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THE GEOLOGY OF EAST TEXAS

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

Sam Houston

Cultivated mind is the guardian genius of democracy . . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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PREFACE.

The great importance of the Tertiary beds of southeastern Texas from an economic point of view is now beginning to be realized and appreciated. During the existence of the Geological Survey of Texas, 1888 to 1894, the prevailing opinion of the people of eastern Texas was that geological work might benefit western Texas but could be of little assistance to them, and this opinion had much to do with the opposition that led to the discontinuance of the survey. The passing years, however, have shown the erroneous nature of this idea and have proved something of the true value of the mineral resources of the beds underlying the region. In them is stored, in the form of beds of lignite, a vast amount of material which must be our hope for fuel throughout the coast country after the present oil supply has been depleted. Associated with them are deposits of iron ores which, probably, are only second in quantity to those of the Great Lakes Region and are the equal in quality of any brown ores found anywhere. The accumulations of oil that, beginning with the Lucas well at Spindletop, have been found by the drill and have played an important part in the development of this region, are all within their sediments. The domes of the Coastal region are an integral part of them and contain possibly as large an amount of salt as is known within a like area in the world. From the known extent and thickness of beds as proved by drilling it has been estimated that there is here at least one ton of salt for every inhabitant of the earth's surface. These domes also hold a vast amount of sulphur and they are today supplying more than 90 per cent of the sulphur produced in the United States. There are also numerous other substances of value within these formations.

With this potential wealth of mineral resources now only partially developed it is essential that a careful study be made of the deposits in order that every assistance possible may be given to the development of the area.

The Geological Department of the Southern Pacific Lines in Texas and Louisiana, in the course of its work on the oil conditions and mineral resources of the territory tributary to its lines in southeastern Texas, has made detailed investigations of a portion of the area and the general results are deemed of sufficient interest to warrant publication.

Upon the request of Prof. J. A. Udden, Director of the Bureau of Economic Geology of the University of Texas, the matter of such publication was taken up with the President of the Southern Pacific Lines in Texas and Louisiana, Mr. W. B. Scott, and the Chairman of the Executive Committee of the Southern Pacific Company, Mr. J. Kruttschnitt. The request met with their approval and the accompanying "Report on the Geology of East Texas" has been prepared as a contribution from the Southern Pacific to the increase of knowledge of the region.

To assist in the development of this region and that lying south of it, it seemed best to give briefly the character of all underlying beds, to combine with the reports of the geologists working under the writer the observations of other workers in the same field and the broader results of his own personal investigations, and to add his interpretation of them, in order that a full resume of our present knowledge of the geology and mineral resources might be available to those who may desire such information for the direction of future exploration and drilling. By treating the subject in this way the writer has gone somewhat further into the matter than was at first contemplated.

The personnel of the Geological Department of the Southern Pacific Lines, whose work has contributed to this report, is as follows:

E. T. Dumble, Consulting Geologist....1897–1918.
W. F. Cummins, Geologist...........1902–1918.
W. Kennedy, Assistant Geologist......1902-1916.
Lee Hager, Assistant Geologist........1903-1904.
L. P. Garrett, Assistant Geologist......1903-1908.
C. L. Baker, Assistant Geologist.......1912-1913.
J. R. Suman, Assistant Geologist......1912-1917.
J. W. Bostick, Assistant Geologist......1916–1918.
W. W. Kelley, Assistant Geologist..........1917.

E. T. D.

THE GEOLOGY OF EAST TEXAS

By E. T. Dumble, Consulting Geologist,
Southern Pacific Company.

Chapter I

INTRODUCTION

The special area covered by this report[1] is a strip of country over 100 miles in width lying between parallels of 30° 30′ and 32° and extending from the Sabine to the Brazos or the line of the Houston & Texas Central Railway.

The mapped area includes, in whole or in part, the following counties:

Anderson	Leon	Robertson
Angelina	Limestone	Rusk
Brazos	Madison	Sabine
Cherokee	Montgomery	San Augustine
Freestone	Nacogdoches	Shelby
Grimes	Navarro	Trinity
Houston	Newton	Tyler
Hardin	Panola	Walker
Jasper	Polk	

A proper presentation of its geological features, however, involves a consideration of a more extended region. Consequently, the report embraces more or less detail of a very considerable portion of Texas and parts of Louisiana and Arkansas.

THE REGION

The region is a part of the Gulf Coastal Plain. This plain is composed of sediments laid down in former extensions of what are now the waters of the Gulf of Mexico, and began with the submergence at the commencement of the Cretaceous. These deposits required longer or shorter periods for their accumulation and alternated with periods in which there was little or no deposition and others when parts of the deposits already laid down were carried away through erosive agencies and redis-

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[1]Mss. of this report was submitted Aug. 10, 1918, published Feb. 1920.

tributed over the land or deposited in bodies of fresh water. This was brought about by the fluctuations of the levels of the land surface as compared with those of the waters of the Gulf. Deposition continued intermittently through the Cretaceous and Tertiary to the present, with but few interruptions of major importance.

Our present land surface is due to the gradual recession of the strand line of the Gulf, and the Plain itself does not even now terminate at the water's margin, but stretches outward to the one hundred fathom line of sea depth. That this is its true structural limit is shown by the fact that beyond this line the bottom of the sea slopes downward with great rapidity.

For the most part the sediments forming this plain in eastern Texas are in beds of rather loosely compacted materials which as a whole slope gently toward the Gulf. Thus, as we travel coastward, we come upon successively later and later formations, the surface exposures of which form a series of belts of varying width roughly paralleling the present shoreline.

As the waters slowly receded from these various formations and they were exposed as land surfaces they were seized upon by erosive agencies and gradually sculptured into their present topographic forms.

The alternations of broad bands of clays and sands with other bands of more compact sandstones and clays which extend westward from the Sabine are reflected in the topography by belts of comparatively level country bounded to the south by lines of hills more or less abrupt on their northern faces and dipping southward with a gentle slope to the succeeding plain.

These belts are in turn dissected by the many streams crossing them and this results in a hilly or gently rolling country. Practically all the elevations are directly due to erosion, and earth movements have had little effect on the present surficial aspect of the region.

While there is comparatively little evidence at the surface today to show the effects of orogenic action we do find unmistakable evidence that there were at least three periods in which earth movements of considerable extent affected this area and that two of these were accompanied by active volcanic eruptions.

Of these movements one began toward the close of the Austin

Chalk deposition, a second is known in connection with the upper Eocene and the third occurred during or at the close of the Upper Pliocene.

The effects of these movements are often masked by the level-lying succeeding deposits. Only a few of the volcanic necks of the Cretaceous are known and those of the Eocene are as yet undiscovered, although the ejectae which form so large a·portion of the upper Eocene and Oligocene deposits indicate that they may have been within our own borders.

The area of our report includes only a portion of the Tertiary deposits of this great plain.

LITERATURE

There have been published numerous reports and papers, some not now accessible to the general public, which treat to some extent of the geology of this region. Reviews of earlier publications have been given by Hill[1], Penrose[2], Dumble[3], Veatch[4], Deussen[5], and others

Among the publications of special interest as descriptive of this area and of the same formations in contiguous territory the following may be mentioned:

The existence of lignite and iron in this region was referred to by several of the early voyagers, and in 1839 Dr. J. L. Riddell published in the American Journal of Science a description of the lignite beds on the Trinity below Hall's Bluff.

B. F. Shumard in his First Report of Progress[6] gives briefly

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[1]Hill, R. T., Present Condition of Knowledge of the Geology of Texas. Bull. U. S. Geol. Sur. No. 45, 1887.

[2]Penrose, R. A. F., First Ann. Rep. Geol. Sur. Tex. 1889.

[3]Dumble, E. T., Iron Ore Districts of East Texas. Second Ann. Rep. Geol. Sur. Tex. 1890. Report on Brown Coal and Lignite, 1892. Problem of the Texas Tertiary Sands, Bull. Geol. Soc. Am. Vol. 26, pp. 447-476, 1915.

[4]Veatch, A. C., Geology and Underground Water Resources of Northern Louisiana and Southern Arkansas. U. S. Geol. Survey Prof. Paper No. 46, 1906.

[5]Deussen, Alex. Geology and Underground Water-Supply of Southeastern Texas. Water-Supply Paper No. 335.

[6]First Report of Progress of the Geological & Agricultural Survey of Texas, 1859.

the results of his reconnaissance of the region. He made two general sections. The first began at Sour Lake and passed through Hardin, Tyler, Jasper, Sabine, San Augustine, Nacogdoches and Rusk counties to Marshall in Harrison county. The second was from Henderson in Rusk county through Cherokee, Anderson, Freestone and Limestone counties to Waco. In this report he calls particular attention to the deposits of brown coal or lignite and iron ores and to the occurrence of petroleum at Sour Lake.

Buckley[7], in his Preliminary Report, gives some details of these and in his First Annual Report goes more into particulars regarding the various deposits of iron ores and lignites in several counties and the petroleum near Melrose in Nacogdoches county. He also mentions the oil seep in the Gulf near Sabine Pass and the oil at Sour Lake.

In his Second Annual Report Buckley also refers to the lignites of this area.

Loughridge gives a very concise statement of the geology of this region in his Report of Cotton Production in Texas in Reports of the Tenth Census.

The first publications to deal particularly with this area were those of Penrose in the First Report of Progress and First Annual Report of the Geological Survey of Texas. In these the broader features were mapped out clearly and a beginning was made in the work of securing detailed geological knowledge of East Texas. The general geologic section is given together with descriptions and analyses of the different deposits of iron, lignites, marl, oil, salt, etc.

In the Second Annual Report of the Geological Survey of Texas the work so well begun by Penrose is continued and expanded. Under the general title Report on the Iron Ore Districts of East Texas there appears as comprehensive a statement of the general geology and mineral resources as was possible under the conditions existing at that time. In the Introduction

[7]Preliminary Report of the Geological & Agricultural Survey of Texas, 1866.

First Annual Report of the Geological & Agricultural Survey of Texas, 1874.

Dumble gives an historical sketch of the iron industry of East Texas, a general statement regarding the topography of the iron ore districts, an adaptation of the geology as given by Penrose and his conclusions regarding the character and mode of occurrence of iron ores. The possible fuels and their utilization are briefly treated by Birkenbine and Lerch, followed by a description of the counties where workable iron ores were thought to occur. These reports on counties gave what details of geology were obtainable but were mainly devoted to a description of the location, character and quality of the iron ores and other economic minerals. Kennedy reported on Cass, Marion, Harrison, Gregg, Morris, Wood, Upshur, Van Zandt and Henderson counties; Herndon on Smith county; Walker on Panola, Shelby, Rusk, Nacogdoches and Cherokee counties, and Dumble on Anderson and Houston counties. Accompanying the report was a map which showed the general distribution of the ores.

In the Third Annual Report, published during the following year, Kennedy makes a special report on Houston county, and gives quite fully the general geological features and mineral resources so far as they were understood or could be determined at that time. Our later studies enable us to better classify some of the formations described by him but otherwise the report needs little change.

This report is followed by a description of a general section made from Terrel to the Gulf directly across our region. This section has been the basis of much of our later work. In this description the Timber Belt beds of Penrose are divided into two members called the Lignitic and Marine and the latter is subdivided into the basal or Mt. Selman and the upper or Cook's Mountain. Similarly the Fayette beds of Penrose are separated into three members.

He defines the Lufkin or Angelina county deposits, later found to be the same as those described as the Yegua, the age of which was definitely fixed by the accompanying fossils. He describes the sands around Corrigan and correlates them with those called Fayette because of certain fossils found near them. He also describes the overlying clays which form so large a portion of the surface of the area mapped and gave them the name Fleming.

In the Report on Brown Coal and Lignite Dumble maps and describes the lignite deposits of this area.

In the Fourth Annual Report Kennedy makes a report on the geology of Robertson and Grimes counties and gives a general description of the various formations. Later discoveries of fossils necessitate some change in the references of these beds.

During the fifth year of the work of the Geological Survey Harris was employed in the study of the large collections of Tertiary fossils which had been brought in by the members of the survey. The paper he prepared for publication in the Fifth Annual Report described and figured all of these forms. The drawings for this report were beautifully done and the plates made from them were very fine. Unfortunately, the State did not publish the report nor any other portion of the Fifth Annual. Harris then selected the forms that were new and published them in the Proceedings of the Academy of Natural Sciences of Philadelphia[8]. A paper on the fossils from the Deep Well at Galveston was published in the Bulletin of American Paleontology and in the same publication he has since described and figured the marine fauna of the Midway and Wilcox formations of the entire Coastal Plain, with which he has included all forms belonging to these two formations found in our Texas region prior to publication. A similar report on the Claiborne fauna is now in process of publication.

Kennedy in a paper, Iron Ores of East Texas[9], brings together a good description of the iron ores of East Texas with many analyses taken from the reports of the Survey.

He also published a paper entitled The Eocene Tertiary of Texas East of the Brazos River[10], in which he gives a more detailed account of the beds with sections and lists of fossils and a resume of the history as he interprets it.

Hayes and Kennedy, in Oil Fields of the Texas-Louisiana Coastal Plain[11], furnish a map showing distribution of the Tertiary in southeast Texas and general statement of the geology followed by details of the coastal oil fields.

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[8]Proc. Phil. Ac. 1895.

[9]Trans. Am. Inst. Min. Eng., 1894.

[10]Proc. Acad. Nat. Sc. Phila. 1895.

[11]Bulletin U. S. G. S. 212.

In United States Geological Survey Bulletin No. 260 Fenneman covers some of the same ground.

In the publications of the University of Texas Mineral Survey Phillips has a Bulletin which gives analyses and microscopic studies of the Coastal Oil, and another on Coal, Lignite and Asphalt Rocks, to which Brooks and B. F. Hill contributed a portion of the descriptive matter and Harper a valuable chapter on the analyses of Texas asphalts.

Simonds in his list of Mineral Localities of Texas brings together the reported localities of all East Texas minerals.

Ries, in Clays of Texas[12], describes a number of the clays found in this region and gives analyses of them.

Phillips, in connection with Worrell and Drury McN. Phillips, published as a Bulletin of the Bureau of Economic Geology "The Composition of Texas Coals and Lignites" and the use of Producer Gas in Texas, which should be of value in future utilization of the lignites of East Texas.

Harris, in his work as State Geologist of Louisiana, was assisted by Veatch, who was studying the artesian water conditions of Louisiana and Arkansas. The examinations were extended into parts of East Texas and among the fossils collected at the locality four miles north of Corrigan and at one or two other localities between that point and the Sabine, as well as on that river, species were found which indicated the Jackson or Upper Eocene age of the beds. This was announced by Harris[13] with other results of these examinations. Veatch[14] later also described the occurrences. To the Corrigan sands of Kennedy he applied the name Catahoula and correlated them with the "typical Grand Gulf" which immediately overlies the Vicksburg and is of Oligocene age. He also refers the Fleming beds to the Oligocene.

Deussen embodies the results of his examination of this region in his report "Geology and Underground Water-Supply of Southeastern Texas"[15].

From this report and the geological maps accompanying it, his

[12]University of Texas Bulletin 102.

[13]Geol. Sur. La. 1899-1902.

[14]U. S. G. S. Prof. Paper No. 46.

[15]U. S. Geological Survey Water-Supply Paper No. 335.

understanding of the geology appears to differ somewhat from that of Veatch and Harris, and he apparently uses the names given by Veatch to cover very different series of beds from those to which they were originally applied. While this may be somewhat confusing, the change of name of a sand need have no effect on its water-bearing quality and the report is of very practical value.

Dumble, in a paper entitled "Problem of the Texas Tertiary Sands"[16], attempts to clear away as far as possible the various misunderstandings as to the ages of the several sands involved in the description of this area. He reviews the earlier work and uses that of later geologists working under his direction to give the broader features of the geology of the region.

It is this view that is adopted in the following report which is therefore, in part, an expansion of the above paper, but includes many details which could not be given in it and treats the entire subject in a much broader way as it utilizes information taken from many other sources.

[16]Dumble, Bul. Geol. Soc. Am. Vol. 26, 1915.

CHAPTER II

PRE-CRETACEOUS

The entire pre-Cretaceous history of the whole east Texas region is probably that of a land area.

From the beginning of geologic time until late in the Mesozoic it was a part of the ancient land mass, known as Llanoria, originally of great extent, and of which the primordial rocks of the Llano-Burnet region with their fringe of earlier Paleozoics, are now the only visible remnant east of the Pecos river. Supposedly it stretched southwestward into Mexico, connecting directly with the Columbian area of that region. It spread westward and southward an unknown distance. Branner holds that it extended across the Mississippi basin to a direct connection with the Appalachian belt in Alabama. Shuchert[1], however, considers the two areas as separate throughout the entire Paleozoic except in middle Cambrian and upper Silurian time. His eastern border of Llanoria is just west of the Mississippi River. It probably extended over all of east Texas and Western Louisiana, reaching also into southern Arkansas.

In the Texas area this land mass formed the southern and eastern boundaries of the epicontinental seas of Paleozoic, early and middle Mesozoic times, and it furnished much of the materials that entered into the formations laid down in them.

While no remnants of this land are known either in eastern Texas or in the Coast country, evidences of its former existence are sufficiently numerous and plain to warrant these positive statements concerning it.

In all the region east of Llano the earliest Mesozoic rocks known, either from surface exposures or from drilling, belong to the lower Cretaceous. The latest Paleozoic rocks are those of the Bend formation, which is basal Pennsylvanian, and these are only known contiguous to the Llano border.

Along the southeastern border of the Llano region the Cretaceous in places overlaps the Bend and lies upon the older Paleozoics. Along the southern line the Bend seems to be entirely

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[1]Bull. Geol. Soc. Am. vol. 20, p. 427, 1910.

absent. The evidence of the further westward extension of the underlying Bend is found in its exposures along the western border of the Llano area and is obtained from well drilling. A well southwest of Uvalde passed entirely through the Cretaceous into black shale which is believed to represent the Bend. Wells north and west of Uvalde have encountered similar materials below the Cretaceous. The Bend is also well developed in the Paleozoic area west of the Pecos. This would indicate that during the Bend the Llano area was a peninsula extending northward from the Llanoria land mass.

To just what extent the Bend may underlie the entire coastal region east of the Colorado can not now be told. It is, however, probably confined to its extreme western and northern borders. That it does not underlie all of it is known, because materials derived from certain wells sunk east and south of Llano, where the drill has passed through the Cretaceous into the underlying beds, have been studied microscopically by Udden and have proved to be of pre-Cambrian age and of apparently schistose character.

Drake stresses the fact that a large part of the sediments of the Carboniferous and Permian of the central Texas area must have been derived from a land mass lying to the east[2].

Branner in "The Former Extension of the Appalachians across Mississippi, Louisiana and Texas"[3] brings together many facts to corroborate his views and gives proof that the Ouachita sediments as well as those of the Carboniferous of Arkansas, Oklahoma and Texas were similarly of southern and eastern origin.

This Llanoria land of southern and eastern Texas was, therefore, a controlling factor in building the Paleozoic formations of the interior and furnished much of the material which entered into them.

On the interior slope of Llanoria, streams, instead of flowing gulfward as at present, flowed northward or northwestward and emptied their waters, burdened with sediments derived from the erosion of its surface, into the Mediterranean sea that lapped its shores. It was an area of erosion and not of desposition.

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[2]Fourth Ann. Rep. Geol. Surv. Tex. p.

[3]Amer. Jour. Sc. Vol. 4, 1897, p. 357.

Therefore, the probability is that over a very considerable portion of this coastal area no clastic deposits earlier than those of the Mississippi embayment series were ever laid down.

Since we have no evidence at all tending to show the existence, east of the Pecos, of deposits of Triassic or Jurassic age contiguous to Llanoria it may be that during the early Mesozoic the land was base-leveled and stood at only a slight elevation above the sea.

The only Mesozoic beds of marine deposition, earlier than the Cretaceous, known in Texas are of upper Jurassic age and are found in the Malone Mountain region between El Paso and Sierra Blanca. Their continuation, or deposits contemporaneous with them, are found only in Mexico and western United States. It was probably at this time that orogenic forces began to shape the final destruction of this land.

Beginning at El Paso and extending gradually eastward toward Austin there was apparently a downward warping of the old land surface toward the east and south. From Austin the inner border of the zone of warping changed its direction from eastward to northeastward and the subsidence appears to have been toward the south and east permitting the incursion of the Comanchean sea to the eastward of the Llano area.

Whether this movement was simply a gradual sinking of the land or whether it was accomplished by folding, faulting or volcanic action is not known. It is probable, however, that it was of such character that it established in some way the main lines of weakness which have later been further developed within this area. This was the beginning of the submergence that resulted in the Mississippi embayment during the early part of which our east Texas land area finally succumbed to the encroachments of the sea.

This movement also marked the birth of the present Gulf Coastal Plain a part of whose sediments are probably older than the Gulf itself.

CRETACEOUS

The positive geological history of our east Texas region, as written in the sedimentary strata which occupy it, began with the first approach of the waters of the Comanchean sea. The incursion of this sea was greatly facilitated by the flatness of the low featureless plain which was the final stage of the old land area as the result of the long continued erosion of its surface.

COMANCHEAN

Coming from the south the Cretaceous sea first reached the Texas borders in the region of Presidio del Norte on the Rio Grande. Here were deposited the gravel and sand which constitute the lowest beds of this age of which we have knowledge in the Texas area, but which the Mexican geologists claim are somewhat higher in the section than the lowest Cretaceous beds existing there, thus indicating that some interval of time was required after the beginning of the Cretaceous deposition for the advancing sea to reach our territory.

TRINITY

The lowest division of the Texas Cretaceous is known as the Trinity. In its greatest development it consists of three members called in their ascending order Trinity or Travis Peak sand, Glen Rose limestone and Paluxy sand. When the members are all present they indicate the gradual deepening of the sea in that locality to the end of the Glen Rose followed by shallower waters during the Paluxy. There are, however, many places where only sands are found, and it is sometimes difficult to determine whether these are Travis Peak or Paluxy. Where fossils occur there is less trouble, since those in the Travis Peak are oysters or other marine forms, while the Paluxy is usually characterized by plants and fossil wood.

The base leveling of the east Texas area permitted the rapid encroachment of the water so the Trinity sea probably covered the land with considerable rapidity. The gradual extension of the waters to the north and the deepening of the sea to the south is beautifully told in the sediments exposed along the Colorado river on the eastern border of the Llano region.

The erosion of the Colorado and its affluents has channeled through the entire thickness of the early Cretaceous beds and clearly shows the basal sands of the Trinity with the overlying arenaceous limestones of the Glen Rose. These limestones attain their maximum thickness north of Austin and thin toward the northwest; by following the outcrops of the various beds of limestone in that direction we find that they finger out into the underlying sands, showing that they are but deposits in the deeper waters of the sea of which some portion of the Travis Peak sands are the contemporaneous littoral sediments. Just as the Travis Peak grades imperceptibly upward into the Glen Rose, so do these limestones in their turn grade upward into the sands of the Paluxy, where it is present, and at many localities there is no apparent sedimentary break between them.

The thinning of the beds continues to the north and west of the Llano region until the Glen Rose beds entirely disappear and the Paluxy sands are directly superposed upon the Travis Peak, while further north it is probable that the Travis Peak itself is entirely lacking. It is also probable that the basal sands, if present, represent only the Paluxy or even some later stage.

Page[4] calls attention to the fact that the entire Trinity is missing at several places in Burnet county, apparently because of non-deposition, and that the Walnut clays and Comanche Peak limestone directly overlie the Ordovician limestone. Thus the 500 feet of Travis Peak and Glen Rose sediments exposed in the Colorado near the Burnet-Travis county line has entirely thinned out in the distance of 25 miles, due to the fact that parts of the land at the more northern locality, stood too high, even at that date, for the sea to engulf them.

In Oklahoma the Trinity occurs along the southern front of the paleozoic rocks striking eastward from Tishomingo by Antlers and Murfreesboro almost to Antonio, where it is covered by later beds. The Glen Rose member is absent throughout most of its exposure along the line. However, Hill reports its occurrene near Murfreesboro. He uses the name Antlers sand for the northeastern phase of the Trinity formation.

FREDERICKSBURG

The Fredericksburg, which followed the Trinity, also presents different facies in different localities. In its typical development it comprises three members—the Walnut clays, the Comanche

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[4]Page. U. S. G. S. Geological Folio No. 183.

Peak beds and the Edwards limestone. These three divisions are clearly recognizable over a very large area east of the Pecos which includes the line of buttes that forms the Callahan divide and the outcrops south of the Llano region.

Throughout the greater portion of the Texas Cretaceous area the Edwards limestone consists of deposits laid down in clear water of considerable depth and far enough from shore to escape the admixture of terrigenous sediments. In the region of shallower water along the Red River it shows an increase of coastal debris and many of the fossil forms characteristic of its purer phase do not occur in it. It is in fact no longer separable from the underlying Comanche Peak beds, and the two, therefore, are considered as the Goodland limestone, which at its best attains a thickness of only a few feet.

North of Red River and east of Denison the entire Fredericksburg is represented by this Goodland limestone which varies in thickness from 10 to 40 feet.

WASHITA

The Fredericksburg, with its extensive development of deep sea limestones and comparative poverty of shallow water sediments, was followed by the Washita, in which these conditions are largely reversed. It is in the littoral regions of Red River and El Paso that the deposits of the Washita show their widest differentiation and greatest thickness, while in the deep-sea area they are less variable and in most cases of less thickness. In its simplest expression the Washita is composed of a basal limestone, the Washita or Georgetown, overlain by the Exogyra arietina or Del Rio clays and the Buda limestone. This is the section at Austin and south and west to the trans-Pecos region.

The fossils of these various subdivisions of the Washita are very numerous and characteristic. Many of them are seemingly confined to the nearer shore deposits of the northern border, but others are as wide-spread as the fomation. By far the greater number and the greater variety of species found within the seveal beds of this division are those of the shallower water. In the deeper sea more stable conditions prevailed and there were fewer changes of form—so little, in fact, that in the vicinity of

Devil's river and further west certain aberrant forms which are characteristic of the Edwards limestone throughout its extent have persisted or recur and are also found in the Washita (Georgetown) limestone.

The Washita limestone, with a thickness of 80 feet at Austin, shows a separation into several members when followed northward.

In the Red river section the Kiamitia clays form the base. succeeded by the marls and chalky limestones of the Duck Creek beds, capped by the Fort Worth limestone and these, together, show a thickness twice as great as the Georgetown limestone at Austin, which they represent.

The Del Rio clay, also called the Arietina clay, from the name of its most abundant fossil, has a thickness of 80 feet at Austin and consists principally of clays with some gypsum and thin slabs of shell breccia and, at the top, thin layers of arenaceous limestone. In the Red river section the basal clays are practically missing and the Arietina is probably represented only by the Mainstreet limestone of the Denison bed which has a thickness of 15 to 25 feet.

The Buda limestone, with a thickness of 80 feet on the Colorado, also gradually thins to the northward and beyond the Brazos is represented by lime marls and thin limestones. Taff[5], tracing these beds and using the zone of the characteristic oyster *Gryphaea mucronata* as the base of the Buda, found that they continued in marly form to Red river and eastward along that stream to Pottsboro and Denison. These marls were described as the Grayson marls by Cragin[6] and occupy a stratigraphic position above the Arietina or Del Rio and below the Woodbine, thus corresponding to the Buda further south, but whether they cover the whole of Buda time is not yet determined. The conditions are fully stated by Hill[7], who correlates the Buda, in part at least, with the Grayson marls.

In the Denison region the Washita has a total thickness of some 400 feet consisting of the Preston, Fort Worth and Denison

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[5]Fourth Annual Report Geol. Sur. Tex. p. 277 et seq.

[6]Colorado College Studies, 1894, p. 43.

[7]Twenty-first Annual Report, U. S. G. S., Vol. 6, p. 266 et seq.

formations while near Cerro Gordo, Arkansas, the entire series is represented by calcareous clays containing thin beds of limestone with a total thickness of about 250 feet which to this time has not been found susceptible of such division as is used further west.

The marked difference in the character of the upper members of the Comanchean as we pass from the sediments of the deeper waters on the south into the zone of littoral deposition in the Red river region is thus clearly shown. This condition becomes even more pronounced as we go eastward into Arkansas.

Another view of the age of the Buda is that "there are good reasons for believing that the Buda limestone may be represented in the north by at least part of the Woodbine formation. According to the fossil fauna in this latter formation, its age can not be far from that of the Buda limestone."[8]

With the close of the Buda sedimentation came the end of the Lower Cretaceous and the emergence of these deposits from beneath the sea. There was probably a gradual withdrawal of water from the land, and. as the Red river region formed for a long period the littoral zone of the formation and probably was subjected to movements of smaller range than more southern regions, it is possible that a portion of the materials now included in the Woodbine sand, which has been supposed to mark the beginning of the Upper Cretaceous deposits, may have been laid down as shore line deposits at this time and thus mark the final stage of the Comanchean, but the stratigraphic evidence seems to indicate that, taken as a whole, the Woodbine belongs to the Upper Cretaceous.

LOWER CRETACEOUS FORMATIONS OF EAST TEXAS.

	Colorado River	Denison	Texas-Louisiana Line
	Buda	Denison	Denison
Washita	Del Rio	Fort Worth	Fort Worth
	Georgetown	Preston	Preston
	Edwards		
Fredericksburg	Comanche Peak	Goodland	Goodland
	Walnut Clays	Walnut Clays	
	Paluxy		
Trinity	Glen Rose	Antlers Sands	Trinity
	Travis Peak		

[8]Bull. Univ. of Texas, No. 44, p. 65.

EVENTS AT CLOSE OF COMANCHEAN

While there is little evidence of deformation by faulting or folding in the Red river area at the close of the Comanchean, erosion was somewhat active and unconformities occur between the upper Denison beds, comprising the Mainstreet limestone and Grayson marls, and the succeeding Woodbine. This unconformity is clearly shown on the south side of Cedar Mills where the Buda has been entirely removed in places and soft false-bedded sandstone of the Woodbine is in direct contact with the Arietina limestone. The basal clays of the Woodbine are present only occasionally and occur as thin wedges or lenticular masses. At other places the clays seem to lie upon the Buda blue limestone with perfect conformity. [9]

While the erosion of the Lower Cretaceous of northeastern Texas was not extensive and while there may be in places apparent conformity between the Grayson marls and the basal clays and sands of the Woodbine in the Red river region, and the beds show but little evidence of discontinuity of deposition, the fact that there was a long interval of time between the last deposition of the Comanchean and the beginning of the Upper Cretaceous is clearly brought out in their relations as seen south of the Brazos. Here the Woodbine is absent and the Eagle Ford rests directly upon the Buda limestone and this condition continues through the whole sweep of the contact between Waco and Del Rio. They appear conformable everywhere, and yet we know that between the two we had the deposition of the Woodbine. In this area since no erosive action is discernible it is probable that during the interval between the deposition of the Buda and the Eagle Ford the former must have remained very near the water level if not below its surface, since even where very long contacts are observable the two formations appear to be in perfect conformity.

West of the Pecos, however, in certain areas, the beds of the Comanchean were elevated a sufficient length of time for the complete erosion of the entire Washita series and the channeling of the Edwards limestone into deep canyons. This surface was

[9]Taff. Fourth Ann. Rept. Geol. Surv. Tex., p. 282.

again submerged during the Eagle Ford and these channels filled with its shales.

We thus have a central zone in which the movement was practically negligible, with very gentle movements in the northeast bringing the upper beds to the surface, but not so as to completely destroy them, while in the west the elevation must have amounted to hundreds of feet with consequent impetuous erosive action destroying a whole series of beds.

SALT DEPOSITS

The low-lying coast and shallow waters prevailing in the southern and eastern regions were very favorable for the existence of sea basins from which evapóration could remove the water more rapidly than the fresh-water streams could renew it and thus precipitate both gypsum and salt. That such conditions existed may be reasonably inferred from the bodies of salt which are now found in connection with the Cretaceous salt domes. Thus, in the Palestine dome the salt is known to be directly overlain by the Woodbine. Harris, in his section of the formations at Drake's saline in Louisiana shows the salt stock uplifting the Cretaceous limestone and overlain by it and the test well passing through the salt bed into gypsum at 2842 feet. At Grand Saline a somewhat similarly bedded condition exists. It is, therefore, probable that all of the salt now found in these Cretaceous salt domes or islands was deposited during this interval.

There is, however, a possibility that the salt is somewhat older. As we have seen, the Lower Cretaceous sediments of this Northeastern Texas area are comparatively thin and we know that the Trinity sands in Arkansas contain heavy beds of gypsum. It may be, therefore, that these beds of rock salt were laid down about the same time as the Trinity gypsum and it may be that these conditions continued through the greater portion of the Comanchean. At any rate it is Cretaceous.

UPPER CRETACEOUS

With the beginning of Upper Cretaceous time a shallow sea invaded our region and spread northward beyond Red river and westward to the Brazos. Its first sediments were the Woodbine formation which is not found further south than Waco, but extends eastward as far as Clarksville. To the eastward in Arkansas the Woodbine is represented by the lower part of the Bingen sands composed of sands with bituminous, laminated clays containing leaf impressions and lignite beds.

WOODBINE

The Woodbine formation is one of great economic value. On the western border it furnishes a supply of artesian water over a considerable area and in its eastern extension it is the principal oil-bearing horizon of Northeastern Texas and Western Louisiana.

In the Red river region the Woodbine has at its base the variable bed of impure clay, which is often lignitic and sandy, called the Basal clay, overlain by an extensive deposit of brown and yellow ferruginous sandstone carrying siliceous ironstone, known as the Dexter sands. These are capped by a series of lignitic sandy clays with numerous molluscan fossils called the Timber Creek or Lewisville beds[10].

In east Texas the formation has an estimated thickness of 600 to 800 feet.

EAGLE FORD

As the waters became deeper the shales of the Eagle Ford were deposited. On the Colorado it consists of bluish and gray shales and arenaceous laminated shales. In the northern part of the State it is composed of blue and black laminated bituminous clays with large septaria, sands, clays, shales and thin layers of brown sandstone. The clays grade upward into brown sandy ferruginous glauconitic beds interlaminated with beds of clay. These clays carry fossiliferous concretionary masses of limestone and the brown sands, which are locally fossiliferous, are called the Blossom sand[11].

While these distinctions hold for the Texas exposures of these beds the outcrops in Arkansas are not similarly separable and

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[10]Fourth Ann. Rept. Geol. Surv. Tex. pp. 293-294.

[11]Gordon, Water-Supply Paper 276, p. 19.

the Eagle Ford as a whole is represented by the upper portion of the Bingen sand which thus covers the entire time interval of both Woodbine and Eagle Ford in that locality.

Of all the upper Cretaceous deposits, the Eagle Ford seems to be the most uniform and constant. While it has its near shore phase of sands and clays, the bulk of the deposits are limy shales, and these not only encircle the Edwards plateau, but stretch southward into Mexico for 200 miles or more, where they attain a very much greater thickness than anything we know in Texas. Furthermore, these deposits, wherever we find them, whether sands or clays or lime, are usually shales and carry a characteristic fauna throughout their entire extent.

AUSTIN CHALK

During the deposition of the Chalk, which followed, a condition of clearer waters existed, and in the main the Chalk is fairly free from materials derived from the land area and is an almost pure chalk, but there are localities where the clays were carried out and deposited with it, occasionally to such an extent as to make it merely a chalky marl.

In its relation to the underlying Eagle Ford it shows the same variations noted in other similar contacts. In the central part of the State the division is quite clearly defined and the line of separation can be fairly well made out even on the Rio Grande east of Del Rio. Further west the distinction is not so readily apparent, and in the region of the Big Bend of the Rio Grande, where the Eagle Ford takes on a more marly character and the Austin chalk is marly also, it is difficult to find the dividing line without careful examination of the fossils.

This is noticeable also in northeastern Texas where it loses its chalky character and from Sherman eastward it assumes more and more the character of a clay marl or marly clay in its basal portion, the chalk condition persisting only in the uppermost portion of the beds, and, finally, in southwestern Arkansas giving way entirely to marl. In eastern Texas the lower marly member is known as the Brownstown marl while the chalk is called the Annona and is one of the best known lithologic units of the Caddo oil-field.

In the south hundreds of feet of this formation are made up of chalk and chalky marls, but toward the end of the period more and more terrigenous sediments were incorporated with these, and the upper margin of the Chalk is not so well defined, since at most places it grades almost imperceptibly into the base of the overlying Taylor marls, there becoming simply limy clays with some sand, and finally passing into the more sandy beds of the Navarro which form the top of our upper Cretaceous series in the eastern field.

TAYLOR AND NAVARRO

On the Colorado the Taylor consists of a calcareous clay or marl which, while yellow in fresh exposures, weathers to a black waxy soil. In its lower portion it is comparatively free from sand, but higher in the section the sand increases and quantities of glauconite occur. The fauna also changes with the appearance of the glauconitic and to this portion of the beds the name Navarro is applied.

In Arkansas the Taylor and Navarro are represented by three members known in ascending order as the Marlbrook marl, Nacatosh sand and Arkadelphia clay with a total thickness of 1200 feet. Throughout the Caddo field the Nacatosh sand is a well recognized horizon and furnishes a considerable quantity of gas.

While these are the latest sediments of the Cretaceous found in east Texas they are not as late as others occurring in the Big Bend region of the Rio Grande or along that river southeast of Eagle Pass. If these latest beds were ever laid down in east Texas they disappeared in the general erosion at the close of the Cretaceous.

UPPER CRETACEOUS FORMATIONS OF EAST TEXAS.

	Colorado River	Denison	Texas-Lousisana Line
Navarro	Webberville	Navarro	Arkadelphia Nacatosh
Taylor	Taylor	Taylor	Marlbrook
Austin	Austin	Austin	Annona Brownstown
Eagle Ford	Eagle Ford	Eagle Ford	Bingen Sand
		Lewisville	
Woodbine		Dexter	

EVENTS AT CLOSE OF CRETACEOUS

The close of the Cretaceous in North America was marked by the Laramide elevation which was the main factor in the formation of the Rocky mountains. This great movement not only affected the rock materials of the trans-Pecos region but was apparently active also in eastern Texas. The beginning of this movement is generally placed in uppermost Cretaceous time if not at its close. The Texas area contains proof not only of similar movement at this time but also of a Cretaceous movement which took place earlier, beginning during the deposition of the Austin Chalk and either continuing to, or being renewed at, the end of the Mesozoic.

As affecting the Texas region this earlier movement began by the formation of a folded area starting in northern Mexico about the 102d meridian and striking south southeast. The evidence is clear that this elevation took place during the period of the Austin Chalk. It has been called the Sabinas barrier and formed the beginning of the Rio Grande embayment. To the north of this barrier the succeeding Gulf Coast Cretaceous sediments are largely clays and sands and include the coal beds of the Rio Grande region. while to the south we find only a great thickness of blue and black shales. The beds of the embayment area are frequently very fossiliferous while the shale beds are practically destitute of fossils.

The Sabinas movement, or that which formed the Sabinas barrier was marked in Texas by Pilot Knob and other volcanoes northeast and southwest of Austin which were active during the close of the Chalk deposits and the beginning of the Taylor Marls as is proven by the ash and other ejectæ from them which are interstratified with and included in these deposits. Some of these volcanoes were certainly submarine.

At the close of the Cretaceous, that is, during the time of the Laramide elevation proper, this movement was intensified in the Mexican region and resulted in raising a land barrier which is now marked by the disconnected ranges and groups of hills that form the eastern border of the valley lying at the foot of the Mexican Cordilleras. This barrier, known as the Tamaulipas range, reaches the present Gulf shore in the vicinity of Tordo bay some 50 miles north of Tampico and forms the southern limit and boundary of the Gulf Coast Eocene. The Eocene deposits found west and south of the barrier are not only of different character, but the fossils they contain are unlike those to the north.

During the Laramide movement in the western Trans-Pecos region the country was folded and faulted with the production of mountain ranges which are our representatives of the Rocky Mountain chain. There was also great volcanic activity in this region which probably continued well into the Eocene. Outside this region, however, the movement was gentler and the entire Texan area was raised along its northern and western borders giving the surface as a whole a gentle tilt in a southeastwardly direction toward the Gulf of Mexico. It is possible that some igneous activity accompanied this movement, especially in southwest Texas.

FOLDS AND DOMES

In eastern Texas and Louisiana the effect of the movement taking place at approximately the time of the Laramide elevation was the formation of folds and domes in the newly deposited materials of the Cretaceous, like those in Freestone county, at Palestine, Drake's and Steen's salines which have maintained their individual characters and now appear as inliers in the Tertiary area.

So far as is now known these uplifts were not accompanied by the intrustion of basalts or other igneous rocks the only intrusives known being stocks of salt, anhydrite and gypsum.

Some idea of the extent of the uplift may be had from the conditions at the Palestine dome. The Woodbine is the surface formation fifty miles northwest of Corsicana. A well drilled at Corsicana found the base of the Woodbine at a depth of 2460 feet. This would give the base of this formation a dip of 50 feet to the mile. The Palestine dome is fifty miles southeast of Corsicana and the Woodbine in place of being 5.000 feet below the surface as its average dip would imply, forms a part of the surface rock. Even with a greatly decreased dip the vertical displacement of these beds at this place must have been from 2500 to 3000 feet. While a part of the present displacement is due to later uplifts than that at the end of the Cretaceous, these were very slight in comparison with the earlier one.

The Palestine dome was unquestionably an island in the early Tertiary sea. The sediments of the Midway or earliest stage of that period are not found on it. Those of the Wilcox occur around it and probably covered it as did the succeeding Claiborne and it is now uncovered because of the erosion of these later beds.

To the north of the Palestine dome, about six miles, is the Keechi island which is, in all probability, connected directly with the Palestine dome but which shows at least 1400 feet less displacement since the Navarro beds are at the surface and it is 1460 feet to the top of the Woodbine as proved by wells drilled near it.

In alignment approximately parallel to the present boundary between the Cretaceous and Tertiary and forty-five to fifty miles from it we find to the north of the Palestine-Keechi island domes the Brooks and Steens salines in Smith county. These are domes similar to the Palestine with Cretaceous rocks at the surface. Whether these are all connected and simply represent peaks of an anticlinal or are isolated upraises is not positively known, but the character and structure of the Midway deposits lying between them and the Cretaceous border seems to favor the former view.

Sabine Peninsula

To this period also must be referred the formation of the Sabine Peninsula, which was first recognized by Harris and which is a very important physiographic unit of eastern Texas and western Louisiana. It is probable that the Laramide elevation outlined this Cretaceous table-land and was the principal agent in its elevation, although later movements may have also had something to do with its present condition.

On the surface this Peninsula is a belt of the Lignitic phase of the Wilcox, in places more than thirty miles in width. From the Cretaceous border north of Texarkana it extends southward along the Texas-Louisiana line to Sabinetown, a distance of 130 miles. It is flanked east, west and south by bodies of Lower Claiborne.

The elevation of its surface at Texarkana is 300 feet and at Sabinetown is 200 feet, a fall of less than one foot per mile.

The rocks underlying this Lignitic Peninsula, as shown by wells, comprise about 450 feet of Lignitic and 250 feet of Midway followed by the Northeast Texas section of the Upper Cretaceous.

The sections from north to south as made, based on drilling records, show the Upper Cretaceous beds dipping southward from Red River at about 50 feet per mile to the vicinity of Vivian, Louisiana. Here the Sabine uplift begins which brings the Cretaceous beds up again to within 500 to 700 feet of the surface thus creating a Cretaceous plateau the southern border of which has not yet been accurately determined but is near Sabinetown, so that it has a length of about 100 miles. It is evident that the displacement at the southern end of this plateau may be even greater that that at the Palestine dome. The eastern and western borders are not definitely known, but it extends westward into Panola and Shelby counties.

Basing the estimate on the top of the Annona Chalk the dip of the Cretaceous betwen Vivian and Sabinetown is 300 feet or about 3 feet per mile. A well on the Jesse Low survey below Sabinetown encountered the Chalk at 1900 feet while deeper wells further south did not find it at all.

West of the line between Vivian and Sabinetown a well on the Jane Thorp survey in Panola county reached the Chalk at 1315 feet, the top of the Cretaceous being put at 265 feet below the surface. Thirty miles south of this well at Flat Fork entered the Chalk at 1690 feet, the top of the Cretaceous in this well appearing to be at 960 feet, indicating either a thinning of the beds above the Annona or their erosion prior to the deposition of the Midway.

The well records also show that the Cretaceous rocks have been folded first along northeast-southwest lines and later at right angles to this.

To the east of this plateau there are a number of domes which are Cretaceous islands similar to those found west of it in the Texas area.*

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*For details of these domes see reports in Geol. Sur. Louisiana, 1899-1902 and Bulletin No. 7 of Louisiana Geological Survey.

CHAPTER III

TERTIARY

INTRODUCTION

At the close of the Upper Cretaceous the waters of the Mississippi embayment receded to an unknown distance southward and the former sea bottom emerged and became a land area. This land area was probably of the nature of a broad plain the flatness of which was broken by the domes, ridges and plateaus arising from the Laramide uplift. The plain itself was probably but little above the sea-level for there is no evidence of extensive erosion in the sands and clays of the Cretaceous which formed its surface. The emergence, however, was of sufficient duration to make a most complete break in the paleontological column. Every species and even many genera of mollusks which inhabited the Cretaceous sea completely disappear at the close of the Cretaceous and we find an entirely new fauna beginning in the Tertiary. The same is true of the plant remains so far as they are known.

With the incoming waters of the first Tertiary sea there began the deposition of the sediments which cover the whole of Eastern Texas.

The Tertiary deposits of this region are sediments laid down, for the most part, in comparatively shallow water, during periods of slow and gentle oscillations. Apparently the conditions surrounding their deposition were not greatly different in character from those now existing along the Gulf Coast although the indications are that some phases had much greater extension than at present.

The first deposits are those of marine waters alternating with those of lagoons and swampy areas followed by others which were laid down by streams and wind in land areas similarly alternating with lagunal deposits. They consist principally of lightly compacted clays and sands with some limestone. Interbedded with or included in these are considerable amounts of gypsum, beds of lignite, deposits of oil, salt and sulphur and much ferruginous material in the form of glauconite, siderite, pyrite and limonite. The formation, as a whole, dips gently seaward at the rate of 5 to 40 feet per mile with occasional variations in direction and amount.

On the basis of these differences in mode of deposition and of their fossil contents the beds have been separated into several groups. The following table gives the subdivisions of this series as it applies to eastern Texas:

THE TERTIARY FORMATIONS OF EAST TEXAS

	Brazos:		Trinity:		Sabine:
	Lafayette		Lafayette		Lafayette
	Lagarto				
				Woodville	
Neocene	Lapara				
			Fleming	Burkeville	Fleming
	Oakville				
	Fleming	Navasota		Coldsprings	
			Onalaska		
Oligocene	Corrigan				
			Catahoula		Catahoula
		Manning?	Manning		Manning
	Jackson	Caddell?	Caddell		Caddell
		Wellborn	Wellborn		
		Fayette?			
		Yegua	Yegua		Yegua
Eocene	Claiborne				
		Marine	Marine		Marine
		Carrizo	Queen City		
	Wilcox	Lignitic	Lignitic		Sabine
	Midway	Midway	Midway		

TERTIARY SECTIONS

The special region considered in this report is forested and in places densely wooded. The best opportunities for study are the sections found along the various rivers crossing it from north to south and the cuts along the railroads which traverse it in the same direction.

These rivers from east to west are the Sabine, Angelina, Neches, Trinity, Navasota and Brazos. The railways include the Gulf, Colorado & Santa Fe, Jasper to Carthage; the Dallas Branch of the Texas & New Orleans; The Houston, East & West Texas; the International & Great Northern; Trinity and Brazos Valley; Madisonville Branch of International & Great Northern, and the Houston & Texas Central. In addition to the roads crossing it, the Missouri, Kansas & Texas, Cotton Belt and others give valuable sections. The sections made along these lines show clearly the general composition of the beds entering into the different formations and the changes which occur in the deposits as we pass from the eastern border to the interior of the State.

EOCENE

The earliest period of the Tertiary is known as the Eocene and is divided into the Midway, Wilcox, Claiborne and Jackson stages. Of these the Midway and Claiborne are composed principally of marine deposits while the Wilcox and Jackson comprise deposits both of marine and palustrine character, the palustrine portions representing inshore deposits approximately contemporaneous with the offshore deposits of the marine portions, and in places interlapping with them.

The Midway and Wilcox together form the Lower Eocene. The Claiborne is the Middle Eocene and the Upper Eocene has similarly only one member, the Jackson.

MIDWAY

The Midway formation, first named by Smith and Johnson from an Alabama locality, was more fully described by Harris in his report on The Tertiary Geology of Southern Arkansas in the second volume of the Annual Report of the Geological Survey of Arkansas for 1892 and in his American Bulletin of Paleontology under the title of the Midway Stage, where he has also described and figured the fossils which characterize it. These beds or parts of them had been described previously in connection with other deposits and by various authors. Deussen[1] gives a fair resume of publications treating on the beds now referred to the Midway with their equivalencies as understood at this time.

General Character and Thickness

The Midway beds are marine sediments and comprise in their area of outcrop a series of interbedded clays and sands usually dark bluish or black but occasionally light yellow in color, micaceous, frequently laminated, and sometimes gypsiferous, interbedded with limestones or calcareous nodules and boulders. Fossils are abundant both in the limestones and in the beds of sands and clays.

In the eastern part of the State where there is no outcrop and the beds are known only from materials encountered in drilling wells these beds are found to be predominatingly clayey with glauconite and sand in thinner layers and with thin beds of sandstone and limestone.

In thickness they vary from 200 to over 400 feet.

Deposition and Relation to Underlying Beds

The Midway sea swept inland from the south gradually submerging the Cretaceous land but in our Texas area ceased its encroachment before it had reached the limits of its predecessor, the Ripley sea. It swept around the domes and ridges but its rather shallow waters, though they may have been somewhat deeper than those of the Ripley, did not engulf them all.

To the northeastward in Arkansas, it reached inland entirely across the Cretaceous and its beds overlap the Bingen sand and are in direct contact with beds of Paleozoic age which underlie it.

The highest beds of the Cretaceous which formed the sea bottom on which the basal Eocene or Midway deposits were laid down were of sands and clays and at no place were there any limestones at the surface. It is probable that much of the material of the Midway was directly derived from these and, therefore, the two series of soft materials coming together frequently

[1]Deussen, A. Water-Supply Paper No. 335.

fail to register any unconformity. Consequently, at many places where the contact has been observed there is no apparent stratigraphic break and in weathered surfaces it is at times very difficult to distinguish the two formations. As a whole, however, the Cretaceous beds are massive and the basal Tertiary are distinctly stratified and this aids in separating them in the absence of fossils.

While this lithologic similarity between the Upper Cretaceous and basal Eocene largely obscures it in places, there is an actual erosional unconformity between as seen in Georgia and on the Frio and Rio Grande rivers in Texas.

Area of Outcrop

The contact of the Midway and Cretaceous on the Brazos river, which for our present purpose we may use as our southwestern boundary, is found in a bluff in Falls county, one and one-half miles north of the line of Milam county.

To the south and west of this point the beds cross the Colorado below Webberville and the Rio Grande in southern Maverick county and their final exposure in North America is found about 30 miles east of Monterey in Mexico, near Ramones, on the Pesqueria or Salinas river.

Northeast of the Brazos the Midway outcrop is found in a belt stretching along the Cretaceous front in a northeasterly direction to the southwestern portion of Hopkins county, a distance of about 175 miles. In its narrowest part it is less than five miles in width but in the vicinity of Wills Point it broadens out to some 15 miles.

North and east of this it is covered by the Wilcox overlap until it again appears at the surface in the vicinity of Malvern, Arkansas, resting directly upon the Paleozoic beds and overlain by the Wilcox. It here forms a belt from one to four miles in width and extends northeastwardly by way of Little Rock to Independence county.

In northeastern Texas the Midway underlies a stretch of undulating prairie country with interspersed patches of timber land. The timber is mostly black jack and post-oak with a few black ash and sycamore trees along the creeks.

DETAILS OF SECTION

Kennedy found the contact between Midway and the underlying Cretaceous at only two places.

At the bluff on the Brazos river in Falls county one and one-half miles above the Milam county line he found at the base a massive bed of blue clay 14 feet thick, with Baculites and other Cretaceous fossils. Resting upon this was a bed one foot thick of blue clay which he considered transitional between the Cretaceous and the overlying five feet of blue clay and sand breaking into nodules and conchoidal fragments and weathering into a grayish yellow. This bed contained such caracteristic Midway fossils as *Apporhais sp.*, Ald. *Ostrea pulaskensis,* Har. *Venericardia alticostata,* Con. *Cucullaea macrodonta* Whit, *etc.*

The other contact appears about four miles west of Elmo, Van Zandt county, where the dark blue laminated clays of the Midway rest upon the bluish weathering yellow marls of the uppermost Cretaceous.

The basal Midway clays here are thinly laminated, have occasional nodules of limestone and broken bivalve shells in the upper portion. They have a thickness of 30 feet and are overlain by brownish gray sands also carrying limestone boulders.

In the Brazos section, half a mile below the contact, a bluff at Blue Shoals has at the base laminated blue or black fossiliferous clay overlain by blue indurated clay with boulders or concretions of limestone containing *Ostrea pulaskensis.* Harris *Enclimatoceras ulrichi* White. *Cucullaea macrodonta* Whitf. *Venericardia alticostata,* Con. and other forms.

Milam bluff or Black bluff on the Milam county line is forty feet in height and composed of clays and calcareous beds, black at bottom, but yellow or greenish at top, with many fossils. Cribbs bluff further south shows the dark blue laminated clay overlain by interbedded limestones and yelow clays with many fossils.

The uppermost portion of the beds in this section is seen in Smiley's or Oyster bluff two miles north of the mouth of Pond Creek where laminated sands are interbedded with laminated clays, concretions and hard limestones, carrying such fossils as *Ostrea crenulimarginata, Pleurotoma anacona, P. ostrarupis*

Plejona praecursor, Pseudoliva ostrarupis, Cerithium penrosii, C. Whitfieldi, Leda milamensis, etc., which Harris says represent the equivalent of the Naheola or Matthews Landing beds of the Alabama section.

This is overlain by beds which are referred to the Wilcox.

Going northward exposures are found along Salt Branch of the little Brazos and, in the vicinity of Tehuacana, Midway limestones are found which, from the fossils, Harris considers to be about the middle of the formation.

The contact of the Midway and Cretaceous is well shown on the steep western and northwestern faces of the Tehuacana escarpment northwest of the Mexia gas-field. Baker's section is:

1. Fossiliferous, hard brown Midway limestone, irregular, and nodular-bedded, forming the cap rock of the Tehuacana hill, ... 4 ft.
2. Fine, loose, massive yellow sand, ... 22 ft.
3. Clay, mottled green-gray and brown, coarsely laminated otherwise like (5) below, ... 70 ft
4. Yellow, very sandy, massive clay with small calcareous nodules, ... 12 ft.
5. Light brown very thinly laminated paper shale for the most part, although some of the shale is coarsely laminated and nodular, plastic when wet, and small white calcareous concretions. When wet the shale is clayey and has a greenish-brown color. Small flakes of selenite are found along seams. This clay weathers into black soil, ... 15 ft.
6. Black Cretaceous clay, dense, with small calcareous nodules, ... 15 ft.

All the beds except No. 2 are fossiliferous, and all beds above No. 6 are Midway Eocene in age.

The Midway beds occur in the region of Mexia covering an area extending as far west as Tehuacana, a distance of ten miles and east of Mexia something like six miles. On the north these beds occur near Wortham and southward the line of contact between the Midway and Lignitic crosses the railroad near Mile Post 157, or a short distance south of the town of Thornton.

These deposits are made up mostly of dark blue shaly clays with occasional streaks of a reddish to yellowish brown shale with small white calcareous concretions and crystals or thin flakes of selenite, the whole weathering into black soil. The calcareous concretions and selenitic flakes, however, are not persistent throughout the beds, but appear to lie in patches irregularly distributed throughout the territory. Some of the shale appears to be nodular and some of the nodules have a brownish granular appearance.

The general dip of these beds is toward the southeast at the rate of about 100 feet to the mile. In places this dip is interrupted by a slight folding, which, while in a general way agreeing with the trend of the dip, often appears to lie across it. A cutting in a creek about six miles east of Mexia shows one of these cross folds. The southeastern dip is somewhat modified by a fold which appears to have a northwest-southeast axis along the strike of the beds. The dips as shown in this fold are about 10 degrees northeast on the eastern side and approximately 10 to 15 degrees on its southewestern limb. The overlying material in this section is red and brown sands with flattened boulders of ferruginous sandstone belonging to the basal Lignitic.

From the structural conditions shown in this section and another near Shiloh on the Trinity and Brazos Valley Railroad, it would appear that at the close of the Midway stage there were orogenic movements that folded these deposits before the overlying Lignitic was laid down.

Kennedy gives the following general section of the beds in their exposures around Wills Point[1].

1.	Yellowish brown sand containing calcareous boulders of sandstone, limestone with thin veins or seams, occasional nodules of crystalline calcite, and fossil remains,	30 ft.
2.	Yellow laminated clay with thin particles of yellow sand and boulders of silicious limestone, ...	90 ft.
3.	Massive bedded clay, showing no signs of lamination, containing numerous boulders similar to those of No. 1, . .	30 ft.
4.	White limestone with great numbers of fossil casts, chiefly *Turitella (?) Cardita planicosta. Ostrea (?)* and other bivalve shells, ...	8 ft.
5.	Brown sand, ...	2 ft.
6.	Limestone similar to No. 4 , ...	10 ft.
7.	Bluish gray sand	30 ft.

[1]Third Ann. Rept. Geol. Surv. Tex. p. 49.

8. Dark blue laminated and much jointed clays with thin sandy partings, containing small bivalve shells chiefly, and having a thin pavement of siliceous nodules near its upper surface, ... 62 ft.
9. Ponderosa marls, ...

262 ft.

A characteristic feature is the presence of numerous boulders of gray limestone containing thin veins or seams of crystalline calcite and fragments of gasteropods. While occasionally occurring in the upper brown clays, the boulders are mostly imbedded within the gray sands of the formation near the contact of the lower beds with the Cretaceous. In places they are seen lying in the sands, forming an irregular bed.

Another feature of the yellow clays is the numerous nodules or concretions of carbonate of lime found in them. throughout the whole of the area traversed by the section as well as in the thinly laminated brown clays or their accompanying overlying brown sands.

The Midway is not exposed at any point within the region covered by our map, but eastward in Louisiana it has been brought to the surface by the elevation of the Many and King domes and certain black prairies west of Mansfield are thought to be underlain by it.

Fossils

The fossils identified by Harris as having been found in these beds in eastern Texas and Louisiana are:

Enclimatoceras ulrichi White
Ostrea pulaskensis Harris
Ostrea crenulimarginata Gabb
Venericardia planicosta Lamarck
Venericardia alticosta
Cucullaea saffordi
Crassatella gabbi
Volutilithes limopsis Conrad
Turritella mortoni
Pleurotoma anacona
Pseudoliva
Natica
Modiola stubbsi

Fusus harrisi
Leiostoma ludoviciana
Volutilithes rugatus
Flabellum conoideum

This fauna is very meagre as compared with that of the formation as found east of the Mississippi.

West of San Antonio the Midway appears to carry plant remains and Berry[3] has identified 10 species from collections made at Earle by Deussen and L. W. Stephenson from beds referred to this formation. These are:

Pourouma texana Berry, n. sp.
Ficus denveriana Cockerell
Ficus occidentalis Lesq.
Ficus sp.
Platanus aceroides latifolia Knowlton
Cinnamomum affine Lesquereux
Laurus wardiana Knowlton
Asimina eocenica Lesq.
Dolichites deusseni Berry, n. sp.
Terminalia hilgardiana Lesq.

WILCOX

The name Wilcox (from Wilcox county in Alabama where the formation is well exposed) was proposed as a formation name by Crider to take the place of the term Lignitic, which was in use previously for the same beds, because of the present rule to use geographical names for such purposes.

While the Wilcox is largely lignitic in character even in Alabama, it contains, interbedded with these materials, strata containing marine or estuarine fossils by means of which it has been separated into four formations. These are, beginning at the bottom, the Nanafalia and the Tuscahama, which includes the beds at Gregg's and Bell's landings on the Alabama. Above the Tuscahama are the Bashi or Wood's Bluff and Hatchetigbee.

The beds here referred to this stage were described by Penrose in the First Annual Report of the Geological Survey of Texas

[2]Harris, Paleontology of Midway Formation, Bul. Am. Paleontology, Vol. 1, 1896, p. 117.

[3]U. S. G. S. Prof. Paper 91, p. 9 etc.

as part of the Timber Belt or Sabine River beds. Kennedy first differentiates them in his Tertiary Section[4] where the Timber Belt Beds of Penrose are divided into the Lignitic and Marine. The line there drawn between the Lignitic and Marine placed the Queen City beds of white and red sands and clays with the lower member, but later investigations show that it does not belong with the Lignitic but with the Marine.

The term Wilcox will be used here in this sense for the series of beds which is found in this region lying above the Midway and below the Queen City sands which are the basal member of the Middle Eocene.

Deposition and Areal Distribution

At the end of the Midway a large portion of the area covered by its deposits was transformed into land by the recession of the sea and there are many indications of a long interval of erosion between its close and the beginning of the Wilcox deposition which followed. The exposures of the contact of the two formations on the Rio Grande give positive evidence of this.[5]

As before, the deeper waters were to the south and the approach of the Wilcox sea was from that direction. At the maximum of its transgression it submerged most if not all of the Midway land and portions of the Cretaceous. Along the entire coastal portion of this embayment the waters formed a broad belt of lagoons and shifting seas with littoral and palustrine deposits. Marine conditions, as shown by character of the sediments and fossils, usually are only found many miles to the seaward of the inner border.

Both of these phases of the Wilcox occur in east Texas.

The marine phase is found outcropping on the Sabine river in the northeastern part of Sabine county. The name Sabine has been suggested for these beds by Veatch from the "typical development of the formation along Sabine river in Sabine county, Texas and Sabine Parish, Louisiana, and from noteworthy exposures at Sabinetown Bluff".

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[4]Third Ann. Rep. Geol. Sur. Tex. p. 50.

[5]Dumble, E. T. Jour. Geol. vol. XXIII p. 488.
Stephenson, L. W. U. S. G. S. Prof. Paper 90, p. 73.

The exact limits of this area of interbedded marine deposits existing west of the Sabine is unknown but can not be very extensive, unless it spreads seaward below the succeeding Claiborne, as the great area lying north and west of this, in which the formation is exposed, is occupied by deposits representing the other phase of the Wilcox which we know as the Lignitic.

These Lignitic deposits represent a period when the coastal plain was made up of swamps, lagoons and bayous, the extent of which will be best understood when we say that within the limits of east Texas the present main surface exposures of these deposits extend over an area 140 to 200 miles from north to south and from 100 to 250 miles from east to west and that the beds continue indefinitely coastward beneath the succeeding formations, but in that direction possibly merge into or are replaced by the marine deposits of the Sabine phase.

The topography of the country occupied by the Lignitic beds is but little broken and consists of gently rounded hills of no great elevation. Where more broken country appears, as it does in places, it is usually due to the fact that the Claiborne which formerly overlay the greater part of it, owing to the resistant quality of some of its beds, has not been entirely eroded and thus forms belts of higher hills.

Correlation With Other Areas

From the marine fossils found in the Sabine river at Pendleton Harris determined the age of the beds at that locality to be the same as the Nanafalia substage of the Alabama section which belongs to the Lower Wilcox of that region. The fossils from Sabinetown, four or five miles south of Pendleton, were found to belong to the fauna of the Woods Bluff (Bashi) substage which is part of the upper Wilcox.

Berry[6] says of the Lignitic beds that within the area occupied by them no fossils representing the animal life of the period either of land or sea have ever been found with the exception of the teeth of a Wasatch species *Crocodylus grypus Cope,* recently found in Texas, and a few fish scales. So far as the fossil

[6]U. S. G. S. Prof. Paper No. 91, p. 37.

flora of the Texas area has been determined it indicates that the Lignitic beds are not older than the Holly Springs sand or middle Wilcox and well logs in western Lousiana indicate that the beds of the lower Wilcox have been transgressed and covered by these later beds and do not appear at the surface.

This implies a gradually deepening sea making successive inroads over the land surface and that contrary to the conditions of the Midway where the lowest beds may be found at the inner margin of the outcrop, the marginal beds of the Wilcox, as found here, are nearer the medial portion of its general section. Such gradual encroachment of the sea argues similar long exposure of the coast lands of the Midway with consequent opportunity for considerable erosion.

Sabine Phase

SABINE RIVER SECTION.

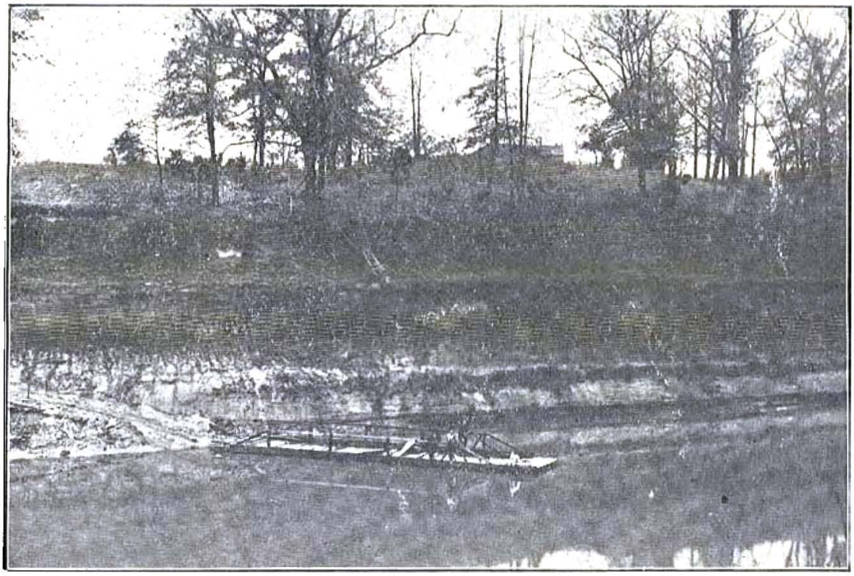
The exposures along the Sabine river described by Harris and Veatch[7] seem to correspond in large measure to the Alabama section and show an interbedding of the lignitic and marine phases.

Passing down the river from Logansport the outcrops were small and unsatisfactory until Hamilton was reached, 30 miles below. No fossils were found and contradictory dips were observed so that it was impossible to determine the exact stratigraphic relation of these outcrops to those further down the river. Veatch's impression was that they were lower Lignitic and lower that the Nanafalia beds at Pendleton, and the sections and structure seem to fully warrant this conclusion.

The sections given show finely laminated dark lignitic clays with large calcareous concretions overlain by sands and clays with lignite. These materials correspond with those found at the base of the Wilcox in the wells of the Caddo field.

These sandy clays with calcareous concretions continue down the river and apparently compose the line of hills below Hamilton and are again exposed in Rock Bluff between Hamilton and

[7]Geol. Rep. La., 1899.1902.



WILCOX FORMATION.
Pendleton Bluff.

Chambers Ferry where the concretions contain imprints of leaves.

The first marine fossils on the river were found near Moran's landing, above the mouth of Patroon bayou, where, below 10 feet of light yellow sand with fine clay partings, there was 8 feet of blue laminated sandy clay with *Venericardia planicosta* and an undetermined *Anomia*.

Near Moran's landing the river turns eastward and in these southwesterly dipping beds, goes down the section again with exposures of the sandy laminated clays, calcareous concretions and lignites.

On Mason Creek, a tributary of Patroon bayou, Baker found the following section:

1. Fine sandy light gray clay, well laminated, with large blue-gray clay ironstone concretions ellipsoidal in form and as large as 10 ft. in longest diameter, good ripple-marks. Upper half stained yellowish-brown with limonite, ...35 ft.
2. Medium-grained greensand with a small percentage of oolitic glauconite; fossils, ...2½ ft.
3. Lignitiferous brown sandy clay with small lenses of impure lignite, ... 2 ft.
4. Cholocate-brown carbonaceous clay, ... 3 ft.

A few marine fossils were found in the lower portion of (1) and also in (2).

There are good exposures of Wilcox along Mason Creek from its head to its junction with Patroon Bayou.

Carter's Bluff on the river shows 15 feet of dark blue laminated unfossilferous sandy clay. A ledge of limestone boulders extends almost across the river above the ferry and below it a 6-inch bed of lignite appears capping the clay. Another bed of calcareous concretions appears in the clays 30 feet above it. At this point the river again turns west.

This section is probably repeated in part or extended at mouth of Patroon bayou where two small beds of lignite occur. This is only a short distance north of Pendleton where we again come up into the interstratified marine and lignitic deposits. The following section may be seen one-fourth mile above the ferry, just above the mouth of a small stream.

9. Light gray to brownish laminated clay, ... 7.5 ft.
8. Ledge of impure limestone concretions, ... 2.5 ft.
7. Greenish brown and light blue clayey sand, with iron concretions and fossils, ... 4.5 ft.
6. Blue joint clay, fossiliferous, ... 2.5 ft.
5. Limestone boulders, fossiliferous, in dark gray sand, ... 1. ft.
4. Dark gray sand, ... 2. ft.
3. Stratified lignitic clay, ... 1. ft.
2. Yellow and gray sand, ... 5. ft.
1. Wavy, alternate layers of blue sand and clay, ... 6. ft.

The dip is here to the westward about 1 to 50.

Baker's section of Pendleton Bluff is as follows:

Top.

1. Coarse Lafayette orange sand with a few quartz and chert pebbles, imperfectly laminated. The surface color is yellowish-brown. The top member is mottled and more clayey .... 15 ft.
2. Sticky laminated chocolate-brown clay interbedded with with brown micaceous sand carrying plant fragments.. 15 ft.
3. Laminated brown and dark blue sand and clay, con cretionary and with greensand. Oolitic greensand mainly distributed in thin layers, more or less continuous, ... 4 ft.
4. Fossiliferous bed containing an abundant fauna. Fossils in a soft medium-grained dark gray sand, locally with greensand, containing small particles of clay and very small lenses of lignite. Contains abundant sphaerosiderite concretions, especially near the top. Weathers dark greenish-brown, ... 6½ ft.
5. Medium to coarse-grained sand with numerous thin interbedded wavy and irregular layers of lignitiferous clay. Sand either brownish or more often, when containing pyrite, dark greenish-gray. Contains elliptical concretions of clay ironstone. Sometimes the layers of unconsolidated sand will be as thick as from 4 in. to 1 ft. and then will become an alternation of thin bands of sand and lignite averaging less than ¼ inch in width. Limonite staining common. Sand micaceous, ... 8 to 10 ft.

Base.

Fossils are numerous at each of these exposures, but are somewhat better preserved in the first mentioned section. Harris' list is as follows:

Modiola alabamensis
Barbatia cuculloides
Leda corpulentoides
Cardium tuomeyi, Ald.
Ceronia,

Pleurotoma silicata,
Pleurotoma Natchi
Cancellaria quercollis, var. greggi,
Pseudoliva velusta, var.
Pseudoliva petrosus
Levifusus indentus,
Levifusus supraplanus
Levifusus pagoda
Levifusus trabeatus

Mazzalina plena
Tritonidea pachecci
Nassa exilis
Cassidaria brevidentata
Turritella mortoni
Turritella praecincta
Natica eminula
Natica aperta
Natica alabamensis
Solarium bellense

Such typical lower Eocene species as *Levifusus supraplanus, Buccinanops ellipticum, Turritella praecincta, Natica aperta, N. alabamensis, Solarium bellense and Pleurotoma silicata,* show the equivalency of these beds to the Nanafalia horizon in the Alabama section.

Down the river about half way from Pendleton to Sabinetown, but on the Louisiana side there is a 3 ft. ledge of lignite cropping out near the water level. It is overlain by gray sands of recent river origin.

A short distance below the Sabinetown ferry and on the Texas side of the Sabine there is a most interesting section. This bluff is from 115 to 120 feet high, counting from the surface of the river at a medium stage of water. It is located on a bend of the river where the latter pursues a nearly east-west direction. Though the dip is locally very considerable here as shown in little side gorges, often as much as 1 to 50 it appears light along the bluff as a whole, for the direction of the latter is nearly on the line of strike.

The main features of the various component strata of Sabinetown bluff are as follows:

8. Sands and ferruginous conglomerates, ...9 to 16 ft.
7. Ferruginous sandstone, ... 1 ft.
6. Lignitic clay, ...15 ft.
5. Yellow sand, ...25 ft.

4. More or less alternating shaly lignitic clay and sand. The latter weathers yellowish; the shaly clay sometimes light brown or pinkish, ... 40 ft.
3. More or less clayey sand, often greenish and fossiliferous in concretions; with a hard layer above, ... 15 ft.
2. Fossiliferous blue sand with concretions, ... 6 ft.
1. Brittle, shaly, drab clay, ... 2 ft.

Baker says of the bluff:

"The banks of the Sabine river in the vicinity of Sabinetown are of light brown or light gray sand, 20 or 25 feet in height. This river sand is probably derived from the Wilcox formation. A layer of pebbles cemented by iron oxide into a conglomerate is seen on the Louisiana bank 300 yards above the Sabinetown ferry, also at Sabinetown and in the bluffs between the mouth of Low's creek and Columbus.

"In the Sabinetown bluff the basal layer is chocolate sandy and shaly clay, overlain by medium-grained dark green fossiliferous sand with many large and small blue iron carbonate concretions. The fossils in the sand are soft; those in the concretions not so well preserved. Above comes a layer with oolitic greensand overlain by chocolate sandy carbonaceous clay. The upper bed of this section of the Wilcox is structureless light brown sand, 15 feet or more in thickness."

The fossils collected from this locality as well as from Pendleton were identified by Harris and are figured in his Louisiana Report for 1899.

The list is as follows:

Leda aldrichiana, var.
Venericardia planicosta,
Kellia prima,
Mactra bistriata,
Corbula alabamensis,
Ceronia,
Pholas alatoideus,

Pleurotoma huppertzi,
Volutilithes petrosus,
Levifusus trabeatus,
Nassa exilis,
Calyptraphorus trinodiferous,
Fusoficula juvenis,
Natica eminula,
Sigaretus declivus.

The Sabinetown fossils are those of the horizon of the Woods bluff beds in Alabama.

The bluff section on the Palagauche a few hundred yards above its mouth is virtually the same as on the Sabine river at

Sabinetown. At a second exposure, about one mile above the mouth of the Palaguache, the dip is at least 10 degrees in a south of east direction. Dip observations here vary all the way from 10 to 17 degrees. The beds are very fossiliferous greensands and 20 feet thick.

The general section seems to show that the basal Wilcox in this immediate region belonged to the Lignitic phase and was succeeded in the upper Nanafalia portion of Lower Wilcox time by the Sabine phase and this persisted until the Claiborne.

Unless fossils have been found in wells drilled west of the Sabine river which indicate the beds of this phase, they are not known elsewhere in east Texas. Baker, however, found marine Wilcox fossils southwest of San Antonio.

Lignitic Phase

GENERAL CHARACTER AND AREA

These beds comprise a series of sands, sandstone, clays and lignites having an aggregate thickness of 1200 feet or over.

The sands are variously colored, being yellow, brown, gray or blue, with occasional thin beds of black, often shading into one another in endless variety, and, with the exception of the dark blue or black beds, present no uniformity of coloration for any distance. In structure they are mostly coarse-grained with irregular deposits of fine-grained silty sand, laminated or thinly stratified, massive, cross-bedded and frequently interlaminated with clay.

The clays occur interstratified and interbedded with the sands or, as irregular deposits, usually laminated. Massive and stratified beds also occur in portions of the area, sometimes nearly free from sand, but the greater portion occur as sandy or micaceous clays. Plastic potter's clay and refractory clays occur in abundance. In color they are generally dark blue, gray or black, although deposits of red, brown and yellow clay occur.

The lignites belonging to this stage, and from which these beds derive their name, occur widely spread throughout the whole area; they lie in beds of varying thickness, from two to four feet being most common, although deposits of six, nine and ten feet are by no means of rare occurrence. Beds of even greater thickness have been reported as being found in well-borings. The actual number of lignite beds existing in these deposits is not known. Six have been recorded as underlying each other at distances varying from 2 to 120 feet.

Throughout the Texas area the lignite beds everywhere form conspicuous objects in this formation but no attempts have yet been made to correlate them with each other.

