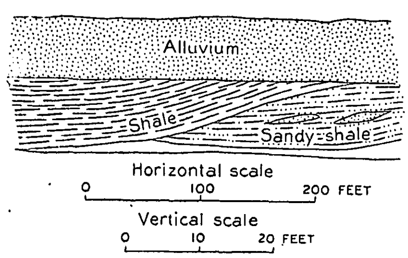


FIGURE 23.—Sketch showing relation of the beds in bluff on Colorado River 2 miles below the Fayette-Bastrop county line in Fayette County, Tex.

Laminated lignitic shale, 10 feet thick, is exposed on Colorado River 2 miles below the Fayette-Bastrop county line in Fayette County. The beds are gently undulating. The dip is 1° S. 22° E. About 100 yards below this point a lens of sandy shale containing concretions of sandstone lies below the shale. (See fig. 23.)

On Colorado River at the mouth of Cedar Creek, 2½ miles west of West Point, the Yegua formation in descending order shows 12 feet of blue shale, 2 feet of sandy shale, 7 feet of lignitic shale, 2 feet of brown shale, and 40 feet of brown sandy shale containing a 2-foot bed of lignite. (See Pl. XXIV, *A*.) The beds dip 1° N. 50° E.

At the San Antonio & Aransas Pass Railway bridge on Colorado River, 2½ miles north of West Point, the Yegua formation shows 12 feet of blue sand with irregular discontinuous laminae of clay half an inch thick, 5 feet unexposed, 2 feet of blue clay with concretions of ferruginous sandstone 1 foot thick and 3 to 4 feet long. The beds dip 2° S. 80° E. A quarter of a mile downstream 12 feet of gray sand, with clay partings 1 to 2 inches thick, are exposed. The beds seen at the railroad bridge dip beneath this sand.

On Colorado River, 2 miles east of West Point, the Yegua formation shows 1 foot of sand, 2 inches of lignitic shale, 8 inches of sand, 1 foot of blue lignitic shale, 2 feet 6 inches of sand, and 6 feet of blue lignitic shale. The beds dip gently downstream.

On Colorado River, about 1½ miles north of Plum, there is exposed 18 feet of laminated black lignitic clay dipping about 2° N. 50° E. This clay is a member of the Yegua formation.

Section of Yegua formation on Colorado River half a mile below the mouth of Rabbs Creek, about 3½ miles northwest of La Grange.

	Feet.
Blue clay; weathers brown	15
Friable white sand	1
Blue clay; weathers brown	10
Friable white sand	1
Blue sulphurous clay	10
Brown clay	3
Friable white sand	1
Blue clay; weathers brown	8±
Friable white sand	1 (?)
Laminated blue and brown sandy clay	10
Blue clay with black leaf impressions	1
Lignite	1
Blue clay with leaf impressions	12
Lignite	1
Blue clay	3
Covered	6
Lignite	1
Blue clay	6
Black lignitic clay	6
	97

The beds dip 1° S. 25° E.

The leaves listed below were collected from beds of this section:

Fossil leaves from bluff on Colorado River, half a mile below the mouth of Rabbs Creek, Fayette County, Tex.

[Identifications by Edward W. Berry.]

	A	B	C	D
Anemia eocenica Berry	×			×
Arundo pseudogoepperti Berry	×	×		
Coccolobis claibornensis Berry		×		
Coccolobis columbianus Berry		×		
Citrophyllum eocenicum Berry		×		
Ficus sp. (fruit) new sp.				
Oreodaphne obtusifolia Berry			×	×
Thrinax eocenica Berry (?)		×		

A. Occurs in the Yegua formation at other places.
B. Occurs in the Yegua formation in Louisiana and in its stratigraphic equivalents in States to the east.
C. Occurs also in the Jackson formation.
D. Occurs also in the Wilcox deposits.

The upper Claiborne or Yegua age of the beds at this locality would thus seem to be indicated. The stratigraphic position of the several exposures on Colorado River is shown graphically in Plate IX (in pocket).

Section in Gonzales County.—The following exposures of the Yegua formation were noted in Gonzales County:

Near the Galveston, Harrisburg & San Antonio Railway, about 2 miles east of Nixon, the beds of the Yegua (?) formation include 2 feet of red sandy clay, 18 inches of brown indurated sand, and 2 feet of brown sandy shale with calcareous nodules. About 300 feet east of this place another exposure shows 5 feet of green calcareous shale containing fossiliferous concretions of limonite 4 to 6 inches in diameter. This shale overlies the red sandy clay noted above. The fossils are too poorly preserved to admit of identification.

Yellow fossiliferous sandstone concretions crop out on the Nixon-Smiley road about 4 miles east of Nixon and about a quarter of a mile east of the crossing of the Galveston, Harrisburg & San Antonio Railway. The concretions carry specimens of *Plejona* sp., *Tellina mooreana* Gabb? and *Corbula* sp.

Three feet of blue clay containing masses of selenite 2 to 6 inches in diameter and 2 inches thick are exposed on the Nixon-Smiley road about 3 miles west of Smiley.

A well at Smiley belonging to V. B. Colley, 1,465 feet deep, is said to have penetrated a bed of lignite 4 feet thick at a depth of 250 feet. This lignite probably lies at the same horizon as that exposed 2½ miles west of West Point; at the San Antonio & Aransas Pass Railway bridge on Rabbs Creek; and in the shaft on the Burch place 6½ miles south-southeast of Caldwell. It is in the lower part of the Yegua formation.

Six feet of yellow and red mottled sandy clay is exposed in the bluff fronting Elk Creek 3 miles southwest of Smiley, and this clay is underlain by green shale with calcareous nodules in a roadside gully 1 mile southwest of Smiley.

Two feet of ferruginous yellow sand is exposed on a small branch leading into Elm Fork about an eighth of a mile east of Smiley.

Four to five feet of green shale with iron concretions is exposed on a small branch crossing the Smiley-Sample road about half a mile east of Smiley.

Section on San Antonio River.—The Yegua formation is exposed on San Antonio River from a point 4 miles south of Poth, in Wilson County, to the Wilson-Karnes county line.

On San Antonio River, about 1,000 feet below the crossing 4 miles south of Poth, the Yegua (?) formation consists of 15 to 20 feet of fossiliferous brown clay (fossils too poorly preserved for identification); 10 feet of bluish gray plastic shale; and a lens of yellow indurated sand, 10 feet thick, which appears at the south end of the bluff only.

At the falls of San Antonio River, 2 miles above the wagon bridge at Falls City, Karnes County, the Yegua formation in the river bluff and in the bed of an abandoned channel of the river shows 6 inches of a white bed largely made up of silicified plant remains (?); 1 foot of gray shale with organic matter (stump 8 inches in diameter and 1 foot high standing erect); 2 feet of a white bed largely composed of silicified plant remains; 2 feet of yellow indurated sand; 6 feet of reddish-brown sandy shale; 2 feet of hard gray leaf-bearing sandy shale; 1 foot of blue sandy shale; 3 feet of light-gray sandy shale; 5 inches of moderately hard brown lignitic shale; and 4 feet of compact green lignitic shale. The strike of the beds is S. 40° W. and the dip SE. 132 feet to the mile. (See Pl. XXIV, *B*.)

Section in Atascosa County.—In the banks of a small creek at Christine there is exposed 3 feet of mottled blue, yellow, and white sandy clay; the mottling is due to weathering.

A bed of lignite 8 feet thick was struck at a depth of 60 feet in a well at the ranch house of Emmanuel Tom on Matate Creek, 3 miles west of Campbellton. A number of prospect holes show 8 to 13 feet of lignite in this vicinity.

Section on San Miguel Creek.—On San Miguel Creek, 8½ miles north of Tilden, the Yegua formation consists of 8 feet of yellow calcareous clay with concretions 2 to 3 feet in diameter and 10 feet of lignite with interstratified layers of bituminous shale or "bone." The dip of the lignite is 1½° S. 77° E. A section of the bed of lignite, as exposed in a shaft adjacent to the creek, is shown in figure 24.

On San Miguel Creek, 8 miles east-northeast of Tilden and 700 feet above the crossing of the Crowther-Tilden road in McMullen County, the Yegua formation includes 8 feet 8 inches of brown lignitic shale, 2 feet of brown shale, 1 foot of brown lignitic shale, 5 feet of gray-brown sandy shale with plant remains, and 3 feet 6 inches of brown slightly sandy shale with plant remains.

Section near Tilden.—The character of the beds near Tilden is indicated in the following well log:

Log of well No. 1 of Bowling Green-Texas Oil & Gas Co., 8 miles east-northeast of Tilden, Tex.

	Thickness.	Depth.
Quaternary:	*Feet.*	*Feet.*
Black earth	25	25
Fayette sandstone:		
Soapstone and clay	200	225
Green sandrock, dry	3	228
Soapstone and clay	82	310
Lignite	2	312
Soapstone and clay	23	335
Green sandrock, dry	3	338
Soapstone and clay	62	400
Lignite and shells	40	440
Soapstone and clay	40	480
Yegua formation:		
Dark shale	35	515
Solid lignite	8	523
Shale and lignite	17	540
Seashell rock	1	541
Shale and lignite	13	554
Green sandrock, dry	9	563
Green sandrock; salt water; some gas	57	620
Soapstone and clay	15	635
Green sandrock; salt water; much gas	90	725
Brown clay	53	778
Quicksand, dry	12	790
Brown clay, quite sandy	115	905
Soapstone, white	21	926
Sandstone; flow of water almost fresh	9	935
Brown clay, sandy	10	945

The lignite between 515 and 554 feet lies at the same horizon as that exposed on San Miguel Creek, 8½ miles north of Tilden; on the Tom Ranch, 3 miles west of Campbellton; on San Antonio River, 2 miles above the wagon bridge at Falls City; on Colorado River, half a mile below the mouth of Rabbs Creek; at a point 7 miles south-southeast of Giddings; and on Owl Creek 1½ miles east of old Warda, in Fayette County. These beds occur in the upper part of the Yegua formation.

Section on Frio River.—The Yegua formation is exposed along Frio River from a point 8 miles northwest of Fowlerton to a point 2½ miles west-southwest of Tilden. The exposures are largely obscured by Quaternary silt and gravel, which occupy most of the valley.

On the San Antonio, Uvalde & Gulf Railroad, 1½ miles east of Dull, there is exposed 4 feet of green plastic shale with rounded yellow limestone concretions, 2 to 10 inches in diameter, and small masses of gypsum.

Five miles east-southeast of Fowlerton the Yegua formation shows 15 feet of greenish-gray calcareous sandy shale.

Twenty-five feet of green calcareous, slightly sandy shale is exposed on the Tilden-Fowlerton road about 5 miles southwest of Tilden.

Six miles southwest of Tilden, on the Tilden-Fowlerton road, the upland is capped by 1 foot of gray sandstone overlying a green shale.

Section on Nueces River.—Along Nueces River beds belonging to the Yegua formation are successively crossed in ascending order from a point about a quarter of a mile above

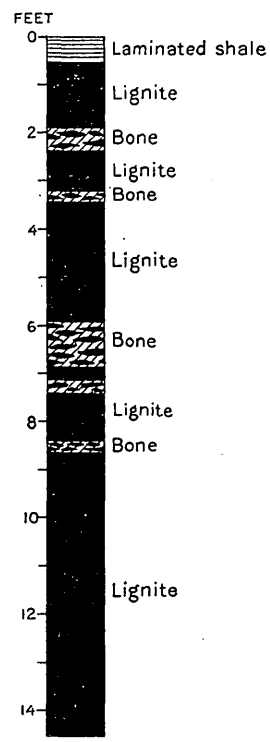


FIGURE 24.—Section of lignite bed exposed in shaft on San Miguel Creek, 8 miles east-northeast of Tilden, Tex.

the Holland dam, 10½ miles southeast of Cotulla, to a point about 1½ miles west of the McMullen county line.

The basal beds of the Yegua formation, which consist of 2 feet of green shale with lime nodules overlying 2 feet of brown shale that carries brown sandstone concretions, are exposed on the Cotulla-Tilden road 7⅓ miles east-southeast of Cotulla.

Next in ascending order are the beds exposed at the Holland dam on Nueces River, 10½ miles southeast of Cotulla. (See Pl. XXIV, *C.*) These beds consist of 8 feet of laminated blue argillaceous sands with bands of brown sand ranging from 1 inch to 1 foot in thickness, 1 foot of brown sand, 1 foot of yellow calcareous sand, and 3 feet of blue massive argillaceous sand.

At the crossing on Altito Creek, on the Cotulla-Tilden road 8¼ miles east of Cotulla, 4 feet of greenish-gray weathered calcareous shale is exposed. About 1,000 feet west of the crossing washes along the road expose 6 feet of weathered dark-green sandy shale.

A whitish-gray compact noncalcareous, argillaceous sandstone crops out on the prairie beneath a thin coat of soil on the Matthew Cartwright ranch, section 226 (?), about 14 miles southeast of Cotulla.

At the site of old Fort Ewell, 23 miles southeast of Cotulla, 2 feet of green shale with small lime nodules is exposed. The shale weathersto red.

A bed of fossil oyster shells occurs 2 miles north-northeast of the old Mexican village of Guahuco, 21½ miles southeast of Cotulla.

An excavation for a small storage reservoir has been made near the road from the Dobie to the Camerone ranch, 6 miles east of old Fort Ewell. The material excavated is a yellow sandy clay, the original color of which is blue.

FAYETTE SANDSTONE.[24]

Name.—Penrose in 1890 published the following description of what he called the "Fayette beds": [25]

They consist of a series of clays and sands, very characteristic in their color, mode of occurrence, and associations, and are easily distinguished from any other beds in the Tertiary series of Texas. They include all those beds found on the Brazos, Colorado, and Rio Grande which lie between the uppermost fossiliferous strata of the marine Tertiary (Cook's Mountain) below and the post-Tertiary clays, limestones, and pebbles above. Above the uppermost of the marine Tertiary already described, on the Brazos and Colorado rivers, occurs a series of clay and sandy strata, the clay rapidly becoming more and more predominant as we go up the series until the beds are composed almost exclusively of it. Then again the sandy beds suddenly assume predominance and extend upward to the post-Tertiary beds. The lower or clayey part of the series composes a little over half of the formation, and the sandy beds compose the rest.

These beds represent the "Grand Gulf" series of Hilgard's Mississippi section.

Dumble in 1892 separated Penrose's "Fayette beds" into two parts. The lower part, consisting of clay, he called the Yegua division, and the upper part, consisting of sandstone, he called the Fayette division.[26]

The formation was minutely defined by Dumble in 1903 as follows: [27]

This name (Fayette sands) was originally used by Penrose for the entire series of deposits between the top of the Marine (Cook's Mountain) beds and the base of the Coast clays. Investigation shows that this would embrace deposits of different ages, and the name is here used with restricted significance for that subdivision of the Tertiary to which it is most applicable. Some confusion has arisen from the fact that two somewhat similar beds of sands occur in the Texas area, separated by a band of clays of variable thickness, so that, at times, we may pass from one to the other without noticing the change. The lower of these sandstones is the Fayette sands, as here described, and is of lower Claiborne age, while the upper, which will also be described in the following pages, under the name of Oakville beds, is shown by its fossils to belong to the Miocene.

The name Fayette is used in this report with the significance given it by Dumble in the quotation cited. However, as will be shown later, the deposits are not of lower Claiborne age but of Jackson age.

The name is derived from that of Fayette County, Tex., where the beds are typically exposed.

Stratigraphic position.—In the region west of Brazos River the Fayette sandstone lies conformably above the Yegua formation, but in eastern Texas and western Louisiana it

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[24] Partial synonymy of the Fayette sandstone:

Fayette beds [included the Yegua, Fayette, Frio, Oakville, Lapara, and Lagarto formations]: Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47-58, 1890.

Fayette division: Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, pp. 154-157, 1892.

Fayette sands [included the Catahoula of east Texas]: Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 60-62, 113-116, 1892.

Wellborn beds: Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., pp. 45-46, 1893.

Fayette sands [included the Catahoula of east Texas]: Kennedy, William, The Eocene Tertiary of Texas east of the Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, pp. 95-99.

Grand Gulf [included the Fayette]: Veatch, A. C., The geography and geology of the Sabine River, Louisiana Geol. Survey, pp. 132-134, 141, 1902.

Fayette sands [included the Catahoula of east Texas]: Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 21-23, 42-61, 1903.

Fayette sands: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 32-40, 1903.

Catahoula formation [included the Fayette]: Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 42-43, 1906.

Catahoula sandstone [included the Fayette]: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 68-72, 1914.

[25] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., p. 47, 1890.

[26] Dumble, E. T., Report on the brown coal and lignite of Texas Texas Geol. Survey, pp. 148-154, 1892.

[27] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min Eng. Trans. Vol. 33, p. 32, 1903.

lies above the Jackson formation. West of Colorado River it is overlain conformably by the Frio clay, but east of Colorado River it is conformably overlain by the Catahoula sandstone.

Lithology.—The formation is made up of gray sandstone and sand, brown and chocolate-colored clay, and lignitic clay and lignite. The sandstone is at some places flaggy, at others massive. It contains large quantities of silicified and opalized wood, and in some localities it is fossiliferous. The texture of the sand and sandstone is generally coarse, and the grains are either angular or rounded. In certain areas the beds of sandstone are cemented with an opaline matrix into zones of very hard blue quartzite, which is quarried. The lignite is usually impure and of low grade. Beds of volcanic ash, which are in places leaf-bearing, are interstratified with the clay and lignite. The clay is in some beds white, resembling kaolin, but burning tests show that it can not be used for making white ware unless it is mixed with large quantities of foreign clay. Some of the clay may be classed as fuller's earth, having been successfully utilized for this purpose.

The lithologic aspect of the Fayette sandstone is in some respects similar to that of the overlying Oakville and Catahoula sandstones, and because of this resemblance they are difficult to discriminate and have often been confused, the Oakville having been mapped with the Fayette, and the Fayette with the Catahoula.

The quartzite of the Oakville and the Catahoula formations resembles the quartzite of the Fayette, and the beds of gray sandstone of the Catahoula that contain silicified and opalized wood bear a striking resemblance to certain beds in the Fayette that have a similar content. The Fayette, however, is much less calcareous than the Oakville and is at most places separated from it by a bed of clay—the Frio clay. The Oakville does not contain the chocolate-colored clay, the lignite, and the fuller's earth found in the Fayette.

In eastern Texas the Fayette becomes thinner, and it finally disappears completely before it reaches central Louisiana. It contains no lime, and it is separated from the overlying Catahoula by no bed of clay. The only lithologic differences appear to be the presence of chocolate-colored clay and lignite and of invertebrate-bearing sandstone. The boundary line between the two formations must therefore be so drawn as to exclude these index beds from the Catahoula. As the Fayette of western Louisiana and eastern Texas is very thin and lies immediately beneath the Catahoula, it has at times been mapped with that formation and the Catahoula has been mapped with the Fayette.

Thickness and dip.—The thickness of the formation on the Brazos is 560 feet, on the Colorado about 700 feet, and on the Nueces 480 feet. The dip on the Brazos is 53 feet to the mile and on the Nueces 48 feet to the mile.

Topographic expression.—The Fayette sandstone makes itself known by low hills and westward-facing scarps capped by the hard sandstone and quartzitic members. In this respect the topographic expression of the formation is entirely different from that of the Yegua formation on the northwest or the Frio clay on the southeast.

Paleontology.—The invertebrate fossils are scarce and generally very poorly preserved. The formation is much more fossiliferous in the southwestern part of its area than it is in the vicinity of the Brazos.

Paleontology of the Fayette sandstone.

Invertebrates.

Tellina eburniopsis Conrad and *Cytherea discoidalis* characterize the lower portion of the Fayette in central Texas, and *Ostrea georgiana* Conrad is exceedingly abundant in the middle and upper Fayette of southwest Texas.

Vertebrates.

Carcharodon auriculatus (Blainville) near the bottom of the formation. Ranges from Middle Eocene through Pliocene.

Plants.

Sabalites vicksburgensis Berry, from middle of the formation on Hamilton league, Fayette County, Tex. Also found at Chalk Hills, La., and near Pulliam, Tex., in strata of upper Vicksburg and lower Claiborne or Wilcox ages, respectively.

Calocarpum viridiformis Berry, from middle of formation on Hamilton league, Fayette County, Tex. Also found 4 miles northwest of Hornbeck, La., in strata of lower Catahoula or Jackson age.

Pisonia jacksoniana Berry, from lower part of formation near Plum, Fayette County, Tex. Also found at White Bluff, Ark., in strata of early Jackson age.

Burserites catahoulensis Berry, from strata north of Hornbeck, La. Also found at Harmons Creek, Walker County, Tex., in strata of late Jackson or early Vicksburg age, and at Stryker, Polk County, Tex., in strata of Vicksburg? age.

Cedrela jacksoniana Berry, from strata north of Hornbeck, La. Also found at White Bluff, Ark., in strata of early Jackson age, and at Stryker, Polk County, Tex., in strata of Vicksburg? age.

Bombacites jacksonensis Berry, from middle of the formation near Somerville, Tex. Also found near Christie, La., and near Miraflores, Webb County, Tex., in strata of Jackson age.

Conocarpus eocenica Berry, from strata near Miraflores, Webb County, Tex. Also found near Christie, La., in strata of Jackson age.

Terminalia phaeocarpoides Berry, from strata near Miraflores, Webb County, Tex. Also found near Christie, La., in strata of Jackson age.

Dryophyllum brevipetiolatum Berry, from Trinity County, Tex. Also found 4 miles northwest of Hornbeck, La., in strata of Jackson age.

Sapindus georgiana elongata var. nov., from strata near Miraflores, Webb County, Tex. Also found 4 miles northwest of Hornbeck, La., in strata of Jackson age.

Areal extent.—The outcrop of the formation is coextensive with the belt of country already described as the Wellborn plain. It occupies parts of Burleson, Washington, Lee, Fayette, Gonzales, Wilson, Karnes, Atascosa, Live Oak, McMullen, and La Salle counties. (See Pl. VIII.)

Correlation.—The correlation and discrimination of the Fayette sandstone has been difficult because of the paucity of identifiable fossils, the close lithologic resemblance between it and the overlying formations, and the gradation of sandstone beds into clay beds.

The nonmarine blue quartzite exposed at Grand Gulf, Miss., was described in 1857 by Wailes, who called it the "Grand Gulf sandstone." [28] This quartzite in Mississippi overlies the fossiliferous Vicksburg limestone and is of Oligocene age. Later Hilgard applied the name "Grand Gulf" to the group of strata exposed in southern Mississippi between the Vicksburg and the coast Pliocene ("Orange sand" or "Lafayette").[29]

In 1871 Hilgard published a "Geological map of the Mississippi Embayment," which showed the geology of the Coastal Plain of Texas.[30] On this map the "Grand Gulf Tertiary" is shown as extending from the Rio Grande to Florida. The area shown in Texas included strata now referred to the Yegua, Jackson, Fayette, Catahoula, Frio, Oakville, Lapara, and Lagarto formations.

Loughridge in 1884 described the "Grand Gulf" of Texas as follows:

> Immediately south of the Eocene there is a belt of sandstone extending across the State that has been referred to the Grand Gulf, of probably Miocene age. Its northern limit enters the State at the lower part of Sabine County and outcrops on the Trinity River near Trinity Station, in Trinity County, forming a bluff about 100 feet in thickness. In Washington County, near Chapel Hill and Burton, the sandstone appears near the surface exposed in railroad cuts; in Fayette County, at Lagrange, it forms a bluff over 100 feet high on the south side of the river; in De Witt County it outcrops in the high hills on the north and in the bed of the river at Hellgate ferry, near Cuero. Still southwest, from all that can be ascertained from reports and other sources, the upper limit of this group forms a line of hills via Oakville, Live Oak County, southwestward through Duval County to the Rio Grande, at Rio Grande City. * * *
>
> These sandstones contain no fossils so far as known, and identification of the group is dependent wholly upon the position and character of its rocks.[31]

The beds described included the Fayette and Catahoula sandstones of eastern Texas and the Oakville sandstone of southwestern Texas.

Penrose in 1890 described the "Fayette beds" and correlated them with Hilgard's "Grand Gulf" of Mississippi. (See p. 75.) It has been previously pointed out that the "Fayette" of Penrose included the Yegua, Fayette, Catahoula, Frio, Oakville, Lapara, and Lagarto formations.

In 1892 Dumble divided Penrose's "Fayette" into two groups, the lower of which he called the Yegua and the upper the Fayette. He stated:[32]

> Three miles north of Corrigan * * * a deposit of white sandstone occurs, containing casts of shells. The fossils found here have been referred to the Eocene by Dr. Dall, on the strength of the existence of the casts of *Cardita planicosta.* * * *
>
> These beds (Fayette) were referred to the Grand Gulf (Miocene?) of Hilgard by Dr. Loughridge and in previous reports of this survey.

A footnote is added as follows:

> The other fossils of this horizon from this and other localities have been studied by Mr. Gilbert D. Harris and found to be characteristic Eocene species.

The next contribution was made by Kennedy. In a report on Grimes County, Tex., published in 1893, he wrote:[33]

> The northern portion of Grimes County is occupied by a series of thinly stratified beds of sands, clays, and lignites, and occasional thin beds of sandstones, being a part

[28] Wailes, B. C. L., Agriculture and geology of Mississippi, pp. 216–219, 1857.

[29] Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, pp. 147–154, 1860.

[30] Hilgard, E. W., On the geological history of the Gulf of Mexico: Am. Jour. Sci., 3d ser., vol. 2, pp. 391–404, 1871.

[31] Loughridge, R. H., Report on the cotton production of the State of Texas with a discussion of the general agricultural features of the State: Tenth Census U. S., vol. 5, p. 21, 1884.

[32] Dumble, E. T., Report on the brown coal and lignite of Texas, Texas Geol. Survey, p. 154, 1892.

[33] Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., p. 15, 1893.

of deposits which cover a wide area, extending from the Sabine River westward to and beyond Brazos River, and which have hitherto been placed at the base of the Fayette beds. They belong to the beds described by Dr. Penrose as a "series of clay and sandy strata, the clay rapidly becoming more and more predominant as we go up the series," and the base of the formation becoming "composed of clays and lignite beds."

These deposits have been hitherto considered as the equivalent of the Grand Gulf series of Hilgard's Mississippi section, and considered as of Miocene age.

They are now assigned to the Eocene for the following reasons: In 1890 the first invertebrate forms observed by the present Survey in the Fayette beds were found by Mr. E. T. Dumble in the sands immediately overlying these clays in Lee County. During the course of the work of the Survey of 1891 a number of fossils were found in Polk County near the top of the gray sands and sandstones in undisturbed deposits, also directly overlying these beds, and again, during the present year's field work, Mr. J. A. Singley found fossils in the laminated lignitic sands and clays on the Yegua River, at Bluff crossing, in Lee County.

During the course of the present season's work in Brazos County, fossils have again been discovered in the gray sandstones directly overlying and in contact with these beds. All these fossils have been studied recently by Mr. Gilbert D. Harris * * * and assigned by him to the Eocene, he having found among them such typical fossils as *Cardita planicosta* Sowerby, *Calyptraphorus velatus* Conrad, and others. These belong to the Claiborne division of the Eocene, and their occurrence in the laminated lignitic sands and clays and in the gray sandstones necessarily places these deposits in that division. * * *

In 1894 Dumble separated the Oakville from the Fayette. He wrote: [34]

On the coastal slope the Frio beds of the Eocene are succeeded by a series of deposits which in a general way resemble the underlying Fayette sands and have hitherto been regarded as a part of those beds. While it is possible to distinguish between them, the differentiation is complicated in many instances by the overlap of still later beds largely derived from both these and the Fayette and therefore bearing a very close resemblance to them lithologically.

In 1902 Veatch published a report on the geology of Sabine River, and from it the following extract is taken: [35]

For stratigraphical purposes, and until fossils are found which will render the beds susceptible of division, it would seem well to include under this term Grand Gulf the lower portion of Hilgard's Grand Gulf or that portion which contains sandstone beds. These form a stratigraphic unit readily distinguished from the thick beds of green calcareous clays which overlie them and which are now known to be Chattahoochee Oligocene.

No animal remains, save a few unios, have yet been found in the Grand Gulf sandstones. Kennedy reports an Eocene fauna from the *base* of the series and on these fossils correlates the beds for several hundred feet *above* the outcrop with the lower Claiborne. These fossils, which prove to be Jackson, can hardly be said to prove the age of the beds *above* them, and considering the overlap of the Grand Gulf beds on the Jackson, as shown in Louisiana, it is not surprising to find Jackson fossils in the sandstones a few feet above the Jackson clays. Considering the evidence at hand, there seems to be no reason for regarding the Grand Gulf sandstones of Texas as different from the Grand Gulf sandstones of Louisiana and Mississippi. The finding of a Chattahoochee fauna in the green clays adds to the characters in common between these beds and the same beds across the Mississippi.

In 1906 Veatch gave the name Catahoula formation to the sandstone member of Hilgard's "Grand Gulf group" to take the place of the term "Grand Gulf," which had been previously used with this significance.[36]

In 1914 Deussen wrote: [37]

The fossiliferous Vicksburg limestone, as developed east of Louisiana, does not outcrop in Texas, nor has it been found in wells so far as known. The investigations of G. C. Matson have shown that the Vicksburg limestone of Alabama grades into sandstone toward the west. Sandstone replaces the upper part of the Vicksburg in western Alabama, more of it in Mississippi, and still more in eastern Louisiana, and in western Louisiana it replaces the whole Vicksburg, and even some beds of Jackson age are lithologically similar and apparently can not be separated.

As here interpreted, the Catahoula sandstone is a lithologic and stratigraphic unit which transgresses several biologic zones. Stated differently, it is conceived to be of different ages and to have been laid down at different epochs in the respective regions of its occurrence. In central Texas, in the region of the Brazos, it is largely of Jackson age. In eastern Texas it is largely of Vicksburg age. According to Matson, the vertical transgression continues across Louisiana into Mississippi, where the formation lies above the Vicksburg.

In a footnote he adds:

Studies made by the author since this report was written seem to indicate that the Catahoula sandstone as here described is not a stratigraphic unit but comprises two formations of similar lithologic character, the one at the base being of Jackson age, whereas the upper sandstone is of Oligocene age. The name Wellborn was applied by Kennedy to the lower of these two sandstones.

The evidence at hand does not indicate that the Fayette sandstone is of lower Claiborne age. It has not been possible to find the lower Claiborne faunas reported from these sandstones north of the Nueces. Though

[34] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 550, 1894.

[35] Veatch, A. C., The geography and geology of the Sabine River, Louisiana Geol. Survey, pp. 132-133, 1902.

[36] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 42-43, 1906.

[37] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 69-70, 1914.

most of the fossils found are poorly preserved and difficult to identify, there is nothing about them that suggests their affinity with the lower Claiborne. On the contrary, such specimens as have been collected, including *Ostrea georgiana* and *Tellina eburniopsis*, suggest Jackson affinities rather than Claiborne. Furthermore, the fossil leaves collected from the formation point decidedly to an age later than the lower Claiborne. It seems fairly certain, therefore, that the Fayette sandstone is not of lower Claiborne but of Jackson age.

On the other hand, Veatch's statement that "there seems to be no reason for regarding the Grand Gulf [Fayette] sandstones of Texas as different from the Grand Gulf sandstones of Louisiana and Mississippi" does not seem to be in accord with the facts. If the occurrence of the fossil *Ostrea georgiana* is significant, the Fayette sandstone of southwest Texas belongs entirely to the Jackson epoch, for this fossil occurs above them, in the base of the Frio clay. Paleontologically, therefore, the Fayette sandstone of southwest Texas is considerably different from the Catahoula sandstone of Mississippi.

Recent work by Deussen and Matson in western Louisiana and eastern Texas has shown that fossiliferous gray sandstone, chocolate-colored and lignitic clay and lignite, and quartzite are found at the base of the formation that has been mapped there as the Catahoula, lying above fossiliferous Jackson clays. The flora and fauna of these beds indicate their close association with the Fayette beds of Texas. Their thickness in this section can not exceed 200 feet, and they appear to represent the eastern extension of the Fayette sandstone of Texas. They have heretofore been included with the Catahoula. Matson states that this sandstone disappears completely farther east. The problem is made more complex by the disappearance of the typical Catahoula sandstone toward the west and the Oakville sandstone toward the east.

It would therefore seem that the Fayette sandstone is a stratigraphic unit of Jackson age, which has its greatest development in southwestern Texas and becomes thinner eastward, toward Louisana.

Section on Davidson Creek.—Gray sandstone containing large quantities of silicified wood is exposed on the road about 5 miles north of Lyons, Burleson County.

At a small falls on Davidson Creek, 2½ miles east of Lyons, on the Merle-Lyons road, the beds of the Fayette sandstone include 10 feet of lignitic shale, 2 feet of indurated sandstone, and 1 foot of green shale. The beds dip 1° S. 12° E.

On Davidson Creek, about 2½ miles above the crossing of the Gulf, Colorado & Santa Fe Railway, about 4½ miles northeast of Somerville, the beds of the Fayette sandstone consist of 1 foot of impure lignite, 3 feet of hard sandstone, 3 feet of soft sandstone, 2 feet of chocolate-colored clay with traces of lignitic matter, and 2 feet of laminated sand. The beds dip ½° S. 40° E.

Section along Gulf, Colorado & Santa Fe Railway in Burleson and Washington counties.—The following sections show the character of the beds included in the Fayette sandstone along the Gulf, Colorado & Santa Fe Railway in Burleson and Washington counties:

In a shaft on the J. C. Murray farm, about 2½ miles northwest of Lyons, the Fayette sandstone exposes 3 feet of blue massive shale, 2 feet of gray sandstone, 8 inches of blue massive shale, 1 foot of gray sandstone (which is not present in another shaft about 135 yards to the south), 5 feet of blue massive shale or fuller's earth (?), and sandstone of undetermined thickness.

On a small stream a quarter of a mile east of Lyons the Fayette sandstone includes 4 feet of green calcareous shale with interbedded layers of sand 3 inches thick, 4 feet of soft gray sandstone with layers of calcareous shale, and 2 feet of sandstone. The beds dip southeastward.

In the pit of the Somerville Fuller's Earth Co. about 2½ miles west of Somerville there is an exposure of gray sandstone and about 12 feet of underlying brown shale or fuller's earth.

On a branch of Yegua Creek about 1½ miles northwest of Somerville there is a lens of laminated shale 5 feet 2 inches thick with interstratified layers of sand 1 inch thick overlying massive brown shale or fuller's earth with flakes of gypsum. The shale contains specimens of *Bombacites jacksonensis* Berry. The beds dip ½° ESE.

A ravine about 200 yards south of the railroad station at Somerville exposes 6 feet of dark-red and greenish sandy mottled clay, overlying 2 feet of bluish pack sand.

Section between Colvin and Burton, in Lee and Washington counties.—On Yegua Creek, 1½ miles above the mouth of Cedar Creek, about 5 miles west of Somerville, the beds exposed, in descending order, include 10 feet of sand, 6 feet of laminated lignitic sand, and 10 feet of cross-bedded sand. The beds dip S. 30° W.