Entering the State from northwestern Louisiana and southwestern Arkansas the Wilcox is found overlapping the Midway and resting directly on the Cretaceous. From the first appearance of the uncovered Midway in Hopkins county the contact between the Midway and Wilcox is found along a line running southwesterly through Rains, Van Zandt, Harrison, Navarro, Freestone, and Limestone counties to the Brazos. South of the Brazos the Wilcox overlaps the Midway in places to the Colorado river, beyond which a narrow belt of Midway is usually found between it and the Cretaceous. The broad expanse of the Wilcox exposure in eastern Texas is narrowed to 15 miles where it crosses the Brazos and to 10 miles on the Colorado.

In the northeastern portion of the State the Lignitic is still covered in interstream areas by uneroded areas of the Claiborne, the main body of which formation is found overlying it to the south.

In thickness these beds vary from 800 to 1200 feet.

The areas in east Texas in which the Lignitic beds form the surface material are usually comparatively level or only gently rounded in contour. This slight relief does not afford very good opportunities for detailed study of the different beds comprising it and it is only from observations made over a rather wide field and comparison with well logs that a definite idea can be obtained regarding them.

Kennedy, in his study of the iron ore deposits of northeastern Texas, examined in detail Cass, Marion, Gregg and Harrison counties. His generalized section of the Lignitic beds of Harrison county gives us perhaps our clearest knowledge of the beds in the eastern portion of the State[8].

The lowest beds of this section are composed principally of stiff black micaceous sands and clay containing numerous deposits of iron pyrites. In the deep well at Marshall these sands and clays had a reported thickness of 953 feet and rested on blue limestone which was in all probability a boulder such as those seen in similar deposits in the Sabine river section and which are found at base of formation in wells drilled in the Caddo oil fields east of this.

Overlying this are yellow and white sands; micaceous, black sand or clayey sand, irregularly laminated and with interbedded lignites; black clay passing upward into blue clays interbedded with lignite, the series having a total thickness of 100 feet.

Vaughan's section at Port Caddo Landing[9] east of Marshall shows below the Queen City beds 55 or 60 feet of interbedded grayish sands and bluish clays with one small lignite seam, underlain by low-grade lignite associated with iron ore, ferruginous sandstone and calcareous concretions. The concretions, when broken, showed fossil leaves which were identified by Knowlton. These beds correspond to part of the upper member of Kennedy's section.

Harris[10] states that the hard boulders of the Wilcox are of common occurrence in Caddo well sections. and as they are not often found below 450 feet, the dividing line between the Wilcox and Midway in that field has been drawn at that depth.

To the westward as we near the old shore line our records show a much larger admixture of sands and more lignite. The section of the well at Mineola, which is given in full in the Third Annual Report of the Geological Survey of Texas, page 82, shows below the upper gray water-bearing sand, nearly 600 feet of

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[8]For details of surface exposures of these beds in northeastern Texas reference may be made to Kennedy's reports on Cass, Marion, Gregg and Harrison counties in Second Annual Rept. Geol. Sur. Texas, Robertson County, Fourth Annual Report, and The Eocene Tertiary east of Brazos river. Proc. Ac. Nat. Sc. Phila. 1895, and Dumble's Report on Brown Coal and Lignite.

[9]Am. Geologist, vol. 16, 1895, p. 308.

[10]U. S. G. S. Bul. 429, p. 121.

interbedded sands and clays, at times micaceous or pyritiferous with beds of lignite and some limestone (probably in form of boulders).

A somewhat different condition is noted in the section of the deep well at Sulphur Springs as given by Gordon[11]. This well passed through 810 feet of materials assigned by him to the Wilcox, and 324 feet of Midway, into the underlying Cretaceous. The beds referred to the Wilcox in this section are apparently more nearly akin to the Marine phase of the Wilcox than to the Lignitic. By far the greater part are shales with which are interbedded some clays and sands and two small seams or boulders of limestone. Toward the lower portion of the section the shales carry fossils and in the black shale with iron concretions, which forms the basal member of the supposed Wilcox, *Venericardia planicosta* was found. The other fossils are not enumerated and it is possible that the line between Midway and Wilcox should be drawn at 684 feet, or below the second limestone and the fossiliferous material referred to Midway. This would be more in accord with the general Lignitic section.

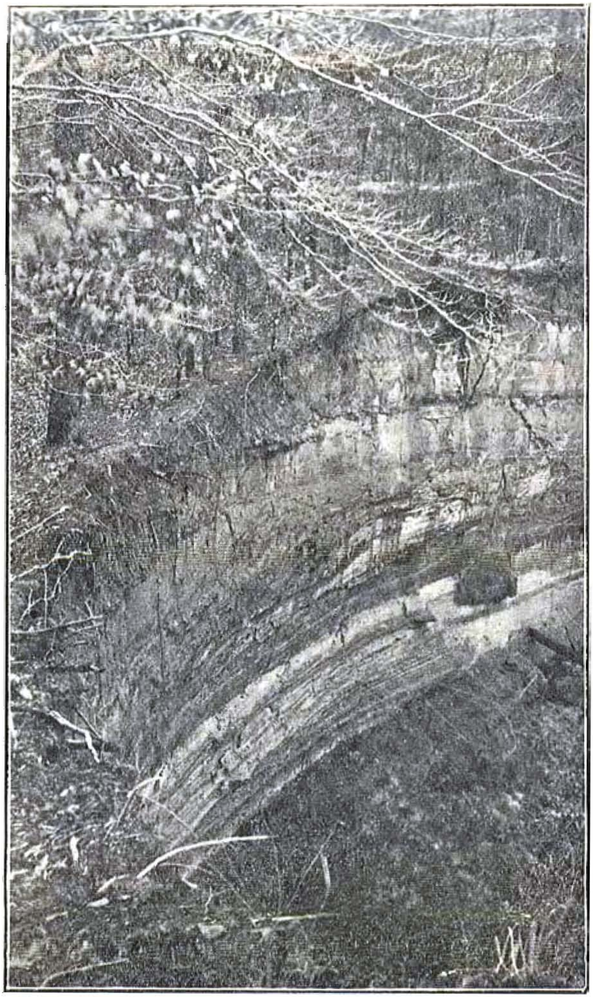
BRAZOS RIVER SECTION.

A contact between the Wilcox and Midway is found at Oyster Bluff of Penrose on the Brazos River, better known as Smiley's Bluff, two miles above the mouth of Pond Creek. Kennedy's section shows at the base 9 feet of blue and gray sand, partly laminated, overlain by a thin bed of hard fossiliferous limestone. Four feet of laminated clay immediately overlying this was filled with Midway fossils including *Cerithium penrosei* Har., *Pseudoliva ostrarupis* Harris, *Leda milamensis* Har, etc.

This bed forms the top of the Midway and the basal Wilcox overlying it consists of ten feet of thinly stratified yellowish gray clay, sand and blue clay with occasional rounded boulders of calcareous sandstone.

Good sections of the Lignitic can be seen on the Brazos below this point at the various shoals and bluffs. Among them may be

[11]U. S. G. S. Water-Supply Paper 276.



WILCOX FORMATION.
Patroon Bayou, Sabine County.

mentioned Bee or Black shoals and Calvert Bluff. In all these sections the formation is shown to be more sandy than in East Texas and the prominence of the lignite beds is striking.

The section at Gibson gin near Calvert shows this clearly:

1.	Surface soil and gray and brown sand	25 ft.
2.	Alternate strata of blue clay and calcareous sandstone	42 ft.
3.	Brown coal	2 ft.
4.	Bluish-gray sand, blue clay and calcareous sandstones	46 ft.
5.	Brown coal	1½ ft.
6.	Bluish gray sand	23½ ft.
7.	Brown coal	5 ft.
8.	Blue sands and sandstones	55 ft.
9.	Brown coal	2 ft.
10.	Red clay	8 ft.
11.	Bluish-gray calcareous sandstones and blue clay	22 ft.
12.	Brown coal	2 ft.
13.	Blue sand	76 ft.
14.	Brown coal	10 ft.
15.	Blue sand with thin seams of sandstone	265 ft.

As an indication of the thickness of the beds in this section it may be stated that a well at Franklin obtains its water supply from these beds and is 1208 feet deep. The well is wholly in Lignitic strata.

MAPPED AREA

In the region mapped the materials of the Lignitic are at the surface over the northern parts of Sabine and San Augustine counties, all of Shelby and Panola and the eastern portions of Nacogdoches and Rusk, besides a broad belt along the western border.

For the most part this country is gently rolling. The ridges are of moderate elevation and their summits are usually covered with remnantal patches of the ferruginous sandstone or iron ores of the Claiborne, or with the iron conglomerate derived from them. Therefore, throughout this area it is usually only the lower portons of the ridges and the valleys which yield exposures of the Lignitic. The beds are similar to those of the upper portion of the formation as described by Kennedy: Carbonaceous clays and sands with beds of lignite.

The section along the Sabine River has already been given. The last outcrops described which are positively Wilcox are those of the Sabinetown bluff and a small exposure about one mile farther down the river.

The final appearance of the Wilcox consists of four feet of the fossiliferous greensand of the bluff section overlain by brown and chocolate laminated clay.

SANTA FE RAILWAY SECTION

For comparison with the Sabine River section, the uplands section along the Santa Fe railway from Duff Siding to Flat Fork as made by Baker may be given:

1. Thin-bedded grayish-brown sands of the Wilcox, containing limonite-stained layers overlain by mottled Lafayette.
2. Very much decomposed oolitic nodular greensand of rusty brown color, blue-black on fracture planes.
3. Chocolate-gray sandy clay, carbonaceous, thinly laminated, seamed with limonite-stained and cemented streaks, which run along cracks and joints at various angles with the bedding. The weathered surface is grayish or brownish, depending on the amount of iron present.
4. Shaly chocolate-brown and grayish carbonaceous clay.
5. Coarse sand, cross-bedded, angular to subangular, containing specks of greensand and greensand in thin layers. It oxidizes to various shades of brown and reddish brown.
6. Laminated sands and clays, generally gray or brownish in color and containing thin layers of hard material limonite-stained and cemented. A portion of the clay is light yellowish-green in color and quite plastic. In places there is a grayish mottling. It weathers a light greenish brown with a cracked earthy surface or rounded slopes. The maximum thickness is 10 ft., most of which is laminated chocolate carbonaceous clay.
7. Laminated clayey sand, mainly gray in color, though much of it is stained with limonite.
8. Dark blackish-brown carbonaceous laminated clay, above which lies 1½ feet of chocolate-brown clay.
9. Greenish-gray thinly laminated sand.
10. Thin layers of cross-bedded coarse sand interbedded with grayish sandy clays. The thin layers of clay have a wave-like bedding. The maximum thickness is 6 ft. The clays are cream-colored sandy and loose, weathering into miniature badlands.

11. Surficial light yellowish-red mantle rock, 2 to 3 ft. The weathered Wilcox resembles the Lafayette even in the mottling, but it does not contain the pebbles.*
12. Thinly laminated brownish and grayish sand grading downward into .... 5 ft.
13. Light brownish-drab shelly-bedded clay fine-grained sand, blotched with yellow sulphur.......................... 5 ft.

Local unconformity with irregular contact:

14. Light yellowish-brown medium-grained cross-bedded sand with its upper surface exceedingly irregular. 2 to 4 ft.
15. Laminated brown clayey sands. The clays quite carbonaceous, ranging in color from chocolate-brown to black and laminated enough to be called a shale. It is probably never entirely free from sand and there are partings of brown sand layers and thin plate-like beds cemented by iron oxide.
16. Dark brown carbonaceous shaly clay with large crystals of selenite. This clay is thinly laminated.
17. Much cross-bedded light brown sands capped by 3 feet of light brick-red soil, which maintains its average depth irrespective of the surface irregularities. It is simply weathered Wilcox, and contains no Lafayette gravels Some of the Wilcox sand layers are indurated into a medium-hard sandstone. Some of the sandstone is in very thin plates in which the cementing material is most generally iron oxide. Other indurated aggregations are rather irregular in shape and have for the most part a thin "shelly" irregular bedding. The sand grains are medium-coarse and sub-angular. Mica is present and probably also magnetite.

    At the south end of this cut the cross-bedding gives way to a persistent southeastward dip of 7 or 8 degrees, which may, however, be a depositional dip. Within this general dip is minor cross-bedding between the major layers. Some of the sand beds are massive, but most of them are very thin-bedded.
18. The cut at Flat Fork exposes at a maximum 15 ft. of cross-

*It is notable that we see no undoubted Lafayette between Tenaha and Center. These lower lying areas have undergone more post-Lafayette erosion than the ridges of more resistant formations, and the Lafayette, in all probability once present, has been almost entirely removed. The red surficial weathering of mantle rock suggests that the formation of the red color in the Lafayette may have taken place subsequent to its deposition. At any rate, the red coloration of this weathered zone of the Wilcox is of recent date.

> bedded clayey sands, generally light yellowish-brown in color, with some limonite concretions and the more clayey portions weathering into semi-badlands, streaked and mottled with light gray. There are also fragments of silicified wood and thin-bedded lenticular and laminated limonitic layers. The sand is micaceous, thin-bedded, and rather light-grained. The surface soil of the region traversed is bright brick-red in color.
>
> In the vicinity of the 145th Mile Post some of the surficial sandy clay is light cream-colored on the surface. A feature here is the presence of irregularly shaped "pipe" concretions averaging about one inch in diameter, solid, and composed of clear quartz sand firmly cemented by calcium carbonate. The exterior surfaces of these are irregular and cavernous.

The deeper or lower beds of the Wilcox are known in this vicinity from a well drilled just north of Flat Fork, which passed through the Lignitic and Midway and well down into the Upper Cretaceous.

The log of that portion of the well which belongs to the Lignitic shows simply alterations of sands and clays with occasional boulders or shells of limestone and a single seam of lignite. These beds have a thickness of 850 feet. No sign of fossils was found in this series.

The underlying Midway beds are 230 feet thick.

In all this section, therefore, there is nothing similar to the fossiliferous greensand beds found in the river valley only 20 miles east of it, although the two sections quite surely carry beds of like age.

FOSSILS

From Berry's reports on plant-bearing outcrops of the Wilcox Port Caddo Landing gave the following species as revised:

Apocynophyllum tabellarum (?)
Asplenium eolignitica
Canna eocenica
Cinnamomum affine
Combretum ovalis
Dryophyllum moori
Ficus planicostata maxima
Ficus schimperi
Ficus vaughani

Grewiopsis tennesseensis
Meniphylloides ettingshauseni
Metopium wilcoxianum
Nectandra lancifolia
Nectandra sp.
Oreodaphne obtusifolia
Persea longipetiolatum
Sabalites grayanus
Terminalia hilgardiana.

He states:

"None of these are species peculiar to the Ackerman formation or lower Wilcox of the eastern Gulf region; 3 occur in the Ackerman formation and the Holly Springs sand; 2 are known only from the Holly Springs sand; 1 is found in the Ackerman formation and Holly Springs sand as well as in post-Wilcox deposits; 1, the characteristic *Meniphylloides ettingshauseni*, is peculiar to the Grenada formation or uppermost Wilcox. The conclusion is inevitable that the deposits at Port Caddo are of late Wilcox age.

"From the Sabine river leaf remains are reported from calcareous concretions just below Harts Bluff on the Louisiana bank. A short distance below Hamilton and just above Chambers Ferry similar materials carry leaf impressions, and a small amount of rather poor material was collected. This was deposited at the New York Botanical Garden, where I have studied it. The only identifiable forms are *Grewiopsis tennesseensis* Berry, which also occurs south of Grand Junction, Tenn., and *Leguminosites? arachioides* Lesquereux of the Denver and Fort Union formations of the Rocky Mountain province. This outcrop is 7 or 8 miles along the dip above Sabinetown, where, according to Harris, the marine fossils indicate the Bashi formation. The fossil plants, though too few for precise correlation, indicate a horizon not older and probably younger than the Holly Springs sand or middle Wilcox of Mississippi".*

"Alexander Deussen discovered an outcrop containing Wilcox plants on Calaveras Creek about 500 yards east of the San Antonio & Aransas Pass Railway in Wilson county, Texas.

"The small clay lens at the base of the section contains much

*U. S. G. S. Prof. paper No. 9 p. 58.

comminuted vegetable matter and rather poorly preserved impressions of leaves, among which the following are recognizable:

Bumelia pseudotenax (?)
Calycites ostryaformis
Cassia bentonensis
Diospyros brachysepala (?)
Ficus vaughani
Gleditsiophyllum eocenicum
Mespilodaphne eolignitica
Rhamnites berchemiaformis
Sabalites grayanus
Sapindus bentonensis
Sapindus linearifolius
Terminalia lesleyana (?)

Of the 12 species 2 are new and therefore without stratigraphic significance. In comparison with the floras of the Wilcox of the eastern Gulf area it may be noted that none of the species from Calaveras Creek are confined to the Ackerman formation or lower Wilcox. Three species are confined to the Ackerman formation and Holly Springs sand; 1 to the Holly Springs sand; and 6 to the Holly Springs sand and Grenada formation. It seems evident that the outcrop is of about the same age as those at Benton and Malvern in Arkansas, or somewhat younger, and is certainly not older than the Holly Springs sand or middle Wilcox of Mississippi.

CLOSE OF LOWER EOCENE

The Lower Eocene closed with the deposition of the last sediments of Wilcox age. As the waters withdrew, a broad fringe of new land was added, not only to the Texas coast, but throughout the entire Mississippi embayment area. The proofs of this interval of emergence are found in the physical evidence of erosion of the Wilcox beds prior to the deposition of the basal beds of the Middle Eocene. This is known at several localities in Georgia as well as in the Texas area. It is further indicated by the fact that there are localities in which the Queen City beds are missing, probably from non-deposition on areas of higher ground and the Mt. Selman beds rest directly upon the Lignitic.

Further evidence of it is found by Berry[1] in the littoral character of the basal beds of the Claiborne (Queen City-Carrizo in Texas and Tallahatta or Buhrstone in Georgia), in the great overlap of the Claiborne, and in the vast changes which took place at that time in the fauna and flora of the region.

It is probable that the withdrawal of the sea at the close of the Lower Eocene and the consequent emergence as land of the area of the coastal marshes was accompanied by some folding or by renewal of the upward movement of the Cretaceous-Tertiary interval. This is indicated by the conditions surrounding the various domes of northeastern Texas and western Louisiana.

The evidence is that the deposits of the Midway failed to cover some if not all of these domes or islands but that it did cover the lower-lying Sabine Peninsula. The Lignitic, on the contrary, seems to have mantled them all and their existence today as Cretaceous islands in this Tertiary terrain is due to the erosion which has removed this mantle and brought the older rocks again to light.

Away from the islands the Lignitic strata have usually a very slight dip but on their flanks the Lignitic dips away at considerable angles although somewhat less than those of the underlying Cretaceous. In the immediate vicinity of the mound these dips may be as great as 60 degrees but this rapidly decreases with distance until within two miles or less the dip has again become normal.

Just how great these movements were is not yet known but it is thought most probable that the dome materials were forced upward through or into the overlying Wilcox at this time and prior to the deposition of Lower Claiborne. This may represent only a part of the movement which has taken place since the initial elevation at the close of the Cretaceous as there is evidence of other movements of less extent at still later date.

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[1]Prof. Paper, U. S. G. S. No. 91, p. 37.

Chapter V

EOCENE—CONTINUED

CLAIBORNE

Following the interval of elevation and erosion of the Wilcox the seas again transgressed the land area, and in them there was deposited a series of formations "which contain the most persistent and widely developed marine beds of the Coastal Plain", and which have been found to extend from Maryland to the Tamaulipas mountains in Mexico. These are known as the Claiborne Group.

This group, which includes all of the deposits of the Middle Eocene, takes its name from the bluff at Claiborne on the Alabama river, where some of its beds are extremely rich in well preserved fossils. These were first studied by Lea and Conrad, who established the Eocene age of the fauna.

The section at the type locality has at the base nearly three hundred feet of unfossiliferous sands and sandstones which were originally called the Buhrstone, but later were given the local name of Tallahatta sands. The beds overlying them and constituting the fossiliferous portion of the exposure have a thickness of 150 feet. This has been separated into two portions and each of these again subdivided. Immediately overlying the Tallahatta sands are the Lisbon beds, followed by the Ostrea sellaeformis beds, the three divisions forming the Lower Claiborne. The two upper divisions, known as the Claiborne or Gosport sands, and the White Bluff marl which overlies it, are the Upper Claiborne.

The surface exposure of the Claiborne in Alabama rarely exceeds 15 miles in width.

In Texas the narrowest part of the normal exposure of the Claiborne is found on the Colorado river and has a width of twenty-five miles. In eastern Texas, on the Sabine the entire exposure is less than 10 miles in width, on the Neches river it has a width of 90 miles, and along the Rio Grande, which crosses the formation obliquely to its dip, the belt has an exposure of 150 miles.

At Claiborne Bluff the fossiliferous beds are of marine origin. In the Texas region the representatives of the Lower Claiborne have been expanded into formations showing alternations of marine and swamp or lagunal conditions, but the fact that they are all correlative of the Claiborne is fully proven by the identity of the great numbers of fossils they contain.

To distinguish these formations the following names have been given, beginning with the bottom:

Carrizo, called Queen City beds in East Texas, and being the lithologic and stratigraphic correlative of the Tallahatta.

Marine, a subgroup which includes the Mount Selman, Cook's Mountain and Nacogdoches formations, and which contains not only the most highly fossiliferous of the beds, but which is especially valuable for its deposits of iron ores.

Yegua. This formation, largely palustrine and lignitic east of the Nueces, becomes partly marine in southwestern Texas.

Fayette. Deposits of white sands and clays with plant remains east of the Colorado, but partly marine on the Rio Grande.

Frio. Clays and sands largely palustrine in origin, but with some marine sediments[1].

Deposition and Character

The Claiborne sea coming in from the south and east covered all of east Texas northward to Red river and westward beyond the line of the Cretaceous islands, which it probably covered, as it certainly covered a part of the Sabine Peninsula to the eastward. It thus extended over by far the greater part of the Lignitic land area of northeastern Texas and northwestern Louisiana.[2]

[1]Of the few marine fossils found by us in the Frio there were none characteristic of beds later than the Lower Claiborne and it was accordingly referred to that group. There is a possibility, however, that further collections may make it necessary to change this reference and that the Frio may belong to the Upper rather than the Middle Eocene.

[2]Harris suggests that it is probable that De Soto parish in Louisiana and Shelby, Panola and Harrison counties in Texas may have constituted an island in Claiborne time. U. S. G. S. Bulletin No. 429, p. 121.

The earliest sediments laid down in the Claiborne sea were the sands and clays of the Queen City beds. These were followed by the great body of greensands, sands and clays of the Marine. The deposits of both of these stages probably extended over this entire area, and the broad exposure of the Lignitic now found at the surface in this region is due to the fact that so large a portion of these overlying beds has been removed by erosion.

While marine conditions prevailed in the Texas area and over the Sabine Peninsula to or beyond its eastern boundary, they were there replaced, in part at least, by palustrine conditions somewhat similar to those of the preceding Lignitic. This resulted in a great embayment area bounded on the east by the Peninsula and on the west by the Islands and extending from Red river on the north southward to the 32d Parallel, or below, in which the deposits of the Marine substage present a marked difference from their continuations eastward or southwestward.

The whole of the sediments of this substage were characterized by a considerable percentage of greensand and other iron-bearing minerals, the decomposition of which gave rise to some lean iron ore, but principally to ferruginous sandstones. It was within this embayment, however, that the greater quantities of these iron-bearing materials were deposited and where they were decomposed, altered, recombined and segregated into the very extensive beds of workable iron ores which make this preeminently the iron ore region of the State. Practically all deposits of workable brown ores are confined within the boundaries of this embayment.

Here and there, within the Marine, lignitic conditions existed for a short time, but probably 700 to 800 feet of marine sediments were laid down before the shallowing seas finally brought back the sea marshes and lagoons similar to those of the Wilcox.

This marked the beginning of the Yegua, the deposits of which form a belt along the Marine front, but do not extend up into the embayment. The Yegua in this area becomes more and more sandy toward the top and finally gives way to the white sands and joint clays of the Fayette, a lagunal of fresh water deposit with fossil palms and other plants. This completed the cycle of the Claiborne or Middle Eocene.

There is evidence here of local movements during the Lower Claiborne deposition and of more general movement at its close.

Distribution

From its very narrow exposure on the Sabine, the northern boundary of the Claiborne strikes northwestward, passing east of San Augustine, Nacogdoches and Henderson to the eastern line of Smith county. It there turns westward to Athens, then south to the Trinity river west of Palestine, and from its crossing of that river southwestward to the Brazos between Calvert and Hearne. To the northeast of this main body there are remnantal bodies of considerable area in Gregg, Harrison, Upshur, Marion, Morris, and Cass counties and there may be other outliers in the Lignitic area which have not yet been mapped.

From the Brazos the southwestern course of the northern boundary is continued to the Atascosa river north of Floresville in Wilson county, where it turns west to Zavalla county and then south to the Rio Grande.

Its southern border, which is its contact line with the Jackson, is more regular and more nearly parallel to the present Gulf coast.

Topography

Between the Trinity and the Sabine the country in which the Marine forms the surface varies in elevation from two hundred to six hundred feet above the Gulf and sometimes, though rarely, the hill tops are seven hundred feet or more in height.

The highest points in the region, like Mount Selman and Gent Mountain, in Cherokee county, Hynson's Mountain, in Harrison county, and many others, have their summits capped by a horizontal, or almost horizontal, bed of iron ore or sandstone, and to this covering they owe their existence, it having protected them from the erosion which has worn down the surrounding country. It has also given rise to a striking topography very much like that of the western lava plains on a small scale. The hills, locally called "mountains," sometimes occur as flat-topped hills—the "butte" and "mesa" of the west—and at others spread out in broad plateaus, sometimes covering an area of twenty or thirty square miles, deeply cut by the steep sided canyons, and often showing an almost perpendicular slope. Such regions afford a beautiful upland country, with a soil far different from the surrounding lowlands, and a climate excellently adapted to the cultivation of fruit. Gent Mountain, in the western part of Cherokee county, is a beautiful example of this plateau country. It comprises over twenty square miles of area, is largely underlaid by iron ore, capped by a sandy soil, and thickly covered with oak and hickory. From its summit, looking south and west, can be seen the lowlands of the Neches river bottom, and beyond, the rolling country of Anderson county. To the north can be seen Gray's mountain, Grimes mountain, Ragsdale mountain, and many other iron-clad hills. To the east looms up a similar range, constituting the iron ore plateau of Rusk and New Birmingham.[1]

This bold topography, however, is practically limited on the west by the Trinity river. Beyond that stream the heavy deposits of iron are unknown, and unless beds of ferruginous sandstones occur, there is nothing to bring about such differences of elevation as those found between the Trinity and the Sabine. Between the Trinity and the Brazos, therefore, the Marine beds, while hilly, are not so rugged as further east.

Correlation With Other Areas

The Claiborne is the most highly fossiliferous deposit of the Texas Tertiary. The marine fossils occur in quantities very generally distributed through the area and may of them in excellent preservation. Large collections were made at various localities by the Geological Survey of Texas and these were carefully studied by Harris, who prepared a full report on them. Unfortunately this failed of publication, but his lists were preserved and are now at the University of Texas. In this study he had for comparison collections made by himself at the type

[1]R. A. F. Penrose, Jr. Geol. Surv. Tex., 1st Ann. Rept. pp. 8, 9.

localities of Lower and Upper Claiborne, Jackson and Vicksburg, and he visited Philadelphia and Washington for study of type specimens in the collections there. Therefore, when our collections were sufficient to decide his reference should hold.

As the writer understands the correlation made by Harris on the basis of the marine faunas found in our Texas beds, all of our Claiborne up to and including the Fayette sands belong to the Lower Claiborne series of Alabama and nothing he found in the marine fauna indicated an Upper Claiborne age for any of these beds.

Berry, however, considers the plants of the Yegua the equivalent of those found in the Gosport and of Upper Claiborne age.

CARRIZO

NAME

Owen described a large area of sands occurring in Maverick and Dimmit counties and found in typical development around Carrizo Springs.[1]

CHARACTER

These comprise sandstones of varying color, texture and thickness. The prevailing color is a grayish-yellow, weathering light-brown. Some of the beds are white when freshly broken. In texture they range from fairly hard sandstone, lying in beds of two to four feet or more in thickness, to thin slabby, fairly soft and almost shaly structure. No fossils except a few plant remains have been found in them.

These sands have a broad area of outcrop on the Rio Grande, where at times they overlap the entire Lower Eocene and stretch northward over the later Cretaceous. In this region not only is their unconformity evidenced by this overlap, but by actual erosion of the underlying Wilcox as well.

The Queen City beds[2] of East Texas are the eastern equivalent if not the direct extension, of the Carrizo. They are well

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[1]Geol. Sur. Tex. First Rept. Progress, p. 70.

[2]Kennedy, Third Ann. Rept. Geol. Sur. Texas p. 50.

developed in the vicinity of Queen City in Cass County, where they show a thickness of 65 feet. They comprise a series of laminated or thinly stratified white and red sands and sandy clays frequenty merging into one another and forming a mottled sandy clay or clayey sand.

Where the surface contact has been observed between the Queen City and Wilcox no erosional unconformity has been seen, but evidence of erosion is found in the occurrence of water-worn boulders of clay and of laminated clay and sand derived from the Wilcox in the basal member of the Queen City as at Port Caddo Landing,[1] and also in the fact that at times the Queen City is missing and the contact is between the Lignitic and Mount Selman.

The deposits are of littoral character and, so far as known, contain no organic remains.

The beds are economically important, because they form one of the best water-bearing horizons of the region underlain by them, as the water is of excellent quality and free from mineral matter.

AREA OF OUTCROP

Because of the apparent conformity between the two, the Queen City was for a long time considered the upper portion of the Wilcox formation, and is so described in most of the reports on East Texas. On this account, the areas of outcrop of the Queen City have not been separately outlined.

The beds occur on the surface at various localities in Cass county. In Marion county, near Jefferson and in Harrison county, the Queen City appears at numerous localities immediately underlying the yellowish-brown sandstone here forming the base of the Marine. The same beds are found at Willow Switch near Longview, at Gladewater in Gregg county, in the vicinity of Tyler and at Wilkins Mill in Upshur county.

Kennedy states that the Queen City in Harrison takes on a more argillaceous character than in Cass, and the individual beds are heavier, the white beds at times attaining a thickness of two or three and occasionally of even five and six feet. When

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[1]Vaughan, T. W. Am. Geologist, Vol. 16, p. 308.

these beds outcrop along water courses the stream bed and banks are generally strewn with pellets of pure white clay ranging from the size of a pea to that of an egg. The beds are variable in thickness and in some sections seem to be absent and the Marine beds are found in direct contact with the Wilcox. This is exemplified in Kennedy's Mt. Selman section, which seems to show the base of the Mt. Selman resting upon 2 feet of worked-over material of the Lignitic and this on lignitic clays.

Four miles north and one mile west of San Augustine there is another section exposed which may indicate a similar condition.

1. Streaked light green and yellowish brown clayey sand showing little structure, but containing large concretions of limestone, the same being exceedingly hard and containing some fossils .... 9 ft.
2. Dark blue or blackish green clayey sand weathering dark brown. Contains some fossils and abundant small pyrite crystals. Structureless at bottom, but toward top is poorly laminated. Locally contains lenses of laminated chocolate colored clay, pieces of lignitized wood and green colored siliceous concretions of iron carbonate which weather reddish-brown. Locally ferruginous concretions and also considerable gypsum are to be noted ....8 to 10 ft.
3. Streaked light brown and chocolate colored somewhat clayey sand containing numerous minute flakes of selenite. This sand weathers light brown to yellowish brown and locally yellowish patches resembling sulphur occur. In places the sands are carbonaceous as evidenced by small angular fragments of lignitized wood. This member is for the most part structureless, but in places it shows poor wavy bedding ....15 ft.

It is very probable that between No. 2 and No. 3 of the above secton that we have the contact between the Lignitic and Marine. The lower member here is certainly Lignitic.

In the section made along the Houston. East & West Texas Railway between Garrison and Nacogdoches the Queen City was not recognized. This, however, may have been simply because of its comparative thinness and lack of exposures.

On the Sabine river the final appearance of undoubted Wilcox, as has been stated, is about one mile below Sabinetown bluff. The first beds showing fossils of Claiborne age are found at Bayou Negreet. The general course of the river is apparently very nearly along the strike of the beds, so that the distance between the two, stratigraphically, is rather small. Nothing was observed here to show the possibility of the occurrence of the Queen City between them, and it is probably not exposed on the river. It occurs, however, in the interstream areas.

At Duff siding near Mile Post 128 on the Santa Fe Railway, the Queen City is made up of thinly laminated sands with separate laminae usually less than ½ inch in thickness. They are alternately striped light gray, stained brown and yellow by limonite, and pink. The material is mainly fine sand with a very few thin streaks of blue-gray clay. The bedding is not parallel, as layers pinch out or enlarge and one bed locally transgressed over the planes of several others. The Queen City here is unconformably overlain by the Lafayette.

These beds also outcrop apparently in the middle reaches of Low's creek.

In Leon county Baker found the Queen City beds well exposed north of Flynn on the Houston & Texas Central Railroad, where the top of the grade is a region of sand hollows and dunes.

Marine

This term was used by Kennedy to designate the beds of marine origin which are found overlying the Queen City and underlying the Yegua. They form the uppermost division of Penrose's Timber Belt or Sabine River beds and are the iron ore bearing beds of east Texas. In this area they have a thickness of 700 feet or over.

The Marine comprises an extensive series of greensands, greensand marls more or less altered and containing large quantities of iron carbonates and limonite, glauconitic sandstones and clays, green fossiliferous clays, black and yellow clays with limy concretions, brown and yellow sand, occasional deposits of black sand containing gypsum crystals, pyrite, and at wide intervals small deposits or thin seams of lignite. The prevailing deposits are greensand in their several characters.

The deposits are largely of marine origin. Even the beds of lignite do not always indicate such marsh conditions as those of the Lignitic, since the largest deposit known in the entire formation, which is found north of Laredo, is a true cannel coal and was deposited along a sea beach.

Kennedy's division of the Marine into two phases or formations was based largely on lithologic grounds.

The lower or Mount Selman is generally heavier bedded and made up for the most part of dark green and brown sands and sandstones, the iron carbonates and limonite being distributed through the beds or occurring as thin seams. While fossiliferous to some extent the fossils are much fewer than in the upper phase and occur almost altogether in the form of casts. The upper or Cook's Mountain is to a great extent looser sands and clays with heavy beds of laminated brown ore. It contains a large and beautifully preserved fauna.

While this lithological difference may not hold good at all points and while even in this area it may be difficult to draw a definite line between the two, the great paucity of life in the lower beds is in marked contrast with the vast assemblages of forms in the upper, and the leaching out of the shell material in the lower beds is an added characteristic.

To these phases a third has now been added to include the transition between the Cook's Mountain and the Yegua. These will be called the Nacogdoches beds.

While these phases are recognized, owing to the difficulty of making a satisfactory division of them in the area mapped, they will not be treated separately in the description.

MT. SELMAN

Name and Occurrence.—The section along the St. Louis & Southwestern Railway between Bullard and Jacksonville is quite typical of the basal portion of the Marine, and Kennedy used Mount Selman, the name of the town about the center of the section to designate it.

The Mount Selman, although occurring almost everywhere below the Cook's Mountain, is the only portion of the Marine found north of the Sabine river, and it appears there now only in remnantal areas of a former widespread cover. It forms the tops of the table lands and occurs in isolated patches covering small hills and is underlain by the Queen City. South of the Sabine it is found in Rusk, Cherokee, Smith, Henderson and Anderson counties and is overlain and succeeded to the south by the Cook's Mountain.

Character and Relation to Underlying Beds.—The Mount Selman comprises brown sands, blue clays, greensands, glauconitic sandstones, and nodular and laminated iron ores.

Throughout their extent in east Texas the beds are iron-bearing, but the workable deposits, as now known, are confined to Cass, Marion, Gregg, Harrison and Upshur counties.

The ores comprise both brown ore or limonite and iron carbonate. These occur in nodular or geodal forms in the glauconitic sands, in thin lenses and irregular ledges, as more or less honeycombed thin sheets and layers, and in irregular masses.

Fossils occur but sparingly and usually as casts only, the material of the shell having been entirely removed or replaced. At the base and throughout the beds the form most generally distributed is *Venericardia planicosta,* Lam., but other bivalve shells occur and shark teeth, usually of small size, are also found.

Where the Mount Selman is found overlying the Queen City there is usually found a ferruginous parting ranging from one inch to a foot and a half in thickness. This parting is generally present in some one of its may forms of gravel, ferruginous sandstone, bands or fragments of laminated ore. This is the basal bed of the Marine in northeast Texas.

When the Queen City is lacking and the Mt. Selman rests directly on the Lignitic, this ferruginous bed is not found and the basal bed is usually a greensand or dark clayey sand with pyrite and some casts of fossils.

In the Rio Grande area the Carrizo is always present and apparently grades upward into the base of the Marine with no ferruginous parting such as is found at the Queen City-Marine contact.

COOK'S MOUNTAIN

Name and Occurrence.—Cook's Mountain lies two miles west of Crockett and furnishes such an excellent section of a part of the upper member of the Marine that Kennedy applied this name to it. The Mount Selman and Cook's Mountain divisions grade into each other so imperceptibly that a line of separation would be but an arbitrary one. Kennedy used the state of preservation and condition of inclosed fossils in an attempt to indicate approximately the limits which might be assigned to each. On this basis he placed the northern border of the Cook's Mountain along a line beginning near Mount Enterprise in Rusk county, striking west and passing south of Jacksonville and then southwest by Palestine, Centerville and Franklin to the Brazos river about where the north line of Burleson county begins. From this rather indefinite boundary the Cook's Mountain outcrop extends southward to the Yegua contact.

Character.—The prevailing deposits of the Cook's Mountain are the greensands in their various characters, but with these there are interbedded black and gray sandy clays, black and yellow clays with calcareous concretions, brown sands and black sands with gypsum crystals. They also carry large quantities of ferruginous material occurring principally as heavy beds of laminated bown ore.

The beds are highly fossiliferous and the fossils occur in well preserved condition. Some two hundred species have already been determined from the beds, but it is not probable that all have been identified even yet.

NACOGDOCHES

Under this name are grouped the transitional beds which lie between the well recognized Cook's Mountain greensands and the massive gypsiferous clays of the Yegua. They are fully described in the section along the Houston, East & West Texas Railway. The top of the series is placed where the last marine fossils are found. Some fossil plants are also found in it.

SABINE RIVER SECTION

Harris describes the beds at the mouth of Low's creek as follows[1]:

"One and one-half miles to the south of Sabinetown bluff in the bed of Low's creek at the ford, Lower Claiborne fossils are found.

[1]Geol. Sur. La. 1899. p. 67.

But beneath the same in what is presumably Lignitic material, a vast number of *Pecten cornuus* occur. The beds at the water-mill are of this lower layer. They are replete with oolitic iron ore, greenish when freshly exposed, reddish when weathered.

About a mile above this point there is an exposure of fossiliferous and pyritiferous greensand with many soft and poorly preserved fossils, most of which are lamellibranchs. This must be just below Veatch's locality 18, which he states is the last appearance of the Wilcox on the river and resembles the section of his No. 19, of which he says:[1]

"*Low Creek beds.* The peculiar beds described from Low's creek, near Sabinetown, in 1899 and referred provisionally to the Lignitic show a much better development on the Sabine near the mouth of Low's creek at stations 19 and 20. The beds here furnish a much more complete fauna, especially at the Negreet outcrop, and Harris is inclined to regard the material as having a decided Lower Claiborne aspect. Directly above it is a well marked Lower Claiborne fauna and the position of these beds at or near the line of parting between the Lower Claiborne and Lignitic is fully proven.

Section at 19.

	Feet	In.
1. Gray sand	5	
2. Gray and yellow unstratified clay containing ferruginous gravel. Beds 1 and 2 lie unconformably on those below	25	
3. Dark green limestone filled with large grains of greensand. Characterized by great numbers of *Pecten cornuus* and crustacean remains	5	
4. Fossiliferous oolitic greensand with occasional spots of green clay, weathering red	7	
5. Ledge of green limestone containing small rounded greensand grains. Weathers red		4
6. Fossiliferous green clay with much greensand	10	

The fossils are all small and rather poorly preserved. Dip S. 50° W. 1:60.

Just above the mouth of Bayou Negreet a low ledge is exposed under a bed of gray and yellow sands and clays. Here twenty-five feet of the same material seen in foregoing section is exposed."

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[1]Geol. Sur. La. 1902. p. 172.

The section at mouth of Bayou Negreet shows the continuation of these beds[1]:

		Feet
1.	Light gray and yellow sandy clay with gravel at base. Extends over whole outcrop	20
2.	Dark greenish brown clay with greensand grains. About four feet from base is a harder portion of the bed forming a little terrace	13
3.	Very fossiliferous indurated green marl weathering brown. Contains among other shells *Ostrea falciformis*	4
4.	Hard limestone with many large *Venericardia planicosta*	2
5.	Covered. (Mouth of Bayou Negreet)	20
6.	Laminated, chocolate colored clay	2
7.	Hard, gray limestone with imperfect shells and bowlders of the underlying material. Contains *Ostrea falciformis* Similar in every respect to Lower Claiborne outcrop described in 1899 from Low's creek. Shows large masses of coral	3
8.	Same material as that occurring in basal beds of the Claiborne as shown at locality 19, described above, but here containing a greater percentage of clay. This outcrop has more of the appearance of normal greensand marl. It weathers into six distinct shelves because of difference of hardness in different portions of the bed	25

Layer 7 of this section crosses the river at right angles giving rise to a very marked shoals. The river flows against the inclined edges of the strata. Dip from a long exposure, S. 20° W. 1:25.

"In the middle of the river opposite the mouth of Bayou Negreet there is a rocky island, 7 feet high, made of ferruginous conglomerate. The conglomerate shows casts of *Venericardia planicosta*. *Volutilithes* and *Unio*."

Following this distinctly marine deposit there appear beds of a lignitic character.

At the first bluff, on the Texas side below McClauahan's Shoals, Baker found:

		Feet	In.
1.	Mottled bluish-gray to reddish-brown clayey sand, structureless, light brick-red in upper 10 ft. and in places light buff and cream colored. Mottling indistinct	25	
2.	Flint and quartz gravel, rounded, averaging from size of a pea up to an inch in diameter		4

[1]Geol. Sur. La. 1902, p. 128.

Unconformity.

3. Brownish-black lignitiferous clay, interbedded with medium grained brownish-gray sand, and wavy-bedded and laminated lignitiferous sand and clay. The alternations' are frequent. The beds contain hard local aggregations of reddish-brown ferruginous sandstone. In the upper part is laminated brownish-black lignitiferous clay, with some layers up to 9-inches thick of dark brown lignitiferous sand containing patches of lignitiferous clay.............. 6
4. Medium-grained light gray sand weathering light yellowish-brown, with flakes of mica forming an almost perpendicular bank at low water stage 12

Two hundred yards below the bluff 6 feet of chocolate-brown lignitiferous sand and shaly clay overlies 3 feet of coarse greenish sand. In the upper portion of the coarse sand are thin cross-bedded layers of lignitiferous clay. Above the lignitiferous clay is 2 feet of post-Eocene ferruginous pebble conglomerate at the usual "spring line". Near the base of the chocolate-brown clay are numerous irregular-shaped clay ironstone concretions, none of which are larger than 1 foot in diameter. The beds dip to the southeastward at the rate of about 1 foot vertical to 50 feet horizontal, but this is perhaps not the absolute amount or direction of dip.

The next exposures one-fourth mile lower down show the recurrence of marine conditions, the beds dipping 8½ degrees South 4 degrees West. Here six feet of chocolate brown sandy and shaly clay is overlain by very fossiliferous concretionary and oolitic greensand.

One-fourth mile farther down the river, thin layers of oolitic greensand are interbedded and overlain by chocolate-brown sandy clay. The fauna carried by the greensand layers is of Cook's Mountain age. The chocolate-brown shaly clay carries irregular blotches of sulphur and limonite. About 20 feet of this clay overlies the fossiliferous greensand. The dip is southward. Lenses and pockets of greensand and small concretions are found in the clay. Ferruginous conglomerate is strewn along the banks. A well defined terrace on the west bank of the river marks the "spring line" at the contact of the bedrock and surficial formations.

The fossils at these two last localities are very abundant and well preserved.

A little less than two miles below the mouth of Bayou Negreet there begins a great oxbow bend in the river, deflecting it temporarily toward Columbus nearly two miles from its general southerly course. The beds forming the banks of this bend are very fossiliferous and Veatch has given the following sections of the exposures. He states[1]:

"Along the east and west reach above Columbus, on the Texas bank, there are a number of outcrops of very fossiliferous Lower Claiborne. At 21 a long shelf, ten feet high, shows the following section:

		Feet
1.	Gray and yellow sands and clays	15
2.	Very dark gray fossiliferous laminated clay with lines of concretions. Contain a characteristic Lower Claiborne fauna. Among other forms *Belosepia ungula, Turritella nasuta* var. *houstonia. Clavilithes penrosei, Cornulina armigera* (small)	9
3.	Covered	3
4.	Very fossiliferous greensand. Many fossils silicified	2
5.	Finely laminated bluish gray sandy clay with traces of vegetable matter	6

Dip here seems to be due south.

A quarter of a mile below this outcrop, at 22, the following section is shown:

		Feet
1.	Unexposed to top of bank	14
2.	Pebble conglomerate	2
3.	Laminated, dark brown clay and yellow sand, containing fossils irregularly through the whole mass. *Anomia ephippoides* is very common	23

Dip a little west of south.

The best collecting in the Lower Claiborne occurs at 23, two miles by river, above Columbus.

		Feet	In.
1.	Gray and yellow sandy clay with small ferruginous gravel. Clayey portions weather into little pinnacles	20	
2.	Bluish gray laminated clay with sand partings and oc-		

[1]Geol. Sur. La. 1902, p. 129-130.

casional patches of sand. Marked ledge of concretions in upper part of bed............................11
3. Dark green shell limestone weathering red. Contains many specimens of *Arca rhomboidella*................. 6
4. Same as 2 but much more fossiliferous.............. 4

Dip southwest.

The lower layer is filled with a great variety of beautifully preserved Lower Claiborne forms.

Columbus. The bluff at Columbus is much complicated with landslips and it is impossible to get a very satisfactory section. The following is from the best exposures:

		Feet
1.	Fine gray sand, tinged with yellow	8
2.	Pebble conglomerate	2
3.	Drab clay with small concretions	4
4.	Ledge of fossiliferous dark grey limestone with *Plicatula filamentosa, Pectunculus idoneus, Arca rhomboidella*	1
5.	Light green, laminated, fossiliferous clay	20
6.	Light green, laminated, fossiliferous clay with large numbers of *Ostrea johhsoni*, var. and *O. falciformis*	4
7.	Ledge of calcareous concretions	1
8.	Same as 5	3

Bluff so complicated with landslips that dip observations are unsatisfactory; dip seem to be south, a little east."

The last fossiliferous exposure referred to the Marine by Veatch is found just where the oxbow is completed and the river resumes its normal southeasterly course. At this point the dip changes from West of South to Southeast and so continues. Only a short distance below, the beds referred to the Yegua (Cockfield) make their appearance with this same dip. It is, therefore, probable that the beds at Veatch's locality 24 are the basal Yegua rather than the uppermost Marine.

The width of the surface exposure of the Marine where it is cut by the Sabine river is about four miles. The average dip of the beds throughout their exposures on the river is about S. 20° W.

Taken as a whole the pre-Yegua, Lower Claiborne section found on the Sabine river differs considerably from those farther west.

The Queen City beds seem to be entirely wanting.

The Marine here begins with highly fossiliferous strata which give place below Bayou Negreet to lignitic beds with a small amount of iron in the form of carbonate nodules. This soon passes upward into other greensands and sands with many well preserved fossils and those form the bulk of the section. The Mt. Selman phase of beds marked by fossil casts is not apparent, and except for the lignitic member below the middle of the section, the fossils are present in abundance from bottom to top. The iron contents are negligible, while five miles northwest, the hill at Irona gives a typical Mount Selman iron-bearing section.

Going westward from the river we find on Low's creek some good exposures of the Lignitic beds capped by the greensands. At the lower wagon bridge the section shows:

Carbonaceous clays and sands, most typically with thin leaves of brown, black, or dark-blue clay interbedded with medium-grained sands, brown or gray in color. Some of the sand layers are a foot or more in thickness.

Sections higher up the creek show greensand marls overlain by chocolate brown sandy clay and greenish-brown clay with oolitic greensand and small calcareous concretions. These upper beds contain fossils.

The Wilcox-Claiborne contact is apparently shown on a small creek tributary to the Paloguacho on the Gaines survey.

At the base are structureless drab clays, which are followed by glauconitic sands carrying some fossil casts and in turn overlain by laminated drab and chocolate colored sandy clays, carbonaceous and gypsiferous, with partings of gray sand. In this member there occurred large concretions up to 3 feet in diameter of carbonate of iron, extremely hard and containing veins of calcite. Above this the deposits get rather more sandy and gypsum and pyrite occur abundantly, a dark blue color being imparted to the clayey sands. The thickness along the creek here is something like 30 feet. The dark blue sandy clays, which are probably Wilcox, are directly overlain by a layer of iron ore which forms the capping of several small hanging valleys and also seems to be the cause of a terrace which runs along some 20 feet above the creek. This is probably the base of the Queen City or of the Marine if the Queen City is not present. This was not determined here. Nothing excepting boulders of iron ore and sands are exposed from here to the top of the hill some 135 feet above the blue clayey sand.

The Irona iron deposit is located on the top of the Claiborne escarpment which rises immediately south of this creek to a height of more than 200 feet. A large part of the slope is talus strewn and the hill is covered with a dense forest growth of oak hickory, sweet-gum and short-leaf yellow pine. The section is as follows:

1. Loose sand.
2. Iron .... 4 ft. max.
3. Covered .... 135 ft.
4. Laminated iron "ore".
5. Dark green coarse, loose sand with abundant small crystals
6. Sandy light brown clay with flaky selenite and abundant small particles of lignitiferous matter; unconsolidated and structureless.
7. Shaly light chocolate-brown sandy clayey with large roundish concretions of blue sphaerosiderite seamed with crystalline calcite.
8. Loose, coarse sand, some grains of which are coated, probably with silicate of iron and potassium. Weathers dark greenish-brown and contains casts of *Venericardia*, *Corbula*, *Leda*, *etc.* On seams and cracks the color is dark reddish brown.
9. Light gray sand clay.

SANTA FE RAILWAY SECTION

The section made along the Santa Fe Railway gives a more complete series of the beds. The Queen City is present at Duff, as has been stated. South of Duff the Mount Selman is first seen in the form of brown sands, in which thin beds of laminated ores are interstratified. Few exposures were seen between this point and Bland Lake, where there occurs a loose sand of light buff color which is also found at Arenosa 10 miles northwest of San Augustine. This is practically the top of the Mount Selman in this section, as just south of it, the fossiliferous greensands begin, and these continue at the surface to a point between Mile Posts 118 and 117, some four miles south of San Augustine. South of this the exposures along the railroad are of the transitional clays and sands and are unsatisfactory. The final appearance of Cook's Mountain greensand is at Birdwell Siding one-third mile south of Mile Post 109. This gives the Marine beds an exposure along this line of nineteen miles.

Baker says of this section:

"There are four phases of the Lower Claiborne (exclusive of the Yegua) along this line of traverse. At the base are the Queen City beds, succeeded by the iron-bearing, generally unfosiliferous Mount Selman sands and clays. Next in upward succession comes the member of fossiliferous greensand known as Cook's Mountain, overlain by the sands and clays of the Cook's Mountain,Yegua transition, in which there are a few thin layers of greensand. The iron-bearing Mount Selman forms the dominating ridge."

SAN AUGUSTINE SECTION

The details of the beds around San Augustine are of interest. The following is the section at Mile Post 121, G. C. & S. F. Ry.:

1. Dark reddish-brown altered greensand with concretionary limonite, both in laminated and concentric forms. The iron in concretionary form is found mainly at the contact of the weathered and unweathered greensand. Small calcareous concretions are rather abundant in the altered zone. Although these occur in the top of the less altered zone they are comparatively rare there, suggesting their possible origin from the gypsum of the unaltered greensands.
   This grades downward into:
2. Greensand—green clay containing secondary selenite in crystals often as large as half an inch. Abundant dark green oolites; all smaller in diameter than the head of a pin, also small flakes of "clastic" selenite. The oolites in the weathered specimens are set in a whitish matrix, probably calcareous. The green clay is in very small balls and nodules which in unweathered specimens form a matrix for the oolites.............................10 **ft.**
3. Light gray, fine grained, thin-bedded, sandy clay with small flakes of selenite and a minor percentage of oolitic greensand in small, very dark green concretions. Poorly preserved fossils.............. .... 3 **ft.**

The material taken from a well close at hand is a grayish-blue, rather light oolitic greensand clay with fossils. This represents less altered material than any mentioned in the foregoing section.

There is 15 feet of the clayey greensand exposed in a cut 200 yards north of Mile Post 121. This exhibits various degrees of alteration. It has gypsum and calcareous concretions. The limonite is mainly distributed in thin, irrregularly-laminated layers runnng at various angles with the horizontal, but nearer the horizontal than the vertical. The greensand exhibits a very imperfect shaly lamination. The superficial, unconsolidated, weathered product is dark brownish-green below, becoming a dark reddish-brown above. The gravel in the surficial layer is mainly composed of irregular angular pieces of ferruginous concretions.

Section on creek joining Ayish Bayou just north of railroad station:

1. Greensand.
2. Chocolate-brown clay with thin flakes of selenite............ 7 ft.
3. Greensand with thin local layers of iron ore............15 ft.

Dodecahedrons and cubes of pyrite were found in the top of member No. 1 of the above section.

At the falls on this creek member No. 1 is a dark green, very clayey greensand. The clay balls have a fibrous structure like slickensides. Member No. 2 is on the whole rather badly fractured and when wet has a bluish-green color.

Detailed section at San Augustine from the top of the hill at Little Rock to the G. C. & S. F. Railway north of the station:

1. Very ferruginous reddish-brown Lafayette locally with pebbles or with hard coarse sandstone cemented by limonite.

Unconformity:

2. Beach or reef bed of hard silicified and calcified greensand marl containing *Ccutella, Ostrea, Pecten* and large gasteropods. This layer forms a ledge at the first Baptist Church, around the top of the circum-valley of White Rock and elsewhere on the top of the hill. Layer appears to be almost entirely made up of comminuted shells ....10 ft.

3. Altered greensand with local ferruginous layers............24 ft.
4. Altered greensand with small calcareous nodules. Horn corals, *Venericardia*, *Corbula*, and other fossils........ 5 ft.
5. Thinly and irregularly laminated ferruginous layers with interbedded greensand lenses. Two feet below the top is a thin, harder concretionary layer...................... 7 ft.
6. "Shelly" layered fossiliferous greensand with slickensides 6½ ft.
7. Thinly-laminated, shaly, chocolate-brown sandy clay, sulphurous and limonitic, with thin black carbonaceous lenses, flakes of selenite, and crystals of pyrite. Clay, stickier and less sandy than lower, varying from light bluish-gray and light chocolate to rusty in color. Upper layer is fine and bluish-black in color like material seen in the well on the upper Nacogdoches road 5 miles west of San Augustine. At the contact of this clay with the overlying greensand are falls on all three creeks of this vicinity............9½ ft.
8. Thinly, and irregularly, laminated limonitic layers with small lenses of greensand.............................. 4 ft.
9. Altered oolitic greensand clay, dark green below, dark brown above with *Corbula* and *Venericardia*. Has nodular limonite coated greensand clay ironstone at base. Massive, jointed, with slickensides common along joint planes, slickensides coated a dark purplish color ....9 ft. 3 in.
10. Layer of ferrufginous concretions, non-continuous, with concentric structure of shells of limonite around the outside with a hard compact brown center, perhaps of iron carbonate, dotted with oolites of greensand. Averages about .... 6 in.
11. Altered clayey greensand like (9). Fosiliferous.......... 4 ft.

These beds are exceedingly fossiliferous and are notable for the number of echinoderms they contain in comparison with beds of similar age at other localities.

The Cook's Mountain around San Augustine is unconformably overlain by dark reddish-brown sandy and clayey alluvium containing many small angular fragments of iron oxide. Some of this is Lafayette, some is residual from Lafayette, and another portion is either residual from the Cook's Mountain or is recent alluvium. These accumulate to a thickness at least as great as 15 feet. The beds of the Cook's Mountain dip very slightly southward and have a total thickness of 100 feet or more.

The road from San Augustine to Nacogdoches runs over the

Cook's Mountain beds and there are numerous localities where fossils are found in abundance.

H. E. & W. T. RAILWAY SECTION

The line of the Houston, East & West Texas Railway does not afford as good exposures of the Mount Selman and Cook's Mountain as are found either east or west of it.

The contact of the Lignitic and Claiborne is near Fitze, the first station south of Garrison, where deep cuts on the ridge expose red cross-bedded sand with some ledges of ferruginous material. This does not appear to belong to the Queen City, but to the Mount Selman.

A mile south of this the greensands come in and are seen in the cuts between that point and Nacogdoches.

The scarp which usually marks the line between the Mount Selman and Cook's Mountain does not appear in this section and the section does not show any dividing line.

In the lower lands, along the lower slopes of the hills, and in the stream valleys in the vicinity of Nacogdoches and south, east and west of that town the surface rock is fossiliferous greensand marl. Where unaltered, the greensand marl shows various shades of green in color and contains an abudant fauna of gasteropods, lamellibranchs, corals, echinoids, cephalopods, and shark's teeth. The shark's teeth belong to the genus *Synecodus*. A single species of the cephalopod, *Belosepia*, was found at several localities. About seventy-five species were found in all, fifty of which were collected from one locality. Much of the fresh greensand has a finely oolitic texture. Ferruginous concretions occur abundantly in the greensand. Where unaltered these concretions are composed of sphaerosiderite. The iron in the greensand oxidizes readily, imparting to the altered greensands various shades of brown and brownish-red. In the altered greensands the fossils are in the form of casts, but when the rock is fresh the original shells are preserved. Nodules of clay are locally abundant in the greensand member. The strata of this member are thinly bedded and locally vary much in degree of consolidation, the concretionary portions being very hard and compact while the greater part of the formation is comparatively friable.

NACOGDOCHES BEDS

On Aaron's Hill, on El Camino del Rey, 200 yards west of Houston, East & West Texas Railway passenger station at Nacogdoches, the following section is exposed:

Nacogdoches:

1. Mottled sandy clay, brick-red to bluish-gray, weathers under grass roots to buff sand ....6 ½ ft.
2. Unconsolidated but finely laminated fine-grained sand, flesh colored to chocolate, unfossiliferous. Contains small aggregations of limonite, cross and wavy bedding very noticeable in upper part ....17 ft. 3 in.

Unconformity with difference of 3 feet in verticality along the irregular line of contact.

Cook's Mountain:

3. Alternating layers of argillaceous sandstone and arenaceous clay (both are "greensand marl") thin bedded for most part. Weathers rusty brown in outcrop, greenish in color when fresh. Contains fossil casts and varies in degrees of compactness. Contains much material resembling oolite or rolled small clay balls varying in size up to 1-10 inch diameter ....22 ft. 5 in.
4. Dark drab, arenaceous, clayey greensand with abundant fossil casts, weathering to earthy-brown, and seamed by thin bands of earthy yellow limonite................2 ft. 8 in.
5. Very friable light green greensand, weathering to brownish or reddish-brown .... 2 ft.
6. Dark green arenaceous and clayey greensand, dark-purple in color, with fossil casts. Very oolitic ....1 ft 6 in.
7. Better indurated, dark green sandstone, alternating with purple with much iron carbonate and many casts of shells 2 ft. 5 in.
8. Dark bluish, clayey, greensand, thinly laminated and containing many fossil remains. 3 feet from base is a bed of oyster shells 2 inches thick. Alters to a reddish-brown ferruginous surface rock. ....6 ½ ft.

At Orton's Hill on El Camino del Rey one mile east of the last described locality and just east of the wagon bridge over Lanana creek, the following is the section:

Nacogdoches:

1. Sand mottled in places, but mainly reddish-brown in color, with some cross-bedding. 35 feet above the base is a layer

of medium-coarse, and for the most part angular, conglomerate with boulders up to 6-inches in diameter. The smaller particles are much better rounded than the larger. The pebbles are ferruginous sandstone. They may not all be detrital, but some may be concretions in the bed....45 ft.

Cook's Mountain:

2 Fine-grained sand, less consolidated than in (1), bluish-white when fresh; where altered, exhibiting various shades of yellow and brown, depending on the percentage and form of the iron contained. Upper 30 feet structureless, lower 10 feet rather finely laminated ....40 ft.

3. Finely laminated, fine, unconsolidated sand, with nodules of clay, chocolate brown and greenish-gray to black in color.. 6 ft.

4. Greensand marl, thin-bedded, friable, with abundant fossil casts, oolitic structure, with layers containing nodular iron. Mainly clayey, but with a minor amount of sand which increases in percentage towards the top. The least altered rock is a dark bluish-green, where most altered and nearest the surface it is rusty yellowish-brown..........28 ft.

There is no unconformity apparent in the Orton's Hill section, but the angular conglomerate in the upper member is noticeable. The above sections have been selected as typical. They also indicate that the clay and sand Eocene member is both conformable and unconformable on the underlying greensand and that there are layers of greensand containing characteristic fossils interbedded with the clay and sand Eocene member. In the harder ferruginous beds and nodules of this transition member casts of Claiborne fossils are found. Since no fossils or greensand have been found in this region in the lithologically very different lower Yegua, it is judged most logical to group the sand and clay Eocene member in the Marine as an upper and shallower water phase.

In places it rests on the Marine greensands with an irregular contact; in other localities the member appears to rest with conformity on the Marine. The sand and clay member exhibits much cross-bedding and frequent alternation of sand, clay, shale and gravel. The individual beds are not persistent, but notably lenticular. These structural characteristics and the relatively clastic composition of the deposits, point to a shallowing of the site of sedimentation after the epoch of greensand

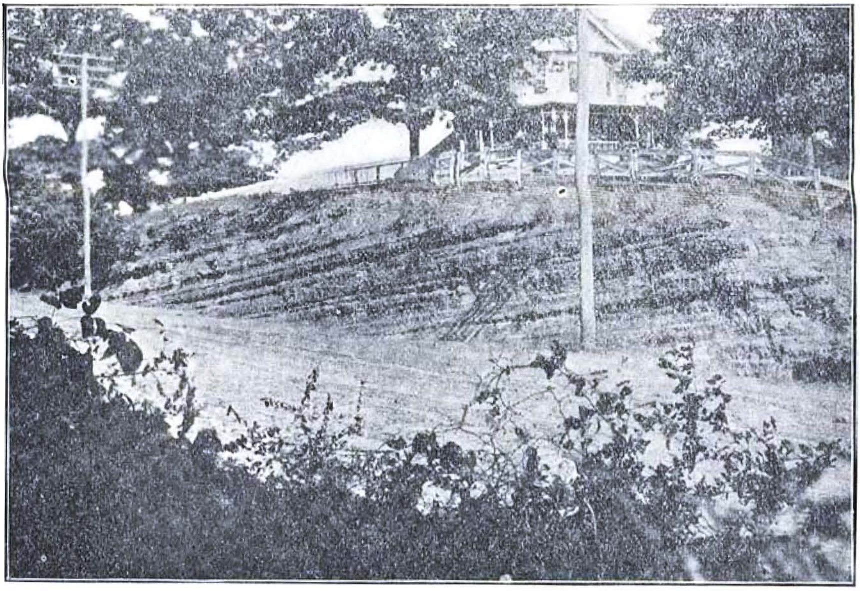

Fig. 1. MARINE FORMATION.
Exposure on Aaron's Hill, near Nacogdoches.

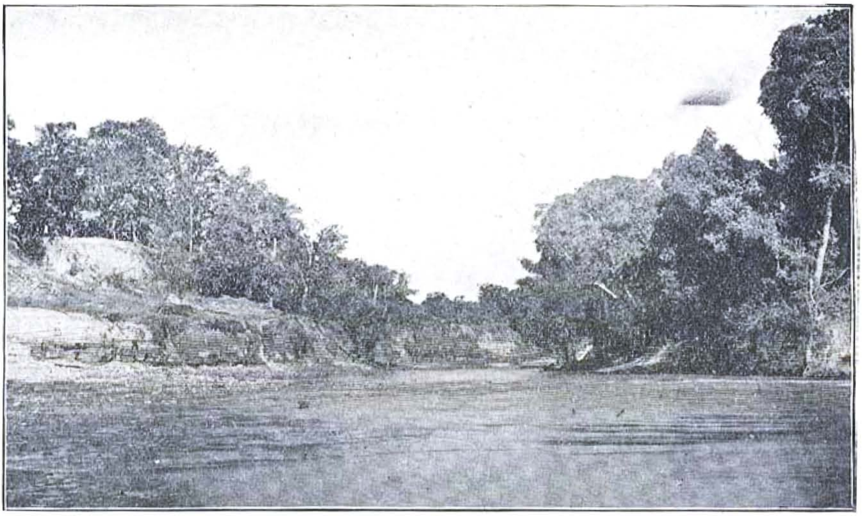

Fig. 2. YEGUA FORMATION.
Westmoreland Bluff, Trinity County.

deposition and the coming on of littoral, estuarine and partly terrestrial conditions. This sand and clay member is considered, therefore, as distinct frrom the light-colored gypsiferous beds of the Yegua, although the sand and clay member is, in places, gypsiferous. It is regarded as a distinct lithologic unit, constituting the end of a cycle of Marine deposition, and to distinguish it the name of Nacogdoches is suggested for it. The occurrences noted above are outliers capping the Cook's Mountain.

The greensands of the Cook's Mountain are found to the south as far as Climax, where the transitional beds between the Cook's Mountain and Yegua begin. These Nacogdoches beds occupy nearly seven miles of the section passing under the more massive clays of the Yegua near Davidson.

A cutting on the Houston, East & West Texas Railway 100 feet north of Culvert 129A and 150 yards north of Mile Post 128, 1¼ miles south of Climax siding, southern Nacogdoches county, is interesting. There are two unconformities shown in this one section, the one between the Nacogdoches and the partially consolidated post-Yegua surficial member and one in which the Lafayette overlies with marked discordance both the Nacogdoches and the post-Yegua partially consolidated surficial member.

In the base of the section is exposed some 35 feet of Nacogdoches sands and clays thinly laminated, dipping 10 degrees to the southeast. The Nacogdoches is here mainly a thinly laminated medium-fine light gray sand carrying small broken flakes of selenite. The sand is interbedded with thin layers of blue-gray clay of a thickness of from 1/32 inch to 2 inches. There are also some layers of limonitic stained sands and sandstone varying in thickness from the neighborhood of 1/32 inch to about 8 inches. Some of these layers are cemented into a medium-hard sandstone by limonite.

Among the plants collected from this locality, Berry identified a new species of *Citrophyllum*.

The upturned edges of the tilted Nacogdoches strata are bevelled off to a horizontal plane and unconformably overlain, by horizontally bedded red and light gray sands and sandy clay partially consolidated, which exhibit mottling in lenticular layers rather than in the irregular blotches more characteristic of the Lafayette. In composition it is mainly medium-grained sand with a considerable proportion of clay, containing tiny flakes of selenite. On freshly broken surfaces the color of the reddish portions is seen to be pink or old rose. About 10 feet of this member is exposed at the top of the cut. On the south this entire thickness is cut off by an angular unconformity, the plane of which dips about 40° to the southward. The exact relationship of this member is not known.

Overlying this plane of unconformity is unconsolidated and structureless material which belongs to the Lafayette, varying in texture from medium-grained clayey sand through coarse grit to medium-coarse conglomerate; in color, from whole patches which are dark red or light gray, to irregular mottling in blotches of these two colors; in structure, from absolutely structureless to an imperfect sorting in layers of finer and coarser pebbles, the layers of which are not always horizontal. while the conglomerate exists in small to large irregular bunches; in composition, from clay to quartz with some flakes of selenite, and to conglomerate mainly of subangular or rounded ferruginous pebbles with a few well-rounded quartz pebbles; and in induration, from loose unconsolidated sands to ferruginous cemented, fairly hard conglomerate with most of the sand exhibiting on the surface a casehardening which gives it a noticeably solid appearance. Some of the material has very contorted laminae, thin layers of red and white being interspersed. Where it overlies the Nacogdoches next above the irregular contact, it includes small pieces of thinly-laminated Nacogdoches shales, with their bedding or lamination planes running in every direction and angle.

The Nacogdoches beds are well shown in the exposures along streams flowing southward into the Angelina river in Nacogdoches county and in some of the river bluffs. They also appear in the lower reaches in the tributaries on the south side of the river.

Above the interbedded greensands, carbonaceous and gypsiferous clays already described, the following beds were found in Durazno or Wills creek, which rises east of Lufkin and flows northward into the Angelina.

Above the higher beds of greensand found on this creek comes, first, a structureless, massive sand weathering on the surface to a light buff, but underneath the surface of a light brownish-gray. The sand contains black and brown plant fragments and is at least 12 feet in thickness.

Higher up the creek and higher stratigraphically the next rock exposed is fine sand, alternating in thin layers of dark brown and gray, about 1/16 inch in thickness and containing plant fragments. A thickness of 8 feet is exposed.

The next exposure gives the following section:

1. Laminated and shaly light brown sand.
2. Light brown, massive, medium-fine sand.................. 1 ft.
3. Sandy clay, light chocolate brown ....1 2/3 ft.
4. Laminated light gray-brown sand with thin non-continuous streaks of dark chocolate-brown. Blotches of yellow sulphur. Plant fragments..............................1½ ft.
5. Brown clay .... 2 in.
6. Laminated brown layers limonite-stained and cemented.... 1 in.
7. Light brown finely laminated fine sand with dark brown seams and plant fragments............................½ ft.
8. Very thinly laminated light grayish-blue fine sand containing thin layers of dark brown and chocolate-brown. Contains plant fragments, has wavy laminations, and weathers brown on surface .... 4 ft.

The next higher exposure consists of:

1. Drab laminated sand with limonite-stained seams....... .. 6 ft
2. Brown laminated sand with plant remains................ 3 ft.
3. Chocolate-brown sand with black plant fragments and yellow blotches of sulphur. The upper foot gives way along bedding planes to dark blue-gray sandy clay............2½ ft.

Above this then, is 5 feet of laminated, fine to medium, drab sand with thin seams stained brown with limonite and containing selenite flakes and brown plant fragments. The sand contains a considerable proportion of clay.

The next exposure shows 4 feet of gray to brown sand with yellow sulphur and brown plant remains, while the highest exposure examined in this creek gives 7 feet of coarse loose sand, light gray when unweathered, but light yellow when weathered. The sand contain flakes of selenite up to 1/16 inch in long dimension.

Similarly, on the west of the railroad a creek on the northern boundary of Angelina county, tributary to the Angelina river, gives the following sections going up-stream:

Lowest section exposed gives:

1.	Covered with surficial material	15 ft.
2.	Alternating layers of light-brown sand and light-gray sandy clay. The sand layers relatively and absoltuely increase in thickness toward the top until they are 2 to 3 inches in thickness	10 ft.
3.	Gray medium-grained sand inter-bedded with thin layers of chocolate-brown clay and with thin layers of limonite hardened sand The percentage of clay gradually increases toward the top. Where the sand and clay come in contact the sand is stained brown with a thin film of limonite	10 ft
4.	Chocolate-brown clay with small fragmentary remains	2 ft.
5.	Same as (3) but without hardened sand layers	22 ft.

The bedding planes are wavy and the beds correspond very well with those overlying the fossiliferous greensands at Aaron's and Orton's hills, Nacogdoches.

About 2 miles up-stream there is an exposure of 15 to 20 feet of thinly-bedded alternating sand and clay. At the base the clay is very dark brown, almost black, with very thin layers of gray sand separating the clay layers. In the middle portion of the section chocolate-brown clay predominates, while toward the top 2 inch beds of chocolate-brown clay alternate with layers of the same thickness of light gray or light brown sand. The basal member here corresponds to the strata found at the base of Trewick's Bluff, 2½ miles east of the Texas & New Orleans Railroad bridge across the Angelina river, and to the beds lying above the greensand on Orton's and Aaron's hills, Nacogdoches, and to those found on Procella and Mill creeks, respectively, northwest and northeast of Lufkin, Angelina county.

One of the best sections of the upper Nacogdoches found is that of the next exposure about 100 yards up-stream from that last noted. There is here a perpendicular bank 60 feet in height.

The lower 40 feet is made up of thin alternating layers of light gray to light brown sand and chocolate-brown clay. The upper 20 feet is mainly a light brownish buff loose sand. The laminated sand layers in the lower part of the section exhibit wavy laminae. The upper 20 feet is also thinly bedded, especially in its middle portion. The upper 20 feet differs in reality very little from the lower 40. It has a larger percentage of light brown sand an an occasional thin layer of chocolate clay.

Mill creek north of Lufkin repeats the section even more in detail.

The lower horizon exposed on Mill creek has thin-bedded alternating sands and clays containing carbonized material at base and thin seams of very impure lignite. The dip is from 5 degrees to 7 degrees to the southward. The sand varies in color from gray-blue through brownish-gray to reddish-brown, depending on the amount and state of the contained iron. One exposure shows 8 feet of finely laminated brownish-gray sands seamed with yellow limonite stains and containing thin films and blotches of carbonized leaves. One hundred yards farther upstream thinly laminated, alternating dark brown clay and light brown sand layers are exposed. Fourteen feet above the base of the section is a layer varying from a knife edge to 6 inches in thickness, containing carbonized fragments of plant remains which are also found in the strata above and below. The individual layers are at the maximum not much more than an inch in thickness and most of them are about ¼ inch thick. The beds lie practically horizontal and are cut by a normal fault of 10 inches vertical displacement.

This is followed by a section giving 3 feet of blue-gray clay at the base succeeded by 6 feet of very carbonaceous brown sandy laminated clay, in turn succeeded by 3 feet of laminated fine sand stained with limonite and sulphur, and containing brown plant fragments. The brown clay middle member is in places so carbonaceous as to exhibit a very thin seam of brown coal.

The next exposure shows at the base 2½ feet of blue gray clayey sand, overlain by 8 feet of thinly laminated gray-brown crossbedded sand, having at base 4 feet of alternating laminated sand and layers containing thin bands of alternating sand and black carbonaceous matter from 2 to 6 inches in thickness and separated by layers of the laminated sand several times their own thickness.

The next section has a thickness of 15 feet. The lower 3 feet is mainly chocolate-brown shale, but inter-bedded with thin sand layers. The upper 12 feet is mainly sand with streaks and blotches of brown carbonaceous matter. Above this, in next section, 12 ft. of light blue laminated sands containing brown blotches of carbonaceous matter.

In upward succession in the next exposure comes 4 feet of soft, chocolate brown, loose sand with carbonaceous matter, and streaks and blotches of sulphur. It is overlain by 4 feet of light gray sticky clay.

The next exposure upstream is probably the base of the Yegua.

From the sections given it will be apparent that the marine conditions of the earlier Nacogdoches gave way slowly to the palustrine. The transition beds between the two formations show some alternation of conditions with, however, on the whole, a gradual shallowing of water at the site of deposition, passing from the typical marine conditions with the greensand facies through shallower water, lagunal, and estuarial conditions with the carbonaceous and lignitic sand and clay facies into littoral or true terrestrial conditions in the light buff gypsiferous sands and clays containing the great abundance of silicified wood.

The exact line separating the Marine from the Yegua is somewhat difficult to draw on this account. We have drawn it here as at the type locality, where the more massive gypsiferous clays begin. Here these clays come in above the highest fossiliferous beds of the Nacogdoches (which contain remains of both marine animals and plants) and in place of the abundant marine fauna characterizing the typical Yegua we have found between the Sabine and Trinity only occasional nests of poorly preserved forms.

THE ST. LOUIS & SOUTHWESTERN SECTION

This was the line of Kennedy's section as published in the Third Annual Report of the Texas Geological Survey[1]. The Mount Selman section as given by him is as follows:

[1] Third Ann. Rept. Geol. Sur. Tex., p. 53.