On Nails Creek, near the Ledbetter-Colvin road, about 8 miles northeast of Ledbetter, the beds consist of hard gray sandstone with *Tellina eburniopsis* Conrad?; some distance below there is 15 feet of gray sand and 15 feet of sandy shale.

On the R. M. Johnson place, on the Thomas W. Ward league, at Colvin, Lee County, there is 18 feet of soft white kaolin-like laminated clay; burning tests show that the clay is not suited for the manufacture of white ware. The bed becomes thinner to the northwest.

On the S. O. Tatum farm, on the David Ayers league, about 5 miles northwest of Burton, the beds include 6 feet of gray calcareous clay, 1 foot of white sand, 2 feet of brown clay, 8 inches of white sand, and 9 feet of brown massive shale or fuller's earth.

On the B. F. Elliott farm, on the Daniel B. Fryar league, about 4½ miles northwest of Burton, Washington County, the beds exposed include 10 to 20 feet of hard blue quartzitic sandstone, overlying 20 to 30 feet of brown sandy clay with irregular seams of lignite (?) 1 to 2 inches thick.

On Kerr Creek, on the H. Eberhardt farm, about 4 miles northwest of Burton, the beds exposed consist of 7 feet of sandy shale, 6 inches of lignitic shale, and 3 feet of lignite. The beds dip 1½° N. 30° E.

Section between Ledbetter and Carmine, in Fayette and Washington counties.—In a prospect shaft on the Richard Hardy survey, in Washington County, northeast of Ledbetter, a bed of lignite, said to be 9½ feet thick, was encountered at a depth of 54 feet. A second bed, 8 feet thick, was struck at 87 feet, and 1 foot of water-bearing sand was struck at 101 feet. This lignite has been mined at Ledbetter. Other exposures occur on a branch of Owl Creek, 2 miles southwest of Nechanitz, Fayette County; on Colorado River, 2½ miles northwest of La Grange; and on the W. F. Hamilton league, 3 miles south of West Point. The beds in general strike S. 40° W.

On a branch of Turkey Creek, on the Burkhart tract, about 2 miles northeast of Ledbetter, in Washington County, the beds exposed consist of 4 feet 6 inches of gray sandstone, used locally for building purposes, 35 feet covered, 2 feet of yellow shale, 2 feet of hard brown shale, and 5 feet of soft brown shale or fuller's earth (?).

In a small gorge on the headwaters of Turkey Creek, on the Burkhart tract, 2½ miles northeast of Ledbetter, in Washington County, the beds consist of 5 feet of gray laminated sand, in part volcanic ash, and infusorial earth; 6 feet of white clay, soft and laminated; and 2 feet of brown lignitic shale.

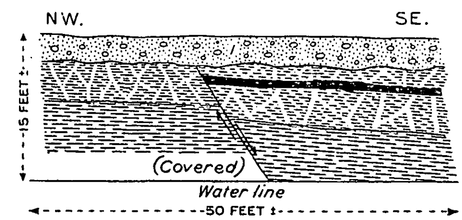

FIGURE 25.—Sketch of fault cutting Eocene beds on Colorado River 2½ miles northwest of La Grange, Tex.

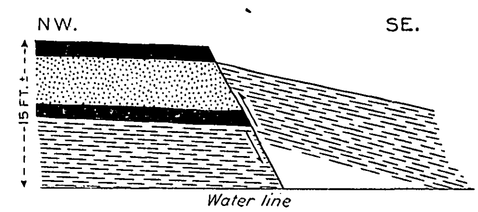

FIGURE 26.—Sketch of lower or second fault cutting Eocene beds on Colorado River 2½ miles northwest of La Grange, Tex.

Section on Colorado River.—On Colorado River the Fayette sandstone is exposed from a point 2½ miles northwest of La Grange to a point a quarter of a mile north of the railroad bridge at La Grange.

On Colorado River, 2½ miles below the mouth of Rabbs Creek and 2½ miles northwest of La Grange, there is exposed a bed of lignite 2 feet thick, which rests upon gray sandy clay and is overlain by 15 feet of gray clay. The dip of the beds is about 3° S. 55° E.

A small fault (see fig. 25) cuts the Eocene beds 100 or 200 feet below this exposure. A second fault (see fig. 26) shows 100 to 200 feet below the first fault. At the second fault a quarter of a mile below the fault first mentioned 15 feet of lignite overlies the gray clay and underlies gray sand.

On the left side of the river, about 1½ miles northwest of La Grange, the Fayette sandstone shows 15 to 20 feet of gray laminated sandy shale, 10 feet of sand with laminae of lignite, 4 feet of porous gray sand. Blue sandy shale 10 feet thick is exposed 20 feet below the gray sand.

Fifteen feet of gray sand is exposed in the right bank of Colorado River about a mile above the Missouri, Kansas & Texas Railway bridge at Lagrange.

Section at Plum, Fayette County.—One mile west of Plum there is exposed 5 feet of hard blue semiquartzitic sandstone, 2 feet of lenses of white kaolin-like leaf-bearing clay with *Pisonia jacksoniana* Berry, and 15 feet of brown clay.

Section on Buckner Creek, Fayette County.—On a branch of Prairie Creek, a tributary of Buckner Creek, near the northwest corner of lot 81, W. F. Hamilton league, 5 miles north of Lena spur, there is exposed 5 feet of greenish-gray shale with numerous concretions of gypsum 2 to 3 inches in diameter and fossiliferous concretions of red hematite (altered greensand) 6 to 10 inches in diameter.

A small prospect shaft a few yards from this locality struck below the greenish-gray shale a bed of green fossiliferous clay 8 feet below the ground. The fossils include *Corbula wailesiana* Harris (?) and *Venericardia planicosta* Lamarck.

In a drill hole 300 yards east of the northwest corner of lot 81, W. F. Hamilton league, about 3 miles south of West Point, blue fossiliferous clay with marine fossils, shark tooth, etc., was struck at a depth of 21 feet. This bed is 24 feet thick, and it rests upon water-bearing sand.

The shark tooth is *Carcharodon auriculatus* (Blainville), a species that ranges from the middle Eocene through the Pliocene and has a very wide geographic distribution. It has been reported in the United States from the Eocene of South Carolina and Alabama and from the Miocene of Maryland.

A hard blue semiquartzitic sandstone has been quarried on the J. Barton league, where the San Antonio & Aransas Pass Railway crosses Jack Young Creek, about 3½ miles south of West Point. Here 15 feet of beds of hard blue rock, from 1 to 2 feet thick, alternate with beds of unconsolidated laminated gray sand. (See Pl. XXV, *A*.)

Ten feet of brown shale is exposed on a branch of Jack Young Creek, near the northwest corner of the J. Barton league and about 3½ miles south of West Point. This shale underlies the hard blue sandstone in the quarry just mentioned.

Lignite is exposed in the banks of a ravine which drains into Prairie Creek about 500 feet south of the north line and about 200 feet west of the east line of lot 84 of the W. F. Hamilton league, 3 miles south of West Point. This is the same lignitic series described on page 85.

On the north line of the W. F. Hamilton league, about 3 miles southeast of West Point, 3 feet of volcanic ash with fossil leaves overlies 10 feet of brown shale or fuller's earth (?). The volcanic ash is in the form of small lenses, a number of which occur in the same zone in the vicinity. The fossils from this exposure have been identified by Berry as *Sabalites vicksburgensis* Berry and *Calocarpum viridiformis* Berry.

On Buckners Creek, at road crossing, about 2½ miles northeast of Muldoon, an exposure shows 20 feet of white laminated sandy clay, 3 feet of bluish sand, 10 feet of brown sulphurous shale, 6 feet of brown to yellow water-bearing sand, 6 inches of white sandstone, 2 feet of brown shale, and 2 feet of yellow sand which contains small masses of asphalt (?) 3 inches in diameter. The beds dip 3° S. 25° E.

Section at Muldoon, Fayette County.—The following section is shown in a well at the corner of First and Kerr streets, Muldoon, Fayette County.

Log of well of John Kerr, at Muldoon, Tex.

[Description of samples by Alexander Duessen.]

	Thickness.	Depth.
	Feet.	*Feet.*
Quaternary: Soil and subsoil	15	15
Fayette sandstone:		
Yellow-brown fine-grained slightly argillaceous sandstone	15	30
Lignite	4	34
Bluish-gray sandy clay	36	70
Light bluish-gray friable argillaceous, very fine-grained sand	10	80
Green calcareous fossiliferous shale	120	200
Blue limestone with some fine grains of pyrite	1¼	201¼
Yegua formation:		
Green calcareous fossiliferous shale	138¾	340
Greenish-gray glauconitic marl; fossiliferous	1	341
Green-black sandy clay; slightly fossiliferous	59	400

Log of well of John Kerr, at Muldoon, Tex.—Continued.

	Thickness.	Depth.
Yegua formation—Continued.		
Tough, plastic green-brown slightly fossiliferous shale	*Feet.* 100	*Feet.* 500
Tough, plastic green-brown slightly fossiliferous shale; slightly calcareous	30	530
Green-black fossiliferous shale	25	555
Green-black slightly fossiliferous shale	39	594
Green-gray argillaceous sand; only slightly calcareous	45	639
Green-black calcareous sand; contains very fine-grained quartz with some mica and possibly some glauconite (?)	1	640
Green-gray slightly calcareous, argillaceous sand	111	751
Bluish-gray fine-grained slightly argillaceous sand	44	795
Cook Mountain formation (?):		
Samples represent a number of distinct beds	55	850
Green-gray slightly sandy fossiliferous shale	50	900
Samples indicate two separate beds; one is a nonfossiliferous compact lignitic, noncalcareous shale; the other is a plastic, sticky dark-green fossiliferous calcareous shale	99	999
Green calcareous fossiliferous plastic shale	91	1,090
Green fossiliferous calcareous shale with poorly preserved fossils	40	1,130
Dark-green calcareous plastic shale	45	1,175
Green calcareous fossiliferous plastic shale	235	1,225
Dark-green calcareous plastic fossiliferous, shale	75	1,300
Dark-green calcareous plastic fossiliferous shale; green-brown fine-grained loose, slightly calcareous sand at 1,340 feet	65	1,365
Green calcareous fossiliferous plastic shale	45	1,410
Fossiliferous shale	15	1,425
Green-black fossiliferous shale	75	1,500
Mount Selman formation (?):		
Record missing	40	1,540
Brown porous fine-grained sand; slightly calcareous, probably water-bearing	20	1,560
Sample lacking	15	1,575
Fossiliferous shale	100	1,675
No record	27	1,702
Green-black calcareous fossiliferous shale	28	1,730
Brown lignitic shale	14	1,744

Section between Gonzales and Shiner, in Gonzales County.—Sandstone is exposed at Maurin, west of Dilworth, and on the road between Maurin and Dilworth.

Section on Guadalupe River.—On the south side of Guadalupe River, 6 miles S. 30° E. from Gonzales, the Fayette sandstone includes the following beds:

Section of Fayette sandstone on Guadalupe River, 6 miles below Gonzales, Tex.

	Feet.
Gray cross-bedded sand	2
Impure kaolin-like clay	6
Hard gray sandstone	4
Gray sand with mud cracks	6
Gray sand with several thin beds of fossiliferous sandstone; specimens of *Tellina eburniopsis* Conrad?	10
Very hard sandstone	½
Soft slightly glauconitic fossiliferous sand with specimens of *Tellina eburniopsis* Conrad?	3
Hard sandstone	½
Soft slightly glauconitic sand	½
Hard dark sandy clay	¼
Gray yellow sand	1
Gray sand	50
	83¾

Section in southern part of Gonzales County.—At a creek crossing on the Galveston, Harrisburg & San Antonio Railway about 3 miles east of Smiley the beds of the Fayette sandstone expose 2 feet of reddish-gray argillaceous sand, 1 foot of gray sandstone, and 3 feet of gray sand with silicified twigs and roots.

Two feet of hard gray sandstone is exposed in the bank of a creek at the crossing of the Smiley-Sample road, 4½ miles east of Smiley. The sandstone, when broken, has a brownish tint, indicating the presence of iron.

At the creek crossing of the Smiley-Sample road about 4½ miles east of Smiley 30 to 40 feet of irregularly bedded, hard gray sandstone makes up the bluffs along the creek.

Ten feet of hard gray sandstone, containing silicified wood, is seen in a small bluff fronting Castleman's Fork, at the crossing of the road from Smiley to Pilgrim, about 4½ miles southwest of Pilgrim.

A hill that rises 55 feet above the surrounding plain on the north side of the road from Smiley to Pilgrim, 4 miles southwest of Pilgrim, is capped with 30 or 40 feet of hard gray to blue sandstone carrying silicified or fossil wood. This bed overlies 2 feet of gray flaggy sandstone, which in turn overlies 5 feet of green sandy shale.

On Rock Creek, about 6 miles south of Smiley, 6 inches of hard gray fossiliferous sandstone with *Cytherea discoidalis* Conrad and *Corbula alabamiensis* Lea overlies 5 feet of gray arenaceous shale.

A hill that rises 50 to 60 feet above the surrounding plain a mile east of the exposure last mentioned is capped by the hard gray sandstone of the Fayette formation.

Section on San Antonio River.—San Antonio River crosses the Fayette sandstone from a point 4 miles west of Falls City to a point a third of a mile southeast of Hobson.

At Conquiesta crossing, on San Antonio River, about 4 miles west of Falls City, Karnes County (see Pl. XXV, *B*), the Fayette sandstone shows 20 feet of hard bluish-gray sandstone with silicified wood, 60 feet of brown shale or fuller's earth, 3 feet of lignite, and 1 foot of hard sandstone with silicified wood. The shale dips 2½° N. 80° E.

In a bluff on San Antonio River, on the San Antonio & Aransas Pass Railway, 1 mile southeast of Falls City, the Fayette sandstone is composed of 7 feet of green gritless compact shale, 7 feet concealed, 13 feet of bluish-gray medium hard sandstone with silicified wood, 4 feet of soft bluish-yellow sandstone, and 1 foot of very hard blue semiquartzitic sandstone. The dip of the beds is about ½° E.

On San Antonio River about half a mile N. 21° W. of Hobson, Karnes County, the Fayette sandstone contains 10 feet of gray medium soft sandstone with silicified twigs, 5 feet of gray sandstone, and 5 feet of gray sand. The beds dip 4° S. 70° E.

Section in western Karnes and eastern Atascosa counties.—A bed of yellow clay, 2 feet thick, containing numerous specimens of fossil oysters, is exposed on the road about 1½ miles northeast of Tordia post office, in the southern corner of Wilson County.

Six feet of yellowish flaggy sandstone carrying silicified wood is exposed in a small ravine north of the place where the Oakville-Floresville road crosses Tordilla Creek, in Atascosa County.

Near the south corner of the John R. Baker league, about 1½ miles southwest of Tordilla Mountain, in Atascosa County, the Fayette sandstone shows 2 feet of grayish-white flaggy sandstone, 25 feet concealed, 3 inches of hard blue fossiliferous sandstone with *Lucina* sp. and *Corbula* sp., 15 inches of gray flaggy sandstone (lens), 5 feet of yellow argillaceous sand with nodules of lime 2 by 3 inches in size, 30 inches of yellow laminated sand, 30 inches of yellow sandy clay, 2 inches of yellowish-gray argillaceous flaggy sandstone, and 30 inches of gray flaggy sandstone.

Fossiliferous gray sandstone containing specimens of *Corbula alabamiensis* Lea? is exposed on the Falls City-Campbellton road near the south corner of the J. M. Hefferman survey, in the southeastern part of Atascosa County.

At Tordilla Mountain, in the western corner of Karnes County, the Fayette sandstone shows 20 feet of hard blue semiquartzitic sandstone forming cap rock of hill, 3 feet concealed, 3 inches of green talclike shale (lens), 57 inches of reddish-gray sandstone, 30 feet concealed, 2 feet of brown impure lignite(?), 2 feet of brown sulphurous shale, 56 feet concealed, and 1 foot of yellowish-gray argillaceous sandstone.

Section south of Karnes City, Karnes County.—The following well log indicates the character of the Fayette sandstone 313 feet beneath the surface in the southern part of Karnes County:

Log of well No. 1 of the Manhattan Oil Co., 11 miles south of Karnes City, Tex.

[Samples collected by Winslow Robinson; samples 1 to 129 examined by Alexander Deussen; samples 147 to 162 examined by J. A. Udden. Fossils identified by C. W. Cooke.]

	Thickness.	Depth.
	Feet.	*Feet.*
Recent:		
Brownish-black loam	1	1
Frio clay:		
Pinkish-yellow, fine-grained, siliceous silt with volcanic ash	123	124
Gray, medium coarse sand; fragments of clear quartz predominant; some jasper(?), some orthoclase, and some pinkish calcite. Sand is water-bearing, the water rising within 79 feet of the surface	62	186
Pinkish-yellow siliceous silt with volcanic ash	35	221
Fragments of white lime and volcanic ash	9	230
Fragments of plastic greenish-blue compact talclike shale	1	231
Hard pinkish-white limestone	10	241
Very fine-grained grayish-yellow calcareous sand and volcanic ash	7	248
No sample; reported white limestone	2	250
Fayette sandstone:		
Plastic, light green, calcareous shale	63	313
No sample; probably boulder	2	315
Plastic, light green, calcareous shale	10	325
Fossiliferous shale, with *Spisula parilis* (?) Conrad, *Corbula* sp., decorticated	10	335
Plastic light-green shale with lime fragments	12	347
No sample; probably sandstone	2	349
Green fossiliferous plastic calcareous shale	10	359
Green plastic slightly calcareous fossiliferous shale, with *Corbula* sp., decorticated	10	369
Green plastic fossiliferous slightly calcareous shale	20	389

Log of well No. 1 of the Manhattan Oil Co., 11 miles south of Karnes City, Tex—Continued.

	Thickness.	Depth.
Fayette sandstone—Continued.	*Feet.*	*Feet.*
Fragments indicate a bed of green calcareous shale carrying *Corbula* sp., decorticated	10	399
Probably a concretion	18	417
Green calcareous plastic gritless shale and greenish-gray hard limestone	2	419
Brown and green shale with hard white limestone	10	429
Drab sandy shale	10	439
Drab plastic slightly calcareous, sandy shale with some limestone	10	449
Brown lignitic shale	30	479
Dark slate-colored plastic shale and talclike clay with white limestone	5	484
Hard very fine-grained bluish-gray sandstone	12	496
Hard slightly calcareous gritless green shale	3	499
Dark olive-green compact limestone	3	502
Pinkish-white compact limestone	2	504
Green shale and yellow limestone	10	514
Greenish-blue shale	13	527
Greenish-gray hard fine-grained siliceous limestone	3	530
Blue calcareous shale	1	531
Bluish-gray argillaceous limestone; other fragments of white limestone	1	532
Blue calcareous, sandy shale	10	542
Blue sandy, calcareous shale and blue calcareous shale	10	552
Plastic blue calcareous shale containing Foraminifera	10	562
Blue shale	10	572
Blue plastic shale with spherical diatoms	10	582
Dark-blue sandy, calcareous shale with spherical diatoms	10	592
Blue plastic fossiliferous shale	9	601
Yellow shale and limestone	3	604
Light-blue sandy shale	10	614
Plastic blue slightly arenaceous shale with white limestone	10	624
Blue shale	8	632
Blue plastic shale	9	641
Blue fine-grained sand	10	651
Blue sandy shale	9	660
Hard blue fine-grained sandstone	4	664
Blue sandy shale	10	674
Blue plastic shale	11	685
Blue sandy shale	19	704
Yegua formation:		
Brownish-black plastic shale and lignite	20	724
Blue shale and lignite; specimens of *Corbula* sp., decorticated	41	765
Blue plastic shale	43	808
Lignite (foreign?), bluish-gray sandstone, and limestone	5	813
Blue shale	3	816
Lignite (foreign?), bluish-gray sandstone, and limestone	3	819
Blue shale	10	829
Lignite (foreign?) and blue shale	10	839
Blue plastic shale, with specimens of Foraminifera	20	859
Blue shale	21	880
Lignite (foreign?), bluish-gray sandstone, and limestone	11	891

	Thickness.	Depth.
Yegua formation—Continued.	*Feet.*	*Feet.*
Blue shale	60	951
Blue sandy shale	20	971
Fragments of blue plastic sandy shale	20	991
Blue very fine-grained sand, composed of grains of quartz	10	1,001
Blue sand and blue sandy shale	10	1,011
Bituminous shale or lignite	2	1,013
Blue sandy shale	50	1,063
Blue sandy fossiliferous shale	20	1,083
Fragments of blue sandy shale and light greenish-gray calcareous shale	10	1,093
Bluish-gray sand	20	1,113
Blue medium hard sandy shale	10	1,123
Blue slightly sandy shale	50	1,173
Blue plastic shale	10	1,183
Cook Mountain and Mount Selman formations:		
Blue fossiliferous sandy shale	10	1,193
Blue argillaceous sandstone	10	1,203
Blue plastic shale, with specimens of *Cylichna* sp., and *Turritella nasuta* Gabb, lower Claiborne (Eocene) species	10	1,213
Blue fossiliferous shale, with specimens of *Corbula* sp. and *Tellina*? sp	10	1,223
Blue fossiliferous shale, with specimens of *Turritella* sp. and *Corbula* sp	10	1,233
Blue calcareous plastic fossiliferous shale, with specimens of *Corbula* sp., *Turritella* sp., and *Venericardia* sp	30	1,263
Blue sandy shale	10	1,273
Blue sandy shale, with *Corbula* sp., *Venericardia* sp., and *Turritella* sp	50	1,323
Blue argillaceous sandstone	10	1,333
Blue sandy fossiliferous shale	10	1,343
Blue argillaceous sandstone	20	1,363
Blue sandy fossiliferous shale	40	1,403
Blue glauconitic sandy shale	10	1,413
Blue fossiliferous shale and blue sandy shale	10	1,423
Blue shale, white limestone, and blue pyritic sandstone	127	1,550
Blue shale, blue sandy shale, and white limestone	73	1,623
Blue plastic shale and blue sandy shale	10	1,633
Blue shale and blue sandy shale	10	1,643
Blue sandy, glauconitic shale	10	1,653
Blue sandy, fossiliferous shale	30	1,683
Blue noncalcareous, sandy shale and blue fine-grained sand	10	1,693
Blue glauconitic (?) shale and blue glauconitic sand	10	1,703
Blue glauconitic sandy shale and blue glauconitic sand	10	1,713
Blue glauconitic (?) sandy shale	10	1,723
Gray silty sand and sandy silt	50	1,773
Sandy gray silt and silty clay, containing concretions of soft white aluminous material	120	1,893
Greenish-gray sandy silt	30	1,923
Greenish-gray silty sand	10	1,933
Greenish-gray sandy silt	10	1,943
Dark-gray sandy silt	30	1,963
Dark greenish-gray sandy, clayey silt, containing some lumps of a white kaolinlike soft material	10	1,983
Greenish-gray sandy silt	18	2,001

Section on Atascosa Creek.—The following sections of the Fayette sandstone are exposed on Atascosa Creek in Atascosa and Live Oak counties.

In a small gorge 3 miles north of Campbellton the Fayette sandstone shows 3 feet of greenish-gray massive shale, 3 inches of soft gray sandstone, 2 feet of greenish-gray massive shale, 6 inches of hard whitish-gray sandstone, and 4 feet of greenish-gray massive shale.

In a creek bank on the Karnes City-Campbellton road, about 6½ miles east of Campbellton, the Fayette sandstone shows 18 inches of calcareous white shale, 8 inches of yellow sulphurous shale, 6 inches of white shale, and 1 foot of greenish-gray shale.

Yellow clay containing many specimens of *Ostrea georgiana* Conrad is exposed on the Karnes City-Campbellton road, about 4¾ miles east of Campbellton. Twenty feet of gray sandstone, overlying this fossiliferous clay, crops out about 100 feet to the south.

On the Karnes City-Campbellton road, 1½ miles southeast of Campbellton, the Fayette sandstone contains 1 foot of hard blue semi-quartzitic sandstone with silicified wood, 5 feet concealed, 5 inches of hard blue sandstone, 1 foot concealed, 5 inches of gray sandstone, 4 inches of fossiliferous gray sandstone, 3 inches of greenish glauconitic fossiliferous sandstone, 3 feet concealed, 6 inches of fossiliferous gray sandstone, 2 feet concealed, 1 foot of white clay, 10 feet of soft yellowish-gray sandstone, 3 feet of argillaceous gray sandstone, 4 feet of yellowish-gray sandy shale, 3 feet of laminated gray argillaceous sand, 1 foot of yellowish-gray sandy shale, 9 inches of laminated gray argillaceous sand and 4 feet of yellowish-gray laminated sandy shale. The fossiliferous beds contain *Cerithium?* sp., *Nucula* sp., *Cytherea* sp., and *Corbula alabamiensis* Lea.

About 4¾ miles southeast of Campbellton the Fayette sandstone has 7 inches of hard fossiliferous sandstone, 15 inches of yellow shell breccia or fossiliferous marl, made up of *Ostrea georgiana* Conrad?; 10 inches of yellow clay, 7 feet concealed, 18 inches of calcareous white clay, 25 feet? concealed, and 6 feet of yellowish-gray shale.

On Atascosa Creek, about 7 miles south of Campbellton, the Fayette sandstone has 11 feet of yellow and gray irregularly bedded sandstone, 1 foot of laminated yellowish-gray sand, 6 inches of greenish-gray shale, 18 inches of yellow sand and shale interstratified in beds 3 to 6 inches thick, 3 feet of greenish-gray shale, 8 inches of bluish-white laminated sand, 3 inches of greenish-gray shale, 3 inches of bluish-white laminated sand, 15 inches of greenish-gray shale, 1 foot of bluish-white laminated sand, 15 feet of grayish-brown shale, 2 feet of yellow sand, 15 feet concealed, 2 feet of fossiliferous green clay, 3 feet of fossiliferous indurated brown sand, 11 feet of brown cross-bedded sand, 5½ feet concealed, and 7 feet of brown lignitic shale with sulphur efflorescence. The fossiliferous beds contain specimens of *Cytherea* sp. and *Corbula alabamiensis* Lea?

Section near Crowther, McMullen County.—Two feet of gray flaggy fossiliferous sandstone is exposed 1,000 feet south of the post office at Crowther. The beds, which average 2 feet in thickness, carry *Plejona petrosa* (Conrad)?, *Murex?* sp., *Turritella* sp., *Leda* sp., *Corbula* (2 sp.), *Tellina* (probably several species, very abundant), *Tellina eburniopsis* Conrad?, and *Crassatellites* sp.

The Fayette sandstone in Opossum Hill, 1½ miles S. 30° W. of Crowther, contains 8 feet of hard blue irregularly bedded sandstone, 3 feet of laminated and flaggy gray to yellow sandstone, 38 feet concealed, 20 feet of greenish-gray sandy shale, 5 feet concealed, and 10 feet of weathered brown plastic shale.

Section on Frio River.—Frio River crosses the Fayette sandstone between a point 4 miles southwest of Tilden and a point 3 miles west of the McMullen-Live Oak county line.

The basal beds of the formation are found on the Tilden-San Antonio road 3⅛ miles north of Tilden. One foot of gray sandstone is exposed.

Four feet of yellowish-gray flaggy to laminated sandstone is exposed in the bottom of a gorge on the Tilden-Fowlerton road, about 3½ miles southwest of Tilden.

On the Tilden-San Diego road, about 5 miles S. 10° E. of Tilden, the Fayette sandstone consists of 9 feet of detached masses of yellow-brown noncalcareous sandstone and white silicified and opalized wood, 14 feet of soft yellow friable sandstone, 15 feet of yellow shale, 15 feet 4 inches of grayish-yellow soft sandstone, 20 feet 4 inches of gray shale, 23 feet of soft yellowish friable scoriaceous sandstone (the scoria due to the removal of fossils), 24 feet 6 inches of yellowish-gray flaggy sandstone, and 26 feet of yellowish-gray calcareous flaggy sandstone.

On the Tilden-Fowlerton road, half a mile S. 10° W. of Tilden, the Fayette sandstone shows 15 feet of gray flaggy sandstone, overlying 15 feet of green shale.

The Fayette sandstone at a point 1.9 miles S. 10° E. of Tilden shows 5 feet of gray fossiliferous flaggy sandstone, 7 feet of green shale, 10 feet of greenish-gray sandy shale, and 10 feet of alternating beds of gray sandstone about 6 inches thick and shale 2 feet thick. The clays contain masses of selenite averaging ¼ by 3 by 4 inches in size.

On the Tilden-San Diego road, 2 miles S. 10° ± E. of Tilden, the Fayette sandstone contains 1 foot of hard light-brown sandstone, 3 feet 8 inches of calcareous highly cross-bedded gray sand, 2 feet of greenish-gray calcareous sandy shale in one part of the exposure and in another part gray shale with interbedded flags of fossiliferous gray sandstone, 4 feet concealed, and 2 feet of gray thin-bedded sandstone.

On the Tilden-Oakville road, 3 miles east of Tilden, the Fayette sandstone contains 3 feet of hard gray cross-bedded sandstone in lenses, 3 feet of laminated argillaceous sandstone interbedded with fossiliferous sandstone flags, and 18 feet of brown shale.

Five feet of bedded hard gray sandstone is exposed in the bed of a creek which crosses the road from the Byrne ranch to Crowther, 3¾ miles south of Crowther.

Three feet of cross-bedded hard blue siliceous semiquartzitic sandstone caps the upland 3 miles east of Tilden on the Tilden-Oakville road. Much silicified wood, weathered out of the underlying sandstones, is strewn over the surface.

A bluff 20 feet high overlooking Frio River, 3¾ miles south of Crowther, consists of gray sandstone capped by a bed of sandstone 2 feet thick.

These sandstones extend northward, forming the Wellborn escarpment. About 3¼ miles south of Crowther the top of the scarp is 60 feet above the lowland on which the road lies and is capped by 10 feet of gray sandstone.

The topmost beds of the Fayette formation are shown in a low bluff 9 miles east-northeast of Tilden. Here 10 feet of gray bedded sandstone is exposed. The dip is approximately 2° N. 40° W. The sandstone is overlain by green clay 10 feet thick, probably the basal beds of the Frio clay.

Section on Nueces River.—Nueces River flows diagonally across the Fayette sandstone from a point 6 miles west to a point 3 miles east of the La Salle-McMullen county line. Here it turns northeast and follows the strike of the beds to a point 1 mile west of Shiner's ranch house, a total distance of about 30 miles. The outcrops are largely obscured by silt and gravel.

At a creek crossing on the road from Dobie ranch, about 21½ miles S. 15° ± W. of Fowlerton, the Fayette sandstone shows 3 feet of greenish-gray sandy clay, 2½ feet of soft light-gray argillaceous sandstone, and 2 feet of compact light-green shale.

On the opposite or south side of the creek, about a quarter of a mile S. 70° W., the beds consist of 6 inches of gray argillaceous sandstone, 2 feet of gray clay, probably weathered green shale, 4 feet of green shale, 3 inches of gray sandstone, and 2 feet of green shale.

Two feet of light-gray sandy shale is exposed about a mile southeast of the Camerone ranch house, on the road to the Miles ranch. Masses of crystallized aragonite weathered from the underlying shale and sandstone lie on the surface; these average 4 to 5 inches in diameter and are stained pink in places.

On the road from Miles ranch to Shiner's ranch, 12 miles S. 10° W. of Tilden, the Fayette sandstone shows 3 feet of yellowish-gray sandy clay, 8 inches of yellowish-gray soft calcareous sandstone, and 1 foot of yellow laminated sandy clay.

FRIO CLAY.[38]

Name.—The Frio clay was named by Dumble in 1894 for Frio River, in southwestern Texas, on which stream it is typically exposed.[39]

Stratigraphic position.—In the eastern part of the area under consideration the Frio clay lies conformably beneath the Catahoula sandstone, but in the western part of the area it lies unconformably beneath the Oakville sandstone.

[38] Partial synonymy of the Frio clay:

Fayette beds [included the Frio]: Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47-58, 1890.

Frio clays: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 554-555, 1984.

Frio clays: Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 22-23, 30-66, 1903.

Frio clays: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 40-43, 1903.

[39] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 554-555, 1894.

Lithology.—The Frio includes green and pink clay that contains small nodules of lime, green sandy calcareous clay, and beds of light-green marl consisting of lime and kaolinic material with pisolitic structure. South of Atascosa Creek the lower beds include layers of brown fossiliferous marl of marine origin, beds of gray sandstone, and in places concretions, from 4 inches to 3 feet in diameter, of hard, compact green siliceous limestone, stained with manganese. Fragments of agatized wood, beds of volcanic ash, and nodules and masses of white chalcedony may also be seen in places.

Thickness and dip.—The thickness of the Frio clay ranges from 235 to 705 feet. On the Brazos the Frio is largely overlapped by the Oakville sandstone. On the Nueces its thickness is 500 feet, and its dip is about 30 feet to the mile.

Paleontology.—North of Atascosa Creek the clay contains no marine fossils so far as known. In McMullen and Duval counties the lower beds carry *Ostrea georgiana* Conrad. Fragments of fossil wood have been found at some places, but the species they represent have not been determined.

Areal distribution.—The formation outcrops in a belt of country that ranges in width from 1 to 10 miles and that trends northeastward across Webb, Duval, McMullen, Live Oak, Karnes, Gonzales, and Fayette counties. (See Pl. VIII.)

Topographic expression.—The Frio clay, which is soft and easily eroded, underlies the Frio plain. (See p. 9.)

Correlation.—The sparse fauna of the Frio clay makes its correlation difficult. The lower beds in southwest Texas carry *Ostrea georgiana* Conrad, which may indicate a deposit of either late Eocene or early Oligocene age. The upper beds may be in part of early Oligocene age, but until further evidence is available the formation is classified as of late Eocene (Jackson) age.

In eastern Texas beds of clay that are in general of similar lithologic composition overlie the Catahoula sandstone. These clays were originally described by Kennedy[40] under the name Fleming beds and were by him subsequently erroneously correlated with the Frio clay. Later Matson found a Miocene fauna in the upper part of the Fleming clay of eastern Texas and western Louisiana. indicating that this part of the formation at least is of Miocene age and corresponds in time with the Oakville sandstone of southwestern Texas.[41]

Work done by Matson in 1912 along Sabine River showed that the beds heretofore called Fleming represent probably two stratigraphic units instead of one. The upper unit belongs to the Miocene; the lower unit is probably a part of the Oligocene.

The Catahoula sandstone of eastern Texas disappears west of Colorado River. Its time equivalent in southwestern Texas may be the upper part of the Frio clay.

Section in southern part of Gonzales County.—In a railroad cut about 1,000 feet south of the station at Sample there is about 5 feet of yellowish-white calcareous, argillaceous fine-grained sand with lime nodules about 1½ inches in diameter, which is a member of the Frio clay.

On a small branch about 1 mile northeast of Sample the Frio clay is represented by 2 feet of yellowish-white sandstone, overlying 2 feet of green calcareous shale with lime nodules.

Three feet of green calcareous clay containing lime nodules is exposed on the road from Sample to Westhoff, near the Gonzales-De Witt county line, about half a mile northwest of Westhoff. Five feet of green, calcareous clay containing lime nodules is exposed in the bank of a creek about a quarter of a mile northwest of the post office at Westhoff.