1. Gray surface sand ....10 ft.
2. Brown sand, ferruginous pebbles and iron ore............15 ft.
3. Mottled sand ....10 ft.
4. Brownish-yellow sand ....4 ft.
5. Brownish-yellow sandstone ....10 ft
6. Alternate strata of laminated iron ore and brown sand, the ore generally from two to ten inches and the sand from one to two feet thick.............................. 8 ft
7. Dark green sand containing casts of small bivalve shells.. 5 ft.
8. White clayey sand ....1 ft.
9. Dark green, nearly black, sand containing thin seams of ferruginous material near top, and also containing small fish teeth and *Venericardia planicosta* and *Sphaerella antiproducta* in very small numbers ....12 ft.
10. Brown sand ....10 ft.
11. White sand ....10 ft.
12. Alternate strata of brown sand and laminated iron ore, ore generally wavy and not more than two to six inches with sand from one to two feet thick ....20 ft.
13. Pale-blue and brown clay mottled in places and laminated in others ....15 ft.
14. Alternate strata of glauconitic brown sand and iron ore, the ore generally irregularly deposited, laminated and silicious and not exceeding six inches to one foot, the sand from six inches to two feet thick...........................55 ft.
15. Brown sand forming surface at Bullard, altered greensand changing to yellow a few feet underground..............40 ft.
16. Dark green sand containing a few fossil shells and fish teeth ....24 ft.
17. Lignite or "black dirt" containing leaves.................. 2 ft.
18. Dark lignitic clay .... 5 ft.

Nos. 17 and 18 of this section belong to the Lignitic beds.

This is generalized from the many sections made between Bullard and Jacksonville and brings out in some measure the extremely ferruginous character of this portion of the Marine. This is further shown in the section three miles north of Rusk, as given by Penrose[1]. This section also includes the lignitic member of the Mount Selman, which is apparently near the same position in the section as that seen on the Sabine river. At the top we have beds belonging to the Cook's Mountain series. The section is as follows:

[1] First Ann. Rept. Geol. Surv. Tex. p. 31.

1. Gray and buff sands .... 8 ft.
2. Hard brown sandstone ....1 to 3 in.
3. Brown resinous laminated hematite ....1 to 3 ft.
4. Altered fossiliferous greensand ....30 ft.
5. Gray clay, stained by iron in places....................... 5 ft.
6. Dark gray sand, with glauconite specks and rusty pyrites, giving rise to many ferruginous springs..................20 ft.
7. Gray and chocolate clays, ferruginous in places............35 ft.
8. Interbedded seams of gray and chocolate clay and fossiliferous glauconite marl, sometimes indurated and partly altered; nodules and lenses of clay ironstone............40 ft.
9. Gray clay, with seams of sand, and some clay ironstone.... 5 ft.
10. Interstratified gray and chocolate clay...................... 5 ft.
11. Lignite .... 1 ft.
12. Chocolate clay ....1 to 1½ ft.
13. Lignite .... 1 ft
14. Chocolate clay .... 6 ft.
15. Interbedded chocolate clay and small seams of lignite, 1-8 to 1-2 inch thick, at base of section.

The upper portion of the Cook's Mountain is well shown in Kennedy's Alto section:

This section embraces a series of greensands and altered glauconitic sands and sandstones lying close to the top of the "Cook's Mountain" beds. The section combines the whole of the greensand deposits from Alto, 8 or 10 miles eastward, to the edge of the Angelina river "bottom lands", and the whole, or the greater portion, of the section may also be taken as representative of the structure of the country from Alto southwestward to the Neches. The section shows:

1. Gray sand ....5 to 20 ft
2. Ferruginous sandstone .... 1 ft.
3. Iron pyrites and lignite ....½ to 1 ft
4. Laminated iron ore and brown sand.................10 to 15 ft.
5. Brown and yellowish-brown altered glauconitic sand with streaks and nodules of calcareous matter and containing *Terebra houstonia* Harris, n. sp., *Pleurotoma (Surcula) gabbi* Conrad, *Ostrea sellaeformis*, var. *divaricata* Lea, *Pinna*, sp., *Trigonarca pulchra* Gabb, *Pseudoliva vetusta* Con., *Volutilithes petrosa* Con., *Latirus moorei* Gabb, *Corbula texana* Harris, *Corbula aldrichi*, var. *smithvillensis* Harris, *Dentalium minutistriatum* Gabb, *Venericardia planicosta* Lam., *Venericardia rotunda* Lea, *Clavilithes*

regexa Harris, n. sp., *Phos texana* Gabb var., *Distortrix septemdentata* Gabb, *Solarium acutum*, var. *meekanum* Gabb, *Terebellum*, *Calyptrophorus velatus* Con., *Mesalia claibornensis* Con., *Anomia ephippioides* Gabb, *Cerithium vinctum* Whitf., *Pecten claibornensis* Conrad, *Pecten deshayesii* Lea, *Plicatula filamentosa*, Con., *Cytherea texacola* Harris, *Cràssatella texana* Heilp., *Turritella nasuta* Gabb, and many of these in profusion.[1] .... 6 ft.

6. Yellowish-brown and grayish-brown, often grayish-green, indurated greensands containing most of the fossils found in No. 5 and an additional fauna of *Pleurotoma* (*Drillia*) *nodocarinata* Gabb, *Volutilithes petrosa* var. *indenta* Conrad, *Caricella subangulata* var. *cherokeensis* Harris, *Cassidaria brevicostata* Ald., *Pholadomya claibornensis* Ald., *Byssoarca cuculloides* Con., *Martesia texana* Harris, n. sp., *Dentalium minutistriatum* var. *dumblei*, n. var., *Natica newtonensis* Ald., *Natica limula* var., *Rimella texana*, var. *plana*, new var., *Cancellaria panones* Harris, n. sp., *Clavilithes* (*Papillina*) *dumosa*, var. *trapaquara* Harris, *C. humerosa*, var. *texana* Harris, *Cassidaria brevicosta* Ald., *Turritella dutexta* Harris, *Scutella caput-sinensis* Heilpr., and fish teeth ....20 ft.
7. Greensands with casts of fossils .... 6 ft.
8. Brown altered glauconitic sandstone with casts of fossils..30 ft.
9. Greensand with fish teeth and *Conus sauridens* Con., *Anomia ephippioides* Gabb, *Byssoarca cuculloides* Con., *Trigonarca pulchra* Gabb, *Volutilithes petrosa* Con., *Volutilithes precursor* Dall, and others belonging to Nos. 5 and 6 ....8 ft.

These beds are at the surface until covered by the Nacogdoches some three miles north of Wells. The transition beds continue along this line to one mile south of Pollock, where the massive clays of the Yegua are found.

TRINITY RIVER SECTION

The exposures along Trinity river and its tributaries west of the International & Great Northern Railway are very numerous and characteristic.

The Wilcox-Marine contact crosses the river in the vicinity

[1]The lists of invertebrate fossils given in this and succeeding sections of the Claiborne are based on Harris' Mss. Catalogue of Tertiary Fossils made in 1893 and now at the University of Texas, and have not had the benefit of his later revision.

of the north line of Leon county. A series of bluffs on the east bank of the river give the following sections:

Wooter's Bluff:—This bluff is on the Thompson headright about four miles above the mouth of Elkhart creek, and is probably ten to twelve miles below the Wilcox-Marine contact. The Mount Selman beds are here found to be unfossiliferous, although the higher grounds lying some distance away from the river show brown sandstones and altered greensands with a few fossils. The section at the bluff appears to be more of a lignitic nature toward the base.

1. Brown and yellowish-brown sand ....10 to 15 ft.
2. Clay ironstone ....1 to 3 in.
3. Dark gray micaceous clay, weathering brown on outside....20 ft.
4. Clay ironstone ....1 to 2 in.
5. Dark blue or bluish-black micaceous clayey sand........2 to 6 ft.

Hall's Bluff:—On the Murchison headright just below mouth of Elkhart creek:

1. Gravel and sand ....25 to 30 ft.
2. Fossiliferous sandstone containing *Ostrea sellaeformis*, var. *divaricata* Lea. *Cerithium vinctum* Whitf., and casts of others .... 4 ft.
3. Red sandstone ....10 ft.
4. Yellowish-white sand .... 2 ft.
5. Brown clay with gypsum crystals .... 6 in.
6. Yellowish-white sand .... 5 ft.
7. Irregular stratum of clay ironstone boulders .... 8 in.
8. Dark greensand, weathering brown, containing fish teeth, but no invertebrates ....6 ft.
9. Brown sand .... 4 ft.

Brookfield's Bluff:—A bluff a little south of west from Crockett, on the Brookfield headright, three miles below the mouth of Hurricane bayou:

1. Structureless greenish drab clays containing white calcareous nodules up to one inch in diameter. Contains 5 feet from base a 3-inch sandy layer that is packed with gasteropod and lamellibranch remains. Also near the top there is a layer of fossiliferous indurated greensand containing oysters, etc. This clay weathers out to brown and black soil and underlies the post-oak country encountered for

some ways back from the bluff on the road to Porter Springs.

2. Concretionary limestone layer of yellow to buff color exhibiting the cone-in-cone structure very well....1 ft.
3. Structureless drab and yellowish brown clay....25 ft.
4. Laminated chocolate shaly clays with intercalated layers of yellowish brown sand; contains at the top a 3-inch layer of concretionary clay ironstone ....20 ft.
5. Brown sandstone in heavy bed ....10 ft.
6. Clay ironstone .... 1 ft.
7. Laminated dark blue sand and light gray clays with iron pyrites ....8 ft.
8. Lignite .... 2 in.
9. Same as No. 7 .... 5 ft.
10. Thin seam of ferruginous sandstone .... 6 in.
11. Same as No. 7, getting darker in lower portion of the beds and covered with a yellowish efflorescence of sulphur. Water issuing from these beds is sulphurous and the springs show considerable quantities of hydrogen sulphide to level of river ....15 ft.

No. (1) is probably the lowest member of the Cook's Mountain and the fossiliferous beds beginning at this locality are much more prominent farther down the river.

This would give the Mount Selman beds an outcrop on the river of at least twenty miles.

The small amount of iron in these sections compared with those east is very noticeable.

Alabama Bluff:—This bluff is about six miles below Brookfields in an air-line. It was originally considered to mark the top of the Marine beds on the river, but we find overlying it a broad expanse of the Nacogdoches, so that it is now regarded as the top of the Cook's Mountain only:

1. Fossiliferous greenish-blue clay .... 4 ft.
2. Greensand altered to a brownish-yellow sand with thin strata of ferruginous material interstratified and containing *Volvula conradiana* Gabb, *Conus sauridens* Conrad, *Pleurotoma* (*Surcula*) *gabbi* Con., *Pl.* (*Cochlespira*) *engonata* Con., *Pl.* (*Surcula*) *moorei* Gabb, *Pl.* (*Drillia*) *nodocarinata* Gabb, *Pl.* sp., *Ancilla* (*Olivula*) *staminea* Con., *Anomia ephippioides* Gabb, *Plicatula filamentosa* Con., *Trigonarca pulchra* Gabb, *T. corbuloides* Con., *Leda houstonio* Harris *Pseudoliva vetusta* Con. var., *Volutilithes pe-*

trosa Con., *Caricella demissa.* var. *texana* Gabb, *Turricula (Conomitra) texana* Harris, *T. polita* Gabb, *Latirus moorei* Gabb, *Corbula alabamensis* Lea, *Cadulus subcoarcuatus* Gabb, *Fusus mortoni*, var. *mortonopsis* Gabb, *Clavilithes penrosei* Heilprin, *Phos texana* Gabb, *Distortrix septemdentata* Gabb, *Cassidaria planotecta* Ald., *Solarium bellastriatum* Con., *Natica arata* Gabb, *N. limula* Con., *Mesalia claibornensis* Con., *Turritella nasuta* Con., *Spirorbis leptostoma* Swain, *Turbinolia pharetra* Lea ....5 to 6

3. Ferruginous sandstone with iron ore ....1 to 2
4. Green sand and ferruginous material same as No. 2, and containing same fossils with addition of *Pleurotoma heilpriniana* Harris, *Ostrea sellaeformis*, var. *divaricata* Lea, *Pinna* sp., *Byssoarca cuculloides* Con., *Lapparia pactilis*, var. *mooreana* Gabb, *Venericardia planicosta* Lam., *Crasatella texana* Harris, *Cytherea texacola* Harris, *Clavilithes (Papillino) dumosa*, var. *trapaquara* Harris *Natica* sp., *Turritella nasuta* var. *houstonia* Harris, *Belosepia ungula* Gabb, *Eriphyla trapaquara* Harris................4 ft.

COOK'S MOUNTAIN SECTION

Cook's Mountain, a hill about two miles west of Crockett, rises 460 feet above sea-level and shows a more or less precipitous face on every side. Its face, however, is marked by a series of benches, and Kennedy made the following section on the eastern side from Milam branch to top of mountain:

1. Brown ferruginous sandstone with occasional casts of a small bivalve ....10 ft.
2. Yellow-colored cross-bedded altered glauconitic sand ....40 ft.
3. Brown sand and sandstone with occasional seams of fer-
5. Iron ore .... 1 ft.
6. Brown sand containing *Bulimella kellogii* Gabb, *Terebra texagyra* var. Harris, *T. houstonia* Harris, n. sp., *Conus sauridens*, Con., *Pleurotoma (Surcula) gabbi* Con., *Pl. (Cochlespira) engonata* Con., *Pl. (Drillia) nodocarinata* Gabb., *Pl. (Drillia) texana* var. *pleboides* Harris, *Pl. (Mangelia) infans* var., *Pl.* sp., *Ancilla (Olivula) staminea* Con., *Ostrea alabamensis* Lea., *O. sellaeformis* var. *divaricata* Lea, *Anomia ephippioides* Gabb., *Plicatula filamentosa* Con., *Avicula* sp., *Pinna* sp., *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *V. petrosa*, var. *indenta* Con., *V. precursor* Dall var., *Caricella sub-angulata* var. *cherokeensis* Harris, *Lapparia pactilis* var. *mooreana* Gabb., *Latirus moorei* Gabb., *Cornulina armigera* Con., *Corbula alabamen-*

sis Lea, *Venericardia planicosta*, Lam., *Cytherea texacola* Harris, *Clavilithes regexa* Harris, n. sp., *Phos texana* Gabb. var., *Distortrix septemdentata* Gabb., *Scala*, *Natica arata* Gabb., *N. limula* var., *Sigaretus declivis* Con., *Calyptrophorus velatus* Con., *Turritella nasuta* var. *houstonia*, Harris, *T. nasuta* Gabb., *Belosepia ungula* Gabb., and the corals *Occulina* Heilpr., *Turbinolia pharetra* Lea., *Trochosmilia mortoni* Gabb and Horn, and *Endopachys maclurii* Lea. A number of fish teeth also occur in this bed......15 ft.

This description is amplified by Suman in his section along Navarro road from point in creek bottom, âpproximately one mile east of Cook's Mountain, to top of mountain, the creek bottom being about 160 feet below top of mountain:

1. Creek bottom. Red sandy alluvial clay.................... 7 ft.
2. Light bluish gray or drab massive sticky clay containing aggregations of small gypsum crystals. Covered at surface by mottled dark red and light gray sandy clay until the upper 1 ft. containing gravel. Also contains one foot below the surface rounded concentric limonitic concretions up to 2 feet in diameter .... 8 ft.
3. Dark purplish brown finely laminated clayey shale. Is gypsiferous and carbonaceous. Contains partings of yellowish brown sand, and one sand layer 3-inches thick was noted. In one place there is a sand dike about four feet deep in the clayey shale ....15 ft. 6 in.
4. Mottled material. Maximum exposures of about 10 ft. along road. Is covered by ferruginous and quartzitic gravel along surface in places. Is mainly a mottled reddish brown and gray sandy clay ....50 ft.
5. Fine sand, gray when unweathered, but stained reddish on surface. Is cross-bedded and gypsiferous and contains layers of laminated gray shaly clay and laminated iron ore. Shaly clay layers are from few inches to 1 foot thick. The bedding planes are for the most part wavy, and lenticular sand layers are noticeable. The sands are locally laminated with limonitic layers and chocolate colored clay layers are to be noted. Ferruginous seams are noticeable along joint planes. The gypsum occurs as small flakes of selenite 1-32″ in diameter and less. Mottled toward top ....26 ft. 3 in.
6. Ferruginous dark red sandy clay. Contains some laminated gray and brown clayey layers ....19 ft.
7. About one half of this member consists of a coarse-grained, dark red, very ferruginous, slightly gypsiferous, friable

sandstone. Concretionary and pisolitic ferruginous material in places with warts up to 2 inches in diameter. These layers of sandstone are up to 1 foot in thickness, and are interbedded with a cross or wavy irregularly thin-bedded sandy clay which is alternately streaked gray and reddish brown in thin streaks. The sandstone which has a yellowish green or yellowish brown color when freshly broken forms the flat rocky surface of Cook's Mountain. At the northwestern rim of the mountain a medium-grained, dark brown sandstone containing casts of lamellibranchs in abundance is found. It is massive but may, in all probability, be the equivalent of the member above described which occurs on the southern rim......35 ft.

8. Covering the flat top of Cook's Mountain is a thin veneer of gravel made up of quartzose and granitic well rounded pebbles of even grain and averaging 1½ inch in diameter.

To the south of Cook's Mountain and Alabama bluff the Cook's Mountain beds are succeeded by the Nacogdoches, which extends along the river to the vicinity of Robbins Ferry east of the Leon-Madison county line, where it is finally overlain by the Yegua.

From beds of the Nacogdoches on Cane creek, five miles southwest of Crockett, Berry identified the following species of plants:

Cladasporites fasciculatus Berry
Cuprusinoyglon dawsoni Penh.

The last appearance of the fossiliferous Marine beds on the Trinity is near the mouth of Boggy creek in southeastern Leon and in northeastern Madison counties.

WHEELOCK AND VICINITY

Among the more noted fossil localities of the Cook's Mountain are those around Wheelock in Robertson county.

The fossils described by Gabb were obtained from Cedar creek near Wheelock. In the list of species described by that writer we find *Belosepia ungula* Gabb, *Murex (Odontopolys) compsorhytis* Gabb, *Fusus mortonopsis* Gabb, *Neptunea enterogramma* Gabb, *Pleurotoma, Turris kellogii* Gabb, *T. texana* Gabb, *T. retifera* Gabb, *T. nodocarinata* Gabb, *Eucheilodon reticulata* Gabb, *Scobinella crassiplicata* Gabb, *S. leviplicata* Gabb, *Dis-*

tortrix septemdentata Gabb, *Phos texana* Gabb, *Pseudoliva fusiformis* Con. mss., *P. linosa* Con., mss., *P. carineta* Con. mss., *P. perspectiva* Con. mss., *Gastridium vetustum* Con., *Agaronia punctulifera* Gabb, *Fasciolaria moorei* Gabb, *Cymbiola texana* Gabb, *Mitra mooreana* Gabb, *M. exilis* Gabb, *Erato semenoides* Gabb, *Neverita arata* Gabb, *Monoptygma crassiplica* Con. mss., *Architectonica meekana* Gabb, *Spirorbis leptostoma* Swain, *Turritella nasuta* Gabb, *Dentalium minutistriatum* Gabb, *Ditrupa subcoarcuata* Gabb, *Bulla kellogii* Gabb, *Volvula conradiana* Gabb,*Corbula texana* Gabb, *Cibota mississippiensis* Con., *Anomia ephippioides* Gabb[1].

The whole, or nearly the whole, of these species were obtained by the Texas Survey during the course of the work in that region, and several others have been added to the above list.

The section shown on Cedar creek and in the immediate vicinity is as follows:

1. Brown prairie sandy soil with occasional blocks or fragments of ferruginous sandstone containing great quantities of *Plicatula filamentosa* Gabb, and *Spirorbis leptostoma* Swain ....5-15 ft.
2. Brown altered greensand and clay........................ 4 ft.
3. Thin seam of ferruginous sandstone.................... 1 ft.

Nos. 2 and 3 contain quite an extensive fauna comprising *Actaeon punctatus* Lea, *Bulimella kellogii* Gabb, *Terebra houstonia* n. sp., Harris, *Conus suaridens* Conrad, *Pleurotoma (Surcula) gabbi* Con., Pl., *Pl—, Pl. (Cochlespira) engonata* Gabb, *Pl. bella* Con., *Pl. (Surcula) moorei* var., Gabb, *Pl. (Drillia) nodocarinata* Gabb, *Pl. terebriformis* Mr., n. sp., *Pl. (Drillia) texacona* Harris, *Pl. (Borsonia) plenta* Harris, *Cancellaria tortiplica* Con., *Ancilla (Olivula) staminea* Con., *Pseudoliva vetusta,* var. *pica, P. vetusta* Con., var. *fusiformis* Lea, *Ostrea alabamensis* Lea, *O. sellaeformis,* var. *divaricata* Lea, *Anomia ephippoides* Gabb, *Plicatula filamentosa* Conrad, *Byssoarca cuculloides* Con., *Trigonarca pulchra* Gabb, *T. corbuloides* Con., *Nucula magnifica* Con., *Leda opulenta* Con., *Yoldia claibornensis* Conrad, *Marginella semen* Lea, *Volutilithes petrosa* Con., *V. pre-*

[1] Journal Acad. of Nat. Sci. of Phila., Second Series, Vol. 4, pp. 376-389 and plates 67 and 69.

cursor Dall, *V. dalli* Harris, n. sp., *Turricula polita* Gabb, *Latirus moorei* Gabb, *Cornulina armigera* Gabb, *Petropsis conradi* Dana, *Corbula aldrichi*, var. *smithvillensis* Harris, *C. texana* Gabb, *C. alabamensis* Lea, *Dentalium minutistriatum* Gabb, *Dentalium minutistriatum* Gabb, var. *dumblei*, n. var., *Venericardia planicosta* Lam. *Cytherea tornadonis* Harris, *C. bastropensis* Harris, *Fusus mortoni* var. *mortonopsis* Gabb, *Phos texana* Gabb, var., *Distortrix septemdentata* Gabb, *Tuba antiquata*, var. *texana* n. var., *Solarium scrobiculatum* Con., *S. vespertinum* Gabb, *Natica arata* Gabb, *N. limula* Con., *N. semilunata*, var. *janthinops* n. var. *Sigaretus inconstans* Ald., *S. declivis* Con., *Pyrula (Fusoficula) penita* Con. var., *Mesalia claibornensis* Con., *Turritella nasuta* Gabb, *T. dumblei* Harris n. sp., *Aturia* near *zic-zac*. *Belosepia ungula* Gabb, *Flabellum* sp., *Turbinolia pharetra* Lea and *Lunulites* sp.

4. Pale to purplish-pink clay found 200 yards farther down Cedar Creek than No. 3. Very few fossils found in this bed .... 4 to 6 ft.
5. Dark grayish-green sand containing, in addition to the greater number of the fossils found in No. 2, the following: *Pleurotoma childreni*, var. *bitota* Harris, *Cancellaria panones*, var. *junipera* Harris, *Cancellaria gemmata* Con., *Volutilithes petrosa*, var. *indenta* Con., *Cadulus sub-coarcuatus* Gabb, *Chrysodomus enterogramma* Gabb and *Solarium acutum*, var. *meekanum* Gabb ....
6. Green sand with laminae of clay containing nearly the same fauna as in Nos. 3 and 5 with *Actaeon punctatus* Lea and *Pl. retifera* Gabb[1], additional .... 4 to 6 ft.
7. Dark brown and purplish-brown sand and clay, laminated with fossils in sand, to bed of creek .... 2 ft.

The next section west of this is on Campbell's Creek, near Dunn's ranch and about six miles west of Wheelock. This shows:

1. Black soil .... 2 to 4 ft.
2. Brown sand with calcareous material .... 4 to 8 ft.
3. Ferruginous brown sandstone and sands, altered greensands with *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. (Drillia) nodocarinata* Gabb, *Pl. (Borsonia)*

[1] Harris Mss.

plenta Harris, *Ancilla (Olivula) staminea* Con., *Ostrea sellaeformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Nucula magnifica* Con., *Pseudoliva vetusta* Con., var., *P. vetusta*, var. *fusiformis* Lea, *Volutilithes petrosa*, var. *indenta* Con., *V. precursor* Dall, *Latirus moorei* Gabb, *Corbula texana* Gabb, *Venericardia planicosta* Lam., *Fusus mortoni*, var. *mortonopsis* Gabb, *Phos texana* Gabb, var. *Distortrix septemdentata* Gabb, *Sigaretus declivis* Con., *Mesalia claibornensis* Con., *Turritella nasuta* Gabb, *Turritella dumblei* Harris n. sp., *Belosepia ungula* Gabb...... 4 ft.

4. Black laminated clay, enclosing *Conus sauridens* Con., *Pleurotoma (Surcula) gabbii* Con., *Pl. childreni*, var. *bitota* Harris, *Pl. (Drillia) nodocarinata* Gabb, *Pl. (Borsonia) plenta* Harris, *Ostrea sellaeformis* var. *divaricata* Lea, *Pseudoliva vetusta* Con. var., *Volutilithes petrosa* Con., *Latirus moorei* Gabb, *Venericardia planicosta* Lam., *Cytherea tornadonis* Harris, *Chrysodomus enterogramma* Gabb and *Natica arata* Gabb .... 2 ft.
5. Indurated greensand with *Occulina*, *Turbinolia pharetra* and *Endopachys maclurei* corals and in addition to the fossils found in No. 4 *Ancilla ancillops* Heilpr., *Byssoarca cucculloides* Con., *Pseudoliva vetusta* var. *fusiformis* Lea, *Volutilithes precursor* Dall., *Cornulina armigera* Con., *Corbula aldrichi*, var. *smithvillensis* Harris, *C. texana* Gabb, *Dentalium minutistriatum* Gabb, *Fusus mortoni*, var. *mortonopsis* Gabb, *Phos texana* Gabb, *Distortrix septemdentata* Nabb, *Solarium scrobiculatum* Con., *S. acutum*, var. *meckanum* Gabb, *Pyrula (Fusoficula) texana* Ald., *Mesalia claibornensis* Con., *Turritella nasuta* Gabb[1]................1 ft.
6. Laminated fossiliferous blue clay ....10 ft.
7. Alternate strata of yellowish sand and blue clay, clay 6-inches and sand from 4 to 8 inches thick .... 4 ft.
8. Brown sand ....1½ ft.

BRAZOS RIVER SECTION.

The Brazos river section of the Marine begins two miles south of Calvert bluff, but the lower beds are largely obscured by the river deposits.

A section at the International Railway bridge across the Brazos river shows:

[1] Harris Mss.

1.	Yellow sandy clay, with nodules of lime	20 ft.
2.	Brown sandstone, interstratified with brown sand	4 to 6 ft.
3.	Dark green, almost black, micaceous unfossiliferous sand	5 ft.
4.	Thinly laminated dark green sand	6 ft.
5.	Irregular belt of ferruginous sandstone	½ to 1 ft.
6.	Dark green, almost black, sand, to water	3 ft.

From this point to Collard's Ferry the exposures are unsatisfactory and no fossiliferous beds were found.

The bluff at Collard's ferry extends nearly a mile along the river and is twenty to twenty-five feet high. The section is:

1.	Brown sand	10 ft.
2.	Indurated brown altered greensand	8 in.
3.	Brownish-green altered greensand	4 to 6 ft.
4.	Grayish-green sand	10 to 15 ft.

Nos. 3 and 4 of the section contain *Pleurotoma* (*Surcula*) *gabbi* Con., *Pl. childreni* Lea, var. *bitota* Harris, *Cancellaria minuta* Harris, *Olivella bombylis*, var. *burlesonia* Harris n. var., *Ostrea sellaeformis* var. *divaricata* Lea, *Plicatula filamentosa* Conrad, *Pecen deshayesii* Lea, *Pinna* sp., *Byssoarca cucullоides* Conrad, *Leda opulenta* Con., *Pseudoliva vetusta* Con., variety *Volutilithes petrosa*, var. *indenta* Con., *Lapparia pactilis*, var. *mooreana* Gabb, *Latirus moorei* Gabb, *Corbula aldrichi*, var. *smithvillensis* Harris, *Dentalium minutistiratum* Gabb, *D. minutistriatum*, var. *dumblei* Harris n. var.,*Venericardia rotunda* Lea *V. alticosta*, var. *perantiqua* Con., *V. planicosta* Lam., *Cytherea* sp., *C. texacola* Harris, *C. bastropensis* Harris, *Clavilithes* (*Papillina*) *dumosa*, var., *trapaquara* Harris, *Fusus mortoni*, ver. *mortonopsis* Gabb, *Clavilithes penrosei* Heilprin, *C. humerosa*, var. *texana* Harris, *Pleurotoma* (*Clathurella*) *fannae* Harris, n. sp., *Solarium scrobiculatum* Con., *S. alveatum* Con., *Natica semilunata*, var. *janthinops* Harris n. var., *N. newtonensis* Ald., *Sigaretus declivis* Con., *Pyrula* (*Fusoficula*) *penita* Con. var., *Rimella texana* Harris, n. sp., *R. texana*, var. *plana* Harris n. var., *Calyptrophorus velatus* Conrad, *Turritella*, sp., *Belosepia ungula* Gabb, *Trochita*, sp. and coral *Turbinolia pharetra* Leo.

5.	Dark blue laminated clay	6 to 8 ft.
6.	Brown coal in river	4 ft.

At Niblett's shoals, two miles and a half below Collard's we find twelve to fourteen feet of lignitic shales, sands and lignites lying beneath twenty feet of river loam.

Moseley's Ferry is an historic place in the Texas Tertiaries. It was visited by Dr. Ferdinand Roemer in 1847 and described in his book on Texas. He speaks of it as "consisting of alternate strata of brown ferruginous sandstones and of dark colored plastic clays, both teeming with fossils". The bluff here extends along the river a distance of about 1,500 feet and is from 25 to 30 feet high. With the exception of the upper 15 feet of brown sand it is fossiliferous throughout. The fossils are very well preserved, exceedingly plentiful and easily obtained. The dip of the beds as shown in this bluff is between 50 and 55 feet per mile, but it may be said that throughout this region as well as other portions of the older Eocene reliable dips are very hard to obtain.

Section at Moseley's Ferry, Brazos River:

1. Brownish yellow surface loam.............................15 ft.
2. Thin stratum of fossiliferous iron ore in boulder form.... 6 in.
3. Blue laminated fossiliferous clay .... 3 ft.
4. Fossiliferous iron ore, running under the river about 100 yards below the ferry .... 2 ft.

Nos. 2, 3 and 4 contain an extensive fauna, comprising *Levifusus trabeatoides* Harris, n. sp., *Conus sauridens* Con., in great numbers, *Pleurotoma (Surcula) gabbi* Con., *Pl. (Cochlespira) engonata* Con., *Pl., (Drillia) nodocarinata* Gabb, *Pl. terebriformis* Mr., *Pl. (Borsonia) plenta* Harris, *Ostrea sellaeformis* var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Byssoarca cuculloides* Lea, *Pseudoliva vetusta* var. *Volutilithes petrosa Con.*, *Volutilithes precursor* Dall., *Turricula polita* Gabb, *Latirus moorei* Gabb, *Corbula texana* Gabb, *Dentalium minutistriatum* Gabb, *Dentalium minutistratum* var. *dumblei* new variety, *Venericardia planicosta* Lam., *Cytheria texacola* Harris, *Cytheria tornadonis* Harris, *Chrysodomus enterogramma* Gabb, *Phos texana* Gäbb, var., *Distortrix septemdentata* Gabb, *Tuba antiquata* var., *texana* new var., *Solarium acutum* var. *Meekanum* Gabb, *Sigaretus declivis* Con., *Mesalia claibornensis* Con., *Turritella nasuta* Con., *T. dumblei* Harris, n. sp., *Pyrula* (*Fusoficula*) *texana* Ald., and several corals.

5. Laminated fossiliferous blue clay containing *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl.* (*Cochlespira*) *engonata* Con., *Pl.* (*Borsonia*) *plenta* Harris, *Pl.* (*Surcula*) *moorei* var. *Levifusus trabeatoides* Harris n. sp., *Ancilla* (*Olivula*) *staminea* Con., *Pseudoliva vetusta* var., *Volutilithes petrosa* Con., *Dentalium minutistriatum* Gabb, *Venericardia planicosta* Lam., *Leda opulenta* Con., *Cytherea texacola* Harris, *Distortrix septemdentata* Gabb, *Mesalia clatbornensis* Con., *Turritella nasuta* Fabb and *Belosepia ungula* Gabb .... 6 ft.
6. Fossiliferous iron ore .... 2 ft.
7. Altered fossiliferous greensand found at north end of bluff. 10 ft.
8. Fossiliferous iron ore .... 2 ft.

Nos. 6, 7 and 8 contain *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbii* Con., *Pl.* (*Drillia*) *nodocarinata* Gabb, *Pl.* (*Borsonia*) *plenta* Harris, *Levifusus trabeatoides* Harris n. sp., *Anomia ephippioides* Gabb, *Pseudoliva vetusta* Con. var., *Latirus moorei* Gabb, *Venericardia planicosta* Lam., *Distortrix septemdentata* Gabb, *Turritella dumblei* Harris n. sp., *Byssoarca cuculloides* Con., *Solarium acutum*, var., *meekanum* Gabb.

9. Green sand, dark green near ferry, but altering to a brown near north end, and merging into No. 7, measuring at ferry .... 5 ft.

This bed contains *Conus sauridens* Con., *Pleurotoma* (*Surcula*) *gabbi* Con., *Ancilla* (*Olivula*) *staminea* Con., *Ostrea sellaeformis*, var. *divaricata* Lea, *Anomia ephippioides* Gabb, *Pseudoliva vetusta*, Con. var., *P. vetusta*, var. *carinata* Con., *Peropsis conradi* Dana, *Corbula texana* Gabb, *Venericardia planicosta* Lam., *Cytherea texacola* Harris, *Fusus mortoni* var. *mortonopsis* Gabb, *Phos texana* Gabb, var. *Distortrix septemdentata* Gabb, *Turritella nasuta* Gabb, and *Tenuiscola trapaquara* Harris n. sp.,[1] *Turbinolia pharetra* Lea, *Endopachys maclurei* Lea and other corals.

10. Thinly laminated blue clay, changing into brown near top, and weathering to a light blue toward the bottom; the

[1] Harris Mss.

upper brown portion contains fossils similar to those in No. 9, and the lower blue contains occasional crystals of selenite ....15 ft.

11. Dark, almost black, fossiliferous sandy clay................10 ft.
12. Thin seam of black clayey sand, jointed and stained brown along joints and on outside, apparently unfossiliferous.. 1 ft.
13. Same as No. 11, extending into river and forming a ledge in bottom of river ....14 ft.

Nos. 11 and 13 contain *Pleurotoma childreni* Lea, var. *bitota* Harris, *Yoldia claibornensis* Ald., *Pseudoliva vetusta* Con., var. *Tellina mooreana* Gabb, *Venericardia planicosta* Lam., *Cytherea bastropensis* Harris, *Turritella nasuta* Gabb.

The contact of the Marine and Yegua is seen in a bluff on the Brazos river about 500 yards south of the mouth of the Little Brazos, with the following section.[1]

1. Black soil .... 2 ft.
2. Brown loam with limy concretions ....25 ft.
3. Fine brownish-yellow sand with occasional streaks or pockets of gravel ....15 ft.
4. Gravel, with rolled cretaceous shells ....2 to 4 ft.

Yegua Clays:

5. Pale blue clay, unfossiliferous .... 5 ft.

Marine beds:

6. Dark greensand showing fossils in lower portion........2 to 5 ft.
7. Dark colored laminated sandy clay containing *Terebra houstonia* Harris; *Levifusus trabeatoides* Harris n. sp.; *Pseudoliva vetusta* var.; *Pseudoliva vetusta* var. *pica; P. vetusta*, var. *clausa; Trigonarca corbuloides*, Con.; *Pleurotoma (Pleurotomella) quasites*, Harris; *Nucula magnifica*, Con.; *Leda opulenta*, Con.; *Latirus moorei*, Gabb; *Corbula alabamensis*, Lea; *Venericardia planicosta*, Lam; *Phos texana*, Gabb., var.; *Natica arata*, Gabb.; *Natica semilunata*, var. *janthinops* new var.; *Sigaretus inconstans*, Ald.; *Yoldia aldrichiana* ....4 ft.
8. Ferruginous sandstones .... 8 in.
9. Same as No. 7.

In this section the gypseous clays are not seen nor do they appear anywhere in the river banks. This, however, may be expected as their position is obscured by broad, deep deposits of river alluvium which cover wide areas and form the bottom lands of the Brazos. East of the little Brazos these clays are found occupying their proper position at several places.

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[1]Fourth Annual Report Geol. Sur. of Texas, 1892.

CHAPTER V.

CLAIBORNE, CONTINUED:

YEGUA

NAME

The lowest member of the Fayette beds of Penrose was a series of clays and lignites. Their inclusion in his Fayette was due to the fact that he found no marine fossils in them, and as he had made the final fossil-bearing beds of the Marine the top of his Timber Belt beds, these were excluded. When we found Claiborne fossils in this basal clay member it became necessary to separate it from the Fayette and the Yegua formation was instituted to include the series of gypseous and saliferous clays, sands and lignites overlying the Cook's Mountain greensands and underlying the Fayette white sands and clays.

THE TYPE SECTIONS

The original differentiation resulted from an examination made by the writer and party in 1892, starting from Giddings and going northeastward along Elm creek, a branch of the Yegua. This creek runs in a general northeasterly direction, which is about the strike of the formations in this vicinity, and thus the course of the creek very nearly coincides with the line of parting between the Cook's Mountain and overlying Yegua clays.

Owing to the numerous twists and turns of the creek the two sets of beds are found first on one side of the stream and then on the other. In some localities nothing but Marine is seen, but within a few hundred feet the Yegua is the only series exposed. Under these conditions it is extremely difficult to give any idea of the thickness or dip of the beds. The general structure of the territory, however, appears to be:

1. Thin scattering gravel in places.
2. Thinly bedded and in places laminated sands and clays with lignitic sands and thin streaks of lignitic material.
3. Thinly stratified blue and brown clay weathering to a brownish

yellow, the layers from ½ to 2 inches thick.

These beds show also in places laminated dark blue and pinkish colored clays carrying large blocks of selenite enclosing small fossil forms.

4. Thin streaks of ferruginous material, probably originally carbonate of iron. This streak lies in the form of a pavement of kidney shaped or ellipsoidal flattened bowlders from one to three feet in length and from six inches to one foot in thickness. These bowlders are usually concentric in structure and break in thin layers, but in some portions toward the head of the creek into square blocks. A thin streak of ferruginous or altered glauconitic sand underlies this pavement and is generally associated with it. This sand is highly fossiliferous and the fossils are usually fairly well preserved. These appear to have a strong Claiborne facies.
5. Laminated dark almost black clay. This clay breaks up into nodules or cuboidal blocks with rounded ends and carries a considerable fauna and also a small quantity of selenite. The fauna is usually found in nests or a large number in one place, while a considerable portion of the clay is barren. The bed is jointed and broken in places appears to be faulted. The joints are usually within a few degrees of perpendicular and are filled with thin sheets or plates of selenite. These beds are broken by a thin streak of ferruginous material similar to No. 4.
6. Pale bluish gray clay carrying fossils and gradually changing to a slightly altered glauconitic sand.

This appears to be the lowest bed visible in this section and is thought to be the top of the Marine beds.

Beginning near the head of the creek and going eastward, or down the creek, the details of the section are as follows:

On the northeastern corner of the Thornton Kuykendall Survey the surface of the country is covered with a heavy deposit of chocolate colored clay carrying a considerable quantity of selenite crystals. and in the stream there appears a small exposure of hardened brownish, somewhat green-shaded, sand or soft sandstone carrying *Anomia ephippoides* and other Cook's Mountain fossils.

The next exposure is about half a mile down the creek, where the section seen is as follows:

1. Pale blue and brown clays weathering a brownish-yellow with nodules of iron ore at base.................... 20 ft.

2. Thin sheet of ferruginous sandstone with dark colored greenish to black sand carrying fossils (Loc. 206),..6 to 8 in.
3. Thinly laminated dark-blue, almost black, clays with streaks of sulphur between the laminae. These clays carry fossils in nests,......... ....15 ft.

Coming down the creek to about a quarter of a mile west of Orell's Crossing the only deposits seen consisted of pale blue to brown clays carrying selenite. These do not appear to be more than ten to fifteen feet in thickness at exposure, but nowhere could the base be seen until the locality here mentioned was reached. The section (Loc. 205) seen at this place was:

1. Surface soil,....................................1½ ft.
2. Laminated or thinly stratified sands of a yellowish gray and brownish yellow color with strata from a half to two inches in thickness,.......................... 8 ft.
3. Laminated dark-blue and pinkish colored clays carrying large pieces of selenite. Occasional fossils, mostly *Distortrix septemdentata* and *Turritella* are seen, but these are generally in a poor state of preservation,.... 6 ft.
4. Thin streaks of ferruginous material lying in flat kidney shaped concretions with a half to one inch of fossiliferous sand on lower side...............................6 to 10 in.
5. Laminated dark blue, almost black, clays, carrying fossils in nests. This clay breaks up into cuboidal blocks or nodules with rounded ends and the bed is joined with almost perpendicular joints filled with thin sheets of selenite. It also appears to be faulted in places...... 5 ft.
6. Thin streaks of ferruginous material similar to No. 4 of above section, ...6 in. to 1 ft.
7. Laminated clays similar to No. 5 to creek,............. 4 ft.

A peculiarity about the fauna found in this section is the smallness of the fossils and the dwarfed appearance of the *Turritella, Pleurotoma* and *Volutilithes.*

A short distance below Orell's Crossing the blue clays carrying selenite, No. 3 of above section, appear and these form the only exposure seen until a short distance above Price's Crossing, where a small exposure of ferruginous sand was seen. At this locality (Loc. 84-K) a few small corals were obtained. Here and there the belt of ferruginous sandstone with fossiliferous sand occurs, but in most of the exposures the fossils were poorly preserved or existed only in the form of casts. The material overlying these beds is chiefly brown ferruginous sand of recent age intermixed with scattering pockets of gravel.

A short distance below Price's Crossing a section (Loc. 204) shows:

1. Black soil, ...1 to 2 ft.
2. Thinly stratified blue and brown clay weathering to a yellowish brown, carrying considerable quantities of selenite and casts of fossils. These beds also carry a few badly decayed specimens of *Distortrix septemdentata*, and *Turritella* ....15 ft.
3. Ferruginous sandstone or kidney shaped bowlders of ferruginous material in a concentric form, ... 6 in.
4. Altered fossiliferous greensand carrying a considerable fauna of Lower Caliborne fossils .... 4 in.
5. Pale blue laminated clays carrying some fossils, to creek,.. 5 ft.

The dip of these beds appears to be S. E. 6 degrees.

A bend in the creek here brings the clays and ferruginous sands to the other side of the creek, but the general section remains the same. About 100 yards further down the creek the section is clearer and the greensand at base much thicker and carries a larger fauna with much better preserved fossils. The section (Loc. 203) at this place shows:

1. Drift material, brown sand with gravel and flint pebbles.. 5 ft.
2. Laminated blue clay with brown sandy streaks. This bed carries badly decomposed *Distortrix septemdentata* and *Turritella* ....10 ft.
3. Ferruginous sandstone in thin pavement and streaks...... 1 ft.
4. Dark green slightly altered greensand carrying well preserved fossils of Claiborne age, ... 2 ft.
5. Heavy bed of ferruginous sandstone bowlders, seen, ... 2 ft.

The course of the creek at this place turns sharply towards the southeast and about five hundred yards farther down the gypsum-bearing clays are found overlying the fossiliferous blue clays unconformably.

At Evergreen Crossing a bluff of about 30 feet shows laminated clays and sands with some show of sulphur near the base.

Near the mouth of Elm creek on the Yegua river at Bluff crossing a section is as follows:

1. Gray sand soil,....................................1 to 2 ft.
2. Orange sandy loam, gravel on top or mixed in through it, some platy iron,..............................5 to 8 ft.
3. Chocolate clays interbedded and laminated,..........6 to 8 ft.
4. Brown sand, micaceous,.........................1 to 1½ ft.
5. Lignitic clays: chocolate brown to black, with sulphur, pyrites, mica and plant remains, *Nucula magnifica, Phos* and *Cardita planicosta,* etc.,.......................... 6 ft.

The line between the Cook's Mountain and Yegua in this, the type locality, is drawn at the base of the massive selenite-bearing clays. The Yegua here, as shown by its fauna, is, beyond question, Lower Caliborne in age, and apparently marks a shallowing of the Cook's Mountain seas and a much broader area of lignitic deposits than is seen during the Marine.

From Elm creek the Yegua continues five or six miles southeastward to the vicinity of Nail's creek, where it is overlain by the Fayette sands and joint clays.

AGE.

The original collections of fossils made from these beds were studied by Harris, who determined the following forms:

Ostrea sellaeformis, Lea.
Plicatula filamentosa, Con.
Pinna sp.
Pectunculus idoneus, Con.
Trigonarca pulchra.
Nucula magnifica, Con.
Leda opulenta.
Leda houstonia, Har.
Venericardia planicosta, Lam.
Chama sp.
Crassatella trapaquara, Har.
C. antistriata, Gabb.
Cytherea bastropensis, Har.
Corbula alabamiensis, Lea.
Dentalium minutistriatum var. dumblei, Har.
Terebra texagyra var., Har.
T. houstonia, Har.
Conus sauridens, Con.
Ringicula trapaquara, Har.
Volvula minutissima, Gabb.
Pleurotoma gabbi, Con.
P. nodocarinata, Gabb.
P. bitota var. Harris.
P. texacona, Gabb.
P. plenta, Har.
P. crassiplicata, Gabb.
P. reticulata, Gabb.
Pleurotoma sp.
Cancellaria gemmata, Con.
C. tortiplica, Con.
C. panones var. smithvillensis, Har.
C. minuta, Har.
Ancilla staminea, Con.

Pseudoliva vetusta, Con.
Volutilithes petrosa, Con.
V. petrosa var. indenta, Con.
Lapparia pactilis var mooreana, Gabb.
Turicula polita, Gabb.
Latirus moorei, Gabb.
Fusus mortoni mortonopsis, Gabb.
Phos texana, Gabb.
Distortrix septemdentata, Gabb.
Cassidaria planotecta, Aldrich.
Tuba antiqua var. texana, Har.
Solarium bellastriatum, Con.
S. scrobiculatum, Con.
S. alveatum, Con.
S. acutum var. meekanum.
Natica arata, Gabb.
N. limula, Con.
N. semilunata var. janthinops, Har.
Natica sp.
Pyrula texana, Aldrich.
Triforis sp.
Mesalia claibornensis, Con.
Turritella nasuta var. houstonia, Har.
T. duxtexta var. Har.

Vaughan lists the following corals from collections made on this creek and the West Yegua[1]:

Corals from Elm Creek.

Flabellum cuneiforme var. pachyphyllum, Gabb & Horn.
Turbinolia pharetra, Lea.
Madracis sp.
Endopachys maclurii, Lea.

From West Yegua.

Balanophyllia irrorata var. mortoni, Gabb & Horn.

In 1908 Kennedy and Garrett made further examinations along Elm Creek, from the report of which the foregoing description was made. The collections furnish additional species, as follows:

Flabellum cunciforme Gabb and Horn
Turbinolia pharetra, Lea.
Endopachys maclurii, Lea.
Cadulus subcoarcuatus.
Anomia ephippioides.
Arca sp.
Clavilithes penrosei, Har?
Syrnola trapaquara, Har.
Solarium huppertzi, Har.

East of the Brazos few fossils are found in the Yegua, but on the Rio Grande, where the series of beds referred to this formation are more sandy, fossils are very abundant. From the collections made at exposures of these beds in the banks of this

[1]Vaughan, T. W. Eocene and Lower Oligocene Coral Faunas. U. S. G. S. Monograph 39, p. 28.

river by Penrose and Dumble[2] between a point 10 miles south of Laredo and one four miles north of Zapata (Carrizo), where these beds are overlain by the Fayette, Harris determined the following forms[1]:

Ostrea alabamensis, Lea.
O. alabamensis var. divaricata, Lea.
Amomia ephipioides, Gabb.
Venericardia planicosta, Lam.
Cythera texacola, Heilp.
Tellina mooreana, Gabb.
Corbula alabamensis, Lea.
Conus sauridens, Con.
Pleurotoma nodocarinata, Gabb.
Volutilithes petrosus, Con.
Volutilithes petrosus var. indenta, Har.
Levifusus trabeatus, Con. var.
Lacinia alveata, Con.
Cornulina armigera, Con.
Certhium sp.
C. webbi, Har.
Natica recurva var dumblii, Heilp.
Turritella nasuta var. houstonia, Har.

MAPPED AREA

The lignitic clays and sands of the Yegua are exposed over an extensive area between the Brazos and the Sabine.

The belt has an average width of 12 miles. Its greatest width, 22 miles, is found along the Neches river, while on the Sabine it narrows to 5 miles. In dip it varies from 40 feet to the mile to more than 100, and has a thickness of 400 to 800 feet.

GENERAL CHARACTER

The clays are laminated, thinly stratified, and massive in structure, and chocolate, dark blue, brown, and gray in color. The cone-in-cone structure first noted on Atascosa creek in the Nueces section, is also found in the basal beds of this area. The sands and sandy clays, which are sometimes micaceous, are brownish drab, buff and gray. They range from laminated to massive and are often cross-bedded. Laminated clays and sandy clays, sometimes leaf-bearing, frequently occur as lenses, pockets, and nodules in the sands, even when the latter are cross-bedded. Similarly, lenses of sand are found in the laminated, jointed clays.

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[2]Penrose, First Annual Report Geol. Sur. Tex. p.
Dumble, E. T. Geology of Southwestern Texas. Trans. Am. Inst. Min. Eng., 102, p.

In the lower portion of the beds the clays seem to predominate. The middle portion seems to carry the most lignitic matter, and the sands prevail in the upper beds.

Both clays and sands weather to light colors, mostly yellow or dirty white, and some of the sandy clays show typical bad-land weathering. The topographic expression is generally flat.

In the upper beds, referred to this formation by Baker and Suman, some of the sands have a porcelaneous cement, others limonitic, and still others contain streaks and balls of white clay having the appearance of porcelain.

Lignitic material is abundant, disseminated through the beds in fragmentary form, as carbonaceous coatings, and in lenticular beds; but only a few deposits of workable lignite are known to occur in the Yegua east of the line of the International & Great Northern Railway in Houston county.

Gypsum is very abundant. In the lower portion of the beds, where it predominates, it occurs as large masses of selenite of irregular form. Elsewhere it occurs as crystals of selenite, sometimes of large size, or as fragments intermingled with the sands and clays.

One of the most unusual and characteristic features of the Yegua in this area is the quantity of clastic selenite which occurs. At times the particles of this mineral equal or exceed in amount the quartz grains in the sandstones. Saliferous strata also occur.

The cannon-ball concretions of the Rio Grande are found here in abundance. While some of these are of spherical shape, as on that stream, many of the clay-ironstone concretions are in the form of flattened masses, some of them 2 to 3 feet in diameter. They are usually altered to limonite, and these limonite concretions and impregnations are characteristic of the beds east of the Trinity. Occasionally the limonitic concretions have streaks of calc-spar through them, but true calcareous concretions are apparently absent. Silicified wood is plentiful as logs of large size and as fragments scattered through the formation from bottom to top, but none of it is opalized.

Marine invertebrate fossils occur occasionally as poorly preserved casts in connection with pockets or concretions of greensand marls. Fossil plants are found abundantly at many places.

The relation of the Yegua to the underlying Marine was discussed in the description of the Nacogdoches beds which connect the two.

SABINE RIVER SECTION

On the Sabine river the outcrops of the Yegua are unimportant. According to Veatch they are characterized by unfossiliferous lignitic clays with large calcareous concretions and are the lithological counterparts of beds of the Lignite phase of the Wilcox.

His only section is that of a bluff nearly four miles southwest of Columbus, which shows:

1. Fine white sand, ... 20 ft.
2. Dark gray to blue sandy clay with fine sand partings and occasional beds of yellow sand, in many places a foot thick. Contains many poor plant impressions and a few calcareous concretions, ... 28 ft.

Dip S. 20° E. 1:20.

A quarter of a mile south of the above outcrop, at Lawhorn's bluff, 26 feet of laminated sandy clay, containing many large calcareous concretions, is exposed. A bed of impure lignite, a foot thick, occurs about three feet above low water-level. Dip S. E. 1:70.

Three shelves of dark colored clay appear near water level between Lawhorn's bluff and Robinson's ferry. At one of these the bed is 6 feet thick and has the usual covering of light colored sands.

Deussen, in his plat of section[1] shows a series of clays or shales one-fourth mile below Robertson Ferry carrying such Yegua forms as *Pleurotoma terebriformis, Marginella semen* and *Corbula oniscus.* This is the uppermost bed of Yegua known on the river, as half a mile below it Veatch found the Jackson well exposed.

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[1]Water-Supply Paper 335, Plate IV.

SANTA FE RAILWAY SECTION

The exposures along the Santa Fe Railway are not very satisfactory. The last Cook's Mountain was seen at Birdwell siding. A mile and a half south of Brunson there is an outcrop of lignite which is also found in wells drilled in the vicinity. Between Mile Posts 106 and 101 the interbedded clays and sands appear in the cuts. The contact with the Jackson is supposed to lie between Mile Posts 101 and 100.

TEXAS & NEW ORLEANS RAILWAY SECTION.

On the Texas & New Orleans Railroad the base of the Yegua is found in a cut about one mile south of Platt.

Near the base of this section there is exposed 5 feet of a chocolate-brown thinly laminated shale stained yellow with sulphur. Next in upward succession comes 3 feet of light buff or gray, cross-bedded, medium-coarse material, which has the texture of sandstone, but is made up for the most part of angular fragments of platy selenite. It is much cross-bedded. In upward succession it is found that the selenite clastic is interbedded with light gray sandy shale containing many fragments of silicified wood. The materials of this formation weather mainly to a light creamy buff, although locally they are yellowish brown from limonite. The soils of the formation are either of a light buff color, or are grayish and brownish mottled, or rather uniformly reddish-brown. Strike N. 60° E. Dip 2° S. E.

In the cuts to the south evidence of local folding was obtained, one small anticline being noted.

The following section was noted south of Bridge 135-F:

1.	Chocolate colored, laminated shale,	4 ft.
2.	Gray to brown gypsiferous sandstone,	2 ft.
3.	Drab and reddish-brown mottled clay,	3 ft.
4.	Drab colored, soft, clayey shale. Contains a layer of hard limonitic shale,	25 ft.

South of Manton a thin-bedded sandy shale seemingly calcareous and rather resistant to weathering is exposed in a few small cuttings. It is of a gray to drab color. This same material was noted near Dunagan and here it is covered by about 2 feet of a dark-gray sand, which carries much silicified wood in large fragments and a thin layer of gravel made up of rounded pebbles of quartz, jasper, and clay iron ore.

Between Dunagan and Huntington cuts expose thin-bedded gray gypsiferous clayey sandstone overlain by a gray sand which contains gravel lenses and many fragments of silicified wood. There is a brown limonite layer occurring in the thin-bedded material here that is fairly persistant.

ST. LOUIS SOUTHWESTERN RAILWAY SECTION

The upper portion of the Yegua section in this vicinity is shown along the St. Louis Southwestern Railway between Broaddus and Monterey.

Broaddus in San Augustine county is located about the middle of the Yegua section and the line runs southwestward to Monterey, where it strikes the contact of the Yegua and Jackson.

Light brown laminated sands outcrop ¼ mile southwest of Broaddus. These contain brownish carbonaceous fragments and thin plates of limonite-cemented sand. Silicified wood is abundant. These beds have a thickness of about 4 feet. They weather light greenish-gray and brown, and contain a variable percentage of clay. The brownish layers are in association with films of limonite.

At the cut 200 yards south of Mile Post 668 and between that Mile Post and Broaddus station is the following section:

1.	Very light gray-brown sandy clay with thin non-continuous films of limonite varying from 1-32 to 1-8 inch in thickness,	4 ft.
2.	Light chocolate-brown carbonaceous clay, sandy,	4 in.
3.	Dark chocolate-brown carbonaceous clay,	6 in.
4.	Light brown sand,	2 - 3 ft.

The same section in general is found at Bridge 310, one-fourth mile south of Broaddus, where the very dark brown carbonaceous shaly clay 1½ feet thick, is underlain by 2 feet of very light brown clayey sand fracturing into compact rectangular blocks, and carrying plant fragments. A silicified log was found in place in the brown layer. In the lower sand thin plates of light gray indurated sandstone are found locally. Thin non-continuous layers of limonite are common and one long cylinder-shaped concretion made up of concentric layers of limonite-cemented sandstone was found in the lower clayey sand.

A good section is found in a gully to the south of the north end of this bridge. Here the laminated, clayey sands are exposed for a thickness of 8 feet. The laminae are plainer and finer at the base, while above, the blocks fracture semi-conchoidally into irregular fragments. The color is light brown, and large, concentric limonitic concretions (2 or 3 feet in long dimension) are found.

Under Bridge 309 there is about 5 feet of clay, light chocolate-brown at the base and light sulphur-yellow above. The clay contains in places thin, non-continuous, brown carbonaceous layers and little balls and lenses of sand. It is speckled and streaked with rusty limonite which also coats fracture planes.

At Bridge 308 are streaks of yellow sulphur in the clays. Above are about 10 feet of light-brown case-hardened sands with streaks and blotches of yellow sulphur and brownish limonite. Thin, irregular and non-continuous contorted beds of more compact sand are scattered through the section. This passes into a partially "shelly" gypsiferous sandstone at the top.

In the superficial layers overlying the clay in the next cut to the southward (Mile Post 666) are rough boulders of a ferruginous-cemented hard conglomerate made up of pebbles of quartz, chert, and silicified wood. This is the local representative of a Lafayette ferruginous conglomerate which is widespread in southwestern San Augustine county, extending at least from north of the Marine outcrop as far south as the Catahoula outcrop. The basal bed in this cut is shaly dark-drab sulphurous clay, 5-7 feet thick, and weathering a light yellow. The sulphur is in streaks, blotches, or small roundish concretions which are rough, sometimes mammillary, on the surface. The dip is 3° S. 15° W. (Mag.). The section is:

1. Surficial Lafayette; light buff to dark-brown, mottled, mainly sand, but with gravel and rough rounded bowlders of ferruginous-cemented sand-matrixed conglomerate, some of which are 6-8 inches in diameter,. . 4 ft.
2. Light brown, medium-grained sand, speckled brown and whitish, laminated. Whitish grains, perhaps decomposed gypsum,. . . . . 3 ft.
3. Fine light, gray-brown, clayey sand, impregnated with salt, making semi-badlands, imperfectly laminated throughout, but with better laminae at top. Top layers sulphurous . . . . 8 ft.
4. Light drab clay, weathering dark, dirty-green, with concretions and thin, non-continuous lenses of clay ironstone, ... 8 ft.
5. Brown medium-grained, gypsiferous sand with sulphur concretions, plant fragments, and limonite. Weathering into pinnacled semi-badlands,. . . . . .10 ft.
6. Gray-drab clay, weathering dark dirty green, with whitish concretions, ...2 - 4 ft.
7. Layer with white rounded concretions, perhaps calcareous 2 in.
8. Black to dark brown clay ironstone, amorphous, compact, with dendritic markings, probably of manganese dioxide. Iron in form of limonite . . . . .1 ft. 1½ in.
9. Clay like (6), but without concretions,. . . . . 2 ft.
10. Clay ironstone like (8),. . . . . .1 ft. 2½ in.
11. Clay like (9),. . . . . 3½ ft.
12. Thin-bedded, shaly limonite-stained clay,. . . . . 2 in.
13. Brown limonite-stained clayey sand; at top consisting of thin bands of dark-green clay, alternating with sand. Contains thin bands of dark-brown ferruginous sandstone, ... 2 ft
14. Shaly, dark-drab, sulphurous clay, weathering light yellow, ... 7 ft.

The two top members of the Yegua section are approximately horizontal. The dip varies from 3° to 0° within 300 yards, going southward.

In the small cut just to the south of the one last described, there is 6 feet of Yegua which either belongs on top of No. 2 of the last section, or else grades into Nos. 2 and 3 horizontally. The lower 3 feet is rather massive, laminated sand, alternating layers of light-buff to brown, succeeded above by 6-inches of very dark-brown carbonaceous shale, overlain by 3-inches of whitish to brownish-yellow laminated clay, with 3 feet of dark-brown clay on top. There is a small anticline in the central portion of the outcrop of the carbonaceous layers and the entire length of the cut forms a low anticline which includes the small one. At the south end of the cut No. 2 of this section comes down below the track level for its entire thickness of 3 feet. It is here more indurated than in the last section, but the induration is irregular and produces a rather "shelly" appearance.

The southern limb of the anticline probably brings these strata below Bridge 307, where there is 6 to 8 feet of brown and gray, laminated, soft sands under a 6-inch carbonaceous brown shale, overlain by 2 feet of brown, shaly clays, capped with 6 feet of light drab, laminated sand. Sulphur is found just above the carbonaceous layer.

The cut at Mile Post 665 shows 4 feet of light brown, sandy clay with limonitic concretions, weathering light buff. There is some sulphur, especially in juxtaposition with the concretions.

At the cut 200 yards south of Bridge 304 and 400 yards south of Mile Post 665 there is at the base 3 feet of light brown sulphur and limonite-blotched sand passing upwards into 3 feet of carbonaceous, brown clay, weathering dark reddish-brown.

In the cut 200 yards south of Mile Post 664, at the north end, is 4 feet of the dirty green clay with white nodules. The unweathered portion is lighter green, or light grayish-brown. As the dip is northward, this clay overlies the beds farther south, which are light green, clayey sand, at least 10 feet thick. Small balls and lenses of light-gray sandstone are found. These clayey sands weather very gray and are approximately horizontal at the south end of the cut.

In the cut at Mile Post 663 the dip is 1½° S. 45° W., but somewhat variable. The section here is:

1. Light gray clay, weathering dirty green, with large, dark brown, lenticular ironstone concretions coated on fracture planes with black oxide of manganese,........ 5 ft.
2. Light, greenish and grayish, sandy clay with irregularly distributed brown plant fragments,.................10 in.
3. Dark brown carbonaceous clay,....................... 2 in.
4. Light green sticky clay,............................ 4 in.
5. Light gray, medium-grained sand, with clastic gypsum

flakes. The lamination is imperfect, but is apparent from local, thin, indurated layers of sand. Weathers into semi-badlands, ... 6 ft.

Some of the concretions in the upper member are 20 feet in diameter.

Two hundred yards southeast of Mile Post 663, with its top 6 feet below the track level, is 6 feet of loose sand varying in color from light buff to light yellowish-brown, depending on amount of iron present. The sand weathers into semi-badlands with rain-erosion monuments from 1 to 2 inches in heaight. At this locality is a small prairie 4 or 5 acres in extent and having a small "saline" on its western border.

The Lafayette has a thickness of 7 feet at Warsaw. The long trestle over the Attoyac and Angelina just above their junction is over ¾ mile in length. No terraces are to be seen in this flood plain, although there are several flood-channels cut into the general bottom level. Both banks of the flood-plain are composed of red and gray Lafayette sands and both rise gradually to 25 or 30 feet above the general level of the flood-plain. A very flat country begins to the west of the Angelina river and continues westward across Angelina and Trinity counties, underlain in part by the Yegua and in part by the Jackson clays.

Light gray sands, succeeded above by 8 feet of brown, carbonaceous sandy clay, varying in color, on account of the amount of carbon present, from light chocolate to nearly black, is found in the first cut west of Mile Post 659. The light sandy layers break with a semi-conchoidal fracture and contain plant fragments. Unconformably overlying the brown clay, is 4 feet of light gray, friable, cross-bedded sandstone, hardening along joints. This sandstone is composed of coarse, subangular grains of quartz, grains of the same size and contour of a light colored mineral and some black chert. It contains streaks and balls of a white clay-like substance which gives the appearance of porcelain. It contains pebbles or emulsion balls of white clay and its contact with the underlying clays forms a line of small springs. It is probably the base of the Jackson at this point. The maximum thickness is 6 to 7 feet, 4 feet being an average. Its basal 2 inches, in the middle of the cut, is partially quartzitic.

Although, in the east of the cut, its contact with the underlying Yegua runs as a plane surface for 300 yards, to the west, it occupies an erosion channel in the Yegua clays and is much more cross-bedded. Cross-bedding and contorted bedding is very common in the middle of the cut.

Three hundred yards east of Monterey and 200 yards east of the west end of the cut, is a lens of light-brown clay coming in between two cross-bedded layers and dipping eastward. The general color of the cross-bedded material is very light gray. At one place it is overlain by shaly porcelaneous sandstone resembling the Jackson.

HOUSTON, EAST & WEST TEXAS RY. SECTION.

The Houston, East & West Texas Railway is somewhat barren of good exposures but from the divide near Lufkin there are creeks running northward into the Angelina and southward into the Neches which parallel the line of road and these give better views of the formation.

East of Lufkin, where the Angelina and Neches river railroad crosses Durasno creek, we find an exposure which has at the base a layer mainly composed of clay ironstone concretions from 2 to 5 feet in diameter and from 4-inches to a foot in thickness. The material of these gray concretions is very fine-grained and is well compacted into an amorphous mass of hard rock. In color it is a light greenish-gray in the interior, but the outside is covered with a ¼ inch film of brown or reddish limonite stain. Some of the concretions have good cone-in-cone structure. This concretionary layer is overlain by 6 feet of thinly laminated light gray sandy clay shale.

This is near the base of the Yegua and lithologically is similar to the basal beds on Elm creek.

The next exposure in upward succession shows 4 feet of chocolate-brown, carbonaceous shale, with medium-grained, limonite-stained sand at the base. Higher up, an exposure gives 6 feet of light gray sand, fine-grained and thinly laminated, with filmy partings of brown carbonaceous matter. The highest exposure on the creek exhibits 3 feet of dark chocolate-brown, thinly-laminated clay shale.

From the head of Durasno creek we cross the divide between the Angelina and the Neches and seven miles south of Lufkin find the headwaters of Bear creek, a tributary of the Neches river, which flows in a general southerly direction and gives other sections of the upper Yegua.

The highest exposure on this creek shows 2½ feet of brown friable sandstone containing flakes of selenite. The bedding is not very conspicuous and the beds are of medium thickness. The rock is irregularly stained with limonite and contains small clay balls.

The next section below has, at the base, one foot of blue, fine-grained sand, streaked with yellowish-brown limonite stain, overlain by 3 feet of thinly-bedded, brown clayey sand carrying brown plant fragments. The limonite seams have sometimes the form of slender cylinders. Where these cross each other on the surface they weather out into figures resembling the fillings of the cracks in sun-cracked muds. The limonite-stained layers are locally hard enough, because of their iron-stained content, to be called sandstone. This 4-ft member outcrops in its full thickness for a considerable distance along the stream. It is a friable, thin, and irregular-bedded sandstone, predominantly brown in color, but mottled with little contrasting shades of brown. The color is due to carbonaceous material or limonite, or to local leaching. In texture it is fine to medium-grained angular sand. Flakes of selenite are found sparingly. Locally, a thin non-continuous lens of brown carbonaceous clay or sand is noted. Much of it is stained and seamed with yellowish irregular blotches, probably of sulphur or alum. All of it carries plant fragments of a dark chocolate-brown color.

Farther down comes in 3 feet of thinly laminated chocolate brown clay with numerous leaf impressions. The clay is very soft and friable. It is underlain by 1 ft. 3 inches of thinly laminated, gray, carbonaceous, fine-grained sand, which has small non-continuous layers of brown carbonaceous matter and abundant plant fragments, sometimes carbonized, but generally dark-brown.

The next exposure exhibits the following section:

1. Light drab to chocolate clayey sand, carbonaceous and gypsiferous, ... 4 ft.
2. Very carbonaceous, fine, soft clay with streaks of sandy clay, and many leaf impressions,.................... 1 ft.
3. Chocolate-brown to greenish-gray, gypsiferous and carbonaceous clayey sand and sandy clay,.........1 ft. 6 in.

Farther down is 7 feet of fine-grained sand, brownish-cream to light chocolate-brown in color, containing sparsely distributed selenite flakes. The lowest 3 feet is more massive than the upper portion, which is more leached than the lower beds and weathers a lighter cream color. This member outcrops for about a mile along the creek. In places 10 feet of it is exposed in nearly perpendicular banks, weathering creamy-buff. Underneath the surface the sand is a light blue-gray.

Next is 4 feet of thin-bedded, laminated, carbonaceous, brown and drab clayey sand with plant fragments, weathering light gray.

The lowest beds downstream are soft, fine, light-gray sand, gypsiferous and carbonaceous, exhibiting more or less lamination.

These sections bring out plainly the sandy character of the upper beds of the Yegua. A short distance south the fossiliferous clays of the Jackson appear.

TEXAS SOUTHEASTERN AND GROVETON, LUFKIN & NORTHERN RAILROAD SECTION

The sections exposed along the Texas Southeastern and Groveton, Lufkin & Northern railroads between Lufkin and Apple Springs give a fair idea of this portion of the Yegua. In the first cut west of the junction of this road with the St. Louis Southwestern Railroad at least one-half mile east of Mile Post 15 and near Lufkin, are the following beds:

At the east end of the cut is 2 feet of chocolate clay weathering on the surface to light-gray. This disappears 100 feet farther west, where the overlying surficial sands come down to meet it in a line diagonal to the bedding. At the very base of this lower member is a light sulphur-yellow, compact clay very similar to that noted in exposures in the lower reaches of

Procella creek. Westward in the same cut the section is made up entirely of Lafayette material, and, at the extreme west end, a maximum of 3 feet of blue-gray sandy clay is unconformably overlain by this Lafayette.

One-fourth mile west of Mile Post 15, and 8 feet below the track-level, there is at the base 2 feet of light-gray, medium-grained sand, weathering buff. Immediately to the west is 2 feet of brown to drab clay, apparently underlying the sand. Here are large fragments of silicified wood. Some of the clay is compact, brittle, light-gray, and probably calcareous. There is 4 feet of this clay in the southwestern portion of the cut.

At cut one-fourth mile east of Mile Post 14 there is 4 feet of thin-bedded, compact sandstone, very light-gray in color. Most of it is a medium-coarse grit with a large proportion of eroded crystals of selenite. In some of the sand there are small clay balls less than one-third inch in diameter.

The cut at Mile Post 14 shows 4 feet of cross-bedded and laminated sand with clastic selenite and sandy clay overlain by 7 feet of amorphous, mottled dark-blue-gray and red clayey sand of the Lafayette. There is much petrified wood here.

At the second cut one-half mile southwest of Mile Post 14 there is at the base ten feet of typical light-gray, contorted and cross-bedded sands, overlain unconformably by 5 feet of mottled sandy clay of the Lafayette. The lowest beds, as usual, contain petrified wood. The sand, in places, is thin-bedded, in other places, massive. In induration, it varies from quite compact to very friable. Some of it has elastic selenite and quite a large proportion of clay.

The long cut at Mile Post 12 exposes 10 feet of thin-bedded or shaly sand with thin-bedded lenses of clay ironstone, the largest of which are 5 to 6 feet in diameter. At the west end of the cut, near the base, two small layers of thin-bedded ferruginous sandstone are separated by 1 foot of cross-bedded laminated sand.

Directly west of Mile Post 12 the following section is exposed, beginning 10 feet below the track level:

1.	Gray surface sandy soil with humus, ...	4 ft.
2.	Light sulphur-yellow laminated sandy clay, ...	4 in.

3.	Thinly laminated, cross-bedded, medium-grained, light brownish-gray, lenticular sands,	6 ft. 1 in.
4.	Blue sandy clay,	6 in
5.	Sand like (3),	6 in.
6.	Shaly clay,	3 in.
7.	Sand like (3), but containing thin seams of brown carbonous matter	2 ft.
8.	Thinly laminated sandy, blue-gray clay	3 in.
9.	Sand like (3), (5) and (7),	1 ft.

All members weather buff. All the sands are cross-bedded and, locally, vary in thickness. The strata are apparently horizontal. In one place thin seams and lenses of brown limonite sandstone were noted. There is much petrified wood.

In cut just west of Pery flag station and section house 2 feet of light-gray clayey sand with just a faint tinge of green is overlain by 2 feet of sticky, gray-blue clay with roundish clay ironstone concretions. Overlying is 18 inches of Lafayette mottled clay.

One hundred feet west of Bridge 2.87 and 20 feet below the rail, there is at the base 10 feet of laminated, light-blue clay with small spherical ironstone concretions up to a foot in diameter. These beds weather as typical badlands, forming light buff colored, sharp gully and rounded knob exposures. Overlying them are 10 feet of very thinly laminated light brown shales, limonite-stained and carrying seams of brown carbonaceous matter, and becoming sandier toward the top. Then come, in upward succession, 2 feet of very dark-brown chocolate, carbonaceous, thinly laminated shales, followed above by 6-inches of compact, sulphur-yellow clay with carbonaceous matter, overlain by surficial rounded pebbles of granite, quartz, chert, and metamorphic rocks. Two hundred and fifty yards farther west the dip is 40° S. to 60° W. and there is exposed about 20 feet of thin-bedded, carbonaceous sandy clay, weathering buff.

In the long cut one mile east of Blix is exposed about 15 feet of thin-bedded, sandy shale carrying very thin seams of sulphur-yellow color and of limonite. On surface exposures the color is light buff. There is considerable cross-bedding and much silicified wood.

Just south of Vair the cut at Mile Post 21 exposes 5 feet of dark drab to chocolate-brown carbonaceous shale.

At a cut 20-1-2 miles from Groveton there is at the base 3 feet of light-gray, laminated clay with layers about 1-16 inch thick of limonite-stained hard clay. Above is a 6-inch layer of brown carbonaceous clay, overlain by 4 feet of clay similar to that at the base. Fragments of silicified wood are found in the clay.

Then, to the westward, begins a series of light gray sandy clays which weather into badland forms very light buff in color. In these clays are nodules and disc-like concretions of clay ironstone and fragments of silicified wood.

Eighteen and three-quarter miles from Groveton, a cut exposes 3 feet of light brown, laminated clay, overlain by 2 1-2 feet of soft, medium-grained, gray sandstone. The clay is gypsiferous. The dip is 3° to the northeast.

About 150 yards northeast the rock is mainly gray sand interbedded with very thin clay seams. The sand, which is mottled in many places, is more massive and predominant at the top. There is 6 feet of this probable Lafayette surficial member.

For 1½ miles northeast of Apple Springs cream-colored clays containing fragments of silicified wood and weathering into semi-badlands form the surface exposures, but not over 4 feet are found in any one section. There is in these beds a considerable amount of iron occurring as disc-shaped concretions and in thin layers. These are the top of the Yegua beds in this traverse.

This section, beginning not far from the base of the last, runs southwest instead of south. Apparently the middle portion of the section is more sandy than was found east of the Attoyac, and the upper portion carries large quantities of silicified wood and flattened cannon ball concretions which were not observed there.

INTERNATIONAL & GREAT NORTHERN RY. SECTION

The Cook's Mountain-Yegua contact crosses the International & Great Northern Railway about half way between Mile

Posts 41 and 42, or 3½ miles south of Crockett. Here the light colored gypsiferous clay of the Yegua is seen for the first time in this section.

One-fourth mile north of Mile Post 42 is 4 feet of Yegua dark-gray sticky clay, weathering cream-colored and cracking on surface. Here are petrified logs, the largest of which is 1½ feet in diameter.

The cut one-fifth mile north of Mile Post 44 (just north of Cut siding) exposes 10 feet of Yegua coarse sand. The quartz grains are subangular and the sand contains grains of clastic selenite. There are also fragments of silicified wood. The whole exposure is lightly mottled. The original color of the sand is buff or cream. Now it is colored in blotches and patches with light brick-red. There are a few angular fragments of black material, perhaps chert. Some of the wood contains veinlets and botryoidal incrustations of hyalite.

From these localities Prof. Berry had determined the following species of wood:

I. & G. N. Ry. Cut. Between Crockett and Lovelady:

Lower Yegua	Other Gulf States.	
Phoenicites occidentalis Berry		
Dryophyllum n. sp.	Claiborne	
Myristica catahoulensis Berry		
Cedrela n. sp.		Jackson
Mespilodaphne n. sp.		Jackson
Nectandra n. sp.		Jackson
Nectandra n. var.		
Nyssa n. sp.	Claiborne	
Carpolithus n. sp.		

From here to Wooters Station (one-fourth mile west of the coal mine and just south of Mile Post 48) the topography is typically flat Yegua. Some small exposures of Yegua clay weathering light yellow are seen. The cut at Mile Post 48 and south of there to Wooters Station shows 20 feet of Yegua drab sandy, partially laminated clay, weathering cream-colored and containing thin flakes and concretions of limonitic-cemented material. Petrified wood is found here in abundance.