Section on San Antonio River.—San Antonio River crosses the Frio clay from a point about 5 miles west of Panna Maria to Helena. Three feet of green calcareous clay containing lime nodules is exposed about 1¼ miles west of Panna Maria.

On San Antonio River about three-fourths of a mile above the bridge on the Panna Maria-Karnes City road (see Pl. XXV, *C*) the Frio clay contains 10 feet of calcareous clay; 1 foot of greenish-white sandy, calcareous clay; 4 feet of greenish shale; 1 foot of greenish-white sandy, calcareous clay; 10 feet of green shale; 1 foot of greenish-white sandy, calcareous clay; 4 feet of green shale; and 1 foot of green shale

[40] Kennedy, William, A section from Terrell, Kaufman County, to Sabine Pass on the Gulf of Mexico: Texas Geol. Survey Third Ann. Rept., pp. 62-64, 113-123, 1892; The Eocene Tertiary of Texas east of Brazos River: Acad. Nat. Sci. Philadelphia Proc., 1895, pp. 93-95.

[41] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 72-73, 1914.

that has a nodular structure. The dip is 2° N. 42° E.

In the face of a bluff overlooking San Antonio River at Panna Maria there is exposed 15 feet of greenish-white sandy clay with numerous lime nodules.

Two feet of greenish-gray calcareous clay, seamed with lime, is exposed on the Helena-Panna Maria road about half a mile east of Panna Maria.

On Cibolo River, about 1 mile below the crossing of the Helena-Panna Maria road and about 1½ miles east of Panna Maria there is exposed 8 feet of greenish-gray calcareous clay, overlying 4 feet of yellow sandy clay.

On San Antonio River at the bridge on the Karnes City-Helena road, about 1½ miles southwest of Helena, there is exposed 12 feet of greenish-gray shale; 5 feet below the shale is fairly soft calcareous gray sandstone.

Section in western part of Karnes and eastern part of Atascosa counties.—Four feet of soft greenish argillaceous sandstone is exposed near the Hicock ranch house of the Alfred Donovan League No. 145, in the southeastern part of Atascosa County, and 4 feet of greenish-gray argillaceous sand in a gully about a mile northwest of it.

One foot of green compact shale, containing limestone concretions 5 to 6 inches in diameter, is exposed by the side of the Karnes City-Oakville road about a mile east of the crossing in Shockley Hollow, in the southeastern part of Atascosa County.

Extensive beds of volcanic ash are found in the Frio clay in the western part of Karnes County, about 10 miles west-southwest of Karnes City.

Four feet of greenish-yellow sandy shale, overlying 1 foot of compact green shale, is exposed on the Karnes City-Oakville road about one-fourth of a mile southeast of the southeast corner of Atascosa County. Lenses of gray sandstone, 2 inches thick and 6 inches long, occur near the base of the greenish-yellow sandy shale. Nodules of chalcedony 2 to 3 inches in diameter are scattered through the sandy shale.

Two feet of greenish-gray laminated sandy clay with nodules of calcareous, sandy shale, overlying 6 inches of greenish-gray argillaceous sand, is exposed in a pit at the cotton gin at Lenz, Karnes County.

Section in Live Oak County.—Greenish-gray shale, 3 feet thick, containing sandstone concretions, is exposed on the Campbellton-Oakville road at the crossing of a small creek about half a mile north of milepost 18 out of Oakville, in the northern part of Live Oak County. The sandstone concretions, which average 1 foot in diameter, are septarial in structure, aragonite forming the septa.

On San Cristobal Creek at the crossing of the Campbellton-Oakville road, about 11 miles north-northwest of Oakville, Live Oak County (see Pl. XXV, *D*), the Frio clay shows 14 feet 4 inches of soft pinkish-gray argillaceous sand; 6 inches of pink sandy clay; 1 foot of hard pinkish-gray laminated sandstone; 8 inches of pink sandy clay; 2 feet of pink argillaceous, calcareous sandstone in beds 4 inches thick; and a lens of pinkish-gray calcareous, argillaceous sandstone. The dip is 2° S. 50° E.

In the bed of Atascosa Creek at the crossing of the Oakville-Crowther road about 8 miles northwest of Oakville, there is exposed 6 inches of green argillaceous, sandy limestone, overlying 7 inches of green calcareous, sandy clay.

Log of well of U. S. I. Realty Co. at Fant City, 8¼ miles north of Oakville, Live Oak County, Tex.

[Geologic interpretation by Alexander Deussen.]

	Thickness.	Depth.
	Feet.	*Feet.*
Frio clay:		
Gray gritty plastic clay	65	65
Pinkish-gray lime and volcanic ash (?)	35	100
Green clay	40	140
Green gritty clay	15	155
Green calcareous, sandy clay	10	165
Green gritty, calcareous clay	195	360
Green sandy clay	21	381
Green marl with lime nodules	39	420
Hard green argillaceous limestone and green brittle clay	44	464
Green sandy, argillaceous limestone	26	490
Fayette sandstone:		
Green sandy limestone and green sandy clay	55	545
Light greenish-gray argillaceous limestone and green gritty clay	75	620
Greenish-gray limestone and dark green calcareous sandstone (?)	40	660
Green sandy, calcareous clay	115	775
Blue calcareous plastic clay	145	920
Green gritty, calcareous clay	50	970
Calcareous sand, chiefly quartz; fragments angular to subangular	30	1,000
Gray calcareous, quartzose sand	140	1,140
Dark grayish-green shale	133	1,273
Green sandy clay (sand ?)	17	1,290
Dark-green shale	21	1,311
Light-green sandy clay	2	1,313
Dark-green shale	14	1,327
Fossiliferous marl	5	1,332
Green brittle clay	21	1,353
Calcareous greenish-gray sand, with fragments of fossils	2	1,355

Log of well of U. S. I. Realty Co. at Fant City, 8¼ miles north of Oakville, Live Oak County, Tex.—Continued.

	Thickness.	Depth.
Yegua formation:		
Green clay with fragments of blue argillaceous limestone	*Feet.* 14	*Feet.* 1,369
Greenish-gray fossiliferous clay	2	1,371
Green clay	13	1,384
Fossiliferous marl	5	1,389
Green clay	14	1,403
Greenish-gray clay	3	1,406
Brown lignitic, sandy clay	34	1,440
Fossiliferous marl	31	1,471
Green clay ?	57	1,528
Fossiliferous sand and fragments of magnetite and limonite	26	1,554
Green sandy clay	5	1,559
Gray sand	24	1,583
Green clay and sand	77	1,660
Green sandy clay	78	1,738
Green calcareous clay	29	1,767
Green shale and green clay	13	1,780
Dark-green clay	17	1,797
Greenish-white clay and dark-green clay	31	1,828
Green plastic clay	13	1,841
Green clay	52	1,893
Bluish-gray calcareous, sandy clay	19	1,912
Green calcareous, sandy clay	15	1,927
Green sandy clay	13	1,940
Dark-green compact clay	44	1,984
Greenish-gray sandy clay	29	2,013
Dark-green hard clay	15	2,028
Cook Mountain and Mount Selman formations:		
Green calcareous clay	42	2,070
Hard green clay	56	2,126
Dark-green clay with some glauconite (?)	87	2,213
Green calcareous fossiliferous clay	48	2,261
Gray calcareous fossiliferous sand	26	2,287
Green plastic fossiliferous clay	34	2,321
Light-green sandy, calcareous clay	36	2,357
Dark-green compact clay	54	2,411
Green fossiliferous calcareous sand and sandy clay	38	2,449
Green sandy clay with glauconite	28	2,477
Dark-green sandy clay	29	2,506
Green sandy clay with little glauconite	35	2,541
Green glauconitic sandy clay	29	2,570
Green compact clay	33	2,603
Green glauconitic sandy clay	25	2,628
Compact green clay	25	2,653
Green glauconitic sandy clay with fragments of lignite (?)	31	2,684
Green plastic clay	10	2,694
Green sandy clay, flecked with lime	15	2,709
Green, compact clay	8	2,717
Green glauconitic fossiliferous clay	176	2,893
Green sandy clay	239	3,132
Dark-green clay	83	3,215
Dark-green fossiliferous clay	47	3,262
Gray quartzose sand	17	3,279
Dark-green fossiliferous clay [a]	181	3,460
Dark slate-colored clay	32	3,492
Gray quartzose sand	25	3,517
Dark-green clay	40	3,557

[a] The following fossils were identified: Foraminifera: *Turbinolia pharetra* Lea, *Marginella semenoides* Gabb, *Neverita arata* Gabb, *Corbula deusseni* Gardner (?), *Venericardia* sp. A typical lower Claiborne fauna.

Section on Frio River.—Frio River crosses the Frio clay from a point about 3 miles west of the McMullen-Live Oak county line to its junction with Nueces River, about 3 miles west of Oakville.

The basal beds of the formation are exposed at the Byrne ranch house, 9 miles east-northeast of Tilden. This section is described on page 91. The green clay overlying the sandstone probably represents the basal beds of the Frio.

Four feet of gray thin-bedded sandstone and 4 feet of overlying green shale containing small lime nodules is exposed on the Tilden road a quarter of a mile southwest of the Byrne ranch.

Oyster shells (*Ostrea georgiana* Conrad) are embedded in a green clay a mile south of the Byrne ranch house.

Six feet of green shale containing small lime nodules averaging a quarter of an inch in diameter and overlying a bed of brown shell marl 4 feet thick, carrying fossil oysters, is exposed on the Tilden road, 1½ miles southwest of the Byrne ranch.

On the Tilden-Oakville road, one-fourth of a mile east of milepost 7 out of Tilden, there is exposed 1 foot of yellow marl with numerous specimens of *Ostrea georgiana* Conrad, overlying 2 feet of green shale.

In the bed of Frio River, about 7 miles northwest of Oakville, 6 inches of hard crystalline limestone concretions, forming a pavement and having the appearance of a stratum of limestone in the bed of the river, overlies 2 feet of white argillaceous sand with limestone concretions, and this in turn overlies 6 inches of limestone.

On Frio River, about 300 feet below the bridge on the Tilden-Oakville road and 4 miles northwest of Oakville, the Frio clay shows 11½ feet of greenish-white sandy clay (lens), 2 feet of pinkish-gray sandy shale (lens), and 1 foot of light-brown sandy shale.

About 600 feet below the bridge the pinkish shale, containing limestone concretions 3 to 10 inches in diameter, is 6 feet thick above the water line. This is the type locality of the Frio clay.

Section on Nueces River.—Nueces River crosses the Frio clay between a point 1 mile west of Shiner's ranch and the junction with Frio River about 3 miles west of Oakville.

On the Tilden-San Diego road about 13½ miles south of Tilden, 6 feet of gray sandstone in beds 6 to 8 inches thick is exposed.

On the Tilden-San Diego road in McMullen County, about one-fourth of a mile north of milepost 18 out of Tilden (see Pl. XXVI), the Frio clay shows 1 foot of greenish-gray sandy shale, with nodules of light-brown chalcedony averaging 2 by 6 by 10 inches in dimensions, overlying 10 feet of greenish-gray clay. The dip is ½° S. 20° W.

On the Tilden-San Diego road, about one-fourth of a mile south of milepost 18 out of Tilden, the Frio clay exposes 4 feet of green talclike shale; 3 inches of white sandy limestone; 2 feet of greenish-white indurated sandy shale; 4 feet of green compact shale; and 20 feet of greenish-gray sandy, calcareous shale. The beds dip 1° S. 50° E.

About 6 feet of massive greenish-gray sandy clay is exposed on the San Diego-Tilden road, about half a mile north of milepost 20 out of Tilden.

Section at Los Picachos Hill.—At Los Picachos Hill, in Duval County, a mile south of the McMullen county line, almost due south of Tilden, the Frio clay, consisting of 10 feet of greenish-gray marl in beds 10 to 12 inches thick and dipping 20° S. 30° E., is exposed. These beds lie not more than 40 to 50 feet below the top of the Frio formation.

A microscopic examination of the marl by Mr. E. S. Larsen indicates that it is chiefly a fibrous carbonate (probably calcite), containing a few quartz grains of fragmental origin and some pisolitic areas of brownish, nearly isotropic material, probably kaolinic or bauxitic.

A chemical analysis of the marl follows:

Analysis of marl in the Frio clay from Los Picachos Hill, Duval County, Tex.

[Analysis by W. T. Read, March, 1914.]

Silica (SiO_2)	24.87
Alumina (Al_2O_3)	4.24
Ferric oxide (Fe_2O_3)	3.51
Calcium oxide (CaO)	46.01
Magnesium oxide (MgO)	1.55
Sodium and potassium oxides (Na_2O+K_2O)	1.33
	81.51

Qualitative tests show that the marl contains considerable carbon dioxide (CO_2).

OLIGOCENE SERIES.

CATAHOULA SANDSTONE.

Name.—The Catahoula sandstone was named by Veatch in 1906 from Catahoula Parish, La.[42]

Stratigraphic position.—The formation lies conformably above the Fayette sandstone in Washington and Fayette counties and unconformably beneath the Oakville sandstone south of Lavaca County.

Lithology.—The formation consists of hard blue quartzose sandstone; green, blue, and brown massive talclike clay; calcareous gray cross-bedded sandstone containing lenses of white kaolin-like clay; green sandy clay; and gray bedded sandstone. It contains abundant petrified wood but no lignite or lignitic clay.

Thickness and dip.—Along the Brazos the formation is about 200 feet thick. It becomes thinner toward the south and disappears completely south of Colorado River. It dips southeastward at the rate of about 40 feet to the mile. Toward the sea the formation thickens to 1,200 feet.

Topographic expression.—Where the formation crops out it forms westward-facing scarps and low hills capped with blue quartzite. The soft sandstone is in places eroded into badlands. (See Pl. XXVII, *A*.)

Paleontology.—No marine fossils have been found in this formation, but some fossil plants have been collected. Petrified wood is associated with the beds, but it has not yet been studied in detail.

Areal extent.—The formation crops out on a narrow strip of land lying between the outcrops of the Fayette and Oakville sandstone north of Colorado River in Fayette and Washington counties. (See Pl. VIII.)

Correlation.—The formation is continuous with the Catahoula sandstone of east Texas and Louisiana. Its correlation with that formation is discussed in detail in the description of the Fayette sandstone. (See pp. 82–84.)

Section in Washington County.—In a cut on the Gulf, Colorado & Santa Fe Railway about a quarter of a mile south of the crossing of

[42] Veatch, A. C., Geology and underground water resources of northern Louisiana and southern Arkansas: U. S. Geol. Survey Prof. Paper 46, pp. 42–43, 1906.

Yegua Creek, in Washington County, the Catahoula sandstone is exposed as 4 feet of hard gray sandstone overlying 6 feet 2 inches of gray sandstone.

In an old quarry on the Williams farm, 2 miles southeast of Somerville, there is exposed 15 feet of hard gray sandstone containing silicified wood and a lens 5 to 20 feet thick of white talclike clay resembling kaolin. Burning tests indicate that this clay is not a true kaolin and that it is not suited for manufacturing white ware.

About 15 feet of hard gray sandstone is exposed at Quarry, Washington County, on the Gulf, Colorado & Santa Fe Railway. The sandstone is utilized for making crushed rock.

About 10 feet of laminated gray sandstone, overlying 3 feet of green hard fine-grained shale is exposed on Kerr Creek about 4 miles northwest of Burton.

On the McHenry Winbourn (?) survey, about 4 miles north of Burton, the beds of the Catahoula sandstone show 5 feet of hard brown shale, 6 inches of white marl, and 3 feet of hard brown shale.

Section on Colorado River.—About 10 feet of light-gray sandstone and 10 feet of underlying green clay is exposed on Colorado River about a quarter of a mile north of the railroad bridge at La Grange.

On the La Grange-Columbus road, on the north side of the Colorado, near La Grange, the exposure at the crossing of Cedar Creek

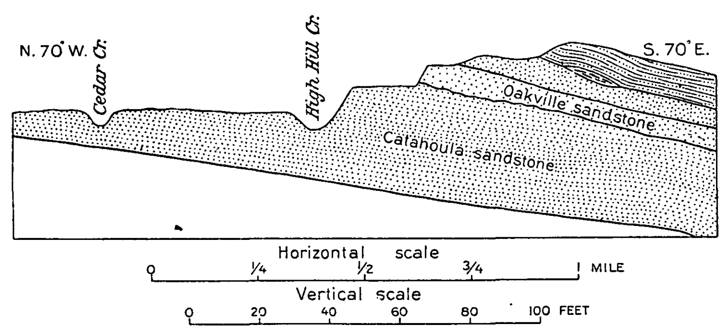

FIGURE 27.—Sketch profile showing geologic relations of formations on Cedar Creek and High Hill Creek near La Grange, Tex.

and that at the crossing of High Hill Creek are quite different, owing to the southeastward dip of the rocks. This difference is shown in figure 27. On Cedar Creek there is exposed 30 feet of green calcareous sandy clay with no formation above it except surficial material. On High Hill Creek the green calcareous sandy clay, having a thickness of 10 feet, is overlain by more than 20 feet of sandstone belonging to the Oakville sandstone.

At the point where the Gulf, Colorado and Santa Fe Railway crosses a creek about a mile northwest of Gay Hill 15 feet of alternately hard and soft gray or white sand is exposed.

About 100 yards south of Gay Hill station a cut shows 20 feet of dark-gray calcareous clay.

In a small gorge on the S. O. Tatum farm, 5 miles northwest of Burton, the Catahoula sandstone (see Pl. XXVII, *B*) contains 3 feet of cross-bedded gray sand; a lens of kaolinlike, fine-grained tough white clay, exposed for a length of 75 feet and for 10 feet vertically; and a bed of bluish sand. Burning tests show that the clay is not suited for making white ware. These beds overlie those of the Fayette sandstone, which are exposed about 300 yards to the north.

Section on Buckner Creek, Fayette County.—Green clay of the Catahoula formation and overlying hard gray sandstone of the Oakville formation is exposed on Allens Creek, a branch of Buckner Creek, on the Cedar-La Grange road, about 5 miles southwest of La Grange.

Section near Flatonia.—White calcareous clay containing calcareous nodules is exposed near Flatonia.

MIOCENE SERIES.

OAKVILLE SANDSTONE.[43]

Name.—The Oakville sandstone was named by Dumble in 1894 from Oakville, Live Oak County, where it is typically exposed.[44]

Stratigraphic position.—The formation lies with pronounced unconformity on both the underlying Catahoula sandstone and the Frio clay, in places overlapping them considerably. On Nueces River it lies probably unconformably beneath the Lapara sand. North of Guadalupe River it lies unconformably below the Lagarto clay.

Lithology.—The formation consists largely of gray sandstone. At some places it is soft and highly calcareous; at others it is hard. The sandstone is generally cross-bedded or its bedding is very irregular. It includes some lenses of clay and conglomerate. Its materials were apparently laid down by rapid currents in shallow water.

Thickness and dip.—The thickness of the Oakville formation ranges from 180 to 603 feet. Its thickness on the Brazos is 200 feet and its dip is 40 feet to the mile to the southeast; its thickness on the Nueces is about 300 feet and its dip is 40 feet to the mile.

Paleontology.—The formation contains no marine fossils but many remains of vertebrates. The species identified include *Coenopus* sp., *Protohippus medius* Cope, *Protohippus perditus* Leidy, *Protohippus placidus* Leidy, and *Aphelops meridianus* Leidy. (See Pl. XXVIII.)

Areal distribution.—The formation crops out in a belt of country, from 1 to 10 miles wide, that trends northeastward across Duval, McMullen, Live Oak, Bee, Karnes, De Witt, Lavaca, Fayette, and Washington counties. (See Pl. VIII.)

Topographic expression.—The Oakville sandstone in part forms the Washington prairies and the Oakville plain, the topographic features of which are described on page 9 of this report.

Correlation.—The fauna of the Oakville sandstone indicates its Miocene age.

The formation does not extend east of Grimes County. In eastern Texas its equivalent in age is a calcareous clay (a part of the Fleming clay), which carries an identical fauna.

Section in Grimes County.—C. L. Baker collected from clay beds half a mile south of the Madisonville branch of the International & Great Northern Railway, 5 miles northeast of Navasota, the following Miocene vertebrates, identified by Dr. W. D. Matthew.[45]

Merychippus, small species, resembling *M. seversus* but probably not identical; upper molar and fragments of foot bones. Age indicated, middle Miocene; but upper Miocene or lower Pliocene is not excluded.

Rhinoceros, cf. *Aphelops*, fragments of teeth, head of radius. Age indicated, Miocene.

Camelid, cf. *Protolabis* or *Procamelus*, fragment of lower molar, astragalus, navicular, unciform; fragments of foot bones, (?) symphysis of jaw. Age indicated, Miocene or Pliocene.

Testudo, large species, fragments of carapace.

Crocodilian remains; fragments of skull.

Dr. Matthew states:

Fauna * * * is certainly not earlier than middle Miocene of Osborn's correlation, nor younger than lower Pliocene. Absence of all characteristically upper Miocene or lower Pliocene mammals points to middle Miocene as the proper correlation. But there are two points which should be considered as making for a possible later date than the comparison indicates: (1) Our land faunas are most derived from the north and northwest, and older types may have lingered longer along the Atlantic and Gulf coasts than in the northwest, thus making the fauna seem older than it is. (2) Knowlton regards the Mascall on plant evidence as upper Miocene. This, if accepted, would set our whole scale of continental Neocene horizons a little higher than does Osborn's correlation. If you give much weight to these considerations they might serve to set the correlation up to upper Miocene. The fauna is quite decidedly older than the Blanco.

Section in Washington County.—According to Kennedy, sandstone extends diagonally southwestward across Brazos River at Hidalgo Falls, 5 miles west of Navasota. It is overlain a short distance west of the stream by a gray

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[43] Partial synonymy of the Oakville sandstone:

Miocene Tertiary strata: Shumard, B. F., Acad. Sci. St. Louis Trans., vol. 2, pp. 140–141, 1868.

Grand Gulf: Loughridge, R. H., Report on the cotton production of the State of Texas with a discussion of the general agricultural features of the State: Tenth Census U. S., vol. 5, pt. 1, p. 679, 1884.

Fayette beds [included the Yegua, Fayette, Oakville, Frio, Lapara, and Lagarto formations]: Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47–58, 1890.

Navasota beds [included Oakville sandstone and Lagarto clay]: Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., pp. 9–15, 43–44, 1893.

Oakville beds: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 556–559, 1894; Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 43–60, 1903.

Dewitt formation [included the Oakville, Lapara, and Lagarto formations]: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 74–76, 1914.

[44] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 556–559, 1894.

[45] Letter of Dr. Matthew published by Dumble. Dumble, E. T., Problem of Texas Tertiary sands: Geol. Soc. America Bull., vol. 26, p. 472, 1915.

calcareous, thinly bedded sandstone, which rises 100 feet above the stream and forms a scarp that extends westward for several miles.[46]

About 100 feet of brown shale is exposed in the banks of a small creek on the Derrick farm, about 3½ miles west of Burton. A jaw bone of an extinct rhinoceros was taken from the shale. The following report was made by Mr. J. W. Gidley, of the United States National Museum, on this specimen:

The bone from Washington County, Tex. (see Pl. XXVIII), is a part of an upper jaw containing four anterior teeth on the left side. It represents an extinct species of rhinoceros. The teeth are so much worn, however, that the specimen can not be assigned to any particular species, but it is apparently new. It resembles in some respects some of the European late Miocene Aceratheres, and it may be provisionally assigned to the genus *Coenopus*. The development of the premolars, as indicated by the great prominence of their posterior internal cusps, is further advanced than in any known Oligocene form, so that the species may probably be referable to a middle or upper Miocene horizon, perhaps even to one in the Pliocene.

Cross-bedded calcareous gray sand crops out on the Burton-Long Point road about 3½ miles north of Burton.

Gray calcareous sandstone crops out on the Burton-Long Point road 2 miles southwest of Long Point.

About 20 feet of gray calcareous clay containing small lime nodules is exposed 125 yards north of the railway station at Burton, Washington County.

As early as 1860 Shumard [47] called attention to the occurrence of Miocene beds in Washington County. In a letter published in 1863 he wrote:

Not among the least important results of the survey is the discovery, in Washington and adjoining counties, of an extensive development of Miocene Tertiary strata, referable to the age of the Miocene deposits of the Mauvaises Terres of Nebraska, which have yielded such a wonderful profusion of extinct mammalian and chelonian remains. The Texan strata consist of calcareous and siliceous sandstones and white, pinkish, and grayish siliceous and calcareous marls. The calcareous beds are often almost wholly composed of finely comminuted and waterworn shells, chiefly derived from the destruction of Cretaceous strata, and in places abound in fossil bones and plants, usually in a fine state of preservation. The bones have been usually found in excavations for wells, at depths varying from 20 to 60 feet below the surface, and consist of genera closely allied to or identical with *Titanotherium*, *Rhinoceros*, *Equus*, and *Crocodilus*.

[46] Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., p. 44, 1893.
[47] St. Louis Acad. Sci. Trans., vol. 2, pp. 140-141, 1863.

Section on Colorado River.—The following sections of the Oakville sandstone occur in the drainage basin of Colorado River:

The basal beds of the Oakville are exposed on the La Grange-Columbus road at the crossing on High Hill Creek, about 2¼ miles east of La Grange. A description of this exposure is given on page 96 and is shown in figure 27.

The lower 40 or 50 feet of the section exposed on the west side of Monument Hill, 1 mile southeast of the post office at La Grange, consists of calcareous flaggy sandstone, with interstratified beds of brown calcareous clay. The upper 20 or 30 feet is firm gray sandstone.

The La Grange-Columbus road crosses the gorge of Rocky Creek about 4 miles east of La Grange. The bluffs at this crossing are capped by 10 to 12 feet of irregularly bedded hard gray sandstone.

A columnar section of the Oakville sandstone exposed on Colorado River is shown in Plate IX (in pocket).

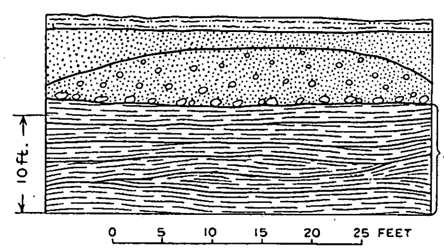

FIGURE 28.—Sketch of section 1 mile south of Moulton, Tex.

Section in Lavaca County.—The following sections of the Oakville sandstone were observed in Lavaca County:

About 3 feet of coarse angular sand containing clay balls and 10 feet of underlying calcareous white sandy clay is exposed a mile south of Moulton. (See fig. 28.) At Shiner gray sand with alternating beds of white clay is exposed.

Section on Guadalupe River.—Ten feet of yellowish-white argillaceous sand with lime concretions is exposed in the bank of a creek on the Westhoff-Cuero road about half a mile southeast of Westhoff.

About 2 miles farther southeast gray calcareous shale containing small lime nodules is exposed.

On Clear Fork Creek where it is crossed by the Westhoff-Cuero road, about 3 miles northwest of Lindenau, the Oakville sandstone shows 2 feet of yellow sand with lime nodules an inch in diameter, 1 foot of soft yellow sandstone (lens), and 3 feet of gray sand.

Section on Nueces River.—Nueces River crosses the Oakville sandstone between Oakville and the site of old Fort Merrill. The following section is exposed at Oakville:

Section of bluff on Sulphur Creek at bridge on the Oakville-Beeville road at Oakville, Tex.

[See Pl. XXIX, *A*.]

	Ft.	in.
Lapara sandstone:		
Blue clay with streaks, patches, and nodules of white lime	5–6	
Blue sand	3	
Small lenses of black flint pebbles		2
Blue sand		2
Blue limy clay		3
Blue coarse cross-bedded sand		2
Fine black flint pebble conglomerate		2
Blue coarse cross-bedded sand	1	
Conglomerate of black flint pebbles, about half an inch in diameter, cemented by yellow ferruginous sand		1–6
Erosional unconformity.		
Coarse-grained sand		6 (?)
Conglomerate made up of pebbles and cobbles of black flint, etc., cemented by a ferruginous sand	1	
Unconformity.		
Oakville sandstone:		
Bluish-white calcareous sandy shale, containing lime nodules 2 to 3 inches in diameter	1	
Blue shale in bands 3 inches thick alternating with bands of yellow ferruginous clay 1 inch thick	6–8	
Gray poorly consolidated calcareous sandstone	2	6
Blue shale		4
Soft laminated calcareous sandstone	3	
Yellow clay		3
Slightly consolidated sandstone		4
Irregularly bedded and cross-bedded sandstone	2	6
Coarsely laminated, poorly consolidated sandstone	3	
Wavy, loosely consolidated yellow calcareous sandstone	1	6

The beds dip N. 70° E. at an angle of 1°.

About 3 feet of greenish sandy clay containing small white lime nodules half an inch in diameter is exposed in Friday Hollow, 1 mile east of the courthouse at Oakville. At a point about 100 yards to the east 4 feet of yellow weathered clay and 4 feet of underlying hard-bedded gray sandstone interbedded with layers of softer sandstone is exposed.

At Bartlett's Ford on Nueces River, about 2 miles south of Oakville, the Oakville sandstone contains interbedded sands and clays with gypsum, 5 feet of mottled brown and gray rusty clay and sandy clay, and 15 feet of brown sandstone.[48]

On Nueces River, at the mouth of a creek 3 miles south of Oakville,[49] there is exposed 14 feet of sandstone containing narrow fissile bands of lime concretions, 20 feet of green clay, 3 feet of interbedded green and brown sandy clay, and 4 feet of light sea-green sand.

At a bridge over Nueces River at Mikeska, Live Oak County (see Pl. XXIX, *B*), there is exposed a lens of pink sandy and calcareous clay 3 feet thick, overlying coarse brownish-yellow sand 3 feet thick.

At the site of old Fort Merrill, 3 miles southeast of Mikeska, beds of the Oakville sandstone consist of 5 feet of cross-bedded coarse porous yellow sand; 20 feet of reddish-brown shale, greenish-blue in spots; 3 feet of coarse gray nonstratified sand; 24 feet concealed; and 5 feet of stratified yellow sand.

The beds of the Oakville sandstone between Oakville and Mikeska contain, according to Dumble, *Protohippus medius* Cope, *Protohippus perditus* Leidy; *Protohippus placidus* Leidy; *Aphelops meridianus* Leidy.[50] According to Cope, who identified the fossils, they represent a "Loup Fork" or an upper Miocene zone.

Section in McMullen County.—On the McMullen-Duval county line, near the Tilden-San Diego road, south of Tilden, there is a low hill which is capped by 5 feet of hard greenish-gray irregularly bedded sandstone, in beds averaging a foot in thickness.

Lomo Alto, a conspicuous hill in the southern part of McMullen County, about 1½ miles north of the McMullen-Duval county line and three-fourths of a mile west of the Tilden-San Diego road, is capped and preserved by 25 feet of hard gray sandstone, in beds ranging in thickness from 10 inches to 3 feet. The beds dip N. 50° E. at an angle of ½°. (See Pl. IV, *A*, p. 12.)

MARINE MIOCENE AND PLIOCENE.

Marine deposits of Miocene and probably of early Pliocene age are exposed in Brazoria County and the counties to the east and may extend some distance southwestward toward the Rio Grande. These deposits are correlated with the Oakville, Lapara, and Lagarto formations. They do not outcrop in the area here considered.

[48] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 46–47, 1903.
[49] Idem, p. 48.
[50] Idem, p. 44.

At Galveston these beds are found from 2,158 to 2,920 feet beneath the surface. They consist of green clay, indurated fine gray sand, dark clay with lignitized wood and fruits, corals, fish vertebrae, and marine fossils, sandy clay, shell conglomerate, and blue clay with lime nodules. The fossils include *Arca carolinensis*, *Turritella subgrundifera* var., and *Natica eminuloides*. A similar fauna was found at a depth of 649 to 688 feet at Bryan Heights, near Velasco, in Brazoria County.

PLIOCENE SERIES (NONMARINE FORMATIONS).

LAPARA SAND.[51]

Name.—The Lapara sand was so named by Dumble in 1894 after Lapara Creek, in Live Oak County, Tex., where it is typically displayed.[52]

Stratigraphic position.—The formation is exposed only on Nueces River, where it lies unconformably (?) above the Oakville sandstone and conformably (?) below the Lagarto clay.

Lithology.—The formation consists of sand and interbedded and cross-bedded limy clay. The sand is sharp, coarse, and friable and contains clay pebbles and lime concretions. The clay is of several colors—pink, light red, green, and others. At some places it contains lime nodules and at others clay pebbles.

Thickness and dip.—The thickness indicated by well records is 75 to 455 feet, and the dip is about 34 feet to the mile southeast.

Paleontology.—Worn fragments of bone have been found in the formation, but they are difficult to identify. The fossils found indicate that the beds are of Pliocene (Blanco) age. Dumble reports the occurrence of bones and teeth of small animals in the interbedded sands exposed in a gulch 1½ miles north of Barlow's ferry, on Nueces River, 1½ to 2 miles east of old Fort Merrill. According to Cope, these remains are of middle Pliocene (Blanco) age.[53]

Areal extent.—The formation is exposed in Nueces Valley, in Live Oak County, between Oakville and Dinero.

Correlation.—The Lapara sand has been found only in the valley of Nueces River. If it extends farther east it is overlapped completely by the Lagarto clay. The time equivalents east of the Brazos are some members of the Fleming clay. On the other hand, a fauna identical with that occurring northeast of Navasota—a fauna that is distinctly older than the Blanco or that represented by the Lapara sand [54]—has been found at Cold Springs, in San Jacinto County, in the upper part of the Fleming clay. This fact would seem to indicate that the stratigraphic equivalents of the Lapara are not exposed east of the Brazos.

Section on Nueces River.—A section of the Lapara sand in the Nueces Valley has been given in connection with the description of the Oakville sandstone. (See p. 99.) Additional outcrops are described below.

Interbedded sand (or grit) and clay are exposed in a gulch 1½ miles north of Barlow's ferry, on the Nueces, 1½ to 2 miles east of old Fort Merrill.

Pink clay or shale with green mottling, like that seen in the shale found at old Fort Merrill, is exposed for a distance of 2 feet above the water line at a point 100 feet above the bridge at Dinero, Live Oak County. About 500 feet below the bridge coarse yellow poorly bedded calcareous sandstone may be seen to a level of 5 feet above the water line.

LAGARTO CLAY.[55]

Name.—The Lagarto clay was named by Dumble in 1894 from Lagarto Creek, in Live Oak County, where it is typically exposed.[56]

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[51] Partial synonymy of the Lapara formation:

Fayette beds [included the Yegua, Fayette, Frio, Oakville, Lapara, and Lagarto formations]: Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47-58, 1890.

Lapara division: Dumble, E. T., The Cenozoic deposits of Texas: Jour Geology, vol. 2, pp. 559-560, 1894.

Lapara beds: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 44-60, 1903.

Dewitt formation [included the Oakville, Lapara, and Lagarto formations]: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 74-76, 1914.

[52] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 559-560, 1894.

[53] Dumble, E. T., op. cit., pp. 52-53.

[54] Dumble, E. T., Problem of the Texas Tertiary sands: Geol. Soc. America Bull., vol. 26, pp. 470-473, 1915.