A specimen collected at Wooters was sent Prof. Berry who identified it as *Cupressinoxylon dawsoni* Penh.

Yegua light drab clay with limonitic plates and concretions is found underlying the extensive flat at Lovelady and also between Mile Posts 53 and 54. Fragments of silicified wood are found in all these exposures. The flat surfaces are covered with a plentiful sprinkling of Lafayette-derived gravel similar to that about Huntington and elsewhere in Angelina county. These gravels probably once occupied a higher elevation than they do at present, but their position has been successively lowered by the erosion of the more easily transported materials under them, leaving them as a more or less permanent surface capping in a region of low relief and consequently of streams with low powers of transportation.

Between Mile Posts 53 and 54 a large portion of the material exposed is medium-grained, gypseous sand stained yellow locally, perhaps with sulphur. Just north of Mile Post 54 the drab clay contains thin plates of very light gray opaline-cemented sandstone. Between Mile Post 54 and 55 coarse sands, sometimes partially consolidated, contain flakes of clastic selenite.

Overlying this the Jackson is first encountered to the south of Mile Post 55 as thin, irregular and shelly-bedded, friable, creamy and buff sandstone.

Nevil's Prairie, which lies southwest of Lovelady, is underlain by the beds of the upper Yegua which, in this vicinity, carry great quantities of silicified wood and numerous limonitic concretions. At the southeast margin of the prairie on Cedar creek is five feet of chocolate imperfectly laminated jointed clay with a few small lenses of sand, overlain by laminated grayish sand. Three-fourths mile downstream from the last mentioned exposure on Cedar creek is the following section:

1.	Brown carbonaceous shaly clay, locally lignitic............	2 ft.
2.	Greenish-drab sticky ball joint clay with leaves............	1 ft.
3.	Poor quality brown lignite	1ft.
4.	Brown carbonaceous clay	

From these localities Berry identified the following forms:

Near Antioch, 4 miles southwest of Lovelady.

Upper Yegua.		Other Gulf States.	
Anemia eocenica Berry	Wilcox		
Mimosites georgianus Berry		Claiborne	Jackson
Cupanites n. sp.		Claiborne	
Sapindus georgiana Berry		Claiborne	Jackson
Sapindus formosa Berry	Wilcox	Claiborne	
Laurinoxylon n. sp.		Claiborne	

Nevil's Prairie, 5 to 7 miles southwest of Lovelady.

Upper Yegua.		Other Gulf States.	
Arundo pseudogoepperti Berry		Claiborne	Jackson
Lygodium kaulfussi Heer		Claiborne	Jackson
Momisia americana Berry		Claiborne	Jackson
Ficus n. sp.		Claiborne	
Inga n. sp.		Claiborne	
Mimosites georgianus Berry		Claiborne	Jackson
Sophora wilcoxiana Berry	Wilcox		
Citrophyllum n. sp.		Claiborne	
Sapindus georgiana Berry		Claiborne	Jackson
Sapindus formosa Berry	Wilcox	Claiborne	
Sterculia n. sp.		Claiborne	
Persea n. sp		Claiborne	
Oreodaphne n. sp.		Claiborne	
Mespilodaphne n. sp.		Claiborne	Jackson
Nectandra n. sp.		Claiborne	Jackson
Apocynophyllum n. sp.		Claiborne	Jackson

TRINITY RIVER SECTION

On the Trinity river the exposures referred to the Yegua extend from Robbins Ferry, northwest of the mouth of Kellison creek, to Calhoun's Ferry, just south of the line between Houston and Walker counties. The width of the beds at this point is about eleven miles and along the river there are bluffs that give excellent exposures of the formation.

It will be seen from these sections that with the exception of the very top, the beds are much more argillaceous than in the Neches basin and that they carry beds of lignite of workable thickness and quality. This condition continues to the westward.

Kennedy placed the contact at Alabama bluff, several miles up the river, where the first selenitic clays are seen, but Baker and Suman decided that this was part of the Nacogdoches or transition beds between the Cook's Mountain and the Yegua and placed the line at the base of the more massive clays which are unfossiliferous.

No exposures were found below the final appearance of the Nacogdoches just above Robbins Ferry and the mouth of Kellison creek, where the following section occurs:

1. Blue gray, clayey sand with a few small calcium carbonate cemented sandstone concretions; structureless, change in color to lighter shades as top is approached. Top 5 - 10 feet is a reddish brown color, ...20 - 25 ft.
2. Dark blue-gray, very sandy, muscovitic joint clay, with small lignitic lenses and black carbonaceous plant fragments and clay ironstone concretions. Imperfectly laminated, ...15 ft.
3. Cross-bedded sand, carrying lumps of clay and with erosion unconformity between it and underlying clay which is believed to be local. Sands, medium-grained, light greenish-gray in color, containing a number of lignitized wood fragments and at top a thin layer of limonitic sandstone, ... 3 ft.
4. Clay like (2). Upper 2 feet sandier than lower portion, 8-10 ft.

Spring creek, or Spring branch, enters the Trinity river between Kellison creek and Westmoreland Bluff. It has steep, deep, and narrow, gully-like banks cut in the present river flood plain. The main creek and its branches have sent arms with cuspidate margins up into the second bottom terrace. The lowest exposure forms a falls. The section here is:

1. Grayish-brown, sandy, terrace alluvium, with the calcareous nodules characteristic of the terrace alluvium in this vicinity.
2. Brownish-black to brown, carbonaceous, shaly clay. At least ....1.5 ft.
3. Lignite, good quality, hard, firm, of dull lustre. (In all probability the same bed as that exposed in Westmoreland Bluff) ....4.5 ft.
4. Gray drab sticky clay ....1.5 ft.

Westmoreland Bluff is four miles west of the town of Weldon. The section is as follows:

1. Mottled, grayish and rusty, river alluvium with the usual ferruginous cemented gravel layer at the base. Very

sandy and gravelly. Has calcareous concretions and represents the second bottom of the Trinity River,......

2. Carbonaceous, black, finely laminated shale, locally lignite, with petrified logs, one of which measured three feet in diameter, ... 3 ft.
3. Blackish carbonaceous shale with small selenite crystals, thinly laminated. Much of it dark-brown in color. Greenish-drab, sticky, laminated clay. This member is represented at the east or upper end of the bluff by 25 feet of sandy clays, interbedded with dark, carbonaceous shales. The clays are mainly light drab in color. At one place were found *in situ* the lignitized roots of a tree. Between the east and west ends of the bluff this horizon is occupied by a very much cross-bedded, laminated, iron-stained and concretionary, brown sand containing large trunks of trees and lenses of clay. The large petrified logs are black in color and silicified, in places changed to finely fibrous brown calcite. The outer surfaces of the logs are rough and ribbed as if they had undergone partial decay before being buried. The concretions are mostly flat disks or imperfect, sometimes tuberous, and "cannon balls". They are composed of fibrous calcite and iron carbonate,................7 - 25 ft.
4. Grayish-brown, interbedded sands and clays. One foot of bluish-black carbonaceous sandy clay in middle of lower sand member. Upper three feet yellowish-brown clay, ...10 ft.
5. Black and brown, carbonaceous clayey sand with small black leaf fragments, ... 9 in.
6. Laminated, dark-brown sand, ... 1 ft.
7. Greenish-drab, compact, sticky clay,................. 6 in.
8. Chocolate-brown, thinly laminated, carbonaceous shale.... 1 ft.
9. Lignite. Middle of bed compact, hard, of dull lustre, and good quality. Top and bottom badly checked and slaked by weathering. Covered with water at overflow stages ....3 1-2 - 5 ft.
10. Dark drab, fine clay, fracturing into small fragments. Unctuous and polished on fracture surfaces,.......... 2 ft.
11. Sand, more compact, laminated, brown in color, with small crystals of selenite. Lower one foot with greenish-blue cast. Stained rusty with limonite along lamination planes and, locally, yellowish with sulphur,.......... 5 ft.
12. Unconsolidated, fine-grained, dark gray, micaceous sand..4.5 ft

The two upper shoals at the bluff are made by the lignite bed, which lies at low water level. At the southern or lower end of the bluff the coal bed forms a low broad anticline with its shorter axis in an east-west direction, in which direction it outcrops above low water level for about four or five hundred yards. On both limbs where it dips below the low water level it forms a shoal.

Lying above (2) farther upstream is plastic slaty gray clay, above which is loose, coarse to medium-grained gray and brown loose porous sand in which are limonitic concretions. There are balls and lenses of blue clay in the lower portion of the sand with their longer axes arranged as various angles with the horizontal, indicating local unconformity and erosion of underlying clay before the deposition of the sand, similar to conditions at the lower plane of the cross-bedded sand layer in Westmoreland Bluff.

The following section is shown at Hyde or Spanish Bluff on the Trinity river. The elevation of the second bottom terrace surface is here 30 feet above the first bottom surface. At the lower end of the bluff there is at the base 4 feet of greenish, micaceous, fine clayey sand, carrying lignitized logs, above this, seams of lignite interbedded with grayish sand, and at the top 1 foot of drab joint clay. The section at the main bluff is:

1. Reddish-brown, loose, loamy sand of the second bottom with fossil *Unios*.

Unconformity:

2. Dirty green, fine, micaceous sand, very imperfectly laminated, locally brown with carbonaceous matter, more laminated and jointed in the lower 6 feet, where it is brown, carbonaceous and more clayey...............15 ft.
3. Impure lignite, ...1.5 ft.
4. Lignite, very irregular in thickness .... 2 ft.

A section at the lower end of Pine Bluff, Trinity river, one mile below the mouth of Negro creek, follows:

1. Alluvium with calcareous nodules, light gray at base, but brown above, ...15 - 20 ft.
2. Ferruginous-cemented Lafayette-derived conglomerate with casts of *Unios*, ... 3 ft.

Unconformity, involving and bevelling beds (8) to (3).

3. Greenish-gray sandy joint clay,....................... 3 ft.

4. Lignite, very irregular in thickness, ... 2. ft.
5. Lignite, very irregular in thickness, ... 2 ft.
6. Gray, laminated, cross-bedded, fine sands with thin, interbedded layers of dark gray clay, ... 3 ft.
7. Dark gray sandy joint clay with fragments of lignitized logs, ... 1 - 2 ft.
8. Compact, laminated, dark gray-brown, fine sand, lenticular, ... ½ - 1 ft.
9. Clay like (7), ... 1 1-3 ft.
10. Sand like (8) .... 1 1-3 ft.
11. Lignite, lenticular, soon pinching out, ... 1 ft.
12. Lignitiferous shaly clay, brownish and black, ... 1 ft.
13. Laminated, fine-grained, gray to brown sand, very carbonaceous, with knife edge, thin, alternating, dark gray and black layers, ... 4 ft.

The beds dip 2 degrees N. E. at the north end of the bluff.

There is another bluff about three-quarters of a mile downstream from Pine Bluff on the Madison county side. Here there is about 25 feet of Yegua, cross and wavy-bedded, laminated gray sand, with interbedded layers and pockets of drab joint clay. It is overlain by light brown, sandy alluvium, with a surficial black sand layer. Three-fourths of a mile farther downstream, also on the Madison county side, is a second bluff, having exposed at its base 10 feet of Yegua, gray, laminated, clayey sand, dipping about 30 to the east. Above is 20 feet of yellow, sandy, alluvial clay. One mile farther downstream, on the Madison county side, is a third bluff with 10-15 feet of laminated, light-gray, Yegua, sandy clay in a series of very low folds.

BRAZOS RIVER SECTION

The base of the Yegua on the Brazos river is found in the bluff about 500 yards south of the mouth of the Little Brazos river, where, overlying the fossiliferous Marine beds, there is 5 feet of unfossiliferous, pale blue clays. At Munson's Shoals the section shows:

1. Brown river loam of sand and fine gravel, ...18 ft.
2. Black sandy loam and clay loam mixed with brown sand containing gravel and a few drift pebbles, ... 2 ft.
3. Pale blue clay .... 8 ft.
4. Bluish-green lignitic clay, breaking into blocks and con-

taining broken plant remains, extending across the river and forming shoals........................ 6 ft.

At Jones' bridge we have:

1. Yellowish gray sand, ...32 ft.
2. Bluish-green, sandy clay, containing fragments of lignite and breaking into ovoid blocks,........................46 ft.

Penrose's section at Sulphur Bluff is as follows:

1. Light brown, hardened, sandy clay,...................10 ft.
2. Lignite, ... 1 ft.
3. Gray sand .... 1 ft.
4. Lignite, ...¼ ft.
5. Interbedded gray sand and chocolate and greenish clay, turned white in places on the surface,..............20 ft.

The whole bluff is coated with sulphur.

The contact between the overlying sands and these clays is seen on the south side of the James Hope Survey in a section showing:

1. Gray sand and gravel,............................... 1 ft.
2. Gray sand containing great quantities of silicified wood. The wood is usually in large pieces—four to six feet in length, and bleached white,....................... 5 ft.
3. Gray, indurated sand, with ledges of soft sandstone,......10 ft.
4. Gray sandstone, joined and thinly bedded, forming base of Wellborn sand, ... 8 ft.
5. Dark brown lignitic clay, showing yellow bands from ¼ to 1-2 inch in thickness and coated with an efflorescence of sulphur, to water, ...20 ft.

No. 5 corresponds to the upper brown clay of Penrose's section of Sulphur bluff.

For the purpose of comparison and as showing the Marine fossils of this formation, the section as observed in the Rio Grande may be given:

RIO GRANDE SECTION

Ten miles south of Laredo, and about the same distance, by river, above the Webb-Zapata county line, we find the first deposits which, from their fossil-contents, we can, with certainty refer to the Yegua clays. This is a bluff, nearly a mile in length, on the Texas side of the river. Here are exposed a series of interbedded greensands, brown sand and chocolate clay, with lenticular masses of red sandstone. Near the top of the hill there is a bed of altered greensand containing quantities of fossils, among which Mr. Harris determined:

Lacinia alveata, Con.
Natica recurva var. dumblei, Heilp.
Cerithium sp.,
C. webbi, Har.
Anomia ephippioides Gabb.
Ostrea alabamiensis Lea.
Cornelina armigera Con.

The round concretionary masses, called cannon-balls, are abundant, both in the bed of greensand and in the red sandstone. The chocolate, sandy clays are cross-bedded.

A mile below this, a bluff on the Mexican side shows more clearly the characteristically clayey nature of the Yegua. This bluff is nearly 2 miles in length, and is composed of indurated blue or gray clay, interbedded with altered greensand and gray-brown sands. It contains a thin bed and seams of lignite. Beyond this, a bluff, 75 feet high, shows the chocolate sands and clays, highly variegated in color—purple, red, pink, yellow and brown—and capped by a brown sandstone which weathers black in places. A considerable amount of iron pyrites and gypsum are present.

About the line of Webb and Zapata counties there is a bluff 60 to 100 feet high, which is a half mile or more in length. The beds are nearly horizontal, as seen from the river, which here flows east. The base of the hill shows a band of buff and greenish sands, slightly calcareous, with large concretions—8 to 10 feet in diameter. This is overlain by an extremely hard, limy band of grayish color, which shows on its upper surface a breccia of a very large gasteropod.

Overlying this is a series of sand of varied colors and a second limestone layer, very rich in fossils, including such forms as *Conus sauridens*, Con.; *Ostrea alabamiensis*, Lea; *O.*

Geol. S. W. Texas, Trans-Am. Inst. Min. Eng., pp. 961-964.

divaricata, Lea; *Volutilithes petrosus,* Con.; *V. petrosus* var. *indenta,* Con.; *Tellina mooreana,* Gabb; *Corbula alabamiensis,* Lea; *Cytherea texacola,* Heilp.; *Natica recurva* var. *dumblei,* Heil.;*Turritella nasuta* var. *houstonia,* Har.; *Venericardia planicosta,* Lam.

The next bluff, 2 miles below, on Texas side, showed only brown sands, without fossils, for a height of 60 feet, but at the mouth of Dolores creek we again find the greensands in hill 20 to 35 feet high, with beds of oysters from bottom to top.

Four miles below this there is a low reef of hard, gray limestone, weathering to a greenish-gray color. It is concretionary in places. Four miles above San Ignacio there is a bluff 300 yards long and some 60 feet high. Below the alluvial deposits it is composed of buff sands and sandstones, with seams of lignitic clays, sands and greensands.

At the top of the sandstone there is a fossil-stratum about 8 inches thick. This gave:

Pleurotoma nodocarinata, Gabb (?),
Levifusus trabeatus, Con., var.
Tellina mooreana, Gabb.
Corbula alabamiensis, Lea.
Venericardia planicosta, Lam.
Cytherea sp.
Natica recurva var. dumblei, Heilp.
Volutilithes petrosus, Con.
Ostrea alabamiensis, Lea.

Gypsum and cannon-balls occur, as well as numerous white calcareous concretions. The bombshells contain traces of lignitic materials. The dip here is normal—S. E. Two miles below, a bluff on the Mexican side of the river, composed of the gray sandstones with calcareous concretions, shows a distinct northeast dip. The same sandstone, still dipping northeast, appears as a reef at San Ignacio. The exposures at the mouth of Salidita creek, about 2 miles below San Ignacio, show a bed of siliceous limestone, with beds of altered greensands. This is overlain by a buff sandstone which, in its next appearance, is seen to be cross-bedded and jointed.

Four miles below San Ignacio the river bluff shows this same buff sandstone underlain by greensands. The buff sandstone is quite calcareous, carries gray nodules and shows concentric weathering.

A mile below this exposure the dip changes from northeast to northwest, and shows somewhat greater angles than is usual in these beds, amounting to as much as 10°. The materials exposed are semi-indurated sands, with more compact boulders of the same material. This is overlain by blue and green ferruginous clays, which weather a deep-red and show concentric weathering. White, calcareous concretions abound in this bed. Yellow, sandy clay, becoming more compact toward the top, succeeds the heavy clays. No gypsum was seen, and but little sulphur.

Two miles below, the dip again changes to southeast, and the buff sandstone shows beds of flagstone, which are somewhat calcareous and contain black, chert grains. These beds continue to a point 4 miles north of Carrizo, where we find the contact of the clays of the Yegua with the Fayette sands.

CHAPTER VI.

CLAIBORNE CONTINUED

FAYETTE

NAME

The name was originally used by Penrose[1] for the entire series of deposits lying between the top of the Marine beds and the Orange Sand or Lafayette. As has been already shown, the basal member of these beds was separated under the name Yegua. Further investigation proved that the name still embraced deposits of different ages, and it was finally restricted to the sands and light colored clays overlying the Yegua and, if the Frio belong in the Upper Eocene, the uppermost bed of the Middle Eocene of the Texas section.

TYPE SECTION

The type locality of this sub-stage is on the Colorado river, in the extreme western corner of Fayette county.

White Marl Bluff at Shipp's Ford, near the county line between Fayette and Bastrop counties, forms the final fossiliferous exposure of the Cook's Mountain beds.

The railroad bridge crossing the river two miles north of West Point rests upon an excellent exposure of the chocolate clays and sands of the Yegua with its characteristic sideritic concretions. The first high bluff down the river from this location was called by Penrose Chalk bluff from its color. The base of this bluff is made up of beds belonging to the Yegua, but higher up a different formation comes in which is characterized by light colored sands and joint clays which belong to the Fayette.

Criswell creek just east of West Point gives excellent exposures of the Yegua-Fayette contact. The uppermost Yegua in this locality is a chocolate sandy clay splotched with yellow and containing plant remains. The basal Fayette is a

[1] First Annual Report Geol. Sur. of Texas, p. 47.

white sandstone, rather fine grained, with a few yellow ferruginous markings. Overlying this sandstone are white sandy shales with yellow ferruginous sand laminae.

The difference between the two formations is striking. Not only are the colors distinct, but the lignitic or carbonaceous matter so prevalent in the Yegua is missing entirely in the lower Fayette and the siderite or limonite concretions are replaced by a few knobs of ferruginous sand.

The Fayette beds are well shown in Pine Bluff, which is at the sharp bend of the Colorado at west end of Old River, about four miles northeast of West Point.

At this exposure there is at the top 70 feet of gray and white sand interbedded with white and watery green clay. This is underlain by beds of similar clay alternating with thin seams of lignite and with chocolate clays. Penrose's section is as follows:

1.	Quaternary drift.	
2.	Interbedded gray and white sand, white and watery-green clay	70 ft.
3.	Hard water-green clay, like in (2)	4 ft.
4.	Lignite	2 ft.
5.	Similar strata to (2), light chocolate color on surface	3 ft.
6.	Lignite	1 ft.
7.	Similar strata to (5)	7 ft.
8.	Chocolate clays, with black leaf and reed impressions	½ ft.
9.	Hard watery-green clay	4 ft.
10.	Lignite	1 ft.
11.	Hard light green clay	5 ft.
12.	Similar strata to (8)	½ to 1 ft.
13.	Hard, light green clay	6 ft.
14.	Lignite	1 to 2 ft.
15.	Hard, light green clay	10 ft.

Gates' Bluff, two and a half miles east of Pine bluff gives the top of the Fayette and its contact with the Jackson. At this place a bed of lignite is just at top of water level in river. It is overlain by ten feet of interbedded clayey sands, shaley to thin-bedded, with some carbonaceous streaks and is strongly jointed. Its top is an old land surface and the section shows a line of silicified stumps standing upright and evidently in place as they grew. Between them are pot-holes filled in with the darker sands of the overlying impure lignitic band, which is here taken to be the base of the Jackson.

No marine fossils were found in the Fayette beds, but leaf impressions were seen in abundance, and gypsum and sulphur were present in nearly all the beds.

Nowhere in the Colorado section were any sands seen which appeared to represent the Wellborn beds. All of the sediments apparently referable to the Jackson belong to its lignitic and fresh water phases, and are presumably later than the Welborn, which seems wanting in this section.

RIO GRANDE SECTION

As in the case of the Yegua, the Rio Grande section gives a clearer idea of the character and fossil contents of these beds. While the sediments are largely of marine deposition on the Rio Grande, the materials entering into them are similar to those of the Colorado section.

The Rio Grande beds may be divided into two parts. The lower part extends from Zapata to the northern line of Starr county and is made up of greenish clays and sands interbedded with buff sands with some calcareous matter and greensands. These beds are very fossiliferous.

The upper part, extending from the Starr county line to Roma, while not differing so much lithologically from the lower, has a larger proportion of the buff sands and its only fossil seems to be the very large oyster called by Penrose *Ostrea georgiana,* but identified by Harris as *O. alabamiensis* var. *contracta* of Conrad.

The fiirst exposure of the Fayette beds in the Rio Grande region is described by Dr. Penrose as follows:

"Four miles above the Texas town of Carrizo, and on the Mexican side of the river, is seen a bed of woody lignite 1½ to ft. thick, overlain by 10 ft. of buff sands and underlain to the water's edge by 4 ft. of greenish-gray clay. The Rio Salado flows into the Rio Grande from the Mexican side opposite Carrizo. The town of Guerrero is on this river 6 miles from the mouth, and in this distance are seen many outcrops of buff sandstone, often rising in abrupt ledges through the

Geol. S. W. Texas, pp. 37-8-9-40.

river alluvium. Most of the houses, churches and fences of the town are built of it."

At Carrizo the beds yielded the following fossils:

Lacinia alveoata, Con.
Ostrea alabamiensis var. contracta, Con.

Similar exposures are seen just below Carrizo, where the river runs more nearly in the strike of the beds. After it again turns southeast the bluff sands form low bluffs for 2 or 3 miles, when we find, on the Mexican side of the river, in a long, low line of exposures, a greenish, sandy clay, partly indurated, but variable. with harder green concretions, which are more or less calcareous. Here we found: *Lacinia alveata*, Con.; *Volutilithes petrosus, Con.; Cornulina armigera*, Con.; *Cytherea bastropensis*, Har.; *Tellina mooreana*, Gabb. A similar exposure, just below, on American side, was a mile or more in length, and showed many undulations. This was in turn succeeded by exposures of buff sandstones, which here seem to dip about 6 degrees to the SE. This condition continues to the mouth of a small creek just north of Rancho Ramireno, which "cuts through a series of low bluffs, ledges of interstratified buff sandstones containing gray concretions and septaria, and chocolate, black and greenish-blue, semi-indurated clays, dipping 1 to 2 degrees southeast."

The forms identified by Prof. Harris are: *Ostrea contracta*, Con.; *Conus sauridens*, Con.; *Volutilithes*, sp.; *Venericardia planicosta*, Lam.; *Semele lienosa*, Con.; *Cytherea bastropensis*, Har.; *Lacinia alveata*, Con. var.; *Pseudoliva vetusta*, Con.; *Natica recurva* var. *dumblei*.

There is a fossiliferous layer near the mouth of the creek and forming its bed. This shows a mass of shells much comminuted. The few specimens wheich we found entire had, doubtless, weathered from the softer buff sands, as we found them in place in that material. These clays and sands are highly colored, and as usual show considerable cross-bedding. In the drift we found many beautiful agates, chalcedony and petrified wood—which here made its first appearance on our trip. The buff sands and interbedded materials form a reef below the mouth of the creek and continued down the river several miles, when a bluff was found on the Mexican side which showed "interbedded hard and soft, calcareous sandstones and clay seams," and containing *Volutilithes petrosus*, Con., *Turritella nasuta*, Gabb,; *Lacinia alveata*, Con.?; *Anomia ephippioides*, Gabb; *Leda opulenta*, Con.; *Venericardia planicosta*, Lam.; *Tellina mooreana*, Gabb; *Cytherea bastropensis, Har.*

Numerous calcareous concretions are found, and the sand occasionally contains coarse, black and gray siliceous grains the size of mustard-seed and larger.

Just below the mouth of Tigre creek there is another exposure of the buff sandstone and its interbedded clays and sands, with grayish, limestone concretions of all shapes and sizes. Some of these concretions seem to contain masses of decomposed iron-pyrites only, but the most of them are fossiliferous. In the buff sandstone we find only specimens of oysters, all other forms being confined to the concretionary beds or particular masses. Some of these contain all their fossils (except oysters, which remain as shells) simply as rusty casts, while in others all the forms are fairly preserved.

Among these are: *Venericardia planicosta*, Lam.; *Turritella nasuta*, Gabb; *Volutilithes petrosus*, Con.; *Crassatella rotexta*, Con. var.; *Cytherea bastropensis*, Har.; *Pseudoliva vetusta*, Con.; *Conus sauridens*, Con.; *Cornulina armigera*, Con. var.

A very short distance above the Zapata-Starr county line there is a long exposure, on the Mexican side, of bluish-gray clays, capped by a bed of fossiliferous greensand. The next exposure, however, is again of the buff sandstone, with very large concretions, and showing a distinct synclinal structure. In appearance, it closely resembles the materials of the Fayette beds on the Colorado river, north of LaGrange. Then follows the bluff, of which Dr. Penrose gives the following section:

1.	Indurated, light-brown sand	3-6 ft.
2.	Loose, light-brown sand	10 ft.
3.	Gray clay	5 ft.
4.	Oyster-bed. *Ostrea alabamiensis* var. *contracta*	1 ft.
5.	Gray clay	1 ft.
6.	Oyster-bed	1 ft.
7.	Detritus to water's edge	4 ft.

In this section the oysters, some of which are a foot or more in length, occur not only in the oyster-beds, but scattered through the buff sands also. Two miles below, the beds are still more clayey in their nature, as is shown by the following section made at Las Guerras bluff, the point at which the river makes its sharp turn to the northeast, 5 miles or more west of Roma:

1.	Greenish-yellow clays, indurated, thin-bedded, and carrying gypsum and sulphur	20 ft.
2.	Oyster-reef. *O. alabamiensis*, var. *contracta*	1-2 ft.
3.	Calcareous bed	1-2 ft.
4.	Buff clays, partly indurated. Oysters	8-10 ft.
5.	Bright-colored, sandy clays, with gypsum, sulphur and lignitic matter	8 ft.
6.	Very hard sandstone, bedded and banded in brown, yellow and red colors	12 ft.

The gypsum in No. 1, of above section, was of yellow color, and occurred in seams ½-inch thick, and in crystalline masses of considerable size. I suspect that this bed will be found to be the base of the Frio clays, since my notes state that its dip is only 4 degrees, while that of the calcareous and underlying beds is about 7 degrees. The lower beds are referred to the Fayette on the strength of the persistence in them of the large oyster, which has been used as one of the characteristic fossils of this sub-stage.

The buff sands continued toward Roma, and the oyster-reef, with the same large oyster, was seen in the river-bank at that town. One mile below, however, where the final exposure of the buff sands was observed, no oysters were found.

Between the Colorado and the Brazos, the Fayette was found along Nails creek north of Ledbetter overlying the Yegua and underlying the fossiliferous Wellborn sandstone of the Jackson.

MAPPED AREA

East of the Brazos river the Fayette has been found only in detached bodies overlying the Yegua north of the Jackson border. These are simply remnantal portions left by an erosion interval which separated the Middle from the Upper Eocene.

The Fayette does not appear along the Sabine river.

The most easterly area recognized was a mile southwest of

Huntington, Angelina county, on the Texas & New Orleans Railroad. A hill on the Renfroe place which rises twenty-five feet above the surrounding Yegua clays is made up of a light-gray quartzose sandstone ranging in consolidation from a hard sandstone to a well indurated quartzite.

Some four miles west of this locality there is a larger area surrounding the town of Homer. This town is underlain by a light bluish-gray, cross-bedded sandstone. North of the town, it changes to a white sandstone of medium grain, evenly bedded, and is moderately hard. It is quarried for local use.

To the southward the sandstone is overlain by light cream-colored clay, thin-bedded to massive and showing cross-bedding in places.

About one-fourth mile north of Homer, at the head of a small creek, is the first exposure noted. Here there is about 2½ feet of black surface loam, containing much carbonaceous material and very much resembling a poor grade of peat. At the base of this loamy material there is a thin layer of gravel, made up of fragments of silicified wood, ferruginous clay stone, quartz, and quartzitic material, all of the fragments being sub-angular to rounded. Below this is a brown limonitic layer about six inches thick and made up of hard, concretionary limonitic clay. This member of the section was found to occur only in a few places. Underlying and forming the base of the section is a white to cream colored clay, sometimes, when damp, dull gray, hard, compact, fine-grained, which breaks with a semi-conchoidal fracture. This clay is jointed and in the joints a black carbonaceous material resembling lignite occurs. It evidently has washed in from the overlying loam. Little could be seen of the bedding of the clay, but in some places it seemed to be thin-bedded, while in others it was more massive with cross-bedding showing in a freshly broken piece.

Going down the creek the clay outcrops along the banks and makes up the creek bottom. In one little gully the clay is exposed to a thickness of five feet and several four foot sections were noted. In no place, except at the east and west ends of the deposit, could the bottom of the clay be seen. Here it was seen to rest unconformably upon a gray, thin-bedded sandstone which tilted locally at an angle of about 25 degrees. The clay was unconformable on this sandstone in all respects as regards dip, and the plane of contact was found to be much warped. The clay thinned out to the east and west, which showed that the deposit was of a lenticular nature.

In an east-west direction this deposit extends for about 2000 feet. To the north and south its extension is not very well known.

Two similar areas occur along the line of the Houston, East & West Texas Railway. One of these is north of Burke, the other southeast, extending almost to the Jackson contact. The hill north of Burke is about three miles long north and south. The northern end is made up of a gray to white sand or sandstone, and a measured thickness of 20 feet was observed. The sandstone is thin-bedded in places, and varies locally from soft to hard. Pieces of silicified wood are found in the sandstone, which is fine-grained throughout. Lamination planes can be seen in the apparently massive, well indurated material. Some of the beds are up to one foot thick.

The topography here is gently rolling. On top of the hill a log of silicified wood was found, which was about 25 feet in length and 2½ feet in diameter.

On this low hill near Burke, is an exposure of grayish-white, soft sandstone with blotches of black material. The quartz grains are rounded and the black blotches seem to be due to some kind of stain on the quartz grains. About one-fourth mile farther north on side of hill is found a thin-bedded, greenish-gray, shaly clay with partings of grayish sand. In the sand small shining crystals resembling selenite were found.

On the west side of Jacks Bayou, just east of Blix, in Angelina county, there is a ridge of sandstone of light gray color. The ridge is 20 feet in height, and a well 50 feet deep found only the same sand. The rock is a fine grade of very light gray sandstone, with medium-sized quartz grains and grains of magnetite. It is medium hard and lies in layers of about one foot in thickness.

Suman found an isolated outcrop of similar rock at Huston Park, one and a half miles southeast of Alto, in a hill rising about 75 feet above surrounding country, which contains about 60 feet of a hard, indurated, massive, white to gray, or cream-colored sandstone. This material does not resemble any other encountered in this vicinity, and is hard to account for. Lithologically, it seems to resemble the Fayette sandstone as observed near Burke, but no fossils were seen. There is a ridge running for about three miles through the country that is capped by this rock.

Baker considers this a remnant of the Fayette, which indicates that in this region the Fayette originally not only overlay the Yegua, but overlapped upon the Cook's Mountain beds.

To the west of the localities described, there are other areas of the Fayette which are similarly related to the Yegua and the Jackson. Three of these are found along the Houston-Trinity county line northwest of Groveton, and in the vicinity of Pennington. The description of one will serve for all.

On the north side of East Prairie on the farm of Mrs. Bluffington on the D. Ashworth Survey, two miles north of Pennington, there outcrops a fine-grained gray to whitish colored sandstone varying in hardness from soft to almost that of a quartzite. It contains an abundance of a black mineral resembling magnetite in small specks. It varies from massive to cross-bedded and very locally may be thin-bedded. Near the top of the hill there is 8 feet of the harder rock outcropping over about five acres. The rock varies rapidly in this area from hard to soft. It is underlain down the hill by ten or twelve feet of cross-bedded, fine-grained, soft, white sandstone. In the creek bed below this there outcrops some lignite. The sandstone is used locally for building chimneys.

West of the Trinity similar exposures are found along Bedias creek north of the Yegua-Jackson contact as far west as the northeast corner of Grimes county.

The Fayette has not yet been certainly identified on the Brazos, owing to the presence in that vicinity of the Wellborn sandstone of the Jackson, which has been confused with it. Whether both are present here, or whether the Fayette was entirely eroded before the deposition of the Wellborn, has not been determined. That the two are separate and distinct sands is fully proven by their general character and fossils.

The Fayette in East Texas consists of very light colored sands and clays with some lignite, and only plant remains as fossils.

The Wellborn is predominatingly a brown sand with remains of marine invertebrates.

There are no materials in any of the Jackson beds east of the Brazos corresponding to those of the Fayette inliers in the Yegua which have been described.

The stratigraphic relations are such that the two could not belong to the same horizon.

CLOSE OF THE CLAIBORNE

At the close of Claiborne deposition, the sea again receded, thereby adding a broad belt of land to the growing terrane of the Coastal Plain. How far this recession may have reached is unknown, but the indications are that the period of the recession was not as great as that between the Lower and Middle Eocene.

In East Texas this recession was accompanied by an elevation of the beds which, while extending from the Sabine to the Brazos, attained its maximum east of the Neches. This is indicated clearly by the fact that the Fayette beds, which are normal on the Colorado, begin to show erosion west of the Brazos, on which stream they are doubtfully present, and eastward are only known by remnantal areas to the Neches drainage, beyond which they are entirely unknown. In this area not only has the Fayette been entirely removed, but the underlying Yegua has also been scored.

While a large portion of this erosion must have taken place during the interval between the recession of the Claiborne sea and the transgression of the Jackson, it is possible that a part of it belongs to that period of the early Jackson in which the Wellborn beds were laid down between the Brazos and the Trinity-Neches divide. The greater erosion eastward, however, was in all probability due to greater elevation above sea-level.

Veatch finds evidence of a post-Claiborne movement in connection with the salt dome at Winfield and there are indications of similar movement around the Palestine dome.

These movements evidently had their beginning in the Sabine region during the Marine, as is shown by the conditions at the base of the Nacogdoches in the type locality. It was the movement beginning then which changed the shore line of the Claiborne sea from the northeasterly trend which it had had in common with the Midway sea and with the waters of the Wilcox to the east-west line which has prevailed east of the Neches river from that time to the present.

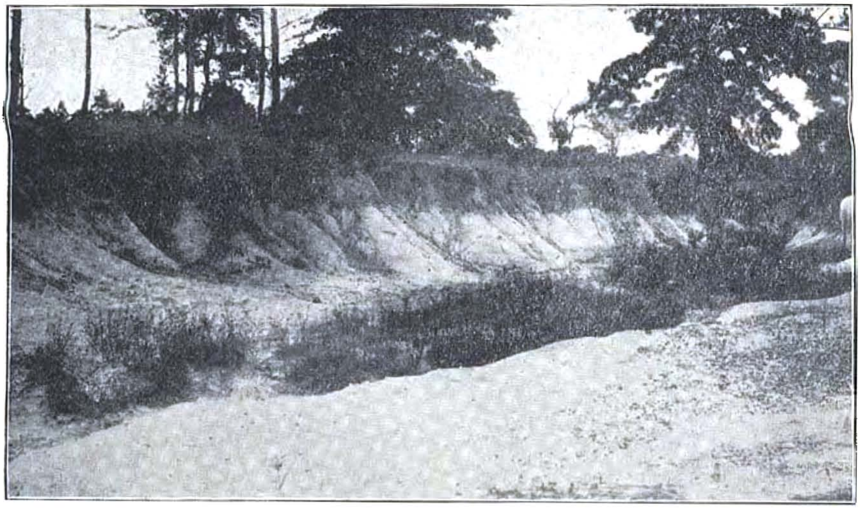

Fig 1. FAYETTE FORMATION.
Near Homer, Angelina County.

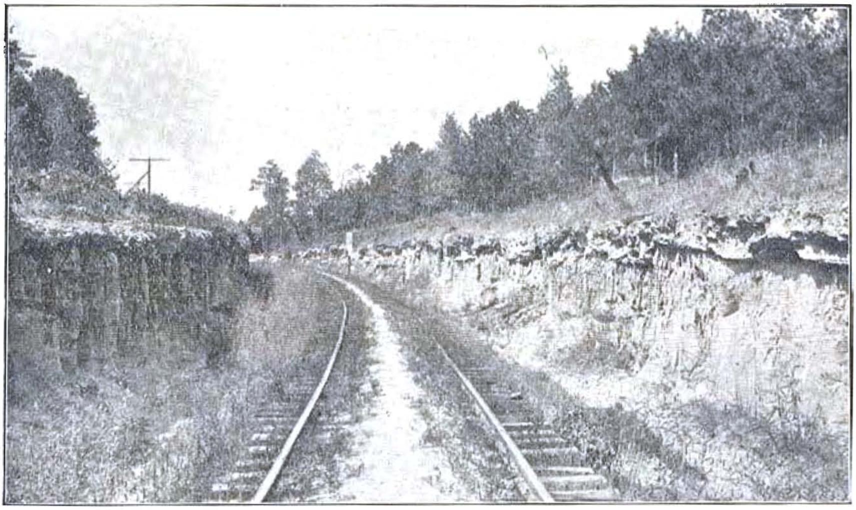

Fig. 2. JACKSON FORMATION.
Cross bedded sandstones on H. E. & W. T. R. R. Mile Post 100.

Chapter VII

JACKSON

Name

Conrad found at Jackson, Mississpippi, a series of deposits which carried a large and well preserved fossil fauna which was intermediate in age between the Claiborne and Vicksburg, and which he described and called the Jackson. The beds are described as calcareous marls and lignitiferous clays, but later descriptions add a bed of siliceous sands at the top.

In the bluff at Yazoo City, 180 feet of the calcareous clay is exposed. It carries crystals of gypsum and many marine fossils in addition to bones of the Zeuglodon which characterize the Jackson of the embayment area.

The entire thickness in Mississipppi is estimated at 350 to 450 feet.

The marine fauna of the Jackson has been found to contain nearly as many species as that of the Claiborne, and, although the number common to both is comparatively small, they are of Eocene types and the formation is considered to be the uppermost division of that series.

The discovery of the Jackson in Texas was due to Harris and Veatch[2], who found and recognized Jackson fossils in the vicinity of Corrigan, on the Sabine, and in material gotten from an oil well at Sour Lake.

Later, Vaughan, on the basis of a restudy of the fossils found near Wellborn, referred the Wellborn sands to the basal Jackson, but it was left for Baker and Suman to work out the extent and character of the beds referable to this horizon lying between the Sabine and the Brazos.

General Character and Thickness.

The Jackson, like other divisions of the Eocene in Texas, while made up largely of marine deposits, has also its share of those

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Crider, Bul. U. S. Geol. Sur. 283, p. 35.

[2] Louisiana Geol. Sur. 1902, p. 25.

laid down in lagoons and swamp areas. In some regions, in fact, it is the principal lignite-bearing formation. In addition to these deposits, which it has in common with the underlying Claiborne, it is especially characterized by terrestrial deposits and by materials derived from volcanic flows and eruptions.

The lowest beds are fossiliferous sands and clays. These are followed by calcareous clays and sands, also fossiliferous, lignitic sands and clays, beds of volcanic ash and other materials of igneous origin, and some limestones and sandstones. Of the sandstones, some are quartzitic in character and some have a porcellaneous cement. The fossils of the sandstones are largely casts, but in the clays they are well preserved. Zeuglodon bones were found at one or two localities.

The Jackson is distinguished by the fact that in it the clay ironstone and limonitic concretions of the underlying Yegua are replaced by calcareous concretions and by a greater proportion of sands and sandstones. Some of the Jackson sands are very hard, even quartzitic, but are always light gray in color and are fossiliferous in places. Volcanic ash beds are also characteristic. The top of the Jackson is placed where the chocolate laminated clays and carbonaceous sands give place to coarse "rice" sands or sandstones and yellowish green, structureless clays and claystones.

These beds have a thickness in Angelina county of between 400 and 600 feet and are probably thicker on the Trinity and to the west of that stream.

Distribution

The outcrop of the Jackson on the Sabine has a width of about four miles. As it strikes westward, it gradually becomes wider until it reaches the divide between the Neches and the Trinity in the vicinity of Groveton. In this region it attains its maximum surficial width, which is about eighteen miles. The belt then strikes southwestward, crossing the Trinity west of the town of Trinity. The outcrop on the river along the line of dip narrows to five miles. Between the Trinity and the Brazos it has an average width of eight to nine miles and crosses the latter stream southwest of Wellborn.

Disposition and Relation to Underlying Formations

So far as can be determined from the contacts we have seen between the Claiborne and the Jackson, the newly emerged Middle Eocene sediments which formed the surface of the coastal fringe at the beginning of the Upper Eocene showed little change in condition in the vicinity of the Colorado. The Jackson sea, coming in from the southward, in the vicinity of the Brazos, transgressed the Claiborne land to the northeastward rather slowly at first, but more rapidly later. The basal or Wellborn sands and their overlying lignitic deposits are well developed on the Brazos and eastward to the Trinity river. These basal deposits, however, do not extend beyond the divide between the Trinity and the Neches rivers. From the Neches eastward these sands are replaced by the medial or Caddell clays, which form the basal beds between the Neches and the Sabine.

Between the emergence of the Claiborne and the deposition of these basal beds the greater part of the Fayette east of the Brazos was removed by erosion and in consequence the Wellborn sands are in immediate contact with the Yegua between the Brazos and Trinity, while east of the Neches the contact is between the Yegua and the Caddell clays. The Yegua shows an eroded surface at the contact at some localities, as at Mile Post 659 on the Missouri, Kansas & Texas Railway.

In this area, therefore, the Jackson began with the marine conditions on the Brazos and land in the east. The marine conditions gradually extended to the Sabine and were succeeded to the westward by those which permitted the deposition of lignitic beds. Finally, littoral conditions prevailed along the entire front.

During the period there were volcanoes in active eruption. Some of these were probably located to the seaward of our area, while others were within the region now occupied by its sediments, and furnished volcanic tuff and ash for its beds. To this source is also due the large amount of opaline matter now occurring as opalized wood and as the porcellaneous cement of the many sand beds.

Subdivisions

At the base of the Jackson we find sandstones of rather fine grain, gray and brown in color, interstratified with lignitic clays and sands and overlain by sandy carbonaceous shales carrying silicified logs. These are the Welborn beds, and are followed by greenish clays and sandy clays with calcareous concretions and greensand, and other clays with gypsum and sulphur. They have been called the Caddell beds. West of the Groveton divide these clays are also lignitic and not fossiliferous. The upper member consists of a series of lignitic clays and sands with which are interbedded brown sandstones, some of which have a porcellaneous cement while other are quartzitic, the uppermost portion being carbonaceous sandy clays with gypsum and sulphur. These are called the Manning beds.

In connection with the Caddell beds and continuing up into the Manning we have extensive beds of volcanic ash and some volcanic tuff.

Correlation With Other Areas

Kennedy found a number of fossils in the sandstones of Williams Quarry on the Stephenson League three miles east of Wellborn, which Harris identified as follows, classing them as Lower Claiborne. These were found near the base of the sands:

Yoldia claibornensis
Venericardia planicosta
Cytherea bastropensis
Siliqua simondsi
Mactra sp. a
Corbula alabamiensis
Turritella sp.
Cancellaria penrosei
Pleurotoma quassalis
Cylinchna kellogii

Deussen made futher collections in this vicinity and says[1]:

"Vaughan is of the opinion that the horizon represented by the hard fosiliferous sandstone of the section on the Robert

[1] Water-Supply Paper 335, p. 72.

Stephenson League is probably very low in the Jackson."

He does not enumerate the fossils, but as he probably had a fuller collection than that which Harris examined and as the Wellborn is apparently the continuation of the sands forming the base of the Jackson to the east, the Wellborn sands are removed from equivalency to the Fayette, as was formerly held, and placed at the base of the Jackson.

The fossils of the Caddell clays which occur on Tar Kiln creek four miles northwest of Diboll are well preserved and represent an horizon considerably higher than the Wellborn. The only Zeuglodon bones found were in connection with the Caddell. The Manning sands which overlie these contain many imprints of fossils, mostly lamellibranchs, but they are somewhat poorly preserved.

It is probable that when the present collections are properly studied it will be found that practically all of the Jackson time is represented in our section.

Details of Section

BRAZOS AND GRIMES COUNTIES

Wellborn:—Kennedy[1] describes these beds as follows:

These sandstones, with their accompanying gray sands, although here tentatively denominated the Wellborn beds, belong to and help to form a part of, the series of gray sands and sandstones extending across the State from the Neches river in Polk county as far west as Sunnyside church, in Lee county[2].

In Grimes county these beds have been narrowed down to a belt occupying an irregular area lying between the calcareous sands and sandstones of the Navasota beds and the underlying dark gray sands and lignites of the Yegua group, and appear only as isolated patches.

In Brazos county the gray sands and sandstones form an irregularly defined belt of varying width extending across the county from the edge of the Navasota bottom lands on the east to the Brazos river on the west. They are hard, close-grained,

[1]Fourth Annual Report, Geol. Sur. Tex. p. 45.

[2] Probably not Wellborn, but Fayette.

and compact, occasionally showing a tendency to become quartzitic. The country occupied by them is generally flat and prairie-like, covered by gray sand, and few outcrops of continuous ledges of the sandstone can be seen anywhere.

Small outcrops occur at several places on the Sam Davidson and James Hope leagues, on the western side of the county, where the belt has an apparent width of nearly three miles. These outcrops are irregular in areal extent and thickness, and appear usually as isolated patches or "knobs" surmounting the small rounded hills forming the uplands of this region. The sandstones here rest upon the upper beds of the lignitic sands and clays found farther north. A section on a small creek on the south side of the James Hope headright shows:

1.	Gray sand and gravel	1 ft.
2.	Gray sand, with great quantities of silicified wood	5 ft.
3.	Gray indurated sand, with ledges of soft sandstone	10 ft.
4.	Gray sandstone, jointed and thinly bedded	8 ft.
5.	Dark brown lignitic clay, showing yellow streaks and sulphur efflorescence	20 ft.

Near the mouth of White's creek the gray sandstones are seen capping the higher grounds. Here these rocks are arranged in three ledges, showing an aggregate thickness of 20 feet, and rest upon the dark brown clays of the lignitic deposits. No fossils have been obtained from them, except a few small dicotyledenous leaves, but their direct continuity with the fossil-bearing sandstones has been traced along a series of small outcrops across the county by way of Minter Springs and Wellborn to the junction of the two on the R. Stephenson league.

Going east from Wellborn, light gray laminated sandy clays and thin beds of sandstones appear in the cuttings and washouts along the south side of the R. Stephenson league for a distance of several miles. About three miles to the southeast of the station, at Dr. Williams' quarry[1], on the same league, an exposure of regularly bedded gray sandstones appears along the north bank

[1] This is locality from which fossils were collected, the list of which was given in connection with the correlation of these beds.

of a small stream. The general section at this place appears to be:

1. Gray sands, showing some distance down the creek....2 to 8 ft.
2. Thinly laminated, light gray (almost white) sandy clays 2 to 8 ft.
3. Broken deposit of sandstone, containing fossils.............. 2 ft.
4. Regular and even bedded gray fossiliferous sandstone...... 6 ft.

On the Brazos river Kelly found what he considers the base of the Wellborn in a bluff just north of Koppe's bridge west of Wellborn. His section shows:

1. Dirty brown clay with a layer of dark brown limonitic concretions five feet from base. Fossils at base........15 to 20 ft.
2. Brownish-gray, fossiliferous clay, showing limonitic layers 1-16 to 1-4 inch thick. Toward top it contains beds of sand 1-inch thick .... 6 ft.
3. Lignitic clay interbedded with yellow clay. Some limonite concretions. Balls and lenses of lignite showing manganese in cracks. A few light to dark gray concretions of siderite .... 4 ft.
4. Interbedded sands and clays. Beds of clayey sandstone mark the base of this section. The layers are one to three inches thick, well bedded, poorly indurated, coarse to medium greensand, color dirty white to greenish white. The middle is more argillaceous, whiter, thin-bedded, with layers of lignite an inch thick. The upper 3 feet more sandy, thin-bedded and showing stains of limonite. Silicified wood is plentiful in these beds ....10 ft.

Members one and two are probably Wellborn.

A mile and a half south of Batte's ferry, he found the following:

1. Thinly bedded sand and sandstone, some beds colored deep yellow by iron. Bedding very thin, but persistent. Nodules of pyrite are present .... 3 ft.
2. Very soft sandstone with fine laminations, yellow to reddish brown in color .... 1 ft.
3. Interbedded white sands and dirty gray shales. Sands in beds less than 1-inch thick, breaks in flags and rings when struck .... 2 ft.
4. Blue, fine-grained sandstone, poorly indurated .... 1 ft.

Below this some two miles, Penrose found:

1. Cross-bedded, gray sand, hardened in places ....10 ft.
2. Hard greenish clay, with seams of chocolate clay........12 ft.
3. Lignite .... 1 ft.
4. Hard greenish clay .... 6 ft.
5. Lignite .... 2 ft.
6. Calcareous, gray sand, with indurations .... 6 ft.

Dip of the strata 1 to 5 degrees south. Many imperfect leaf impressions and considerable amounts of iron pyrites are found in the clay. These beds probably belong to the Caddell clays, which are also shown in a section on the river five miles west of Millican and one mile above the mouth of Boggy creek, as follows:

1. Thin-bedded, fine-grained sandstone, dirty white in color and locally stained with limonite. Silicified tree trunks...... 6 in.
2. Massive yellow sandy clay, weathering bluish white........ 3 ft.
3. Sandy clay with small flakes of sandstone.................10 ft.
4. Interbedded sandstones and lenticular sand beds............ 3 ft.
5. Loose, cross-bedded, coarse to medium grained sandstone with clay band at top and bottom .... 1 ft.
6. Medium grained, massive sands .... 3 ft.
7. Light yellow sandy clay, white siliceous scale partings.... 7 ft.
8. Lignite .... 9 in.
9. Light green clay, weathers to powder .... 1 ft.
10. Lignitic clay .... 6 in.
11. Light green clay like (9) .... 9 ft.
12. Fine and coarse grained, gritty clay, weathing into irregular fragments ....5 ft. 6 in.
13. Volcanic ash bed. In places pure ash, cross-bedded, in others mixed with clay; has lenses and one small bed of lignite; pyrites ....15 to 20 ft.

The Manning beds were not identified in the river section, but the contact between the Jackson and Corrigan occurs about one mile above the Santa Fe bridge.

The base of the Jackson crosses the Houston & Texas Central Railroad at Iola.

In the barrow pit, extending south from Bridge No. 143.04 of the Trinity & Brazos Valley Railroad, the following section is exposed:

1. Laminated, gray-brown and greenish-gray to light brown sandy shaly clays ....10 ft.
2. Gray brown, soft, shelly sandstone stained with iron and in places taking on a reddish-brown color .... 4 ft.

This section is very probably of Jackson age and represents the northern limit of that formation in this vicinity. From this point south all of the cuttings are in the Jackson, until we get about 23 miles south of Singleton.

The cutting one-half to three-fourths of a mile south of Iola exposes 10 feet to 15 feet of a yellowish-gray to light greenish-brown structureless, somewhat sandy, ball clay. It weathers out a dirty, gray-brown, and has calcareous nodules in places near the surface. These nodules are, however, very scarce. The material is more sandy, locally, and a soft, fine-grained, gray sandstone may be noted in places. This sandstone shows up better just south of the cut.

About one mile north of Grimes Station the following section is exposed, dipping 1° S. 60° E.:

1. Gray-brown, laminated and shelly, sandstone, fine-grained, and varying from soft to hard, the whole being much stained with iron .... 8 ft.
2. Laminated, gray and gray-brown, fine-grained sands......3½ ft.

The dip flattens out towards the middle of the cut. The section is covered by a dark, reddish-brown clayey soil.

The section is typical Wellborn. In the barrow pit 10 to 25 feet below Bridge No. 136.82 these shelly and laminated to thin-bedded gray sandstones still continue.

Immediately north of Grimes a cutting exposes the following section:

1. Yellowish-brown clay, containing gravel and petrified wood..2-3 ft.
2. Cross-bedded, medium grained, gray sandstone, for the most part soft and stained brown on the surface............ 4 ft.
3. Brick red clayey layer, probably formed by water acting on No. 4 .... 3 in.
4. Laminated, sandy, chocolate brown shaly clay..........8 in.-1 ft.

In the gray sandstone, large pieces of petrified wood are to be found.

These beds all belong to the Wellborn.

MADISONVILLE BRANCH SECTION

The Yegua-Jackson contact on the Madisonville branch of the International & Great Northern Railway comes in the bottom of Big Bedias creek. Loose, fine-grained, brown Wellborn sands 3 feet thick occur in a cut half way between Mile Posts 35 and 36. A section in a cut one-third mile north of Mile Post 36 exhibits the following:

1. Shelly bedded, light brown, very friable, clayey sandstone.. 6 ft.
   (Contact between (1) and (2) not seen.)
2. Very light gray, coarse grained sand with angular fragments of flint. The lower 1 inch to 1 foot is irregularly indurated and contains small masses of white clay .... 1 ft.
3. Light brown sandy ball clay .... 5 ft.
4. Light brown, shelly bedded sandstone. Passes into loose creamy laminated sand to the north along the strike.... 2 ft.

At Mile Post 35 is 4 feet of light brownish cream clay carrying volcanic ash and very similar to the clay exposed on the Missouri, Kansas & Texas Railway between Willard and Groveton, in Trinity county. Locally, there are thin white shelly layers of claystone. When at all consolidated it is thinly laminated. Underlying it in downward succession are, (1) very light gray, loose, thinly laminated, medium grained sand 3½ feet thick; (2) compact, light gray-drab ball clay stained with sulphur and limonite, much jointed and broken into small fragments, 2 feet thick.

One-half mile north of Mile Post 34 is 6 feet of white imperfectly bedded volcanic ash mixed with coarse angular transparent quartz sand.

Between Mile Post 34 and Bedias thin, shelly-bedded, light-brown sandstone outcrops. In a cut one-fifth mile north of the 34th mile post is the following section.

1. Thin, shelly-bedded, light brown sandstone.
2. Medium grained, light gray-brown, very friable sandstone with leaves .... 2 ft.
3. Thinly and irregularly laminated nodular light brown sandy clay .... 8 ft.
4. Laminated brown and gray sand .... 3 ft.
5. Chocolate-brown carbonaceous shale with thin interbedded layers of gray sand in middle .... 1 ft.

The two basal layers have a dip of 6° south, or a little east of south. Silicified logs with veins and incrustations of hyalite are found in the section.

About 2-3 miles some south of west of Bedias along a high ridge, overlooking South Bedias creek bottom to the south, there outcrops a sandstone of medium to fine grain and of varying degrees of hardness. In places the sandstone is white in color and tends to be soft. In others it is bluish gray in color and indurated to a quarzite. The matrix of the sand grains is in places of an opaline nature, in others it is fine granular, and the color is for the most part white or gray, but local discolorations to yellowish-brown and reddish-brown occur. This sandstone has been prospected extensively along the ridge and pits are to be found in it everywhere. The greatest thickness that could be measured from these was 5 to 6 feet. The rock mass is probably from 25% to 30% quartzite.

On this same ridge about 2½ miles south of west of Bedias on the Iola road the sandstone is found locally to be packed with fossil casts. The fauna includes gasteropods, as well as lamellibranchs. *Venericardia planicosta* is very prominent, together with a *Cytheria, Turritella* and a fusiform cast. While this material is apparently identical with that found along the Houston, East & West Texas Railway two miles north of Corrigan, Polk county, it belongs to the basal or Wellborn beds and corresponds to the Stephenson League locality.

From the 32nd to the 27th mile posts there are shallow exposures of the characteristic brown shelly-bedded Jackson sandstone, quite friable, with more massive friable sandstone 1 foot thick. At the 27th mile post are light, greenish-yellow, clayey, fine-grained, unconsolidated sands about 3 feet in thickness. The topography is a very gently rolling, dissected peneplain. One-third mile south is brown, irregularly laminated clay 1 foot thick, underlain by 2 feet of greenish-brown drab, waxy-lustred clay, much fractured and plastic.

The following section is at Mile Post 26:

1. Dark brown, sandy loam with Lafayette-derived pebbles and silicified wood fragments .... 4 ft.

Unconformity:

2. Brown sandy shale, locally partially indurated .... 1 ft.
3. Greenish-brown drab, much fractured, plastic clay .... 4 ft.
4. Brown shale .... 3 in.

5. Dark brown carbonaceous shale .... 6 in.
6. Brown shale .... 3 ft.

The characteristic weathering color of the Jackson is dark, reddish-brown. Southward in the above section a bed of dark-brown, carbonaceous shale 1 foot thick is found in No. 3, arched in the shape of a low anticline 100 feet across and 4 feet high, which to the southward dips beneath the surface. This carbonaceous layer lies between two layers of No. 3 and is equivalent to No. 5. Below No. 6 is a layer 3 feet in thickness similar to No. 3. Still farther south, 100 yards north of Mile Post 26, No. 5 again appears at the surface in a low anticline. These clays are apparently a part of the Caddell beds.

One-half mile to the west is an old pottery works. Here 4 feet of shelly-bedded, brown, sandy shale is overlain by the same thickness of cream-colored, cross-bedded, contorted bedded and thinly laminated, volcanic ash. The section is unconformably overlain by dark gray sandy loam 1-2 foot thick with Lafayette-derived pebbles and fragments of silicified wood. One hundred yards upstream the volcanic ash is overlain by 2 feet of brown carbonaceous shale.

The Manning beds in this section are first found at Mile Post 25 as a brown, cross-bedded sand 5 feet thick, locally case-hardened and with a much fretted surface, which is overlain by four inches of dark gray, sandy loam, with Lafayette-derived pebbles and fragments of silicified wood. At Lorimer siding the above mentioned bedrock section is overlain by light-brown, poorly laminated clay 2 feet in thickness. One-third mile south of Mile Post 25 is the following section.

1. Dark brown soil, residual and alluvial with Lafayette-derived pebbles and wood fragments .... 2 ft.

Unconformity:

2. Light gray, clayey sand with white calcareous nodules...... 3 ft.
3. Gray, cross-bedded fine sand .... 3 ft.

Light gray, medium well indurated sandstone, weathering brownish, 3 feet thick, is exposed one-fourth mile north of Singleton. Wells at Singleton penetrated 10 feet of lignite at depths approximating 50 feet. There is a parting of brown carbonaceous clay at a depth of 8 feet below the top of the bed. The lignite has a roof of rather hard sandstone about 13-16 feet thick. The water at Singleton is very poor. One-fifth mile south of the Singleton station, exposed in cuts on both the International & Great Northern and Trinity & Brazos Valley railroads, is light gray, cross-bedded, medium-grained sand 2 feet thick. Associated with this, is very light gray, or cream colored, volcanic ash cemented on fracture planes by light gray opaline silica, giving the rock a brecciated appearance, the fragments of white powdery ash, being 1-8 inch or less in diameter. At Mile Post 23 the ash, which is here thin-bedded and gritty, while the ash 200 yards north is not appreciably gritty and is finer, is underlain by brown, shelly-bedded sand and sandstone 2 feet thick.

The contact between the Jackson and Corrigan is found between the 23rd and 22nd mile posts.

From the Madisonville branch to the Trinity river the Yegua-Jackson contact follows the course of Bedias creek, which flows about one mile south of the line between the two formations.

TRINITY RIVER SECTION

The Trinity river affords one of our best sections of the Jackson. Its most northern exposure on this stream is found about one-fourth mile north of Calhoun's Ferry, at the corner of Madison, Houston and Walker counties. Here indurated Wellborn sandstone forms two large rapids, with an estimated combined fall of at least 6 feet. The rapids are formed by massive medium-grained, opaline-cemented, light gray sandstone. Interbedded with this is the usual "shelly," brown, clayey sandstone. The sandstone contains many carbonaceous leaf imprints. The lower fall has a 4 ft. drop over a ledge of sandstone at least 6 feet thick. Overlying the sandstone is a foot of lignite, overlain unconformably by blue-gray and brown mottled, sandy, alluvial clay. Just above the upper shoals, second bottom terraces are present on opposite banks of the river. Natural levees, sometimes 10 feet in height and forming very perfect embankments, are found along the Trinity. Alluvial deposits extend from Calhoun's Ferry almost to Kittrell on the Calhoun's Ferry-Trinity road. The Jackson is found on this road just south of Dillard's creek.

The section at Calhoun's ferry follows. The dip at this exposure is from 2½ to 4½ degrees to the southward. This exposure is on the Walker county side, or the north bank:

1. Light brown, clayey, alluvial sand. Gravel at base, which forms terrace at the north end of the bluff ....10 ft.

Unconformity:

2. Shelly-bedded, dark, grayish-brown clay, sandy and yellow-stained in middle, with plant fragments. Poorly consolidated ....15 ft.
3. Lignite, impure, with carbonaceous clay. Lignite of poor quality. Upper seam of greenish, waxy clay. Forms shoal in river .... 5 ft.
4. Dark brown, shelly clay at north; farther south changes to plastic, slickensided, greenish-brown clay ....1 1-4 ft.
5. Lignite, good quality, dull lustre, forming shoal in the river ....4.5 ft.
6. Light greenish and yellowish-green joint clay, waxy and non-plastic, with black oxide of manganese. Laminated, sandy, cross-bedded, and with carbonaceous fragments in middle. Weathers light gray to cream colored. Upper 3 feet darker when unweathered than the lower portion................ 7 ft.
7. Sandy, gray clay, poorly laminated, with plant fragments.. 2 ft.
8. Poor lignite and blackish, carbonaceous shale............1.5 ft.
9. Hard, firm lignite, locally burned..........................2.5 ft.
10. Light brown sand, with carbonaceous fragments.......... ½ ft.
11. Light greenish, fine-grained sand, pyritiferous and sulphurous, thinly and irregularly laminated......................6 ft.
12. Light gray sand, fine-grained, micaceous, irregularly and shelly-bedded, much jointed, with small black fragments of *Salix* and other leaves...............................2.5 ft.
13. Dark gray-drab clay, jointed and imperfectly laminated...... 5 ft.
14. Chocolate-brown, carbonaceous, sandy clay................. 1 ft.
15. Fine-grained sand, thin and irregularly laminated, yellowish-stained light gray, with thin plates of dark brown carbonaceous matter and small lignitic fragments..... 7 ft.
16. Dark greenish-gray, laminated, joint clay with lignitized fragments, and with irregular lenses of fine light gray sand. Sand locally in irregular pockets with cross-bedded

structure. Weathers grayish and light brown and contains lignitized fragments. Sand in upper half................15 ft.
17. Dark greenish-gray, sandy, sticky, joint clay, mainly sand in upper half .... 7 ft.
18. Dark brown, carbonaceous clay with lignitized fragments.. 1 ft.
19. Lignite .... 1 ft.
20. Dark gray, fine-grained sand, clayey, thinly laminated...... 2 ft.

Total of Jackson in this section is 86 feet.

One-fourth to one-half mile below the end of the above bluff is the following section:

1. Irregularly laminated sandy clay, yellow-stained brown.... 7 ft.
2. Hard, firm, dull-lustred lignite with thin lenses of brown carboneaceous clay. Lignite makes shoals ....2¾ ft.
3. Dark brown, carbonaceous shaly clay...................... 1 ft.
4. Laminated, gray, fine-grained, yellow stained sand.......... 3 ft.
1. Grayish-brown, carbonaceous, shelly sandstone .... 5 ft.
2. Laminated, sulphurous, chocolate clay .... 5 ft.
3. Like (1) and sulphurous .... 4 ft.
4. Cross-bedded, loose, gray sand, fine-grained. Laminated and more indurated at the base. Locally indurated to a fine-grained, thin-bedded sandstone ....25 ft.
5. Poorly laminated and shelly sands, somewhat clayey, highly sulphurous and carbonaceous. Gray brown in color......12 ft.
6. Sandy clays and sands, dark brown to black, highly carbonaceous and sulphurous, poorly laminated. Lignitiferous. Locally contains sandy pipe concretions .... 8 ft.

The bluff here is 63 feet high, measured with hand-level. The sandstone carries fairly good plant fragments and casts of marine lamellibranchs were noted on one piece of sandstone on top of the bluff. The sandstone also shows selenite flakes. In almost all of these bluffs streams with exceedingly steep sides are to be found. These are canyon or gully like in form. At Weiser's Bluff, springs highly charged with sulphur issued from the bottoms of the gullies.

Just below Weiser's Bluff, in a stretch where the river flows N. 30° W., there is a bluff on the Walker county side which exposes some 60 feet of Jackson. Here there is no perceptible dip. At the base is 10 feet of bluish-gray, laminated, shaly clay, overlain by grayish-brown, shelly sands, 40 feet in thickness, and this is covered by 10 feet of gray sandstone.

Cincinnati Bluff, about one mile downstream from Weiser's Bluff, is also on the Walker county side, and is slightly higher than Weiser's Bluff. The section at Cincinnati Bluff is very similar to that of Weiser's Bluff, except that the upper 15 feet is composed of light reddish terrace material.

About 4 feet of lignite is exposed in a shoal on the south bank of the river just above the mouth of Wright's creek. Just below the mouth the following section is exposed on the north bank:

1. Alluvium with calcareous nodules, light brown in color, but blackish towards top ....20 ft.
2. Lafayette-derived gravel .... 2 ft.

Unconformity:

3. Light brown, shelly, sulphur-stained, clayey sand..........1½ ft.
4. Impure lignite ....2/3 ft.
5. Light brown, gray, laminated and cross-bedded carbonaceous sand ....10 ft.

One-half mile below the mouth of Nelson creek there is a rock shelf on the south bank which juts out into the water and rock shoal extending across the river with a 4 ft. fall. The following is the section:

1. Brownish, irregularly laminated and "shelly" clayey sand..10 ft.
2. Lignite .... 3 ft.
3. Indurated gray sandstone layer forming rapids .... 1 ft.
4. Irregularly, cross-bedded and laminated sands .... 6 ft.

No perceptible dip was noted in this section. The bed of lignite and other strata of the above section outcrop upstream continuously to slightly above the mouth of Nelson creek.

The next shoal downstream is made by lignite. At the base of this exposure is thinly laminated, gray, carbonaceous sand 3 feet in thickness, locally partially indurated into irregular surfaced shelly sandstone. Above is dense black lignite 2 feet in thickness, with top of the bed not seen. One-fourth mile farther downstream, the next shoals exposed 3 feet of thin, shelly-bedded, brown, carbonaceous sandstone. The next exposure one-half mile downstream is situated on the south bank like the last two. The section is:

1. Light brown, sandy clay with whitish calcareous nodules, dark gray on the surface—alluvium ....20-25ft.

Unconformity:

2. Light grayish-brown, clayey sand, poorly laminated, carbonaceous .... 6 ft.
3. Dark brown, carbonaceous shale, forming a fairly good roof for the lignite .... 6 ft.
4. Lignite, non-lustrous, not waxy, much weathered, varying in thickness, light in weight .... 5 ft.
5. Sandy, dark brown, carbonaceous shaly clay with many black plant fragments .... 3 ft.

Below the above section, at the east end of the bluff, is the following section. The dip here is 2° S. 70° W.

1. Laminated sand, like basal member of section last given.
2. Poor grade lignite .... 1 ft.
3. Brown carbonaceous sand .... 1 ft.
4. Gray, thinly laminated volcanic ash, sandy and carbonaceous 3 ft.
5. Volcanic ash, very fine-grained, cream-colored, laminated..2-5 ft.
6. Brown clayey sand, highly sulphurous and carbonaceous. shelly .... 3 ft.
7. Shelly brown sandstone .... 3 ft.
8. Brown clayey sand .... 3 ft.

At the east end of the bluff the lignite is overlain conformably by a layer of Lafayette-derived gravel.

One-half mile downstream, on the south bank, is another bed of lignite. The section here is:

1. Light brown, sandy, alluvial clay with calcareous nodules.
2. Limonite-cemented layer of Lafayette-derived gravel.
3. Brown carbonaceous, imperfectly laminated sand.......... 7 ft.
4. Dark brown, shaly clay, sandy, firm, carbonaceous and highly sulphurous ....2½ ft.
5. Dense, dull black lignite ....5¼ ft.
6. Shelly, compact, sticky dark brown carbonaceous clay, with lignitized fragments ....½ ft.
7. Laminated blue sand, cross and contorted bedded, and with layers and lenses of blue clay, pyritiferous............. 5 ft.

The dip here is 2° West. This exposure is opposite the mouth of Dillard's creek. The partially indurated sand beneath the lignite forms shoals.

At the bluff 2 miles south of the town of Trinity the Thompson Brothers Lumber Company have a pumping plant. This bluff is about one-half mile long and affords quite the finest exposure of Jackson yet seen. The dip is 2½° to the southeast. The section is:

1. Alluvial sandy clay with calcareous nodules, mainly light brown in color, but is greenish-gray near the surface at a short distance from the river .... 25 ft.
2. Lafayette-derived gravel layer.

Unconformity:

3. Thin and shelly-bedded, brown and gray sand .... 15 ft.
4. Massive, fine-grained gray or brown sand, loose, imperfectly laminated or cross-bedded locally .... 11 ft.
5. Chocolate-brown, sandy clay banded towards top and of drab color. Thin-bedded and laminated. Contains one 5 ft. drab, clayey sand layer about 8 feet above base. The upper portion is very sandy and well stratified .... 16 ft
6. Clayey, brownish, sulphur-stained, shelly-bedded sands Clayey layers, dark gray in color. Some of the sands are also cross-bedded and of gray color. Contains lignitized stumps with marks of borers........................ 31 ft.
7. Lignite .... 1′2″-2½′
8. Dirty-green, sticky clay, locally copperas-stained........... 4 ft.
9. Lignite .... 2½ ft.
10. Dirty-green clay, unctuous, much fractured.................. 2 ft.
11. Dark blue-gray, medium-grained sand, laminated .... 3 ft.
12. Dark greenish-gray, compact clay with plant fragments weathering light gray .... 2 ft.
13. Dark brown, sandy, carbonaceous shale.................... 11 ft.

Total Jackson exposed in above section 100 feet.

A bed of lignite outcrops in a low bluff on the west bank, one-half mile below Clegg's shoals. This bluff trends east and west along the strike of the beds. The same bed of lignite outcrops on the east bank about one-half mile farther downstream, where the dip is one degree or less in a southward or southeastward direction. The section is:

1. Yellowish, sandy alluvium, generally with Lafayette-derived pebbles at base.

Unconformity:

2. Laminated, medium-grained brownish sands.

3.	Lignite, hard, firm, dull lustre, semi-conchoidal fracture....	4 ft.
4.	Brown sand, carbonaceous, locally clayey..................	4 in.
5.	Lignite	6 in.
6.	Dark gray, carbonaceous clay	4 ft.
7.	Laminated gray, medium-grained sands, contorted and cross-bedded	6 ft.

The next two exposures farther downstream are about 2 miles distant from each other. They consist of 15 feet of thinly laminated light gray, fine sand. The upper exposure has 2 thin seams of carbonaceous matter within 4 or 5 feet of the top. It is folded in broad, very low waves with one abrupt vertical downfold of 2 ft. in the same horizontal distance. The lower exposure is locally stained with yellow, has slightly contorted bedding and is overlain unconformably by 2 feet of ferruginous cemented Lafayette-derived conglomerate.

A bluff two miles north of Riverside and about 200 yards west of the International & Great Northern Railway may present in its basal member, the upper part of the Jackson formation and the contact between it and the overlying Corrigan.

INTERNATIONAL & GREAT NORTHERN RY. SECTION

There are few exposures of the Jackson on the International & Great Northern Railway. On the line between Trinity and Houston counties the base of Jackson shows thin, irregular and shelly-bedded, friable, creamy to buff sandstones.

There is 8 feet of volcanic tuff exposed just north of Mile Post 16, with its base not seen. When pure this tuff is of a light yellowish-cream color, but when mixed with sand it is grayer. The whole is much cross-bedded, with sharp planes of demarkation between beds dipping at different angles. Another peculiarity is small ellipsoidal bodies of very fine clay or tuff included within the main deposit. The plane between beds dipping in different directions are flat or irregular surfaced. Another peculiarity is the cross-laminae in which coarser grains form lighter-colored laminae, interbedded with laminae of darker Francisco. The purity of these ash beds would naturally lead gray, finer materials. This deposit is almost certainly of eolian origin. It duplicates almost exactly sections of sand dunes to be seen south of the Presidio and near the Cliff House at San one to the conjecture that they must be wind-blown deposits, and the cross-bedded structure of this exposure renders the view rather certain. The volcanic ash is overlain a short distance to the south by poorly indurated, medium-grained, gray sandstone, locally mottled.

Tyler and East Prairies, northwest of Groveton, are in reality one large prairie with a narrow neck of timber reaching across near the middle. Together they approximate six miles in an east-west direction by 2½ to 3 miles in a north-south direction.

The surface of the ground on these prairies is very rolling and they do not present the smooth surface noted in other prairies to the east. For the most part the prairies are well drained by shallow, broad gullies emptying into Little White Rock and Louisville creeks.

The town of Pennington is situated about the middle of the prairie, near the south line of the Prado League, Trinity county. Near the central northern end of the prairie a deep gully cuts into the underlying formations and the following section is exposed:

1.	Surface sand and soil of the prairie, a gray sand for the most part containing abundant gravel of red color and large size, together with large blocks of petrified wood	2 to 3 ft.
2.	Cross-bedded clayey sands of varying thickness and often missing from section. Petrified wood	2 ft.
3.	Limonitic concretionary layer	2 in.
4.	Drab clay, somewhat sandy, weathers out whitish about the same as No. 6 except that No. 6 is somewhat stained with iron	3 ft. 6 in.
5.	Yellowish-brown, limonitic, concretionary layer, for the most party very continuous	2 to 3 in.
6.	Yellowish-brown to drab sandy clay, with layers of gray sand, sometimes 1-16 of an inch thick. The clay is gypsiferous and tastes of alum. Weathers out whitish	2 ft.

The materials of the section above given weather along the gully in badlands form. No dip was noticed.

These beds are near the base of the Jackson.

The wood found in No. 2 of this section was identified by Berry as *Cladasporites fasciculatus* Berry, which is found in both Claiborne and Jackson beds in the Coastal area.

While it is certain that the sections as given between the

Brazos and central Trinity county contain deposits which are the equivalents in time of the Caddell clays, the mottled gray and brown fossiliferous clay with fossiliferous limestone nodules which constitute these beds eastward from the divide between the *Trinity and Neches rivers are entirely absent, being replaced by* lignitic clays and sands.