[55] Partial synonymy of the Lagarto formation:

Fayette beds [included Yegua, Fayette, Frio, Oakville, Lapara, and Lagarto formations]: Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 47-58, 1890.

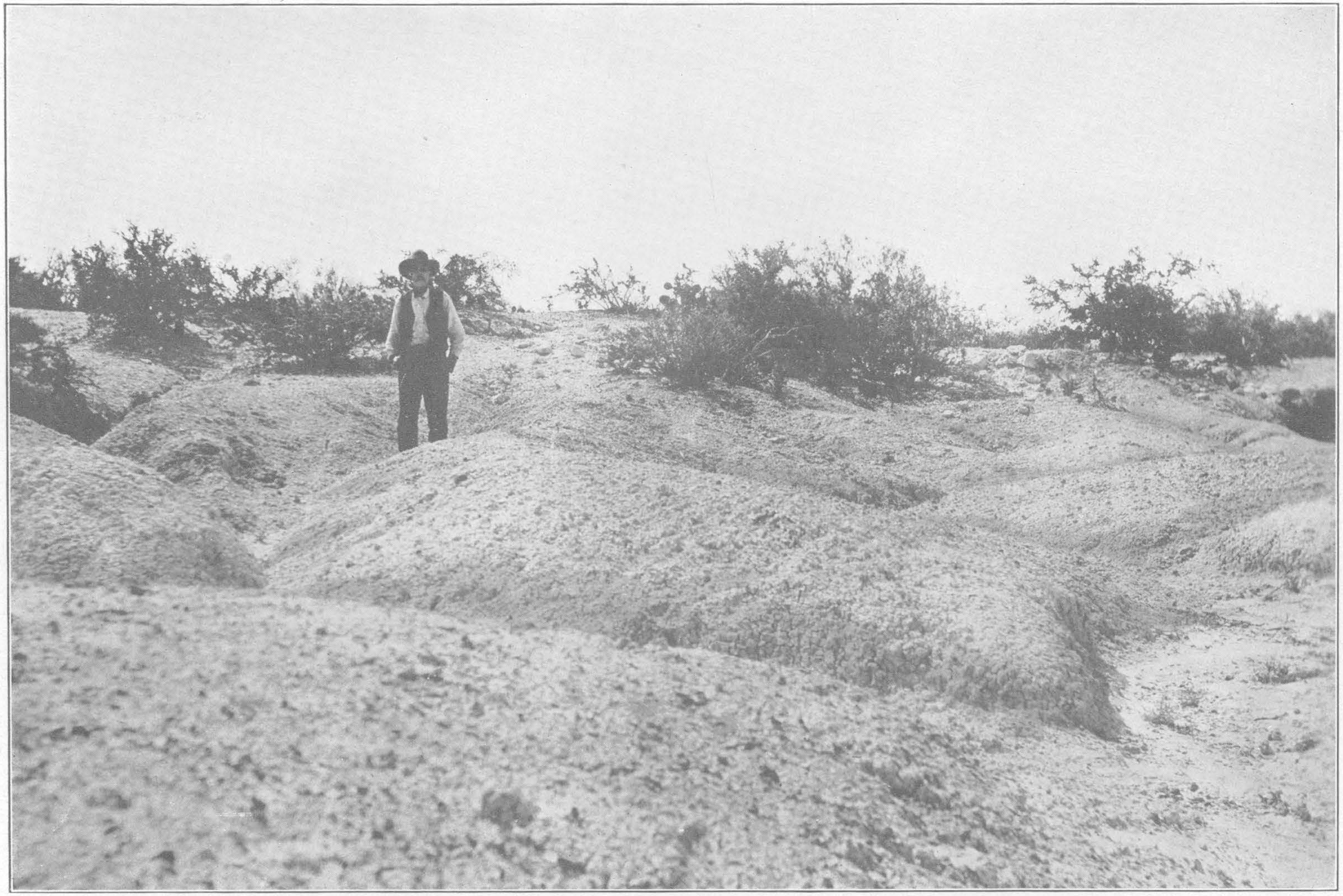
Navasota beds [included Lagarto clay and Oakville sandstone]: Kennedy, William, Report on Grimes, Brazos, and Robertson counties: Texas Geol. Survey Fourth Ann. Rept., pp. 9-15, 43-44, 1893.

Lagarto division: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 560, 1894.

Lagarto beds: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 60-63, 1903.

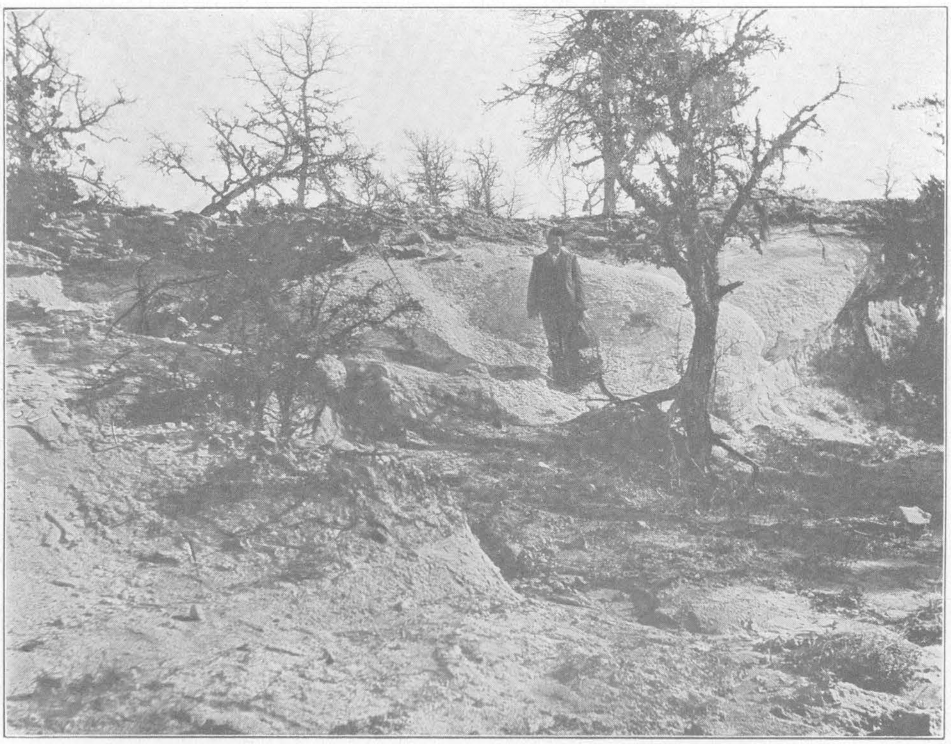
Dewitt formation [included Oakville, Lapara, and Lagarto formations]: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 74-76, 1914.

[56] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 560, 1894.

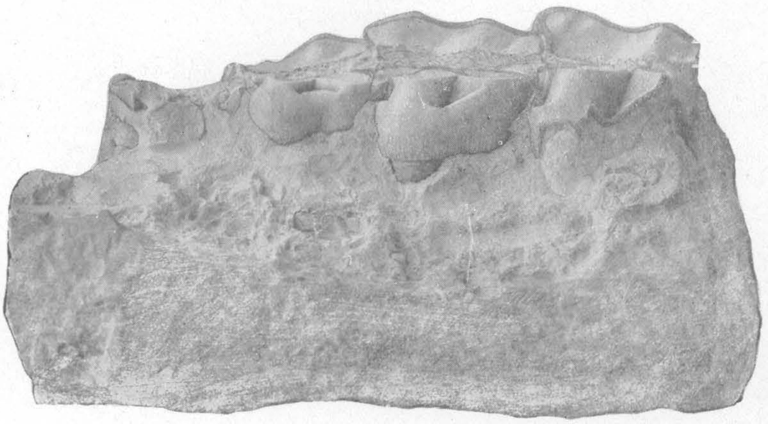


FRIO CLAY ON ROAD BETWEEN TILDEN AND SAN DIEGO, McMULLEN COUNTY, TEX., A QUARTER OF A MILE NORTH OF MILEPOST 18 OUT OF TILDEN.

A. BADLANDS FORMED BY GRAY SANDS OF THE CATAHOULA SANDSTONE 5 MILES NORTHWEST OF BURTON, WASHINGTON COUNTY, TEX.

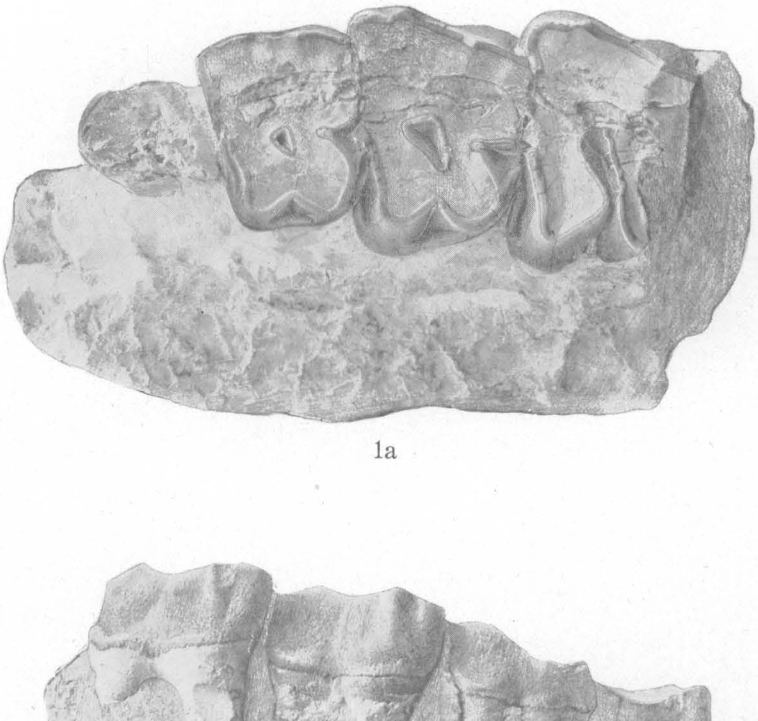


B. LENSES OF KAOLIN-LIKE CLAY IN CATAHOULA SANDSTONE 5 MILES NORTHWEST OF BURTON, WASHINGTON COUNTY, TEX.

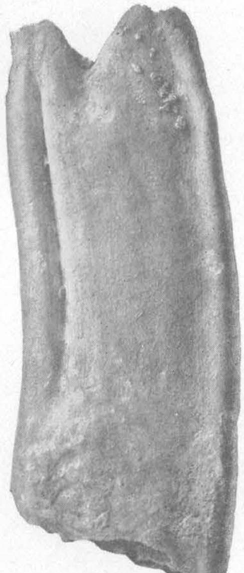


1

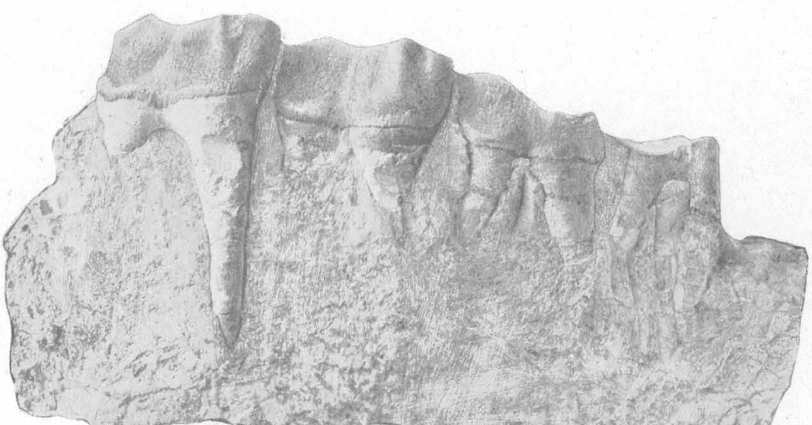
2



1a



2a



1b

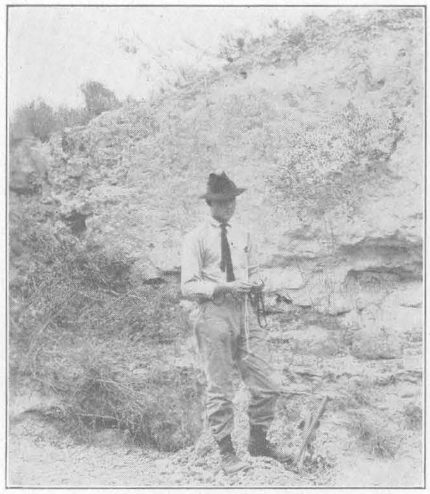
VERTEBRATE FOSSILS FROM MIOCENE AND PLEISTOCENE DEPOSITS.

1, 1a, 1b. Fragment of a jaw bone of a fossil rhinoceros (*Coenopus* sp.) from the Oakville sandstone about 3½ miles west of Bastrop, Washington County, Tex.

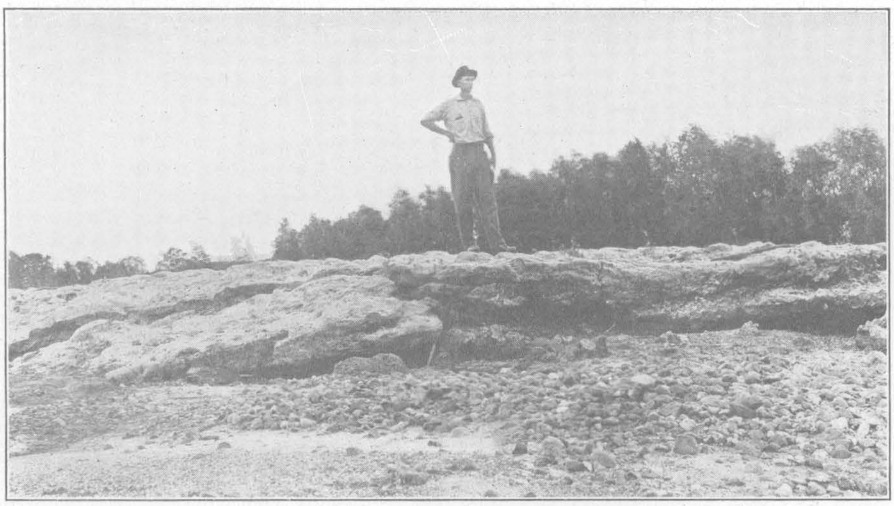
2, 2a. Molar of *Equus* cf. *E. excelsus* Leidy (?) from terrace No. 6 of Colorado River at Austin, Travis County, Tex.

A. LOWER BEDS OF OAKVILLE SANDSTONE EXPOSED ON SULPHUR CREEK AT BRIDGE ON OAKVILLE-BEEVILLE ROAD AT OAKVILLE, LIVE OAK COUNTY, TEX.

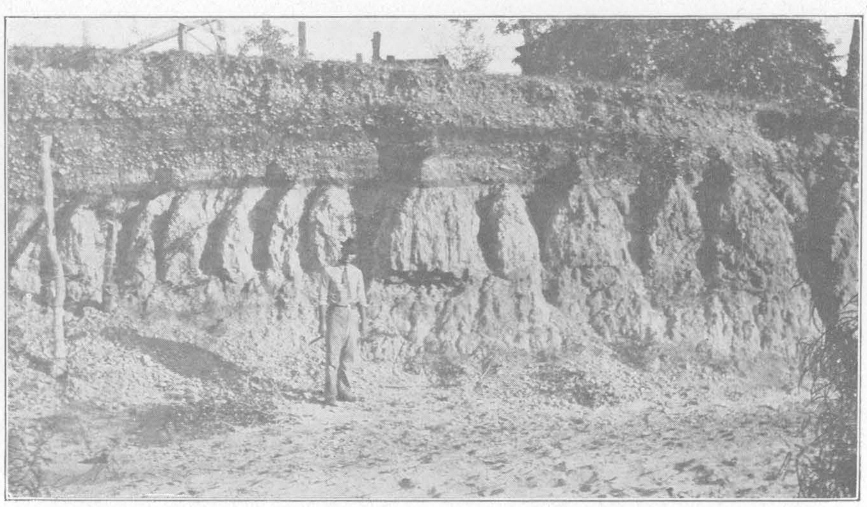
B. LAPARA SAND LYING UNCONFORMABLY ON OAKVILLE SANDSTONE ON NUECES RIVER AT BRIDGE AT MIKESKA, LIVE OAK COUNTY, TEX.



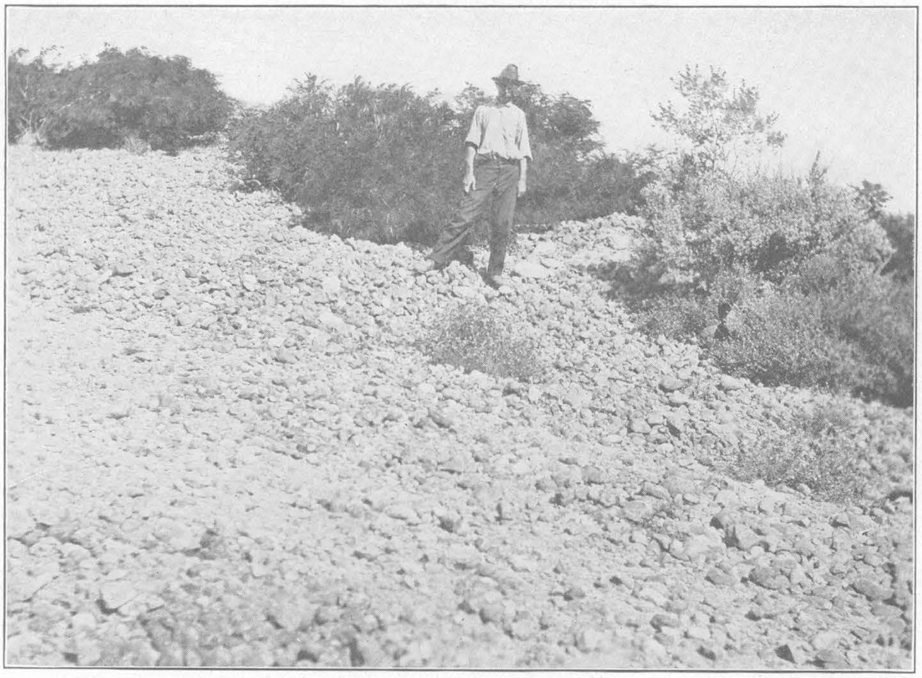
A. LIMESTONE OF REYNOSA FORMATION RESTING UNCONFORMABLY ON LAGARTO CLAY ON RAMIRENA CREEK, ABOUT 3 MILES NORTH OF LAGARTO, LIVE OAK COUNTY, TEX.



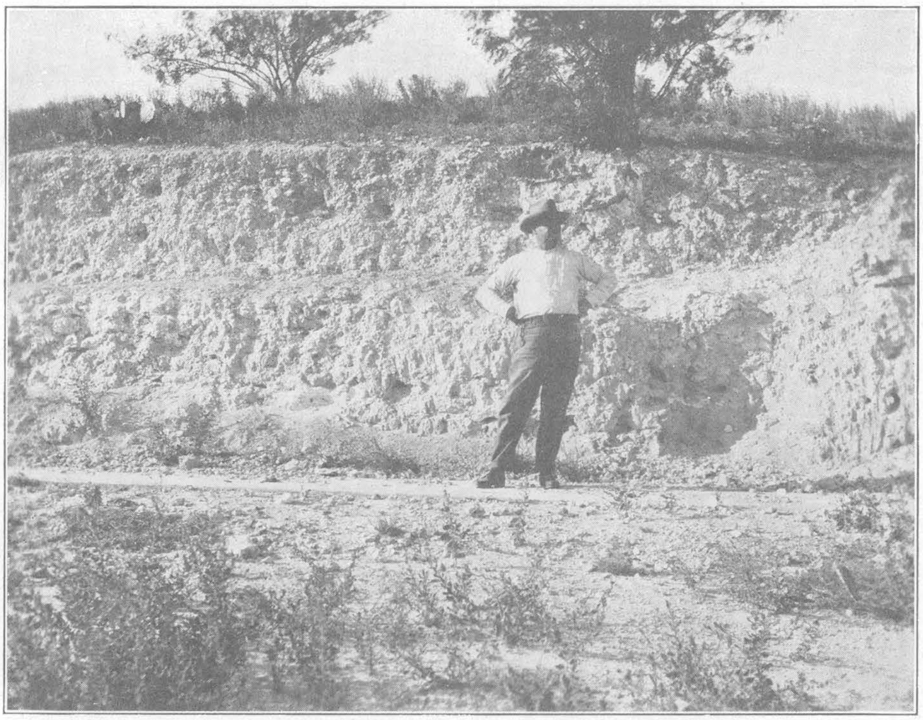
B. REYNOSA FORMATION IN BED OF COLORADO RIVER ABOUT A QUARTER OF A MILE BELOW THE UPPER WAGON BRIDGE AT COLUMBUS, COLORADO COUNTY, TEX.



C. PLEISTOCENE GRAVELS RESTING UNCONFORMABLY ON REYNOSA FORMATION ON PRICES CREEK, ABOUT 12 MILES SOUTH OF CUERO, DE WITT COUNTY, TEX.



A. REYNOSA FORMATION OCCUPYING HIGH DIVIDE BETWEEN LEONA AND NUECES RIVERS, 6½ MILES WEST OF BATESVILLE, ZAVALLA COUNTY, TEX.



B. REYNOSA FORMATION CAPPING PLATEAU HALF A MILE N. 20° E. OF COURTHOUSE AT CARRIZO SPRINGS, DIMMIT COUNTY, TEX.

Stratigraphic position.—In Nueces Valley the Lagarto clay lies conformably (?) above the Lapara sand. North of San Antonio River it lies unconformably above the Oakville sandstone. It lies unconformably beneath the Reynosa formation.

Lithology.—The formation consists of pink and green mottled clay, sand, and sandstone. At some places the clay is capped by a bed of sand and gravel, cemented by lime, representing probably the basal beds of the Reynosa formation. At places where limestone or calcareous sandstone caps the clay stringers of lime extend downward into it for a distance of 8 or 10 feet. At other places the clay contains numerous nodules of lime and is highly charged with manganese. At still other places semicrystalline limestone pebbles with manganese dendrites, probably derived from the underlying Frio clay, are also present.

Thickness and dip.—The formation ranges in thickness from 346 to 647 feet. The thickness of the beds in Nueces Valley is 200 $\pm$ feet; the dip is southeast and ranges from 20 to 40 feet to the mile. On Brazos River the thickness is about 400 feet and the dip is southeast at the rate of about 34 feet to the mile.

Paleontology.—No organic remains of any kind, so far as known, have been found in these clays.

Areal extent.—A narrow outcrop appears in Nueces Valley between Dinero and Lagarto. North of San Antonio River the formation outcrops in a belt of country extending northeastward through Karnes, De Witt, Lavaca, Colorado, Fayette, Austin, and Washington counties. (See Pl. VIII.)

Correlation.—The stratigraphic position of the Lagarto clay above the Lapara and beneath the Reynosa indicates that it is of later Pliocene age.

Dumble suggests that the equivalents of the formation in the region east of the Brazos are the upper members of the Fleming clay and regards the beds at Woodville, in Tyler County, as the eastern extension of this clay.[57]

Section on Colorado River.—Exposures of the Lagarto clay in the drainage area of Colorado River are described below.

At Halsted, 6 miles east of La Grange, the Lagarto clay lies unconformably on the Oakville sandstone. At the base of the clay is a bed of gravel containing worn Cretaceous shells.

At a creek crossing on the La Grange-Columbus road about 8 miles southeast of Ellinger, in Colorado County, the Lagarto clay shows 5 feet of bluish-gray sand in beds 5 inches thick, 2 feet of blue clay, 4 feet of bluish-gray sand, 7 feet of blue clay containing nodules of lime one-fourth to one-half inch in diameter, 3 feet of blue sand, 6 inches of yellow sandstone, 6 inches of blue sand, 5 feet of yellow sandstone, and 4 feet of blue clay. The strike is S. 20° W.

Three feet of blue sand and 3 feet of underlying blue and red mottled clay are exposed at the Galveston, Harrisburg & San Antonio Railway bridge across Colorado River at Columbus, Colorado County.

Section on Guadalupe River.—The sections of the Lagarto clay described below were observed in the drainage area of Guadalupe River.

Fifteen feet of brownish-yellow argillaceous sand, which is here and there replaced by clay, is exposed in a ravine near the railroad station at Lindenau, De Witt County.

Eight feet of yellow sandy clay with lime nodules half an inch in diameter is exposed in the valley of Deer Creek about half a mile southeast of Lindenau.

At the creek crossing of the Lindenau-Cuero road, 3¾ miles west of Cuero, the Lagarto clay shows 2 feet of gray sandstone overlying 8 feet of green calcareous shale. The beds dip about 1° to the southeast.

Twenty-five feet of yellow sandy clay containing lime nodules is exposed on Guadalupe River at the bridge on the Cuero-Clinton road about 2 miles southwest of Cuero.

Section on San Antonio River.—The following section is exposed at Goliad:

Section on San Antonio River at crossing of Galveston, Harrisburg & San Antonio Railway at Goliad, Tex.

	Feet.
Lissie gravel (?):	
White adobe or limy sandy clay	5
White calcareous clay	3
Coarse conglomeratic limestone with small balls of yellow and green clay one-half inch in diameter	2
Reynosa formation (?):	
Soft limy clay with balls of yellow or limonitic clay 2 to 6 inches in diameter	1½
Cross-bedded limestone	3
White cross-bedded sandy limestone	1
Concealed	3
Unconformity.	

[57] Dumble, E. T., Problems of the Texas Tertiary sands: Geol. Soc. America Bull., vol. 26, p. 473, 1915.

Lagarto clay (?):	Feet.
Mottled pink and yellow shale	10
Concealed	20
Mottled pink and green sandy clay	2

Section on Nueces River.—On Ramirena Creek, about 3 miles north of Lagarto, Live Oak County (see Pl. XXX, *A*), the white limy sandstone of the Reynosa formation rests unconformably on the mottled pinkish-red and green shale of the Lagarto formation.

At the type locality on Lagarto Creek half a mile northwest of Lagarto the white limestone of the Reynosa formation, 30 feet thick, rests on 30 feet of the mottled green, pink, and white clays with numerous lime concretions of the Lagarto formation.

Fifteen feet of mottled red, white, and green clay similar to that seen at Lagarto, but here much more highly charged with lime, is exposed at the place where the Lagarto-Casablanca road crosses Penitager Creek, 3½ miles northwest of Casablanca.

On the Lagarto-Casablanca road 3 miles northwest of Casablanca 1 foot of conglomerate composed of lime pebbles rests unconformably on green Lagarto clay containing lime spots and markings.

PLIOCENE (?) SERIES (NONMARINE DEPOSITS).

REYNOSA FORMATION.[58]

Name.—Penrose[59] first used the name Reynosa for a bed of limestone found by him at Reynosa, Mexico, in the Rio Grande Valley, about 50 feet above the level of the river. Later Dumble applied this name to the lithologically similar limestone and limy deposits of late Pliocene age described below in detail.

The position of the limestone at Reynosa, only 50 feet above the streamway and 732 feet below the limestone at Torrecillas, 100 miles to the northwest, would seem to suggest that it occupies a lower terrace than the Torrecillas and Realitos terraces, and that its age is Pleistocene rather than Pliocene. However, until more definite information can be obtained as to the age of the limestone at the type locality, it is considered advisable to continue the use of the term Reynosa as it was used by Dumble and Kennedy, it being well established in the literature with this significance.

Stratigraphic position.—The Reynosa formation lies unconformably above the Lagarto clay and is overlain unconformably by the Lissie gravel.

Lithology.—The lithologic constituents of the formation are a conglomerate of flint or siliceous manganese-stained limestone pebbles, cemented with lime, very hard in some places but in others soft and tufaceous; lenses of pink, manganese-stained limy clay; coarse limy sand and sandstone; and soft tufaceous limestone. The bedding is extremely irregular. Small ridges and knolls are capped with the limestone, and the intervening depressions are occupied by red or brown loam.

The color of the red loam residue produced by the weathering of the limestone is due to ferruginous sandy clay similar to that in the Citronelle formation, farther east, and probably derived originally from the same source. The Reynosa is therefore composed of Citronelle-like materials mingled with limy materials derived originally from the limestone formations of western Texas. The lime now in the beds, however, is probably largely of secondary origin, having been precipitated from solution.

East of Colorado River the Reynosa is composed of coarse red sand; mottled blue, brown, orange, red, and yellow sand and sandy clay; and beds of more or less fine gravel made up of pebbles of quartz, chert, flint, orthoclase, jasper, and granite. It contains many small ferruginous concretions, the largest half an inch in diameter. All the materials are generally highly oxidized. In places small pockets and lenses of blue or red clay may be found. Cross-bedding is common, the beds in general having no semblance of stratification.

Many small cuts that show the eastward development of the Reynosa formation may be seen in Waller, Austin, and Colorado counties. Most of these cuts show 3 or 4 feet of mottled red, yellow, and brown sand or sandy clay containing small ferruginous concretions. One mile southeast of Waller, in Waller County, there is a deposit of yellow

[58] Partial synonymy of the Reynosa formation:
Reynosa division: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 560-563, 1894.
Reynosa limestone: Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, p. 17, 1903.
Reynosa beds: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 63-70, 1903.

[59] Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., p. 63, 1890.

sandy clay, 4 feet thick, containing small ferruginous concretions or pebbles about a quarter of an inch in diameter. Five feet of yellow mottled sandy clay is exposed in a cut on the Houston & Texas Central Railway a quarter of a mile west of the railroad station at Hempstead. About three-quarters of a mile west of the station the banks of a small branch show 7 feet of red sandy clay.

Thickness and dip.—The Reynosa formation ranges in thickness from 560 to 1,505 feet. Its thickness on the Colorado is 600 feet, and its dip is 30 feet to the mile; its thickness on the Nueces is 200 to 300 feet, and its dip is about 20 feet to the mile to the southeast.

Paleontology.—No fossils have been found in the formation.

Areal extent.—The formation crops out in a belt of country that extends northeastward through Duval, McMullen, Live Oak, Bee, Goliad, De Witt, Lavaca, Waller, Colorado, and Austin counties. (See Pl. VIII.)

Topographic position of outcrop.—The materials of the Reynosa form the Realitos terrace between Colorado and Guadalupe rivers and the Torrecillas and Realitos terraces south of the Guadalupe.

Correlation.—In the area east of Colorado River the formation is lithologically more nearly like the Citronelle formation of eastern Texas and other Gulf States, which is believed to be of about the same age. Its equivalent in the interior south of Brazos River is probably the Uvalde formation.

Section in Austin County.—Coarse calcareous sandstones appear in places in the southern part of Austin County beneath sand and gravel of later age. Gray calcareous sandstone is exposed in the banks of Brazos River at Cochrans Ferry, near the old Buckhorn post office, and a similar sandstone is exposed at Sealy.

Section on Colorado River.—About 20 feet of cross-bedded gray sandstone is exposed on the Weimar-Columbus road a mile east of Borden station, in Colorado County. This outcrop is provisionally referred to the Reynosa.

Between 15 and 20 feet of hard gray sandstone is exposed on the La Grange-Columbus road at a point about 5 miles northwest of Columbus. The sandstone is overlain by gravel that forms a terrace.

About 8 feet of hard gray nonfossiliferous sandstone is exposed on Colorado River about a quarter of a mile below the wagon bridge a mile north of the post office at Columbus. (See Pl. XXX, *B*.)

Eight to 10 feet of porous blue semi-indurated sand is exposed on Colorado River about a quarter of a mile below the wagon bridge at Columbus.

Gray limy sandstone is exposed 2 miles southeast of Alleyton on the road from that place to Eagle Lake, in Colorado County.

Four feet of gray limy sandstone is exposed in the bed of McKenzie Creek on the road from Columbus to Altair, in Colorado County, about 5 miles southeast of Columbus.

Forty feet of hard gray limestone is exposed on Colorado River at the mouth of McKenzie Creek, about 6 miles southeast of Columbus. The bluff is capped by a 10-foot bed of fairly hard gray sandy manganese-stained limestone containing isolated small pebbles of quartz a quarter of an inch in diameter.

Section in eastern part of De Witt County.—Light-colored gravel and heavy white calcareous conglomerate mantle the surface in the vicinity of Terryville, in the east corner of De Witt County.

Section on Guadalupe River.—Shoals are formed on Guadalupe River on the Charles Lockhart league, about 9 miles southeast of Cuero, by a coarse yellow sandstone that contains very fine waterworn pebbles less than an eighth of an inch in diameter.

Six feet of yellow argillaceous sand is exposed on Prices Creek at the bridge of the Galveston, Harrisburg & San Antonio Railway, about 12 miles southeast of Cuero. (See Pl. XXX, *C*.)

About 200 feet below the bridge the Reynosa formation is exposed in the form of sandstone boulders, 4 to 5 feet in diameter, in the bed of the creek.

Section in Bee County.—On Medio Creek, where it is crossed by the Galveston, Harrisburg & San Antonio Railway, about 7 miles northeast of Beeville, the Reynosa formation is represented (?) by 5 feet of mottled greenish-white and pinkish-white calcareous shale highly charged with manganese, separated below from 1 foot of greenish-white argillaceous sandstone by concealed rocks 2 feet thick, the whole being overlain by 10 to 12 feet of material belonging to the Lissie gravel.

About 10 feet of limy mottled red and white clay is exposed in the south bank of a creek that is crossed by the San Antonio & Aransas Pass Railway 7 miles south of Beeville.

Section between Lenz, Karnes County, and Beeville, Bee County.—White porous limestone caps the hills on the road from Lenz to Campbellton between a point 4½ miles north of Lenz and the eastern corner of Atascosa County. A similar limestone crops out on the road 1 mile south of Lenz, and a bed 5 feet thick caps the hill 1 mile south of Monteola. This bed may also be seen at Monteola.

White earthy limestone is conspicuously exposed at Mineral, Bee County. Its thickness ranges from a few inches to 40 feet.

Five feet of limy conglomerate, consisting of siliceous limestone cobbles, 2 to 5 inches in diameter, cemented by lime, caps the hill on the Orangedale-Mineral road about 7 miles northwest of Orangedale, in Bee County.

From Orangedale northwestward for a distance of 5 miles white earthy limestone is exposed at intervals on the Orangedale-Mineral road.

At Orangedale a well 68 feet deep is said to have passed through 48 feet of white earthy limestone. Below the limestone was a red sandy clay.

Between Beeville and Orangedale small cuts by the roadside show 4 to 5 feet of white marl or porous soft earthy limestone. Most of the outcrops are on lower ground and at creek crossings. The higher lands are covered with a reddish-brown sandy loam.

Sewer trenches dug at Beeville cut at a depth of 13 to 14 feet a hard lime conglomerate referred to the Reynosa formation. The conglomerate consists of hard gray siliceous limestone pebbles, one-fourth to one-half inch in diameter, cemented with lime.

Section between Oakville and Lagarto, Live Oak County.—White marl or earthy limestone is exposed at intervals on the Oakville-Beeville road 3 or 4 miles east of Oakville.

One foot of white limestone is exposed at Lapara post office, Live Oak County.

At old Fort Merrill, 5 miles southeast of Mikeska, the upland is capped with 20 feet of gray loam or silt. At its base is 2 or 3 feet of white limy sandstone, cross-bedded in places.