GROVETON SECTION

The relationship of the three stages of the Jackson are found in the Groveton section which was made along the Groveton, Lufkin & Northern Railroad between Apple Springs, where we found the top of the Yegua, and Groveton, and on Caney creek south of Groveton.

The first section south of Apple Springs shows:

1. Sticky, bluish gray clay containing sandy ferruginous concretions in places ....1½ ft.
2. Clayey sand, massive, grayish to light brown, fine-grained, gypsiferous .... 2 ft.

Cutting 2200 feet north of Mile Post 15 exposes the following:

1. Thin bedded, gray to white and light brown sandy clay and shaly clay, similar to No. 4 .... 5 ft.
2. Highly carbonaceous clay, or poor grade lignite chocolate brown in outcrop .... 6 ft.
3. Gray, thin-bedded to massive, slightly gypsiferous sand.....10 ft.
4. Dark chocolate brown shaly clay with no visible structure, except near the top, where thin bedding is seen. Contains sulphur along joint planes .... 8 ft.

The third member is made up of even-grained small rounded clear quartz pebbles stained slightly with iron.

Dip of beds in direction S. 25° E. is from 1° 20′ to 2°, being higher in northern end of cutting.

Between 800 and 2000 feet north of Mile Post No. 14 the following section is exposed:

1. Light brown clayey sand .... 5 ft.
2. Thin bedded, fine-grained, gray sandstone alternating with a laminated mauve sandy shale, slightly gypsiferous.... 7 ft.
3. Massive, fine-grained, sandstone, gray in color .... 2 ft.

4. Thin-bedded, light brown, slightly carbonaceous, sandy shale, containing local incrustations of a gypsiferous nature....25 ft.

The fourth member contains large fragments of silicified wood having a dull earthly lustre. Dip on the second member measured at S. 25° W. was 1° 20′. This member in the north end of cut grades into a slightly carbonaceous sandy clay, dark brown in color. Covering all is a thin veneer of quartzitic gravel. At Mile Post No. 15 the fourth member is seen to carry a hard ferruginous layer about three inches thick.

Near Mile Post No. 12, a section of 4½ feet shows alternating bluish-gray, laminated, shaly clay and dark red ferruginous sandstone about equally developed in layers averaging 9-inches thick.

Cutting 800 feet north of Mile Post No. 11 (Alabama creek) exposes about 8 feet of a light brown and bluish-gray, sticky sandy clay containing numerous rounded limestone concretions which are up to 2 feet in diameter. These concretions are fossiliferous and a collection, mostly casts, was made. Among the genera might be mentioned: *Cardita, Leda, Dentalium, Natica, Turritella* and numerous other gasteropods and lamellibranchs, in addition to a species of coral, which belong to the Caddell clays.

Cutting 1750 feet south of Mile Post 9 exposes the following section:

1. Brown surface sand up to .... 1 ft.
2. Dark gray to black sandy clay, mottled reddish brown in places .... 1 ft.
3. Yellowish brown to brown clayey sand containing gravel, but pebbles are of noticeably smaller size, although of same material as (4) .... 3 ft.
4. Yelowish brown clayey sand containing quartzitic pebbles and fragments of silicified wood. Pebbles are rounded and of all sizes from 1-8″ to 2″ in diameter................ 3 in.
5. Light brown to chocolate brown, carbonaceous shaly clay containing leaf impressions .... 5 ft.

At Mile Post 8 and immediately to the south there is a cutting exposing about 10 feet of a chocolate brown, carbonaceous shaly clay, thin bedded, and containing leaf impressions. Near the middle of the section is 3 inches of a grayish to yellowish brown cross-bedded sandstone. Some few tiny flakes of selenite show upon the surface of sand partings in the clay. At Mile Post 8 the clay seems to butt up against 3 feet of gray, highly cross-bedded sandstone. Limonitic concretions, oval in shape, and with a concentric structure, were observed scattered through the section.

Immediately north of the bridge over Piney creek (Bridge 7.32) there is a bank about 20 feet high which exposes a very good section as follows.

1. Brown carbonaceous, thin-bedded shale .... 4 ft.
2. Medium grained sandstone, much cross-bedded. Irregularly interbedded with a thin-bedded sandstone and a sandstone bedded in layers up to 4 inches thick.................... 7 ft.
3. Alternating beds of medium grained, rather soft, yellowish brown to gray sandstone and a grayish brown, carbonaceous, fine-grained rather hard sandstone, successive layers being about 2 inches thick......................... 4 ft.

To the south of Caney creek (Bridge 4.75) about 100 yards and on the eastern side of the track, there is a low ridge running down to the track. It is made up of a very resistant, fine and even grained, gray sandstone. The sandstone is made up of small rounded quartz grains with a matrix of a quartzitic nature. The sandstone is very hard, breaks with a splintery fracture, and contains large fragments of silicified wood. The silicified wood has a dull earthy lustre and the grain shows up very well. This ridge does not rise more than 5 feet above the surrounding country and the rock is only seen exposed over a limited area.

Near the section house about three quarters of a mile northeast of Mile Post No. 3 the following section was observed:

1. Yellowish brown sand containing quartzitic pebbles, rounded and up to 2-inches in diameter......................... 1 ft.
2. Mottled dark bluish gray and reddish brown clayey sand.. 3 ft.
3. Gray, rather hard, even grained and rather fine-grained, cross-bedded sandstone .... 2 ft.

In the creek bottom the gray sandstone is seen to be thin-bedded and cross-bedded and to contain thin layers of chocolate brown clay containing fragmentary plant impressions.

Just north of junction of the Groveton, Lufkin & Northern Railroad with the Missouri, Kansas & Texas Railway, one mile northwest of Groveton, is a cutting exposing 5 feet of a highly cross-bedded, even grained, gray sandstone overlain by about 4 feet of brown sand carrying many quartz pebbles up to 1½ inches in diameter.

Cutting one-eighth mile north of the above section exposes at the bottom 5 feet of the gray, even grained sandstone which is locally cross-bedded, thin-bedded, or massive, and contains in some places limonitic concretions, while in others a slight yellowish brown mottling is noticed. At one point the sandstone contains angular fragments of volcanic tuff up to 2-inches in diameter. Clay nodules are contained in the sandstone and also in the overlying sand which covers the sandstone to a depth of 5 feet. The sand here is yellowish brown to gray in color and carries quartz pebbles.

Three miles east of Trinity, on the Missouri, Kansas & Texas Railway at the crossing over White Rock creek, there is an exposure in the creek bottom of about 1 foot of a white, soft, volcanic tuff, underlain by at least 3 feet of a calcareous soft, stiff clay, which is irregularly bedded and mottled chocolate brown and gray. This material is carbonaceous and fragments of wood were found in it. Immediately overlying the tuff is a layer of gravel about 6 inches thick, and the whole is covered by about six feet of gray sand.

Up the creek, and on its eastern side, about one-fourth mile from bridge there is a bluff rising about 80 feet above the creek made up mostly of a gray, rather resistant, even and fine-grained sandstone, containing a few casts of fossils. This rock stratigraphically overlies the tuff.

The top of the hill is covered by a quarzitic gravel made up of rather coarse pebbles of quartzose and chalcedonic material. In one place, about one-fourth mile east of the bluff, gravel was seen to a thickness of 7 feet and was being excavated for local use. This high bluff extends up the river for two miles.

Carrying the section southward along creeks south of the Missouri, Kansas & Texas Railway, some two miles southwest of Westville on White Oak creek, the following section was observed:

Thin-bedded, laminated and wavy, cross-bedded, clayey sands and sandy clays grading in places into only slightly arenaceous clays. The colors are for the most part grayish and brownish, but all graduations from yellowish to buish or drab were seen.

This material weathers honey yellow locally, but in most places weathers yellowish-brown. Contains abundant organic matter in shape of leaves, stems, etc. The dip here was in one place 2 degress to the south. This dip is believed to be local.

A hill 70 feet in height with a summit area of 2½ to 3 acres is found in the bottoms of Dean creek. The creek flows along the northern and northeastern base of this hill. In the bed and banks of the creek is found the following section:

1. (a) At the south, directly under the northeast base of the hill, there is 12 feet of thinly laminated brownish to buff sand carrying thin streaks of brown carbonaceous material, but becoming sandier and thicker bedded toward the top. The bedding here is also slightly irregular.
1. (b) At the north, along the creek banks is exposed 10 feet of thinly laminated, light brown to drab sandy clay carrying plant fragments. The bedding is not very regular and the individual beds are not of uniform thickness. At the easternmost locality examined the beds dipping 3-1-2° to the southward, 50 yards south the dip is 8° to the southward, while 100 yards south of the latter locality, the dip is apparently 4 or 5 degrees to the westward, but this apparent dip may have been caused by slumping.
2. Dark brown, carbonaceous clay, gradually becoming lighter with a lessening in the amount of carbonaceous matter towards the top .... 1 ft.
3. Lignite, poor in quality .... 1 ft.
4. Base, dark brown carbonaceous clay, total thickness unknown.

Above the bed 1 (a) the surface of the hillside is strewn with blocks of sandstone. A rim of sandstone in place surrounding the top of the hill is in places a massive bed 3 to 4 feet thick. Locally, these sandstone blocks are quartzitic; in places they exhibit imperfect lamination and break in blocks thick enough to be suitable for dimension stone. The sandstone contains thin flakes of selenite and much of it case-hardens on the surface on exposure to air.

About one-half mile above the A. Wicker Survey there is exposed 5 feet of medium to fine-grained gray sands poorly laminated and cross-bedded, the same being clayey in places. These sands dip 2° S. 20° W. and they are underlain in the creek bed by chocolate shaly clays.

On the A. Wicker Survey there outcrops a fine-grained, gray sandstone containing casts of lamellibranchs and also showing ripple-marks. The fossils are probably brackish-water forms. The sandstone is underlain by 2 feet of lignite coal and this in turn is underlain by black, carbonaceous clay.

One-half mile below this place there is exposed 6 feet of chocolate colored, shaly, sandy clay with layers up to 2½ inches thick of gray sandstone.

Much fossil wood was collected along this creek.

For the first half mile upstream from the Beaumont & Great Northern Railroad bridge, on the east bank of White Rock creek and below mouth of Caney creek is the following section:

1.	Grayish brown, fine-grained, fairly compact sandstone, in some places in one large layer and in other places in several layers, full of plant remains, mainly Palmetto........	4 ft.
2.	Yellowish and brown laminated sandy clay stained with sulphur and limonite	12 ft

Above ths was found opaline-cemented sandstone resembling that of the Catahoula, and the beds are practically the top of the Jackson in this region.

The plant remains from these beds identified by Berry are as follows:

Caney and White Rock creeks, 6 to 10 miles east of Trinity:

Uppermost Jackson at Corrigan Contact	Other Gulf States.	
Lygodium mississippiensis Berry	Catahoula	
Sabalites vicksburgensis Berry	Vicksburg	Catahoula
Dryophyllum n. sp.	Claiborne	
Anona texana Berry		
Myrcia catahoulensis Berry	Catahoula	
Apocynophyllum n. sp.	Claiborne	Jackson

HOUSTON, EAST & WEST TEXAS RAILWAY SECTION

Tarkiln creek flows into the Neches about four miles north-west of the Houston, East & West Texas Railway crossing of that river. Suman found on the Hobbs Survey exposures of a mottled-brown and bluish-gray, sandy and highly gypsiferous clay containing Eocene fossils in a fair state of preservation. Locally, the clay contained limestone concretions with concentric structure and these contained an abundant fauna of lamellibranchs, gasteropods and corals. A good collection was made. This material resembles very much that found on the Groveton, Lufkin & Northern Railroad 800 feet north of Mile Post No. 11 at an elevation of 300 feet. The following forms were identified:

Ostrea c. f. contracta	Tellina sp.
Arca sp.?	Turricula sp.
Venericardia planicosta Lam.	Bulinella kellogii Gabb
Venericardia rotunda Lea	Turritella nasuta Gabb
Pectunculus idoneus Con.	Turritella houstonia Har.
Pectunculus sp.?	Solarium alveatum Con.
Crassatella texana Heilp.?	Solarium huppertzi Har.
Crassatella flexura	Volutilithes petrosus
Corbula alabamiensis Lea	Cassidaria sp.
Corbula oniscus?	Calyptrea sp.
Cytherea tornadonis Har.?	Dentalium dumblei Har.
Tellina mooreana	Flabellum wailesii Con.

In the yellow, sandy concretions are many large *Pinna, Pholodomya, Echinoderms,* small *Haminea grandis,* etc.

The exposure on rail line in south bank of Neches river shows the lignitic clays and sands of the Caddell. There is a succession of clays and sands, brown to grayish-brown in color, apparently massive in places, but for the most part laminated or shaly. The clay breaks into nodular pieces. It grades into more or less sandy clay and is interbedded with laminated lignitic sands. A band of lignitic material is overlain by calcareous sandy beds which carry numerous impressions of lamellibranchs.

The clays are overlain in the vicinity of Fant by massive, cross-bedded sands which are apparently unconformable with them. Just south of Mile Post 100 these sands are in turn succeeded by sandy shales which also seem unconformable on the Fant sand. In these shales there are bands of volcanic ash, and by the side of the road there are several opalized stumps standing upright in the ash with their roots spread into the shales underlying as though *in situ.* The trunk of one of these has a diameter of twelve inches and is solid. Another is twenty inches in diameter with a hollow center. It was partly rotted before being buried and the opalization filled the joints and hollows. The Fant sands carry some siliceous gravel and the shale has a few feruginous concretions.

Baker's section here is as follows:

1. Much cross-bedded, light cream colored sand containing irregular, non-continuous lenses and layers of light drab clay. The lenses and layers of clay have curved, irregular outlines and lie in the sands often at attitudes at variance with the horizontal. The sand is medium-coarse in grain and sub-angular to rounded in contour. Some of the seams and lenses of clay are dark brown from the included carbonaceous matter. The sand shows imperfect lamination, which lamination effect is aided by thin layers stained with sulphur and limonite. At the south end of the cut there is at the top about 2½ feet of thin-bedded, light cream sandy clay alternating with thin layers of light brown, much like the clay at Potomac (Mile Post 99). Maximum thickness ....15 ft.

Unconformity with irregular contact, suggesting the erosion of a channel before the deposition of the overlying beds.

2. Nodular, sandy clay, light brown in color, weathering to a light buff or a light drab, sulphurous. Locally carbonaceous about 1 foot above base. Upper 10 feet of light buff color. Thickness varies, up to ....20 ft.
3. Thin-bedded, unconsolidated, light brown sandstone with small dark, drab clay nodules and thin irregular lenticular layers of clay with thickness up to 1-4". Irregularly stained with sulphur and limonite. Carries also brown plant fragments and locally exhibits case-hardening with a light purplish-blue tinge ....12 ft.

In the gully immediately to the south of this cut is exposed a maximum of 27 feet of the light drab, sulphurous, sandy clays unconformably overlain by light gray to cream colored, cross-bedded sands similar to those described under (1) above. At the north end of the cut at Mile Post 100 small grains of tuff (?) were mingled with the quartz grains. These sands are locally indurated and then are light bluish or purple-gray in color. The induration is irregular and gives a nodular aspect to the rock. The spaces between jointed blocks are seamed with the cementing material and these seams standing out as ridges give a cavernous or honeycombed appearance to weathered surfaces. It is only the top layers from 1 to 2 feet in thickness which are so indurated and locally some of the overlying gravel of the surficial member has also been cemented. The surficial indurated layer projects over the underlying less resistant sands. The induration follows the contour of the present surface and the indurated zone is a broad low dome in shape. In the vicinity of Mile Post 100 cross-bedding is very greatly developed.

At the extreme south end of this cut, near the road crossing, there is exposed at the track level 1 foot of very fine white ash with base not seen. This ash is locally indurated on the surface exposures. Some of the cross-bedding, especially at the south end of the cut, with planes meeting each other at abrupt angles, suggest either a sand dune, a bar or spit, or the downstream side of a river "towhead."

Between Mile Post 100 and Mile Post 99 sands similar to those at Mile Post 100, and locally case-hardened, are exposed.

In the cutting about one-fourth mile north of Potomac, on the Houston, East & West Texas Railway, the following section was noted:

1. Case-hardened, indurated, perhaps calcareous-cemented, light gray to light cream colored sandstone weathering in cavernous or large honeycomb form and containing in the surficial layer, *in situ*, rounded pebbles of quartzitic and granitic rocks. Massive. Thickness ....1 ft. 4 in.
2. Friable, fine-grained, somewhat cross-bedded sand with selenite flakes. Color is light cream to light brown .... 3 ft.

In both members were noted small clay balls and fragments of what resembled volcanic tuff. The matrix here may be tuff. The general dip of the lower member was southward at low angle. This surficial member (No. 1) may represent re-cemented, both residual and transported material, and may belong to the Lafayette. The cementation of this member is irregular and it shows a tendency, locally, to be more indurated along joints, which gives it the cavernous appearance. Locally it is compact and is a medium hard sandstone.

In the creek bed immediately west of Houston, East & West

Texas Railway, about 200 yards north of signal board "Potomac," there outcrops a stratum of lignite 3.5 feet thick, which burned in the camp fire. On exposure to the air it slacks. The stratum is covered by about 4 feet of chocolate colored, shaly clay and two feet of surficial material. It is black in color, of light weight, and breaks with an irregular fracture. This material outcrops along the creek for a distance of about 60 feet.

Cutting in creek bed immediately northeast of signal board "Potomac" shows 8 feet of a light cream colored sandy clay, case-hardened and standing with vertical walls. It is gypsiferous and slightly carbonaceous, often containing leaf imprints. The material shows imperfect lamination and locally it may be stained yelowish brown by limonite. The sand in this clay is very fine-grained.

Section exposed 1000 feet south of Potomac shows 3 feet of medium grained sand, gray and yellowish brown to cream colored, thick bedded at bottom of exposure, but grading into thin-bedding and lamination at top. Covered by 3 feet of a chocolate brown, highly carbonaceous clay, sandy locally. This is in turn covered by about 1 foot of gravel. The sand member is clayey locally and contains mud balls. About 300 feet farther south the sand member is exposed up to 3 feet and is finely laminated and cross-bedded. Contains plant remains. At Bridge 99-C, 7 feet of the sand member is exposed in the creek bank. Locally, it contains sandy clay layers and layers of chocolate brown, carbonaceous, shaly clay up to 1-8 inch thick. The dip here is 3° S.

Three hundred and fifty feet north of Mile Post No. 97 the following section is exposed:

1. Lafayette. Light mottled reddish brown and gray, locally, and dark brown elsewhere, sandy clay. Contains much gravel made up of quartz, chalcedonic and metamorphic pebbles and small angular blocks of a hard sandstone, probably derived from a local source. Large siliceous wood fragments up to 2 feet in length are found here too. Case-hardening on surface .... *8 ft.*
2. Fine, dark brown clay .... 2 ft.
3. Laminated, fine sand, light gray to light brown and containing plant fragments and tiny flakes of selenite .... 3 ft.

An excellent collection of marine invertebrate fossils in a fine state of preservation was made from well dug about 200 feet west of Bridge 96-C along the Benford tram. These shells came from a blue clay at a depth of 28 feet.

A very interesting locality is that on the northwest corner of the J. M. Deane League, Trinity county, about 5 miles due west of Potomac.

On the northwest corner of this League, near the Trinity county line, in the bed of Rocky creek, the following section is exposed:

1. Chocolate colored, laminated shaly clay.................... 2 ft.
2. Thin-bedded, soft, gray to yellowish brown sandstone containing casts of fossils, both lamellibranchs and gasteropods 1 ft.
3. Alternating thin-bedded chocolate to drab shaly clay and yellowish brown sand ....1½ ft.
4. Gray to white clayey sand standing with perpendicular walls. Contains abundant poorly preserved lamellibranch shells for the most part of only about three species.............. 8 ft.
5. Cross-bedded, coarse, dark gray and bluish gray angular grained sand. Some few green grains resembling glauconite were seen in this sand. Locally almost a shell marl and locally contains lignitized wood. Shells of *Ostrea* abundant in places .... 3 ft.
6. Greenish blue, shaly clay, thin-bedded and massive and grading locally into chocolate brown colored clay. Contains many fairly well preserved lamellibranch remains.....3½ ft.

Approximately one-half mile below the above locality there is a hill rising about 50 feet above the creek, on the eastern bank. It is capped by a white sandstone containing a few casts of fossils. Locally, the sandstone is indurated to a quartzite, but for the most part it is of medium hardness. Some few leaf impressions were noted. The material underlying this sandstone, found outcropping in the creek bed, is a buff clayey carbonaceous sand underlain by laminated drab to chocolate colored shaly clay with parting of yellowish brown sand.

In the creek bed were picked up teeth and spines of sharks and rays *Synecodus, Odontaspis,* etc., scutes of a marine turtle and fragmentary limb bones of small mammals. From this locality there was also collected a jaw fragment of what was possibly a creodont carnivore. A good collection of marine invertebrates was secured here.

MANNING SECTION

The section in eastern Angelina county is similar. The Caddell clays with fossils are found at Donovan. Between Donovan and Manning chocolate clays with gypsum and sulphur-buff compact, unctuous clays and dark clays with limonite are found.

Shawnee prairie is three miles north of Manning. The prairie is covered with a good growth of grass and is said to be good farming land. The clay underlying the prarie is very gypsiferous. The following is the section of the clays underlying Shawnee prairie:

1. Light chocolate brown, plastic clays containing sulphur and fibrous gypsum, stained with reddish and brownish limonite on joint planes. Contains numerous casts of Eocene fossils, among them a large *Pinna*, also *Volutilithes*, *Venericardia*, *Corbula texana*, and several other lamellibranchs and gasteropods. These casts are found in the clays and in thin sandy layers, in some places well laminated and medium well indurated ....10 ft.
2. Light buff, compact unctuous clay often breaking with a conchoidal fracture. Stained yellowish brown on joint planes with limonite. Weathers cream colored.......... 6 ft.

The upper member is the base of the Manning beds.

The rocks exposed in the gullies in the lower portion of Manning are gypsiferous sands and chocolate clays with plant fragments. These two rocks frequently alternate in thin beds. In some of the sands are small fragments of fibrous pumice and a light greenish clay directly overlying this tuffaceous sandstone under the bridge west of the church contains some fine ash.

In cutting about 100 yards southeast of the depot at Manning there is exposed about 3 feet of a dark gray to brown, irregularly thin-bedded sandstone containing casts of fossils. The casts occur in a layer near the bottom of the section and quite a few of the same forms found in the cutting at Mile Post 101-G on the Houston, East & West Texas Railway were recognized. In these "shelly" bedded sands are often found clay inclusions in the

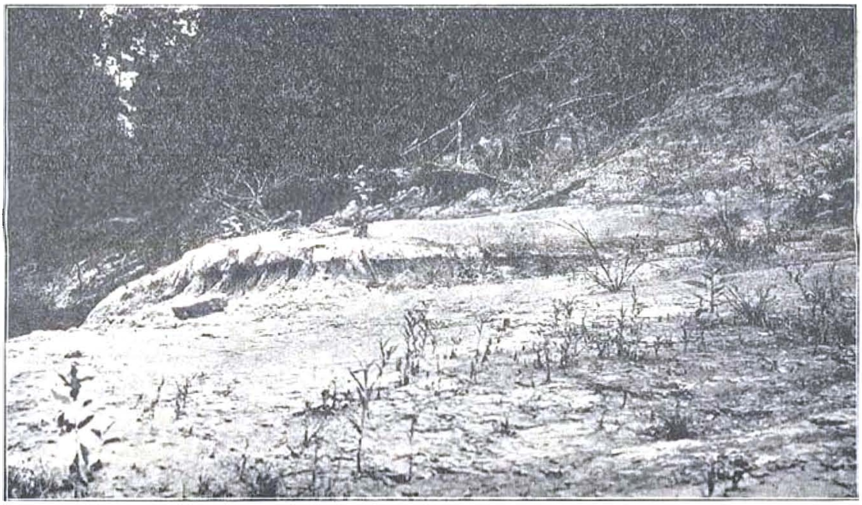


Fig. 1. JACKSON FORMATION.
Volcanic ash on White Rock Creek, Trinity County.

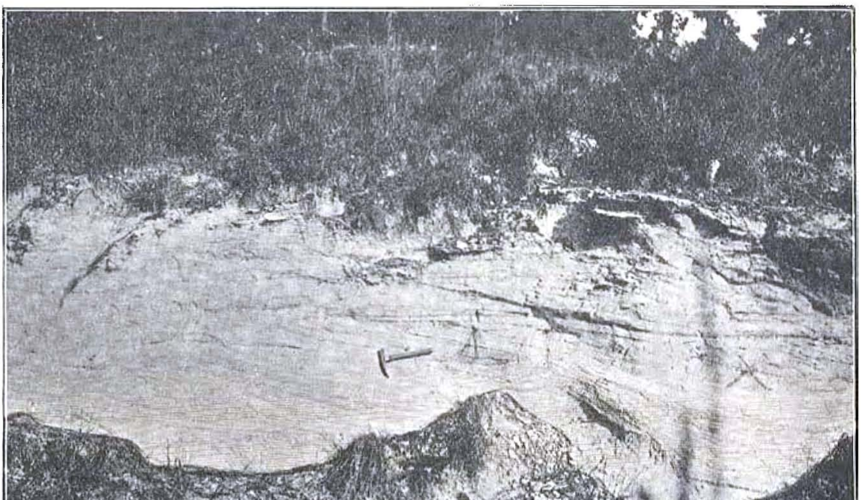


Fig. 2. JACKSON FORMATION.
Volcanic Ash 2 miles east of Corrigan.

form of thin small lenses or lumps, in color generally dark gray or brown.

The country north of Manning is one of very low relief, but to the south and east the topography becomes gently rolling and a series of low hills is to be seen.

On the sides and top of the low hill east of Manning a coarse-grained, medium hard, light gray sandstone is found in massive beds. This stone has a whitish granular cement which resembles some phases of the Catahoula.

Some three miles south of Manning, along the tram and to east and west of it, there outcrops a sandstone of various degrees of induration, gray to brown in color, fine-grained, and for the most part massive, but in places thin-bedded. This sandstone contains numerous casts of fossils, for the most part lamellibranchs, but some gasteropods were found. This sandstone resembles in every way that found in the vicinity of Potomac on the Houston, East & West Texas Railway.

The creek beds here expose soft sandstones and arenaceous clays of a prevailing light brown color and massive to thin-bedded.

A section down a creek flowing south and emptying into the Neches some 3 miles above the place where the Manning tram crosses the river exposes, along the banks, brown carbonaceous sands and clays, massive to thin and irregularly bedded, which continue to within 2 miles of the river. These materials undoubtedly belong to the Jackson as exposed near Potomac. On the tops and edges of hills are sandstones of various degrees of induration, from soft to hard and quartzitic and usually containing casts of fossils. This sandstone varies from thin-bedded to massive, but it is for the most part fine-grained with a cementing material of a more or less porcelaneous nature. These sandstones are for the most part of white to grayish-brown color, the brown shales being irregular and caused by iron stain. Locally, there is a prevalence of "pipe concretions" in this material. Lignitiferous sandy clays were to be found along the creek in some places.

CADDELL SECTION

The type locality of the Caddell clays is in the vicinity of the town of that name in western San Augustine county near the Angelina river. It was at this place that Veatch found some of his Jackson fossils, including the specimen of Zeugledon. In the immediate vicinity the ordinary Jackson non-fossiliferous clays, weathering brownish and containing calcareous fossiliferous nodules, outcrop for an estimated thickness of 30 feet. The larger nodules are dark brown in color and are calcareous sandstones in composition. These calcareous rocks in places form a thin continuous bed, and near the top of the bluff rising above the Angelina bottom a solid thickness of at least five feet was noted.

Near the foot of the hill on which James Mott's house is built are dark chocolate clays, succeeded above by greenish, coarse sands and greenish clays weathering purplish. Ten feet higher in the section are clays with calcareous nodules.

Bridge creek, which flows southward from White City, six miles east of Caddell, shows the following:

In the first exposure on this creek is about 4 feet of Yegua, interbedded light greenish-gray, loose, medium grained sands and light chocolate, sandy clays containing sulphur. The clay is also in balls and small lenses in the sand.

These beds continue until opposite White City station, where basal Jackson clay with large calcareous nodules is found. Farther down the Jackson brown friable sand and sandstone come in with local hardenings, probably with calcareous cement. The hardest sandstone seen was almost quartzitic and light green in color. Farther down still are fossiliferous green clays, weathering brown, and resembling greensand. In these are fossils and a great amount of selenite. In places the Jackson contains limonitic concentric concretions 1 foot in diameter.

Lower down on the creek the clay becomes unctuous, in color gray-drab, and breaks with a semi-concentric fracture. Separating the clay layers are thin films of fine, light brownish gray sand, while towards the top of one 12 foot section is a light buff, finely-laminated, fine, clayey, brittle, but not well consolidated sandstone. In the continuation of this same section a hundred yards downstream the clay is chocolate-brown and sulphurous, with apparently a slight northward dip.

The Jackson basal clays are found along Clear Creek for at least two miles. Very dark green grains, probably greensand, are irregularly distributed through the clays, some portions of which are entirely free from them, while others in immediate juxtaposition will have many. There is a great deal of sand in much of this clay, but still a large percentage of it is quite free from sand. In the creek just below the last section described are some fragments of a 3-inch light gray sandstone layer containing casts like those noted on the old tram southeast of White City and on Shawnee Prairie. The thin sandstone comes from above the clay. Above the thin sandstone layer in the same section comes in a very light buff, compact clay. In less than one-fourth mile downstream we run into the Jackson sandy clay with greensand, outcropping in the bed of the creek.

Two thin sandstone dikes, of 1-inch and 2½ inches in width, were noted in the first deep cut in the brown clays. These cut the clays in a nearly perpendicular position almost at right angles to the bedding planes. Two other dikes were noted.

Just east of the east line of the Lucas headright is a hard sandstone, fine-grained, light gray, and well cemented, which is probably a local lens, similar to exposure near Huntington and Burke and on Stovall creek.

The exposure at McGilbery Bluff on Bug creek near the east line of the John Lucas headright and 1 mile from the Angelina river at the edge of the Angelina bluff, carries a rich fauna of the Caddell, mainly of large *Pinna* and small gasteropods. A lens of grahamite measuring about 2 inches across was found in the dark purplish, ferruginous, fossiliferous sandstone. The section follows:

1. Chocolate clay ....35 ft.
2. Greenish-brown, sticky clay with thin films of sand of green color, greensand, and ferruginous concretions, blackish or brownish on surface and dark purplish red inside, containing an abundant fauna. Much of the clay resembles that of the basal Jackson near the head of Clear creek...... 7 ft.
3. Dark green sandy clay, very sulphurous. Sand layers often brownish-yellow. Contains much gypsum. Fossils found in the clay. Characterized by large rounded ellipsoidal clay ironstone concretions of a length of 3 feet and over.. 3 ft.

All members contain abundant selenite. The concretions of number 2 are in thin layers 3 to 6 inches thick and run in definite planes, but are not continuous. The chocolate clay (1) is of the same bed as is seen higher up on this creek. As usual, it is sulphurous. It also contains ferruginous concretions, both of the concentric and flat-layered types.

SANTA FE RAILROAD SECTION

On the line of the Santa Fe railroad the Yegua-Jackson contact was not determined closely, but is probably between Mile Posts 100 and 101.

There is 8 feet of thinly laminated clay, mainly dark chocolate-brown in color, but the more sandy layers grayish, with some thin limonite-stained layers. There is about 8 feet of light brown sand in cut just north of Mile Post 100.

Between Mile Posts 99 and 100 the friable thin, shelly-bedded light brown sandstones resemble those on the Houston, East & West Texas Railway between Potomac and Hammock, in northern Polk county, and in the vicinity of Manning, southern Angelina county.

Light, yellowish-green, sticky clay 2 feet thick and containing small masses of limonite is exposed one-fourth mile south of Mile Post 99. The top of the section at Mile Post 99 consists of 5 feet of thin-bedded, light brown, very friable sandstone stained with sulphur, underlain by about 15 feet of light brown, carbonaceous, laminated clay, weathering reddish-brown and interbedded with thin friable sandstones, some of which are cross-bedded.

At the south end of the cut at Mile Post 97 a layer one foot thick of soft sandstone outcrops, made up of medium sized sub-angular quartz grains and carrying clastic flakes of selenite. The sandstone shows a very imperfect lamination, mainly brought out by thin films of iron oxide. It contains also small fragments of a black mineral, which is perhaps magnetite. This sandstone is lenticular, passing along its bedding into unconsolidated clayey sand. It is underlain by sandy, light bluish-gray clay, weathering on the surface to cream-color, forming semi-badlands, and about 6 feet thick. There is considerable cross-bedding, especially in the more sandy portions. The sandy clays and clayey sands are thinly laminated. The section here much resembles that at Mile Post 100 on the Houston, East & West Texas Railway in northern Polk county, in structure, composition and materials. The two exposures belong to the Jackson and lie at nearly the same horizon. Close to the north end of the cut there is a marked concentric structure in the clayey sands. The core is a massive sand, 3-5 feet in diameter, and is surrounded by a concentric shell 1-2 feet thick, made up of alternate, irregular and wavy rings of sand layers stained with limonite separated by layers not so stained. Three such core structures are seen. They may very likely have been formed since the deposition of the beds and may be of the nature of concretions.

Th same general characteristics are seen in the several Jackson exposures south to half way between Mile Posts 96 and 97.

One-half mile north of Mile Post 94 there is 5 feet of Jackson sulphurous, light chocolate-brown clay, underlain by 1½ feet of light gray laminated sands. The clay is rather coarsely laminated and when unmixed with sand is plastic. Often, however, they are intermixed with sand and are stained with limonite along the platy layers. The base of the section is about 10 feet below track level.

The soil of the Jackson is dark brown, tinged with red, the color being characteristic of the foundation. This color is only a thin surface veneer seen in recent cuts. The Jackson topography is very gently rolling.

The last Jackson clay is seen at Mile Post 94. It is thinly laminated and a light yellowish-green to greenish-gray in color with thin irregular and small plates of harder limonite-cemented clays. The maximum thickness of the exposure is 4 feet. It is overlain by the same thickness of Lafayette. The Jackson clay here is plastic and when damp has a bluish-drab color.

SABINE RIVER SECTION

Our knowledge of the Sabine river section of the Jackson is limited to Veatch's sections, which are as follows[1]:

About three-fourths of a mile below Robin's Ferry, at 30, there is an outcrop of 5 feet of blue fossiliferous clay on the Texas side of the river. It shows at this stage of the river two

[1] Geol. Sur. La., 1902, pp. 131-2.

large concretions of hard white fossiliferous limestone. The outcrop yielded a rather extensive Jackson fauna, including *Umbrella planulata* and many large *Capulus americanus.*

At 31, a shelf of the same fossiliferous clay shows on the Louisiana side. The fossils here are not so well preserved. Dip S. 20 degrees E.

Between this outcrop and the outcrop of the Grand Gulf near Anthony's Ferry, ledges of Tertiary clays show at 32, 33, 34, and 35. At 34 a few fossils are exposed.

Section at 33

1.	Dark gray and brown mottled sandy clay ("buckshot clay")	18 ft.
2.	White and yellow pebbly sand	5 ft.
3.	Blue-clay, weathering brown	10 ft.
4.	Irregularly bedded, laminated, slate colored clay and yellow sand	3 ft.
5.	Laminated chocolate-colored clay with occasional thin seams of yellow sand and small calcareous concretions	8 ft.

The layers 3, 4, and 5, show a southward dip of 1:25. Near the northern end of the exposure is a small fault with a throw of about 6 feet.

North of Anthony's Ferry, according to Veatch, these clays are succeeded by the Catahoula sandstone, giving the Jackson outcrop on the Sabine a width of between three and four miles.

VOLCANICS

Beds of volcanic ash in this area have been known and utilized commercially for many years. More recently the fuller's earth derived from the alteration of the ash has also come into use.

The ash occurs in several ways. Principally it forms beds two feet or more in thickness, some of which are traceable for many miles and form excellent working horizons in the formation. These beds are usually pure ash without admixture of other sediments and must, therefore, have been laid down very quickly or in very quiet waters. In some localities, as near Corrigan, the ash is mixed with diatomaceous material as though laid down in ponds or lakes, and at others it shows the dune like structure of deposits by aeolian agencies on land surfaces.

The fuller's earth is met with also under various conditions. Sometimes it occurs as a part of the same stratum as the ash, in which case the ash is usually found at the base and the fuller's earth at the top, but this is occasionally reversed. Most frequently, however, the fuller's earth occurs in separate beds and in lenses and balls in the sands. Owing to the clayey nature of the fuller's earth its true character has not been recognized as fully as it should have been, and many occurrences have been regarded as clay. Our more recent investigations indicate that these showers or floods of volcanic ash and tuff have furnished a much greater proportion of the materials constituting the beds of our Coastal area than has ever been suspected. This is true not only of the Jackson, but of the succeeding formations as well.

CLOSE OF THE EOCENE

In the uppermost beds of the Jackson we see the last formation of strictly marine deposition which is now found exposed within the Texas Coastal Plain. The close of the Eocene, therefore, marks the final withdrawal of the sea from this area as the major medium of sedimentation and the substitution of fluvial and aeolian agencies and deposits upon low coastal lands and their continuations in deltas and lagoons.

In this particular region the story of the emergence is not so well told as it is further south. Our investigations below the Rio Grande prove that the Gulf Coast Eocene extends southward in Mexico to the Conchos river, which flows along the northeastern face of the Tamaulipas range, reaching the Gulf east of San Fernando in Tamaulipas.

The beds of the Yegua are characteristically exposed on the Conchos near Angeles as lignitic shales capped by yellow clays with shaly sandstones and clays with cannon-ball concretions. Down the river at Sonada there are blue and yellow gypsiferous clays interbedded with sandstones. The top of the Yegua is found in a hill one mile west of Mendez, where it is capped by the Fayette. Directly east of San Lorenzo creek, which flows into the Conchos near Mendez, rises the Sierra de Pomeranes, a range of high hills trending northwest and southeast. The western slope of these hills is composed of sandstone of Fayette and possibly of Jackson age and the top and eastern face is formed of the Frio clays overlain on the coastal margin by beds of marine Oligocene. The upper portion of the Frio in the Pomeranes hills, as well as in exposures on the river west of Tepetate, is made up of greenish clays and soft sands interstratified with heavy beds of gypsum. In the hills the deposits of gypsum include beds of alabaster and selenite, as well as massive gypsum. These extensive deposits of gypsum interbedded with the greenish clays and soft sands prove that the end of the Eocene was marked in this region by slow emergence and by dessication. That this emergence was pre-Oligocene is clearly shown by the relations of the beds of the two formations.

Similar conditions are believed to have existed in eastern Texas and to have resulted in the deposition of a large part of the beds of salt and gypsum which are now found in such abundance in connection with the Coastal Domes of the region.

CHAPTER VIII.

INTRODUCTION

Practically all of the deposits of post-Eocene age of the Coastal Plain of Texas, so far as their outcrops show, are non-marine. They consist of fluviatile and aeolian deposits and of sediments laid down in lagoons, estuaries or deltas, marked only by very scant remains of plants, land animals, fishes and brackish water invertebrates. The only vestiges of possible sea-shore conditions found are a few occurrences of a coquina in which the fragmentary shells are too comminuted to permit identification. In certain localities the conditions of sedimentation apparently remained the same through successive epochs, so that there is no lithologic break to mark the parting, and in others the formations are connected by transitional beds.

Such fossils as have been gathered from various localities in these beds show that they include deposits of Oligocene, Miocene, Pliocene and Pleistocene age, but in many places it is difficult, if not impossible, to fix a line between the beds of one of these series and those of the others, or to separate the deposits into satisfactory groups, such as will serve as distinctive in different areas. Until some basis can be found on which to make such division, it will be necessary to use group names, each of which will, where possible, include a mappable unit, and refer it to its nearest series.

OLIGOCENE

In Mississippi, the Jackson is followed by a series of limestones alternating with beds of sandy fossiliferous marl, which is called the Vicksburg. In the fossils of these beds, which are abundant and well preserved, we find very few of the forms occuring in the Claiborne or Jackson Eocene, and encounter many that are new. This formation is considered to be of Lower Oligocene age.

Overlying the fossiliferous clays and limestones of the Vicksburg there is a series of sandstones and greenish clays of different lithological aspect from any of the beds of the Mississippi Eocene. The only fossils found in them are remains of land plants and fresh water shells. These were first observed by Wailes at Grand Gulf, Mississippi, and were given that name. Owing to the confusion that has arisen in the use of this name through its application to beds of somewhat similar lithological character, which occur at other localities and have been found to be of different ages, and, in order to furnish a name not likely to be misunderstood, Veatch proposed the name "Catahoula" as a synonym for the "typical Grand Gulf" from Catahoula Parish in Louisiana where the beds are counterparts of those at the original locality. These are also considered to belong to the Oligocene.

Further eastward the Catahoula, or Upper Oligocene, is replaced by marine deposits and is represented by several subdivisions which are based on fossil contents.

Southward in Mexico the Lower Oligocene is present as beds of yellow sandy clays with quantities of the large foraminifer *Orbitoides papyracea* Bou. which is characteristic of the Vicksburg. The upper Oligocene with similar yellow sandy clays includes heavy beds of nummulitic limestone and a considerable fauna of echinoderms, corals and other marine invertebrates, proving its position in the Oligocene column.

Deposition and Character

At the beginning of the Oligocene, that part of East Texas which was later covered by its deposits was a land surface, on the higher portions of which were exposed not only sands and clays, but probably very considerable bodies of volcanic agglomerates, tuffs and ash which had accumulated during Jackson time. Along the coastal belt, occupying large basins or depressions, there were probably great deposits of salt and gypsum. So far as present surface conditions indicate this land condition continued through the entire period of Lower Oligocene, and not until its close did the lagunal and estuarine waters take possession of this territory.

Therefore, no trace of any marine deposits referable to the Vicksburg have been found in East Texas, nor is there any indication that the sandstones overlying the Jackson and referred to the Oligocene are, in any part, representative of Vicksburg time. Such deposits, however, may exist to the seaward and be overlapped by the later beds.

With the beginning of the Upper Oligocene, erosion seemingly became more active, especially in the area occupied by the tuff and ash, and these furnished the principal part of the large quartz grains which make up the present rice sands and of the clays and fuller's earth which are interbedded with them. Apparently volcanic action had not entirely ceased, for there are beds of ash interbedded in the Corrigan which are original deposits and not derived from earlier ones.

CORRIGAN

In the Texas region Veatch applied the name Catahoula to the sands and clays which overlie his Jackson and underlie his Fleming. According to his map, the base of his Catahoula on the Houston, East & West Texas Railway is over four miles north of Corrigan. This would include the beds which furnished the Jackson fossils mentioned by Harris[1] as coming from Kennedy's original locality, "a cutting on the Houston, East & West Texas Railroad 4 miles north of Corrigan, Polk County," earlier referred to the Claiborne, and which now forms the base of our Manning beds. Veatch's Catahoula, therefore, as mapped included the sandy formations lying between the Caddell clays and the Fleming clays, a part of which are Jackson and a part later.

Matson[2] calls attention to this and correlates the Jackson member (Manning sands) with the Fayette, with which it has really nothing in common, being a marine formation while the Fayette of East Texas is a fresh or brackish water deposit, underlying instead of overlying the Caddell clays.

Veatch expressly limited the use of the term Catahoula to such beds as were of true Grand Gulf age and his name is therefore retained for such beds as can be clearly referred to the Grand Gulf. Overlying the beds to which the name Cata-

[1] Geol. Sur. La. 1902, p. 25.
[2] U. S. G. S. Prof. Paper 98, p. 224.

houla can thus apply, we find a series of transitional beds connecting the Catahoula and the Fleming, which cannot well be separated from it, and we will use Kennedy's older name of Corrigan for the entire group of non-marine deposits which lie between the Jackson and the Fleming and together constitute our only mappable unit. They are supposedly, for the most part, of Upper Oligocene age.

General Character and Relations

The Corrigan comprises coarse "rice"[1] sands and sandstones with some clays at the base, overlain by finer sands and by yellowish green clay and claystones. The clays and claystones carry pyritic nodules and streaks of lignite and weather yellow to cream color. The sands are coarse to fine-grained and may be friable, cemented with opaline or porcellaneous matter, or hardened to a dense gray-blue quartzite. There are local unconformities between the sands and clays and the sands often carry clay balls and are occasionally cross-bedded. Volcanic ash occurs abundantly, both unaltered and in altered forms as fuller's earth and clays. The Corrigan is noted for the abundance of fossil palms, and the fossil wood which occurs in it is often opalized. Remains of animal life are almost unknown.

These are the beds to which Vaughan's name of Catahoula properly applies.

In the exposures of the Trinity river region, while the basal beds or Catahoula are the same as those to the eastward, there appears to be at the top a transitional zone, in which sands of the Corrigan type are interbedded with calcareous clays similar to those of the overlying Fleming. On this account the limit is not as well defined as further east, and the upper line is drawn where the sands with porcelaneous cement cease and the clays weather entirely dark brown or black, instead of showing the characteristic yellow weathering of the Corrigan clays. These also carry plant remains and an occasional fragment of bone.

[1] So called because of the resemblance of the grains to those of rice.

These upper beds maintain their character and thickness some distance west of the Trinity river. While they appear to be later than the Catahoula proper, they are definitely connected with it by the character of the sands and clays of which they are composed.

For this portion of the Corrigan the name Onalaska has been proposed, from the name of a town in Polk county which is located on them. Excellent exposures may be found on Rocky and Kickapoo creeks east of Onalaska and on Harmon creek northeast of Huntsville.

Stratigraphically, this group lies unconformably upon the Jackson. Lithologically, the base corresponds closely with the typical Grand Gulf, while the top is very similar to some of the Oakville beds of the Nueces section, but is older.

It seems probable that the Corrigan represents some portion or all of the Oligocene above the Vicksburg, and that while the base may be Grand Gulf, the upper portion is possibly Miocene.

Area and Thickness

As mapped, the Corrigan is broadest on the Sabine river, where its outcrop has a width of over twelve miles. It extends westward as a belt of irregular width, narrowing to three miles in the northeast corner of Polk county. It widens again on the Trinity where the outcrop swings to the southwest. At the crossing of the Navasota river north of Nelleva Junction it is less than three miles in width and is but little more on the Brazos.

Tht thickness of these beds is estimated at 450 feet.

SABINE RIVER SECTION

The only details we have of the Corrigan on the Sabine are those given by Veatch[1]:

The Grand Gulf sandstones extend along the Sabine from Anthony's ferry to near Burr's ferry. The southeastward dip observed in the Cocksfield ferry beds and the Jackson continues to a point below Hattan's ferry with a tendency to show an

[1] Geol. Sur. of La. 1902, p. 133.

increased dip. Near Burr's ferry the dip becomes much less, being 1:300.

A shelf of soft, fine, gray sandstone with a slight amount of calcareous matter is exposed on the Louisiana side a little more than one mile above Anthony's ferry.

Half a mile below, a much larger shelf occurs near low water level. It extends well across the river, producing a decided acceleration of the current. The section is:

1. Yellow and brown silty sand to top of bank .... 8 ft.
2. White to grey sand with faint traces of stratification. Contains pebbles at base ....10 ft.
3. Hard, fine-grained quartzitic sandstone .... 2 ft.
4. Greyish-blue, jointed sandy clay becoming lighter and more sandy above ....15 ft.
5. Soft, white, fine-grained sandstone .... 8 ft.
6. Coarse-grained quartzitic sandstone .... 3 ft.
7. Grey to drab, jointed sandy clay .... 3 ft.

Dip S. E. 1:50.

At Anthony's ferry a small flat-topped bluff on the Texas side shows no rock. On the Louisiana side, a little below, 4 feet of fine-grained Grand Gulf sandstone shows near water-level.

Just above Snell's landing, a flat-topped bluff 35 feet high shows at its base 8 feet of blue sandy clay.

At Snell's landing high bluffs appear on the Texas side and extend for two miles down the river

Section at Snell's Landing:

1. Fine white sand with pebbles at base......................25 ft.
2. Covered ....12 ft.
3. Coarse, indurated white sand, capped with a layer of sandstone about a foot thick .... 8 ft.

Water level.

Dip S. E. 1:25.

A mile below this exposure there is a good exposure:

1. Unexposed to top of bluff ....40 ft.
2. Yellow sand, containing boulders of buff colored, laminated, leaf-bearing clay ....35 ft.
3. Coarse, white, cross-bedded, rather quartzitic sandstone,

mottled with yellow .... 6 ft.
4. Greenish-yellow sandy clay ....20 ft.
5. Unexposed ....10 ft.

Water level.

Bed 2 shows a phenomena almost identical with that shown in the K. C. P. & G. R. R. cut near Shreveport, where the beds are presumably of lower Eocene age. Five hundred yards below this section, this bed is much more fully developed. Here the bed is covered with a regularly bedded, laminated, brown to slate-colored clay, three feet thick, with abundant plant impressions.

This line of bluffs extends along the river half way to the mouth of Bayou Toro. The quartzitic sandstone increases in thickness, reaching a maximum of 10 feet near the lower end. This sandstone layer indicates that the line of bluffs are about on the line of strike and hence the dip is S. E.

Near Hattan's ferry on the Louisiana side the following section is shown:

1. Drab, iron-stained clay, crumbling into small irregular pieces ("Buckshot clay") ....17 ft.
2. Fine white sand with many small pebbles .... 3 ft.
3. Blue clay weathering yellow (Grand Gulf) .... 5 ft.

A flat topped bluff on the west side of the river 2 miles below Hattan's ferry, shows a ledge of green jointed clay about five feet thick. The great southward dip, 1:25, exposes about 20 feet of this bed.

Sandstone ledges cause several shoals in the river below this outcrop but afford no good exposures. Four miles below, a ledge of fine-grained, porous sandstone shows a slight southward dip 1:300.

About half way between this and Burr's ferry, a range of high hills, rising over a hundred feet above the river, approach the river on the Texas side. One hill-point just reaches the river and exposes a ledge of sandstone near the water line. Forty feet above water level a ledge of sandstone 25 feet thick outcrops in the hillside, in many places forming a protruding ledge and giving rise to a number of small waterfalls where little streams from the hills flow over it.

About a mile above Burr's ferry, there is a small outcrop of soft white sandstone. This is covered with the usual pebble-bearing sands and pinnacled clays.

SANTA FE RAILWAY SECTION

On the line of the Santa Fe Railway in Jasper county, the base of the Corrigan is found just south of Brookland and it passes under the Fleming about 5 miles north of Jasper.

Between Mile Post 94, where the last exposure of Jackson was noted, and Brookland the railroad runs in a flat swampy country showing only Lafayette sediments in one small cut.

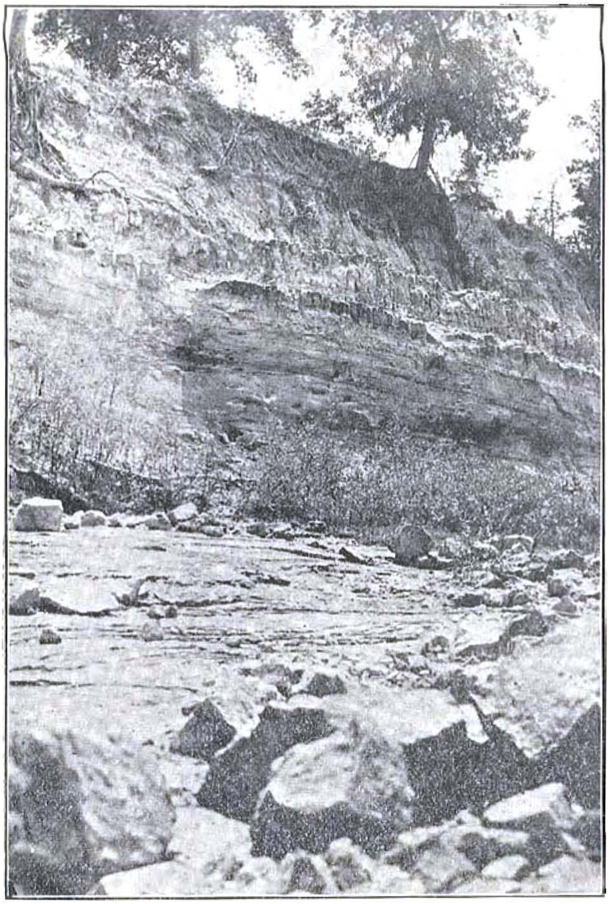
The Catahoula light green sandy clays outcrop in the long shallow cut which begins one fourth mile north of the 89th mile post, where there is a thin layer of porcellaneous sandstone overlying them. There are thin lenticular layers of hardened clay within the looser clay and an irregular lens of sand overlies it. The sand is cross-bedded and carries thin streaks of sulphur-yellow clay.

Southward, porcellaneous-cemented sandstone is encountered, but only as relatively thin layers interbedded with clay, and the first exposure north of the 86th mile post is of light drab, consolidated clay.

In the next cut to the south and beyond it the Catahoula greenish-drab clay contains calcareous nodules similar to those of the Fleming. Similar clay with similar concretions is found within the Catahoula outcrop on the road between Bevilport and Aldridge in western Jasper county.

The north end of a cut south of Mile Post 86 is in Catahoula drab, or grayish-green, clay, and in the next cut just north of Mile Post 85 the unconformity between the Catahoula and Lafayette is well shown. At the base 7 feet of light gray, sandy Catahoula clay. Above lies 10 feet of cross-bedded Lafayette. The contact between the two is irregular, and small lenses and ridges of the Catahoula project up into the Lafayette, which is light brick-red in color.

The last Catahoula outcrop is three-fourths of a mile north of the 79th mile post, where thin, irregularly-bedded, coarse, porcellaneous sandstone at the base is overlain by 5 feet of yellow-



CONTACT OF JACKSON AND CORRIGAN FORMATIONS.

View on Trinity River near Trinity.

ish-green clays with sulphur. On surface exposures these clays are bluish or grayish-green.

The fossil plant *Palmoxylon texense,* which was described by Berry, was collected from the Corrigan at this locality.

In northern Jasper county, between the Angelina river and the line of the Gulf, Colorado & Santa Fe Railway, the area of the outcrop of the Catahoula forms the usual high sandy ridge of much dissected, mature topography, overlooking the lowlands of the Yegua and Jackson to the north and of the Fleming to the south. In this region the differential relief is 200 feet at a maximum and the surface is practically all reduced to slopes, forming hills and ridges dissected by deep valleys, which are narrow and steep in their upper courses. Recent rejuvenation, also noted farther westward on the Catahoula ridge, is very apparent at the headwaters of Beef creek, which lie in Sections 146 and 151 of the land of the Houston Oil Company. The heads of the valleys have the broad, shallow and gently convex profiles characteristic of early to middle old-age erosion stages. Lower down the stream courses, the valleys abruptly break away into narrow, deep, box gorges, characterized by recent and still effective gully erosion. Some of the inner gorges are 50 feet, or more, deep. Above the recent trenches the gently sloping profiles of the old valleys are easily distinguished. The amount and thickness of Lafayette on the summits of some of the hills and ridges is surprisingly large. Locally, it is not less than 100 feet thick. It contains a large amount of ferruginous-cemented, coarse grit and conglomerate, more of which was noted here than anywhere else where the Lafayette has been examined. Mossy Hill, northeast of the old Truitt Place, near the head of Beef creek, is a ridge several hundred yards long, made up of ferruginous conglomerate at least 20 feet in thickness, and probably thicker. The hill-sides throughout the region of Catahoula outcrop are covered with fine gravel, which averages about one inch in diameter. The hydrated iron oxide locally cementing the pebbles into conglomerate was most likely deposited as bog-ore in springs and ponds.

In many localities the upper slopes of the hillsides are thickly strewn with large fragments of silicified tree trunks. Nowhere else has the writer[1] noted silicified wood in as great abundance and in as large pieces as on the hillsides at the head of Beef creek. It is found in the Lafayette deposits and may have been indigenous to that formation, although that is by no means certain. Fragments two feet or more in diameter and ten or twelve feet long exhibit no signs of rounding by rolling or water wear, but it must be remembered that all this silicified wood is very brittle and is easily broken with a sharp fracture along annual growth rings, and at right angles to these rings. Large fragments in the beds of the present creeks, where they are subjected to attrition are nearly as angular and sharp on fractured edges as the silicified wood of the upper hillsides.

The more resistant beds of sandstone or hardened clay in the Catahoula, when underlain and overlain by loose clays, often form terrace-like benches on the sides of hills.

Numbers of small mounds were seen on the Barney Land and Robert Stone grants south and southeast of the wagon bridge over Beef creek and between Beef and Alligator creeks.

Soft, greenish clays, partially indurated clays, mixed sands and clays are present in large amounts; sandstones, in all degrees of consolidation from those easily broken with the fingers to hard quartzites; of all textures, from very fine to coarse grits; in structure, massive, thin-bedded or cross-bedded; and in color, from brownish or yellowish limonite-stained to white porcellaneous and silicified, are all found in the Catahoula of this vicinity.

ANGELINA RIVER SECTION

Immediately below Bell's ferry on the Angelina river near its intersection with the Ayish bayou, the distinct shoals and rapids commence. The first outcropping noted was of a clay, bluish-green in color and usually somewhat arenaceous. This clay is always yellow to yellowish-green on the outcrop. It forms shoals and also outcrops in the banks of the river to 15 feet above the water level. At the top of the clay a series of springs issue forth.

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[1] Baker.

Between the B. C. Lowe and the J. Conn surveys a series of bluffs begin which determine the course of the river and cause the deflection noted on the map. The first bluff rises some 50 feet above the water and the strata dip some 3-4 degrees S. 50 W. The section here is as follows:

1. Lafayette, clayey sand, lightly mottled for the most part. A film immediately overlying the clay 1-3 inch in thickness is a contorted limonitic iron ore cementing the sand grains and gravel. This layer is probably caused by springs. Overlain by gravel which passes upward into mottled clayey sand ....15 to 20 ft.

Unconformity:

2. Dark dirty green, gypsiferous clay, fractured with limonite stains on fracture planes, which vary from yellowish brown to brick red in color. Selenite is in small fibres and is common. Member becomes more indurated toward the top and here it passes into a sandstone much like No. 4 ....12 ft.
3. Ferruginous layer, botryoidal, mammillary .... 4 ft.
4. Sandstones, well indurated, light buff to yellowish brown in color, depending on the percentage of iron. Occasionally shows psuedolamination caused by seams of limonite. Medium-grained in texture. Matrix fine granular to porcellaneous. Mainly massive, locally cross-bedded. Is indurated sufficiently to form a perpendicular cliff and the top is a bench .... 6 ft.
5. Sandstone, cross-bedded, varying in induration from medium-hard to loose sand, containing ferruginous concretions, local layers having porcellaneous cement. Harder layers form benches between softer. Medium to coarse-grained. Color light brown when wet and light buff when dry. Stained by limonite ....
6. Yellowish green and greenish brown clay, compact and much fractured and where wet often dark copperas blue. Weathers dirty white .... 4 ft.

TEXAS & NEW ORLEANS RAILROAD SECTION

The outcrop of the Corrigan on the Texas & New Orleans Railroad does not exceed six miles in width, with Rockland nearly in its center. It has about the same width here as on the Houston, East & West Texas Railway.

It would appear that the outcrop of this formation is wider both to the east and west of these railway lines, where an upper member composed almost entirely of greenish clay is exposed on Rocky creek and on the Angelina river between Bell's and Bohler's ferries, which does not seem to be represented in the sections along the railroads.

The Jackson-Corrigan contact is south of Mile Post 107.

In the first cut north of Mile Post 106 clays are interbedded with the porcellaneous sandstone. The section is:

1.	Massive, medium indurated, porcellaneous cemented sandstone	2 ft.
2.	Dark sulphur-yellow shaly clay, tasting of sulphur	4 ft.
3.	Very shaly and "shelly" friable porcellaneous cemented sandstone	1 ft.
4.	Dark green sandy clay, irregularly stained dark-brown. Upper 4-inches almost entirely dark-brown	2 ft.
5.	Whitish, poorly indurated, porcellaneous cemented sandstone	6 ft.

Dip 2½° S. 10° E. Strike S. 80° SW.

At the cut just south of Mile Post 106 the porcellaneous sandstone comes down to the track level and overlies the green clay. This sandstone is very shaly and thin-bedded. The top layer of the sandstone is more massive and typical. At the south side of the cut there were noted two small lenses of green clay interbedded with the porcellaneous sandstone. The maximum thickness of the underlying compact, dark yellowish-green clay is 4½ feet. The sandstone contains fragments of the underlying clay.

The last bedrock exposed north of the Neches river is at 106-B, where about 3 feet of green, compact, sticky Catahoula clay is associated with local indurations of light brown, fine-grained sandstone, small blocks of which are found on the surface.

Light green, sticky, Catahoula clay, 7 feet in thickness, locally sandy, and with thin sandy layers, and small limonitic concretions and layers is found in the first cut north of the Angelina-Jasper county line. It is overlain by 18-inches of case-hardened, light gray, alluvial sandstone with pebbles.

The bluffs at Rockland are capped by massive, light gray porcellaneous cemented sandstone breaking into large blocks. Under the Texas & New Orleans Railroad bridge over the Neches is a rapids formed by a layer of light brown, hardened, sandy clay. Between these two rocks is greenish clay with local sandstones which sometimes, but not always, show porcelaneous cement.

At Rockland, the section between the track and the oil loading rack is as follows:

1. Porcellaneous cemented sandstone capping the hill........
2. Light green clay, sticky, compact, fractured into very small blocks. More than ....10 ft.
3. Compact, horizontal massive layer of coarse sandstone with large grains of quartz and metamorphic rocks, rounded to subangular, with a fine whitish granular matrix........ 4 ft.
4. Clayey sand, partially indurated, yellowish green, coarse... 8 ft.

The first cut south of the water tank at Rockland gives:

1. Porcelaneous cemented sandstone.
2. Clay, green, sandy, loose, weathering light gray............10 ft.
3. Compact sandstone layer, otherwise same as No. 4....5-18 in.
4. Thin-bedded clayey sand, friable, light brown, locally limonite stained, with whitish granular matrix. Very poorly and irregularly laminated .... 3 ft.

At the base of the next cut, porcellaneous cemented sandstone lies on greenish Catahoula clays. The lower beds here are light greenish-gray sands and clays, very poorly consolidated, and weathering into semi-badland forms. There is a thickness of about 15 feet of these in the cut 1 1-8 mile south of Rockland. These clays are overlain by porcellaneous sandstone in the first cut within the mile limit south of Rockland.

The Catahoula formation is last seen at Mile Post 101, where the porcellaneous cemented sandstone is found.

NECHES RIVER SECTION

The Neches river flowing southeastwardly through the Corrigan furnished the following sections:

To the west of the point where the Carter-Kelley Lumber Company tram crosses the Neches and along the southern bank, a series of high bluffs rise above the river. They expose at the top and well down the sides a medium to coarse-grained sandstone having a porcellaneous matrix. Underlying this is a white claystone, somewhat arenaceous and of various degrees of induration. The sandstone is in places indurated to a quartzite and would make a good rock for concrete work.

Approximately one-fourth mile down the Neches from the point where the Manning tram crosses there is an outcrop of Corrigan sandstone in the bed of the river. This rock causes a shoaling of the Neches at this point and rapids are produced. There is exposed here 15 feet of a medium to coarse grained, rather soft, sandstone with a distinctly porcellaneous matrix. The sandstone is much cross-bedded.

Near the mouth of Shawnee creek, in southern Angelina county, two isolated hills of porcellaneous cross-bedded sandstone are entirely surrounded by the bottom lands of the creek. The locality is within one-half mile of the confluence of the creek with the Neches. One of the hills is about 50 feet high and covers some 4 or 5 acres, the other being smaller. The sandstone is medium-grained, medium hard, locally quartzitic, and breaks with a splintery fracture.

About one-fourth mile east of this there is a big bend in the Neches, known locally as the Devil's Bend. A bluff rising some 35 feet exposes the following section:

1. Soft sandstone, fine to coarse-grained, and constaining plant fragments and clay balls. Porcellaneous matrix.. 8 ft.
2. Yellowish green to greenish-brown clay, weathering yellow to cream colored, and, when indurated, breaking out in cuboidal blocks. Shows thin bedding on weathering. In an east-west direction these beds lie horizontally........15 ft.
3. Greenish brown to chocolate brown clay, weathering dirty brown, the upper 6-inches indurated to claystone so that it stands out as a ledge. Structureless .... 4 ft.
4. Lignite, ignites with a match .... 8 ft.
5. Thin-bedded, sandy clays and clayey sands, greenish-brown to bluish-green in color when fresh, but all weathering cream colored. Contain an abundance of sulphide of iron nodules, the origin of which is evident from the fact that some of the nodules are still in the form of stems of plants, showing that the iron sulphide was precipitated from solution by organic matter partly derived from the

overlying lignite seam. The occurence of the iron sulphide here explains the origin of the bluish green color that is seen everywhere in these clays at the water-level........ 5 ft.

The dip on No. 5 in E-W direction was 2½ degrees at one place.

The rapids on the Neches 1½ miles west of Aldridge have a fall of about 4 feet. They are caused by resistant porcellaneous cemented layers of sandstone overlying a light brown, compact, fine-grained sandy clay with plant fragments. The porcellaneous sandstone is in places finely conglomeratic with subangular fragments of quartz and chert. Large fragments of clay in this conglomerate, together with cross and irregular bedding, indicate channel conditions of deposition and local unconformity.

At Peces Ferry, some 2-3 miles up the river from Smith's Ferry, there outcrops in the bed of the river a bluish-green clay, somewhat arenaceous, slightly plastic, which weathers cream colored to yellow. This clay forms a shoal which extends out half way across the river at low water. Overlying this clay is a collection of angular boulders up to 1½ feet in diameter consisting of sandstone, fine to coarse grained, and varying in hardness from soft to quartzite. This sandstone has a porcellaneous matrix, and could not have been transported far.

Three hundred yards upstream from Smith's ferry there is another outcrop of Corrigan, which runs half the way across the bed of the river. The banks of the river in both these localities are made up of alluvium, but west of the river clays outcrop which lithologically resemble those of the Corrigan, and are succeeded on the higher land by typical Fleming calcareous clays.

Near the top of hill overlooking Smith's ferry, the following section is exposed along the road:

1. Clay, weathering white and containing calcareous nodules..15 ft.
2. Indurated, non-calcareous, arenaceous claystone .... 1 ft.
3. Green clay, weathering dirty yellowish green and containing calcareous nodules ....10 ft.

The upper part of this section may be Fleming, as may also be the lower member, but such material as the indurated layer has not yet been observed above the Corrigan. A good development of arenaceous claystones that belong to the Corrigan was observed in this vicinity and it may be that this section marks the transition between it and the Fleming, such as is found further west at Onalaska.

Rapids on the Neches river, on the eastern boundary of the Ph. Baldwin grant, northeastern Tyler county, 12 miles east-northeast of Colmesneil, and one-half mile below Smith Ferry, are well exposed at a low-water stage. The rapids are formed of medium-hard Corrigan sandstone, carrying plant remains and a large amount of silicified wood. Structure and bedding is very poorly developed, but cross-bedding is present, striking N. 60 deg. E. and varying in dip from 9 to 27 deg. southeast, in a distance of 25 feet normal to the strike. Below the sandstone is two feet of soft, blue-gray, sandy clay. The sandstone surfaces are perforated with long borings elliptical in cross sections with the peripheries of the ellipses flattened. These are made by a small, light green, fresh water crustacean. The Neches river at its low-water stage, is nowhere over 6-inches in depth over the rapids.

The rapids will probably explain the partially drowned conditions on the Neches flood plain above them quite as well as Veatch's postulate of the Angelina-Caldwell flexure.

HOUSTON, EAST & WEST TEXAS RY. SECTION

On the Houston, East & West Texas Railway the first exposure of the Corrigan sands is found at Bridge 95-G, where yellow and brown sandy shales are overlain by a mottled sandy clay carrying fragments of the shale. The relations of the two formations is better shown at Mile Post 94. Here the mottled red and brown sands, shales and clays of the Jackson are overlain by a light yellowish brown sandstone with white markings. The contact shows that the Jackson was eroded prior to the deposition of the basal Corrigan sands and the sandstone contains large fragments of the underlying shale. There is also apparently a difference in dip. The Jackson seems to have an easterly dip, while sandstones dip south.

Between this point and Corrigan, brown sandstones are found and the country is covered with a coarse gray sand.

The quarzitic character of the sands is shown in the old quarry one-half mile north of Corrigan and one-quarter mile east of the Houston, East & West Texas Railway. At the western end the sandstone is medium to fine-grained, medium hard, white to gray and yellowish brown in color. It is for the most part massive, but exhibits some cross-bedding. Locally the sandstone contains hard rounded clay balls. In the eastern end of the quarry the hard sandstone grades into a thin-bedded, softer, rock.

South of Corrigan a white sandy clay with a yellowish tinge is exposed 100 to 200 feet south of Bridge 93-D. In seams this clay has a drab color and small nodules of pure clay in it are brownish gray. Stains of limonite are common. The sand grains are white and being enclosed in a resinous gray to yellowish clay impart to the rock a spotted appearance with many of the white spots no larger than pinheads. The surficial soil is creamy-white sand.

The same material is exposed in the north end of the next cut south. In the center and south end of this cut is seen 3 feet of light brownish-gray, thinly bedded, nodular clay, which weathers white.

In the third cut south of Corrigan there is exposed a foot of broken, cream-colored sandstone of very fine texture with seams and geodic linings of milky-white opal. In this sandstone are nodules of pale yellow clay and a few small flakes of selenite. The Corrigan in this locality is mainly composed of coarse to medium sized angular transparent quartz grains with a few well rounded fragments of black chert and dark eruptive rock cemented together with a milky-white porcellaneous cement. Just west of the track an old quarry, opened to use the rock as ballast, gives an exposure of beds of this typical Corrigan sandstone one foot in thickness. The hill 20 feet or more high directly west of Mile Post 92 is littered over the surface with large blocks of sandstone.

Underneath Bridge 92-C there is 3 feet of light greenish-yellow, greasy, fine nodular clay fracturing with a smooth, unctuous surface, containing sulphur, and carrying large plates of selenite. Overlying this clay is fine cream colored volcanic ash, 7 feet in thickness, friable, and carrying thin seams and lenses of gypsum. This section has below it an outcrop of Corrigan sandstone, but the contact between the two is not visible.

Rather fine conglomerate, bluish on the surface exposure and cream colored or light gray in the interior is found 300 yards south of Bridge 92-B. This conglomerate has pebbles as large as 1-8 inch in diameter of rounded quartz and angular pebbles of local sandstone ranging up to twice that size. This rock weathers cavernous and honey-combed like the topmost layer at Mile Post 100 and is a fair representative of the case-hardened layers which, locally, are quite common at the surface.

A light bluish gray, very porous, coarse sandstone, 4 feet in thickness, with a calcareous (?) cement outcrops 100 feet east of the tract at Mile Post 91. Just south of Mile Post 91 the Lafayette with quartz, jasper and chert pebbles and sandy clay, exhibiting a faintly pronounced mottling into brownish-red and gray, overlies the Corrigan.

At Mile Post 90 there are yellow and white sandy shales dipping 20° N. 70° W.

Bear creek rises 3½ miles southwest of Corrigan and flows northeastward to the Neches, crossing the Missouri, Kansas & Texas Railway just west of Corrigan. It is nowhere more than a mile and a half from the line of the Houston, East & West Texas Railway and gives some interesting sections which are inserted here for comparison with those along the railway which have just been given.

At the crossing of the Missouri, Kansas & Texas Railway it shows about 12 feet of laminated thin and wavy bedded chocolate colored carbonaceous clays with partings of gray sand. On the outcrop these clays weather a dirty white.

One mile, approximately, up the creek from railroad bridge there is a section of 8 feet exposed along the creek bank as follows:

1. Light brown clay or fuller's earth. Thin bedded........4½ ft.
2. White, fine-grained, volcanic ash .... 3 in.
3. Greenish brown, structureless, gypsiferous clays weathering yellowish ....3½ ft.

No. 3 of above section resembles clay outcropping on Missouri, Kansas & Texas Railway between Corrigan and Benford.

Approximately $1\frac{1}{4}$ miles above the railroad bridge the following section is exposed:

1. Gray, fine-grained volcanic ash. Irregularly bedded and fairly well indurated. Contains yellow and yellowish brown limonitic streaks. Forms the top member of the ledge outcropping in creek and is only resistant member in section .... 1½ ft.
2. Brown fuller's earth (No. 1 of previous section) .... 3½ ft.
3. Chocolate colored, carbonaceous, structureless, plastic clay.. 2 ft.

Immediately beyond, the following exceedingly interesting section is exposed:

1. White claystone, thin-bedded, sandy, shaly and seemingly non-calcareous, breaking very easily into angular and spheroidal blocks. Upstream grades into a massive soft sandstone .... 9 ft.
2. Fine-grained, soft, sandstone, yellow to buff in color and extremely irregularly wavy and cross-bedded. Grades horizontally into a highly gypsiferous clayey sand colored brownish green, structureless, and containing a great abundance of small selenite flakes averaging 1-8 inch in diameter. Soft sandstone stands with vertical walls, but clayey sand takes an angle of repose of about 60 degrees. Locally the sandstone contains limonitic concretions up to 1½ inches in diameter .... 10 ft.
3. Drab to chocolate and dark brown slightly arenaceous shale, thin-bedded to laminated, containing minute cavernous spaces filled with a mineral hardness about 3. This material is brittle and breaks out in angular fragments where thin-bedded; not calcite .... 3½ ft.
4. Yellowish brown, structureless clay, weathering yellow to cream colored .... 6 ft.

Overlying the section on top of the hill there is a sandstone with a distinct porcellaneous cement, medium to coarse-grained thin-bedded to massive. The dip on No. 3 member was 3 deg. S., measured north-south.

A short distance further up the creek, the yellowish brown, highly gypsiferous member grades back into the cross-bedded, soft sandstone and within the distance of 8 feet is seen to be overlain unconformably by No. 1 of above section, which here is 9 feet thick and massive, the material breaking out in spheroidal forms.

Under road bridge 1¾ miles southwest of Corrigan and upstream for a short way, there is exposed 8 feet of a fine-grained, white, soft sandstone with a white powdery cement. In the creek bed it is massive, then comes 3 feet of thin-bedded and laminated, and the upper 4 feet is massive.

Approximately 2¼ miles southwest of Corrigan along the creek there is exposed the following section:

1.	Buff to light drab sands, irregularly bedded	4 ft.
2.	Clayey sand, dark blue and greenish blue	1 ft.
3.	Green to bluish green structureless clay with small patches of pyrite	2 ft.

Upstream from here the greenish blue sand and clayey sand is found in sections up to 6 feet and locally it is much cross-bedded. Weathers cream to buff.

In the last 50 feet of the section up the creek the surrounding country becomes rather flat and the only material exposed is a gray colored sandstone, coarse to fine-grained, soft to quartzitic, thin and cross-bedded to massive, its most characteristic feature being the porcellaneous matrix in which the quartzitic grains rest. The smaller sand grains are usually angular to sub-angular and consist, for the most part, of clear quartz grains, but many angular to sub-angular grains of flints and jasper are to be seen. The sand grains are by no means all small in size for locally angular to sub-angular pebbles of quartzose, chalcedonic, and schistose nature are to be seen which are as much as 1½ inches in diameter. Pebbles of black color, conchoidal fracture, and vitreous lustre, resembling obsidian, are somewhat common. Clay balls are very common in the sandstone, and they are more common in the immediate vicinity of contact with underlying clay.

This section is remarkable as being one of the very few of the east Texas Tertiary below the Lafayette to show conglomerates of this character.

One noticeable thing in the section up this creek was that no quartzitic and chalcedonic well rounded and sub-angular pebbles were to be noticed in the creek bed in its lower reaches.

Continuing the railroad section, we find at Laurelia:

1. Loose, coarse, white quartzitic sand.
2. Bright red sandy clay .... 3 ft.
3. Mottled red and brown clayey sand ....30 ft.
4. Red and yellow sandy shales interbedded with coarse grained sand. Some cross-bedding and mottling in more massive portion .... 7 ft.

Unconformity:

5. Coarse-grained, bright orange and red sand with opaline pebbles and opalized wood ....3 ft.

Unconformity:

6. Gray, yellow and brown clayey sands. The more clayey being laminated, the sandy, massive and mottled. Harder layers at top streaked yellow and white as at Mile Post 90......25 ft.