White limy clay or adobe and in places white limy sand cap the high hills on the road from Fort Merrill to Dinero.

On Ramirena Creek about 5 miles north of Lagarto, Live Oak County, 8 feet of white limestone and limy clay, which overlies 10 feet of gray limy, sandy clay that in turn overlies 6 feet of white limy sandstone, rests unconformably on red and green shale of the Lagarto clay. On Lagarto Creek, half a mile northwest of Lagarto, the Reynosa formation is represented by 30 feet of white limestone, which rests unconformably on the Lagarto clay. The same thickness of white limestone is also exposed where the Lagarto-Casablanca road crosses the creek about 5 miles northwest of Casablanca.

Section between Lomo Alto, McMullen County, and San Diego, Duval County.—White limy conglomerate is exposed at the Rodriguez ranch on the San Diego-Tilden road, 5 miles east of Los Picachos Hill, in Duval County.

One mile east of this ranch, on the crest of the Bordas escarpment, there is an outcrop of white limestone, and similar limestone caps a small knoll on the San Diego-Tilden road, one-fourth of a mile east of the Labbe ranch house.

White earthy limestone is exposed at Gray's ranch, 18 miles northwest of San Diego, and similar limestone, 5 feet thick, is exposed at the Medio Ranch, 1 mile southeast of Gray's ranch, on San Diego Creek.

White limestone caps the hill on the San Diego-Tilden road 13½ miles northwest of San Diego, and a similar bed is exposed on this road 12½ miles northwest of San Diego.

White earthy limestone is exposed at the Neil Robinson ranch, 6 miles northwest of San Diego, and similar limestone caps a hill three-fourths of a mile northwest of the courthouse at San Diego.

Section between Springfield, Jim Wells County, and San Diego, Duval County.—White limestone crops out 500 feet southwest of Springfield, in Jim Wells County. Half a mile to the west the upland is capped with the same kind of rock, and similar outcrops extend along the road from this point to San Diego.

Numerous exposures of the Reynosa formation occur in the vicinity of San Diego. At the crossing on San Diego Creek, 1 mile south of the courthouse, the Reynosa formation contains 10 feet of limy conglomerate, consisting of rounded pebbles of yellow and pink limestone half an inch in diameter in a limy matrix; 20 feet of mottled green, pink, and white sandy clay; and 15 feet of hard conglomeratic limestone similar to the conglomerate noted above. The beds dip S. 80° E. at an angle of 1°.

Section between Realitos, Duval County, and Falfurrias, Brooks County.—White limestone, carrying flint pebbles three-quarters of an inch in diameter, protrudes through the soil in places at Realitos. White earthy limestone is exposed on the road 1½ miles east of Realitos, and half a mile to the east is a deposit of pebbles of flint, limestone, and basalt, three-fourths of an inch in diameter, mixed with red sandy loam. About 3¾ miles east of Realitos gravel of similar composition forms a thin veneer on top of white earthy limestone.

Four feet of white conglomerate limestone, overlain by a pinkish-brown silt, is exposed at the crossing on Concepcion Creek, 5½ miles east of Realitos.

White limestone caps the upland in places a quarter of a mile south of Concepcion post office, in Duval County, and 8 feet of white limestone is exposed in the bank of a small creek 8 miles southeast of Conception.

Section at Hebbronville, Jim Hogg County.—White limestone protrudes through the soil in places at Hebbronville.

Section at Los Ojuelos, Webb County.—According to Dumble,[60] at a hill 1 mile south of Los Ojuelos there is exposed 6 to 8 feet of arenaceous limestone, highly concretionary in places. The concretions are more or less conglomeratic, with the usual dendritic crystalline limestone pebbles, together with some siliceous ones in a hard limy matrix. Below this limestone there is 6 to 8 feet of limy sand, with red sand containing concretionary inclusions similar in composition and appearance to the materials of the underlying beds, and 15 feet of thick-bedded pinkish-brown clayey sand.

Below the clayey sand seen at Los Ojuelos there is another bed of limestone, which is underlain by a conglomerate that rests on sand and conglomerate of the Lapara formation.

[60] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 68-69, 1903.

REYNOSA FORMATION (UPSTREAM FACIES, HERETOFORE CALLED "UVALDE FORMATION").[61]

Name.—The following quotation from Trowbridge's report cited in the footnote will explain why Hill's name,[62] "Uvalde formation," is here replaced by Dumble's name, Reynosa formation:

> In 1890 Penrose described a deposit of limestone containing many pebbles and cobbles under the name "Reynosa limestone," from the town of Reynosa, Tamaulipas, Mexico. This limestone overlies what was then called the Fayette sand at Reynosa, directly across the Rio Grande from Hidalgo, Tex. Penrose found Recent shells embedded in the surface of exposures of this formation, and thinking it was Recent, included it in his "post-Tertiary formations." In 1891 Hill described remnants of a formation that consisted of coarse and fine gravel cemented by a calcareous matrix and that occupied terraces 400 to 1,000 feet above the Rio Grande to the north of this region. This he called the Uvalde formation. Dumble applied the name Reynosa division to the series of deposits forming the plateau between Nueces and Rio Grande, which he called the Reynosa Plateau. He stated that the "Reynosa limestone" of Penrose formed the top member of his Reynosa division, which rested on the Lagarto formation. These downstream deposits to which Dumble applied the name Reynosa are now known to be the same as the upstream remnants to which Hill applied the name Uvalde, and the necessity for discarding one of the names has become apparent. In view of the fact that Reynosa as applied to a part of this formation has priority over Uvalde, and that the downstream deposits perhaps afford a better type locality, the name Reynosa has been adopted by the United States Geological Survey and "Uvalde" formation has been abandoned.

[61] Partial synonymy of the Uvalde formation:

Upland gravel: Penrose, R. A. F., jr., A preliminary report on the geology of the Gulf Tertiaries of Texas from Red River to the Rio Grande: Texas Geol. Survey First Ann. Rept., pp. 59-60, 1890.

Uvalde formation: Hill, R. T., Notes on the geology of the Southwest: Am. Geologist, vol. 7, pp. 367-368, 1891.

Uvalde formation: Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with special reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 244-247, 1898.

Uvalde formation: Hill, R. T., and Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Nueces folio (No. 42), p. 3, 1898.

Uvalde formation: Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), p. 3, 1900.

Uvalde formation: 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, pp. 347-349, 1901.

Reynosa beds: Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 63-70, 1903.

Uvalde formation: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 77-78, 1914.

Reynosa formation: Trowbridge, A. C., A geologic reconnaissance in the Gulf Coastal Plain of Texas near the Rio Grande: U. S. Geol. Survey Prof. Paper 131, pp. 98-100, 1923.

[62] Hill, R. T., Notes on the geology of the Southwest: Am. Geologist, vol. 7, pp. 367-368, 1891.

Stratigraphic position.—These upstream Reynosa deposits lie unconformably on beds ranging in age from Upper Cretaceous to middle Pliocene. They are in general not covered by later deposits. Their stratigraphic position is probably at the top of the Pliocene.

Lithology.—Gravel is the characteristic material of these upstream Reynosa deposits. The pebbles of the gravel range in diameter from 1 inch to 5 and 6 inches; the smaller cobbles are usually well rounded, but most of the larger fragments are angular, though their edges are slightly rounded. The composition of the gravel is variable. In the Guadalupe and Nueces drainage basins it consists largely of brown, gray, and black flint, and at many places it is cemented with lime to form a conglomerate. At other places, however, the lime may be lacking. In the Brazos, Colorado, and Rio Grande drainage basins and in a part of the Guadalupe Basin the pebbles consist largely of quartz, flint, jasper, chert, orthoclase, granite, and silicified wood.

The preponderance of gravel is the chief lithologic distinction between the upstream and downstream facies of the Reynosa formation. The limy conglomerate of the upstream facies, however, has a striking resemblance to similar conglomerate in the downstream facies.

Source of material.—The greater part of the material that composes the upstream deposits was derived from the Lower Cretaceous limestones of the Plateau region of Texas, the flints coming from the Edwards limestone. The plateau country has been subjected to great erosion since the time of its uplift, and these upstream deposits represent a part of the eroded material transported to lower ground. The original débris included limestone and flint gravel. Much of the limestone gravel has been removed by solution, and the lime cement of the conglomerate is derived from the solution of the limestone gravel. Probably some of the gravel referred to these deposits has been shifted, reworked, and sorted a number of times. Some of the material, especially that in the Brazos, Colorado, and Rio Grande drainage basins, may have come originally from the Cordilleran region of New Mexico and Colorado and the Wichita Mountains of Oklahoma.

Thickness and dip.—The thickness of these deposits ranges from a few inches to 100 feet or more. The dip is that of the general slope of the ancient plain upon which it was deposited and ranges from 2 to 10 feet to the mile toward the southeast.

Paleontology.—These upstream deposits have yielded no animal remains. They contain considerable silicified wood, which, however, is not indigenous to them, having been derived from older formations by erosion.

Areal extent.—The formation crops out in isolated bodies, ranging in width from a few yards to 10 miles or more, on the high divides of Kinney, Maverick, Dimmit, Webb, Uvalde, Zavalla, La Salle, Medina, Frio, McMullen, Bexar, Atascosa, Live Oak, Wilson, Karnes, Guadalupe, Gonzales, De Witt, Comal, Hays, Caldwell, Lavaca, Travis, Bastrop, Fayette, Colorado, Williamson, Lee, Washington, Bell, Milam, Burleson, McLennan, and Falls counties. (See Pl. VIII.)

Topographic position.—The altitude of the formation in Uvalde County is 970 feet; in Bexar County, 960 feet; in Travis and McLennan counties, 600 feet; in Webb County, 728 feet; and in Lee County, 512 feet. In Washington, Austin, Fayette, Lavaca, and De Witt counties it forms the original surface of the Torrecillas terrace.

Details of occurrence.—A heavy veneer of subrounded flint cobbles that average 2 or 3 inches in diameter form a thick veneer on the prairie at Daffan, 5 miles southwest of Manor, in Travis County, at an elevation of 600 feet.

Flint gravel also appears in the vicinity of Littig, Travis County, at an elevation of about 464 feet.

A thin coat of flint and chert pebbles forms the surface 4 miles southeast of McDade, Bastrop County, and similar material can be seen 3 miles to the east at an elevation of 545 feet.

Cobbles of flint, limestone, and jasper, the largest 2 inches in diameter, form the surface between Paige and Giddings (elevation, 514 feet). Similar materials form the surface of most of the high ground in Lee County. The cobbles consist of flint, jasper, some orthoclase, and silicified wood.

Gravel consisting of rounded cobbles of flint, quartz, jasper, orthoclase, and silicified wood and ranging in diameter from 3 inches to 3 feet occurs 2 to 3 miles east of Ledbetter. The elevation at this place is 443 feet.

A thin veneer of gravel also appears a mile or two west of Carmine, Fayette County.

All the gravel beds here described occupy the divide between Brazos and Colorado rivers.

Large subangular masses of flint, the largest 5 inches in diameter, are strewn on the ground at Manchaca, Travis County, at an elevation of 697 feet.

An extensive body of flint gravel appears about Creedmore, in the southern part of Travis County, at an elevation of 725 feet. Flint gravel appears also at the surface 4 miles west of Dale, Caldwell County, at an elevation of about 520 feet.

A veneer of flint gravel forms the surface of the prairie 2 miles northeast of Hunter, in Hays County, at an elevation of 708 feet. Flint gravel is also exposed in the vicinity of Kingsbury, Guadalupe County, at an elevation of 620 feet.

Brown flint cobbles, 2 to 3 inches in diameter, form a veneer on the prairie along the International & Great Northern Railway from a point 2 miles to a point 6 miles northeast of Bracken, Comal County. A similar bed occurs 9 miles northeast of Bracken.

Flint cobbles are strewn over the surface at Marion and vicinity, in Guadalupe County, at an elevation of 644 feet.

A bed of flint gravel 2 or 3 feet thick covers the hill on the International & Great Northern Railway 3½ miles southwest of Bracken at an elevation of 956 feet.

Flint gravel forms the surface 2 miles southwest of Converse, in Bexar County, at an elevation of 770 feet.

The divide between San Antonio River and Salado Creek is covered with a limy conglomerate and marl from 2 to 15 feet thick, which may be seen at the corner of South Palmetto Avenue and Dakota Street, about 2 miles east of the courthouse at San Antonio.

A quarter of a mile east-southeast of this place the deposits show black clay soil in which flint cobbles are embedded, 4 to 5 feet of indurated white marl containing a few flint cobbles and pebbles, 4 to 6 feet of flint and limestone gravel embedded in a yellow limy clay matrix. The gravel rests unconformably on the Midway formation.

On the divide between San Antonio River and Salado Creek, 1½ miles northeast of Bergs station, in Bexar County, the Reynosa formation contains 10 feet of conglomerate, consisting of flint pebbles and cobbles cemented with lime, overlying unconformably the Indio formation.

Brown flint gravel occurs on the divide between Leon Creek and Medina River on the San Antonio-Frio City road 2 miles west of Leon Station, in Bexar County, at an elevation of 725 feet.

The hill at the cemetery a quarter of a mile west of Castroville is capped with 20 feet of gravel, which in its lower part is cemented with lime into a limy conglomerate. The cobbles and pebbles, which consist of flint and limestone, range from half an inch to 4 inches in diameter. The elevation of this hill is 921 feet.

Flint gravel covers the prairie 2 miles south of Lacoste, Medina County.

A thick bed of flint gravel, brown on the exterior, covers the divide between La Parita and Atascosa creeks, 4 miles east of Christine, in the southern part of Atascosa County, and also the top of Opossum Hill, 1½ miles southwest of Crowther, McMullen County. The elevation of this outcrop is about 440 feet.

Flint gravel, which is in places cemented into a lime conglomerate, forms much of the divide between Seco Creek and Sabinal River, on the Galveston, Harrisburg & San Antonio Railway at an elevation of about 1,000 feet.

An extensive bed of loose flint cobbles at the surface, grading downward into a limy conglomerate made up of flint cobbles cemented with lime, covers the divide between Black Creek and Hondo Creek, north of Pearsall, in Frio County, at an elevation of 780 feet. A similar bed of flint gravel occupies the northwestern part of McMullen County.

East of Tilden, on the Tilden-Oakville road, large subangular and rounded cobbles of flint in considerable number cover the prairie. The elevation of the high point is 480 feet.

The gravel of these Reynosa beds occurs south of Uvalde, in the southern part of Uvalde County, on the divide between Leona and Nueces rivers, at an elevation of 900 to 977 feet.

Similar material occupies the high divide between Leona and Nueces rivers, 6½ miles west of Batesville, Zavalla County. (See Pl. XXXI, *A*.) The elevation is approximately 786 feet.

Limy conglomerate of the Reynosa caps the plateau half a mile N. 20° E. of the courthouse at Carrizo Springs, Dimmit County. (See Pl. XXXI, *B*.) Reynosa gravel occupies the divide between Leona and Nueces rivers 3½ miles west of Loma Vista, Zavalla County, at an elevation of about 620 feet. Similar material covers the divide between Nueces River and Rio Grande on the International & Great Northern Railway, 13 to 18 miles north of Laredo. From 2 to 8 feet of gravel consisting of flint, chert, jasper, orthoclase, quartz, etc., and a considerable admixture of lime and sand is exposed at an elevation of approximately 720 feet.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

LISSIE GRAVEL.[63]

Name.—The Lissie gravel was named by Deussen in 1914, from Lissie, Wharton County, Tex., near which it is exposed.[64] Kennedy had previously described this formation as the "Columbia sands," which form merely the lower part of McGee's Columbia formation. The formation is the same as Dumble's "*Equus* beds," but as the term "*Equus*" is a paleontologic and not a geographic name, and therefore not accordant with the rules of geologic nomenclature, the name Lissie was employed to designate it.

Stratigraphic position.—The Lissie gravel lies unconformably above the Reynosa formation and is overlain by the Beaumont clay.

Lithology.—The formation includes beds and lenses of gravel, beds of coarse red sand, and pockets and lenses of red gravelly clay. The gravel and sand are its predominant constituents. The gravel consists of pebbles and cobbles of quartz, orthoclase, jasper, agate, limestone, flint, chert, granite, and silicified wood, the fragments ranging in diameter from a quarter of an inch to 3 inches, though the smaller are more numerous. They are generally well rounded and waterworn, giving evidence of transportation for a considerable distance.

The materials are in general similar to those of the Citronelle formation of eastern Texas, but there is probably less clay and more gravel in the Lissie than in the Citronelle.

West of Guadalupe River the formation includes beds of white limestone, lime conglomerate in which limestone and flint pebbles are cemented with lime, and gray and ash-colored sand, silt, and clay, which are in places calcareous, in general having a strong resemblance to those of the Reynosa formation.

Source of materials.—Lissie gravel consists largely of reworked materials of the Reynosa formation.

Thickness and dip.—The thickness ranges from 493 to 1,020 feet. The dip is southeastward at the rate of about 19 feet to the mile.

Paleontology.—The formation contains vertebrate fossils of early Pleistocene age, such as *Equus complicatus*, *Equus francisci* Hay, *Trucifelis fatalis*, *Elephas imperator*, *Bison latifrons*, and *Glyptodon*.

Areal extent and topographic position.—Outcrops of the formation appear in Victoria, Jackson, Lavaca, Colorado, Wharton, Austin, Fort Bend, Goliad, Bee, San Patricio, Duval, Jim Wells, Nueces, and Brooks counties. (See Pl. VIII.) It forms the Alice terrace. The formation extends eastward into eastern Texas and Louisiana.

Details of the beds.—In a well belonging to C. Wilson, 4 miles north of Brookshire, Waller County, the Lissie gravel contains 52 feet of red clay (?); 25 feet of sand and gravel, water-bearing; 23 feet of clay; and 37 feet of sand and gravel, water-bearing, with teeth of fossil *Equus* of early Pleistocene age.

Early Pleistocene vertebrates were collected more than 75 years ago by William Hough, of San Felipe, Austin County, from certain beds in the banks of Brazos River and were described by Dr. William Carpenter.[65] The species included *Mastodon*, *Elephas columbi*, a tapir, *Bison latifrons*, *Mylodon*, and *Elephas imperator*.

A number of small pits in the vicinity of Eagle Lake, Colorado County, show 4 to 5 feet of fine gravel made up of pebbles of quartz, orthoclase, jasper, chert, flint, and other materials mixed with red clay and coarse red sand.

At a depth of 25 feet in a well at Lissie, Wharton County, a well-preserved skull of a fossil horse was taken from a bed of sand and small pebbles cemented together in places with lime. The species is *Equus francisci* Hay and

[63] Synonymy of the Lissie gravel:
Columbia formation [included the Lissie]: McGee, W J, The Lafayette formation: U. S. Geol. Survey Twelfth Ann. Rept., pt. 1, pp. 384–408, 1891.
Equus beds: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 563–564, 1894.
Columbia sands: Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 26–66, 1903.
Lissie gravel: Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 78–80, 1914.

[64] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, pp. 78–80, 1914.

[65] Am. Jour. Sci., 2d ser., vol. 1, p. 244, 1846.

is referred by Dr. Hay to the early Pleistocene.[66]

George B. Smith's well at Lissie passed through 18 to 20 feet of light-colored clay, and then entered 16 feet of water-bearing sand and gravel.

Water is obtained at a slight depth in gravel at Nottawa, Wharton County.

The wells in the vicinity of East Bernard, Wharton County, average 60 feet in depth and draw a supply of water from beds of sand and gravel.

In a well belonging to H. Moricke, 6 miles northwest of Pierce, Wharton County, the Lissie gravel contains 50 feet of white sand, 34 feet of water-bearing sand and gravel, 58 feet of red clay, 42 feet of water-bearing sand and gravel, and red clay.

Gravel occurs at or close to the surface and is encountered in shallow wells in Lavaca County south of the San Antonio & Aransas Pass Railway, in the northern parts of Jackson and Victoria counties. The pebbles range in diameter from a quarter of an inch to 1½ inches. Most of them are well rounded, but some are angular or subangular.

Log of well of J. O. B. Young, 1 mile southwest of Edna, Jackson County, Tex.

	Thickness.	Depth.
Beaumont clay:	*Feet.*	*Feet.*
Clay and soil	39½	39½
Sand	5	44½
Clay	6	50½
Sand, water-bearing	6	56½
Clay	58⅔	115⅙
Lissie gravel:		
Sand, water-bearing	10	125⅙
Clay	4¼	129$\frac{5}{12}$
Sand, water-bearing	12	141$\frac{5}{12}$
Clay	42$\frac{1}{12}$	183½
Sand, water-bearing	20$\frac{1}{12}$	203$\frac{7}{12}$
Rock, probably sand or gravel cemented with lime	1	204$\frac{7}{12}$
Sand, water-bearing	7⅚	212$\frac{5}{12}$
Clay	2	214$\frac{5}{12}$
Sand, water-bearing	11	225$\frac{5}{12}$
Clay	4	229$\frac{5}{12}$
Sand, water-bearing	13⅚	243¼
Clay	38½	281¾
Rock	2	283¾
Sand and gravel, water-bearing	27	310¾
Clay	17	327¾
Sand and gravel, water-bearing	37$\frac{1}{12}$	364⅚

[66] Hay, O. P., Contributions to the knowledge of the mammals of the Pleistocene of North America: U. S. Nat. Mus. Proc., vol. 48, pp. 535–549, 1915.

Log of well on the Gibson farm, 4 miles north of Victoria, Tex.

	Thickness.	Depth.
Beaumont clay (?):	*Feet.*	*Feet.*
Yellow clay with lime nodules	15	15
White calcareous sand	1½	16½
Lissie gravel:		
Reddish clay	4	20½
Sand	15	35½
Coarse gravel	1	36½
Sand mixed with coarse gravel	5	41½
Quicksand	6	47½
Clay mixed with gravel	1½	49
Soft argillaceous sand	2	51
Sandstone	½	51½
Water-bearing gravel	8	59½
Coarse gravel.		

The remains of a mastodon have been taken from the banks of Coleta Creek, 8 miles west-southwest of Victoria. The bluff at Goliad is capped with 5 feet of white limy, sandy clay or adobe, which probably represents the Lissie formation.

On the Goliad-Refugio road, 11½ miles south of Goliad, the Lissie gravel is represented by 4 feet of coarse yellowish-gray sand with flint and jasper pebbles at base and 4 feet of underlying bluish-white calcareous water-bearing sand with lime nodules.

About 6 feet of yellow silt or loam with a thin bed of gravel at the base forms the prairie on the divide between San Antonio River and Blanco Creek 6 miles northeast of Berclair. These beds rest on a limy conglomerate, seen in the drainage channels, which may be the Reynosa formation, though it may represent the lower part of the Lissie gravel.

Five feet of the lower limestone is exposed in the bed of a small drain 7 miles northeast of Berclair, near the Galveston, Harrisburg & San Antonio Railway.

On Mucorrera Creek, where it is crossed by the Galveston, Harrisburg & San Antonio Railway, 3½ miles northeast of Berclair, Goliad County, the Lissie gravel consists of 7 feet of ash-colored silt or loam, with small lime nodules half an inch in diameter, and 6 inches of underlying gravel, the pebbles of which are composed of flint, agate, and silicified wood.

On Blanco Creek, where it is crossed by the Galveston, Harrisburg & San Antonio Railway, three-fourths of a mile southwest of Berclair, Tex., the Lissie gravel consists of 10 feet of ash-colored clayey sand or silt grading downward into 2 feet of conglomerate of lime and flint pebbles, half an inch in diameter, in a lime matrix. The remains of a mammoth were taken from the Lissie gravel near this locality.

A number of hills between Beeville and a point on the Beeville-Skidmore road 7 miles south of Beeville are capped with white earthy limestone, which may possibly belong to the Reynosa formation, though its topographic position suggests that it represents the basal part of the Lissie gravel.

A white limestone outcrops on the road 600 feet east of the railroad station at Mathis. It is stated that 40 feet of this limestone is encountered in the wells drilled in this vicinity. Sand is reported to lie beneath the limestone, and water is encountered at a depth of 150 feet.

From beds on Taranchua Creek, a branch of San Diego Creek, vertebrate fossils of Pleistocene age were collected by William Taylor and G. W. Marnock and identified by Cope.[67]

The species include *Elephas primigenius* Blum, *Canis* sp., *Glyptodon petaliferus* Cope, *Equus tau* Cope, *Equus semiplicatus* Cope, *Equus excelsus* Leidy, *Equus occidentalis* Leidy, and *Equus crenidens* Cope.

According to Dumble the beds in which the fossils occur consist of limy sand and gravel, which rest unconformably on the underlying Reynosa formation.

Log of well drilled for the Magnolia Colony, southeast of Alice, Tex.

[Furnished by Tom Leary, contractor.]

	Thickness.	Depth.
	Feet.	*Feet.*
Recent: Black soil	2	2
Lissie gravel:		
Brown sandy clay	4	6
White sand	22	28
White clay and chalk rock	32	50
Do	30	80
White clay	40	120
Reynosa formation (?):		
Pink clay and chalk	58	178
Hard white rock and brown shale	16	194
White clay	34	228
Sticky pink clay	92	320
Soft limerock	8	328
Lagarto and Lapara formations (?):		
Light-brown clay	66	394
Sandy clay	4	398
Soapstone	14	412
Gumbo	23	435
Water sand and boulders	35	470
Lagarto and Lapara formations (?)—Contd.		
Sticky white clay	23	493
Reddish sandy clay	11	504
Red sandy clay and boulders	76	580
Clay and sandrock	8	588
Sandy clay	18	606
Sticky gumbo	12	618
Sandy clay and boulders	47	675
Boulders and clay	7	682
Tough gumbo	7	689
Tough sandy brown clay	111	800
Oakville sandstone (?):		
White rock and clay	27	827
Lead-colored shale	23	850
White rock and clay	30	880
Gray and yellow sand	38	918
Greenish white shale	32	950
Shale and boulders	43	993
Soft rock	19	1,012
Hard brown clay	18	1,030
Boulders and shale	17	1,047
Soft rock	18	1,065
Clay and boulders	7	1,072
Brown clay and boulders	22	1,094
Frio clay (?):		
Hard green clay	26	1,120
Hard tough shale	14	1,134
Soft crumbly shale	19	1,153
Hard green clay	14	1,167
Shale and clay	12	1,179
Gumbo	7	1,186
Green shale and rock	18	1,204
Green and brown shale	28	1,232
Hard brown shale	51	1,279
White rock and boulders	3	1,282
Light-brown clay	24	1,306
Tough green clay	167	1,473
Soapstone and soft slate	37	1,510

[67] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, p. 71, 1903.

BEAUMONT CLAY.[68]

Name.—The Beaumont clay was named by Hayes and Kennedy in 1903 from Beaumont, Tex., near which it is typically exposed.[69]

Stratigraphic position.—The Beaumont clay lies above the Lissie gravel and below the Recent sands.

Lithology.—The formation includes blue yellow-weathering calcareous clay containing small lime nodules; yellow and blue sand, which is in places calcareous; blue and red mottled sandy clay; and oyster beds.

[68] Partial synonymy of the Beaumont clay:

Port Hudson: Loughridge, R. H., Physico-geographical and agricultural features of the State of Texas: Tenth Census U. S., vol. 5, pt. 1, p. 22, 1884.

Coast clays: Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 564-566, 1894; Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 70-74, 1903.

Beaumont clays: Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 27-28, 1903.

[69] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 27-28, 1903.

Thickness and dip.—The thickness of the formation ranges from 300 to 900 feet, and the dip is 20 to 30 feet to the mile to the southeast.

Paleontology.—Marine fossils occur in places in the formation. The species include *Rangia cuneata* Gray, and *Ostrea virginica* Gmelin. Vertebrate fossils, among them *Elephas* and *Equus*, also are found, but these may not be contemporaneous with the deposits, having been possibly eroded from the underlying Lissie gravel. Buried logs and bark and leaves of trees are encountered in many well borings.

Areal extent.—The formation outcrops in Fort Bend, Brazoria, Wharton, Matagorda, Jackson, Calhoun, Victoria, Goliad, Refugio, Bee, San Patricio, Nueces, and Kleberg counties. (See Pl. VIII.) The formation forms the surface of the flat level prairie described as the Coast Prairies in this report. It is coextensive with the Beaumont terrace.

Correlation.—In the writer's opinion the Beaumont of Texas represents the western extension of the Port Hudson formation of Louisiana and Mississippi. The Port Hudson strata were originally discriminated by Hilgard in Louisiana in 1869.[70] Loughridge described beds in Texas under this same name in 1884.[71] Dumble described the beds in Texas as the "Coast clays" in 1894.[72]

Hayes and Kennedy's section of the Coastal Plain of Texas, published in 1903, included Recent or Port Hudson clay, Beaumont clay, Columbia sand, and Lafayette sand.[73]

These authors evidently regarded the Recent sand and clay of the coast marshes and the Recent river alluvium as the equivalent of Hilgard's Port Hudson, but this correlation is questionable, for the Beaumont clay is merely the western representative of the beds which Hilgard included in the Port Hudson.

Details of occurrence.—At Garwood, Colorado County, the Beaumont clay consists of 6 feet of blue sandy clay with small lime concretions. It rests on the Lissie gravel. At Wharton, it consists of similar material 20 feet thick.

[70] Hilgard, E. W., Summary of results of a late geological reconnaissance of Louisiana: Am. Jour. Sci., 2d ser., vol. 48, pp. 332–333, 1869.

[71] Loughridge, R. H., Physico-geographical and agricultural features of the State of Texas: Tenth Census U. S., vol. 5, pt. 1, p. 22, 1884.

[72] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 564–566, 1894.

[73] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 26–30, 1903.

Four feet of plastic yellow clay is exposed 1 mile east of the courthouse at Bay City, Matagorda County.

At Palacios, on Matagorda Bay, the Beaumont formation consists of calcareous clay, 8 feet of which is exposed.

Log of well of H. Anderson, 3 miles west of Palacios, Matagorda County, Tex.

[Furnished by E. L. Larson, driller. Geologic interpretation by the writer. See Pl. IX.]

	Thickness.	Depth.
Recent:	*Feet.*	*Feet.*
Black clay soil	3±	3±
Beaumont clay:		
Mottled blue and red clay with lime nodules	56	59±
Sandy clay	20	79
Sand	18	97±
Sand and sandy clay	17	114±
Sandy clay	40	154
Red clay with lime concretions	19	173
Mottled red and green clay with lime nodules	21	194
Compact, red, sticky clay	20	214
Mottled red and green clay with lime nodules	20	234
Calcareous, mottled, red and green clay with lime nodules	37	271
Mottled red and green clay with fragments of shells	19	290
Mottled red and blue clay with lime nodules	98	388
Light blue clay	98	486
Sandy clay	21	507
Slightly sandy clay with sticky clay below	20	527
White rock, probably calcareous conglomerate	½	527½
Argillaceous sand	14	541½
Rock	......	......
Very hard blue clay	......	......
Gravel mixed with red clay, containing some gas		
"Shell"	......	......
Hard sandstone containing some gas	......	......
Rock	½	546⅛
Fine-grained, yellowish-brown, calcareous, water-bearing sand	13⅞	560

At a depth of 58 feet in a well 4 miles southwest of La Ward, Jackson County, well-preserved specimens of *Ostrea virginica* Gmelin and *Rangia cuneata* Gray were found.

A section of J. O. B. Young's well 1 mile southwest of Edna is given on page 109 of this report. The upper 115⅙ feet of this section, consisting mostly of clay, represents the Beaumont formation.

On Navidad River, about 3 miles below Redbluff, Jackson County, the Beaumont clay consists of 11 feet of blue clay and 2 feet of underlying blue sand weathering yellow. On Lavaca River, about 5 miles south of Vanderbilt, Jackson County, the Beaumont clay consists of 12 feet of gray and blue clay.

Four feet of blue clay, with lime nodules about a quarter of an inch in diameter, is exposed just above the water in Lavaca River near the Calhoun-Jackson county line.

On Lavaca Bay, 1½ miles northwest of Nobles Point, Calhoun County, the Beaumont clay consists of 6 feet of mottled yellow, red, and blue clay and 8 feet of underlying blue clay with lime nodules an inch in diameter.

Specimens of *Ostrea virginica* Gmelin and *Rangia cuneata* (Gray) and the crown of a mammalian tooth were taken from a depth of 125 feet in a well at Mitchell Point, on Lavaca Bay, Calhoun County.

At Alamo Beach, Calhoun County, the Beaumont clay consists of 3 feet of yellow laminated slightly argillaceous sand and 3 feet of underlying mottled blue and red laminated clay, with poorly preserved marine fossils.

Log of well of V. E. Damstrom, three-fourths of a mile north of Olivia, Calhoun County, Tex.

[Samples identified by the writer.]

	Thickness.	Depth.
Recent:	*Feet.*	*Feet.*
Brownish-black loam or soil	6	6
Beaumont clay:		
Mottled pink and green calcareous clay	24	30
Light-green calcareous clay	30	60
Fragments of fossil oyster and other shells	10	70
Species include barnacles and *Rangia?* sp. (Young).		
Green and pink calcareous clay	50	120
Green and reddish-pink fairly hard calcareous clay	20	140
Pink hard calcareous clay	20	160
Green calcareous medium hard clay	40	200
Blue noncalcareous medium hard clay	30	230
Reddish-pink medium hard clay	20	250
Blue plastic medium hard clay	35	285
Fragments of fossil oysters and other shells; also some light-brown sand; bed is probably a shell conglomerate or shell marl	20	305
Fragments of fossil oysters in pink calcareous clay	15	320
Green and pink calcareous medium hard clay	32	352
Coarse-grained light-brown calcareous sand	18	370

Five feet of green calcareous clay with lime nodules is exposed in a cut on the Galveston, Harrisburg & San Antonio Railway, 3 miles north of Victoria.

Rangia cuneata (Gray) was found at a depth of 95 feet in a well at Hackberry Motte 3 miles north of Olivia, Calhoun County.

Pleistocene fossils taken from a depth of 370 feet in a well near Alligator Head, Calhoun County, Tex.

[Identifications by T. W. Vaughan.]

Astrangia sp.
Mellita sp.
Terebra protexta Conrad.
Terebra dislocata Say var.
Mangilia cerinella Dall.
Cancellaria sp.
Oliva literata Lamarck.
Olivella mutica Say.
Nassa acuta Say.
Anachis avara Say.
Anachis obesa Adams.
Purpura floridana Conrad.
Pyramidella sp.
Cerithium floridanum Mörch.
Cerithium muscarum Say? var.
Scala humphreysi Kiener.
Turritella sp.
Littorina littorea Say.
Cryptonatica pusilla Say.
Neverita duplicata Say.
Natica sp.
Leda acuta Say.
Arca pexata Say.
Arca incongrua Say.
Arca transversa Say.
Ostrea virginica Gmelin.
Diplodonta semiasper Philippi.
Cardium magnum Linnaeus.
Tellina (Angulus) texana Dall.
Strigilla flexuosa Say.
Chione cancellata Linnaeus.
Anomalocardia rostrata Savage.
Abra aequalis Say.
Petricola pholadiformis Linnaeus.
Pholas costata Linnaeus.
Donax texasiana Philippi.
Mulinia lateralis Say.
Corbula barrattiana C. B. Adams.
Corbula swiftiana C. B. Adams.