The cut at 89-D shows at the base a bed of dark gray, massive sands overlain uncomformably by mottled sandy clay. This has a very irregular surface and is overlain by a shaly conglomerate carrying fragments of the mottled sandy clay.

This in turn is overlain by a yellow clay carrying calcareous concretions.

In no other section of the Corrigan with which we are familiar are there so many local unconformities as in the one under consideration.

In the cut just south of 89-D is Corrigan sandstone, higher than the clays described in the preceding paragraph.

There is about 6 feet of light gray, compact, fractured, sandy clays in the first cut north of Moscow, Mile Post 88. They weather cream-colored and are overlain by 2 feet of brown sandy clay with rounded pebbles, belonging to the surficial member.

On the hillside between the town of Moscow and the railway station there is below, brownish-drab compact clay stained irregularly by limonite and weathering light gray on the surface. Locally, this is sand and not clay. Above, is clay weathering brown which swells up into a pimpled and cracked surface. The top of the hill at Moscow, on the dividing ridge between the Trinity and Neches drainages, is capped with the porcellaneous cemented Corrigan sandstone overlain by the unconsolidated surficial mottled sand, clay and gravel member. The thickness of the Corrigan sandstone on top of the Moscow hill is 15 feet. Immediately under this, with probable unconformable relationship, is a light grayish-green clay.

The topography between Corrigan and Moscow is for the East Texas Coastal Plain and for a region near a drainage divide decidedly hilly. South of Laurelia the relief is not so great as to the north. The higher elevations are capped by the relatively resistant Corrigan sandstone overlying non-resistant clays.

On the Trinity road, one-fourth mile west of Moscow railway station, a hillside gives the following section:

1. Very calcareous, light green clay, imperfectly laminated, with nodules of hard, dense, very finely textured whitish limestone, some of which are as large as a foot in diameter. The surficial weathering of this clay makes the "black land." At least .... 6 ft.
2. Fuller's earth, creamy white, laminated, non-plastic, becoming gritty towards the top ....10 ft.
3. Fine textured, laminated, cross-bedded light yellow clayey sand, weathering whitish to light blue, and with thin seams up to 1-4 inch in thickness of cream colored clay......3 ½ ft.
4. Light gray to light green drab clay weathering cream color on surface .... 3 ft.
5. Fuller's earth like (2) ....½ ft.
6. Clay like (4) .... 3 ft.

Probably the most striking characteristic of all these sections of the Corrigan between the Neches and the Trinity is the large proportion of tuffs, ash and fuller's earth which occur in them. A large portion of these were in all probability derived from the deposits of the Jackson volcanoes. These would include the rice sands, the obsidian of the Bear creek section and elsewhere, the many deposits of fuller's earth and similar materials, such as the swelling clays, and probably a portion of the unaltered ash, etc. But it also seems highly probable that a part of these beds of ash, tuff and the spheroidal weathering clays are original deposits coming from volcanoes active during Corrigan time.

KICKAPOO CREEK SECTION

Kickapoo creek rises north of Groveton and flows southward to Canary, where it is joined by Rocky creek and then flows easterly, passing a mile or more south of Onalaska to its junction with the Trinity.

About seven miles south of Groveton, Kickapoo creek emerges from a rather thick and broad bottom land into the open cut-over land of the Trinity County Lumber Company. Here, on the W. H. Raspberry headright, there outcrops on the bluffs overlooking the creek a fine-grained sandstone, fairly hard, cross-bedded to massive, white to gray in color. Its thickness ranges from two to three feet and it caps the bluff and is underlain by thin-bedded and cross-bedded sands. The sandstone in places contains clay balls and in one place an abundance of casts of fossil leaves was found.

This is near the base of the Corrigan, and two miles below this locality Kickapoo unites with its east branch heading near Willard, and here the clays of the Corrigan outcrop.

The first thing noted along this creek below the junction of its East Fork was the immense sand bars of almost pure white sand derived from the erosion of the Catahoula sands upstream. This sand is in all probability the source of the sands of the Trinity river noted at the Houston, East & West Texas Railway crossing over that river and elsewhere.

This creek has many exposures of Catahoula sandstones and claystones along the banks and as shoals in the river bed. The sandy clays usually show up as yellowish on the weathered surface. It contains much iron as shown by the bluish green color in many places.

Near the middle of the section the quartzose sandstone appeared containing rather large and angular grains of quartz, flint and jasper, all set in a porcellaneous matrix.

Rocky creek, near its confluence with Kickapoo creek, flows through but little bottom land, and has high banks cut into the claystones and sandstones of the Catahoula. The members presented in the section examined of up to 15 feet show for the most part a fine-grained, clayey, soft sandstone or arenaceous claystone of yellowish color on the weathered surface. It resembles very much impure volcanic ash. One section just upstream from the road crossing below the store at Canary is as follows:

1. Irregularly thin-bedded to massive, yellowish, soft, fine-grained sandstone containing at the base some fuller's earth up to 6″ thick. More massive towards the top. Resembles very much an impure volcanic ash .... 8 ft
2. Fuller's earth, a fine grained or unctuous yellowish green clay having a semi-conchoidal or spheroidal fracture when dried out ....2 ft. 3 in.
3. Light yellowish colored to grayish, fine-grained, soft sandstone .... 8 in.
4. Fuller's earth, same as No. 2 .... 2 ft.
5. Irregularly thin-bedded, or laminated and contorted, alternating laminae of a fine-grained, brownish green, clayey sand and a rather pure, unctuous, brownish-green clay resembling fuller's earth. The clayey sand, when in the stream bottom is a bluish green (copperas) color due to the action of the water on the iron in the sand .... 5 ft.

Dip here of 10° to the south, although in other places it is almost horizontal.

Locally, the Corrigan has large, rather angular, calcareous nodules. By far the greater part of the fomation here, especially the upper portion, is made up of yellowish green clay. There is also non-plastic clay (fuller's earth) and some fine volcanic ash.

The creeks in the vicinity of Colita and Canary exhibit long stretches of slack water held back by a resistant layer outcropping farther downstream. Terraces along the streams are apparently due to the same cause. Below a rapids or waterfall, caused by the outcrop of a resistant layer, a gorge, sometimes 20 feet or more deep, is cut which comes to an end downstream at the next rapids or waterfall. The Catahoula in the middle reaches of these streams consists of cream-colored, light gray, light blue and mainly yellowish green sandy clay with locally semi-consolidated layers, and higher up the stream courses nearer the base of the formation with local lenses of opaline-cemented sandstone. Locally white calcareous concretions are found in the clays. Some of these are potato-like, or irregular in form, but most are long, generally branching pipes with

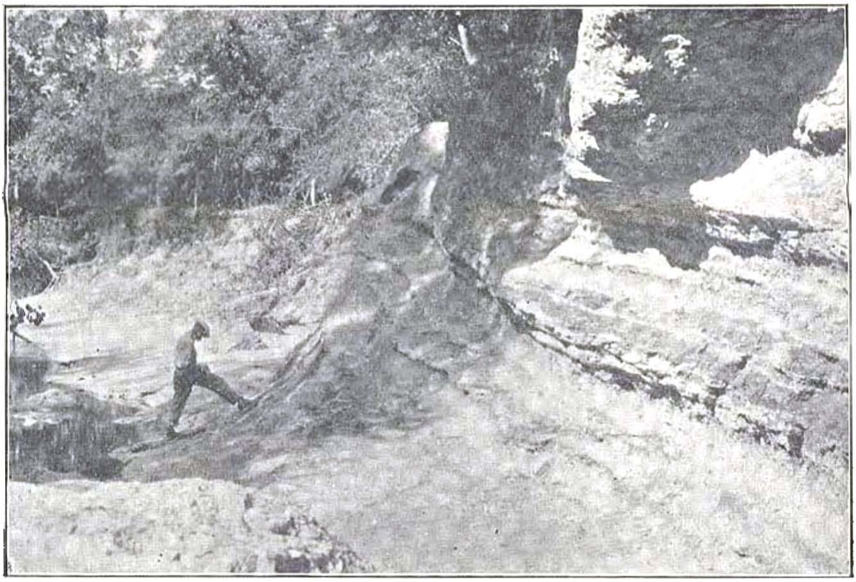

Fig. 1. CORRIGAN FORMATION.
White Rock Creek, Polk County.

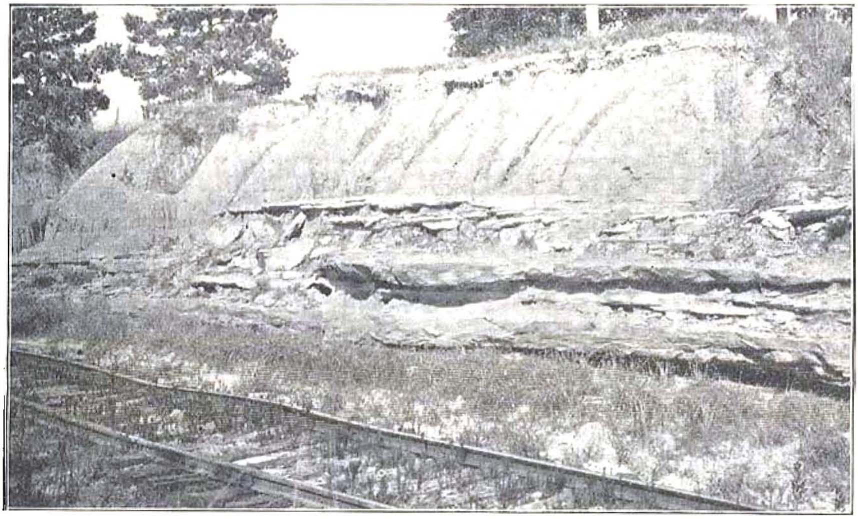

Fig. 2. CORRIGAN FORMATION.
Exposure of sandstones near Riverside.

irregular outside surfaces, sometimes very indistinctly ribbed. A cross-section generally shows them to be porous and some of them appear to have been built up of a growth in a concentric manner around a small central cavity. A number of these cavities may be found in the same "pipe."

Below the mouth of Rocky creek there were exposures of sands, some of which were cemented with the porcellaneous matrix of the Catahoula, interbedded with greenish clays in which calcareous concretions were found in increasing number until finally some two miles southeast of Onalaska these graded up into the green and brown clays of the Fleming that contain quantities of calcareous concretions and weather into black soil Some of the concretions were long pipes with concentric cellular structure resembling slightly the structure of bone. These may be due to the replacement of rootlets.

These transition beds between the Catahoula and the Fleming are the beds we have called the Onalaska.

Going downstream below the Beaumont & Great Northern Railroad bridge the Fleming continued for about two miles. Here the stream makes a N. W. bend and again enters the Catahoula, some excellent exposures being noted. One noticeable thing was the appearance of two very large, black petrified logs.

On White Rock creek in Trinity county east of the International & Great Northern Railway the contact between the Jackson and Corrigan is found near the mouth of Caney creek.

About one-fourth mile above the Beaumont & Great Northern Railroad bridge fossil leaves are found in a medium to coarse-grained, massive to cross-bedded, opaline cemented sandstone believed to form the lowermost Catahoula. Immediately below the sandstone there outcrops along the creek about 7 or 8 feet of laminated chocolate colored, sandy, shaly clays with some fine-grained sands. This lower member in all probability belongs to the Jackson beds and we have the contact here. The contact seems to follow along Caney creek in this vicinity for quite a distance, as the above section is repeated in another place one-half mile above where Caney flows into White Rock creek.

At Chita postoffice, situated on the J. R. Parker Survey, there is a high ridge trending through the country in a southwest-northeast direction and it also probably marks the contact between the Catahoula and the Jackson. This ridge is covered with a very coarse sand made up of angular sand grains, some of which are as much as ⅛ to ¼ inch in diameter. The grains are mostly pure quartz, but occasionally a flint or jasper grain is noticed. Grains resembling rose quartz occurred locally.

TRINITY RIVER SECTION

Between Riverside and the mouth of White Rock creek the Trinity river flows easterly, meandering along the strike of the Corrigan and gives a number of good sections of the lower Catahoula.

Immediately downstream from the bridge at Riverside there outcrops, on the south bank and back from the river, a coarse-grained, cross-bedded, opaline cemented sandstone, for the most part rather soft. This same stone outcrops on the tops of the hills overlooking the river and some 40 to 50 feet above it. On the top of the hill there is an old quarry in this material. Here it is rather massive, but still rather soft. This stone has been used extensively by the International & Great Northern Railway in the building of culverts, approaches and abutments. It dresses well and seems to be admirably adapted for this use.

About one-half mile downstream from the bridge the following section is exposed on the south bank:

1. Alternations of sandstone and claystone in 2 ft. layers.... 8 ft.
2. Claystone, weathering whitish .... 3 ft.
3. Coarse-grained, gray colored, rather soft sandstone .... 4 ft.
4. Greenish-brown, sandy clay, weathering yellowish and cream colored. The clay contains many pyritic nodules and, where the water has acted on it, the characteristic "copperas" color is to be seen. Towards the top the clay becomes indurated to a claystone. Structureless...... ...40 ft.

Approximately one-half mile below the mouth of McGee creek, on the south bank, there is exposed at the waters edge 8 to 10 feet of a gray to yellowish, structureless, fine-grained, fairly well indurated sandstone. This sandstone weathers out in cavernous forms.

About one mile below the mouth of McGee creek, on the south bank, there is a bluff overlooking the river in which the following section is exposed:

1. Yellowish sandy clays and clayey sands, for the most part structureless, but showing some cross-bedding. Contain some pyritic nodules ....25 ft.
2. Highly cross-bedded, gray, coarse-grained, porcellaneously cemented sandstone, for the most part soft..............20 ft.

At Gibson's store, which is about one-half mile above the mouth of Carolina creek, there is a bluff on the Trinity county side. It is hardly any higher than the banks of the river, but at the base about 10 feet of gray sands are exposed.

Immediately below the mouth of Carolina creek and along the eastern bank of the creek for quite a ways back from the river there is a bluff rising some 60 feet above the river. The section exposed here is as follows:

1. Greenish-brown clays, weathering yellowish, structureless.. 2 ft.
2. Structureless, indurated, grayish brown, sandy layer........ 2 ft.
3. Clay and sandy clay, greenish-brown when fresh, but weathering yellowish, cream colored and yellowish brown. When near the water it takes on a blue color, due to change in the composition of the iron cement. Contains an abundance of iron sulphide nodules, which are crystalline in places and take on octahedral forms. The clay smells strongly of sulphur and H_2S. In the Carolina creek bed just above the mouth there are a number of springs highly charged with sulphur ....10 ft.
4. Upper part consisting of a cross-bedded, fine-grained, gray to white sandstone, medium-hard to soft. Bottom 15 feet covered with sandstone blocks ....45 ft.

About 1½ miles below old Carolina there outcrops near the water's edge on the south bank of the river about 6 feet of a medium to coarse-grained, hard gray sandstone, for the most part massive. The sand grains have an opaline cementing material. This rock varies from medium hard to the hardness of quartzite.

In the creek there is a section exposed which shows excellently the nature of some of the unconformities within the Catahoula. Here there has been a trough cut into the yellow-weathering structureless sandy clays and in it 10 feet of coarse-grained, cross-bedded sands have been deposited. These sands are bedded so as to show the trough, and the cross-bedding appears as the minor structural feature. The sands vary locally from fine to coarse-grained, but some coarse angular quartz grains up to ⅛ inch in diameter were found and rounded clay balls up to one inch in diameter were also included. In color, the sands are, for the most part, gray and reddish brown, but in one place they were carbonaceous and of a brownish hue. A layer of 2 ft. of arenaceous claystone is also to be included near the base of the section. The sands are considerably iron stained locally.

One-fourth to one-half mile above the Government Lock and Dam at White Rock Shoals there is a shoal extending across the river. The rock making up the shoal is a medium to fine-grained, partly indurated, massive, gray sandstone, stained reddish-brown locally and having many vertical joints. There is about five feet of this material overlain by five feet of gray sands containing some pyritic nodules.

From this point the river turns more nearly south across the strike of the beds.

Chalk Bluff, on the Trinity river, is on the north bank about 200 yards downstream from the mouth of Mill creek. The section is as follows:

1. Cross-bedded, medium-coarse sandstone, some of it with opaline cement, other parts mixed with fine clay. Also contains coarse-grained quartz and rounded clay balls. Buff in color .... 25 ft.
2. Much fractured "mudstone" with curved fracture. Stained brown and red on fracture planes by iron oxide.......... 20 ft.
3. Greenish-yellow loose clay .... 70 ft.

Between this exposure and the Beaumont & Great Northern Railroad over Mill creek the east bluffs of Mill creek are strewn with fragments of Catahoula sandstone of sizes up to 3 or 4 feet by 10 or 12 feet and of all degrees of induration from that so friable it can be broken to pieces in the hand, to hard indurated quartzite. There is some fine conglomerate and palmetto leaves and opalized or chalcedonized trunks are rather common. Three thin ledges of the sandstone, separated by clay, outcrop on these hillsides None of these appear to be over six feet in thickness. The upper one is friable and the lower one has thinned out at Chalk Bluff, where its place is taken by clay. The hillsides are covered with its debris for over a mile along the east side of Mill creek and much of this debris is workable stone.

INTERNATIONAL & GREAT NORTHERN RY. SECTION

There are good exposures of the Corrigan along the line of the International & Great Northern Railway.

Two miles north of Riverside, the International & Great Northern Railway runs close to the outside of a meander curve in the Trinity river. The section follows:

1. Shelly and thin-laminated, light brown sands, in places indurated to a friable rough-surfaced sandstone........10-12 ft.
2. Dark brown and brownish-black carbonaceous shale........ 3 ft.
3. Dark gray, compact, clayey, fine sand, fractured into small pieces and with a dull waxy appearance .... 7 ft.
4. Friable, rough-surfaced, much jointed, light-brown sandstone with plants .... 4 ft.
5. Cream colored, very sandy, clay .... 2 ft.
6. Sandstone like (4) .... 1 ft.
7. Laminated sand, cross-bedded, medium-grained, light gray sands ....10 ft.

All exposures on the Trinity river above this point belong to the Jackson, and the Jackson-Corrigan contact comes in No. 7 of this section. All beds above it belong to the Corrigan.

One-fourth mile downstream from the above section is 25 feet of light brown and gray sand and sandstone, varying in degree of induration from friable to hard opaline-cemented, locally quartzitic. Most of the sandstone shows an irregular lamination.

The following sections are exposed as we go downstream:

The first of these for the distance of a quarter of a mile or more exposes contorted bedded and thin-bedded light drab clay about 10 feet in thickness. One-fourth mile downstream there is 15 feet of gray and greenish-gray sandstone of various degrees of induration, from very friable to hard quartzite. Some of it is clayey and then it is fractured into small pieces and presents an irregular surface. The bedding is contorted. Plant impressions and leaves are plentiful. For three-fourths of a mile above the International & Great Northern Railway bridge yellowish-green clay and blue laminated sands are locally exposed in thin sections on the south bank of the river.

The top of the hill at Riverside is capped with yellowish-green clay with calcareous nodules. This clay is about 20 feet in thickness. It is underlain by a ledge 10-15 feet of light gray, friable cross-bedded sandstone with large grains of pellucid quartz which we have called rice sand. These have their edges partly rounded and their surfaces clouded by abrasion. Underneath the sandstone is 10 feet of light brown hardened clay, much jointed.

Just out of town is a small gully with steep sides excavated in the sandstone and underlying clay. Locally, the sandstone has opaline cement. There is a southward dip of 2 degrees. Underneath the hardened clay is 15 feet of light yellowish-green, loose clay. In the sandstone at the top are pockets, lenses and small nodules of clay.

The first exposure on railroad is 200 yards south of Mile Post 72, which whows 10 feet of poorly bedded, light yellowish-green, sandy clay. The dip is 3° S. W. At the next exposure one-fourth mile south of Mile Post 72 the dip is 2° to the southward. The section is:

1. Hardened, light gray clay .... 4 ft.
2. Light yellowish-green clay carring a few calcareous concretions ....13 ft.
3. Partly as a continuation of the same stratigraphic level as (4) and partly coming in above are thin non-continuous beds of friable light gray, coarse-grained, opaline-cemented, sub-angular, fragmented, quartzose sandstone, interbedded with loose, cross-bedded, coarse and medium-grained sands with small nodules of light yellowish-green clay .... 8 ft.
4. Loose, cross-bedded, friable, light gray, medium-grained, quartzose sand with biotite, selenite, and jasper as accessories .... 9 ft.

Cream colored sandy clay 5 feet in thickness is exposed in the cut at Mile Pose 63. One hundred yards south of Mile Post 75 is the following section:

1.	Friable sandstone, fine-grained, opaline-cemented with plant impressions	4 ft.
2.	Loose, fine-grained, light gray sand	2 ft.

Stratigraphically above the last section in the cut at Mile Post 75 is the following section:

1.	Opaline-cemented coarse and medium grained light brown and gray sandstone locally cross-bedded and stained with limonite. It is locally quartzitic and contains rounded nodules of clay and larger lumps of hardened clay more irregular in outline. Varies greatly in degree of induration	5 ft.
2.	Light yellowish-green clay with calcareous nodules	5 ft.

At Mile Post 76 is 6 feet of light gray, loose, poorly laminated sand. The Onalaska beds seem wanting in this section.

The top of the Corrigan is seen on Harmon creek west of the railroad.

The first exposure, which is near the middle of the Catahoula section, is just above the abutments of the old bridge on the road from Riverside to Smither's farm. It consists of 10 feet of light green clay, much fractured. The second exposure is 250 yards upstream from the last and has 40 feet of light yellowish-green clay, the upper 5 feet partially indurated, overlain by 5 feet of opaline-cemented, cross-bedded, medium-grained sandstone with plant remains. The next exposure shows 25 feet of light yellowish-green clay. The heads of the tributary creeks and gullies have broad bare surfaces of light greenish or cream colored Catahoula clay.

One mile upstream from the last mentioned exposure is the following:

1.	Light gray hardened clay	2 ft. 6 in.
2.	Unconsolidated, light yellowish-green clay	3 ft.
3.	Hardened, light yellowish-green clay	1 ft.
4.	Medium-grained, opaline-cemented, cross-bedded light gray sandstone	4 ft.

At the contact of the sandstone and clay are sulphur springs emitting sulphuretted hydrogen gas.

The next exposure is one-fourth mile upstream:

1. Light gray, cross-bedded, opaline-cemented coarse-grained grit. The particles of the grit are, subordinately, angular, dark colored chert, up to 1-4 inch in size, predominatingly angular, transparent quartz, with a minor amount of small rounded, light gray-drab clay balls, probably derived from the underlying clay. There is a very irregular, unconformable contact between (2) and (1); at one place a lense of medium-grained, light gray sandstone is found in the clay (2) and has an unconformable lower contact with the clay. This is at the top of the clay and is separated from the overlying sandstone by clay from 1 ft. to 6 ft. in thickness ....10 ft.
2. Very light gray clay, hardened and much jointed, rusty on joint planes .... 8 ft.

Three-fourths mile upstream is 4 feet of light yellowish-green hardened clay. One-fourth mile farther upstream is at the base 8 feet of light yellowish green clay. On the hill above, with a covered vertical interval between it and the clay of about 10 feet is light gray, cross-grained, opaline-cemented sandstone 5 feet in thickness. Then after several exposures of a few feet each of light yellowish-green, unconsolidated clay, there comes one with 4 feet of yellowish-green hardened clay with irregular-surface, overlain by 3 feet of loose, light green clay. At an old cotton gin there are 6 feet of very friable sandstones, fine-grained, light gray, and much cross-bedded. The two exposures next upstream have 8 feet of light yellowish-green, unconsolidated, clay. The next exposure has 6 feet of light green, unconsolidated, laminated, fine-grained sand at the base, overlain by 3 feet of fine-grained, light gray sandstone, in which were found two palmetto leaves, as large as the modern palmetto, and resembling it. Another quarter mile upstream is the following section which belongs to the *Onalaska beds:*

1. Gray, medium grained sandstone, locally quartzitic......... 7 ft.
2. Coarse sand packed full of small white porous cylindrical calcareous concretions .... 2 ft.
3. Yellow-green, fine sand ....10 ft.

Further upstream the exposures at the top of the Corrigan are blue and gray clayey sand, locally indurated, with irregular surfaces and, locally, with a few small calcareous concretions. It forms rapids in the creek. The line between the Corrigan and Fleming is very poorly defined here.

West of the Trinity there are good exposures of the lower Corrigan along Nelson creek in the northern part of Walker county.

A traverse of Nelson creek from Moffitt Springs to the head, showed that it flows in the Corrigan. About one-eighth mile above the springs, a rock hill comes down to the creek. It is composed of medium to coarse-grained, massive gray sandstone. An exposure of the same sandstone is to be seen about one-eighth mile above this point, where a rock shoal occurs in the creek. On the Wm. Roock League on the south side of the creek and about one-fourth mile back from it there is exposed, in a bluff overlooking the creek bottom, 8 to 10 feet of medium to coarse grained, massive, white sandstone containing pyritic nodules and having a fine granular matrix. The creek heads just south of the Bedias road. Exposures near the head give 5-6 feet of the yellow weathering, structureless, somewhat sandy Catahoula clay.

THE INTERNATIONAL & GREAT NORTHERN SECTIONS IN GRIMES COUNTY

The Jackson-Corrigan contact comes between the 22nd and 23rd mile posts. A sandstone quarry was formerly worked in the beds near the base of the Corrigan a short distance west of the track. Quartz sand as coarse as rice is reported from a locality 400 yards east of the Trinity & Brazos Valley Railway track a short distance south of Singleton and this is undoubtedly derived from the Corrigan. One-third mile north of Mile Post 21 Corrigan light gray, irregularly indurated, sandstone 2 feet in thickness is overlain by much cross-bedded, opaline-cemented sandstone 6 feet in thickness. White and yellowish-green clays 3 feet in thickness are found 300 yards south of Mile Post 21.

Roans Prairie has blackland soil underlain by light greenish-yellow clay. At depths of from 20 to 30 feet good water is obtained in Corrigan sand or sandstone. There is a small hill of Corrigan sandstone 1 mile south of Roans Prairie station; light greenish-yellow clay between Mile Post 17 and 16; 5 feet of cream-colored clay badland, clayey sand, locally indurated to sandstone, at Mile Post 16. At Mile Post 15 and two-thirds of a mile south there is 3 or 4 feet of cross-bedded friable sandstone, which belongs to the uppermost Corrigan. Three hundred yards south of Mile Post 14 is 2 feet of light gray claystone, the upper 1 foot indurated and fractured. Underneath the last is 5 feet of lowermost Fleming dirty green sandy clay, very poorly laminated and with calcareous cemented nodules of sandstone.

The Corrigan-Fleming contact occurs, therefore, near Mile Post 14.

BRAZOS RIVER SECTIONS

Our Brazos river sections include only the upper beds of the Corrigan and their contact with the overlying formation. As the bulk of the materials belong to the Neocene, the sections will be given later.

Four hundred yards below the line between the E. Clampit and Wm. Kerr tracts, Corrigan quartzite outcrops in the river bank. The rock is 22 feet above low water level.

As here exposed the Corrigan is a medium hard, brownish-gray sandstone with lenses of hard brown quartzite. These quartzitic phases make up at least fifty per cent of the rock mass in this exposure. No estimate can be made regarding the thickness because of cover. The bedding is highly complex, ranging from thick and massive strata to thin-bedded phases with all degrees of cross-bedding and lenticular structure.

Two hundred yards south of this, along the river bank, an exposure shows 23 feet of sandstone. The lower 7 feet of this is present in last exposure, but the 16 foot interval above this shows no quartzite.

Chapter IX

NEOCENE

INTRODUCTION

The Miocene and Pliocene, which, taken together, form the Neocene, are represented to the east and west of us both by marine and by non-marine deposits. Using the marine fossils as a basis, each of the two series has been divided into a lower, middle and upper stage. The character of the vertebrate remains also permits a tripartite division of each series, but the exact equivalency of the Lower, Middle and Upper stages of each as shown by vertebrates and invertebrates has not been ascertained.

All of the materials of Miocene and Pliocene age which occur at the surface in our Texas Coastal area are, as we have said, land or fresh water deposits, but wells drilled to the seaward of these exposed bodies show that they do not continue indefinitely in that direction as land deposits, but that they are replaced by brackish water or marine beds. None of these, however, have given us a clear basis for a division of the beds. Even in the Galveston deep well, which affords us our best marine section, the beds, except those above 458 feet, which are clearly Pleistocene, and those below 2100 feet which carry a distinctly Miocene fauna, are of indeterminate age beyond the fact that they are Upper Tertiary or Lower Quarternary or both. At Saratoga and Batson about 70 miles a little east of north from Galveston the fossiliferous marine Miocene beds are found in wells at depths from 350 to 1200 feet. These are the only inland occurrence of these beds now known and the presence of any of the post-Miocene beds of the Galveston well has not been recognized anywhere in East Texas.

The conditions of the brackish water fauna is somewhat similar. At Burkeville a fauna was found which Dall pronounced Upper Miocene or Lower Pliocene. The vertebrate remains found in same beds Matthew ascribed to the same age. Sixty-five miles south of Burkeville a deep well encountered the Burkeville fauna at 3100 feet and continued in it to 4000 feet, but there is nothing in the overlying beds to definitely fix their age. Nor do the vertebrate faunas east of the Navasota give us much better data for classification. The collections from the vicinity of Navasota and from Cold Springs, according to Matthew, are of Middle Miocene age. Those at Burkeville are of Upper Miocene or Lower Pliocene—none are distinctly Pliocene.

Furthermore, east of the Trinity there does not seem to be any lithological basis for the division of the beds lying between the Oligocene and the Orange Sand or Lafayette. Therefore, these clays with calcareous concretions and their interbedded sands, which together give us our only mappable unit, are grouped under the name Fleming and treated as undifferentiated Neocene covering the time from the Oligocene, or rather from the close of the Corrigan, into the Pliocene.

The Neocene deposits in the East Texas Region, then, consist of only two mappable units: The Fleming beds and the Lafayette or Orange sand. The former comprises such deposits as occur between the Corrigan and Lafayette and covers parts of both the Miocene and Pliocene time. The Lafayette is Upper Pliocene in age.

West of the Brazos a better differentiation is possible and was made in the Nueces river section. In this region the Frio which is of Eocene age is overlain in the neighborhood of Oakville by a body of brown sands lightly compacted and unfossiliferous. Overlying these are fossiliferous sands which were grouped with the lower beds as the Oakville sands. The vertebrate fossils proved to be of Upper Miocene age. The brown sands may represent the Middle Miocene or even earlier deposits. Overlying the Oakville we find the Lapara sands with vertebrate fossils of Lower Pliocene (Blanco) age and these are succeeded by the unfossiliferous Lagarto clays. The deposits west of the Brazos are much sandier than those east of that stream, the Lagarto clays being the only portion that corresponds lithologically with the main body of the Fleming.

This would seem to imply that while east of the Brazos lagunal conditions prevailed from the beginning they did not extend westward until near the end of the period.

FLEMING

General Statement

The deposits which succeed the Corrigan in East Texas probably have no exact counterparts in other portions of the Gulf Coast.

They consist of a broad belt of clays with calcareous concretions which are interbedded with sands. The texture and composition of the component strata indicate that they were deposited in the quiet waters of inland lakes, lagoons or bays beyond the immediate shoreline of the sea and as terrestrial deposits on a comparatively flat coastal plain. The sands show the remains of palms and palmetto. The invertebrate fauna is that of brackish water only while the bulk of the fossil remains are those of land animals.

These deposits are connected with the underlying Corrigan by transition beds and are overlain unconformably by the Lafayette or Upper Pliocene.

The fossils found in them indicate that these deposits cover Middle and Upper Miocene and possible Lower Pliocene time. No forms indicative of the Middle Pliocene have yet been found, but may occur in or near the Woodville horizon.

These deposits,—the Fleming in the east, and the Oakville-Lapara-Lagarto in the west,—are the coastal and terrestrial sediments laid down contemporaneously with those of marine origin seen in the Galveston deep well and in deep wells in the Louisiana area which have yielded remains of Miocene and Pliocene marine invertebrates, no trace of which have, up to this time, been found outcropping in this area.

The Fleming clays were so named by Kennedy from the exposures near Fleming on the Missouri, Kansas & Texas Railway east of Corrigan. His description follows:

The deposits are best seen in the neighborhood of Fleming, where, a little west of the station, the Trinity and Sabine Railway line passes over a high hill made up entirely of them. The same clays also occur in a cut on the line of the Southern Pacific Railway about a mile and a half north of Summit station, in Tyler county.

The clays are dark blue, pale blue, brown, red, yellow, and pale green in color. They occur thinly laminated, or partially stratified and massive and have a strong tendency to joint or break into cuboidal blocks with a conchoidal fracture. The most important bed of clay in this group is a blue clay, partially stratified, but showing a tendency to break up into blocks, and containing numerous concretions of carbonate of lime. This clay is perfectly smooth in texture and graduates into the underlying bed of red clay without any break except that of color, and the absence of the limy concretions which apparently do not occur in the red clay. At least where the beds were examined none were found. The red clay is in every other respect similar to the blue.

Pale green, pale blue and brown clays are found overlying the blue limy clays at the different exposures, but occur most abundantly to the north of Summit station. These colors are not so persistent as the blue, and are probably due to some local cause.

These clays in this portion of the State are overlain by and associated with a series of gray sands, which are mostly coarse grained, sometimes massive ,and in localities cross-bedded and stratified. The typical exposure seen at Fleming shows them to be gray stratified sand containing fossil palm in great quantities, with numerous quartz, jasper and other pebbles, and to have at that locality a thickness of twenty feet

These clays and sands occupy a belt from 15 to 25 miles in width and are followed by the deposits referred to the Lafayette.

SABINE RIVER SECTION

The occurrence of the Fleming on the Sabine is thus descrbed by Veatch, who suggests the name Burkeville beds for it:

Outcrop near Burr's Ferry:—A small outcrop of the greenish-yellow clays of this stage occurs at the water's edge a quarter of a mile from Burr's ferry

Bluff at mouth of Boggy branch:—Bluff just below the mouth of Boggy branch shows the following section:

1.	Stiff black soil	1 ft.
2.	Fine white sand	37 ft.

3. Light yellow, sticky clay, containing large irregular white calcareous concretions. Weathers into a stiff black clay..26 ft.
4. Covered to water level ....17 ft.

The blackland soil which caps this bluff is an erosion fragment of a much thicker bed which shows in the hills west of this exposure. This is a continuation of the blackland belt in which fossils occur at Burkville.

Near Columbia:—Shelf of clay exposed just below the ferry shows the following:

1. Yellow sandy loam mottled with gray .... 7 ft.
2. Fine white and yellow sand containing gravel in the basal portion ....13 ft.
3. Light brown, slick-looking clay, streaked white. Contains small calcareous concretions .... 2 ft.

Water level.

The flat-topped bluff on which New Columbia is situated continues down the river half a mile Near its lower end a ledge of green calcareous clay, two feet thick, is exposed near water level.

Outcrops below New Columbia:—The first exposure of Frio (Fleming) clays below New Columbia is at the log-slide at Knight's landing

1. Brown sandy silt, stained with red and yellow........... 7 ft.
2. Stratified white sand with gravel at base ....17 ft.
3. Green sandy clay ....10 ft.

Two feet of green sandy clay is exposed at base of low pine-clad bluff on the Louisana side between Droddy's landing and Bearden's ferry.

On the map, Plate XXXIV, he places the southern limit of the Fleming at Armstrong's bluff just south of the line between Vernon and Calcasieu parishes, at which point it passes below the Lafayette.

BURKEVILLE SECTION

Baker describes the beds at Burkeville thus:

The general facies of the beds at Burkeville resemble much the Fleming of the type locality and others farther west. Good exposures are most often found in recent gullies in old fields and prairies and these may or may not have a superficial black soil. The walls and promontories of a gully system have rounded outlines, for the material is fine and unconsolidated. In color the Fleming is most generally a light shade of grayish or yellowish-green, often weathering brown on the surface. The surface, when dry, is cracked like ordinary plastic clay. The material is fine clay and clayey sand with small whitish limestone concretions. However, there are at Burkeville larger grayish-brown very fine grained limestone concretions with dendritic markings of manganese dioxide, concretions of large size and rough irregular outline of fine to medium-grained sandstone, and the fossiliferous breccia or beach limestone conglomerate known only from one-half mile east of Burkeville and south of Little Low creek, where fragmentary bones of land mammals and brackish water molluscs were found. In many places the small white concretions are arranged in thin beds parallel to the imperfect lines of stratification. The fine sands are also locally finely laminated and cross-bedded.

Collections of fossils, both vertebrate and invertebrate, were made at this locality. The invertebrates collected by us were sent to Dr. W. H. Dall, who studied them in connection with other collections from the same locality and others of similar age from Louisiana and Georgia. Matson[1] gives the results of this study and lists 10 species from Burkeville. He states that the character of the fauna led Dr. Dall to refer it to the Pliocene.

The list given by Matson[2] includes the following forms:

Ostrea virginia Gmel.
Anomia sp.
Potamides Matsoni Dall.
Potamides Matsoni var gracillior Dall.
Cerithiopsis burkevillensis Dall.
Pachycheilus anagramatus Dall.
Pachycheilus satilensis Aldrich.

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[1] U. S. G. S. Water-Supply Paper 335, p. 72.
[2] U. S. G. S. Water-Supply Paper 335, p. 73.

Fig. 1. CORRIGAN FORMATION.
Quarry in Jasper County, exposing quartzites.

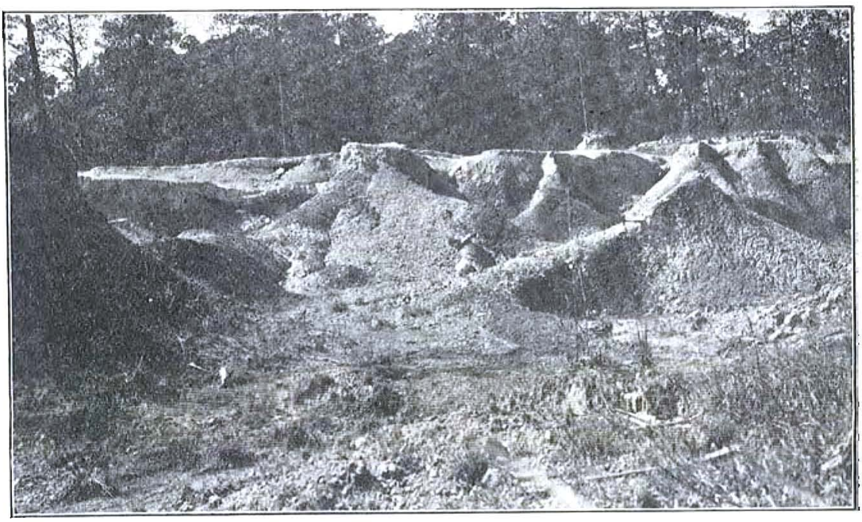


Fig. 2. FLEMING FORMATION.
Typical exposure near Smith's Ferry.

Pachycheilus sauvis Dall.
Paludestrina plana Aldrich.
Neritina sparsalineata Dall.

The mammalian remains were sent to Dr. W. D. Matthew. He reports as determinable:

Tibia of a young rhinocerous, with the proportions of Teleoceras.
Upper molar of a horse, either Protohippus or a long-crowned Merychippus.

He states that both these specimens indicate late Miocene or possibly early Pliocene age, the horse tooth being pretty certain evidence.

It is therefore evident that in the vicinity of Burkeville the base of the Fleming is not earlier than late Miocene nor younger than early Pliocene.

SANTA FE RAILWAY SECTION

On the Santa Fe railroad the contact of Corrigan and Fleming was not seen, but judging from the topography it should be just north of Mile Post 76. From this point to Jasper the exposures show only Lafayette and even south of Jasper the Lafayette is more abundantly exposed in the cuts than is the Fleming. At Mile Post 73 light greenish-gray Fleming clay with calcareous nodules is exposed. This weathers on the surface to dark russet brown. Its maximum thickness is 10 feet. Eight feet of Fleming yellowish-green clay with calcareous nodules is to be seen in the first cut south of Mile Post 72, and at Mile Post 71. At the culvert between Mile Posts 71 and 70 the Fleming is greenish to yellowish-gray and weathers brownish. In the cut running north of Mile Post 70 is 8 feet of Fleming clay with calcareous nodules, weathering dark brown, but greenish-gray when unweathered.

There is at least 15 feet of Fleming with calcareous nodules in the cut at Mile Post 70.

The Fleming is well exposed on both sides of Bridge 69-C. At the south end of the exposure a thickness of 12 feet is seen and this exhibits a very imperfect arrangement of the calcareous nodules in layers, recalling similar conditions at Town Bluff on the Neches in easternmost Tyler County.

In the cut on the curve north of Mile Post 69 is 15 feet of light grayish-brown Fleming with calcareous nodules and some flattish concretions of sandstone like those found in the same formation at Burkeville.

The Fleming outcrops at Bridge 68-B, at Green's Mill, and at Bridges 67-B and 66.

The southernmost exposure of Fleming seen during this traverse consisted of bluish-gray clay situated 15 feet below the track level at Bridge 57-C.

A section of Fleming clay, 100 feet in thickness, outcrops between the lowest Lafayette beds and low water level in Town Bluff on the Neches between Jasper and Woodville. The lowest Fleming exposed, at the water's edge, 5 feet in thickness, is dirty green in color. Above is 10 feet of dark brown clay, the unweathered color being green or bluish gray, but seamed with brown limonite on joint and cleavage planes. In this layer were found fragmentary bones of fossil turtles and a well preserved mammal vertebra, which may be fossil, was found on the surface of this clay. Next above is 30 or 35 feet of light bluish and greenish clay. The upper 50 feet is mainly clayey sand, cross-bedded and laminated, in color dirty green or dark brown. There are calcareous nodules throughout the section and in its middle portion these are imperfectly arranged in more or less wavy and not always parallel layers which give to the beds the appearance of a rude stratification. The top of the Fleming forms a terrace like bench, interrupting the steep profile of the bluff. This bench has been formed by numerous springs which issue from the top of the impervious Fleming and have undermined and washed away the overlying Lafayette.

TEXAS & NEW ORLEANS RAILROAD SECTION

On the Texas & New Orleans Railroad the first exposure of Fleming is at Bridge 101-E, where 18 to 20 feet of yellowish-green clay with a few calcareous nodules is seen. In the first cut above the 100th mile post 7 feet of dark green clay is found and outcrops southward to Bridge 99-D. At 99-C there is at the base 1 foot of friable fine clayey sandstone, slightly case-hardened, overlain by 4 feet of loose "shelly" clay. Then there comes in under the Lafayette a light gray sand and clay locally case-hardened and having a strong taste of alum. From 99-B the Lafayette forms the sole surface exposure.

Thin wavy laminated medium grained sand layers alternating with light brown or light cream clay with whitish calcareous nodules to a thickness of 8 feet overlain by faintly mottled clayey sand mainly yelowish brown in color with small spots of darker red 2 to 3 feet in thickness covered with "black-land" soil to depth of from 6 inches to a foot, are found in a cut on the Moscow, Camden and San Augustine Railway, one-fourth mile northeast of Moscow. The beds here dip almost due east at an angle of 7°.

HOUSTON, EAST & WEST TEXAS RAILWAY SECTION

On the Houston, East & West Texas Railway the Corrigan-Fleming contact occurs near Moscow. The first exposure of the Fleming is under Bridge 89-E 1¼ miles north of the town.

Blue-gray case-hardened sandy clay 2 feet in thickness underlies 3 feet of light mottled surficial member of a light yellow color with a faint mottling of slightly darker yellow or red in the second cut south of Mile Post 86.

One mile north of Seven Oaks 2 feet of case-hardened gray, coarse sandstone is unconformably overlain by the Lafayette. Occasionally the sandstone contains a small bunch of clay or the clay forms the lining of tubes.

One mile north of Leggett and 4 feet below the track level is 1 foot of soft gray clay with blotches of black oxide of manganese along joint faces.

Dark gray, sandy, sticky clay with small white calcareous concretions is found 4 feet below the track level at the north end of second cut south of sign post 1 mile north of Leggett. In these clays were seen several masses (6 or 8 inches long and 1 or 2 inches wide) or compact, hard, light yellow, very fine grained limestone with dendritic markings of black oxide of manganese along cracks. These clays are 3 feet thick. The surficial sandy and clayey member, mottled in its upper 5 feet, has maximum thickness of 10 feet, but the lower 5 feet in the center of the cut is sticky gray sandy clay belonging to the Fleming.

In the north end of the cut just south of Bridge 81-B and below the track level is exposed 12 feet of medium grained loose sand with just clay enough in it to enable it to stand up in typical badlands forms of buttresses built up of small spires. The surficial layer, not sharply demarked from the underlying, is mottled grayish and red. In the light gray sand close to the section's base was noted local concretion-like hardenings of the sand, colored black, probably with wad or some other form of black oxide of manganese. The last three cuts are in the side of the hill north of Leggett station.

The highest point in Polk County is a hill rising 95 feet above its base and situated 2 miles south-southeast of Leggett. The top of this hill is covered with the Lafayette member, with its usual characteristics. Not far below the summit of the hill are 4 springs of good water. The porous sandy Lafayette is underlain by the calcareous Fleming clay and the water stored in the surficial member seeps out when it strikes the top of the underlying impervious clay.

A well drilled for oil 2 miles west of Leggett penetrated 10 feet of lignite at 1000 feet below the surface—probably Jackson.

A well three quarters of a mile northeast of the high hill gives water containing sulphur, lime and salt. It penetrated dark cream colored clay with limestone concretions to a depth of 47 feet. So at a minimum there is 125 feet of the gray clay with calcareous nodules in this vicinity.

The colors of these clays probably are largely dependent on the amount of hydroscopic and interstitial water which they contain.

In the first cut south of 79-E is found the clay with calcareous nodules weathering to a dirty green on the surface. The blue gray clays with calcareous nodules outcrop in the south part of the town of Leggett and underlie a "black-land" prairie one-half mile south of the town.

Clay with calcareous nodules outcrops 20 feet below Trestle 73-A for a thickness of 5 feet, succeeded by 3 feet of mottled surficial member.

There are 6 to 8 feet of the gray clays with calcareous nodules exposed in a cut at Mile Post 72, where some beds are quite sandy and consolidated enough to form thin flaggy friable sandstone.

These Fleming clays extend at least as far south as Livingston, giving the outcrop a width of 28 miles on this railroad.

The contact of the Corrigan and Fleming near Onalaska has already been noted. Southwest of Onalaska the Fleming outcrops half way between Pointblank and Patrick's Ferry over the Trinity. It shows up here as greenish clays with calcareous concretions, weathering out into blackland. This Fleming runs up to within a mile or so of Pointblank.

The Fleming was also found outcropping in a gully about one mile east of Canary postoffice.

TRINITY RIVER SECTION

At Red Bluff on the Trinity River on the James Rankin Survey Fleming greenish-gray clay with calcareous nodules and cross-bedded sands contains a few bone fragments. The beds have a maximum thickness of 15 feet. In the middle of the exposure is a one foot layer of oolitic shore-line limestone conglomerate, containing a very few jasper and quartz pebbles of small size and an occasional bone fragment.

At Pine Island on the N. Amory Survey, in the Trinity bottoms, a portion of the bluff land is now included within the bottom which entirely surrounds it, being bordered by Duck Creek on the south and the river on the north. The northeast corner forms a low bluff on the river at the base of which is 6 feet of dirty green sandy clay with calcareous nodules.

Just east of Camilla there is a considerable body of gray medium-grained friable sandstone in the Fleming.

Similar beds are found a short distance below at Johnson's Bluff, where they also include fresh-water mollusks. These deposits extend along the river to a point south of Drews Landing, near Smithfield. Here an outcrop of Fleming, 10 feet in thickness, shows friable fine-grained gray sandstone in lenticles at the base, with 5 feet of greenish-gray, russet-brown, mottled clay with small, white calcareous nodules overlying it. Fragments of bone were found in this. The Fleming is here overlain by the Port Hudson, with the usual layer of Lafayette-derived pebbles at the base.

A mile below Drews Landing, is a section showing 5 feet of light-gray Fleming clay with calcareous nodules.

COLD SPRINGS SECTION.

Coldsprings, west of the river, is in the midst of an important outcrop of the Fleming. In this region the Fleming brown and gray clay has a considerable portion of brown, buff, and white sand. In places there are large boulders of grayish brown, soft sandstone, some of which are 10 to 12 feet in length. There is also a fine-grained, hard, brown claystone and numerous calcareous nodules. Crystals of selenite are found locally. Pure white sand, with only a minor amount of clay, is also found. Fossils of mammals were found in the region extending from 2 miles north to 2 miles west of Coldsprings. The bones, with the exception of a mastodon's skull (*Trilophodon*), are fragmentary and are scattered through the clays. *Planorbis* was also found at this locality.

Two miles west of Coldsprings on the Coldsprings-Dodge road there is quite a development of Fleming gullies or "badlands." The exposures here show 25-30 feet of Fleming drab to pearly gray colored clay mottled with brown towards the top and on the surface all brown, but the soil is always black and waxy. These clays contain layers up to 2 feet thick of cross-bedded gray to white, fine grained, medium hard, opaline cemented sandstone. The clay also contains an abundance of calcareous nodules.

These "badlands" extend from the above point northeasterly until they reach a point about 1¼ miles north of Coldsprings.

These exposures were searched diligently for fossils and quite a few vertebrate remains were found. Among other things might be noted the jaw bone of a mastodon (*Tetrabeledon*), equus teeth, camel, numerous rodents, alligator (?), turtle, etc. etc. The fossils were collected under the locality numbers of Nos. 344 and 345.

At Evergreen postoffice small lenticular masses of gray fine-grained sandstone are found in blue and green clays carrying calcareous nodules. Three hundred yards from the south line of the Ruth Miller Survey, at Evergreen, brown lignitized wood and bones were found in a well at a depth of 70 feet. Blue clay was penetrated for practically the entire depth.

Collections of vertebrates secured from the Coldsprings horizon, which is above the center of the series of deposits in the Trinity drainage here referred to the Fleming, were sent to Dr. W. D. Matthew, who reports as follows:

344. Two miles west of Coldsprings.

"*Trilophodon* sp., parts of lower jaws and separate molars, mostly well preserved.

The best specimen shows a large part of the lower jaw with m_{1-3} and the molars of the opposite side. Part of the symphysis is preserved, and apparently a little of the alveolus for the lower tusk. Symphysis is moderately long, slender; not decurved. The species is a very small and primitive one in most respects, but the retarding of the posterior teeth so that m^2 does not come into use until m^1 is worn out and dropped is suggestive of Upper Miocene species, such as *T. euphypodon*. The small size and primitive construction of the teeth are more suggestive of Middle Miocene.

Indicated age, probably Middle Miocene.

"*Pecary*, gen. indet., jaw fragment, m^3.

This might be anything from *Perchoerus* (Oligocene) to *Prosthennops* (Upper Miocene). It is small and primitive, so far as the tooth goes, but this is not conclusive, as the progressive characters of this phylum are in the front teeth. I can not identify it with certainty as belonging to any known genus or species.

Indicated age, Oligocene to Upper Miocene.

"*Merychippus* sp., upper and lower teeth.

A rather small and moderately progressive species; it might be Upper or Late Middle Miocene.

" ?*Alticamelus*, distal ends tibia and metapodial.

Indicated age, Middle Miocene to Lower Pliocene.

"Crocodile and Tortoise fragments.

345. Pointblank road, north of Coldsprings.

"Cervid," cf. *Dromomeryx,* horn fragment, calcaneum.

"Camelid, gen. indet., jaw fragments, proximal phalanx.

"Rhinoceros, cf. *Aphelops,* several fragments limb bones, calcaneum.

"Large Rhinoceros, cf. *Teleoceras* or large *Aphelops,* fragments of limb bones.

"Proboscidean, cf. *Trilophodon,* unciform.

Indicated age of the above specimens, Middle Miocene to Lower Pliocene.

345. One and one-fourth miles north of Coldsprings.

"*Hystricops* sp., upper jaw with m^1; lower molar.

This is more primitive than the one known species of this genus, which is Upper Miocene and Pliocene. It is intermediate between it and the supposed ancestral type, the *Steneofiber* group of the Upper Oligocene and Lower Miocene.

Indicated age, probably Middle Miocene.

"*Blastomeryx* sp., last lower molar.

This is apparently distinct from any known species, decidedly more progressive than those of the Lower Miocene, less so than the Upper Miocene species *B. wellsi,* more perhaps than the Middle Miocene species *B. gemmifer.*

Indicated age, late Middle Miocene or Upper Miocene.

"*Oreodont,* gen. indet., upper canine and premolar.

Indicated age, Miocene or Lower Pliocene.

"Carnivore, indet., scapholunar and head of metatarsal.

"Proboscidean, cf. *Trilophodon,* fragments of teeth.

Indicated age, middle Miocene to Pliocene.

"Trionychid fragments.

"Garpike scales.

"?Snake vertebra.

"*Merychippus* sp., cf. *seversus,* upper and lower teeth and fragmentary foot bones; part of right lower jaw, p_4m_2.

This is a Middle Miocene stage, although small and primitive Merychippi do survive into the Upper Miocene and Lower Pliocene. No trace of any of the distinctively Upper Miocene horses among these fragments.

Indicated age, Middle Miocene.

351. Two miles north of Coldsprings.
"Cervid (?*Dromomeryx*) radius.

Indicated age, *Dromomeryx* is Middle Miocene to Lower Pliocene, but this evidence is very slight.

352. Red Bluff, Trinity River.
"*Protohippine* horse, lower tooth.

Indicated age, Middle Miocene to Pliocene; nothing more definite.

"The Coldspring material lacks any of the characteristic Upper Miocene Lower Pliocene Equidae, it has two or three species that appear to be in a Middle Miocene stage of evolution, and it has nothing recognizable as of the distinctively Upper Miocene types. The best specimen is the little Mastodon (*Trilophodon*) which is the smallest and most primitive species I have seen, except for a few very fragmentary specimens out of the Middle Miocene of Colorado (which have been called *proavus* and may represent the same species).

"I do not see anything to modify my former correlation of the fauna with the Middle Miocene (Mascall, Deep River and Pawnee Creek beds): it is rather confirmed by the *Trilophodon*. But, as I wrote before, the survival of the Middle Mocene fauna of the Central Plains to a somewhat later age in Southern Texas would not be unexpected."

Bluish-gray and dirty green Fleming clay outcrops at the town of Oakhurst. There are only two exposures of Fleming on the Trinity Valley Southern Railroad between Oakhurst and Dodge, where most of surface is gravel-covered.

INTERNATIONAL & GREAT NORTHERN RY. SECTION

On the International & Great Northern the Fleming clay has its base about 10 miles north of Phelps. On the Huntsville branch between the 5th and 6th mile posts west of Phelps is a dirty green clay, cracked into small fragments which harden when dry. One-fourth mile west of the 6th mile post is 10 feet of dirty green clay, weathering light cream and with many calcareous nodules. At the base is a few inches of thin flaky, fine-grained sandstone, light gray in color, containing calcareous nodules.

The uppermost Fleming on the International & Great Northern is found between one and two miles north of Willis, Montgomery County. It is generally dirty greenish-gray clay, weathering brown. It also has small calcareous nodules and local lenses of poorly indurated sandstone.

The lower exposure of Fleming on Harmon creek west of I. & G. N. Ry. in Walker County is about two miles below the junction of the east and west forks. It consists of bluish green sticky clays which weather brown and have calcareous nodules. In the lower Fleming on this creek are local lenses of opaline-cemented coarse-grained sandstone. Near the mouth of the east fork and a short distance above it this sandstone is interbedded with the dirty green sticky clay. One mile above the forks is light gray nodular hardened clay, 7 feet in thickness and forming a rapids on the east branch one-fourth mile farther upstream. The base of the section is 5 feet of greenish-gray medium and coarse-grained sand with calcareous nodules locally poorly indurated and with an irregular surface. Above this is 5 feet of greenish gray consolidated and structureless clay. At the top is 5 feet of dirty green sticky clay with white calcareous nodules. The top clay weathers russet-brown. For three-quarters of a mile above this point semi-indurated sandstone forms a series of shoals and backwaters. The rock forming the shoals is full of potholes. Above the shoals the valley narrows and becomes gully-like. One-half mile above where the gorge begins gray, thin, opaline cemented, medium-grained sandstone layers dip southward at an angle of about 15°. Between these sandstone layers are thin beds of a vitreous-lustred fine ball clay, the original color of which appear to have been light greenish-gray, although it is now altered to a yellowish-brown. This clay is non-plastic. The southward dip lessens within 10 feet and is probably one of deposition and not one of deformation. Then the beds dip steeply in the opposite direction at an angle of about 10°. A good section is seen where the Phelps road crosses near the head of the creek. Here is about 10 feet of partially laminated greenish-gray clay with a very few calcareous nodules. A local lens 5 feet thick, of cross-bedded medium-grained, subangular quartz sand is found in the clay. The clay is sandy towards the top. The surficial soil is mottled gray and brick red.

The west fork of Harmon creek, also called Penitentiary branch, heads at Huntsville, where there are good exposures of Fleming clays.

Near the State Farm and on the Midway road 1½ miles northwest of Huntsville, the Fleming consists of light green structureless clay with white calcareous nodules, local indurations of light gray sandstone, and local indurations of light yellowish-green clay with or without calcareous nodules. The clay weathers to russet-brown. The sandstone locally has opaline cement. About one-half mile north is the folowing section:

1. Black land soil with calcareous nodules ....1-2 ft.
2. Fuller's Earth containing very little grit, but a large number of calcareous nodules. Varies in color from cream at the base to light dirty green at top..........................15 ft.
3. Light brownish-drab or cream-colored plastic clay.......... 3 ft.

This section is near the base of the Fleming, although what is probably Fleming is found on this same Midway road about 3½ miles northwest of Huntsville.

GRIMES COUNTY SECTION

On the Madisonville branch of the International & Great Northern Railway the lowermost Fleming is exposed in the cut at Mile Post 14 (14 miles northeast of Navasota) where there is 5 feet of green sandy clay, very poorly laminated and with calcareous cemented nodules of sandstone. All of the nodules were small save one, which was very irregular in shape, resembling the top roots of a tree and 4 feet in length. At the south end of the cut is the characteristic russet-brown weathered soil of the Fleming.

One-third mile south 2 feet of light gray friable sandstone at a lower level than the Fleming mentioned above may be uppermost Corrigan. Two-thirds of a mile north of Anderson there is a total thickness of 4 feet of gray friable sandstone in the Fleming. These are merely locally indurated blocks. Two hundred yards north of the Anderson station there is more of this sandstone, but here the concretions are more rounded and possess no appearance of bedding. The elevation of Anderson Court House is 368 feet, according to the United States Geological Survey.

From Anderson to Navasota the railroad passes over Fleming, mainly clays, but locally with gray brown sands and sandstone. Seven miles northeast of Navasota and one-half mile east of Becker, on this railroad, flat topped mesas, capped by sandstone and very arenaceous limestone begin and continue nearly all the way to Navasota. These are entirely to the south and east of the track and rise about 100 feet above the track level. The Fleming in this vicinity consists of the following materials: (1) sands of all texture from the finest up to coarse grit or fine conglomerate, (2) brown and dirty green clays with calcareous nodules; (3) very arenaceous thin and irregularly bedded concretionary limestone; (4) clay ball conglomerate in a coarse sand matrix. These materials are either channel or littoral deposits. Mammalian bones are found in a layer of coarse grit or fine conglomerate. They are fragmentary, sometimes water worn, and are associated with rolled Cretaceous fossils. Petrified wood, differing from that of the older formations in being less consolidated, lighter in weight and duller in lustre, is found with the bones and shells. Fresh water *Unios* are found in abundance in the clays between the 3rd and 4th mile posts of the Madisonville branch in shallow gullies just to the east of the right of way. The bones are found in the deeper gullies to the east of the second mile post.

South of Navasota the Fleming continues to 1½ miles beyond Crooks, where the Lafayette begins, the uppermost Fleming being made up of dirty green clays with white calcareous nodules. West of this it continues southward and is exposed at the Houston & Texas Central Railroad crossing of Clear creek, just east of Hempstead, where it has the appearance of the Lagarto of the Nueces section and, like it, carries manganese as fragments of wad.

Of the fossils collected from this vicinity, Dr. Matthew makes the following statement:

349. Two and one-fourth miles north of Navasota.

"*Merychippus,* small species, cf. *M. seversus,* but probably not identical, upper molar and fragments of foot bones.

"Rhinoceros, cf. *Aphelops,* fragments of teeth, head of radius.

Indicated age, Miocene.

"Camelid, cf. *Protolabis* or *Procamelus,* fragment lower molar,, astragalus, navicular, unciform, fragments of foot bones, ? symphysis of jaw.

Indicated age, Miocene or Pliocene.

"Testudo, large species, carapace fragments.

"Crocodilian, fragments of skull.

Indicated age, Middle Miocene, but Upper Miocene or Lower Pliocene is not excluded.

"General conclusions: Fauna of Navasota and Cold Springs localities appears to be the same. It 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 mostly 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."

So far as reported, no vertebrate fossils have been found in the Fleming which are referable to the Blanco or other later Pliocene horizon.

The horizon from which the Navasota fossils were taken and that of the Burkeville fossils are similarly related to the Corrigan-Fleming contact and are near the present surficial base of the Fleming beds. The Coldsprings horizon is much higher and is in the upper half of the Fleming. It would, therefore, appear that the base and even the middle of the Fleming west of the Neches is older than the base of the Fleming east of that stream.

BRAZOS RIVER SECTION

On the Brazos river we seem to have the meeting point of the eastern and western phases of the Neocene, and in Hidalgo bluff we find overlying the Corrigan, beds which seem clearly referable to the Fleming, and others that are characteristically Oakville.

OAKVILLE

General Statement

The deposits at the type locality on the Nueces river are those of rapid currents of shallow water, grits and coarse sand, cross-bedded, with some beds of clay, but oftener with balls, nodules or lenses of clay imbedded in the grit. Some of the sand forms a sand-rock which is apparently firm and hard, but much of it is so feebly coherent as to fall apart on a slight blow of the hammer. Local beds of conglomerate occur.

Only a few fossils have so far been found in these beds, but such are determinable—*Protohippus medius,* Cope; *P. perditus,* Leidy; *P. placidus,* Leidy; *Aphelops meridianus,* Leidy, etc.—are sufficient to determine its age as Loup Fork.

In their eastern extension the base of the Oakville is marked by its conglomerate of rolled Cretaceous fossils, oysters, gryphaea and other bivalves, sometimes unbroken but often ground almost to sand.

BRAZOS RIVER SECTION

On the Brazos the Oakville, or basal divsion, consists mostly of soft sandstones and sands which are coarse, gritty, angular grained. These are sometimes laminated and regularly bedded, at others fine-grained and cross-bedded, somewhat lenticular, and often badly contorted, slightly calcareous, yellow to gray colored. In places they carry small white clay pockets and pockets of yellow to grayish white clay. Streaks or lentils of gravel occur throughout the beds. The gravel is usually small, not more than an inch in diameter at any place, but is usually much finer. It may be made up of quartz and chert pebbles, or of rolled Cretaceous shells. The lenticular beds are very irregular in structure and texture, showing the sorting of water action. At one end these beds may be fine sand, which is gradually replaced by fine gravel towards the other, or both ends may be sand, while gravel occupies the center of the lens. These lenses are frequently partly laminated, but the laminae are not regular, being often wedge shaped and of different texture, the coarser and finer material intergrading with each other. Towards the base the beds appear, so far as seen, to be more regular in their texture, hard, close grained and quartzitic in places and interbedded with a bluish colored clay. The quartzitic phase of these lower beds is not uniform but usually interrupted, fine sands often occupying large spaces between the quartzite portions.

These beds present the appearance of having been deposited in rather shallow, turbulent waters, such as might occur along an open coast line subject to violent storms or active tidal work. Or, they may have been deposited in stream channels where the waters have been intermittently rapid and slow. They appear to be mostly of fresh water origin.

Kelley's section of Hidalgo bluff is as follows:

Oakville:

1. Interbedded sandstone and clay, with loose sands. The sandstone ranges from very fine grained to coarse, is massive in one place and laminated in another. There is no regularity in the beds along their horizontal extension and falls have obscured the vertical section in places. This rock is characterized by the following points: It is light gray to yellow in color, generally coarse, beds 2″ to 6″ thick, well indurated when exposed to the air. It forms the caprock of the bluff ....29 ft.
2. Dirty yellow or grayish clay, very massive. Weathering to badland forms. No nodules were found in this member, but the clay is highly charged with lime................16 ft.
3. Loose sand, medium-grained, with several lenses of sandstone exposed in a small area. These lenses have a parallel arrangement, the long axis extending east and west. Rolled Cretaceous fossils were noted and one bone fragment collected on the surface ....11 ft.
4. Clay with lime nodules. Color dirty yellow to gray. Local lenses of reddish-yellow sand. The clay is otherwise massive ....17 ft.
5. Coarse, loose sand capped with 6 inches of indurated sandstone. Rolled Cretaceous fossils and fragments of silicified

wood are present, but no vertebrate remains were noted. The base of the sand carries enough pebbles to constitute a conglomerate ..... 5 ft.

6. Cross-bedded sandstone ranging from a conglomerate with pebbles of sandstone and clay to fine sand. Color gray to yellow ..... 26 ft.
7. A coquina sand formed of small fragments of shell, little or no cement or fine sand. Would make good road material for surface. Color white to gray. Rolled Cretaceous fossils noted ..... 5 ft.

Fleming:

8. Fine grained sandy clay, colored buff or dirty yellow. The material stands in vertical faces along gullies..... 20 ft.
9. Massive light bluish gray clay with streaks and nodules of lime. The interval is so covered by slumping that it is impossible to give a detailed section. The base is less limy than the upper part ..... 54 ft.

Corrigan:[1]

10. Massive clay, slightly sandy with root casts, color dirty gray to yellow. Will not effervesce with hydrochloric acid. Very similar in all other respects to the overlying Fleming ..... 15ft.
11. Sand cemented with a clayey material. The color is a dirty yellow or buff. Casts of roots and balls of clay were noted. The lower two feet of this section is honeycombed with worm holes. This same zone is noted under K-24 at Hidalgo Falls ..... 10 ft.
12. A very complexly bedded sandstone with no quartzite. Color same as above. Grain medium to coarse. A bed of clay 6-inches thick divides 12 and 13 ..... 16 ft.
13. Corrigan sandstone containing lenses of quartzite. Massive to thin-bedded with marked cross-bedding. The color is gray to reddish-brown. Grain medium to coarse..... 22 ft.

There is a marked difference in the exposure at the south and north ends of the bluff. Beds were found in the north end which are identical with beds found just north of Erwin, Grimes County, but these do not outcrop in the south end of the bluff.

East of Hidalgo bluff about half a mile another bluff shows

[1] The Corrigan is considered to be limited by the lime test in separating it from the overlying Fleming.

the Corrigan-Fleming contact with what is probably a representative of the Oakville overlying it.

The entire section as exposed here is as follows:

Oakville:

1. At top the bluff face shows about 80 feet of interbedded clay and sand with some beds of sandstone, the entire section being highly calcareous. Bone fragments may be found in the sands, but so far have not been taken from the clay or sandstone ....80 ft.
2. Coarse loose sand, conglomeritic at the base. The sand is capped with 6-inches of well indurated sandstone. The sand shows marked cross-bedding. Rolled Cretaceous fossils were noted, but no bone fragments were present.... 5 ft.
3. Coquina sand composed of comminuted shell fragments, rolled Cretaceous fossils are present in plenty and a few bone fragments were noted. The rock falls to pieces under the hammer, and the weathered parts can be crushed in the hand. Color dirty white .... 5 ft.
4. Interbedded clay and sand. The sand is fine-grained, locally indurated and stands in vertical faces due perhaps to some clay being present ....15 ft.

Contact—Conformable?

Fleming:

5. Massive clay, blue-gray in color, carrying many calcareous nodules. No fossils were noted in this interval..........50 ft.

Corrigan:

6. Sandy clay, or sandstone, cemented with clay. This rock fractures under the hammer into small cuboidal forms showing the effect of the clay content. One zone shows many worm-borings, with oblate cross-section. Color is yellow to greenish yellow ....15 ft.
7. Thin flaggy sandstone, highly cross-bedded and lenticular in places. The color is dirty white. No opalized wood and very few fragments or pebbles of clay.......... ....16 ft.
8. Interbedded quartzite and sandstone, grayish brown in color. 4 ft.

Beginning at the top of No. 3 there is a marked change in the nature of the sediments present. Sand and sandstone become more plentiful as we go up in the series, the Cretaceous fossils are more plentiful and better preserved, and bone fragments are increasingly abundant.

On the Brazos river near Old Washington a section shows:

1.	Altered brown sandy loam	5 f .
2.	Bluish-gray sand showing lines of stratification in places	1 to 2 ft
3.	Indurated gray sand with pockets of white clay	4 ft.
4.	Clay	½ to 1 ft.
5.	Coarse gray sand	1 ft.
6.	Sandy clay	1 ft.
7.	Fine bluish gray sand	4 ft.
8.	White clay in pockets	2 to 6 in.
9.	Gray sand and sandstone	3 ft.
10.	Clay	6 in.
11.	Coarse angular sand with vertebrate fossils	10 ft.
12.	Gray sandy clay	1½ ft.
13.	Sandstone with streaks of clay to water	3 ft.

In digging a well at Old Washington a piece of a jaw and teeth were found in the sand No. 11 of this section. This is Oakville.

It was from similar beds in this vicinity that the collection of vertebrate fossils was made on which Shumard based his statement of the discovery of an extensive Miocene formation in Texas[1]:

"The Texan strata consist of calcareous and siliceous sandstone, and white, pinkish and grayish siliceous and calcareous marls. The calcareous beds are often almost wholly composed of finely comminuted and water worn 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 ranging from 20 to 60 feet below the surface, and consist of genera closely allied to, or identical with, Titanotherium, Rhinoceros, Equus and Crocodiles."

The Fleming beds occurring in these Brazos river exposures belong to the basal horizons as found at Coldsprings and Navasota and these, as has been shown, are probably of Middle Miocene age. Succeeding them we have, in place of the

[1] Trans. Academy Science, St. Louis, Vol. 2, p. 140, 1868.

Burkeville beds with brackish water fauna, such as occur in the Sabine section, the Oakville beds of Southwest Texas with a vertebrate fauna of Loup Fork age. The stratigraphic equivalence of the Oakville and Burkeville is, therefore, indicated, although the two groups of deposits may not, as a whole, cover an identical time interval

LAPARA

General Statement

The close resemblance, both in texture and structure, of the Oakville and Lapara formations makes it exceedingly difficult at times to say which is Oakville and which Lapara. The Oakville deposits have been described as those of rapid currents of shallow water, chiefly grits, coarse sand, cross-bedded, with some beds of clay, but oftener with balls, nodules or lenses of clay interbedded in the grit. Some of the sands form a sand-rock. Local beds of conglomerate occur. The description of the Lapara corresponds to this very closely. This has been described as sands and clays interbedded and cross-bedded. The sands are coarse and sharp, often forming grits and including pebbles of clay and calcareous concretions. The clays are jointed and parti-colored, light red, green, etc., and in some localities appear as a conglomerate of clay pebbles. Fragments of bone are common in them, but they are so worn as to prevent recognition[1]. Nowhere throughout the whole area under consideration are these Lapara sands in a mappable condition. While it may be said they are present at many localities, they occur only in very small areal patches or within the limits of a vertical section in which they are often overlaid by sands and gravels of a later age, or are overlain by the clays of the succeeding Lagarto.

Throughout the eastern portion a number of Unios are found, together with a number of pieces of bone, but these bones are usually in such comminuted fragments that no identification is possible. The presence of Unios would appear to indicate that a portion of these beds at least were of fresh

[1] Dumble, Journal of Geology, September-October, 1894, p. 560.

water origin. Fragments of bone are common in the beds on the Nueces but they are often so worn as to prevent recognition. The fossils collected there were submitted to Prof. Cope, who pronounced the horizon to be Blanco, and states that nothing from either locality indicates a horizon as low as Loup Fork.

LAGARTO

General Statement

The Lagarto beds of the Nueces were described as a series of sands and clays of a different character from the Lapara, and overlying them. These beds comprise light colored clays —lilac, lavender, sea-green, greenish-brown, and mottlings of these colors, jointed and showing many slips. In places the upper portion contains a considerable amount of sand, gravel, and lime, and the change in a single stratum from one kind of rock to another takes place within a very few feet. Where the limestone or calcareous sandstone caps the clays, strings of limestones extend downwards into them for a distance of six or eight feet. The clays contain quantities of semi-crystalline pebbles with manganese dendritions, and indeed, manganese appears to be one of the characteristics of the clay wherever found. The upper portion of the beds is usually a sandstone. No fossils have been found in them[1].

Although somewhat changeable in some localities, the general description of the Brazos Lagarto may be given as heavy deposits of clay. These clays are brown, weathering snuff colored, yellow, blue and sometimes gray. The general structure appears to be massive, but when dry they break into small blocks. They are all highly calcareous, in places showing nodules of lime, particularly in the darker colored bands. In the yellow, the lime is completely disseminated throughout the whole mass. At irregular intervals, particularly in the yellow colored clays, we find thin seams of a fine-grained more or less laminated sandstone. These seams are rarely more than eight inches to a foot thick, and in places not very continuous. These sandstone bands lie usually from ten to twenty

[1] Dumble, Journal of Geology, September-October, 1894, p. 560.

feet apart, but are somewhat closer at the base of the clays These sandstones also partake of the calcareous nature of the clay in which they are enclosed.

There appears to have been a considerable time interval in this region between the deposition of the uppermost Lapara beds and the succeeding Lagarto. These two are totally dissimilar to each other. The Lagarto is essentially a clay deposition, evidently laid down in much deeper water carrying a great amount of lime. The waters from these beds are usually slightly saline in their nature. On the other hand, the Lapara is essentially a sand, which, with its vertebrate remains and Unio and fresh water shells must have been laid down under fresh or brackish water conditions, and is evidently a coastal or lagunal beach formation. The Lapara appears to have been considerably eroded before the deposition of the overlying Lagarto and the Lagarto itself appears to have been highly eroded before the deposition of the overlying gravels and sands. In some localities these Lagarto clays appear undulating or wavy, but whether this is due to erosion and rounding of the remaining portions of the surface has not as yet been satisfactorily explained.

These clays appear as a wide belt extending from the Brazos river westward to and beyond the Colorado river. They go much farther east than the Brazos, as they tie up with the blue calcareous clays seen south of Navasota and in the vicinity of Howth. They also appear on the eastern side of this river in the neighborhood of Hempstead. A section on the Brenham-Hempstead road between Hempstead and the river shows:

Lafayette:
Lagarto:

1.	Dark soil	1 ft.
2.	Yellowish-brown sand with pebbles	5 ft.
3.	Yellow clay with limy concretions	3 ft.
4.	Gray, soft sandstone pitted and water worn to bed of creek..	8 ft.

On the western side of the Brazos these clays are divided into blue and brownish clay with nodules of lime forming the upper division, and a yellow clay with streaks of sandstone and the lime disseminated through the whole mass forming the lower division. Nodules of lime are rare in this lower division. Broken sandstones, or thin flat bowlders of lenticular form, appear in the upper blue clay, but these, while occupying a definite horizon, are by no means plentiful. The sandstones in the lower yellow clays, while irregular as to their longitudinal extent, are much better developed than those in the blue.

The equivalence of the Lagarto to some portion of the Fleming found in the vicinity of Woodville has been suggested and is considered probable but there is at this time no means of positively determining this.

LAFAYETTE

This name, which was agreed on by Hilgard and McGee to replace the older name of Orange Sands, is here used for those deposits of gravels, sands, and clays often of characteristic orange color, which occupy the belt between the Fleming to the north and the Coast Clays on the south, between the Sabine and the Brazos, their stratigraphic position being between the two formations named. To the northward of this main belt the continuation of these deposits are found in the uplands overlying the older deposits as a mantle and are there usually characterized by the presence of gravel foreign to the sediments which they overlie. Other deposits are found within the upland area which are of the same color and more or less of same lithologic character, except that the gravels are wanting in them. Some of these are separated from the older sediments by an erosion interval while others seem to grade gradually downward into the underlying beds. These may, but probably do not, belong to the Lafayette.

Character and Deposition.

The materials of the Lafayette are primarily sands and gravel of varying degrees of coarseness, with variable amounts of clay, locally pure and lying in thin layers, but, more often, clays mixed with sands. Graduations from pure clays into pure sands through all intermediate stages of sandy clays and clayey sands are met with, but the larger part of the deposits are of sands and clays mixed in various proportions.

Deposits, which can be referred with certainty to the Lafayette, are practically never well stratified and seldom well assorted. Cross-bedding and pockety structures are common. In many places the bedding is irregular and wavy, exhibiting a structure resembling minor intra-stratal crumbling as is seen often in sub-aerial and lacustral sediments. This crumbling is seldom recognized except when thin layers of clays are interbedded with sandy materials. Gravels, when found, are either unsorted and unstratified, or are found in pockets in the clays or sands, or else exhibit rude stratification often in thin layers running out into the other materials, in some places there being but single lines of pebbles running out into the clays and sands.

In the gravel is found quartz, chert, igneous rocks and silicified wood. Concretions of limonite varying in size from that of small shot to masses several feet across are common. Gravels, sand, and clays are often cemented by limonite, derived either from process of secondary precipitation or from chalybeate springs which deposit bog iron ore.

The color of these deposits is very distinctive. The unaltered body color is red of various shades from orange to dark brick or Indian red. The purer clay portions are light blue or gray but the clays as noted above are subordinate in amount. The surface zone is frequently leached a lighter color than the underlying less weathered portions. Mottlings of gray and red are very characteristic of the clayey sands. When such mottling is encountered the gray shades are confined to more clayey portions, while the sandier portions are red. This is, perhaps, equivalent to saying that the more pervious materials have their contained iron in the oxidized state and that the less porous contain iron in the reduced state, probably in the form of carbonate. Thin lenses of clay are gray in color when the interbedded sands are red. Balls of clay are gray and the enclosing sands red in many localities.

Whether the red color was originally possessed by the sediments before being deposited in their present situations or is secondary and subsequent to their deposition is a perplexing question. It may be that part of it is original and part is secondary, for we find residual soils of such older formations as the Wilcox and the Cook's Mountain that are as red as the typical Lafayette and the mottling would suggest that a part at least of the coloration is secondary, since in the mottled beds it is apparently only the more porous portions which have the red color. Roots of plants penetrating the "Lafayette" materials decolorize the red beds, changing the iron back into the carbonate form. It is difficult to see how the red color can be assumed to be primary in that portion of the "Lafayette" which is undoubtedly transported detritus, for the red color is merely a surface coating of the individual grains, and this would be worn off during any considerable transportation.

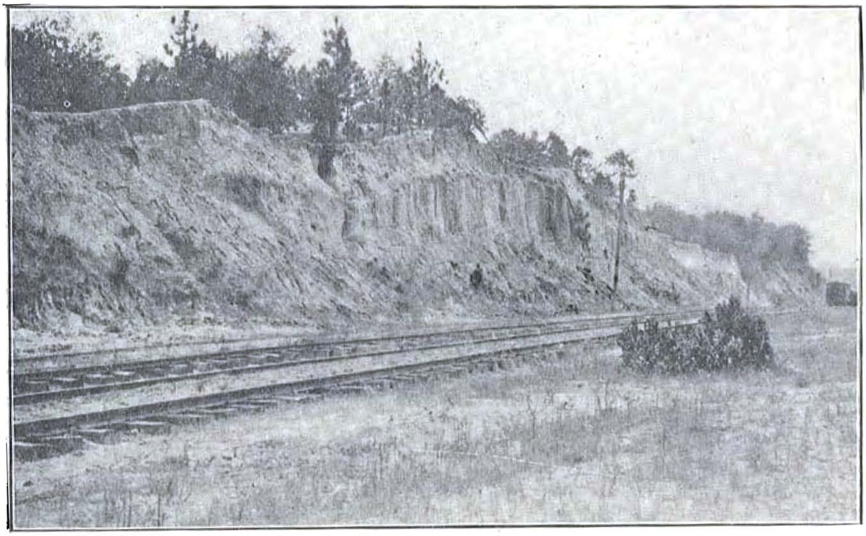
The formation of red residual soils at the present time in the east Texas region would seem to indicate that the "Lafayette" sediments were laid down under climatic conditions essentially similar to those of the present.

The Lafayette gravels were deposited on a peneplained surface. In places, as shown by the unconformity between these gravels and the underlying bed rock formations on the higher hilltops and divides, the peneplained surface was produced by denudation. In other places the peneplain may have been formed by deposition. That monadnocks of more resistant rock persisted above the general peneplain surface is demonstrated by the fact that hills and ridges like those of Irona, Sabine county, Mount Selman and other prominences near Rusk were never covered by the gravels.

While it is possible that the Lafayette might have been laid down in a retreating sea to the littoral of which a constant supply of proper sediment was furnished by fluviatile agencies there is an absolute lack of any evidence of this and the character of the beds rather indicates that the deposition was, for the most part at least, subaerial and the result of fluviatile action.

Details of Sections

On the Sabine we find in the top of Sabinetown bluff a vestige of the Lafayette depositional peneplain, the composition of which has already been given in connection with the Claiborne



LAFAYETTE FORMATION.
View near Colmesneil.

section below McClanahan's shoals. This shows a basal gravel made up of flint and quartz pebbles from the size of a pea to an inch in diameter overlain by structureless clayey sand in mottlings of bluish-gray, reddish-brown, red and buff colors. The quartz pebbles are more abundant here than in similar deposits west of the Palaguache.

Going westward from the Sabine to Milam, Geneva and San Augustine there is found a great thickness of Lafayette sand, often with ferruginous pebbles. In places the orange or red sand is interbedded with thin leaves of gray sandy clay.

Two and a half miles south-southwest of Geneva in the valley of Borregas creek, which is the principal tributary of the Palaguache, there is another portion of the Lafayette depositional terrace consisting of three large remnants the tops of which cover several acres. These are made up of typical Orange Sands carrying large boulders of ferruginous conglomerate.

The Lafayette has a thickness of 20 feet and probably more between Price Creek and Calcote postoffice, where the superficial 3 feet is dark red and the underlying material orange-red. It is characterized by the presence of many fine ferruginous pebbles and by cross-bedding. It is sandy but has the property of standing up in perpendicular gullies 10 feet or more in height. The country is flat and most likely is a remnant of the original Lafayette depositional peneplain.

The Lafayette under the west end of the bridge over the Attoyac is partially stratified and cross-bedded. Thin partings of gray clay separate massive and imperfectly laminated light-gray coarse loose sands stained yellowish-brown on the surface. Thin sheets and laminated layers of ferruginous-cemented sand are seen. The thickness of this section is 10 feet. A spring issues at its base and it is capped with soft ferruginous-cemented dark brown conglomerate of ferruginous pebbles.

The Lafayette in the vicinity of Arenosa postoffice consists of deep sand leached at the surface, but reddish underneath. There is much ferruginous conglomerate, sandstone and pebbles in the Lafayette in this vicinity.

SANTA FE RY. SECTION

Between San Agustine and Jasper the Lafayette is found in many cuts, overlying the Marine, Jackson, Corrigan and Fleming in turn. The exposures through the level Jackson country are but few. They are more numerous in the Corrigan and well shown in the Fleming.

The unconformity between the Catahoula and Lafayette is well shown in the first cut north of Mile Post 85. At the base is 7 ft. of light gray sandy Catahoula clay. Above lies 10 feet of cross-bedded Lafayette. The contact between the two is irregular, small lenses and ridges of the Catahoula projecting up into the Lafayette. The latter is light brick-red in color.

On and near the top of the ridge, near Horton siding there are bodies of Lafayette ferruginous conglomerate. These are found at various places from north of Mile Post 81 to 1-5 mile south, mostly in rather thin layers some of which are laminated with thin layers of nearly pure limonite adhering to the thicker layers of grit or conglomerate. Some of the ferruginous conglomerate is concretionary. At the summit, about 400 yards north of Horton, is a cut 20 feet deep in the Lafayette, which here is cross-bedded, with a minor amount of gravel, and small balls and lenses of a light purplish clay running as curved laminae or as cross-beds. A few fragments of silicified wood, some of which are larger portions of large trunks, may have been derived from the Catahoula, or may belong properly to the Lafayette. The Lafayette sand in many places is coarse and angular like that of the Catahoula. The presence of pebbles indicates that at least some of the Lafayette was not derived from the underlying Catahoula, but was transported from some other places, and therefore that the Catahoula could not have formed a high ridge above the general level at the time the Lafayette was deposited, unless such ridge finally came to be completely covered by Lafayette sediments.

Some of the silicified wood may really be indigenous to the Lafayette. A number of the fragments are large and are not rounded as if rolled or water-worn but are splintered with sharp fractures.

A mile and a half north of Jasper the road enters a gently rolling country covered by Lafayette with its usual characteristics of composition and structure. Occasionally some Lafayette pebbles are encountered in the swampy area. Irregular masses of small pebbles showing little evidence of sorting or stratification are embedded in a coarse cross-bedded sand. The pebbles are subangular to well rounded, average about an inch in diameter, are arranged with their longer axis and flat sides in a horizontal direction, and are composed of quartz, chert, quartzite, some igneous and metamorphic rock, mainly fine-grained, and occasionally a pebble of ferruginous-cemented sandstone and "iron-ore." The surface one foot or more of the ten feet exposed in this cut is leached light brownish gray and the lower portion has light shades of yellowish-red with mottling between an irregular network of dark red and various shades of gray, the latter color being present especially where the composition is clayey.

ANGELINA-NECHES SECTION

In Jasper county east of Bevilport Ferry on the Angelina, the second bottom terrace is nearly 1½ miles in width. Its riverward limit is sharply defined from the first bottom or present river plain, while its bluffward limit is obscure and merges gradually into the upland. Between the eastward limit of the Port Hudson terrace and the town of Jasper the sole surface rock is the Lafayette with its usual composition and color. Pockets of quartzose and cherty gravel are numerous in the Lafayette in the neighborhood, and along the Jasper-Bevilport road there are cuts of ten feet or more in thickness. The depositional peneplain of the Lafayette, so well shown on top of the bluff 140 feet above the Neches river at Town bluff, is also well developed in the vicinity of Jasper and between that town and Bevilport and Bohler's ferries in broad flat uplands separated by rather deep and sharp valleys.

In the angle between the confluence of the two rivers it is difficult to separate Lafayette from terrace deposits. Here the original Lafayette surface was reduced to a rolling one of small differential relief by the time the terrace epoch came on and there is no abrupt break in profile at the line of contact of the two formations.

There are high bluffs of 100 feet or more just east of the Attoyac on the Huntington-Hemphill road. These bluffs are capped by Lafayette ferruginous conglomerate, here overlying the Yegua, but farther south on the Angelina bluffs, near Old Zana postoffice (Caddell of Veatch's map) it caps the Jackson, while on the Gulf, Colorado & Santa Fe Railroad between Jasper and Horton, Jasper county, it rests upon the Catahoula. The materials on the Attoyac bluffs are quartz and chert, subangular to rounded, and silicified wood, which is angular. The cement is dark brown limonite and is locally quite hard.

Town bluff on the eastern boundary of the James Perkins and Wesley W. Hanks grants, central eastern Tyler county, rises 140 feet above the low water-level of the Neches river. Its top, capped with Lafayette, is very flat and has evidently suffered no erosion since the time of the formation of the Lafayette, depositional peneplain. The thickness of the Lafayette capping the bluff is approximately 40 feet. It is mottled, gravelly, clayey sand, with the surface one to four feet leached buff or gray sand and the underlying beds various shades of red with the lowest portions of an Indian red shade. At the edge of the buff cirque-like gullies or "gulfs", blunt-headed and perpendicular-walled or overhanging, often have depths at their very heads of from 20 to 40 feet. This property of the Lafayette of forming perpendicular or overhanging cliffs is partly because of case-hardening, caused by the redeposition of iron salts, leached from its body, on surface exposures, possibly partly because of the deposition of secondary silica, partly because of the Lafayette being clays or clayey sands which gives it tenacity and plasticity and probably partly because of the compact packing together of the constituent materials.

Rejuvenation and deforestation, jointly or separately, have been responsible for the formation of these deep, steep and narrow gullies in the unconsolidated clays and sands of the Corrigan, Fleming, Lafayette, Port Hudson, and the later superficial accumulations. Black land prairies, never covered by timber growth, areas from which most of the timber has been cut, and cultivated or abandoned cleared fields are places where gullies have been formed within the memory of man and where they are still forming. They are also well developed in railway cuts and fills.

TEXAS & NEW ORLEANS RAILROAD SECTION

South of Rockland and just north of Bridge 99-B there is a light gray sand and clay locally case-hardened and having a strong taste of alum. At the cut just north of Bridge 99-C there is at the base one foot of friable fine clayey sandstone, slightly case-hardened, overlain by four feet of loose shelly clay. The stratigraphic position of this member is not known. Beds lithologically similar are known to overlie all formations from the Yegua to and including the Fleming and to be overlain by the Lafayette. It may belong either to the underlying formation, or it may be later, representing the Oakville or some other formation, or it may belong to the Lafayette, being a residually derived portion of that formation.

From here the Lafayette forms the surface to Colmesneil.

In the cut immediately north of Cima siding the Lafayette contains thin layers of laminated earthly iron oxide and perhaps carbonate. Here the Lafayette sands are cross bedded. The thin bands of dark brown, fine-grained, compact iron minerals are irregular in their distribution and do not run parallel to any one plane, but are rather irregularly waving beds not always in the horizontal plane. The structure of the iron minerals is botryoidal, mamillary, or laminated, often enclosing gravel or sand when nearest the pure state, or it may form only a blackish or reddish cementing material for the sand.

The lower portion of the section, below the iron-bearing member, is cross-bedded sand often with a purplish red tinge on the surface. In places it is mottled and in all respects resembles the sand above the iron-bearing member. This upper bed is mottled red and gray and contains small brown concretions of sand cemented by iron oxide. The color of this bed is predominantly orange.

Between these two is the laminated iron-bearing member occupying an irregular zone from 3 inches to 3 feet in width, the individual layers averaging from 1 to 2 inches in thickness and being separated from each other by mottled sands like those above and below the iron-bearing member. A concretion 3 feet in length and with regular surface was noted.

In the cut and fill at Cima siding there is a 30 foot section of Lafayette case-hardened clayey sand, standing in perpendicular walls. The surface leached zone, yellow buff below to light creamy gray on the surface, is from 1 to 6 feet thick. The underlying sand is dark brick-red. Some cross-bedding and mottling is noted in the upper portion.

The Lafayette is well exposed between the top of the grade at Cima siding and Colmesneil. The gravel is arranged in patches of small size or rather uniformly distributed for short distances through the clayey sand. It is in brief, quite irregular in its distribution and amount. Long deep railway cuts will be seen that are free from gravel and again there may be local lenses and pockets almost entirely made up of gravel. Or, it may be sparsely distributed or arranged along lines of stratification. The pebbles are rounded or subangular and are principally quartz, chert, and silicified wood.

Iron-sand concretions, representing local secondary deposition of iron, and varying in size from that of a pea up to irregular friable masses of several square feet are locally found. These generally have a darker shade of red than their surroundings.

Sometimes tilted layers, simulating dip and parallel with each other, are encountered, in some places their structure showing a local unconformity with the underlying or overlying structureless or imperfectly bedded Lafayette. These may represent channel deposits.

In the region between the Texas & New Orleans and Houston, East & West Texas Railroads the surficial gravel and unconsolidated structureless reddish clays and sands capping the tops and sides of elevations are referred to the Lafayette or Orange sand. Overlying and contiguous to the outcrops of the Marine formation the gravels contain many of the ferruginous sandstone concretions of the Marine but elsewhere the gravels are mainly round, subangular, or egg-shaped pebbles of quartz or acidic igneous rock, with here and there a fragment of metamorphic rock. The pebbles occur in great abundance near the confluence of the Bayou Attoyac and the Angelina river, both mantling the surface of the triangular shaped area between the streams and southeast of the Angelina between Warsaw and White City, Angelina county.

While many of the contacts between the Yegua and the Lafayette are unconformable one was found in a creek in northern Angelina county in which no unconformity appeared. The bluff is made up of alternating layers of gray and brown sands and chocolate clays belonging to the Yegua.

Overlying these beds without apparent unconformity is found the mottled surficial member. The lower 3 feet is a layer of brick-red loose sand with very small non-continuous disc-like streaks of very light gray clay. It is overlain by 4 feet of medium-indurated reddish brown on surface and yellowish-brown underneath, medium-grained, rather finely laminated sandstone. The upper 1 foot of this 4 feet is laminated, concretionary, and contorted very ferruginous sandstone with its least altered portions composed of thin seams of black iron 1¼ inches and less in thickness grading out into dark brown sandstone to yellowish-brown sand as leaching and oxidation gradually becomes more prevalent. The whole transition takes place generally in less than an inch.

HOUSTON, EAST & WEST TEXAS RAILWAY SECTION

The southernmost exposure north of the Angelina river on the line of the Houston, East & West Texas Railroad gives a section of about 20 feet of apparently horizontal strata. The lower portion of the section is made up of thinly laminated arenaceous chocolate-colored and drab shales containing leaves, among which were noted *Salix* and *Ficus* (?). These belong to the Nacogdoches.[1] Overlying the shales are Lafayette grayish structureless arenaceous clays, which, when exposed to surficial weathering, are generally mottled with streaks and blotches of bright brick-red. Interspersed with the clay layers are clayey sands, in general unconsolidated but locally cemented by ferruginous material, which, in common with the

[1] A fuller description of these beds was given in connection with the Nacogdoches beds.

clays, locally contain ferruginous concretions and small rounded pebbles coated with dark purplish iridescent iron oxide. When unaltered the clay and sand member is bluish-gray to buff in color, but, on weathering, its contained iron stains the rocks various shades of brown either in a uniform manner or in streaks and blotches which impart to the surface exposure a characteristic mottled appearance. The sands are fine in texture. The description of the sand and clay series with interbedded lenses of chocolate and drab shale, will serve as a general one for the uppermost series of beds exposed in southern Nacogdoches county, and as far south in Angelina county as a point half way between Platt siding and Manton station on the Texas & New Orleans railroad.

The Lafayette gradually looses its red color, becoming more grayish, as the distance from the outcrop of the ferruginous Marine group increases. There is also another notable change as one goes southward and that is in the constitution of the materials of the gravels. Before the Neches river is reached on the southward journey all pebbles of Marine ferruginous sandstone have disappeared and it is only the more resistant materials such as quartz, crystalline rock, chert and silicified wood, that remain. On the northwest corner of the J. M. Deane league a chert pebble with a Paleozoic fenestelloid bryozoan was noted.

At Cleveland, Liberty county, the reddish-colored Lafayette is exposed in low knolls of small extent which are inliers completely surrounded by Port Hudson. Similar inliers are found on the Houston, East & West Texas railroad from Shepherd to Splendora and the Lafayette probably extends some distance south of Splendora. A cut one-half mile north of Splendora shows 2½ feet of light buff fine sandy clay full of small rounded concretions containing a very small percentage of iron. The exposure is lightly mottled. At Mile Post 39 (1½ miles south of Nimrod) there is 4 or 5 feet of Lafayette, very faintly mottled and having small rounded pebbles of quartz and igneous rocks. This cut is on a low ridge just south of the San Jacinto river. Lafayette is found in a cut on a low hill one mile south of Cleveland as 6 feet of mottled gray and red clayey and gravelly sand. The gravel is fine and is almost entirely composed of fine rounded pebbles of brownish ferruginous sandstone. There are a very few pebbles of quartz.

In a flowing well at Gladstill, one-half mile south of Nimrod the following strata were encountered:

	Thickness Feet	Depth Feet
Surface soil	2	2
Red and yellow clay	8	10
Gravel and sand	12	22
Red clay	3	25
Sand and gravel	9	34
Yellow clay	12	46
Sand	19	65
Clay	6	71
Sand and gravel	17	88
Clay	9	97
Sand	8	105
Clay	7	112
Hard shale	18	130
Gumbo	9	139
Hard shale and sand	8	147
Sand and gravel	16	163
Rock	3	166
Gumbo	27	193
Red shale and sand	20	213
Rock	1	214
Gumbo	9	223
Sand	29	252
Rock and shale	13	265
Sand	18	283
Rock	1	284
Hard shale	14	298

The first 163 feet of this well section is Lafayette. Coarse brown sand and fine pebbles of Lafayette were found in the drillings scattered about the well.

In a well at Cleveland, 390 feet deep, an abundant supply of water is found which rises to within 5 feet of the surface. The Lafayette is about 150 feet thick in this well, giving it a southward dip between here and Nimrod of about 18½ feet per mile. Alternating layers of rock (probably sandstone) and softer material of the Fleming were found between 150 and 390 feet. The water stratum yielding the present supply was found at 350 feet.

Overlying the Yegua west of the Houston, East & West Texas railway the Lafayette is usually brown or orange colored ferruginous and gravelly sands underlain locally by shaly light brown clay with fragments of gray clay possible derived from the underlying Yegua. In places the sand carries small pellets of dark brown limonite concretions and at times is cemented with limonite. Cross-bedding occurs and occasionally very thin lenses of grayish clay are embedded in the sands.

There is a covering of Lafayette at Kennard Mill (Central Coal & Coke Company) and at the town of Ratcliff. Overlying the Yegua is 5 feet of cross-bedded sand, the unconsolidated portions reddish-brown in color with thin streaks and beds of more sonsolidated light gray sand. Overlying this is 4 feet of laminated brown clays and sands.

Roark's gravel pit is 3 miles north of Cleveland and about the some distance from the Gulf Colorado & Santa Fe and Houston, East & West Texas Railroad tracks. This gravel is fine and similar to that found at Coldsprings and Urbana. The gravel is mixed with coarse whitish sand. The Lafayette is exposed in a cut at Mile Post 53 on the Houston, East & West Texas Railway. Wells at Napier get a good supply of fresh water in sand and gravel at a depth of 65 feet. Gravel is also found on land belonging to C. B. Udell four miles southwest of Shepherd on the Evergreen road and also on adjoining land belonging to Mr. Bird. It has a coarse brown sand matrix, but will require prospecting to show its depth and areal extent. Gravel was noted at a place between 3 and 4 miles west of the Houston; East & West Texas Railway near Westcott and Normanville. There are also gravels on the surface at various places on the Shepherd-Everett road. Local deposits of gravel are found all the way between Shepherd, San Jacinto county and Willis, Montgomery county. A Lafayette ridge is followed by the road between Kelly's switch (Bareda) and Huntsville. It consists of fine deep-white sand and mottled red and gray clayey sand.

The high ridges in the vicinity of Coldsprings, San Jacinto county are covered with Lafayette sand and gravel, locally cemented with limonite into grit and conglomerate. The dividing ridge between the Trinity and San Jacinto drainages between Oakhurst and Coldsprings is covered with Lafayette gravel. The south bluffs of the Trinity valley, north of Camilla, San Jacinto county, are covered with coarse reddish and mottled Lafayette sand containing small fragments of whitish clays and petrified logs. The upper course of San Jacinto river in southern San Jacinto county is incised to a depth of 10 feet below the Lafayette surface. The Lafayette begins a short but undertermined distance south of Coldsprings and consists of the usual mottled sandy and gravelly facies. At the head of Town creek at Coldsprings there is fine very plastic sandy clay of a dark hematite-red color. Springs issue from the plane of contact between the Fleming and the Lafayette. Here the bluffs of Lafayette are from 35 to 50 feet in height recalling the "Gulf" of McGee.

INTERNATIONAL & GREAT NORTHERN RY. SECTION

On the International & Great Northern Railway there are similar occurrences of the Lafayette. Mottled red Lafayette sand with much gravel is found on the summit of the grade on the International & Great Northern Railway at Mile Post 78 in southern Walker county. Much Lafayette is found on the Huntsville branch of this railroad between Phelps and Huntsville.

In its more southerly exposures the Lafayette has flat, very gently rolling, often swampy surfaces. The southern limit of its outcrop can be distinguished from that of the adjoining coast clays by a low rise, with light undulations, but resembling, on the whole, a maturely dissected terrace. The Lafayette-Port Hudson contact on the International & Great Northern Railway is just north of Spring, approximately at the north line of Harris county.

West of the Trinity river outliers of Lafayette are more numerous where they overlap the Fleming than they are on the other formations. The materials of the Lafayette proper are finer-textured in the region of their outcrop between the areas of the Fleming and the Port Hudson (coast clays) than they are in the isolated outliers farther north. This decrease in coarseness is very gradual, but it is undoubtedly true in a general way. The contact between the Lafayette and Port Hudson is hard to define owing to the extensive overlap of the latter on the eroded surfaces of the former. At the west near the Brazos, where the country is more or less open the contact can be traced by the topography for the Port Hudson peneplain is succeeded by a very low rolling Lafayette country of appreciable, though slight, relief. To the eastward, however, the country is more thickly timbered and the tracing of the contact is more difficult.

On the International & Great Northern Railway, Madisonville branch, the southern limit of the Lafayette is at Willow, 34 miles from Houston and 11 miles northwest of Spring. The topography northeast of Willow is very gently rolling with undrained depressions. The stream gullies are sharp and 10 to 12 feet deep. Some of the Lafayette is very light buff or creamy clayey sand, mottled with red and with small ferruginous concretions.

On the Houston & Texas Central Railroad the first Lafayette is found at Mile Post 30 northwest of Houston. This is the site of the first appreciable rise from the coast prairie. To the westward the Sun Mounds are inliers of Lafayette in the Port Hudson. The more marked rolling topography begins between Mile Posts 39 and 40, just south of the south line of Waller county. The relief gradually increases northward. The northern line of the Lafayette is a short distance south of Howth.

There is a fine exposure of Lafayette sands on the Texas & Brazos Valley Railroad where it crosses the International & Great Northern Railway.

CLOSE OF NEOCENE

In this region the surface of the Lafayette shows considerable erosion prior to the deposition of the fossiliferous marls referred to the Equus beds horizon, which is supposedly basal Pleistocene, and it is involved in the diastrophic movements which preceded the deposition of the Port Hudson. For these reasons the Lafayette is here made the uppermost member of the Neocene, although it is sometimes referred to the Pleistocene or regarded as bridging the Pliocene and Pleistocene.

North of the Lafayette-Port Hudson contact, the amount of movement apparent is not very great and seems to have been simply a gradual regional elevation. To the seaward, although the surface is a great peneplain, drilling shows that the orogenic movements were intense before the deposition of the mantling clays. It indicates in fact that at the close of the Tertiary we had a repetition, perhaps on a somewhat grander scale, of the movements which accompanied the close of the Cretaceous.

As has been stated, the movement at end of Cretaceous time was sufficient to create the Cretaceous domes and the Sabine Peninsula through local elevation of the Upper Cretaceous sediments 2500 to 3000 feet. These elevations were all in the seaward margin of the Cretaceous land mass which in itself showed comparatively little change of level. These domes were almost without exception subsequently mantled by clays and sands of the Tertiary, which entirely masked their character and but for later erosion or the searching enquiry of the drill their presence might not have been suspected.

The same is true in great measure of the Coastal domes. Some few of them may now make themselves known by a slight elevation at the general surface, the Sun Mounds near Hockley and Damon Mound being the highest of them, but for the most part they are either little distinguishable above the general level of the prairies, or only found by drillng. The Sun mounds and Damon Mound, which are typical domes and rise from 70 to 100 feet above the prairie, are capped by Lafayette. Some of the buried domes also show beds of gravel which are properly referable to that formation. These buried domes are covered by variable thicknesses of the Coast clays, ranging from one hundred to several hundred feet, while between the domes we find as much as 2500 feet of materials referrable to the Coast clays of the Port Hudson. The irregularities of the substructure is therefore fully as great as in the case of the Cretaceous domes.

Possibly nothing could bring out the differential movements that have taken place in this coastal area since the Miocene deposition more clearly than the fact that while the Pliocene (?) brackish-water fauna which occurs at Burkeville 150 ft. above sea level is found in abundance at Terry, 66 miles south, at a depth of from 3,000 to 4,000 ft., the marine Miocene fauna which occurs at Saratoga at a depth of 1,000 ft. is only 2400 ft. deep at Galveston, 74 miles south of it.

It seems clear, therefore, that at the close of the Neocene the coastal area of east Texas was subject to extensive oscillation, and it is these movements rather than those of earlier date that are directly connected with the formation of the domes and folds found here.

There are a number of these Coastal Domes already known and they appear to occur in somewhat regular alignments along general northeast-southwest courses, which is approximately the direction of the chain of Cretaceous domes which has been mentioned.

That they are of orogenic origin is fully proven by their composition and by their relation to adjacent deposits. They are in all cases, so far as now known, composed of a core of salt or of gypsum or anhydrite (with which deposits of native sulphur are sometimes associated) which plugs have been forced up through beds of Miocene and later age. This relationship has been definitely shown to exist by the drilling done at Humble and similar domes.

The relation of the bodies of salt, gypsum, and sulphur of these domes to the surrounding sediments indicates that these masses have certainly penetrated 2,000 or 3,000 ft. of the sedimentary strata. The clays sands, and limestones immediately adjacent to or overlying them are tilted at comparatively high angles for this region, the surrounding sedimentaries dip away from them at lower angles, and beds or sills of salt and gypsum extend from the main mass out into the surrounding beds, as sometimes happens with plugs of basalt coming up through similar materials.

Up to this time basaltic matter has not been definitely proven to exist in connection with these domes. Its place is taken by the salt, gypsum and anhydrite. In connection with the close of the Eocene attention has been called to the probability of the accumulation of considerable deposits of these substances at that time. Salt becomes plastic at temperatures far below those necessary for the production of siliceous lavas and would lend itself much more readily to the work of filling any voids caused by crumpling or assisting such crumpling. Salt stocks of this character have long been recognized in the Carpathians and elsewhere in Europe.

In this connection, the following suggestions regarding the domes are made:

The domes are separable into two series: The Interior domes and the Coastal domes.

The bodies of salt found in connection with the Cretaceous domes were probably deposited during the Lower Cretaceous or the interval between the Lower and Upper Cretaceous and the uplift which formed the domes occurred at the close of the Cretaceous.

The salt of the Coastal domes was deposited at the end of the Eocene or beginning of the Oligocene and the movement which resulted in these domes took place at the end of the Tertiary.

The connection of the Coastal domes with the oil fields of the region is in some measure accidental.

The close association of the oil, gypsum, salt, and sulphur in some of the domes has naturally suggested the idea of a common origin or a close relatonship in origin, and this has been widely discussed. Were this true, the oil should be found in connection with all such domes. and such is not the case. We have oil pools where there is no dome and where no salt has been found, and we have numerous domes and bodies of salt, gypsum, and sulphur without any accumulations of oil.

CHAPTER X

QUARTERNARY

PLEISTOCENE

The Pleistocene of East Texas includes the river deposits of the inland belt belonging to the Columbia and their coastward continuation, the Coast clays or Port Hudson, which Kennedy called the Beaumont clays.

They rest unconformably on the Lafayette.

The Columbia phase embraces those deposits which form the second bottom terraces of the main streams. On the Sabine, Angelina, Neches and Trinity rivers they extend well toward heads of the streams. The upland deposits of this stage are of the character of the loess. At the base of these deposits there is usually a layer of gravel derived from the erosion of the Lafayette. The deposits themselves are clays and silts of various colors containing small limy concretions and some gravel. Shells of the Unio or fresh-water clam are found in them and blocks and logs of cypress, which are but little altered, together with the bones of the mammoth, horse, ground sloth, etc.

Nearing the coast these beds grade into clays of the Port Hudson. These are heavy clays of various colors with small lime concretions and local lenses of sand and sandy clays. In places cypress logs are found in these clays at considerable depth and shells, similar to those of the present bay shore, occur in them at places.

GENERAL CHARACTER

As one travels from north to south from Nacogdoches to Polk counties, he passes gradually from a region which is mostly bed rock upland to one that is mostly alluvial lowland.

The divides and interstream ridges of Polk county stand out as much promintoried peninsulas in the bottom lands of the creeks and ridges—the sea of their own debris. South of the Nechse-Trinity divide the southward sloping interstream ridges lie above the bottoms as partially sunken headlands on a submerged sea coast. Between the uplands and the bottom lands there is in most places a noticeably abrupt break, a break in the profile rather too sharp to be explained solely as brought about by the processes of an uninterrupted cycle of erosion. The bed rock formations are not sufficiently resistant to cause this break. The valleys are too broad to explain the almost continuous fringe of steep bluffs between the broad bottoms as entirely the product of lateral planation of meandering streams. There is a mature, in some cases even a youthful, topography of the upland areas with an extreme old age topography of the lowland areas. The topography is partially drowned. It is not all the product of one cycle of erosion or there would be more of a continuous, less perceptible, graduation between the divides and the stream courses. This apparently implies a former base level higher than the present and especially a rising of the base at a rate greater than the down-cutting of subaerial agencies. A former base level lower than a succeeding one, which was responsible for a differential relief greater than the present one between alluvial bottom and bed-rock divides is apparently implied. This epoch of raising of base level is the Columbia-Port Hudson.

ANGELINA-NECHES

In the upper portion of the Trewick's bluff, and comprising the whole of the exposures in Perigue and Carlisle bluffs, as well as the low knobs outcropping above the level of the "saline" crossed by the Angelina river one mile east of the Texas & New Orleans Railroad bridge over the river there is a hard conglomerate, with pebbles mainly of quartz and igneous rocks, and subordinately of ferruginous sandstone in a matrix of coarse sand grains, cemented by iron carbonate and iron oxide. The occurrence of this conglomerate in these bluffs together with the great amount of loose gravel found farther down the valley of the same river may indicate that we have here a formation somewhat similar to the Columbian of the southwestern Atlantic States derived from the surficial beds referred to the Lafayette and deposited by the Angelina during a former time of alluviation of its floodplain.

The upper limits of the river terraces (Port Hudson?) are hard to define in the triangular region between the Angelina and Neches rivers just above the junction of these two streams, because the upland is very low and only very moderately rolling and merges insensibly into the second bottoms. The second bottom can be distinguished from the first and lower bottom by its superior height and its covering of "piney woods" probably signifies better drainage than is possessed by the first bottom. But east of the Angelina, in Jasper county, east of Bevilport Ferry, the second bottom terrace is nearly 1½ miles in width. Its riverward limit is sharply defined from the first bottom or present river flood-plain, but its bluffward limit is obscure and merges gradually into the upland.

TRINITY RIVER

Three terraces, including the pesent flood-plain, are well developed on the Trinity, at Westmoreland and Clarke bluffs. The height of each will average probably close to 25 ft. The prairie level terraces ae still higher and there are traces of a still lower one being developed in the present flood-plain.

At Westmoreland bluff in western Houston county the second bottom alluvium overlying the Yegua is mottled grayish and rusty sand containing gravel with the usual ferruginous-cemented gravel layer at the base. The first bottom below this bluff is black waxy calcareous alluvium derived from the Cretaceous. It appears probable that the second bottom alluvium was laid down before the Trinity river had cut back into the Cretaceous.

Just to the west of the head of Spring creek, near Westmoreland bluff, a minor terrace level between the first and second bottom is noted in a poorly developed bench with its surface about 8 feet below that of the second bottom. It is narrow but has a distinct step downward from the second bottom and heads of gullies have cut back into it nearly to the second bottom. The total number of terraces at Westmoreland bluff is either five or six, five if the proirie level is not counted and six if it is counted. Of these, three or four are main terraces and two are minor terraces.

The remainder of the Spring creek exposures, near its head, are in brown sandy alluvium, containing Lafayette-derived pebbles. This gravel layer is almost universal at the base of the terrace alluvium along the Trinity river from Alabama bluff to Liberty county. The creek shortly comes to an end in a blunt-headed gully. Above the head of this gully is the usual vestige of an older valley with the gentler slopes and gradient of an older erosion sub-cycle.

The first and second bottoms are very well developed in the vicinity of Hyde's bluff. The second bottom soils are either brown sand or black sticky clayey laminae. The underlying material of the second bottom is dark brown with small white calcareous nodules. Underneath this subsoil layer the alluvium is light buff in color.

Negro creek which heads at Volga postoffice, shows some interesting exposures of terrace materials. The exposures near the head show 4 feet of light creamy-gray sandy clay with a very few white calcareous nodules. The lower portions of the creek's course show exposures in terrace material, one of which is 20 feet thick and composed of light gray, medium-grained sand, with very poor bedding. There are contained in it a few Lafayette-derived pebbles. It weathers to brick-red near the surface and locally is mottled. The upper one foot is leached to a brown color. At another exposure farther down the creek the base is very plastic slaty blue clay, cracking much when dried. It is overlain by mottled brown and gray blue sticky clay weathering russet brown, above which is light brown sand. There are a number of small flood-plain lakes in this region as well as lakes and swamps on the higher terraces and valleys of the larger creeks.

The top of Pine bluff below the mouth of Negro creek shows:

1. Alluvium with calcareous nodules, light gray at base but brown above ....15-20ft.
2. Ferruginous-cemented Lafayette-derived conglomerate with casts of Unios .... 3 ft.

Dark brown and brownish gray plastic clay with calcareous nodules outcrop on the edge of the terrace where the railroad spur to White Rock Locks enters the Trinity first bottom one mile south of its junction with the main line of the Beaumont & Great Northern Railroad and a section 10 feet thick is exposed. In the western end of the third cut on the Beaumont & Great Northern Railroad west of the bridge over White Rock creek is a brown clay with small calcareous nodules belonging to the second bottom.

At White Rock Shoals on the Trinity river excavation for the base of the lock on the north bank resulted in the unearthing of remains of mammoth (Elephas) and of a large horse (Equus), of Pleistocene age. The largest tusk of the mammoth measured 9 feet 6 inches in length and 14 inches in circumference at the base. The podial bones were 12-13 inches in diameter at the socket. The scapula, ribs, teeth, limb bones and both tusks of the mammoth were found, but these were very friable and rapidly crumbled on exposure to the air. These remains are important since they give evidence of the Pleistocene age of the first bottom of the Trinity river. The fact that a number of bones of the mammoth were found together indicates that the position in which they were found was the original resting place of the remains. They indicate that the portion of the first bottom in which they were embedded is neither older nor younger than the stage of the Pleistocene in which these mammals lived.

The reddish clayey sand exposed in the higher banks of Kickapoo creek near its mouth is alluvium of the Trinity second bottom. Brownish clay with calcareous nodules, probably second bottom material, is found between Mile Posts 15 and 16 of the Beaumont & Great Northern Railroad.

At Eastham's Plantation, 13,000 acres in extent, and situated in the southwestern corner of Houston county, the alluvium of the second bottom, here so far down stream and so high as not to be subject to overflow, is locally 30 feet in thickness with the usual gravel layer at the base. The level of the second bottom terrace is 55 to 60 feet above that of the first bottom. Both terraces are covered with black land and underlain by brown sandy clays with calcareous nodules.

The Columbia is well exposed further south on the Trinity river in the vicinity of Drews landing, eastern San Jacinto county, where it unconformably overlies the Fleming with a basal layer of Lafayette-derived pebbles overlain by brown clayey second bottom alluvium. Sections of light yellowish-brown sandy clay 5 or 6 feet thick are seen along Big Creek on the Shepherd-Drews Landing road. The Columbia or second bottom has a wide area west of Drews Landing. The following section was made on the west bank of the Trinity one mile below this place:

Top.

1. Light yellowish-brown, fine, sandy alluvial clay, gray at top, Mastodon remains, consisting of limb bones, lower jaw bones, and 19 teeth were found near the base of this member .... 30 ft.
2. Much cross-bedded, medium-grained yellowish-brown sand locally indurated. Its base marks a line of springs...... 4 ft.

One mile upstream from this locality the Port Hudson second bottom bluffs face each other on opposite sides of the river. Between these two places there are stagnant ox-bow lakes on the first bottom. Portions of the surface of the Port Hudson depositional peneplain may be seen between Drews Landing and Shepherd.

The Coast Prairie is a depositional peneplain of the Port Hudson group.

BEAUMONT CLAYS

Kennedy's description of these clays is as follows:

Overlying the Lafayette gravels and sands there is a series of yellow, gray, blue, brown and black clays with brown sands. There are also occasional deposits of red clay. These beds are sometimes thinly stratified or laminated, but frequently massive. The laminated beds are usually interstratified with thin beds of blue and gray or grayish-white sand. The clays carry considerable quantities of calcareous nodules irregularly distributed, in many places shells of Pleistocene or Recent age, and great quantities of decaying wood in the form of tree trunks, bark and leaves. Among these the cypress appears as the most prominent, and among the invertebrate fauna found the *Rangia cuneata* (Gray) and an undetermined oyster are the prevailing forms. in these clays the calcareous nodules do not appear to have any definite position. It is true that they always accompany the blue clays, but they are always found scattered in small pockets and occupying irregular patches a few acres in extent. It is possible that by some chemical action during or after the deposition of the clays the lime had been segregated into small depressions or softer portions of the clays.[1]

The generally low flat condition in which these Beaumont clays occur render attempts to unravel their structure with any degree of certainty somewhat difficult. They, however, are by no means structureless, as the whole of the beds carry sands occupying very irregular positions and lying in very irregular forms. Drilling has shown some of these sand deposits to lie in the shape of short, rather dumpy, or mound-like lenticles, others elongated and rather thin, while yet others form regular beds extending a mile or more in length. The clays themselves are also irregular. In places these occur in a massive form, giving rise through their toughness and tenacity to the term "gumbo" so frequently used by drillers. Often within the middle of these "gumbo" deposits there occur pockets of thinly laminated shaly looking clays, sometimes intermixed with laminae of sand and frequently carrying small quantities of oil. These are the shales and oil shows so frequently recorded in the logs of wells drilled throughout the region. These pockets of "shale", while numerous, are by no means regular as to extent or horizon. In some wells they may occur several times, while in the neighboring wells they are absent.

Another peculiarity regarding these Beaumont clays is the form of the lime found in them. Towards the upper surface and throughout several hundred feet of these clays the lime appears almost altogether in the form of carbonate. At depth this carbonate gives place to sulphate and small isolated nodules of amorphous gypsum are by no means rare. At some localities drilling has shown the gypsum to be in beds from two to four feet thick, but its areal extent is usually circumscribed.

Decayed wood is abundant throughout these clays. This often shows in an almost fresh condition as if it had only been buried a short time. In other localities the decay may be said to be complete, and in some places, particularly in the vicinity of the domes, the wood may be described as carbonized, but not lignitized. Wood brought up in several of the drill holes at Bryan Heights from a depth of over 300 feet was in this condition. Throughout the whole formation the wood is never silicified. In

[1]U. S. G. S. Bulletin No. 212.

this respect it is entirely different from any fossil wood found in the underlying formations, and any silicified wood found may be considered as extraneous and has reached its position in association with the gravel in which it is usually found.

Throughout the whole of the area occupied by these Beaumont clays the only means of obtaining any information regarding their structure or the thickness is by means of wells drilled in the search for oil. Unfortunately, few of the logs are kept with any degree of precision, the records rarely showing the color of the material passed through or the character of the rock encountered when such is met with These conditions render it often difficult to determine to what division the materials passed through belong. However, as the Beaumont clays carry but little gravel and the sands are usually thin, in all probability the appearance of heavy gravels, sands and rock shows that the drill has encountered some underlying formation.

Attention must, however, be drawn to the fact that as the Lafayette extends seaward it loses much of its landward structure. In its seaward extension it assumes a more clayey and sandy phase, the gravel deposits gradually become thinner and finally disappear, the sands thicken to some extent, but even these, in a great measure, lose their identity and become sandstones which eventually grade into a clay.

The Coast Clays are found on the Coldsprings-Cleveland road four or five miles northwest of Cleveland where they occupy a low flat country whose surface is interrupted here and there by small low knolls of Lafayette. The soil of the Coast Clays is a very light buff, very fine, sandy clay loam, forming, when dry, deep, loose and powdery dust of light weight.

Tarkington Prairie east of Cleveland is a portion of the Coast depositional peneplain. It extends from four miles north of Pelican Station on the Gulf Colorado & Santa Fe Railroad southward to the Gulf and is cut into minor prairies by many peninsulas of forest.

The Coast Prairie, on the Galveston-Longview branch of the International & Great Northern Railway extends as far as Spring creek on the Harris-Montgomery county line. It has in this vicinity its usual characteristics, a monotonous flatness, broken only by low circular mounds and smaller lower ant hills; open spaces densely covered with grass and low herbs; with patches of post oak and scrub pine.

Between Grapeland and Mile Post 17 the exposures are mainly gray or buff, loose, fine sand or silt, which resemble the loess. They are underlain by Lafayette which is found at the top of the grade in the two cuts north and south of Salmon, the southern cut being at the Houston-Anderson county line. The loess-like exposures are of fine materials. They are soft and have the property of standing in perpendicularly cut banks, such as would hardly be characteristic of other materials of such fine texture. The difficulty is to distinguish between this loess and loose fine leached residual sand derived from the older formations. At any rate, it can only be expected to be found on these high divides overlying deposits of Lafayette *in situ*.

Since the deposition of Port Hudson the deposits have been greatly eroded as a consequence of regional uplift. The first, second and third bottom terraces so common to the Trinity from Houston county southward and southeastward are cut in the Port Hudson deposits. Whether these terraces mark definite stages in the physiographic history of the coastal plain can not be determined until the lower river valleys and the country south of the Lafayette outcrop have been investigated in more detail.

SURFACE FEATURES

SALINES AND MOUNDS

Two striking features occurring throught this region and which are probably of Pleistocene age are the salines and Mounds.

The salines are depressions of greater or less areal extent and of varying depths which are usually ponds, lakes or marshes during the wet seasons but form dry spots more or less salt-incrusted during the dry seasons. Some are entirely barren, others support a scattered growth of tufts of short grass or salt-loving plants, while the larger ones form palmetto flats. A few have their surfaces dotted with small mounds. Even when dry at the surface the salines are moist a few inches below and the efflorescene is largely sodium chloride or common salt.

These salines appear to be entirely wanting in the area occupied by the Mt. Selman and Cooke Mountain formations and are found only in connection with the palustrinal deposits of the Wilcox, Yegua, Jackson and Fleming:

The mounds of the salines are low, varying from two to four or five feet in height, circular to elliptical in outline and from ten to forty feet in diameter. The soil of the mounds is a loose fine sand which is more loose and porous than that of the lower surface from which it apparently does not differ in other respects. The mounds persisting above the general level have better drainage. The mounds are frequently a mass of ant-hills and on the lower surface are conical ant-hills from a foot to fifteen inches in height.

Four and a half or five miles southwest of Burke, about seven miles from the Neches river, is a low swampy area with "quaking bogs" which are locally called "sucks". Judging from the bones scattered thereabout, the bogs have been the graves of a number of cattle and other animals. The quaking portions of the bog are elevated from four inches to a foot above the surrounding surface. They will shake when one treads over them or stamps upon them. The surface layer is hardened and cracked. Underneath there is a light blue liquid mud mixed with a small quantity of sand, in which a pole was easily pushed to a depth of twelve feet without striking bottom. In the dried surface portions of one of them a sticky elastic substance resembling gelatinous silica was noted. The quaking portions are from four to twenty-five feet across. On the surface of some of the mounds small ferruginous pebbles were found. A brownish fine sand (perhaps quicksand) was brought up to the surface on the end of a pole. On stirring up the liquid mass bubbles of non-inflammable gas rises to the surface. The blue mud has the odor of sulphur.

Small mounds in actual process of formation were noted one and a half miles southeast of Lovelady on the John Forbes grant in the postoak upland near the head of a small western tributary of Gail creek, known as San creek. Here, in a space some sixty feet in length, underlain by Yegua sand and light gray badland clay, are a half dozen small mounds close together and making up an elongated compound mound. From a half dozen small crater-like vents forming the summits of the mounds water in small quantities slowly oozes out, bringing upward with it materials varying in composition and texture from very fine clay to medium-grained sand, dark blue in color when fresh and a tawny yellow on the surface. The phenomena resembles closely those of a very quiescent stage of mud volcanoes. Forty feet of 2-inch pipe was pushed by hand down one of these vents without reaching bottom. A resident of the vicinity informs me that the locations of the vents have migrated during the last thirty years and a few yards to the westward of the present vents are traces of former vents which have now dried up. The vents are ten feet to fifteen feet in diameter and rise two or four feet above the general level. They have been the graves of animals which have bogged down in them. At the time of visit no gases could be seen escaping from these vents, but it is reported that in former times bubbles of gas were seen to escape from them. It is possible, however, that these bubbles were merely of air, which came to the surface as one trod on the quaking ground of the immediate vicinity The "suck" in the Neches river bottom near Blix, western Angelina county, is similar in characteristics to the more pronounced mounds near Lovelady, but it is worthy of note that the one locality is on the uplands and the other in the river bottom.

CHAPTER XI

LIGNITE

GENERAL CHARACTER

The various grades of Brown coal which are found in the United States are known under the general name of Lignite. These are forms of coal which are intermediate in the transformation series between peat on the one hand and bituminous coal on the other. They contain a higher percentage of carbon and much less water than peat, but usually, less carbon and more moisture than bituminous coal.

In color, Lignite varies from brown to a brilliant jet black, but the majority of our deposits are dull black changing to brownish black or brown on exposure. It breaks with a splintery to subconchoidal fracture and normally has a specific gravity of 1.22[1].

The water content is very variable in amount and it exists in the lignite both as combined moisture and as free water. Upon exposure most, if not all, of the latter may evaporate but the water in combination will not do so and even if the coal be heated and this moisture driven off, its equivalent will be re-absorbed or recombined upon exposure to the air.

Prior to the finding of oil at Spindletop in 1901 the mining of lignite was assuming considerable importance in Texas, but the advantages of oil in convenience of use and cheapness in price caused most, if not all, of the mines to be closed down for the time.

As the supply of oil available for fuel uses has decreased and the price increased the use of lignite is again beginning to expand and the time is near at hand when the disadvantages accompanying the use of lignite will be more than offset by the economy which can be effected thereby and we may, therefore, look forward to a constantly growing demand for it.

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[1] For fuller description see Dumble, E. T., Brown Coal and Lignite, Geol. Sur. Texas, 1892.

While not equal to bituminous coal in heating power it is nevertheless an excellent and acceptable fuel under proper conditions and will in time be one of the principal sources of supply for our entire Gulf Coast region.

Methods of Utilization

The principal use of lignite is, of course, for fuel purposes, and includes direct firing under boilers and furnaces, conversion into artificial fuel by briquetting to fit it for household and other uses, charring to produce a fuel between charcoal and coke, gas and by-products, and the manufacture of producer gas and conversion into electric energy through gas engines.

The details of these methods have been given more or less fully in the Report on Brown Coal and Lignite, the Bulletins of University of Texas Mineral Survey and the U. S. Geological Survey Report of Coal Tests at the St. Louis Exposition.

In direct firing success can only be had by proper attention to the character of the fire-box, style of grate and draught arrangements. When these are properly designed for the character of fuel it can be burned very satisfactorily either with hand firing or mechanical stoking. Where the conditions are properly regulated the inconvenience and loss formerly caused by its property of slacking as it dried is practically done away with and the slack coal itself is a good fuel.

Briquetting has also been attempted as a means of overcoming this disadvantage to its general use as a household fuel but apparently no great commercial success has as yet been attained in the manufacture. Up to the present the material used has been the raw lignites, from which most of the moisture has been evaporated by heating, combined and compressed with various percentages of coal tar pitch or asphaltum. A satisfactory fuel of this character demands considerable experimentation to find just what condition of dryness and percentage of pitch will yield, when pressed, a strongly coherent block of proper burning qualities.

In place of simply drying the lignite it may be subjected to a charring process which provides for the recovery of the by-products consisting of gas, oils, and tar. The charred product briquetted with coal tar pitch forms an excellent fuel for all purposes. While no commercial installation of this character has been attempted here estimates, based on experimental runs which show the extent and value of the by-products, seem to indicate the entire practicability of such a scheme,[1].

These various methods have to do with the use of lignite by direct firing and it is probable that each of them will in time play its part in the utilization of this fuel. The demand for electric power at a reasonable price cannot be fully met by such method but it is entirely practical by the use of the gas from the charring process or through the manufacture of producer gas to secure a fuel for gas engines by means of which electric power can be generated at a minimum cost. Careful estimates indicate that at such plants erected in the immediate vicinity of the lignite mines electricity can be generated at a price to compare favorably with those plants in the west using water power, with the advantages of a smaller investment in plant. Or it may be possible to pipe the gas to certain centers for such use. This in the writers opinion, will be one of the chief methods of lignite utilization in the future.

As will have been seen from the various sections we have given conditions favorable for the deposition of Lignite occurred during nearly every stage of the Eocene, but, within the area mapped, it was only during the Lignitic phase of the Wilcox and in the Yegua and Jackson that beds were laid down of sufficient extent and purity to constitute valuable deposits. There are a few beds known in the Marine and it is possible that one or more of these may be of value locally, but extensive deposits such as are found in the beds below and above the Marine are not to be expected.

LIGNITES OF THE WILCOX

The deposits of Wilcox age include the lignite beds in Shelby and Nacogdoches Counties, these occurring in the corner of Freestone, Limestone and Leon counties and in the northern part of Robertson county.

The beds of lignite which occur in the vicinity of Center and

[1] University of Texas Bulletin 307. Fuels used in Texas.

Timpson in Shelby county and extend southwestward to Garrison, Nacogdoches county, are of considerable extent and of excellent quality.

A bed of good grade of lignite, 5½ feet in thickness, outcrops along the beds of two creeks in the southern portion of the town of Center. An opening has been made on this bed at one place and two inclines sunk on the seam. The lignite is used locally for the production of electric power and for fuel in a cotton seed oil mill. It is reached in most of the shallow wells in the southern portion of the town, in which it forms the impervious layer above which surface water percolating down through the pervious sands accumulates in considerable quantity.

There is a deeper coal seam underneath the town, but this lies somewhere between the depths of 300 and 570 feet, since a well 300 feet deep did not reach it but the 570 ft .well penetrated it although exact depth was not given. The two wells are only a few hundred yards apart, but abundant water was secured from a sand at 300 feet in the one, while the other, having substantially the same elevation, got no water above a depth of 570 feet. The water in the three deep wells here rises to within 80 or 100 ft. of the surface.

Two exposures of the lignite were examined. The more northerly shows from bottom upward;

1 Laminated gray sand.
2. Carbonaceous shale with thin streaks of lignite.
3. Solid bed of hard lustrous lignite, 5 ft.
4. Laminated sand.

At the mine the dip in a S 70° E. direction is 2°. The roof and floor are both laminated sand, although a few inches of carbonaceous shale directly underlies the coal. The thickness of the solid lignite is 5′ 6″. Small lenses of sand are found locally in the lignite bed. At the time of visit the mine was not in operation and was flooded with water. The water and a poor roof makes mining difficult at this incline. It may be possible to find a better location by prospecting.

At Timpson the lignite was successfully mined by the Timpson Coal Co. The mine was one and one-half miles south of Timpson and the lignite seam averaged a little over six feet in thickness. The floor was a white clay while the roof was a hard black bituminous clay.

South of Garrison about half a mile mines on opposite sides of the railroad were operated during the years 1900 and 1901. One of these was worked by the East Texas Coal Co., the other by the South Texas Coal Co. Each mine worked out about seven acres of ground. The shaft of the East Texas Coal Co. was 54 feet deep and the lignite seam averaged four and one-half feet in thickness. The roof was blue shale and very little water was encountered.

East of Timpson lignite is reported from several wells dug for water in seams four to six feet thick at depths varying from 55 to 70 feet. Six miles southeast of Timpson on the Attoyac a seam of lignite four to five feet in thickness is exposed. It is therefore evident that these seams of lignite are found pretty generally through an area twenty-five miles in length by six to twelve miles in width and even though they may not all belong to one bed they are all of the same horizon and are similar in character.

We have the following analyses on these lignites:

	Attoyac	Timpson
Moisture	18.26	31.96
Volatile matter	43.51	39.53
Fixed carbon	29.53	23.05
Ash	8.70	5.46
Total	100.00	100.00
Sulphur	2.46	1.46

The difference in moisture in the two analyses is due to the Attoyac samples having been partially air-dried.

West of Garrison the beds of the Wilcox are overlain by those of the Claiborne until we reach the Trinity river. West of that stream the Wilcox again makes its appearance and beds of lignite may be looked for in it. They occur in good development north and west of Jewett.

About eight miles north of Jewett there are two mines which are now in operation; The mine of the Houston Coal Co. at

Evansville has a spur from the Nelleva cut-off of the Houston & Texas Central R. R. while the mine of the Beargrass Coal Company has a spur to the Taylor & Brazos Valley R. R.

The Evansville mine has been in operation for several years and they are now working from the third shaft. The holdings comprise several thousand acres, most of which has been prospected with drilling machines. The mine is operated from a shaft 66 feet deep. The lignite seam is 12 feet thick with one parting at 7 feet. On account of the sandy nature of the formations overlying the lignite, all of the lignite above the parting is left in the mine for a roof. Very little water is encountered in the mine. The coal is shot from place with black powder and shoveled into cars. The lignite as it comes from the mine is dumped from the cars and passes over grate bars which screen it into the lump, nut and slack grades. The capacity of the mine at the time of our examination was about ten cars per day.

The Beargrass mine is about three miles north of the Evansville mine and is operated from a shaft 125 feet. The lignite is 9 ft. thick with a parting 2″ to 4″ thick, 5 to 6 feet from the bottom. Another stratum of good lignite 7 feet thick is known to exist at a depth of 350 feet. The holdings of the Company comprise 1100 acres held in fee and 1200 acres under lease, with possibly 150 acres worked out. Some water is encountered in the mine.

Similar coal is known at other places in the vicinity and there is every reason to believe that this will prove one of the best producing districts of the Lignite belt.

ANALYSES

	Beargrass Mine No. 1	Beargrass Mine No. 2	Houston Co. Coal & Mfg. Co.
Moisture	29.96	27.00	25.70
Volatile	41.68	37.91	33.39
Fixed Carbon	22.24	27.80	31.91
Ash	6.12	7.21	8.90
Sulphur		0.44	1.04

The lignite beds of Robertson county extend from its eastern boundary entirely across it in a general southwesterly direction and underlie approximately the northern one-third of the county. The northern boundary of the lignite beds is approximately coincident with, but extends across the northern line of the county, and the southern limit of the field lies along a line extending from the Navasota river westward to Owensville, and then along the northern bank of Muddy creek to the Brazos river, near the mouth of Little river, in Milam county. This region embraces Tidwell, Beck, Heard, and Bald prairies, together with a series of other small prairies lying across the centre and throughout the northern portion of the county.

Throughout the prairie regions the brown coals appear near the surface at various localities, and are exposed in several of the creeks and washouts traversing these regions. At Headville, on the C. C. Seal headright, the exposure is from four feet to six feet thick, and the deposit on Wilson creek is about the same thickness. Many of the surface exposures, however, are thin and of no economic value. Thus the exposure on the Captain Orvis farm on the southwest corner of the George Robertson league, is not more than two feet of broken crumbly coal. Another outcrop of a similar nature occurs in a creek near the centre of the Joseph Fisher leauge. The coal at this locality is broken and crumbly at the south end, or toward the head of the creek, but as it extends northward it becomes dark brown in color and assumes a woody or peaty structure, having all the characteristic odor of the later material when freshly broken, and also contains numerous fragments of leaves.

The heavier deposits of brown coal found throughout the prairie regions all lie at a depth of forty-five feet and over. A number of borings on the southwest corner of Beck's prairie, on the Wm. Fullerton league, show section of:

1.	From surface to first brown coal	46 to 55 ft.
2.	Brown coal	4 to 4½ ft.
3.	Parting of sandy clay	10 to 12 ft.
4.	Brown coal	7 ft.
5.	Parting clay and sand	6 to 10 ft.
6.	Brown coal	3 ft.

Brown coal also occurs in the neighborhood of Owensville, where it is overlain by a red sandstone. This appears to be the last exposure of the brown coal deposits occurring in the southern portion of the county. At Hearne this coal is found at 408 feet, while in the neighborhood of Wheelock, and at places between this place and Franklin. wells, fifty to sixty feet frequently cuts brown coal.

Throughout the valley of the Brazos and in the region lying between the two rivers, brown coal occurs in the well borings generally at a depth of thirty feet to four hundred feet.

The exposure on the Brazos river west of Calvert is one of the best known of the entire region. This locality furnished the material for some of the earlier experiments in the use of lignite not only under boilers or for household purposes but also for the manufacture of briquettes. The earliest experiments of this character were those of the writer who in 1881 made a shipment of this lignite to Havre where it was briquetted with coal tar pitch as a binder and a serviceable fuel secured. The cost of the pitch, however, and the fact that the air-dried lignite carried ten per cent of moisture (decreasing its heating power to that extent) acted as a bar to the further prosecution of the scheme.

The success of the mines at Rockdale finally brought about the opening of these beds and a number of mines were started, some of which became regular producers and mined over considerable areas.

While some mining was carried on in a small way previously the most active exploitation of the Calvert coal followed the publication of the Report on Brown Coal and Lignite in 1892. The use of suitable grate bars increased its efficiency and later the application of the plans there suggested for locomotive firing to the engines of the Houston and Texas Central Railway made it possible for them to use it acceptably as a locomotive fuel. The records of company show that during a period of more than one year it was used in large quantities and at a considerable saving in cost over the Territory coal then available.

With the coming of oil and cheapening of bituminous coal the use of lignite was discontinued and these mines ceased operations.

At the time of our examination the Southwestern Fuel Co. was operating a mine four miles west of Calvert with a spur to International and Great Northern Railway. Two seams of lignite are worked from one shaft here, one being at 75 feet and one at 175 feet in depth. The upper stratum of lignite is 7½ feet thick and the lower has a thickness of 12 feet. But little timber is used in the mine, a coal roof being carried. Water is encountered in the mine in considerable amount, pumps being installed on both levels, the pumps on the lower seam handling about 30 gallons per minute and that on the upper seam handling over 200 gallons per minute. The lignite is shot from place with black powder. All lignite shipped is screened to about one inch in diameter. The capacity of the mine is 1000 tons per day. About 110 miners are employed. The holdings of the company comprise 1200 acres, of which about 50 acres from the upper seam have been worked out.

Analysis of Calvert coal:

	Southwestern Fuel Co.	Southwestern Fuel Co.	Calvert Bluff aid-dried
Moisture	25.64	30.60	16.45
Volatile Matter	35.55	30.19	40.24
Fixed Carbon	30.28	34.07	35.89
Ash	8.53	5.14	8.95
Total	100.00	100.00	100.00
Sulphur	0.96	0.86	1.17

The lignites of the Wilcox are represented west of the Brazos by the beds in the vicinity of Rockdale.

LIGNITES OF THE YEGUA

While no mining has been done on any of the lignites which occur in connection with the Yegua beds of the area mapped, there are a number of localities at which it is known to occur in beds of sufficient thickness for exploitation.

In the vicinity of Huntington lignite is found in a number of shallow wells and in an excavation made at this town by the Texas & New Orleans Ry. for a water well a bed of lignite was encountered 25 feet below the surface which had a thickness of twelve feet. To the east of this on Gilland creek lignite outcrops which may be a continuation of the bed.

Lignite was also found in wells drilled near Homer and beds of four to seven feet in thickness occur 15 feet beneath the surface at Burke.

In Brown Coal and Lignite two analyses are given of lignites from this belt. A brown coal of the variety pitch coal, from the Angelina river, sent in by E. G. Blount of San Augustine, is of distinctly lamellar structure, black in color, with pitchy lustre, without any traces of plant structure remaining. It is hard, firm, does not soil the hands either on edge or face, and contains particles of jet-like blackness.

The following is the proximate analysis:

Moisture	12.15
Volatile matter	37.14
Fixed carbon	41.19
Ash	6.50
Sulphur	3.02

The Angelina county brown coal has the following composition:

Water	12.40
Volatile matter	36.37
Fixed carbon	37.77
Ash	13.46
Sulphur	Not determined

In Houston county similar lignites are reported by Kennedy[1] from Cochina bayou and westward to Big Piney creek and they are also known to occur at other localities between that creek and the Trinity river, in beds which are in places six feet in thickness.

About three miles north of Lovelady at Wootters Station on the International and Great Northern Railway is situated one of the mines of the Houston County Coal and Manufacturing Company. The same company is also operating the Evansville mine 6 miles S. W. of Jewett on the Houston and Texas Central Railroad.

The main coal seam at Wootters has been prospected rather thoroughly and averages 5′ 10″ in thickness over some 5500 acres. The coal seam dips S 10 E at 2° in the workings and

[1] Geo. Sur. Tex., Third Ann. Rep. p. 34.

it is worked from a two compartment shaft 58 feet deep by the Room and Pillar method of coal mining.

In compliance with the state mining law there is an auxiliary shaft situated 100′ from the main shaft. It is a two compartment shaft also, each compartment being 5′x6′. One of these is used as a runway and the other is an air shaft for ventilating the mine. For this purpose a 10′ fan with curved blades is used. and a very perfect system of ventilation is maintained. The mine is, however, not troubled with gas.

The main roof of the coal is a 3″ seam of fine grained, unctuous, stiff clay. This affords an excellent protection from water and only a minor amount of trouble comes from this source. Three sumps are provided, one of which is at the bottom of the main shaft. These are drained with pumps two of which are operated with gasoline engines and the other by a steam engine.

The coal is usually picked out, very little shooting being necessary. The mine has been particularly free from accidents only one fatality being recorded in thirteen years of operations.

The output of this mine averages about 300 cars per month during the summer and 350 cars per month during the winter, the cars having an average capacity of 60,000 lbs. each. The coal is used for power generating purposes and by packing companies, particularly in Houston.

One mile north of Lovelady the same seam of coal as that worked at the mine is found at 120 feet. Overlying the main seam some 30 feet there is a thin seam of worthless coal.

An analysis of the coal from the mine is given in the report of the U. S. Fuel Testing Laboratory at St. Louis in 1904. The coal has also been analyzed by Dr. Wm. B. Phillips, at the State Testing Laboratory. It is given below:

Moisture 25.58 per cent.

Proximate analysis, Dry Basis:	Per cent.
Volatile and combustible matter	52.90
Fixed carbon	33.00
Ash	13.11
	100.00

Sulphur 0.80%.

Ultimate analysis, Dry basis.

Carbon	57.20
Hydrogen	5.36
Oxygen	21.67
Nitrogen	1.86
Sulphur	.80
Ash	13.11
	100.00

Heating power, dry B. T. U. 10,120.

Kennedy describes the outcrops on the Trinity as follows:

The southwestern lignite field is best developed at Hydes' and Westmoreland bluffs, on the Trinity river. At Hydes' bluff the outcrop extends from near the ferry nearly half a mile in a southeasterly direction. The section of bluff shows:

1.	Yellow sandy loam changing into an ashy gray on top, where cultivated	8 ft.
2.	Conglomerate of ferruginous and siliceous pebbles, broken pieces of nodular iron ore, ferruginated and silicified wood and brown sand	2 ft.
3.	Dark blue sandy clay, having one foot of laminated brown sandy clay on top, in contact with the conglomerate the dark blue clay containing more or less of iron pyrites	10 ft.
4.	Soft lignite very friable and mixed with sand, in deposition very irregular, and extending from two inches to	2 ft.
5.	Light gray sandy clay, the clay becoming more prevalent towards the base of the bed	10 ft.
6.	Lignite	2 to 6 ft.
7.	Dark purple clay	1½ ft.
8.	Gray sand, containing nodules of sandstone	4 ft.

The lower bed of lignite at this place is very pronounced, and forms a ledge in some places six feet wide along the face of the bluff. In texture, it is strong and solid, of a dark glossy luster when first mined, which it retains for some time, but ultimately becomes a dead black, with pitchy streaks. No woody structure visible. Compact uneven to even fracture, shrinkage cracks parallel with and perpendicular to plane of bedding.

This bed averages four feet thick, is from six to fifteen feet above low water level, and is easy of access. It breaks in large cuboidal blocks, and disintegrates slowly when exposed to the air. Its composition is very variable, changing materially at different portions of the bed. One analysis given shows it to have 16.70 per cent of ash, but another determination of a specimen not many yards distant showed only 7 per cent of ash. It is probable that the brown coal from this deposit may, with the good facilities for transportation at hand, be utilized.

ANALYSIS

Moisture	11.80
Volatile matter	36.06
Fixed carbon	32.56
Sulphur	.88
Ash	16.70

There are in Madison county extensive beds of lignite coal but the thickness seems to vary considerably locally and hence no attempt will be made here to indicate workable deposits. The outcrops of coal noted which would stand prospecting with bore holes are given below:

In western Madison county on the James M. Harbor survey along Shepard's creek, on the farm of Mr. Nash, there is exposed 2½ feet to 4 feet of black lignite of light weight and only fair grade as it tends to break out in a shaly manner. It is overlain by 3 feet of laminated chocolate colored, sandy, shaly clays and underlain by 2½ feet of lignitiferous to highly carbonaceous brown to black sandy clays. This outcrop caught fire a few years ago and burned for a long time. It became so troublesome that Mr. Nash was compelled to haul water to extinguish the fire. Lignite coal is found outcropping both below and above the above mentioned locality along Shepherd's creek.

On Cottonwood Prairie in the northwest corner of the Amy Boatwright League on the place of Mr. John McMahon in digging a well 10 feet of lignite coal was encountered at 20 feet. This coal is black and lustrous and seemingly of a very good grade. No data could be obtained as to what overlay the coal.

Two miles north of the above place on the farm of Mr. Will Fannin in the northwest corner of the Simon Jones league in digging a well Mr. Fannin encountered 20 feet of lignite coal at 40 foot depth. He claims that this coal was black and lustrous and was used by the local blacksmiths for forging. Lignite coal outcrops along Iron Creek, south of Mr. Fannin's house, but nothing over 3 feet thick could be found. This deposit would warrant careful prospecting.

On the Wm. Curry Survey on Larrison creek there is found outcropping along the creek 2′-3′ of a fair grade of lignite.

The Yegua beds occur only in a limited area in Grimes county and we know of no lignite in them.

In Brazos county seams of lignite are found at many places at depths ranging from 30 to 60 feet.

The brown coal deposits are usually found in digging wells, and no reliable information can be obtained regarding their quality or thickness. In the northwestern part of the county a deposit crops out in the bank of the Brazos river near Nebelt or Black shoals. It stretches across the river into Burleson county, and on the Brazos county side has a thickness of from 12 to 14 feet, as shown in the following section:

1.	Bluff loam or river deposits	6 ft.
2.	Brown clay	3 ft.
3.	Yellow sand, with gravel near bottom	10 ft.
4.	Brown coal, shaley near top, but becoming compact at base of bed	12 to 14 ft.
5.	Lignite sand	

An analysis of the brown coal in this bed made by Dr. W. H. Melville, chemist of the Geological Survey, shows it to have the following composition:

Moisture	18.33 per cent
Volatile matter	52.62 per cent
Fixed carbon	24.88 per cent
Ash	4.17 per cent
	100.00
Sulphur	87 per cent

Of the Brazos river brown coals of Yegua age this deposit can probably be utilized the most economically. The coal can be readily obtained by stripping, and the transportation facilities are exceptionally good. The Hearne and Brazos Valley Railway passes within two miles, and the level tract of country between the river and the railway line would greatly facilitate the construction of a siding or branch to the mine, which might be built at the minimum cost allowed for this grade of work.

LIGNITES OF THE JACKSON

Lignite in the Jackson is known from White Rock creek in western Trinity county, near Potomac in northern Polk county, and on Cameron creek in southern San Augustine county. Beds of lignite have been found in wells at Groveton, Trinity county. The exposures on White Rock creek, Trinity county, are situated 1½ miles north of the Missouri, Kansas and Texas Railroad bridge over that creek. It is reported that the lignite bed is 6 or 8 feet thick at a minimum with its base not seen. The bed is in the bottom of the creek. On the eastern portion of the Jacobs League about ¼ mile north of Potomac and about 250 yards west of the Houston East and West Texas Railroad 3½ feet of lignite is overlain and underlain by brown carbonaceous shale. Near the southwest corner of the Nathaniel Hyden League in southern San Augustine county a thin seam of lignite varying from 8 inches to 2 feet is overlain and underlain by soft clay. In the Groveton wells nine feet of lignite was found at 52 feet, seven feet at 81 feet, four feet at 101 feet, and seventeen feet at from 337 to 354 feet. The Groveton Light and Ice Company's well at Groveton found beds of lignite as follows: Two feet of lignite at 73 feet, twenty-two feet of shale and lignite at 98 feet, and ten feet of lignite at 120 feet. Other localities in Trinity county where lignite was reported but not examined are: (1) about the middle of the north line of the M. B. Mancha League, where there is said to be also an oil seepage. (2) One half mile southeast of Cochino bayou on the J. Bethea grant on the north line of the county, and (3) near the southwest line of the James Hanley League.

A lignite bed, 5 feet in thickness, outcrops in the bed and the lower portion of the west bank of the Angelina river on the Aaron Ashley Survey, 15 miles east of Zavalla, Angelina county, and is visible only at low water stage. At the time of low water, when the prospect was examined, the lower 2½ feet was submerged. Extreme low water would cover only the lower foot or foot and a half.

The lignite is of a fair quality and breaks in large hard blocks. Samples were secured from the entire five feet of thickness and the entire bed appeared from the physical examination to be fairly uniform in quality. The top of the bed, which is exposed for some 200 yards along the channel of the river, was characteristically checked by weathering, the surface exhibiting a thin whitish effloresence irregular in extent and thickness, but never thicker than a thin film. The weathered coal is in fresh, bright, and hard condition.

The coal bed is directly underlain by 3 inches of brownish carbonaceous clay which is itself underlain by at least 6 inches, with total thickness unknown, of a blue clay. The clay is entirely submerged at extreme low water. All known exposures of the coal are in the alluvial bottom lands of the river. Therefore, the exposure may only represent a local isolated outlier forming an island-like mass flanked on all sides by river alluvium.

There is, of course, the possibility that a workable deposit may be found underlying the higher lands west of the river bottoms. Unfortunately, no wells have been put down on these higher lands which would serve to prove or disprove the presence of workable coal.

The exposure visited is distant some 5 miles from Turpentine, the terminus of a railroad (The Burrs Ferry, Browndel and Chester Railroad) connecting with the Texas and New Orleans Railroad at Rockland. It is also distant about five miles from the St. Louis, Southwestern Railway at Monterey. The coal outcrop could be reached by a spur down the river bottom from either of these railroads.

Lignites are also found along Chalk creek in northern Walker county.

On Kelso creek near the middle of the S. Young Survey about on the line between Walker and Grimes counties there is a hill where the Brooks Brothers prospected for lignite. In this hole at present one can see only about 8′ of rather soft medium grained, gray sandstone, the rest of the hole being filled with sand. Immediately underneath the sandstone, according to Mr. Thomas J. Brooks, there occurs 10′ of excellent lignite with a black color and lustrous appearance. A short ways down the creek another hole was dug and here only 4½ feet of lignite was encountered.

In Grimes county thin seams of brown coal occur in the neighborhood of Kellum Springs, and stretch across the county in a northeasterly direction as far as the Bedias postoffice, near the northeastern corner of the county. A seven foot deposit of brown coal also occurs in Tanyard creek, on the Boatright headright, near Piedmont Springs. This coal as exposed is of the brown grade throughout the upper three feet and is mixed with a brown clay, while the lower four feet, of blacker coal, is too much mixed with a black sand to be of any economic value.

In the record of a boring at Lamb Spring, fifteen miles north of Navasota, brown coal has been reported at various depths and having various thicknesses. Roughly, the section of this well shows:

1.	Brown coal, first seam at 12 feet	2 ft.
2	Brown coal, second seam at 34 feet	2½ ft.
3.	Brown coal, third seam at 38 feet	2 ft.
4.	Brown coal, fourth seam at 41 feet	7 ft.
5.	Brown coal, fifth seam at 52 feet	10 ft.

Several deposits of brown coal are reported as occurring deeper in the boring, but all are accompanied by water. A small deposit of coal also occurs in the bank of the Navasota near Sulphur Springs.

The lignites of the Jackson have not been mined to any extent nor have we many analyses of them. It is probable that in the region west of the Trinity-Angelina divide in which volcanic ash is so abundant that some, if not all, of these lignites will show considerable ash.

Chapter XII

PETROLEUM AND NATURAL GAS

Origin

Two widely divergent theories have been advanced in regard to the origin of petroleum and natural gas.

One of these refers these substances to inorganic sources, that is, makes them the result of chemical action with mineral matter as a base. This theory is supported by the fact that hydrocarbons of this character are found in certain meteorites and in volcanic emanations. Its supporters also claim the presence of igneous rocks in certain fields as further evidence in its favor. We have no real evidence however to show that any oil field of importance has derived its oil from such a source, consequently, while there is no question that oil may be formed in this manner, the majority of geologists of the present day seem to be substantially agreed that the greater part, at least, of oil and gas in place of being of inorganic origin is derived from the remains of plant and animal life and therefore of organic origin.