On the bay front at Rockport, there is exposed 1 foot of hard pinkish-gray sandy limestone with a nodular structure. The occurrence of this limestone is unusual, and it may have some relation to a dome or anticline in this vicinity.

Fifteen feet of yellowish-gray argillaceous sand, containing lime nodules 1 inch to 1½ inches in diameter, is exposed in the bank of a ravine on the Refugio-Sinton road 16 miles southwest of Refugio.

A good exposure of the Beaumont clay may be seen in the bluff at Corpus Christi. (See Pl. XXXII, *A*.) It shows 15 feet of greenish-gray and brown mottled clay with numerous lime nodules averaging half an inch in diameter; 5 feet of brown clay and yellow sand, interstratified; and 15 feet of unconsolidated yellow sand containing small balls and streaks of clay. The beds are very nearly horizontal. About 200 feet to the south the basal yellow sand contains a small lens of gravel made up of clay and limestone pebbles.

Yellow sand is exposed in the banks of San Petronito Creek, where it is crossed by the Texas Mexican Railway 4 miles west of Banquete, Nueces County.

At Robstown, Nueces County, a tooth of *Elephas imperator* has been found.

Yellow compact clay is exposed in sewer trenches dug at Kingsville, Kleberg County.

Gray clay is exposed in the banks of a creek where it is crossed by the St. Louis, Brownsville and Mexico Railway, 6 miles south of Kingsville.

RECENT SERIES.

FLUVIATILE DEPOSITS.

General features.—The fluviatile deposits in the region lie above the Beaumont clay and in places are overlain by beach sand. They consist of silt, sand, mud, and clay, all of Recent age. The thickness of the deposits ranges from 6 inches to 20 or 30 feet. Recent shells, similar to shells of animals now living in the rivers, the Gulf, and the bays of this region, bones of modern animals, and logs and leaves of modern trees are found in the deposits. The material of the Recent deposits has been brought down by modern streams, chiefly during floods, and deposited in bays, marshes, and estuaries along the coast. These deposits form a low terrace, which lies below the level of the Beaumont terrace and rises only a few feet above mean tide. Much of the area is marsh and is covered with salt or sacahuista grass.

Areal extent and details of occurrence.—The deposits are well developed in the southern part of Brazoria County, where they form a strip 5 to 10 miles wide on both sides of Brazos River, immediately adjacent to the coast, built up largely by the action of this stream.

The deposits are also displayed at points on the northern shore of Matagorda Bay, in Matagorda County. They occur also at the mouths of Lavaca River, Guadalupe River, Nueces River, and elsewhere.

BEACH SAND.

Beach sand in places lies above the fluviatile deposits, but it is in part contemporaneous with them. In thickness it ranges from 3 inches to 20 feet.

The material is chiefly more or less rounded, fine gray to yellow quartzose sand containing fragments of Recent sea shells. It forms beaches and islands along the coast, including Galveston Island, Matagorda Peninsula, Matagorda Island, St. Joseph Island, Mustang Island, and Padre Island.

The sand has been washed into position primarily by wave action, chiefly during storms, but after elevation by the waves it is shifted by the wind and in places is piled into dunes.

DUNE SAND.

The dune sand represents the most Recent formation on the Coastal Plain, being now in the process of formation. The dunes cover much of the Beaumont clay in southern Texas, and some of them reach a height of 75 feet.

The material is chiefly light-colored quartzose sand.

The dunes are of eolian origin, being formed of sand that is blown inland from the coast. Some of the sand, however, may be derived from the exposed sandy members of the Beaumont formation.

The dunes are conspicuous in southern Calhoun County, where they cover a strip of country 6 miles wide along Espiritu Santo Bay. This belt extends southward into Aransas, San Patricio, and Nueces counties, lying close to the bays and ranging in width from 4 to 10 miles. In the region south of Baffins Bay it forms a large area, extending 50 miles or more inland and covering large parts of Willacy and Brooks counties. (See Pl. VIII.) The dunes in southern Calhoun County are composed of yellow sand.

The dunes near Rockport form a strip 4 to 5 miles wide along Aransas Bay. The prairie is composed of loose grayish-yellow sand. The outer margin of the belt is fairly well covered with young live oak and thickets of sweet bay. The timber on the inner margin is confined largely to the tops of the mounds, the intervening areas being treeless.

In Willacy and Brooks counties the sand is piled into large shifting dunes. In places between the dunes there are small hummocks, which are covered with a thin growth of mesquite and cactus. In other places between the dunes the loose sand has been completely removed by the wind, leaving exposed and barren of vegetation a hard brown silt subsoil.

A dune about 1 mile wide and 6 or 7 miles long from east to west lies 2 or 3 miles south of Sarita. The sand is here piled 20 to 30 feet above the level of the surrounding prairie. Other dunes occur 1 mile south of Mifflin, 1 mile north of Katherine, and at Los Indos ranch, San Pedro ranch, San Jose ranch, and Topo ranch.

STREAM TERRACE DEPOSITS (PLEISTOCENE AND RECENT).

The streams of the Coastal Plain are bordered by terraces which range in age from early Pleistocene to Recent. Some of these terraces are to be correlated with the seaward-facing terraces and, like them, record successive uplifts in the later history of the Coastal Plain. Others appear to be local and are not related to crustal movements, having been formed by temporary barriers on the streams and changes in the nature of the material encountered by the streams in their erosion of their valleys. The materials composing these terraces are different in different valleys and in different parts of the same valley, and they require separate description. The terraces on each stream will therefore be considered separately.

TERRACES ON BRAZOS RIVER.

Plate XXXIII shows the terraces on Brazos River in different parts of the valley between the outer and inner margins of the Coastal Plain.

No. 1 on the plate is a cross section between Cleburne and Morgan, in the Plateau region west of the Coastal Plain. The bed of the stream is cut 470 feet below the level of the plateau represented by the divide capped with Edwards limestone 4½ miles south of Morgan. Probably there are a number of terraces in this cross section, but only the lower two are sufficiently well preserved to warrant positive recognition.

Terrace No. 1 forms a flat about a mile wide on either side of the stream, lying 50 feet above the bed. It is covered by red to brown silt or loam, which is reworked material derived from the Permian formations of northwestern Texas.

Terrace No. 2 lies 20 feet above No. 1. It is represented by a flat between mileposts 299 and 301 on the Gulf, Colorado & Santa Fe Railway on the north side of the river and at milepost 296 on the south side.

A well-developed flat (No. 7) appears between Rio Vista and Cleburne, on the north side of the river, and near Morgan, on the south side 270 feet above the stream bed and 180 feet below the summit of the plateau. These flats may represent the flat of the Uvalde terrace, which occupies the high divides in the interior portion of the Coastal Plain.

Terrace No. 1 is represented in most of the cross sections on Brazos River shown in Plate XXXIII. Its height above the river bed where it is clearly identified ranges from 30 to 35 feet; at Clay it is given as 50 feet, but it seems more probable that this is terrace No. 2 instead of No. 1. Terrace No. 1 is composed of red sandy clay, and it is subject to overflow in times of great flood.

The terrace is represented by flats more or less broad at Waco, on the east side of the river; at Valley Junction, on the west side; at San Felipe; at Wallis; at Velasco, where it is only 8 feet above sea level; and at Quintana, where it is 4 feet above sea level.

Terrace No. 2 ranges from 40 to to 55 feet above the bed of the river and is composed largely of red sandy clay but has more or less gravel in its basal part. A considerable vertebrate fauna has been collected from terrace No. 2 by Dr. Mark Francis, of the Texas Agricultural and Mechanical College, at Munson Shoals, 5 miles southeast of Stone City. The specimens were found from 20 to 40 feet above the stream. The forms, identified by O. P. Hay, include *Equus*, *Megatherium*, *Mastodon*, *Gomphotherium*, *Elephas columbi*, and *Testudo crassiscutata*. Hay considers that they represent an early Aftonian Pleistocene fauna. Terrace No. 2 is well shown at Waco, Valley Junction, Stone City, near Clay, Hidalgo Bluff, San Felipe, Simonton, Arcola, and Brazoria. Most of the towns on the river are situated upon this terrace.

Terrace No. 3 is also generally present along Brazos River at a height of 70 feet above the bed of the river, except near its mouth, where the surface is too low to show it. It consists of sand and gravel, the pebbles being composed of very resistant rocks, such as flint, quartz, and jasper. Terrace No. 3 is well developed on both sides of the Brazos at Waco, in the eastern limits of Hearne, on the west side of the river opposite Stone City, east of Somerville, on the Missouri, Kansas & Texas Railway south of San Felipe, and at Fulshear, and Wallis.

Terrace No. 4 ranges in height above the bed of the Brazos from 90 to 122 feet. It is generally recognizable wherever the land is high enough for it to have been formed. It is composed of the same materials as Terrace No. 3. It is well shown 5 miles northeast of the railroad station at Waco, southeast of Elliott, at Clay, south of Sealy, southeast of Brookshire, and at Eagle Lake.

Terrace No. 5 ranges from 150 to 170 feet above the bed of the river and is generally recognizable except near the seaward edge of the Coastal Plain. The flat of this terrace is generally covered with gravel. Since it has been elevated to its present position it has been eroded, so it is generally not so perfect as the terrace lying at a lower level. It is noticeable but poorly preserved at Elm Mott, 9 miles northeast of Waco, at Elliott, at Gause, near Bryan, 6 miles southeast of Caldwell, and west of Eagle Lake.

Terrace No. 6 is 212 to 220 feet above the bed of the river and is covered by gravel similar to that which covers terrace No. 5. It can be seen near Ross, north of Waco, near Franklin, and 4 miles northeast of Milano Junction.

The Uvalde terrace or dissected plain is about 310 feet above the bed of Brazos River. As it is very much older than the other terraces it has been elevated to a higher position and consequently has been so completely dissected that it is preserved only on the principal divides. It was originally largely covered with gravel and cobbles, but these are now mostly removed by erosion. It was recognized at Hewitt near Waco, at Milano, at Giddings, and 1 mile south of Gay Hill.

TERRACES ON COLORADO RIVER.

The terraces along Colorado River are nearly identical with those just described on the Brazos. They range in height from 16 to 280 feet, and the higher ones are present only on the inner part of the Coastal Plain. They are covered with similar materials derived from the erosion of the rocks higher up the stream or higher on the sides of the valley. These terraces are represented in the cross sections on Plate XXXIII.

The lowest and youngest terrace ranges in height above the bed of the river from 16 to 28 feet. It represents the work of the immediate predecessor of the present Colorado River, and the materials deposited on the flats are generally red silts and sand. This terrace may be seen at a number of places about Austin; at Webberville, on the northeast side of the river; at Goodman, where it has a width of 1 mile; at Hemphill Bend; at Smithville; at West Point; at La Grange (see Pl. XXXII, *B*); near Ellinger, on the John Petty league, 1 mile above the mouth of Petty's Creek; at Columbus; at Altair; on the northeast side of the river at Garwood; at Wharton; and on the southwest side of the river at Buckeye.

Terrace No. 2 ranges from 24 to 45 feet above the bed of the river, the common position being from 40 to 45 feet. It is composed of red sandy clay or alluvium on a foundation of gravel, made up of pebbles of limestone, quartz, chert, jasper, granite, etc. This terrace has been described by Hill as the "Depot" terrace of Colorado River.[74]

Terrace No. 2 is well marked at Austin, particularly in the southeastern part of the city; between Montopolis and Stones Ford on the south side of the river; 1¾ miles east of Delvalle; at Webberville; in the vicinity of Goodman, where it is 1½ miles wide and known as the Hemphill Prairie; at Bastrop, where it constitutes the principal part of the valley bottom; at Smithville; at West Point; at La Grange; at Ellinger; at Columbus; at Altair; at Garwood; at Wharton, Pierce, and El Campo, which are built upon it; and at Buckeye, where it forms the divide west of the town and is composed of blue, red-weathering clay with lime nodules.

Terrace No. 3 ranges in height above the bed of the river from 52 feet in the lower part of the Coastal Plain to 75 feet near its inner margin. The terrace is composed principally of gravel, the pebbles of which are made up of quartz, feldspar, jasper, granite, chert, etc. These have been derived probably from the pre-Cambrian schists, gneisses, and granites of Llano and Burnet counties.

It is well exposed at the Confederate Home, in the southwest part of Austin; on the

[74] Hill, R. T., Geography and geology of the Black and Grand prairies, Tex.: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 7, p. 352, 1901.

Bastrop-Paige road, about 1 mile east of the wagon bridge at Bastrop; 1 mile west of Smithville; at West Point in a narrow flat south of the Missouri, Kansas & Texas Railway station; at La Grange, at the cemetery east of the Southern Pacific Railway station; at Ellinger; at Columbus, which is largely built upon its flat; at Alleyton; and at Altair.

Terrace No. 4 ranges in height above the bed of the river from 77 feet near the Gulf to 100 feet near the inner margin of the Coastal Plain. It is composed of materials similar to those covering the flat of terrace No. 3, and they have probably a common source of origin and a similar history. The terrace is well developed in Austin, the State capitol being situated upon it. On account of this association it has been described by Hill and Vaughan [75] as the "Capitol" terrace. It is notable at Powell Bend, 4 miles northwest of Bastrop; 2 miles northwest of Smithville; at La Grange, where it is marked by the standpipe of the city waterworks; at Ellinger, where it constitutes an extensive gravel-covered flat; at Glidden, 3 miles west of Columbus; and at Altair, which is built upon its flat.

Terrace No. 5 is not generally well represented on Colorado River, having been identified at only three places. It ranges in height above the bed of the river from 97 feet at Altair to 150 feet at Austin. It is generally composed of gravel similar to that which may be found on terraces Nos. 3 or 4. It is identified at Austin as the flat 2 blocks north of the university campus; near Columbus as the flat 1 mile west of Ramsay; and at Altair, where it forms the higher divides.

Terrace No. 6 has been more widely identified in the northwestern part of the Coastal Plain at heights above the river bed ranging from 160 to 190 feet. It is composed of coarse materials similar to those described for some of the adjacent terraces. At Austin it is represented by the extensive flat at the State Insane Asylum and for that reason was called by Hill and Vaughan [76] the Asylum terrace. It has been identified at Bastrop, where it is represented by the extensive flat east of the town, extending from Schaefer Hill to Red Bluff; at Smithville, where it is represented by an extensive flat north of the town; at West Point, by a flat 3 miles southwest of the town; and at La Grange, by a flat 6 miles north of the town.

The Uvalde terrace is generally present where the country is high enough for it to have been formed. It ranges in height above the bed of the river from 220 to 280 feet and is capped by material already described as the upstream facies of the Reynosa formation. It is present at Austin at a height of 250 feet above the river; at Webberville, 3 miles north of the town, at 280 feet; 2 miles west of Paige; at Giddings; 1 mile south of Flatonia; 1 mile northeast of Ledbetter; at Fayetteville; and at Weimar.

A number of fossils have been found in the materials covering the terraces along Colorado River. Thus in terrace No. 2 at Austin the tooth of a mammoth and a fossil turtle (*Terrapene whitneyi* Hay) have been found and in the same terrace at Stones Ford the tooth of a mastodon. About 2 miles east of the State Insane Asylum at Austin a molar of *Equus excelsus* Leidy (?), an early Pleistocene species, was found in terrace No. 6 at Ridge Top. (See Pl. XXVIII.)

At Hemphill Bend, near Goodman, the skeleton of a modern buffalo was found about 10 feet below the top of terrace No. 1. Five miles upstream from Bay City a tooth of *Elephas columbi* (?) was once found, which probably came from terrace No. 2.

TERRACES ON LITTLE RIVER.

Little River, a tributary of the Brazos, heads in Eastland and Callahan counties and discharges into the main stream in Milam County. As its headwaters cut back as far as the Guadalupe and Nueces, it belongs to the same class of stream and is here considered separately.

The terraces on Little River are shown in Plate XXXIII.

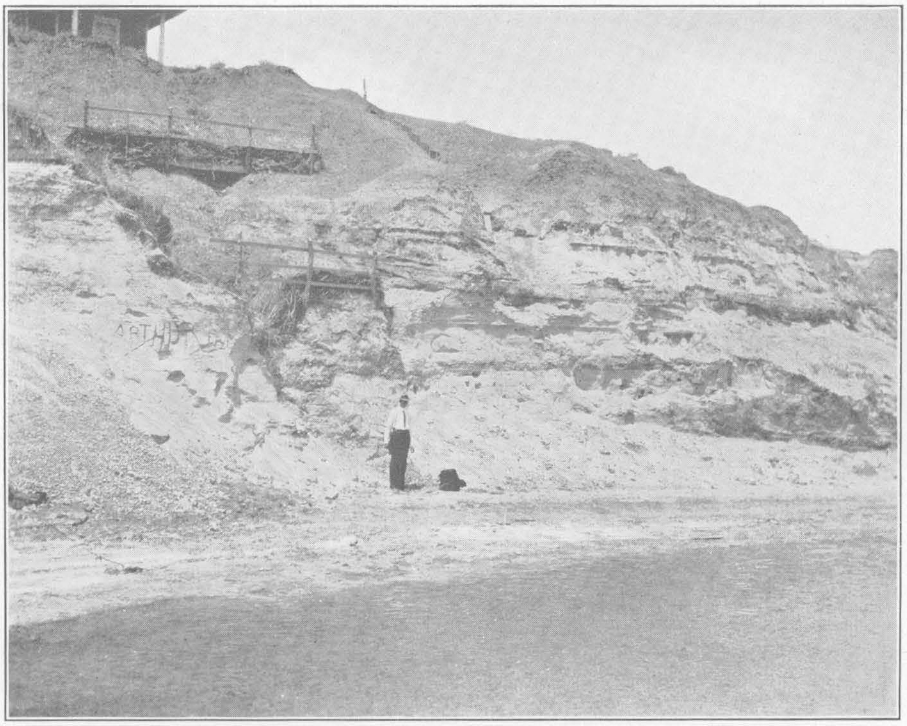
Terrace No. 1 is composed of brown silt and loam and is 32 feet above the bed of the stream at Cameron.

Terrace No. 2 is 42 to 48 feet above the bed of the river. It is poorly displayed at Cameron and is also shown in the vicinity of Temple. It is composed chiefly of dark silt and loam.

Terrace No. 3 is 78 feet above the bed of the river, and it is represented by a flat 2½ miles wide near Holland.

[75] Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and the Rio Grande Plain adjacent to Austin and San Antonio, Tex., with reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 249, 1898.

[76] Idem, p. 249.



A. BEAUMONT CLAY EXPOSED IN BLUFF AT CORPUS CHRISTI, NUECES COUNTY, TEX.

B. TERRACES ON COLORADO RIVER 1½ MILES NORTHWEST OF LA GRANGE, FAYETTE COUNTY, TEX.

Low flat in foreground is terrace No. 1; gravel capping the bluff and resting on the Catahoula sandstone is terrace No. 4.

Terrace No. 4 is 104 to 108 feet above the bed of the river and is composed mostly of limestone gravel. It can be identified in the vicinity of Temple and at Cameron, the latter town being built upon it.

The Uvalde terrace lies 250 to 258 feet above the bed of the river and is veneered with a thick coat of flint gravel. It is well shown southeast of Temple and at Bartlett and at Buckholts.

TERRACES ON GUADALUPE RIVER.

The headwaters of the Brazos and the Colorado have been cut much farther inland than those of the Guadalupe, and if headwater erosion can be used as an index of age the Guadalupe is younger than either of the other two rivers.

A comparison of cross sections on the Guadalupe with those on the Colorado will show some interesting contrasts. The most notable one is the difference in the depth to which they have intrenched themselves below the level of the Uvalde terrace. If the section of the Colorado at Austin is compared with the section of the Guadalupe at New Braunfels, where the geologic formations cut are essentially similar, it will be noted that the Colorado is sunk 280 feet below the Uvalde terrace and that the Guadalupe is sunk only 132 feet below it. This general difference holds good as far seaward as the Oakville escarpment. From the Oakville escarpment to the coast there are considerable differences in the character of the two valleys. If the Beaumont terrace be used as a datum it will be seen that the Guadalupe has cut its channel 70 feet below this level (cross section at Bloomington), whereas the Colorado has cut its channel only 40 feet below it (cross section at Wharton).

In this stretch of the Guadalupe there are terraces that are apparently not represented on the Colorado, so it would seem that in this part of its course the Guadalupe has been subject to influences that were not effective on the Brazos and Colorado.

The lowest terrace on the river is supposed to be below terrace No. 1, as it has been described in other sections. This terrace was noted at two places only, Victoria and Bloomington. At Victoria it is 20 feet above the bed of the river and consequently it can but be considered as the present flood plain. At Bloomington it lies 28 feet above the bed of the river.

Terrace No. 1 is composed of grayish-brown sandy loam or yellow calcareous loam and lies from 30 to 40 feet above the bed of the river. This terrace has been identified at Seguin and also at a place 10 miles east of Seguin; at the bridge, 3 miles west of Cuero; at Victoria, the courthouse being built upon its flat; and on the northeast side of the river at Bloomington.

Terrace No. 2 is composed of gray calcareous clay resting on a pavement of limestone and flint pebbles. It lies from 43 to 55 feet above the bed of the river. It was noted at the following localities: At New Braunfels it is represented by a flat on either side of the river upon which the major portion of the town is built; at the bridge south of Seguin; at Gonzales, the south part of the town being built upon its flat; at Cuero it is represented by wide flats, the west part of the town being situated upon it; 10 miles southeast of Cuero; 3 miles north of Victoria; and at Bloomington and Placedo, where it forms the main divide between Guadalupe River and Arenoso Creek.

Terrace No. 4 is composed of coarse material cemented by lime, and it lies from 60 to 95 feet above the bed of the river. It has been identified at New Braunfels at 79 feet; at Seguin at about 60 feet; at Gonzales at 65 feet; and at Cuero, 1 mile east of the town, at 95 feet above the bed of the river.

Uvalde terrace is composed of flint cobbles and lies from 149 to 245 feet above the bed of the river. It has been identified near New Braunfels on the divide between Guadalupe River and York Creek; at Marion; 1 mile west of Kingsbury; 6 miles south of Smiley; in the vicinity of Edgar; and 3 miles northeast of Yorktown.

TERRACES ON NUECES RIVER.

The geology of the valleys of Guadalupe and Nueces rivers is in a general way similar, each stream crossing the same series of formations in the same order, so that barring crustal movements that may have affected the basins differently, one might expect essential similarity in the form of the topography and the structure of the terraces in the two valleys. When the two are carefully scrutinized, however, some interesting contrasts come to view.

In the Edwards Plateau both streams flow in deep, steep-walled canyons on beds that lie some 800 feet below the level of the plateau. On leaving the plateau the streams emerge upon the Coastal Plain, and of course their intrenchment below the high points of the plain is small compared with their intrenchment in the plateau. On the Guadalupe the point of least intrenchment is at the junction of the plain and the plateau at New Braunfels, where it is 130 feet. (See Pl. XXXIII.) The intrenchment gradually increases in amount downstream, reaching its maximum, 210 feet, where the Oakville escarpment is breached at Cuero. From this point it decreases to the coast, but in this section it is very singularly intrenched 50 feet at Victoria, 45 miles distant from the coast, as compared with 70 feet at Bloomington, 32 miles distant. (See Pl. XXXIII.)

On the Nueces the point of least intrenchment in the middle stretch of the stream (130 feet) is near La Pryor, about 30 miles south of the Balcones scarp, which marks the junction of the plateau and the plain. From this point to Bermuda and beyond, a distance of more than 40 miles, the depth of intrenchment remains about the same, but the valley is more completely filled with alluvium at the lower end than at the upper. A notable increase in the intrenchment is seen at Cotulla, where it is 220 feet. From Cotulla it decreases gradually and more or less regularly toward the coast.

Victoria, on the Guadalupe, and Sandia, on the Nueces, are about the same distance from the coast—45 miles. The upland formation at both places is of the same age. At Victoria the intrenchment is 50 feet; at Sandia it is 160 feet, and similar relations hold downstream, toward the coast. At Bloomington, on the Guadalupe, 32 miles inland, the intrenchment is 70 feet; at Calallen, on the Nueces, 31 miles inland, it is 85 feet.

In general it may be said that in the middle stretches of these two streams the relative intrenchment below the high points of the plain is about the same in corresponding parts of the valleys. In the lower stretches the Nueces is intrenched much deeper than the Guadalupe.

It should be recalled that this same relation holds for the lower stretches of the Guadalupe and the Colorado, the Guadalupe showing the greater vertical intrenchment.

These conditions seem to imply a very considerable differential uplift of the area south of the Nueces in comparatively recent time, which has enabled the Nueces to cut its channel deeper than that of the Guadalupe and the Guadalupe to cut its channel deeper than that of the Colorado.

The lowest terrace on Nueces River is practically the flood plain. It makes its appearance in descending the stream at La Pryor and becomes a stronger feature as the stream is followed southward. It seems to be the northern terminus of the extensive alluvial delta-like plain between Crystal City and Bermuda. Southeast of La Pryor it lies approximately 10 feet above the channel bed and is composed of gray to dark silt or loam. This terrace or alluvial plain has been identified at Cotulla, and 10 miles south of Tilden. Below the last-named place the lowest terrace increases in height above the bed of the river and is represented by more than one terrace. At Mikeska, Live Oak County, the terrace is 20 feet above the bed of the river; at Sandia there are two terraces, one at 30 feet and the other at 40 feet. The latter appears to be the downstream equivalent of the terraces at Mikeska and Tilden.

At Calallen the lowest terrace is 16 feet above the stream bed and the second at 64 feet. The Beaumont terrace lies at 84 feet and is the highest one in this vicinity.

Terrace No. 1 lies from 20 to 45 feet above the bed of the river and consists of gray to drab silt resting on a bed of gravel. This terrace was noted 7 miles west of Uvalde; at Pulliam and La Pryor at a height of 30 feet; at Cotulla at 20 feet; at Shiner's Ranch at 35 feet; at Mikeska at 45 feet; and at Sandia at 110 feet.

Terrace No. 2 lies from 30 to 65 feet above the bed of the river and is composed of much the same sort of material as terrace No. 1. It was noted 7 miles west of Uvalde at a height above the bed of the stream of 65 feet; 1 mile below the bridge of the San Antonio, Uvalde & Gulf Railway at 50 feet; at La Pryor at 45 feet; at Cotulla at 30 to 35 feet; at Shiner's Ranch at 65 feet; and at Mikeska at 65 feet.

The Uvalde terrace lies from 120 to 240 feet above the river bed and is generally composed of flint gravel cemented into a lime conglomerate in places.

It is well represented at the old Tom Nunn ranch, 7 miles west of Uvalde, at a height of

200 feet; at Pulliam, at 190 feet; on the divide between Leona and Nueces rivers, where it is crossed by the Batesville-Eagle Pass road, 6½ miles west of Batesville, at 120 feet; on a small hill 3½ miles west of Loma Vista, Zavalla County, at a height of 130 feet; at Carrizo Springs, on the International & Great Northern Railway, 13 to 18 miles north of Laredo, at a height of more than 220 feet; and on the Tilden-Oakville road, about 7¼ miles east of Tilden, at a height of 240 feet.

The discrepancy in the heights above the bed of the river as well as the discordances in absolute altitude cast some doubt about the validity of these identifications, but at the present time they seem most reasonable, although, it must be confessed, very irregular.

IGNEOUS ROCKS.

Bodies of igneous intrusive rock occur along the Balcones fault zone, at the interior margin of the Coastal Plain. Such bodies are particularly conspicuous in Travis and Uvalde counties, but some are seen also in Hays, Bexar, Bandera, and Kinney counties. The bodies in Travis and Uvalde counties have been described in detail by Hill and Vaughan.[77]

The rocks that form these bodies are basaltic. They include nepheline basalt, nepheline-melilite basalt, orthoclase basalt, plagioclase basalt, and limburgite. Phonolite occurs at a number of places in Uvalde County.

These igneous bodies were forced through the subhorizontal sedimentary formations. There are no surface flows. The intrusions are of four types: (1) bosses, stocks, or necks; (2) laccoliths; (3) laterally intruded sheets, which in places now cap hills; (4) dikes.

A buried sill of decomposed or altered basalt, possibly a bed of volcanic tuff, occurs at a depth of 820 feet (about 230 feet above the base of the Taylor marl) 2 miles southeast of Thrall, in Williamson County. It extends about a mile from north to south and about half a mile from east to west. (See fig. 29.)

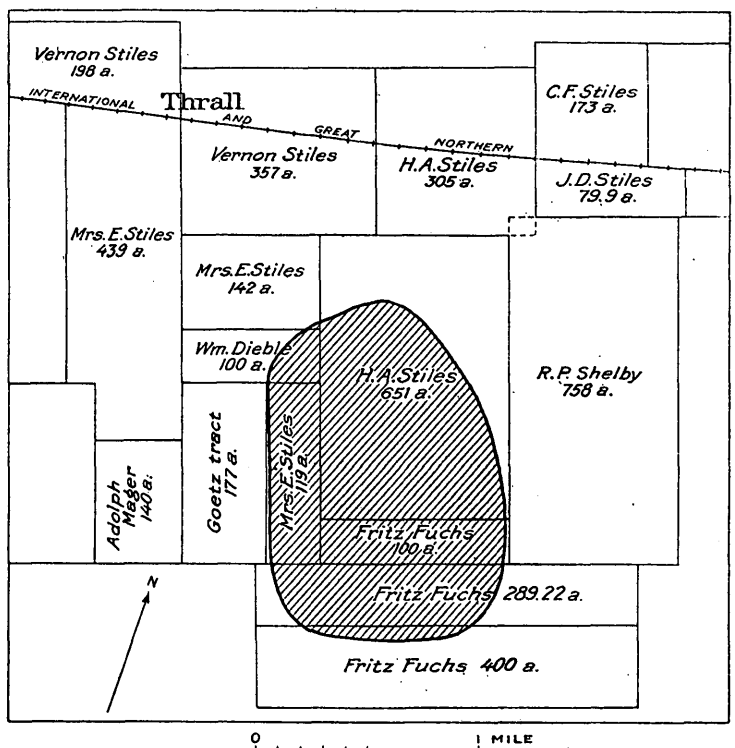


FIGURE 29.—Map of Thrall oil field, Williamson County, Tex., showing extent of the buried volcanic sill (shaded area).

[77] Hill, R. T., and Kemp, J. F., Pilot Knob a marine Cretaceous volcano: Am. Geologist, vol. 6, pp. 292-294, 1890. Hill, R. T., and Vaughan, T. W., Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Tex., with special reference to the occurrence of underground waters: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 256–257, 1898. Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), pp. 3–5, 1900. Hill, R. T., and Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Austin folio (No. 76), p. 6, 1902.

The bed dips very gently to the northwest and is overlain by a somewhat hardened bed of Taylor marl, locally called "cap rock." This volcanic rock is the oil-bearing "sand" of the Thrall field. It was discovered in a hole drilled for oil in February, 1915, and as profitable oil wells were obtained in it its limits were soon determined.

Specimens were submitted to E. S. Larsen, jr., who reported as follows:

The material is no doubt of igneous origin, but the original minerals are now completely gone, and the specimen is an aggregate of calcite, chlorite, and other secondary minerals. The form of the original lath-shaped or tabular feldspar crystals is still well preserved, with a texture similar to that common to basalts. The rock is clastic and is probably a tuff, although it may have been a flow breccia. More accurate determination is not possible, although it was without question derived from a rock closely related to basalt.

A chemical analysis shows the following composition:

Analysis of volcanic rock from wells at Thrall, Tex.[78]

[J. E. Stullken analyst.]

Silica (SiO_2)	31.55
Alumina (Al_2O_3)	19.69
Iron oxide (Fe_2O_3)	12.44
Lime (CaO)	5.96
Magnesia (MgO)	11.08
Sulphuric acid (SO_3)	2.77
Potassium oxide (K_2O)	.08
Sodium oxide (Na_2O)	.04
Loss on ignition	15.64
	99.25

This body is evidently either a sill connected with some near-by volcanic neck or a tuff similar to those exposed near Austin, deposited by a submarine volcano that was active in this vicinity in early Taylor time. In any event the rock is closely related structurally and historically to the Pilot Knob disturbance near Austin.

Pilot Knob, 8 miles southeast of Austin (see Pl. VIII) marks the site of an ancient volcanic eruption, which probably took place at the time the upper part of the Austin chalk and the lower part of the Taylor marl were being deposited. The neck or core of the ancient volcano is represented by three low hills of black columnar nepheline basalt (limburgite), which covers about 9 square miles in the center of an area that is composed largely of tuff and débris. Several small dikes and beds of tuff that are related to the central mass extend outward from it for a distance of 6 miles.

The basalt is pushed up through the Austin chalk, which is marmorized at many places along the contact and lies against the igneous mass, dipping away from it on all sides. In places around the edge of the disturbed area volcanic material is interbedded with the chalk.

A small neck of nepheline basalt lies a few yards east of Tillotson Institute, west of the Houston & Texas Central Railway, in the southeastern part of Austin. A dikelike mass of disintegrated volcanic rock is exposed on the road a short distance south of the Institute.

Another outcrop of basalt lies about three-fourths of a mile west of Stones Ford, a quarter of a mile from the river.

A cut a short distance north of Kouns station shows a mass of tufflike material filling a fissure in the Austin chalk. It is capped with Reynosa gravel. Similar material is exposed on the road about a mile east-northeast of St. Edwards College and at other places.

There are a number of basaltic knobs in Hays County, and a basaltic knob stands in Bexar County about 10 miles northeast of San Antonio.

Tait records the existence of a basaltic

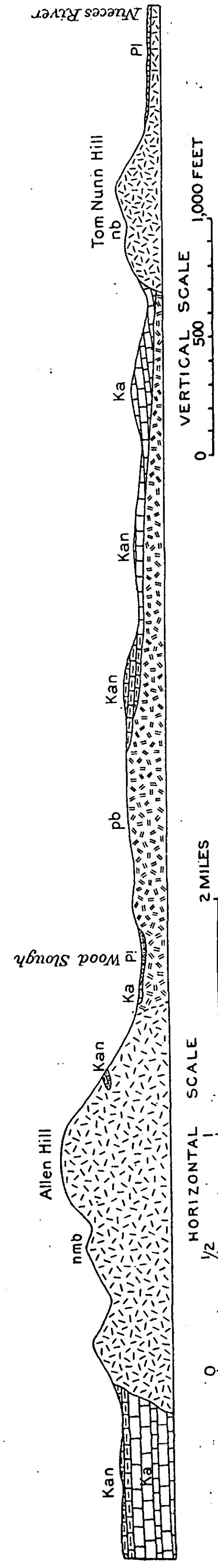


FIGURE 30.—Northwest-southeast section through laccolith 10 miles west-southwest of Uvalde, Tex. (After Vaughan.) Kan = Anacacho limestone. Ka = Austin chalk. nmb = Nepheline-melilite basalt. pb = Plagioclase basalt. nb = Nepheline basalt. Pl = Pleistocene.

[78] Udden, J. A., Oil in an igneous rock: Econ. Geology, vol. 10, p. 585, 1915.

dike in Bandera County 2 miles north of Bandera.[79]

A large laccolith about 5 miles long and from 1½ to 3 miles wide occurs on the west side of Nueces River, about 10 miles west-southwest of Uvalde. On the margin of this laccolith there are masses of nepheline, limburgite, or nepheline-melilite basalt which, owing to their superior hardness, have resisted erosion and thus formed hills composed of basalt or of the Austin chalk or the Anacacho limestone into which the basalt was intruded. The northwest side of the mass is exposed in Allen Hill, the southwest side in Sulphur Peak, the southeast side in Tom Nunn Hill, and the northeast side in Nueces Hill. The low mass between the hills is composed of plagioclase basalt, which has floated the Austin chalk and Anacacho limestone upward on its surface and is now exposed where the limestone has been eroded away. (See fig. 30.)

Weymiller Butte, 11 miles west-southwest of Uvalde; Lewis Hill, 10 miles west-northwest of Uvalde; and Obi Hill, 2 miles southwest of Lewis Hill, are apparently remnants of sills of basalt that were laterally intruded beneath strata which have been removed by erosion. Six miles northwest of Pulliam and 1½ miles east of Wagon Wheel Hill basalt is intruded into the basal layers of the Escondido formation.

There are many small areas of basalt between Nueces and Leona rivers, west of Uvalde. (See Pl. VIII.) An isolated mass of basalt occurs on the top of the hill a mile east of the Tom Nunn ranch, 6 miles west-southwest of Uvalde.

A knob of phonolite, apparently intruded through the Buda limestone, stands 3 miles north of Sansom.

Blue Mountain, which is near Frio River, 2 miles northwest of Chatfield, is a mass of nepheline basalt intruded into the Eagle Ford shale and the Austin chalk. Black Mountain, 3 miles to the west, is the remnant of a sill of nepheline basalt overlying the Austin chalk. Phonolite, which has been intruded into the Edwards limestone, forms a knob 2 miles southwest of Black Mountain. A mass of plagioclase basalt rests upon or is intruded into the Eagle Ford shale 1½ miles north of Ange siding. At this siding a mass of phonolite is intruded into the Eagle Ford shale. Inge Mountain, 2 miles south-southeast of Uvalde (see Pl. II, *B*), is composed of phonolite. Taylor Hill and the hill 1 mile northwest of it are composed of nepheline-melilite basalt, but whether this body is a sill or a laccolite could not be determined, because the structure is concealed by surficial material. The basalt at Black Water Hole on the Frio, 3 miles southeast of Ange siding, is a laccolith intruded into the Eagle Ford shale, which has been tilted by it to a high angle. (See Pls. XXXIV, *B*, and XXXV, *B*.) At Connor ranch, on Frio River 4½ miles southeast of Black Water Hole, phonolite cuts the Austin chalk. Chatfield Hill, on the west side of Frio River at the Southern Pacific Railroad crossing, is a laccolith intruded into the Austin chalk.

Between Frio River and the east line of Uvalde County there are many hills of basalt surrounded by surficial materials, which obscure the contact of the basalt with the older rocks. Large exposures of amygdaloidal nepheline basalt, overlain by the Anacacho limestone, occur along Blanco River south of the Southern Pacific Railroad.

The youngest formation cut by these igneous bodies in Uvalde County is the Escondido, a fact which indicates that the volcanic activity took place in Eocene (possibly Miocene) time, when the Balcones fault was formed.

A detailed description of the petrographic features of the basalts and phonolites of Uvalde County, by Whitman Cross, is given in the Uvalde folio.[80]

A sill of basalt caps Las Moras Mountain 3½ miles northeast of Brackettville. Similar sills cap Turkey Mountain and Pinto Mountain, which stand, respectively, 13 miles east-northeast and 9 miles north of Brackettville.

MINERAL VEINS.

A vein of chalcedony which trends N. 40° E. forms a hill (Los Picachos) rising about 65 feet above the level of the plain 1½ miles south of the north line of Duval County, about 4 miles southwest of Lomo Alto, in McMullen County. (See Pl. XXXV, *A*.) The local geology can be best understood by reference to the accompanying sketch map and section (fig. 31). Here, as shown in the section and as indicated in the exposure at the south end of the hill, there are two parallel veins, which stand vertical. The vein filling was found upon microscopic examination by E. S. Larsen, jr., of the United States Geological Survey, to consist of chal-

[79] Tait, J. L., Texas Geol. Survey First Rept. Progress, p. 66, 1889.

[80] Vaughan, T. W. [and others], U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), pp. 3-4, 1900.

cedony, a crystallized form of silica (SiO_2), in a matrix of opal (a noncrystallized hydrated form of silica). Chemical analyses of the rocks are given in the following table:

Analyses of rocks from Los Picachos Hill in Duval County, Tex.

[W. T. Read, analyst, March, 1914.]

	1	2	3	4
Silica (SiO_2)	24.87	84.41	95.11	98.34
Alumina (Al_2O_3)	4.24	4.74	1.03	1.36
Iron (Fe_2O_3)	3.51	.17	.07	.10
Lime (CaO)	46.01	1.37	.22	.29
Magnesia (MgO)	1.55	.70	.26	.26
Soda (Na_2O) and potash (K_2O)	1.33	.94	.54	.15

1. Unaltered marl from the Frio clay.
2. Wall rock adjacent to dike rock at south end of Los Picachos Hill; opal rock.
3. Chalcedony or dike rock at south end of Los Picachos Hill.
4. Chalcedony or dike rock at north end of Los Picachos Hill.

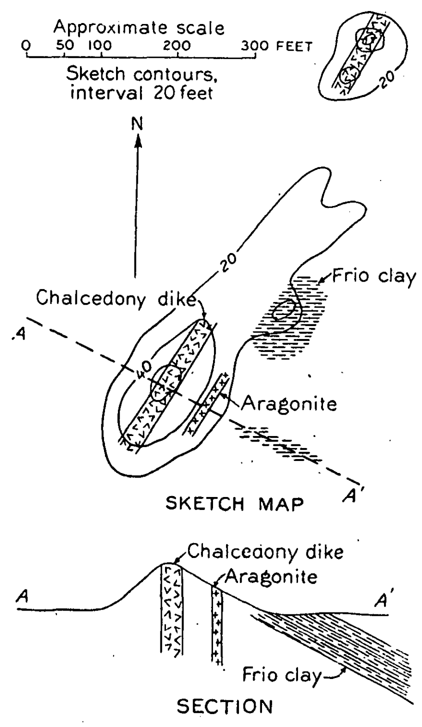


FIGURE 31.—Geologic sketch map and section of Los Picachos Hill, in northern Duval County, Tex.

The vein is bounded on both sides by an altered marl in the Frio clay which has been permeated with silica and is now in the form of opal rock. The wall rock is bedded, the beds standing vertically as shown in the section (fig. 31). About 50 feet east of the vein of chalcedony and parallel to it is a vein of aragonite, a crystallized form of calcium carbonate.

The marl is of distinctly different origin from the chalcedony, being a sedimentary rock deposited probably in a lake or a delta, whereas the chalcedony is formed chemically, representing silica precipitated from a solution which invaded the sediments at this point. The dip of the Frio beds is 20° S. 30° E.

Three masses of quartzose rock, 15 to 20 feet in diameter, somewhat similar to the chalcedony at Los Picachos, occur at Las Tiendas, near the McMullen-Duval county line, about 7 miles south of Gueydan's ranch, in McMullen County.

Knobs similar to Los Picachos occur at a number of other places in Duval County. They are probably related structurally to the Torrecillas uplift and may have some relation to deep-seated igneous activity in this vicinity. So far no exposures of igneous rock have been found in them.

STRUCTURE.

GENERAL FEATURES.

It has already been stated that the formations of the Coastal Plain of Texas consist of a number of sheets of rock that dip gently toward the coast. This general or regional dip ranges from 10 to 70 feet to the mile and averages about 50 feet. The dip of the older formations is slightly greater than that of the younger.

GENERAL DIPS AND STRIKES.

Between Brazos River and a line extending from New Braunfels to Port O'Connor the strike of the Upper Cretaceous and Eocene formations is about N. 38° E., and the dip is southeastward at the rate of 40 to 70 feet to the mile. The strike of the Pleistocene formations is about N. 49° E., and the dip is southeastward at the rate of 20 feet to the mile. West of the line indicated the strike of the older formations becomes more westerly. Between Macdona and Uvalde, for example, the strike of the Upper Cretaceous and lower Eocene beds is about N. 78° E., and the dip of the Escondido formation is southeastward at the rate of about 70 feet to the mile. The Pleistocene formations strike N. 23° E. and dip southeastward at the rate of 30 feet to the mile.

South of a line extending from Spofford to Robstown the strike of the older formations makes a pronounced turn to the north. The strike of the Escondido formation in Maverick County is N. 13° E., and the dip is southeastward at the rate of about 40 feet to the mile. The strike of the upper Eocene and Pleistocene formations in this area is about the same as it is north of the line indicated.

South of a line extending from Laredo to Sarita the strike of the middle and upper Eocene beds changes to a direction a little west of north and that of the Pleistocene formations is nearly north.

The general dip is greatly modified by local structural features, such as faults, anticlines, salt domes, and igneous intrusions. The local features may greatly accentuate or decrease the southeastward dip or may even produce steep reversals to the northwest.

FAULTS.

BALCONES FAULT ZONE.

The Balcones fault zone is a major structural feature of the Coastal Plain. It is expressed in the topography by the Balcones scarp, which marks the northwestern limit of the plain in the region southwest of Temple. The fault zone passes through Waco, lies west of Temple, passes through Georgetown, Round Rock, Austin, San Marcos, and New Braunfels, lies north of Castroville, passes through Uvalde, lies north of Brackettville, and reaches the Rio Grande at Del Rio. It consists of many normal, nearly parallel faults, which are concentrated within a narrow strip of country. On the northwest side of the zone there are large faults of great displacement; on the southeast side there are many smaller faults. The effect of the faulting on the dip of the beds is very pronounced. It chops them into a great many blocks which are tilted at different angles.

The total displacement increases from north to south, being about 500 feet at Austin and about 1,000 feet in Uvalde and Kinney counties. The downthrow is generally on the southeast side of the faults, although along the east margin of the zone there are normal faults with downthrow on the west sides.

A fault of large displacement passes between Waco and the western margin of the outcrop of the chalk on the North Bosque, 4 miles to the northwest. This fault is indicated by the great difference in the depth at which artesian water is found on its two sides.

Traces of faults are seen in the valleys of Noland and Lampasas rivers, near Belton, and faults are conspicuous a short distance west of Georgetown.

At Austin the major fault is easily traceable from Watters southward by way of Spicewood Springs, Amboy, the east foot of Mount Bonnel, Bee Creek, and Oak Hill. The downthrow, which is on the southeast, is 500 feet. Minor faults east of the main fracture are seen in the canyons of Big Walnut, Shoal, Barton, Williamson, and Onion creeks. A section showing fractures is given in figure 32.

A fault is exposed in the western part of San Marcos, the hill on which the Southwest Texas Normal School stands marking the upthrown block.

A fault is exposed at New Braunfels, at Landa's Park. It is accompanied by a decided monoclinal fold of the Edwards limestone. A minor fault may be seen at the old ford on the Guadalupe below New Braunfels.

A fault is exposed on the Cibolo north of Bracken.

In Bexar County the major fault crosses the San Antonio & Aransas Pass Railway, at Viva station, about 2 miles south of Leon Springs. Minor faults occur at intervals between this point and the southern part of Bexar County. The details are shown on Plate VIII.

The major fault crosses Medina River about 5 miles north of Rio Medina post office. Minor faults are exposed between this place and Castroville.

In Uvalde County the major fault is exposed about 5½ miles north of Uvalde.

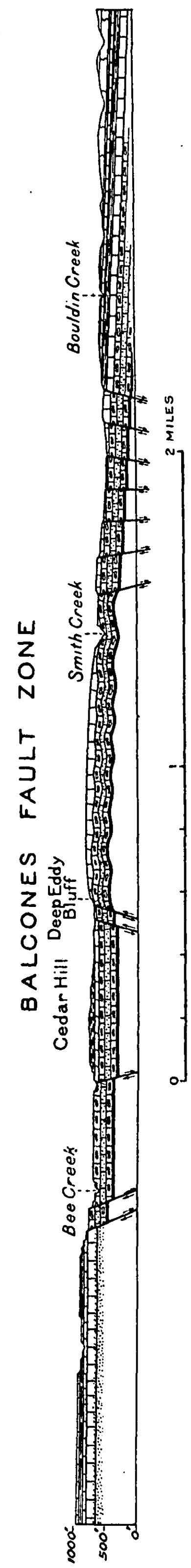


FIGURE 32.—Section along south side of Colorado River, through Austin, showing the details of the Balcones fault zone. (After Hill and Vaughan.)

Many smaller faults lie between this place and a point 3 miles southeast of Uvalde. The faulting in this county may be resolved into two systems—one a series parallel to the escarpment front, which trends northeastward, the other a series that cuts the first at an angle, generally trending northwestward. The faults of both systems show pronounced parallelism in small areas.

A system of normal faults extends from Somerset, Bexar County, northeastward through Luling, Rockdale, Bremond, Groesbeck, and Mexia to Powell, in Navarro County. The system is marked by upthrow on the east side, thus differing from the system of major faults on the west, which has downthrow on the east. The system here described may be called the Luling-Mexia fault system. It marks the eastern limit of the Balcones fault zone, cutting at the surface the Midway and in places the Indio and Carrizo formations.

In a broad way the area in which the Upper Cretaceous formations are exposed south of Dallas may be considered as a large fault block or graben bounded by major normal faults on the west and east sides. The planes of the faults on the west dip southeastward, and those of the faults on the east dip northwestward.

The displacements along the Luling-Mexia fault system range from 50 to 400 feet, and structurally high areas along the east or upthrown side of the fault are characterized by large accumulations of oil in the Edwards limestone or Woodbine sand, the Luling, Mexia, Currie, and Powell oil fields being the conspicuous examples.

The exact age of the faulting is difficult to determine. As it involves the Midway, Indio, and Carrizo formations, it must have occurred after these formations were deposited. The Reynosa formation, which is doubtfully referred to the Pliocene and in places overlies the faulted blocks, is not affected. The movements must therefore have occurred in Eocene, Oligocene, Miocene, or early Pliocene time. The earliest movements may have occurred in Eocene time, and later movements that produced additional faulting may have occurred in Miocene and early Pliocene time.

MINOR FAULTS.

Faulting is not conspicuous in the Tertiary and Quaternary formations of the Coastal Plain east of the Balcones zone, but a few faults have been noted in these formations. These faults rarely manifest themselves by displacement at the surface; they can be seen only in stratigraphic sections, and, owing to the poor exposures, they are not easily found.

A fault striking about N. 30° E. and having a displacement of 100 to 500 feet is exposed in a cut on the Gulf, Colorado & Santa Fe Railway about 1,000 feet north of the depot at Milano. (See fig. 18 and description on p. 60.)

Two normal faults of small downthrow cut the Fayette sandstone 2½ miles northwest of La Grange, on Colorado River. (See p. 85.)

A small fault cuts the Escondido beds at Pulliam, in Zavalla County. (See p. 40.)

Several probable faults are exposed in Wilson County in the vicinity of Lavernia, Floresville, and Sutherland Springs. Several faults have been likewise noted in Gonzales, Bastrop, and Lee counties.

At some places the existence of faults is inferred, though no direct exposures have yet been found. These places are marked on figure 33.

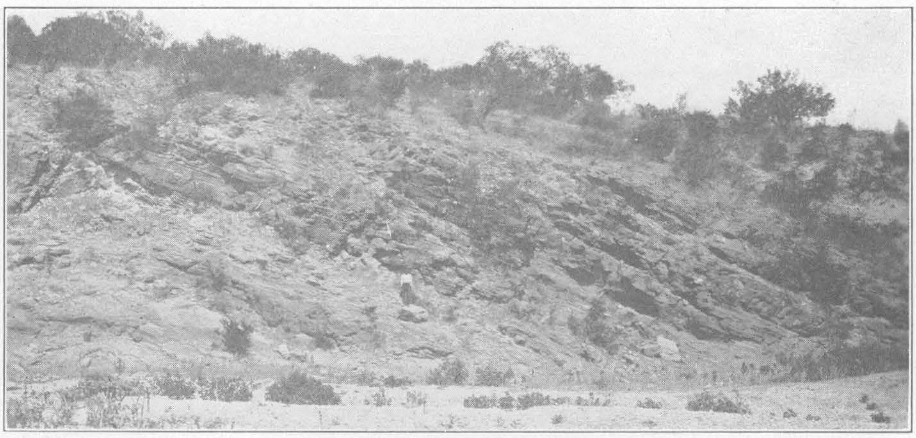
As all of the faults noted outside the Balcones fault zone trend northeastward they are probably minor features of the Balcones system.

TORRECILLAS UPLIFT.

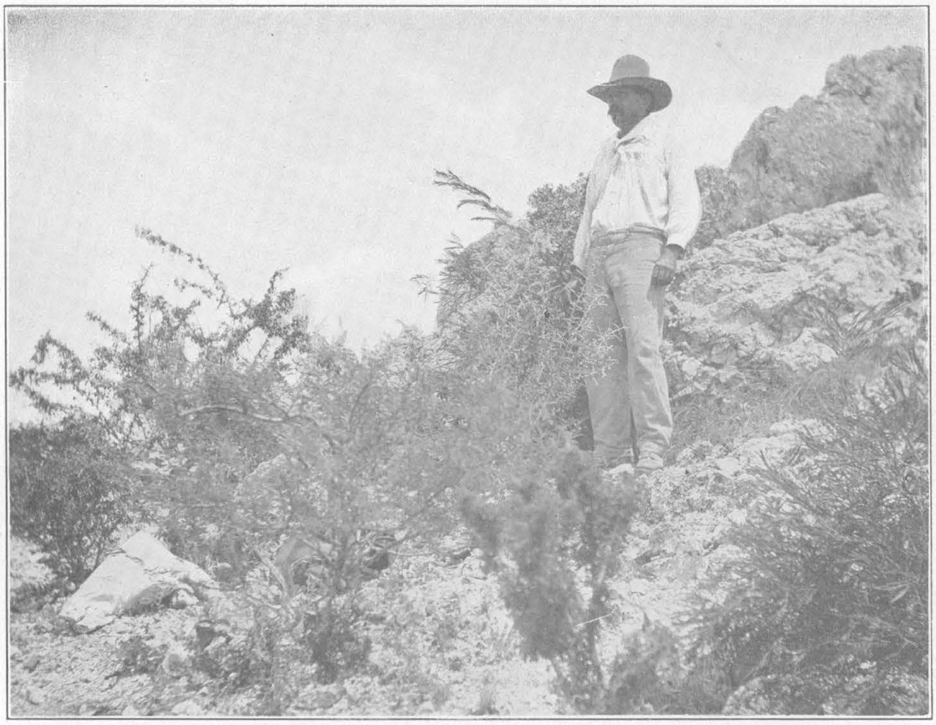
A second pronounced structural feature of the Coastal Plain west of Brazos River is the Torrecillas uplift. This affects an area including the southeast corner of Webb County, the northeast corner of Zapata County, most of Duval County, the southeast corner of McMullen County, and the southwest corner of Live Oak County. The center of this uplift is near Torrecillas and Ojuelos. The vertical movement at these places was probably as much as 200 feet. In the northeast part of the uplifted area the vertical movement was not so great.

Monoclinal folds and small faults probably mark the boundaries of the uplift, though the details of the structure have not yet been worked out. The chalcedony veins of Duval County, the Piedras Pintas, Falfurrias, and

A. SMALL ANTICLINE IN GEORGETOWN (LOWER CRETACEOUS) LIMESTONE IN CUT ON RAILWAY WEST OF CONFEDERATE HOME AT AUSTIN, TRAVIS COUNTY, TEX.



B. EAGLE FORD SHALE TILTED BY INTRUSION OF BASALT AT BLACK WATER HOLE ON FRIO RIVER, UVALDE COUNTY, TEX.



A. CHALCEDONY DIKE AT LOS PICACHOS HILL IN DUVAL COUNTY, TEX.

B. LACCOLITH OF COLUMNAR NEPHELINE-MELILITE BASALT INTRUDED INTO EAGLE FORD SHALE AT BLACK WATER HOLE ON FRIO RIVER, 3 MILES SOUTHEAST OF ANGE SIDING, UVALDE COUNTY, TEX.

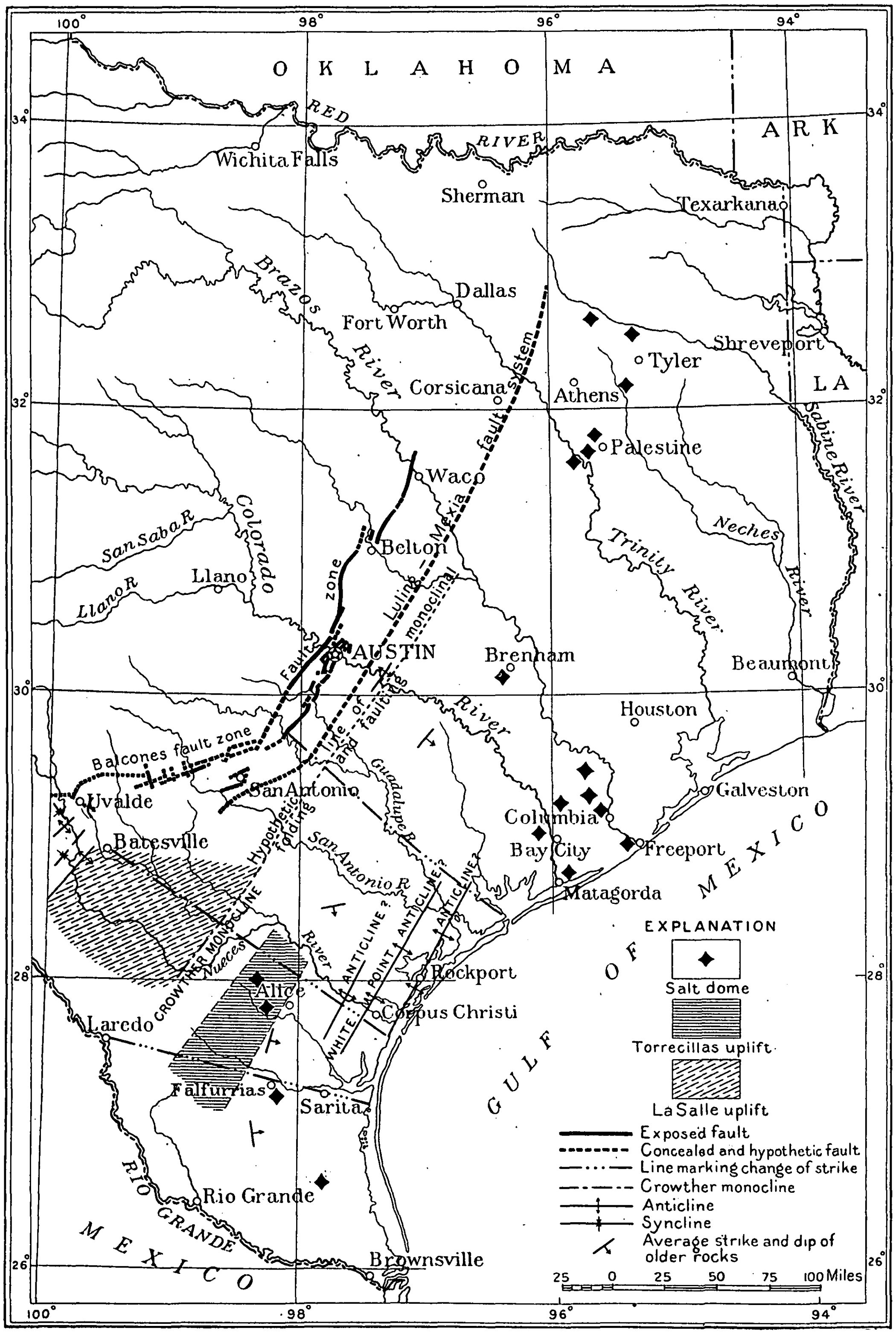


FIGURE. 33.—Structural map of the Coastal Plain of Texas.

other salt domes, and the anticlines on the Nueces below Sandia are probably connected, directly or indirectly, with this uplift.

This uplift is indicated also by the fact that the divide between the Nueces and the Rio Grande has an altitude of 720 feet 18 miles north of Laredo and 872 feet at Torrecillas, about 40 miles to the southeast. At the place indicated north of Laredo and at Torrecillas the divide is capped by the Reynosa formation.

The map shows that no streams cross the Torrecillas uplift in its highest part. The upper course of Nueces River heads directly for it, but instead of crossing the uplift the stream has apparently been deflected by it more than 50 miles to the northeast. Frio River shows a similar though not so pronounced deflection before it joins the Nueces near Oakville. The minor drainage lines on the higher part of the uplift also seem to have been affected by the uplift, for they radiate from it in all directions. This arrangement suggests that the uplift not only diverted Nueces and Frio rivers but that it established a new system of consequent streams upon its slopes.

The change from a northeast to a northwest strike in the formations south of Webb County, already indicated, shows that they have been affected by uplift in this region.

The delta of the Rio Grande is a pronounced feature in southern Texas. Pleistocene formations also attain greater widths in Starr, Hidalgo, Brooks, Kenedy, Willacy, and Cameron counties. These widenings have been caused by the shoaling of the sea floor that accompanied the broad uplift here described.

The chalcedony knobs already described (pp. 121–122) probably represent infiltrations of silica solutions along the line of folding and fracturing that marks the western and northern limbs of the uplift.

The exposures of the Lapara and Lagarto formations are unusual features of the Nueces Valley. They occur very far downstream and are not duplicated on any other stream.

As a consequence of this uplift a large tongue of the Reynosa has been removed by erosion, exposing earlier formations.

An anticline is exposed in a ravine about 1½ miles north of the old Barlow Ferry, on Nueces River about 3 miles northwest of Dinero. The axis trends N. 63° E., and the limbs dip 6° away from the axial line. This is a part of the broader folding along the northern boundary of the uplift.

The Nueces Valley at Sandia (see Pl. XXXIII, in pocket) shows marked entrenchment below the level of the Alice or Mathis terrace (No. 2), an entrenchment not duplicated on other streams or on this stream higher up. The Beaumont terrace (No. 1), which lies 20 feet below terrace No. 2 at Mikeska, stands 50 feet below it at Sandia. The younger terraces show similar conditions. These facts show uplift in this region, which here marks the northeast corner of the Torrecillas uplift.

Finally, the fact that folds and faults mark the boundaries of this uplift seems to be indicated also by the presence of oil and gas in this region. The Reiser gas field, 2 miles west of Aguilares, is on the western limb of the uplift. A number of large gas wells have been drilled on the Jennings ranch, about 22 miles northeast of Zapata. A small gas well has been drilled on its northwestern limb at the Medio ranch, about 14 miles northwest of San Diego.

The Charco Redondo and Mirando oil fields are situated along the west boundary of this uplift, which is marked by the Bordas escarpment.

The movement that produced the Torrecillas uplift was comparatively recent. It involved the Reynosa formation and must therefore have taken place in Pleistocene time. It probably began in early Pleistocene time, but additional movements probably occurred in Beaumont and possibly in later time.

LA SALLE UPLIFT.

An uplift somewhat like the Torrecillas, but not nearly so pronounced, is the La Salle, a structurally elevated mass centering in La Salle County and including the northwestern part of McMullen, the southwestern part of Atascosa, the southern part of Frio, the southeastern part of Zavalla, the eastern part of Dimmit, and a part of Webb County. Its limits are indicated on figure 33. Its eastern border is the Crowther monocline. (See p. 129.) Its western border lies near the Zavalla anticline. (See p. 128.) Its northern boundary is probably a slight monocline, but has not yet been definitely placed. Its southern boundary is undetermined.

The uplift is indicated by the following facts:

The dip on the plateau, which averages 35 feet to the mile, is steeper than the dip east of the plateau, which averages 68 feet to the mile.

The geologic map (Pl. VIII, in pocket) indicates a broadening in the outcrops of the Mount Selman, Cook Mountain, and Yegua formations in the counties named, indicating a flattening of the dip caused by elevation along the eastern border of the Crowther monocline.

Attention has been called to the change in the character of the Nueces Valley as it crosses the eastern part of Dimmit and the western part of La Salle County. (See p. 118.) The stream has intrenched its channel much deeper below the level of the Uvalde terrace in this area than in the area farther west. The wide Recent alluvial plain is lacking, and the stream is actively eroding its channel. The La Salle uplift has no doubt caused the conditions indicated.

ANTICLINES.

The faults of the Balcones fault zone are accompanied by many anticlines, which were formed by the stresses that produced the faults. At some places volcanic activity aided in their formation.

A small faulted anticline is exposed on Big Walnut Creek about half a mile southeast of Watters station, in Travis County. Heavy asphaltic oil occurs in shallow wells at this place.

A small anticline involving a Lower Cretaceous limestone (Georgetown limestone) is exposed in a cut on the International & Great Northern Railway west of the Confederate Home at Austin. (See Pl. XXXIV, *A*.)

Small local anticlines accompany the faults in the southern part of Bexar County. It is with these anticlines and faults that the oil found at Somerset, on Leon Creek, and Alta Vista is associated.

Vaughan [81] records the existence of a pronounced semicircular anticlinal ridge east of Uvalde, extending from Blue Mountain, 2 miles northwest of Chatfield, through Big Mountain, 3 miles northeast of Uvalde, to Frio Hill, 6 miles east-southeast of Uvalde. The crest of this ridge is indicated on figure 33. Big Mountain and Frio Hill are domes of Edwards limestone associated with this anticline. A line of basalt and phonolite intrusions follows the semicircular ridge, but not all the intrusions are on the crest.

The Uvalde-Kinney county boundary line is close to the axis of a gently southward-pitching syncline, indicated by the distribution of the formations. The great basaltic laccolith west of Tom Nunn ranch, on the west side of Nueces River, is on its eastern limb.

Nueces River between Pulliam and the crossing of the Eagle Pass-Uvalde road, 3 miles to the north, flows along a syncline, the axis of which pitches gently to the southeast. The pitch of the axis is about equal to the fall of the river. This syncline is intersected by a small faulted anticline, the axis of which strikes N. 45° E. at Pulliam. (See p. 40.)

The crest of a broad arch, the Herndon Shoals anticline (see p. 48), is visible at Herndon Shoals, on Brazos River, about 5 miles west of Calvert. Gas occurs in the artesian wells at Hearne at a depth of about 700 feet.

The Stone City anticline, the axis of which trends about N. 12° W., probably crosses the Brazos not far above Moseleys Ferry, at Stone City. The beds at the ferry dip 180 feet to the mile S. 80° E., whereas 1 mile above the ferry they dip 180 feet to the mile N. 55° W. (See p. 66.)

A syncline crosses Colorado River about 100 yards downstream from the center of Powell Bend, about three-fourths of a mile northwest of Phelan. It is indicated by a northwestward dip of the lignite bed. The lignite beds exposed in the middle of the bluff dip 1° S. 15° E. The crest of a gentle anticline, here called the Phelan anticline, therefore crosses between the two exposures. A shallow well sunk to prospect for lignite at the lignite mine a short distance south of Phelan encountered a sand that yielded a small flow of gas.

A gentle local arch, here called the Smithville anticline, may be noted near Smithville. The Cook Mountain beds dip N. 40° E. at an angle of 6°, which is a considerable departure from their normal dip. About 4½ miles to the east a small syncline is exposed. The trend of the anticline is therefore apparently east-northeast.

[81] Vaughan, T. W., U. S. Geol. Survey Geol. Atlas, Uvalde folio (No. 64), p. 4, 1900.

An anticline or a large monocline is indicated in Zavalla County. The axis, which is near Crystal City, apparently trends about N. 25° E. A syncline about 3½ miles southeast of Pulliam has already been noted. It would seem that anticlinal or monoclinal uplift has elevated the Indio beds near Crystal City and has enabled Nueces River to cut into them. This uplift may also have some causal relation to the ponding of this stream above Bermuda, which has produced the delta-like alluvial plain already noted. (See p. 118.)

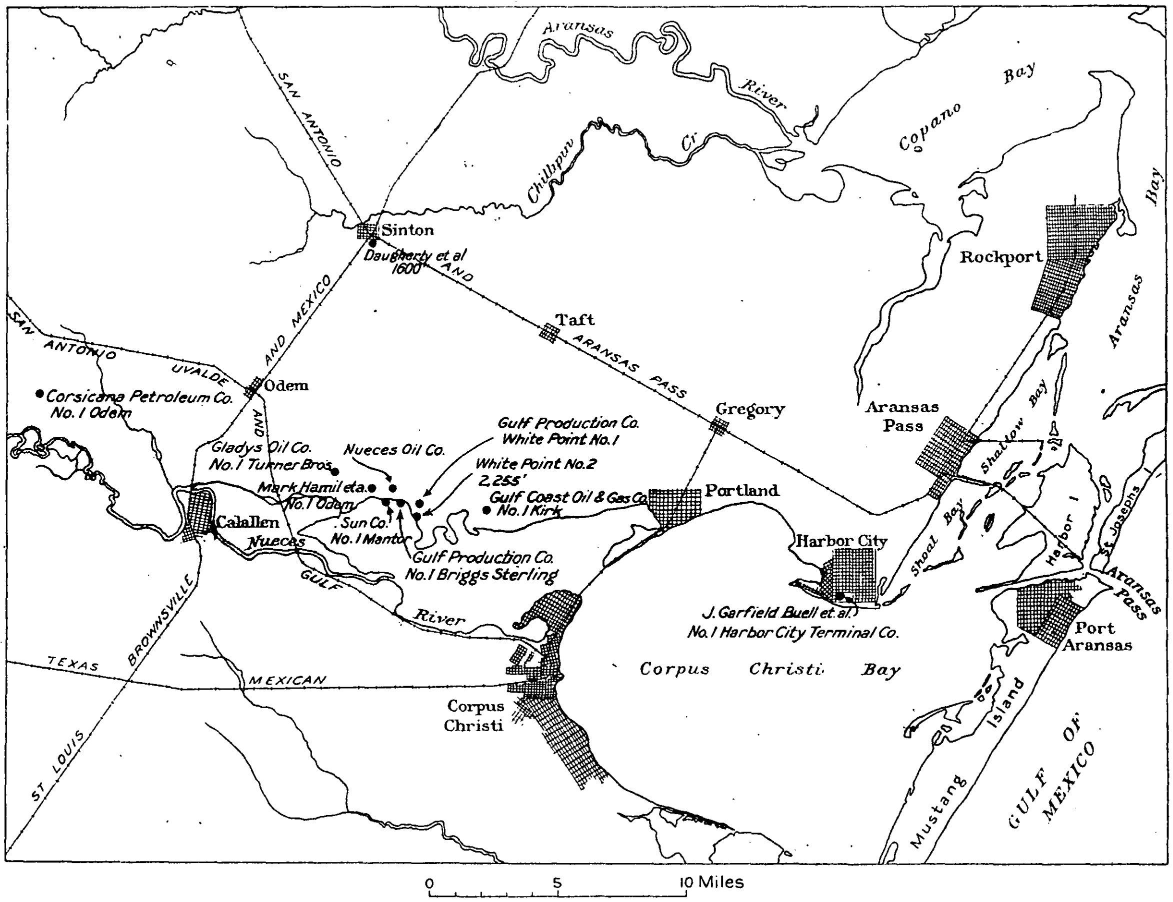


FIGURE 34.—Map of the White Point district, San Patricio and Nueces counties.

An anticline that may be accompanied by structural or salt domes at White Point and possibly elsewhere probably extends from Bloomington through White Point, in San Patricio County, to a point about 6 miles west of Sarita. Faults may accompany the anticline, which is buried beneath Pleistocene formations and has only the faintest surface expression, produced by recent movements along it. An inspection of the profile of the surface between Sinton and Taft shows a gentle rise toward Taft to a crest about 3 miles west of that town. The difference in elevation is very small—only 10 feet—but when taken into consideration with the normal surface gradient, which is southeastward at the rate of about 2 feet to the mile, this rise east of Sinton is significant.

Between Corpus Christi and milepost 7 west the surface is practically level. Between mileposts 7 and 11 it rises 20 feet. There is an erosion channel at milepost 11. West of this locality there is a gentle descent toward the west. The rise between mileposts 7 and 11 may be merely a terrace scarp, though it may have some connection with the anticline.

The Guadalupe is intrenched below the level of terrace No. 2 (Beaumont terrace) at Victoria about 50 feet; at Bloomington, 15 miles downstream in a straight line, it is intrenched about 70 feet. This difference suggests uplift near Bloomington, which is in line with the trend of the White Point anticline.

There is a constriction in Nueces Bay between White Point and the mouth of the Nueces opposite. (See fig. 34.) The tongue-like projection at White Point is no doubt structural and is connected with the White Point anticline.

The occurrence of great numbers of *Ostrea virginica* and other Recent shells on the surface of the terrace at White Point, 35 to 40 feet above the bay, indicates a very recent uplift. This flat is now well above flood level.

Sulphur permeates the beds at White Point, forming small nodules, veinlets, and streaks, and similar deposits have been encountered in drilling.

Gas was discovered at White Point in November, 1914, in a well drilled by the White Point Oil & Gas Co., to a depth of 2,255 feet. The well blew out when the productive sand—probably the Oakville sandstone—was drilled into, releasing about 50,000,000 cubic feet of gas a day. (See Pl. II, *A*, p.12). The escaping gas excavated a huge crater about 100 feet across and 60 to 75 feet deep, which swallowed the derrick. A second well, drilled by the Gulf Production Co., reached the gas sand in February, 1916, at a depth of 2,170 feet and produced an even larger volume of gas. The well became unmanageable and was lost. A crater larger than the first one was excavated.

Gas has also been encountered at a depth of about 720 feet in the district 5 to 7 miles east of Kingsville, close to the axis of the White Point anticline, and more recently several gas wells and one small oil well, have been drilled about 3,000 feet in depth.

Another line of folds and faults known as the Sinton anticline (?) possibly parallels the White Point anticline on the west, but the evidence establishing it is not conclusive. This line apparently passes a little west of Sinton, through Calallen, to a point a little west of Robstown.

Another hypothetic zone of folds and faults, here called the Rockport anticline, extends from Nobles Point, on Lavaca Bay, through Long Mott, Rockport, Ingleside, and Flour Bluff, paralleling the course of the White Point anticline. It is less clearly outlined, however, than the Sinton anticline.

A line extending from La Parita Creek, about 7 miles north of Crowther, through McMullen County to a point about 10 miles west of the southeast corner of La Salle County marks the axis or crest of a monoclinal fold, the Crowther monocline, which is probably accompanied by some faults. In the northeastern part of McMullen County the dip changes from 35 feet to 68 feet to the mile. This fold marks the western limb of the large synclinal valley in which the Nueces flows across McMullen County, and it also marks the eastern limb of the La Salle uplift. The other limb of the synclinal valley is the western boundary of the Torrecillas uplift.

The oil well at Crowther, the gas well on the Byrne ranch (which has the peculiarity of erupting at regular intervals of about 10 hours), the gas well at Tilden, and other wells are probably on or near this monocline.

SALT DOMES.

GENERAL FEATURES.

Salt domes represent intrusions of massive saline cores into sedimentary formations. The intrusions have fractured the strata or have tilted them at high angles around the edges of the core, forming domes.

The domes in the Coast Prairies contain materials that are not found elsewhere on the Coastal Plain. These materials are all of secondary origin and have probably been deposited from solution. They include crystalline limestone (the so-called "cap rock" of the driller), sulphur, gypsum, and rock salt. They are generally covered by unconsolidated sediments belonging to one or more of the formations already described. In some places this cover is very thin; in others it is very thick—more than 1,000 feet thick.

The limestone is at many places dolomitic and at some it is entirely crystalline. The crystalline variety when stained by oil looks like maple sugar. At some localities it is dense. Both the dense and the crystalline limestone may be cavernous. The rock is more than 100 feet thick in places. The lime was probably derived from the highly calcareous rocks near or below the secondary limestone. Some of these calcareous beds are in their original condition—they are marl; others are consolidated, though they contain no crystalline calcite; still others are partly composed of redeposited material, so that between the original marl and the secondary limestone there are all possible gradations. These secondary materials usually occur in the domes in vertical order, from top to bottom, as unconsolidated sediment, porous limestone, gypsum, anhydrite, salt.

The position of the sulphur is variable, but it is most generally found in or near the limestone. Petroleum also is usually associated with the limestone, the overlying sediments, or the sand that lies below the level of the limestone, against a petroliferous shale that covers the salt core.

The salt cores in some of the domes of Anderson, Smith, and Freestone counties lie comparatively close to the surface, and these domes appear to contain no secondary limestone, gypsum, or sulphur.

Some of the salt domes, such as those in Anderson County, which are overlain unconformably by the Indio formation, began to form in very early Eocene time. Movements in some of them have continued until late Pleistocene time.

Many of the domes are buried beneath later formations, which lie unconformably upon them. Those in which no movements have occurred since the deposition of the overlying beds may have no surface expression whatever, although their presence may be indicated by seepages of oil or gas or the escape of sulphureted or other mineralized water in their immediate vicinity. Domes on which late movements have occurred may manifest themselves at the surface.

The origin of these domes is not yet determined. They are usually arranged along lines that lie parallel to the trend of the prominent structural features of the region. Their close relation to lines of faults and folds may be safely inferred, although such lines are not exposed at the surface. One theory assigns to them a volcanic origin, but no volcanic rocks have yet been discovered in association with them. Another and more likely theory ascribes them to ascent of hot, deep-seated saline waters along fault planes and lines of structural weakness, resulting in the

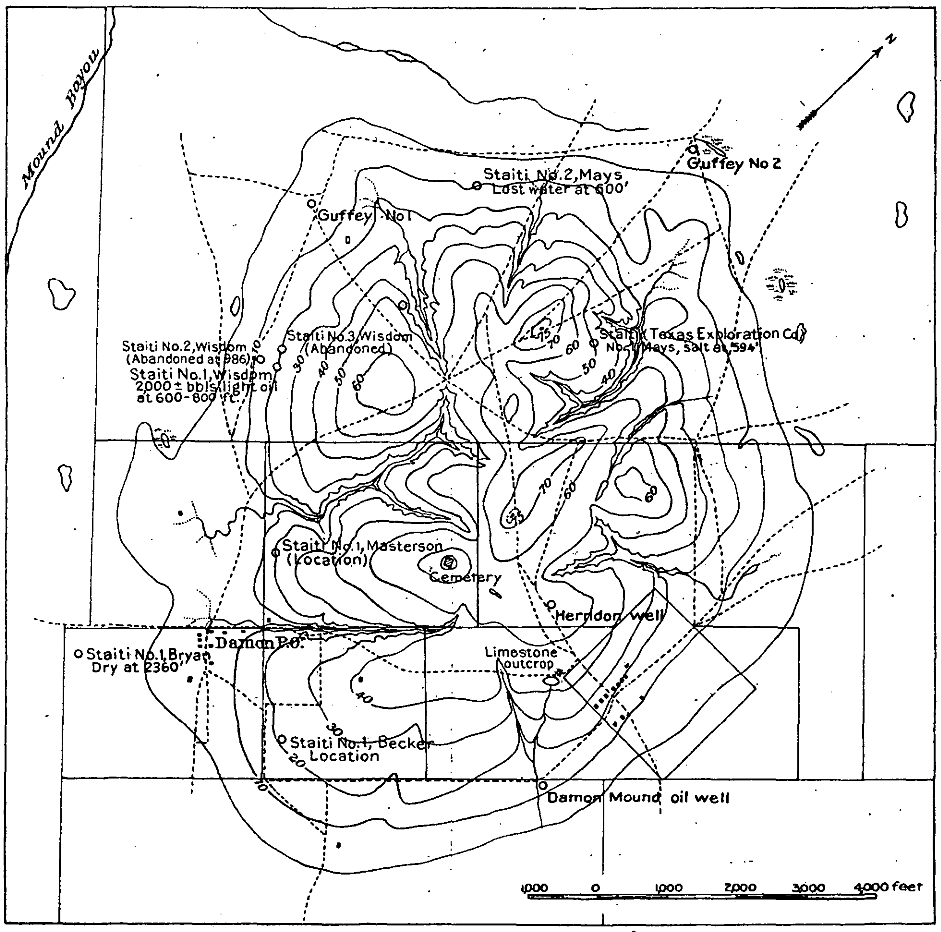


FIGURE 35.—Sketch contour map of Damon Mound, Brazoria County, Tex. (After Hayes and Kennedy.)

cooling of the waters and the precipitation of the salt, which forces the surrounding strata upward. According to another theory, the domes represent detached masses of salt floated or extruded vertically upward along lines and points of weakness from a widespread sheet of rock salt below.[82]

The domes of the Coast Prairie are usually regarded as favorable localities for obtaining oil or gas, and some of them serve as reservoirs for the accumulation of pools of oil.

The salt domes known in the area west of Brazos River include Damon Mound, Kiser Mound, and Bryan Heights, in Brazoria County; Big Creek Dome, in Fort Bend County; Markham and Big Hill, in Matagorda County; Boling Dome, in Wharton County; Brenham Dome, in Washington County; Piedras Pintas and Palangana, in Duval County; Falfurrias Dome, in Brooks County; and Sal Viejo, in Willacy County.

DAMON MOUND.[83]

Damon Mound is on the A. Darst league, in the western part of Brazoria County, about 11 miles northwest of Columbia. It rises 83 feet above the surrounding prairie) about 140 feet above sea level) and is thus a conspicuous feature in the local topography, being visible for a distance of 15 miles or more. It covers about 3,000 acres and has a somewhat regular oval outline. Its longer axis trends northeastward. (See fig. 35.)

The greater part of the hill is covered with blue and red clay. Brown sandy clay and shaly clay appear at the surface on the western slope. These beds probably belong to the Beaumont clay, though they may be older. Several small veins of sulphur, probably deposited by escaping gas, fill cavities in the sandy clay, and sulphur in the form of crystals is scattered through the clay. The sandy clay and the inclosed sulphur is locally called "sour dirt."

A well at Damon post office yields salty water. Wells on the southwestern edge of the mound, near the old town of Damon, yield fresh water.

A bed of soft grayish-white limestone is exposed on San Bernard River about 8 miles northwest of Damon Mound. This bed dips toward the mound at the rate of about 33 feet to the mile. Limestone, probably of secondary origin, was passed through in the Herndon well at depths of 142 to 146 feet, in the Guffey well No. 1 at 644 to 663 feet, and in the well of the Damon Mound Oil & Pipe Line Co. at 260 to 330 feet.

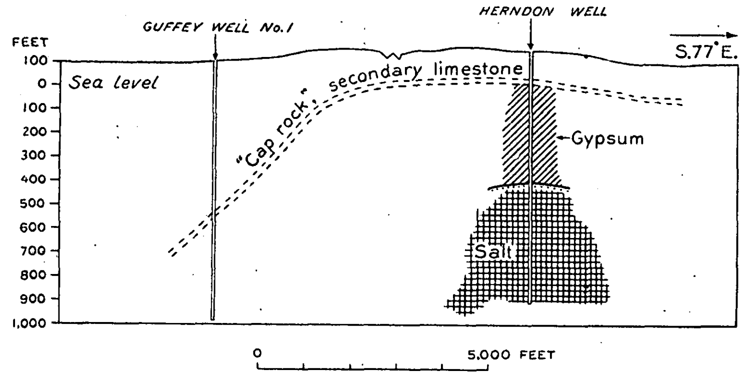


FIGURE 36.—Section across Damon Mound, Brazoria County, Tex.

On the northwest side of the mound the dip of the secondary limestone is northwestward at the rate of about 950 feet to the mile. On the southeast side the dip is southeastward. (See fig. 36.)

At a variable distance below the limestone the salt core is encountered. This core is overlain in places by beds of sulphur and gypsum.

According to Hayes and Kennedy,[84] the Herndon well struck salt at a depth of 573 feet and

[82] Van der Gracht, W. A. I. M., The saline domes of northwestern Europe: Am. Assoc. Petroleum Geologists Bull., vol. 1, pp. 85-92, 1917. Rogers, G. S., Intrusive origin of the Gulf Coast salt domes: Econ. Geology, vol. 13, pp. 447-485, 1918.

[83] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, pp. 35-42, 1903. Hager, Lee, The mounds of the southern oil fields: Eng. and Min. Jour., vol. 78, p. 138, 1904. Fenneman, N. M., Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 282, pp. 89-91, 1906. Harris, G. D., Oil and gas in Louisiana with a brief summary of their occurrence in adjacent States: U. S. Geol. Survey Bull. 429, p. 16, 1910. Deussen, Alexander, Review of developments in the Gulf Coast country in 1917: Am. Assoc. Petroleum Geologists Bull., vol. 2, pp. 23-27, 1918.

[84] Hayes, C. W., and Kennedy, William, Oil fields of the Texas-Louisiana Gulf Coastal Plain: U. S. Geol. Survey Bull. 212, p. 37, 1903.

continued in that material to the bottom of the well, at a depth of 1,160 feet; well No. 1 of the J. M. Guffey Petroleum Co. failed to find salt, although the drill reached a depth of 1,097 feet; and the well of the Damon Mound Oil & Pipe Line Co. also failed to find salt down to a depth of 1,230 feet.

Active exploration of the Damon Mound in search of oil was resumed in 1915, after a lapse of 12 years. The Texas Exploration Co. (H. T. Staiti and others) completed Wisdom well No. 1 in 1915. It is in the northeast corner of block 5 of the B. H. Wisdom subdivision, near the foot of the mound, on its west side. At depths between 600 and 800 feet the drill struck a porous rock, which yielded at first about 1,200 barrels of oil of a specific gravity of 40° Baumé. The drill entered salt at 1,000 feet and extended into it for 1,000 feet without reaching its lower limit.

The Texas Exploration Co.'s well No. 2, Wisdom, a short distance southwest of No. 1, was abandoned as a dry hole at 986 feet. The company's well No. 1, Bryan, was abandoned at 2,360 feet. It is on the plain at the foot of the mound, on the south side. In well No. 2, Mays, about 2,100 feet northeast of Guffey well No. 1, return water was lost at 600 feet. In well No. 1, Mays, a mile east of Guffey No. 1, on top of the hill, salt was entered at 594 feet.

WEST COLUMBIA DOME.[85]

West Columbia Dome is 3 miles northwest of Columbia, Brazoria County, just west of Brazos River and about 12 miles southeast of Damon. It is more or less irregular in outline and rises 30 feet above the level of the surrounding country or 60 to 65 feet above the sea. The material covering the adjacent plain is a brown sand or sandy loam, probably mostly Recent alluvium. The surface of the hill contains much more clay. A minor fold is visible at the surface.

Oil-bearing rock, probably limestone, was encountered in well No. 1 of the Equitable Mining Co. (see Pl. XXXVI) at a depth of 500 feet. Some oil and gas were encountered below this depth, but nothing of commercial value. The well was drilled to a depth of 680 feet, the upper 498 feet of which represents the Beaumont clay and Lissie(?) gravel.

In well No. 2 of the same company a highly porous limestone was taken from a depth of 364 feet. Limestone alternating with sandstone and blue clay was found for some distance below. Sulphur occurs at various depths, generally in the form of small crystals. The well was sunk to a depth of 490 feet without striking salt.

In Arnold well No. 3 of Sinclair and Crosby a little gas and oil were found but nothing of importance. The well reached a depth of 1,214 feet.

Oil in commercial quantity was found in this region late in 1917, when the Tyndall-Wyoming Oil & Development Co. completed a 200-barrel well. Since this time much oil has been produced from this locality, and in August, 1923, West Columbia was one of the most productive fields in the Gulf Coast district.

BRYAN HEIGHTS.[86]

The Bryan Heights dome is in Brazoria County, 3 miles south of Velasco, a little more than a mile from the Gulf coast. It includes an area of 300 acres and rises 30 feet above tide or 19 feet above the surrounding plain.

Seeps of asphalt in small quantities have been known here for many years. Jetlike or asphaltic "sea wax" was frequently picked up on the shore many years before the Spindletop pool was discovered.

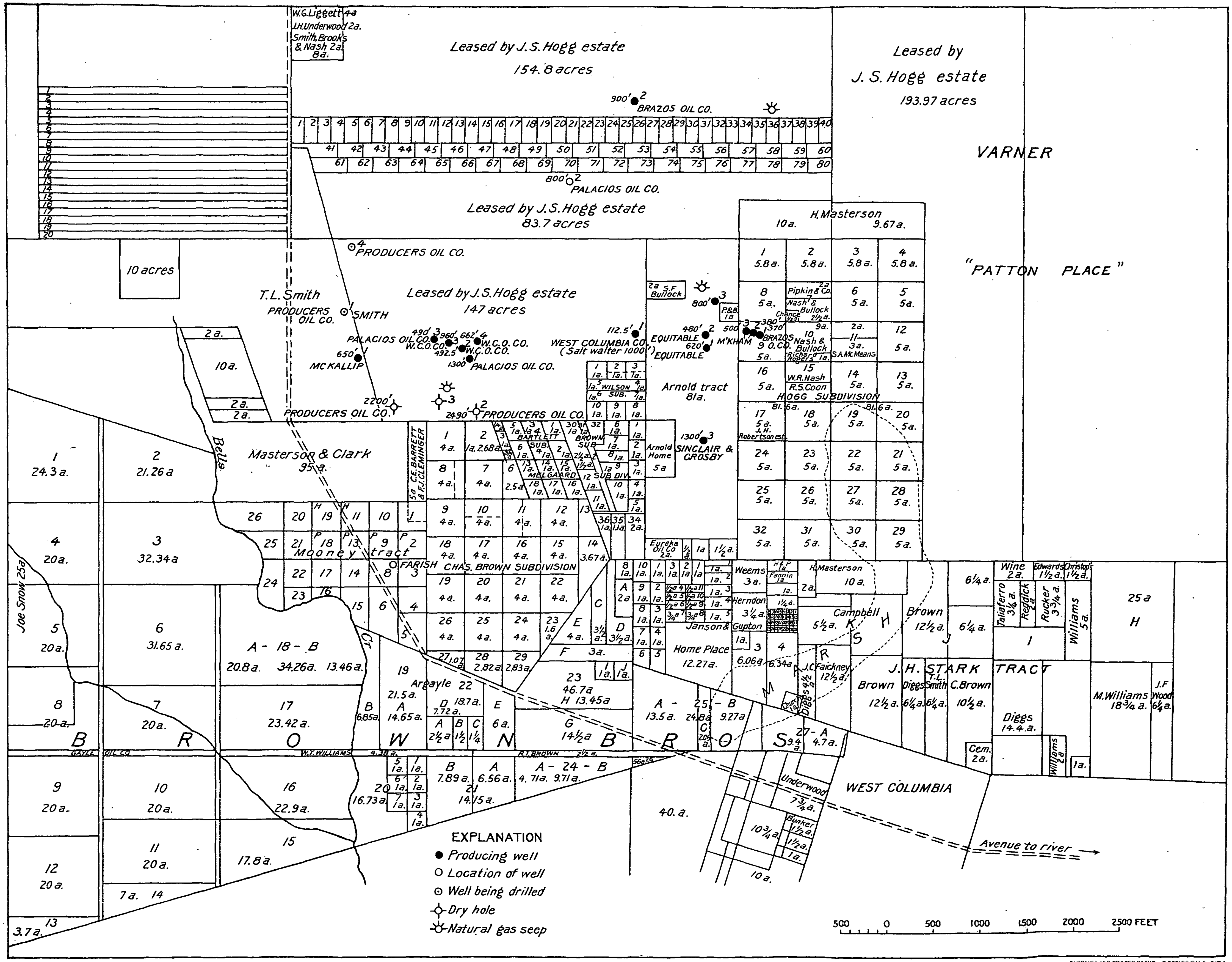
Seven wells were drilled before the autumn of 1904. One of these wells struck gas in large volume, its initial production having been about 6,000,000 cubic feet. The chief constituent of the gas was hydrogen sulphide. Several wells on the hill obtained flows of water between 450 and 500 feet.

The formations passed through in drilling were largely clay, but sand, gravel, and limestone were found in places. A gypsiferous white marl and a crystalline limestone of a yellow sugary appearance, similar to the Spindletop "cap rock" and soaked with oil, was also encountered. Sulphur is mentioned as occurring at or below the oil horizon, and gypsum is said to have been found below that depth.

The Home well yields small quantities of a strong sulphur salt water from an unknown

[85] Hayes, C. W., and Kennedy, William, op. cit., p. 125. Hager, Lee, op. cit., p. 138. Fenneman, N. M., op. cit., p. 88. Oil Investors Jour., February 18, 1907, p. 5; March 5, 1907, p. 17; May 19, 1907, p. 3. Harris, G. D., op. cit., p. 20. Barton, D. C., The West Columbia oil field, Brazoria County, Tex.: Am. Assoc. Petroleum Geologists Bull., vol. 5, pp. 212-251, 1921.

[86] Hayes, C. W., and Kennedy, William, op. cit., p. 127. Fenneman, N. M., op. cit., p. 87. Harris, G. D., op. cit., p. 14.



MAP OF WEST COLUMBIA OIL FIELD, BRAZORIA COUNTY, TEXAS depth. Most of the water from wells on the hill is as fresh as from those of the surrounding plain. The artesian well at Velasco is 1,060 feet deep, and the water is accompanied by gas sufficient to burn at the mouth of the well.

No oil in commercial quantities has thus far been found. The sulphur deposits are extensively worked by the Freeport Sulphur Co.

MARKHAM DOME.[87]

The Markham dome is 6 miles northwest of Markham station, in Matagorda County. It is a low, rounded hill that rises only a short distance above the level of the surrounding plain. Its axis trends northeast.

Oil was discovered by wells drilled in this dome in June, 1908. Since then 66 or more producing wells have been drilled. Oil was first found in sandy strata in shale between 1,306 and 1,370 feet. Some of the wells reached a depth of 1,900 feet. The drilling reveals the presence of a very thick clay cover above the secondary dome materials.

In the Hardy Oil Co.'s well No. 32 oil was found in "rock" from 1,262 to 1,293 feet. In well No. 28 of this company oil occurs in the same "rock" from 1,310 to 1,327 feet. This rock is probably the secondary limestone or "cap rock." The "gumbo" and shale immediately above the "cap rock" belong probably to the Lagarto formation. The "gumbo" and sand in the upper 300 or 400 feet belong probably to the Beaumont clay.

In the Hardy Oil Co.'s well No. 32 the "cap rock" was struck at 1,293 feet; the shale and gumbo above belong to the Lagarto formation, except the uppermost 300 to 400 feet, which belongs to the Beaumont clay. Initial production of oil, 1,000 barrels.

In the Producers Oil Co. well No. 1 salt was struck at 2,923 feet and was drilled into to 3,003 feet. Crystallized gypsum was found just above the salt.

BIG HILL.[88]

Big Hill is in Matagorda County, a few miles from the mouth of Colorado River, about 5 miles northeast of Matagorda village. It lies 1 mile inland from the shore of Matagorda Bay and rises 36 feet above sea level and 12 to 15 feet above the level of the surrounding plain. It is a well-defined symmetrical flat-topped dome that embraces perhaps 100 acres at its highest level. The entire area of uplift, however, is several times that size.

The first well drilled here, about 1902, encountered a 5,000,000-foot flow of gas, largely hydrogen sulphide, at a depth of 900 feet. Considerable development work was done in 1903 and 1904, the production of oil in 1904 amounting to 80,591 barrels. In December of that year salt water invaded the field, and in 1908 the production had declined to 2,000 barrels.

The drillings show that the sedimentary beds above the oil consist chiefly of clay but that

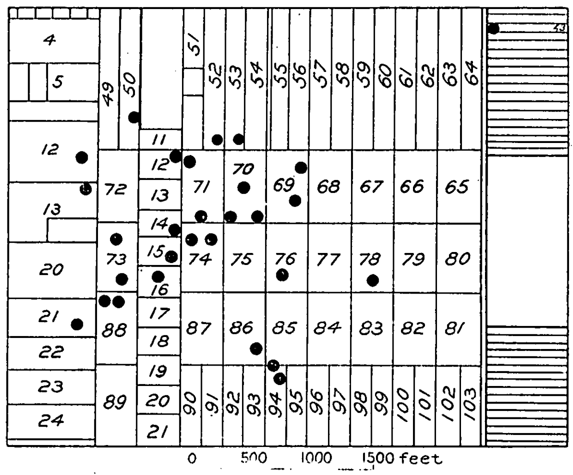


FIGURE 37.—Map of Big Hill oil field, Matagorda County, Tex.

they include sand and thin beds of "rock," limestone in some places and calcareous sandstone in others. Most of the beds carry pyrite, which is more abundant near the oil sand, generally just above it.

At depths ranging from 844 to 1,035 feet the characteristic secondary limestone or "cap rock" is encountered. Some specimens obtained are entirely crystalline limestone; others are highly porous or cavernous. In some wells the limestone is more than 100 feet thick. The cavernous parts were saturated with oil; the denser parts were free from oil but contained gas.

Sulphur is reported from a number of wells at or near the horizon of the oil. It replaces portions of the limestone.

In Lane well No. 1, block 71 (see fig. 37), the porous limestone or "gas rock" was found

[87] Oil Investors Jour., June 19, 1908, p. 1; July 6, 1908, p. 20; February 6, 1909, p. 22. Harris, G. D., Oil and gas in Louisiana, with a brief summary of their occurrence in adjacent States: U. S. Geol. Survey Bull. 429, pp. 20-21, 1910.

[88] Hayes, C. W., and Kennedy, William, op. cit., p. 127. Oil Investors Jour., April 15, 1904, p. 1; January 19, 1908, p. 12. Eng. and Min. Jour., July 28, 1904, p. 138. Fenneman, N. M., op. cit., pp. 63-67. Harris, G. D., op. cit., p. 21.

at 1,035 feet. It contained a large quantity of sulphur. Beneath the limestone the drill struck a marl, which it penetrated to a depth of 1,360 feet.

The "cap rock" or limestone was struck at the following depths in the different wells: Dean, block 12, west side, 844 feet; Griffith 2, block 16, 850 feet; Griffith 1, block 14, 852 feet; Lane 2, block 71, 856 feet; Higgins, block 52, 865 feet; Johnson, block 71, south part, 870 feet; Santa Fe 2, block 76, 855 feet; and Lane 1, block 78, 1,035 feet.

The depths indicate that the part of the limestone explored has the form of a half dome, the highest part of which is at the middle of the west side of the field. (See fig. 38.)

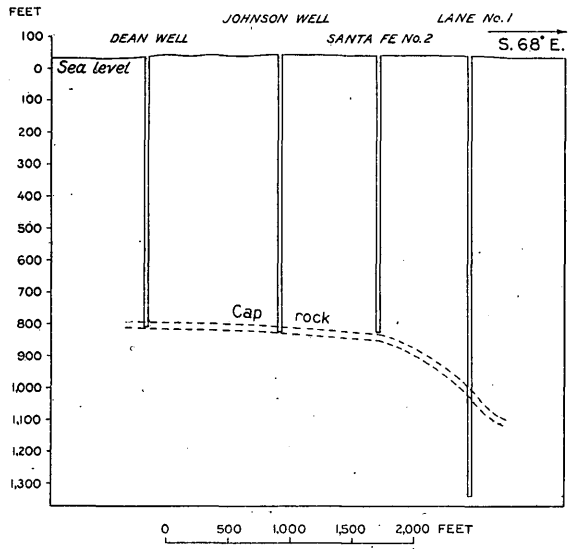


FIGURE 38.—Section from northwest to southeast across Big Hill, Matagorda County, Tex.

Its dip toward the northeast is at least 26 feet in the 500 feet between the Lane well and the Johnson well. The corresponding dip to the southeast is 28 feet to the southern border of the field, 2,000 feet distant. The dip along the eastern edge of the mound is very steep. The limestone probably occupies an area but little greater than that of the surficial hill.

BIG CREEK DOME.[89]

The Big Creek dome is in Fort Bend County, on the Wheat ranch, 8 miles south of Richmond. It was discovered in April, 1922, when the Gulf Production Co. drilled its No. 1 Wheat into cap rock at 600 feet and into rock salt at 715 feet.

Five or six wells have been drilled since the date of this discovery, which have succeeded in outlining fairly well the limits of the dome.

BOLING DOME.

The Boling dome is on the Stephen F. Austin league, on San Bernard River, near the station of Boling, about 14 miles east of Wharton, in Wharton County.

This dome was discovered in August, 1923, when the Gulf Production Co. drilled its No. 1 M. L. Co. well into cap rock, containing oil, at about 500 feet.

Miss Laura Lee Lane gives a report on a sample from a depth of 300 to 360 feet in this well as follows:

> Green calcareous clay streaked with white lime. Washed material contains gray sand ranging from fine to fairly coarse; clear quartz predominating, but 2 per cent varicolored (smoky, yellow, and green); 3 per cent pyrite and chalcopyrite (nodular and crystalline form); fragments of white lime nodules, sandstone, clay, shells, and crystals of calcite and aragonite. A fauna of reworked foraminifera abundant, including *Trochammina*, *Globigerina*, *Textularia*, *Anomalina*, and *Rhabdammina?* sp.
>
> Considering the lithologic and faunal evidence, the age of the material is obviously Fleming.

It is worthy of note that Lagarto (Fleming) beds at a depth of 300 feet at this locality indicate domal or structural conditions.

BRENHAM DOME.

The Brenham dome is near the south line of the Samuel L. Williams league, about midway between Mill Creek and Williams Creek, close to the boundary line of Austin and Washington counties, about 7¾ miles southwest of Brenham.

Small quantities of oil had been observed in water wells for many years, and these observations led to the drilling of the original well in 1915. So far no oil in commercial quantity has been found. The Brenham Oil Co's. well No. 2, Schuerenberg, 600 feet southwest of the first well, pumps 8 to 10 barrels a day of dark-green oil testing 40° Baumé. This well is 1,352 feet deep. The drill stopped in 15 feet of "pay" sand of fine texture and white color.

This dome is on the Washington prairies and is apparently marked at the surface by the arrangement of the local drainageways. The surface in its vicinity is rolling. The surface formation here is the Lagarto clay. Below this clay lie the Oakville, Fayette, and Yegua formations.

[89] Pratt, W. E., A new Gulf Coast salt dome: Am. Assoc. Petroleum Geologists Bull., vol. 6, pp. 252-254, 1922; Deussen, Alexander, Oil development in Gulf Coast fields during 1922: Am. Inst. Min. Eng. Trans., No. 1241-P, pp. 26-28, 1923.

In the Brenham Oil Co.'s well No. 1, Schuerenberg, Cook Mountain fossils (see p. 64) were found between 1,275 and 1,360 feet (probably at 1,320 feet), indicating that the upper part of the Cook Mountain formation was entered. In the Gulf Production Co.'s well No. 1, Thielman, greensand marl of the Cook Mountain formation was struck at 1,600 feet, and in this marl *Pleurotoma reticulata* and *Pleurotoma biconica* (identified by C. L. Baker) were found. In the Brenham Oil & Gas Co.'s well No. 4, Schuerenberg, anhydrite was struck at 1,124 feet and drilled into to 1,383 feet. This same material was encountered also in the Gulf Production Co.'s well No. 1, Schuerenberg.

Here a salt core has evidently uplifted the Cook Mountain beds. The anhydrite lies on top of the salt core and may send out tongues that penetrate the adjacent formations. The oil appears to lie in sandstone that abuts against or stands close to the core and that has been tilted and probably fractured by the intrusion.

Gas was found in the Gulf Production Co.'s well on the Thielman tract, and some distance below it strong sulphur water was struck.

The limits of the salt core have not yet been defined to the west or southwest.

This dome is on a line with the Steen dome, east of Lindale, and the Brooks dome, west of Bullard, in Smith County; with the Keechi dome, northwest of Palestine, and the Anderson dome, west of Palestine, in Anderson County; and with the Butler dome, southeast of Butler, in Freestone County. This line parallels the Balcones fault.

PIEDRAS PINTAS (NOLEDA) DOME.

There is a dome at Piedras Pintas, about 2 miles northeast of Benavides, in Duval County, represented at the surface by a sublevel plain drained by Piedras Pintas Creek. The surface formation there is the Reynosa. The center of the dome is marked by an outcrop of blue quartzitic sandstone, which is exposed in a quarry about a mile north of the railway station. The sandstone contains 92.14 per cent of silica, 1.52 per cent of lime, 1.07 per cent of alumina, and 2.89 per cent of iron oxide. It resembles the Fayette sandstone but may belong to the Oakville.

The first well drilled here, in 1907, found a small quantity of oil. Several wells have been drilled since then, but none of them has found oil in large quantity. The wells are about 550 feet deep. Their logs show mostly clay and shale above the oil rock, which is apparently a secondary limestone or typical "cap rock." Pyrite occurs not far above the oil rock; below it gypsum and hard rock are reported.

Peters well No. 1 was drilled to a depth of 2,791 feet about a mile southeast of the shallow well district. It encountered no gypsum, salt, or "cap rock," though it found some oil. This locality is apparently off the dome, which lies to the northwest, but the showings of oil would seem to indicate that the beds abut against the salt nucleus at a fairly high angle.

PALANGANA DOME.[90]

The Palangana dome is in Duval County, 6 miles north of Benavides and 4 miles north-northwest of Piedras Pintas dome.

This dome was discovered in 1919, when the Sinclair Oil & Gas Co. drilled into rock salt at a depth of 845 feet in its well No. 1, Schallert.

Since this discovery several additional wells, which have been drilled, have defined to a certain extent the limits of the salt. Thus far no oil in commercial quantity has been found in association with this dome.

FALFURRIAS DOME.

The Falfurrias dome is on the Lasseter ranch, south of Falfurrias, at Laguna Salada, in Brooks County. Gypsum crops out at the surface. Wells drilled here entered gypsum a short distance below the surface and continued in it for 600 or 700 feet. No oil was found.

[90] Barton, D. C., The Palangana salt dome, Duval County, Tex.: Econ. Geology, vol. 15, pp. 497-510, 1920.

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