Apparently the first step in such formation of petroleum is the separation and segregation of the fatty materials of the remains of plants and animals by the action of bacteria and it is from the fatty matters thus produced that petroleum and natural gas are derived by natural processes of partial decomposition, distillation, rendering or refining.

The transformation of this fatty material into petroleum and gas is ascribed by many, if not most, geologists to some form of temperature or pressure distillation, or some pocess of fermention, (geodynamic or geochemic agencies) acting on these materials after they have been entombed in the rocks. That is, that the animal or vegetable matter, either as debris or altered into fatty matters such as resins, waxes or adipocere, is embedded in the sediments at the time of their deposition and later converted into petroleum or gas through some of the various methods included under the general statements above.

On the other hand there are those who believe that this transformation takes place before deposition. This would necessitate the decomposition of the organic bodies "elsewhere than in the strata themselves and yet in such a place that the oil would be retained and collected until it was liberated upon the surface of rivers which were depositing the sediment"[1].

We have here in contradistinction to the prevalent theory that the transformation of the fatty materials derived from organic remains into petroleum takes place after the burial of these materials in the sedimentary rocks, through the action on them of pressure distillation, or by some geo-chemic process, one which postulates the formation of petroleum from similar material, by natural processes, at the surface of the earth, without the interposition of geo-dynamic agencies, and its contemporaneous deposition as petroleum with those sediments with which it is originally connected.

The actual formation of petroleum and other bitumens at the surface of the earth in such relation to other sediments as might permit their deposition in the manner claimed for them seems to be fairly well established by observations in various parts of the world.

Among the localities described may be mentioned the small bays of the Red Sea, the region of the Dead Sea, the Mediterranean between Cypress and Syria, the Gulf of Suez, sea marshes in Sardinia and Sweden and numerous peat-bogs.

The actual formation of petroleum and other bitumens in peat-bogs, at the bottoms of bays, along the margin of the sea and even on the sea-floor, would appear to be as well established as any of the facts upon which the pressure-distillation theory is based.

The association of such petroleum with sediments in course of formation, and the readiness with which surface petroleum is carried down and deposited by muddy waters are facts in favor of contemporaneous deposition, which is further sustained by many field observations which seemingly admit of no other explanation. This is especially true of the coastal fields of Texas and Louisiana.

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[1] Murray Stuart, Geological Survey India, Vol. XI, p. 239.

Occurrence

The presence of oil and gas was recognized in East Texas many years before the drill made it available. Seeps of oil and beds of asphalt were known at Sour Lake, Saratoga and elsewhere. Gas springs, sulphur waters and mud volcanoes, all of which are evidences of oil and gas, were known, but no one suspected the vast stores which have been brought to light.

Small wells were found near Nacogdoches, at Sour Lake and Saratoga during the fifteen years preceeding, but the real birth of the oil industry in the Coastal Area of Texas, was the bringing in of the Lucas well at Spindletop, three miles south of Beaumont in January 1901. It has been said of this well that probably no other event in the development of the petroleum industry in the United States caused such a profound sensation, reaching all of the interests concerned with the production and sale of this article, as the unexpected outburst of this well and not until it was found that the petroleum produced by this gusher was 22° Beaume and contained a large proportion of sulphur (thus decreasing its value for refining purposes under processes then in use) was confidence restored to the producers in the Eastern petroleum fields.

The bringing in of the well was followed by the drilling of many wells in the Coast country, and from these we have learned something of the location and nature of the deposits, although there is much that is not yet clear.

As the gusher oil was originally found in connection with the domes at Spindletop, Sour Lake, Humble, etc., it was at first believed that all domes might prove to be oil domes. This was soon found to be a mistaken idea, but even today it is not possible to say, in advance of drilling, whether a given dome will or will not prove an oil producer. We do know, however, that oil is not confined to the domes proper but may occur where no doming is apparent at the surface, provided the underground structure is favorable.

In the Coastal Area of East Texas oil occurs at several horizons beginning with the Cretaceous.

The active deposition of Cretaceous oil began with the Woodbine series.

From Woodbine the outcrop of the formation stretches eastward into Louisiana, where it is known as the Bingen sand, and in the Caddo region the sands are highly petroliferous and furnish the best wells of that belt. The productive oil and gas of the Eagle Ford is confined to the "Blossom sand", which is unknown as such on the Colorado. Gas is plentiful in the Blossom sand in the Caddo field, but such oil as is found there is heavy, and producing wells are rare if not unknown. The bituminous and even petroliferous character of the shale is apparent, however, at many places along its outcrop in central Texas, and it furnishes seepages of a heavy tarry oil from small wells near Waters Park, north of Austin.

The Annona chalk, which is the eastern representative of a portion of the upper Austin or basal Taylor, is a good oil horizon, and the Nacatoch sand, probably the equivalent of part of the Taylor, is an excellent gas horizon. Thus, in Louisiana, there are four distinct horizons of gas and oil in the Upper Cretaceous, the principal of which is the Woodbine, or Bingen, as it is locally known, and it is probable that the oil and gas in these beds are largely indigenous.

The deposits of commercial value occur in connection with folds and domes, and at present are best developed in the area between Red River and the Sabine, but may extend to the west of the latter.

The other occurrences of Cretaceous oil west ofthe Sabine river are confined to the Taylor beds. The pools at Powell, Corsicana, San Antonio, Thrall and other localities find their supply in these beds. In some of these the oil is possibly indigenous, but at Thrall it is probably migratory.

The deposits of Eocene age, in spite of their wide areal distribution in the Gulf Coastal Plain of Texas and Louisiana, have yielded comparatively small amounts of petroleum.

No oil whatever is known in the Midway or Wilcox of the Lower Eocene and only a few small pools have been found in the Marine beds which overlie them. In Nacogdoches county small bodies of oil were found, and another small amount of similar oil was found in these beds at Crowther in McMullen county, some 300 miles southwest of the first. While oil indications may occur at other points, no workable deposits are known.

The Yegua sub-stage of the Claiborne, however, has proved to be a very valuable gas horizon in the region between the Sabine and the Rio Grande, and it may be that it will equal in productiveness some of the sands of the Cretaceous, or even those of the Carboniferous, when it shall have been properly exploited.

Beds of the Jackson and Oligocene, which followed these, are equally destitute of oil.

The probabilities are, therefore, that while the conditions were favorable for the formation and deposition of vast quantities of lignites and an abundance of other organic matter during the Eocene, the conditions for the formation or storage of petroleum were comparatively unfavorable.

The Tertiary oil of the Gulf Coast proper all occurs in sediments of Neocene age, often in or around domes, and frequently in connection with deposits of salt, gypsum and sulphur.

While the shore deposits of the Fleming beds are non-bituminous and no sign of either oil or gas has ever been found in them, the seaward extensions are bituminous to a considerable degree. Small pieces of lignite and asphaltic material have been reported from a widely extended series of wells. Shows of oil appear in these beds at various horizons and good wells have been obtained in them. Wells in the Saratoga field drilled to a depth of over 2,200 feet obtained their supplies from sandy shales belonging to this series.

The Lafayette, which closes the Pliocene in the area, shows in some wells a thickness of 500 feet of sands, gumbos, and clays. They carry water in abundance, but no oil.

Of the overlying Pleistocene deposits the Beaumont clay, of Port Hudson age, is most characteristic. These clays and sands are very variable in thickness. In places the Pliocene beds are found in low hills, surrounded but not covered by the clays, while in others the Beaumont clays show a thickness of 2,500 ft. and more, above these beds.

The probabilities are, as stated, that all the oil of the Louisiana and Texas coastal belt is of Neocene age. It is separable into two classes, shale oil and dome oil. The first is regarded as indigenous to the beds in which it is found, and the second as migratory oil derived from it.

The relations of these two classes of oil are particularly well shown in the Humble field.

The dome oil was first discovered, and the field brought in, in 1904. The wells were comparatively shallow, being usually less than 1,400 feet and the oil, like that of the other dome fields, was of 20 to 24 gravity Beaume. The plug of underlying salt was found at 1,400 to 1,600 ft. over an extensive area.

As the production of this central pool declined, wells were sunk at various distances from it; and the Esperson wells, a mile south of the dome, found a pool of light oil in shales. Later, similar oil was found in shales north of the oil field, and more recently large producers were secured in the shales from 1 to 2 miles east. This oil has a gravity of over 30° Beaume.

The series of beds in which the oil is found here consists of shale and gumbo with some sand and dips away from the dome on all sides. Between the producing area on the dome and that of the shale oil belts on its flanks, there is a strip half a mile or more in width in which oil is not found in any quantity and in this belt the beds are apparently much broken. The conditions indicate that a mass of salt and gypsum has come up through the sedimentary beds which are broken and tilted. This condition is repeated in other domes whether oil is present or absent, and it is probable that the origin and original distribution of the oil was entirely independent of the domes or dome material. The oil was formed in the usual manner and deposited in beds of Neocene age. The movements which gave rise to the domes permitted and facilitated the collection and concentration of this oil into pools. When the uplift which caused one of the domes was close to one of these pools it captured a part or all of its oil which naturally gravitated to the highest point possible. Where oil pools were absent the domes are not oil bearing.

CRETACEOUS OIL AND GAS

One of the first really productive oil fields of the State was that at Corsicana which found its oil in the Taylor marls. When the writer examined the field in May, 1897, there were six small flowing wells which got their oil at 1040 to 1050 feet. Later the field had a wider development and a second field was brought in to the eastward known as the Powell field. This seemed to occupy the crest of a gentle fold with general northeast-southwest strike. While there is a possibility of other similar folds occurring between this and the line of Cretaceous islands none have yet been found.

Gas and oil are found at Mexia and Wortham in the Taylor marls of the Upper Cretaceous. The horizon is substantially the same as that of the oil and gas at Corsicana and the oil at Powell.

The Mexia field is situated in the northwestern portion of Limestone county. Most of the wells are located within the radius of a mile of the town of Mexia, mostly west and northwest, north and northeast of that town. but others have been put down to the south and between Mexia and Wortham on the north. The elevation of Mexia is approximately 530 feet. The wells have depths ranging from 670 feet to 1500 feet.

The Wortham wells are mostly within the town of that name, which is situated on the Houston & Texas Central Railroad in the extreme northwestern corner of Freestone county. Wortham has an elevation of approximately 475 feet. The wells have depths ranging between 1000 feet and 1200 feet.

Well No. 1 of the Mexia Oil & Gas Company tested 14,550,000 cubic ft. of gas per 24 hours, with a rock pressure of 275 pounds per square inch. The gas is entirely dry. It had the comparatively high fuel value of 965 B. t. u. Well No. 3 of the Mexia Oil & Gas Company had a rock pressure of 220 pounds per square inch and produced half to three-quarters of a million cubic feet per day after being allowed to run for some months.

At Wortham the gas emits a strong odor. The first notable well came in during the latter part of May, 1912. The pressure appeared to be about 200 pounds and the production about two and a half million cubic feet per day. The well sprayed black oil claimed to be 28 degrees Beaume gravity. It rapidly went to salt water, claimed to give off an odor of ammonia.

Throughout the area eastward of these occurrences the beds of the Cretaceous are buried beneath the Tertiary sediments, so we cannot know the exact relations.

On the western border of the Sabine embayment the Cretaceous was uplifted and folded prior to the deposition of the Tertiary and similar uplifting occurred on the eastern margin. We have, as yet, found no evidence of such folding between the Cretaceous islands and the Sabine peninsula. Any folding of the interior area at a later date would have involved Tertiary beds and would probably be evidenced by surface conditions. Since the Tertiary of this region shows few structures of this kind, it is probable that such movements were either rare or of limited extent.

The occurrence of Cretaceous oil in commercial quantities in this area could only be expected in connection with such structure, and therefore the chances for productive pools from beds of this age within this Sabine basin seem few.

The only occurrences of Cretaceous beds known in this area are those of the Cretaceous islands in Anderson and Freestone counties and along the western border of the Sabine Peninsula in Panola and Shelby counties, and as yet no commercial production of oil has been secured from them.

The Butler dome in southeastern Freestone county covers an area of about four square miles and the differences in elevation between the lowest and highest points are more than 100 feet. While it has not been studied as carefully as some of the better known localities it has been proven to be one of the chain of Cretaceous islands and the materials exposed are said to include beds from the Woodbine to the Taylor. No drilling has been done to test the oil conditions.

The Palestine dome[1] is located six miles west of Palestine. Here we find a depression of irregular shape, with a maximum diameter not exceeding three quarters of a mile. The bottom

[1] U. S. G. S. Bull. 661, p. 253.

of the depression is occupied by a shallow lake with its surface fifty feet below the general level. The banks on the eastern and northern sides slope upward gradually, but that on the west is more abrupt.

The lowest rock exposed is a sandstone, which, as proved by its fossils, is of Woodbine age. Between this and the underlying body of salt, 140 feet below, there is 85 feet of gray to yellow water sand, 40 feet of dark gray sandy clay, under which there is in places a caprock of hard limestone of varying thickness. Apparently, therefore, the Woodbine rests directly upon the salt mass.

The Woodbine, at its exposure, shows a dip of 46 degrees to the northwest. It is overlain by the Eagle Ford, Austin, Taylor (?) and Navarro beds, all of which dip northwest at angles varying from 40 to 50 degrees. No beds were found which can be referred either to the Midway or the Lower Wilcox, the lowest Tertiary beds being sands, clays and lignites belonging to the Middle or Upper Wilcox. According to Hopkins, these Wilcox beds in the vicinity of the dome show southeast dips of 38 to 57 degrees, which decrease within a mile and a half to 20 or 30 degrees, and within three miles become normal. On the northeast and southeast the Claiborne beds reach within 3 to 5 miles of the dome, but show little, if any, change from normal dip.

Six miles northeast of this locality, the Keechi dome shows the Austin Chalk at the surface, surrounded by the Navarro beds, and these are in turn encircled by the Wilcox, which dips away from the dome at angles varying between 20 and 30 degrees (Hopkins). As in the case of the Palestine dome, the Claiborne is 3 to 4 miles northeast of the Keechi dome.

The thickness of the beds as interpreted from logs of the wells would be approximately 500 feet for the Navarro and Taylor, 800 feet for the Austin and Eagle Ford, and 400 feet for the Woodbine. The salt mass reached at 2200 feet was drilled into for 900 feet, a 30 foot bed of water sand being encountered in it at a depth of 2900 feet.

Hopkins summarizes the possibilities of oil and gas in the Palestine dome as follows:

"The highly folded, faulted, and eroded condition of the

Palestine dome and the general absence of oil and gas as surface seepages and in shallow wells in this area detract from its oil prospects. The tilting and faulting of the rocks probably provided outlets for the escape of oil, and as no evidence of oil exists the conclusion is suggested that no large amount remains here, even if it ever accumulated. It is possible, however, that the soft and dominantly impervious nature of the formations involved in this fold closed up any possible lines of escape for the oil, as its absence at the surface may be interpreted to indicate. The eroded condition of the dome, as shown by the presence of Cretaceous rocks at the surface, and the presence of the salt core within 140 feet of the surface over a large area are also unfavorable conditions, as they eliminate the possibility that oil may be found on the crest of the dome, which might otherwise be the most favorable for its occurrence. Oil in commercial quantities has not yet been found in a salt dome so far removed from the coast as this one.

"The most likely area for the occurrence of oil, if it is present in this dome, is within a belt about half a mile wide that surrounds the area in which salt approaches within a few hundred feet of the surface. The most favorable part of this belt is probably near its inner margin, where the underlying formations may be tilted up against the salt mass and probably end against it.

"So far as observed, there are no subsidiary folds on the flank of the domes that would serve to trap upward-migrating oil; if such a trap exists it is at a considerable distance from the dome or is produced by the pinching out of a porous bed or by a fault."

The Keechie dome has been prospected to some extent.

The Producers Oil Co. Barrett & Grenwood well No. 1 is on the southern slope of the dome, near the contact of the Wilcox and Navarro formations. It is reported to have reached the Austin chalk at 586 feet and the top of the Woodbine (?) sand at 1,686 feet; it penetrated rock salt from 2,200 to 2,900 feet, water-bearing sand from 2,900 to 2,930 feet, and rock salt from 2,930 to 3,130 feet, at which depth it was abandoned. The Woodbine (?) sand yielded 1 or 2 barrels of heavy tarry oil at 1,686 feet. A second well was drilled on the same lease, 1,000 feet east of south of the first. The Austin chalk is reported in this well at about 1,400 feet, and the Woodbine (?) sand, which yielded salt water that could not be bailed below 500 feet, at 2,297 feet. The dip from the first to the second well, as indicated by the Woodbine sand, is about 35°. The possibility of finding oil in this dome is considered better than in the Palestine dome because it appears to be less faulted, the salt core does not come so close to the surface, and the Woodbine (?) sand is within reach of the drill and also deeply enough buried to have retained its oil[1].

While the Navarro and Taylor do not appear to be oil-bearing at either the Palestine or Keechie domes, there may be some place along the general line of uplift where more favorable conditions exist.

Wells drilled along the western border of the Sabine Plateau from Carthage to Sabinetown have found Cretaceous beds at various depths with both oil and gas.

In June, 1916, the Palmetto Petroleum Company, drilling a well on the Trosper farm in the northeastern corner of Panola county, had a blow-out from a sand found at 1050 feet. The flow was estimated at ten million cubic feet of gas and four thousand barrels of water daily. The gas not only came up from the well, but broke out at five different points, one of them a thousand feet away from the well. On June 25th it was estimated that at least 25,000,000 cubic feet of gas was escaping from the six vents.

A number of wells have been drilled in the vicinity, and the chalk has been found at depths varying from 1600 to 1800 feet. Apparently this is near the western border of the Sabine Peninsula, and it is entirely possible that oil may be found here in commercial quantities.

Another locality at which Cretaceous oil has been found is at Flat Fork between Center and Tenaha in Shelby county This is south of the Panola locality and like it, is apparently near the western border of the Sabine Peninsula. The surface formation belongs to the Lignitic phase of the Wilcox and in one of the wells drilled here this formation has a thickness of 840 feet and

[1] Hopkins, U. S. Geol. Sur. Bull. 661, pp. 267.8.

carries some light showings of oil and gas. The underlying Midway is only 140 feet in thickness and overlies the Cretaceous at 980 feet. The Annona chalk was found at 1690 feet and oil was found at 2020 feet. Kennedy reported that properly handled this well might be developed into a producer giving 25 to 50 barrels per day, but that it should be deepened to the Woodbine sands which he estimated would be found at about 2400 feet.

In the vicinity of Sabinetown several wells have been drilled into the Cretaceous.

One mile west of town, the Sabine Ore & Mineral Company drilled a 1500 ft. hole in which the top of the Wilcox was struck at 80 feet and showed a thickness of 980 feet. It was underlain by 200 feet of Midway beds and the top of the Cretaceus (Arkadelpha shales?) was reached at 1265 feet. Some showings of oil and gas were found in these wells.

A well drilled on the Jesse Low Survey four miles south of Sabinetown is reported to have reached the Annona chalk at 1900 ft. This well showed gas at 1100, 1500, 1900 and 2300 feet, and the gas burned for over two years. The total depth of the well was 2332 ft.

Ten miles south of this locality a well was drilled on Housing bayou. The log shows: 580 feet of Yegua materials underlain by over 700 feet of Cook's Mountain with the Wilcox forming the bottom hole from 1315 to 1749 ft. If the Wilcox maintains the same thickness here as in the well west of Sabinetown, 12 miles north, the top of the Cretaceous would be found at 2330 feet, or nearly 1000 feet deeper than in that well.

EOCENE OIL AND GAS

A number of wells drilled into or through the Wilcox and Midway formations, in different parts of this area, have furnished small showings of oil and gas and an occasional seep of oil occurs in them at the surface, but no productive wells have yet been found in either formation, and it is not thought probable that there will be.

In the Claiborne, however, the conditions are more favorable. The Marine beds have been found to be petroliferous in several localities, and while the fields are small, they may be worked with satisfactory results if properly handled.

The first field to be developed in the Marine was that south of Nacogdoches, known as Oil City[1], where operations began in 1877.

The oil is found in shallow wells, practically all of them being less than 400 feet in depth, and the deposits occur near the middle of the Cook Mountain beds. The oil sands are seemingly in small pockets and are irregularly distributed through the beds.

Seepages of similar oil occur in the valley of East creek two miles north of Oil City.

A number of wells have been drilled at Chireno, one of which produced a few barrels of oil from a depth of only 14 feet. Some of the wells in this locality were drilled to a depth of 1600 feet but such oil as is found usually lies near the base of the Cook Mountain beds and like the Oil City deposits occurs in small pockets. A well two miles south of Chireno reported a small amount of oil from what are believed to be Wilcox beds.

The oil of this region has a gravity of 23 degrees Beaume and although used as a fuel oil has excellent lubricating qualities.

Near Enal, a station on the Texas and New Orleans Railroad 40 miles south of Oil City, a well was drilled in search of oil. The generalized section of it shows 255 feet of sands, shales, lignites and gumbo of the Jackson underlain by 500 feet of Yegua clays and sands. Beginning at 765 feet the fossiliferous beds of the Cook Mountain horizon were reached and drilled into for over 500 feet. Small amounts of oil were found at 767, 1205, and 1265 feet, but no production was secured.

Oil seepages occur in the Marine beds both northeast and east of Palestine and the asphaltic sands resulting from them were utilized at one time as street paving material at Palestine and elsewhere. Quite a number of wells were drilled in this region, one of them as deep as 2500 feet. Oil was reported in small quantities at 864 and 1010 feet.

Southwest of Palestine, between Tucker and Oakwoods and south of the salt mine small seeps of heavy asphaltic oil have

[1] Second Ann. Rep. Geol. Sur. Tex., p. 271, etc.
Univ. Tex. Min. Sur. Bul. 1, p. 1, etc.

been found in water wells. These wells are in the Upper Wilcox and presumably the oil is indigenous[1].

In northern Madison county several wells have been drilled for oil and small shows were found at 300 to 400 feet. The indications are that deposits may exist here similar to those of Nacogdoches county.

Other occurrences of oil or gas might be enumerated from these beds but they are all of the same character and while they may be locally valuable, can only be of limited extent.

While the Yegua formation supplies the largest and most productive gas fields of the Texas Tertiary, there is at present no production within the area under consideration and we have but little information regarding prospective production in it.

West of the Colorado heavy gas is found in wells drilled into the Yegua and the gas fields at Aguilares east of Laredo find their supply in these beds. Evidence of its former presence in Grimes county is found at several localities in fused and metamorphosed shales and clays which evidently owe their present condition to the heat of burning gases escaping through fault fissures.

The possibilities of the Yegua in this region as a gas field are well worth investigation.

No commercial deposits of oil or gas have been found in the Jackson although like the Marine it apparently carries both in small quantities at a number of places.

A well drilled in Grahams creek in eastern Angelina county found a little oil in the Jackson beds at 17 to 42 feet. A small amount of oil is still flowing from this well. Similar shows of oil are found in other wells drilled south of these.

Along Pine creek southeast of Bedias in Grimes county small boulders of grahamite are found in the Jackson beds bordering the creek. At Weisers bluff on the Trinity a mass was found in the Jackson eight to ten feet in length and four feet in thickness. Similar material was found on surface at

[1] A possibility exists that the oil is of Cretaceous origin and has reached its present location through breaks in the shales overlying the salt beds.

well drilled in Little survey near Black creek in northeast Walker county. Three wells were drilled here. The first was between 1500 and 1600 feet deep. The second well blew out at 900 feet, the gas burning for several days. A small amount of oil came up with the gas. In the third well gas and hot water were found at 1800 feet. The gas from this well burns continuously when lighted. This oil and gas comes from the Claiborne and Lignitic.

No oil or gas deposits are known in the beds of the Oligoene or in that part of the Neocene which occur in this area.

Chapter XIII

SALT AND GYPSUM

The salt deposits of the coastal region of Texas are of great extent and are scattered over a wide area.

DOMES

By far the most important deposits are found in connection with the domes which occur as Cretaceous islands in the Eocene of the interior and those of later age which are found nearer the Gulf scattered through the Neocene belt. In addition to the inexhaustible supply from these sources a large number of Salines or salt springs occur in connection with palustrinal deposits of the Eocene, many of which could be utilized for the production of salt as some have been during times when other supply was less readily available.

The best known of the salt domes within our area is that southwest of Palestine, a brief description of which was given in connection with the Cretaceous formations of the region.

The core of this dome is a body of rock salt of unknown extent, the presence of which was ascertained by wells drilled into it. The salt was found at a depth of 140 feet. The wells so far drilled indicate that the top of this salt mass or boss is elliptical in form, the major axis having a length of more than four thousand feet. The surface of the salt is somewhat irregular. In the vicinity of the lake the top of the salt seems to be nearly level but to the north and west the wells show a pronounced dip in it. Hopkins says of it[1]:

"Most of the wells reach rock salt at a depth of about 140 feet, or about 160 or 170 feet above sea level the small differences in the depth being due to the surface topography; the upper surface of the salt is thus fairly level in the area near the lake. In the second farthest well to the northeast from the lake, however, the top of the salt was found at 77 feet above sea level, thus showing that the salt mass has a pro-

[1] Bulletin U. S. G. S. 661, p. 261.

nounced dip to the north from the nearest well to the southwest. A well drilled near the western margin of the lake on the west side of the railroad penetrated a jumbled mass of rock and shale to a depth of 500 feet without reaching salt; another well near the northwest margin of the lake penetrated 360 feet of rock without reaching salt. It thus seems that the salt mass dips strongly to the west and reaches a considerable depth near the western margin of the lake. No wells have been drilled on the east or southeast side of the lake, but it is inferred from the topography that this area is underlain by salt at no great depth.

"The shallow salt wells penetrate about 85 feet of gray to yellow water sand and 40 feet of dark-gray to black sandy clay, below which is in places a cap rock of hard limestone of varying thickness. The casing is set on this rock and the well deepened through sand until rock salt is reached at about 140 feet. The main factor controlling the location of salt wells is the presence of a good cap rock which serves as a seat for the casing and also holds up the overlying strata until a large cavity is dissolved out underneath it. When the supporting salt is sufficiently removed this rock, being undermined, caves in, with the overlying formations, forming a large sink hole."

The production of salt at this locality began many years ago, but was discontinued from time to time. Recently it has been renewed and a modern plant has been erected which produces a large quantity of salt of various grades.

The Keechi dome is also underlain by salt but the body of salt is so far down that it can not be utilized under present conditions. The log of a deep well drilled in this dome shows rock salt from 2200 feet to 3030 feet with 30 feet of water bearing sand at 2900 feet.

The Butler dome has not yet been drilled. Consequently, we do not know what its possibilities as a salt producer may be.

The salt of these Cretaceous domes probably had its origin in the evaporation of seawater in shallow bays during the period of Comanchean sedimentation or the Mid-Cretaceous interval.

SALINES

Throughout the East Texas region there is a series of low depressions generally known as "Salines" or "Salt Licks". These are irregular in size and depth—some cover only a few acres, while others cover extensive areas. Some are destitute of vegetation, some have occasional tufts of short grass; others have a sparse covering of salt loving plants, while the more extensive ones generally develop into palmetto covered flats. Throughout the wet season these salines are mostly small ponds or marshy places, and during the summer or dry seasons they form bare spots. Some of these salines have small springs of salt water which flow during the driest season, and some of the larger ones have their surface dotted with small irregularly spaced mounds.

Areally these salines extend over a wide stretch of country and the more important ones may be said to be associated with the main lines of drainage of the region. They lie in the low flat lands bordering the Sabine, Angelina and Neches rivers. A few, such as the Saline on Texas & New Orleans Section 17 in Sabine county, another about three miles south of Jasper, in Jasper county; a Saline near Moscow in Polk county, and McKim's Prairie near Groveton, in Trinity county, appear to form the main exceptions to the rule of the salines being connected with the river drainage channels.

The salines and salt springs occurring near Sabinetown on both sides of the Sabine and near the mouth of Bayou Negreet belong to the Wilcox, "Big Salt" northeast of Lufkin, Bluff Saline and two smaller salines on the Angelina and Attoyac lie within the limits of the Yegua beds and Bear Creek, McKim's Prairie with possibly Stiver, Graham's and a large saline near the mouth of Ayish Bayou are all within the limits assigned to beds of the Jackson age. Graham's and Stiver's are somewhat doubtful as they lie in depressions apparently eroded in the Catahoula sandstones but near the contact with the Jackson. A large salt water spring occurs near Rockland and the waters from this come up through broken beds of the hard gray sandstone found north of Neches river in this region. The saline south of Jasper and probably the one near Moscow belong to the Fleming division.

It may be remarked here that not a single saline has been seen anywhere in the territory occupied by the Cook's Mountain or Mount Selman divisions of the Marine beds and although palmetto flats are common in the other divisions and more particularly so within the limits of the Yegua and Jackson formations these are also entirely absent in the Cook's Mountain and Mount Selman divisions. Thus the Salines are practically restricted to those formations which are largely composed of palustrinal deposits.

ORIGIN OF SALINES

The source of these salts may be placed in the Lignitic, Yegua and Jackson formations, which formations are highly saliferous, while the marine formations of Cook's Mountain and Mount Selman divisions are much less so. The Lignitic beds, as well as those of the Yegua and Jackson, carry large quantities of selenite and sodium chloride. The greater number of these salines, especially those occupying the higher grounds, are associated with springs of salt water. These springs often carry other salts, such as magnesia, lime and sulphur, and by underground erosion, if we may call it so, due to the solution and carrying away of these salts, the bottom of the saline has been gradually lowered until it has reached its present condition. The springs, while fairly numerous, are never very large, but in most instances only rise a few inches above the general level and the water bubbles over a few yards to be lost in the associated sands. Many of them bring up small pebbles, thus forming a small cone around their vent. The springs are often intermittent, but some flow even in the driest period of the year. Efflorescence of saline matter is not so conspicuous in these salines as in the lower ones and it is possible that the greater portion of the salt is carried off by the running water. In the salines with springs portions of the floor is often covered with a sparse growth of coarse grass or palmetto.

Owing to the structure of some of the salt domes, such as King's and Rathbone's domes in northwestern Louisiana, it has been suggested that the larger of the salines may indicate the presence of similar salt domes. Wells have been drilled to considerable depths at these localities and no evidence of the presence of salt beds has been observed.

MOUNDS IN ASSOCIATION WITH SALINES

Many of thse salines have small mounds, or as they are sometimes designated, "mud volcanoes", connected with them. Occasionally these mounds lie around the margins of the salines, but throughout the greater number examined the mounds occupy prominent positions upon the surface of the saline. Mounds occur in connection with the Ayish bayou saline and here they dot the surface as well as occurring around the outer margin. On "Big Salt" Saline in Angelina county, Bluff Prairie, McKim's, Graham's and several other salines these mounds appear almost altogether to rest upon the surface of the saline.

Although these mounds are frequently referred to as mud volcanoes, there are no mud volcanoes, such as have been described as existing in some of the oil fields of the world, known in this portion of Texas, nor in the adjoining portion of Louisiana. The only condition approaching these mud volcanoes are the so-called "suck holes".

These suck holes or quaking bogs were observed n the Neches bottom four and five miles from Blix. Here the quaking portions of the bog are from four inches to one foot above the surrounding surface. The surface layer is hardened and cracked and underneath this is a light-blue liquid mud at least 12 feet deep. Beneath this was a brownish colored fine sand and upon stirring with a pole the mud gave off a few bubbles of non-inflammable gas. The blue mud has an odor of sulphur.

SALINES OF THE WILCOX

There are a number of small salines and salt springs belonging to this formation along the eastern side of the Sabine river, from which it is reported salt was obtained by the earliest settlers and during the Civil War. So far as our investigation go, there appears to be only one on the western bank of the river This is a saline on Section 17, Texas & New Orleans Railroad lands.

This saline occupies an area of approximately 10 to 15 acres surrounded by a slightly elevated sandy ridge. The surface material is a grayish white sand sparsely covered with a growth of short bunch grass. The bare spots show an efflorescence of salt during dry weather. Dotted over the surface there are a number of small mounds rising to heights of 6 to 7 feet and having diameters ranging from a few feet up to 30 feet. A number of small springs of salt water rise from the bottom of the saline and a shallow pit dug for water for drilling purposes gives a fair supply of a strong brine. A well drilled to the depth of 1500 feet gives no evidence of the existence of a body of salt in this saline.

SALINES OF THE YEGUA

"*Big Salt Saline*—This saline lies in Angelina river bottom about one mile east of the Texas & New Orleans Railroad bridge in northern Angelina and southern Nacogdoches counties. It occupies a depression along the stream which is from 12 to 15 feet below the level of the surrounding country. The depresssion is covered with cream-colored sand impregnated with salt, which locally forms an incrustation on the surface. Its surface in places slopes down to the level of the water in the river, but in other places the river has cut a bank from one to three feet thick below its general level.

Vegetation is sparse over the saline and there are patches of considerable extent where the glistening white sands are entirely bare. Some patches are covered by short grass to the exclusion of other vegetation. The palmetto is one of the abundant plants on the saline. Shallow depressions are occupied with ponds of turbid water. There are several island-like masses, some of which cover acres in extent and rise two or three feet above the general surface.

There would appear to be a perennial source of supply of the salt, otherwise the water flowing through the middle and covering it with its flood waters would have been likely to have long since dissolved out the salt. The depression occupied by the saline may have been caused by a leaching of the salt slightly faster than its precipitation.

During the Civil War the saline was worked for salt to supply the local demand. The salt water was secured from shallow wells and the salt evaported in iron kettles, wood being used for fuel.

Bluff Prairie Saline:—This saline lies in the vicinity of Vair Station on the Texas Southeastern Railroad in eastern Trinity county and in the flood plain of the Neches river. The saline begins in the vicinity of Vair, 600 feet southwest of Vair Station. On the south it extends about one half mile south of the tracks of the Texas Southeastern Railroad. On the east it merges into the second bottom of the Neches and on the north into a larger saline known as Bluff Prairie. The southern saline is known as Cedar Brake Prairie. Bluff Prairie extends almost to the river at a place 1½ miles north of the railroad. The surface of Cedar Brake and Bluff Prairies is incrusted with salt during dry weather. The surface soil is a fine white sand. The saline supports a scanty growth of scrub trees and palmetto. In places the surface is entirely bare. The level surface of the prairie is interrupted here and there by low circular or elliptical mounds varying from 2 to 4 feet in height and from 10 to 40 feet in diameter. Small pines or oaks grow on these mounds when the surrounding lower surface supports no arborescent vegetation, but here and there a hawthorn tree grows on the lower surface.

SALINES OF THE JACKSON

Ayish Bayou Saline:—This saline lies about twelve miles north of Jasper between Ayish bayou and the Angelina river and covers only a few acres. The surface is bare and sandy and is surrounded by an elevated rim from five to seven feet high. The material forming this elevated margin appears to be the same as that forming the mounds found within the saline. The water found in small pools is saline. Small limy concretions occur in considerable quantities both on the mounds and surrounding high ground.

Graham's Saline:—This saline is located near the Catahoula-Jackson contact, but from its low level it has been considered as of Jackson age. The saline proper lies on the north side of the Neches river and along the banks of Graham's creek and covers an area of probably twenty acres. The surrounding region is comparatively high and made up of brown sands and sandstones. The surface of the saline is a gray sand, bare in many portions, some of which are over 200 yards in length and between 50 and 75 yards in width. Other portions are covered with palmetto. Some portions of this saline are covered with low mounds from 15 to 20 feet in diameter. These mounds are mostly covered with pine trees. Several salt springs appear in the bottom of the saline and a very strong bold spring of salt water occurs a short distance from its eastern end.

Several wells have been drilled in and around this saline to depths ranging from 700 to 2900 feet, all of which showed heavy flows of hot salt water with a little oil. Well No. 3 produced about 3 barrels of oil with several hundred barrels of water daily. Well No. 9 produced about 10 barrels of oil and over 1,000 barrels of water daily for several weeks. These flows were always accompanied with heavy volumes of sulphuretted hydrogen. No salt beds were found in any of the wells.

Well No. 3 and No. 4 provided a small fauna of Marine (Cook's Mountain) fossils. The first from about 800 feet and the second from a depth as near as could be ascertained of 1200 feet.

It is said salt was made here during the Civil War, but no record is obtainable as to its quality or quantity.

Stiver's Saline:—This is a small saline near the mouth of Shawnee creek on the Neches river. It is much smaller than Graham's Saline, but very much resembles it. No wells have been drilled in this saline, but it is reported salt was made from the brine from small wells sunk to a shallow depth during the Civil War. Shawnee creek runs across the western end of this saline and hard sandstones occur in the bottom of this stream. The ridge along the northern and eastern borders is made up of chocolate colored and grayish clays and sandy clays with thin seams of soft white sandstone near the top.

McKim's Prairie:—McKim's Prairie is located in the southwestern portion of the Jose L. Lopez league in Trinity county and close to the southern boundary line of the Jackson area. This prairie covers an area of 100 to 150 acres, the greater portion of which is covered with small mounds and spots of salt incrustation. Some shallow wells have been dug at various localities but none of them exceed 35 feet in depth.

SALINES AS A SOURCE OF SALT

It is reported that by the earlier settlers and during the Civil War salt was made by boiling the salt water found at several places along the Sabine river. Hilgard mentions salt having been made in a flat two miles south of Myrick's Ferry, Sabine Parish. Salt was also made from the water of a saline near Stone Coal bluff and near the mouth of Bayou Negreet. Salt is also reported as having been obtained from "Big Salt" Saline near Lufkin.

GYPSUM

Throughout the Tertiary deposits in Eastern Texas, great quantities of gypsum, mostly in the form of selenite, makes its appearance. In some of the divisions it is more abundant than in others; thus, it is plentiful in some portions of the Midway, present, but somewhat sparingly, in the Lignitic; entirely wanting in the Queen City beds; very sparingly distributed throughout the lower division (Mount Selman) of the Marine; abundant in the upper or Cook's Mountain division, particularly near the top of these beds. Selenite crystals are even more abundant throughout the Yegua, which succeeds the Cook's Mountain, but almost entirely absent in the Fayette sands, although in the overlying Jackson clays these crystals again appear in great numbers.

Near the top of the Cook's Mountain beds there are large deposits of selenite and in some localities the crystals acquire a large size and most of them are almost, if not altogether, perfect in form. Many of them are twinned. Amongst the localities in which these crystals occur in great profusion may be mentioned a black sand near Forèst in Cherokee county; near the contact between the Cook's Mountain beds and Yegua clays a few miles north of Bryan in Brazos county, where they occur in a yellowish sandy clay and associated with Claiborne fossils; near the southern base of Cook's Mountain in Houston county, a few miles east of Crockett. Here the crystals occur plentifully scattered through a black sand and lie in bunches a few inches apart. The crystals found in this region are as a rule perfectly formed and but rarely twinned.

In addition to the greensand marls and pyrites, the water found throughout the region occupied by these Marine deposits is for the most part alkaline in nature. The destruction of the pyrites sets free more or less suphurous acid, which soon changes to sulphuric acid, and this, by attacking the lime carbonate of the shells, forms gypsum which goes into solution, is carried downward into dark carbonaceous sands and is there precipitated in the form of selenite crystals.

The Yegua is very prolific in selenite crystals; almost everywhere, where the clays of this division are found, these crystals are plentifully distributed through them, and it is difficult to find any source within this division from which these crystals may have been derived. These beds immediately overlie the Marine beds with their abundant supplies of carbonate of lime, sulphuric acid and alkaline waters, and it may be possible that the gypsums now found in the Yegua deposits went into solution in the Marine deposits and were carried up into the Yegua and meeting with its carbonaceous matter were deposited in the form we now find them. It may also be possible that particles of lime carbonate were distributed throughout these clays as original matter and that the destruction of some of the iron pyrites occurring in them set free enough sulphuric acid to form the crystals, but in the light of what is known of the structure of other clays of Miocene and Pliocene age carrying gypsums in another form, it is more likely that the selenite crystals came into both this and the overlying Jackson division in solutions carried by water. Dead pyrites in the form of what the lignite miners call sulphur balls occur in both divisions.

Many of the Jackson clays are highly calcareous, the white colored ones especially so. The darker clays resemble the

Yegua clays, in that they are liberally sprinkled with selenite crystals. Sulphur water also occurs in this Jackson division.

These Tertiary gypsums are interesting only from the peculiarity of their position and the conditions under which they occur. They are of no practical commercial value.

CHAPPTER XIV.

IRON

Introduction

Although much has been written regarding the extent and quantity of the iron ores of East Texas development has been very slow.

General descriptions of the ores were given by several of the early writers and attention called to them by Shumard and Buckley. In 1890 the Geological Survey of Texas published as part of its Second Annual a report on the region subtitled "The Iron Ore Regions of East Texas" in which after a general historical introduction, as full and detailed a description of the ore beds and deposits was given as the facilities afforded us could compass. It included a map giving, approximately, the location and area of deposits of workable ore, descriptions of the beds at many localities and analysis of what we believed to be average ores of the various localities.

Kennedy summarized and discussed the results of this work and added later observations on it in a paper published in the Transactions of the American Institute of Mining Engineers in 1894 entitled "Iron Ores of East Texas."

Phillips republshed the map accompanying the report in the Second Annual Report of the Geological Survey with some additions and wrote several descriptive articles for journals devoted to the iron trade.

Burchard in Bulletin 620 of the United States Geological Survey has a report on "Iron Ore, in Cass, Marion, Morris and Cherokee counties, Texas," in which he describes the work done in the investigation of the deposits preparatory to opening them up in a larger commercial way. From the various openings made for testing the beds he was able to give a much clearer idea of their character and extent than was possible previously when only surface exposures were available.

Probably the greater part of the ores are limonites or other hydrated oxides of iron which are popularly known as brown ore. There are, however, considerable bodies of carbonate ores (spathaic iron or sphærosiderite) and the limonite and siderite are found grading one into the other. Both classes of ore are usually, if not universally, associated with glauconitic sand. Burchard states that ore bodies of any extent are only found in such connection and are wanting in bodies of siliceous sand. When the glauconitic beds are unaltered they frequently carry considerable amounts of spathic iron as nodules and boulders. In the beds of altered greensand these boulders of spathic iron are largely altered to limonite which also occurs through the sands in other than nodular forms. It is probable that a large part of these iron ores have their origin in the siderite and that the iron of the glauconite and pyrite have contributed only a minor percentage to the mass of workable ores.

The origin of these ores has been discussed at some length by Penrose in the First Annual Report of the Geological Survey of Texas and in his report on "The Iron Deposits of Arkansas" in volume one of the Report for 1892 of the Geological Survey of Arkansas.

The workable ores are of two classes: The nodular, geode or concretionary and the laminated.

Kennedy describes the nodular ores as follows[1]: The nodular ore is usually found in the form of irregularly-rounded, oval and flattened or ellipsoidal nodules or boulders from a few inches to one or two feet in length. Outside, these present a smooth appearance and dull or earthy brown color. When broken, the shell presents a striated appearance of yellow and brown colors, formed by the alternate concentric rings of iron-ore and ocher. These striations usually do not exceed one-fourth to one-half inch in thickness, but in some of the larger nodules the iron has a thickness of over an inch, and in many the yellow ochreous concentric rings are absent, in which case the whole shell, with the exception of the brown outer covering, is dark blue. The interior coating of the shell is often a glossy black. Many of these concretions are hollow; a great number, however, have the interior filled with a core of brown

[1] Iron Ores of East Texas, p. 14.

or yellow ocher, similar to that forming the yellow rings; others have dendritic formations of ore spreading through the center and having the ends fastened to the inner side of the shell. Some few, particularly of the flattened oval form, have the entire center filled with convclutions of the inner ring. Most of the rounded forms are either empty or filled with the same character of yellow sand and amongst which they lie.

Buchard says[2]: Both the brown ore and the iron carbonate occur in nodular and geodal forms segregated in glauconitic sand and clay in thin lenses and irregular ledges, and also as more or less honey-combed thin sheets and layers, fine fragments, crusts, small isolated nodules, and irregular masses of almost endless variety. Unconsolidated material, residual from the breaking down of such masses, is found in many places at the surface.

Bowie Hill in Cass county[3] (?) shows the manner of its occurrence excellently:

Generalized section or ore-bearing beds on Bowie Hill.

Residual fragments of limonite in top soil, in places practically solid ore gravel .... 1-3 ft.

Ledge of nodular limonite, more or less solid............. ½ to 1¼ ft.

Scales and thin bands of limonite with a few thicker layers or ledges interlaminated with glauconitic sandy layers. The limonite in this condition ranges from pieces of the thickness of small chips up to masses 1½ feet thick and is scattered through yellowish to red sand and clay. It occurs in overlapping, roughly lenticular streaks, or broken and discontinuous seams. The limonite constitutes, in the sections observed, 20 to 30 per cent, by volume, of the dirt. Thickness of limonite sand and clay.......... 12-15 ft.

Iron carbonate in nodular masses from the diameter of an acorn up to 6 inches, or in thin irregular lenses, embedded or interstratified in glauconitic sand and greenish-black clay called "buckfat" clay. The iron carbonate is in general partly altered to limonite or to reddish hydrated oxides of iron, which form a scale or crust of varying thickness around the carbonate nucleus and along cracks which intersect the masses. Thickness of exposed portions of unoxidized beds .... 1-5 ft.

[2] Bul. U. S. G. S. 620, p. 74. 3. Idem, p. 76.

The laminated ores[4] vary in appearance as well as texture and thickness. In places, these ores occur in thin laminæ of dark brown or chestnut color, interstratified with similar laminæ of bright orange or yellow. These laminæ rarely exceed a quarter of an inch in thickness. At other places, the ores become more massive, occur in beds from two inches to as many feet thick, and vary in color from a dark chestnut-brown to a lighter shade of the same color, with small irregularly disseminated patches of yellow showing throughout the mass. This ore also occurs in thin wavy laminæ of from chestnut-brown to black color, usually having the spaces between the laminæ filled with fine clayey material. This grade is usually of a very crumbly nature, hence the name given to it of "buff crumbly." The laminated ores have also been made to include the botryoidal and mammillated forms frequently found intermixed with other ores.

In addition to these two classes of ore there is a considerable quantity of iron ore of a conglomeratic character spread over the country which is not rich enough in iron to be considered an iron ore.

While ores of both these classes are at times found together the workable bodies of nodular ore occur principally in connection with and interbedded in the Mount Selman deposits lying between the Sulphur and Sabine rivers. Similar ores occur south of the Sabine in the same association as well as in the Cook's Mountain beds overlying them, but they are not present in such quantity and so far as now known are not so promising commercially.

Laminated ores are also found in the Mount Selman in connection with the nodular ores but the bulk of this ore occurs as a blanket formation overlying the beds of the Cook's Mountain. The ore forms a practically continuous bed extending over considerable areas. It varies in thickness from a few inches to 6 or 7 feet and is usually overlain by sands. By its resistance to erosion it has been the preserver of parts of the ancient plateau country in Anderson, Cherokee, Rusk and Harrison counties.

[4] Iron Ores of East Texas, pp. 14-15.

SHELBY COUNTY ORES

Beginning four miles northwest of Timpson there is a broad ridge or plateau extending into southwestern Panola county. This ridge is capped by a deposit of iron ore that is apparently of workable thickness and this is underlain by beds of altered greensand with some nodular ore.

The section is as follows:

1.	Sand	6 ft.
2.	Ferruginous sandstone	6 in.
3.	Laminated iron ore	6 in.
4.	Buff crumbly iron ore	3 ft.
5.	Altered greensand with nodular and geode ores	4 ft.
6.	Sandy clays.	

Analyses of these ores give the following:

	Sesquioxide of iron	Silica	Alumina	Phosphoric acid	Water	Metallic iron
Laminated Ore	64.23	21.20	11.77	0.80	1.80	44.96
Buff crumbly ore	50.72	40.45	7.68	0.25	0.80	35.50

While there has been no development at this locality, the presence of a body of ore of this area and of the quality indicated by the analyses should insure its proper investigation whenever a market for these ores is available.

NACOGDOCHES COUNTY ORES

During the years 1863 and 1864 the McLain bloomary operating in the vicinity of Linn Flat, ten or twelve miles north of Nacogdoches, produced 150,000 pounds of hammered bars from the ores of that vicinity.

Seventeen miles northwest of Nacogdoches there is an elevated area known as the Brewer's Mountain region. This plateau stretches about four miles east and west with a width of two and one-half miles. This is apparently the southeastward extension of the plateau in Rusk county as Elkins or Iron Mountain of similar form and materials lies only seven miles to the northwestward. Brewer's Mountain is capped by a bed of buff crumbly ore which, where it is exposed, shows a thickness of from two to two and one-half feet.

RUSK COUNTY ORES

In the southwestern portion of Rusk county there is a plateau area of which apparently fifteen square miles are capped by iron ores. This is known by the local names of New Salem, Iron Mountain at Gould and Iron Mountain at Glenfawn. The ore is laminated and buff crumbly and varies in thickness, sometimes, as at Glenfawn, being as much as forty inches thick. Taken as a whole the thickness will probably average three feet.

The New Salem area four miles north of the station of Ricklaw, on the Texas and New Orleans Railroad, has been prospected to some extent. It is estimated that some 6,000 acres are covered with the laminated ore, varying from one foot to five feet in thickness, and selected samples of the ore run as high as 55 per cent of metallic iron. An average of 52 samples of laminated ore from this area gave:

Iron	45.25
Phosphorus	.248
Sulphur	.057
Silica	12.19
Alumina	8.67
Lime	trace
Magnesia	.34
Combined water, etc.	13.44

These ores, while high in alumina, will make an excellent foundry iron or one well suited to the manufacture of open hearth steel.

CHEROKEE COUNTY ORES

The most extensive remnants of the limonite capped plateau are found in Cherokee county, forming the divide between the Angelina and Neches rivers. Beginning near Mount Melman this plateau extends thirty miles southeastward to Alto with a width of more than ten miles, but it has been dissected by streams tributary to the rivers named into a number of flat-topped hills or mesas. These hills and mesas vary from a few acres to thirty square miles in area and aggregate approximately three hundred square miles.

The ore districts of this county were mapped by Penrose and his general description of them was given in the First Annual Report of the Geological Survey of Texas from which the following extracts are taken:

The ore belt in this county begins at its southern end, about three miles north of the town of Alto, and runs in a northwesterly and north northwesterly direction through the county into the southern part of Smith county. Going north from Alto the ore is found capping small flat-topped hills and narrow ridges, of limited extent, until we come within five miles of New Birmingham. These ore-bearing areas show the ususal brown laminated ore, but near Alto, their extreme southern limit in the county, it has not reached its full development and continuity as seen to the north of it. The ore is thin, and the hills are scattered, small, and form isolated points, which though low in absolute elevation look high and imposing in comparison with the surrounding flat or gently undulating country. Such eminences are Collins Mountain, Taylor Mountain, Carter Mountain, and many others, varying from one hundred to one hundred and fifty feet above the surrounding drainage level, and some five to six hundred feet above the Gulf of Mexico. In this region, eight miles northwest of Alto, was situated the old Philleo furnace. It was worked during the Civil War, but abandoned immediately after that time, and it was from the immediately surrounding region that it drew its supply of ore. Five miles southeast of New Birmingham we ascend the southern extremity of the main iron range of central Cherokee County, which extends thence in an unbroken table land, running off to the northwest for over twelve miles, and varying from one-half to three miles wide. It bears to the north and east of the towns of Rusk and New Birmingham, and finally ends abruptly at Doyle's Gap, seven miles above Rusk. Throughout this whole area the character of the ore and its associated beds is identically the same. The ore varies from one to three feet thick, is of the usual chestnut color, and is overlain by from three to ten feet of gray sand. The town of New Birmingham is built on the western slope of this range at a distance of one and a half miles southeast of

Rusk, the county seat of Cherokee County, and is the location of the furnaces of the Cherokee Land and Iron Company.

Doyle's Gap is a narrow break, half a mile wide, in the main range, and to the west of it we again ascend the northeast corner of a similar iron-bearing plateau. This is the eastern part of what is known as the Gent Mountain country, which extends hence in a southwesterly direction to within eight miles of the Neches river. Going west from Rusk we strike the southern part of tht Gent Mountain range in six miles, and in about four miles further reach the village of Gent, situated on the southwestern corner of the plateau. This range is almost cut in two by Horse Pen and One Arm creeks, running respectively north and south from the summit, but the two parts are connected by a narrow neck of ore-bearing land. This area is some six miles long by four to five miles wide and is almost continuously underlain by iron ore. From the Summit of Gent Mountain can be seen the sloping country to the west, running to the swampy bottom of the Neches, some eight miles distant. Beyond the river the country can be seen gradually rising into the forest-clad hills of Anderson County. To the south the low, flat, or undulating country forming the Neches and Gum Creek bottoms spreads out in rich pine and gum tree thickets. To the east and north are seen the ore-bearing highlands of central Cherokee County, covered with a thick growth of hickory, blackjack, and post oak, and extending on the east beyond Rusk, and on the north to within five miles of Jacksonville. Gent Mountain is some three hundred feet above the Neches River. For the first two hundred feet the slope is very rapid and then drops more gradually to the river.

The following section on the slope of the plateau and just east of Gent shows the occurrence of the ore:

1. Gray or buff colored sand ....1 to 10 ft.
2. Siliceous sandstone capping ....1 to 2 in.
3. Brown laminated iron ore .... 2 ft.
4. Indurated greensand with thin seams of clay and casts of fossils .... 45 ft.
5. Coarse white clayey sand ....20 ft.
6. Dark blackish-brown sand, more clayey towards the base, nodules of rusty clay ironstone showing shrinkage cracks. 31 ft.
7. Brownish-gray sand to base of section ....11 ft.

To the west and northwest the Gent Mountain range is bounded by Gum Creek, and beyond it the iron-bearing plateau again becomes broken up into numerous flat topped hills and narrow ridges, extending from Gum Creek to the International and Great Northern Railroad, and beyond. The railroad takes advantage of this break in the main range to pass through the plateau country, and it is the only east and west pass in a distance of over twenty-five miles. Among the most prominent of these isolated hills are Iron-Furnace Mountain (the location of the old Young furnace), Gray's Mountain and Grimes Mountain. Beyond we come to another iron-bearing plateau. It begins in its southern extremity at Ragsdale Mountain, three miles west of Jacksonville, and extends on the north to the old town of Larissa, where again it is cut off by Killough Creek. This range is over six miles long, and three miles wide in its widest part. On the east side it slopes off in a series of fertile red and mulatto soils into Gum Creek bottom, which separates it from the Mount Selman range. On the west slope of the plateau is a broad fertile agricultural country, with soils similar to those on the eastern slope, and reaching to the Neches river, a distance of five to eight miles. The ore is of the same general character as that already described. It varies from one to three feet thick, is capped with the usual one to three inches of hard brown sandstone, and one to six feet of gray sand.

The prosperous town of Jacksonville is beautifully situated three miles east of Ragsdale Mountain, and on the southwestern slope of the Mount Selman range. The International & Great Northern Railroad enters the town from the southern end of the range, and the Kansas and Gulf Short Line comes down the southwestern slope, intersecting the International & Great Northern at Jacksonville. Going northeast from the town, the summit of the plateau is reached in about one and a half miles. The ore shows itself in the gullies and breaks of the mountain slope, and is of the same character and thickness as that described on Gent Mountain and elsewhere. The range is of the customary plateau character, is twelve miles long, and varies in width from a hundred yards to a half mile. The sand cap overlying the iron here is much thinner than on many of the other iron-bearing ranges, and often the bare ore bed is exposed directly on the surface of the ground, thus adding greatly to the value of the deposit, as the mining of it requires but little or no stripping. The absence of this covering is doubtless due to the narrowness of the range, which has made it easy work for the surface waters to wash away the loose sand, and also to a westerly dip of the iron ore, which has still farther facilitated the erosion of the surface deposits, by allowing the superficial waters to run off at a rapid rate, and all in one direction. This westerly dip is peculiar to this plateau, and extends along it throughout its whole length. It is doubtless due to a local sinking to the west of the underlying strata, probably before the formation of the iron ore, and also before the plateau was cut out of the Tertiary strata. At Mourt Selman, eight miles north of Jacksonville, the ore on the eastern brink of the range is seventy feet higher than it is on the western side, less than one mile distant. Another result of this dip is to make the eastern slope of the range very steep, and in some places perpendicular, while the western slope drops off much more gradually toward Gum Creek bottom. Mount Selman is simply a part of this range, and the village of that name is situated directly on the summit of the plateau. To the north of it the ore extends for four miles, and reaches its terminus at a point one mile south of the Smith County line, and a little greater distance southeast of the village of Bullard. Here the range ends in a small flat-topped hill a hundred yards long by ten to thirty yards wide. The Kansas and Gulf Short line follows the crest of this ridge from below Bullard to within three miles of Jacksonville.

A short distance south of this is McKee's Gap, which is a narrow break in the top of the plateau and is the only interruption in the continuity of the iron ore throughout its whole twelve miles of extent. The ore of this area is of very regular thickness, varying from two to three feet. The following section on the eastern slope of the range south of Mount Selman shows the occurrence of the ore:

1. Gray sand ....0 to 2 ft.
2. Brown laminated ore ....2 to 3 ft.

3. Indurated greensand .... 30 ft.
4. Detritus.

This region forms the divide between the waters of the Neches River on the west and Mud Creek, the headwaters of the Angelina River on the east. It reaches its highest elevation at Mount Selman, where it is seven hundred feet above the sea. From here north to the limit of the iron ore there is but little change in height, but from there to Tyler it drops off to 531 feet. To the south of Mount Selman the plateau maintains almost the same elevation to within a mile northeast of Jacksonville, when it rapidly slopes off to 525 feet at that town From the summit of the ridge the land slopes off on the east very abruptly for a hundred feet, and sometimes shows two or three successive benches; thence the grade is more gradual down to the settlement of Little Arkansas and to Mud Creek bottom. To the west the grade slopes off in gently undulating hills, with a rich growth of pine, oak, and hickory, and watered by numerous creeks and springs.

The hills on which the ore occurs are steep and show a broad flat plateau-like surface, heavily capped with post oak, blackjack and hickory, generally of a small size, but very dense. The ore crops out on the brink of these hills, forming a protruding rim or crown, and often covering the slopes with great masses which have broken off from the main bed. These plateaus are sometimes as much as twenty square miles and more in area. They are often deeply cut by the ravines of creeks which have originated in springs in the superficial sand and which flow away from the plateau in all directions, cutting deep gullies and exposing the ore bed along their courses. On top of these plateau areas the covering of sand often conceals the ore for a distance of several miles at a time, but it is always found cropping out at the top of the slopes, and in wells, proving its continuity over very large areas.

The ore occurs in a horizontal bed from one to three feet thick, and averages between eighteen inches and two feet in thickness. It is flat on top, but is bulging and mammillary below and lies at or near the summits of the highest hills in the region. In fact, it is to this protecting cap of hard material that the hills owe their existence, as it has saved the underlying soft strata from the effects of erosion, which otherwise would quickly have lowered them to the level of the surrounding rolling country. The iron ore bed is directly underlain by a deposit varying from thirty to forty feet thick of a soft yellow indurated glauconite (greensand). This bed is sometimes hardened into a soft rock, easily cut with a saw or axe, and locally used as a building stone. The interior of the bed, however, where it has not been exposed to the atmosphere, retains the dark green color of unaltered greensand. The main ore bed is usually directly overlain by a thin seam of dark brown and very hard siliceous sandstone, varying from one to six inches thick, and averaging about one and a half inches. It adheres closely to the iron ore bed, though the line of separation is sharp and well defined. Above this is a gray sandy deposit, becoming more clayey and ferruginous towards its base, and varying from one to sixty feet thick. This latter thickness is, however, very extreme, and the average is about six to eight feet. As a rule the thickness of the ore depends in a general way, on the thickness of the overlying sand bed, it being thicker where the sand is less than fifteen or twenty feet than where it is greater.

Burchard reports on the development as follows[1]:

Among the best exposures are those where the ore has been mined, as, for instance, at the several State mines, 3½ miles northwest, 1½ miles north, and 2½ miles northeast of Rusk; at the Star and Crescent mines, 1¾ miles east of Rusk; and at the mines 2¾ miles southeast of Rusk, worked in connection with the Tassie Belle furnace.

The latest and most extensive of the State mines are on the eastwest spur of the plateau, beginning about 2½ miles northwest of Rusk. These workings, which have been inactive since 1909, consist of open cuts and extend westward for more than 1 mile, interrupted by places where the cover of sand is too thick for stripping and by a ravine where the ore bed has been removed by erosion. An unusually good opportunity was afforded to the writer, in November, 1914, to examine the ore

[1] Bulletin, United States Geol. Sur. No. 620, p. 92 et seq.

bed at one place where it had been stripped over an area of about 1½ acres. The regular furrowed surface of the ore bed is particularly well displayed in this stripped area, and when viewed from the top of a high bank of sand the surface resembles an abandoned plowed field in which the furrows are still faintly visible. The ore bed ranges in thickness from 15 to 36 inches and probably averages at least 2 feet. Adjoining the tract where the stripped ore bed is still in place piles of lump ore about 4 feet high have been stacked up over an area of about an acre.

Another locality where mining was done by the State is 2 to 2½ miles northeast of Rusk, around the west rim of a northward-extending lobe of the plateau. The open cut extends around the edge of the hill for a mile or more, and the stripping was carried to a maximum of 10 feet, but averages much less. The ore bed ranges in thickness from 12 to 30 inches. In places it contains a streak of sand, as is shown in the following section:

Section 2 miles northeast of Rusk.

Sand, fine grained, gray, with soil and grass at top	7 ft.
Sandstone, hard, with streaks of limonite	1 ft. 5 in.
Limonite, compact	1 ft. 0 in.
Sand, yellow, soft	5 in.
Limonite, compact	1 ft. 3 in.
Clay, white; base not exposed.	

In this section the "sand cap" probably is merged into the ledge of limonitic sandstone above the ore. At other places the typical layer of sandstone, about 2 inches thick, is at the top of the ore. Near the north end of the workings the sand above the ore contains 3 to 4 feet of fairly hard concretionary sandstone, which rendered the work of stripping more difficult. Ore was carried from this place to the State blast furnace by a steam tramroad. The last operations are reported to have been carried on in 1906.

A good exposure of the ore bed was noted on the west margin 1¾ miles east of Rusk, at the workings of the Star and Crescent furnace, where the last operations are said to have been carried on in 1907. The ore measured 32 to 38 inches in thickness at this place. More ore is still available here, as the cover has not been stripped off to as great a thickness as at the State mines. Ore was trammed down to the blast furnace, a distance of about 1 1-3 miles.

The old mines of the Tassie Belle furnace are 1 to 2 miles farther south along the west margin of the plateau, within a short haul of the furnace. These workings have lain idle for about 20 years. In one cut half a mile northeast of the furnace the ore bed is 27 to 29 inches thick and is covered by 3 to 4 feet of sand at the margin of the stripping. A pile of lump ore 1½ to 3 feet high, 50 feet wide, and about 300 feet long has been left here.

Analyses of the various ores were published in connection with the descriptions in both the First and Second Annual Reports and others are given by Kennedy in his "Iron Ores of East Texas." These show the excellent quality of these ores which are very similar to those of Rusk county.

An average of many analyses gives:

Iron	45.87
Silica	10.59
Aluminia	9.64
Phosphoric Acid	0.189
Sulphur	0.063
Lime	0.13
Magnesia	0.103
Water and Loss	11.87

ANDERSON COUNTY ORES

The iron ore of Anderson County is identical in every respect to that of Cherokee, not only in its general character, but in its mode of occurence and its origin. In fact, it is simply the westerly continuation of the same belt as has been described in that county. Going north from Palestine, the county seat of Anderson County, the main iron-bearing range, is met at about three miles from the town, and extends in a great plateau, often broken up into separate flat-topped hills, from here northerly towards Beaver, Brushy Creek, Kickapoo, and the Henderson County line. To the east this plateau breaks into small hills extending to the Neches River, and to the west it gradually disappears in the same way in the water shed of the Trinity River. This iron region forms the divide between the Neches and Trinity, just as in Cherokee the Selman Range forms the divide between the waters of the Angelina and the Neches.

The ore found here is continuous over large areas, and maintains a very steady thickness of one to three feet. To the south of Palestine the same ore is found, but here the bed is generally thinner and less continuous and the ore bearing hills are more scattered, though the ore is of very good quality.

Just northwest of Palestine the first of the great range of iron bearing hills begins. Its longer axis extends nearly northwest, and it has a length of five miles by a width of about two miles, an area of nearly ten square miles. Its boundary begins in the northern part of the J. Snively survey, runs north through the western part of the S. G. Wells, crossing into the Wm. Kimbro near the northwest corner of the Wells tract. Following a general northwest course through the Kimbro tract it crosses the southwest portion of the S. Hopkins and G. W. Ford surveys into the M. Salisar tract. Its extreme northern limit is near the centre of the tract, where it turns south to near the southern boundary of the survey, and then sharply east to the corner of the Geo. Hanks, at which point it again crosses the Kimbro tract. From here it follows an irregular line, crossing the J. P. Burnet, G. W. Gatewood, and Jno. Shirely tracts, back into the J. Snively and to the place of beginning. The ore is of the laminated variety with some concretionary ore in places.

Just east of this is a much smaller area of similar ore is found, beginning in the northeast corner of the W. Kimbro, crossing the Peter Hinds and David Faris surveys into the southwest corner of the H. Hanks tract. This deposit has a length of about two miles and is not more than one-half mile in width. The ore is similar to that just described (laminated) and has an average thickness of more than two feet.

The third area of high grade ore lies to the north of the two just described and is more extensive than either. On its of the headwaters of the Mount Prairie Creek have cut deeply into it, giving it a very irregular outline. Its south-east corner is about the southwest corner of the Jno. McCrabb survey, and the line bounding it passes northward through the western part of that tract into the J. B. McNealy, of which the deposit covers probably about one-third (the western) part. The line is very irregular here, and crosses into the Elizabeth Grace League, of which it covers an area of about one square mile in the southwestern corner. The line then passes north and northwest through the J. Hendry, F. D. Hanks, and P. O. Lumpkins tracts to its most northern point, on the Jno. Chase survey. From here it passes south through the Lumpkin tract and the eastern edge of the Geo. Andring league to its south-east corner, where it turns east through the Levi Hopkins, Danl. Parker, Jno. Wright, and S. A. Mays tracts to the places of beginning. Its area is nearly fifteen square miles. The ore is similar to that of the other localities mentioned.

Lying to the northeast of this are found two areas forming divides on the waters of Walnut Creek. One of these is on the James Hall survey, the other on the Adolph D. Latlin. The two together may aggregate one square mile.

Six miles east we find another series of hills in the neighbor-hood of Kickapoo. The largest of these has probably an area of three to three and one-half square miles, lying principally in the Jose Peneda grant, but covering also the southern portion of the Jose Chireno.

South of Kickapoo, on the W. F. Pool survey, is a large hill capped with laminated ore. Northeast of that town are two others on the Goss survey and one on the Timmons, and three miles east another hill is found, also on the Goss survey.

Just north of Nechesville are two small hills containing ex-cellent ore. With the exception of a few areas too small to be of economic value these are all the localities at which high grade ores exist north of the railway. South of the railway two areas of similar ore are mapped. These are, however, not very exten-sive. One of them is on the W. S. McDonald tract, the other on the H. Anglin.

There is, however, good ore on the high divide between Still's and Ionie creeks. It has a length of thirteen miles and an average width of a mile and a half, giving an area of say nineteen square miles. The ore on this is of a good quality, but it is not as thick nor as continuous as the beds north of the railroad. The boundary of this bed, beginning in the western part of W. Frost league, passes in a direction northeast by east through the northern portions of the P. Martin, R. Erwin, and Geo. Clewis surveys, crosses the Fien Roberts, G. Killion, W. C. Carter, W. Foreman and S. Yarborough tracts to the T. Pate survey, where it has its eastern point. From here it returns to the place of beginning by a line passing west though the Yarborough league, the Webb and Bennett surveys, and thence southwest through the W. E. Huddlestone, Neville, Killion, Webb, Thos. Hill, J. E. Palmer, Jno. Swearingen, J. W. Humy, T. H. Hamilton, J. H. Gillespie, and Wm. Frost surveys.

In addition to the areas described there are several others which, on account of the thinness and siliceous character of the ore, are not of as great economic importance. One of the largest of these areas is of rectangular shape and lies between the greater high grade ore at the head of Mount Prairie Creeks and those of Walnut Creek, and forming the divide between these creeks. It embraces parts of four surveys, the Elizabeth Grace, James Hall, J. B. McNealy, and John Little. Two other similar areas occur between the first two high grade areas described and the third, lying east and west of Beaver Postoffice respectively.

On the Stephen Crist survey, south of Palestine, there is another area of this siliceous ore, covering more than a square mile; and just south of Ionie Creek are two other hills capped with similar ore. The most westerly of these covers parts of the Wm. R. Wilson, A. Killough, J. Gibson, C. Grigsby, and Jose M. Mora surveys, and the other, beginning in the southeastern portion of the Mora survey, covers parts of the Kennedy, Jno. Blair, C. Adams, R. Walker, B. H. Adams, and W. W. Pharr tracts. It is hardly probable that these ores, if they can be called such, will be utilized at present.

The better ores are similar in composition to those of Rusk and Cherokee counties but apparently average a little higher in iron, as most of the analyses show over 47 per cent.

HENDERSON COUNTY ORES

The ore districts of Henderson county were described by Kennedy in the Second Annual Report. They all belong to the class of laminated ores and the best are found in the eastern portion of the county. By far the most extensive ore region of this county lies in its southeast corner in the district between Mulberry creek on the north, and Caddo Bayou on the south. Towards the east this field is limited by the broad bottom lands of the Neches River, and on the west by a series of deposits of yellow sand. The boundary of this field, beginning at the southeast corner of the James McDonald headright, passes south through the Maria Trinidad Equis headright to the north side of the Juan Jose Martinez survey, then turns east to near the west side of the Thomas Chaffin headright. From this point the line curves around to the northeast corner of the E. Cazanova headright and thence with a gentle curve southwesterly to the southeast corner of the A. H. Caldwell headright. From there the ridge turns southeastward and crosses the Anderson County line on the Alfred Benge headright. The western boundary of the field passes northwesterly through the A. Benge and D. M. Dickerson headrights into the east side of the Isaac Burton headright. Turning northeast it reaches the southwest corner of the Juan Jose Martinez headright, and thence southwest to the southwest corner of the W. L. Scott headright. From here the ore boundary passes north along the W. L. Scott and Simon Boon headrights to Boon Mountain, on the northwest corner of the A. K. Jones headright; thence northeast to the southwest corner of along the south side of the James McDonald headright to the southeast corner. The total area of this field is nearly fourteen square miles.

The regiou covered by this field presents a series of rounded, oval shaped, and long, narrow, steep-sided hills or ridges, having a general uniform elevation of from one hundred and forty to one hundred and sixty feet (bar.) above the bottoms of the creeks in the neighborhood.

The deposits within the region and constituting the ridges are comparatively uniform in their positions, the ore deposit being found at a level of one hundred and forty feet, and where the elevation of the ridge does not exceed this height the ore covers the surface in the form of a flat cap, broken into large boulders, frequently measuring from six to ten feet in length and four to six feet in width, and having a thickness equal to the whole depth of the ore deposit. Such points of the ridges as reach the higher elevations of one hundred and fifty and one hundred and sixty feet are covered with a light gray and yellow colored sand.

The iron ores found throughout the different ore fields of the county are all of the laminated variety of Dr. Penrose's classification, and belong to that division of the laminated ores known as buff crumbly ore. These ores have all a uniform appearance and thickness, and are overlain throughout the whole of the region by a soft brown ferruginous sandstone. This sandstone thickens towards the northeast, and is found in greater quantities in the ore fields around Battle Creek than in the region around Fincastle and Boon Mountain, in the southern field.

While the quantity of ore found in the region forming this field may not show a thickness of more than three feet, and a great extent of the area may not exceed two and one-half feet, the sides of the hills all show a large quantity of debris from which vast quantities of workable ore may be readily and cheaply obtained. The enormous erosion which this region has undergone has been the means of removing the soft underlying yellow colored sands, and allowing the ore blocks and fragments to fall down along the sides of the hills and ridges, until now these accumulated blocks form deposits of ore many feet in thickness, and which will require years of steady mining to remove before the ore beds now in place will require to be touched. It may be estimated that within this ore field each square mile of ore deposits carries in the neighborhood of seven million tons of ore.

The analyses show that these ores are fully equal to any in the region in iron content.

HOUSTON COUNTY ORES

No detailed examination of the iron ores of this county has been made. The ore at localities visited northeast and northwest of Crockett were rather siliceous and lower in iron than ores of the district east and north. They can hardly be classed as commercial ores at present.

The deposits of iron ore briefly described above, all of which lie within the area mapped, and aggregate probably more than three hundred square miles of actual ore beds, are only a part and probably the smaller part of the iron ore deposits of Eastern Texas. Their distance from a proper supply of fuel and limestone and the lack of transportation facilities have retarded their development, but it is only a question of time when they will be opened up and form the basis of a very great industry.

Chapter XV

CLAYS

Among the papers prepared for publication in the Fifth Annual Report of the Geological Survey of Texas was one by Kennedy on the Clays of Texas in which he brought together all the information then available regarding these materials. This report was never printed.

Nearly ten years later Prof. Ries of Cornell University took up the investigation of the clays for the University of Texas Mineral Survey and in Bulletin 102 of the University the results of his examinations are presented. In the preface to this report he says:

"In the limited time available it was out of the question to work out in detail the geological relations of the different clay deposits, but still in most instances the geological age of the deposit was known and the main point was to determine the character and possible practical value of the clays in these different formations.

"The object of this is twofold, viz., to supply the land owner with some knowledge of the clay resources of his region, and to acquaint the prospective manufacturer with the character of the clays occurring in the State. To the former class a brief statement of the possible uses of the clay is most important; to the latter class a statement of the physical characters and chemical composition is the most useful. It should be understood that the report deals mainly with the use of clay for burned clay products. Those seeking clay for the manufacture of Portland cement will find the various analyses helpful.

"The series of tests undertaken for this report are probably the most detailed ever undertaken by a State geological survey, and it is felt that the results obtained have warranted the time and effort spent.

"Briefly summarized, it can be said that the work has developed the presence of an extensive series of refractory and semi-refractory clays in certain of the Tertiary formations of the State. These are the Lignitic and Marine formations. They extend across the State in a northeasterly direction from Bexar county to Bowie county, and are crossed by a number of important lines of railroad."

This bulletin records a number of clays from the area under discussion and gives in the most satisfactory way their character and qualities. In the following statements it has been freely used together with the reports of the Texas Geological Survey and our later investigations.

The clays found in this area may be classified as follows:

Fire clay, Pottery clay, Brick clay, Slip clay.

1. Fire clay. The term fire clay belongs to those clays which are capable of resisting fire to a marked degree, or, in other words, to those which are refractory and fuse only when exposed to a high temperature.

Its use should be restricted to those clays whose fusion point is at least above that of cone 27 (3038°F. or 1670°C.) Good refractoriness is, therefore, the most important quality of a fire clay, whatever variation it shows in its other properties, such as plasticity, tensile strength, air shrinkage, etc.

The main use of fire clay is for the manufacture of fire brick. These are made of many different shapes to suit the conditions under which they are to be used.

2. Pottery clay. The clays employed under this head are those employed for the manufacture of common red earthenware, stoneware, white earthenware and porcelain.

Earthenware Clays. These are used in the manufacture of the lowest grades of pottery, such as common flower pots, etc. The main requirement of them is sufficient plasticity to turn on a potter's wheel, freedom from an excess of grit, and adaptability to burn to a hard, dense body at a low temperature.

Stoneware Clays. These differ from earthenware clays in their denser burning character and greater refractoriness.

Stoneware is usually made from a refractory or semi-refractory clay, and the best results are obtained by employing a mixture of materials. Where the two clays are mixed together, the one is selected on account of its dense burning qualities, the other because of its low shrinkage and possibly also its refractoriness. A stoneware clay might be as refractory as one used for fire brick, but differ from it in its denser burning qualities.

3. Brick clay includes clays which can be used for common, pressed or paving brick. Many common brick clays can be used for drain-tile or red earthenware manufacture, and most of the semi-refractory buff-brick clays found in Texas could be applied to the manufacture of common stoneware, No. 2 fire brick, terra cotta or floor tile.

4. Slip clays are those containing so high a percentage of fluxing impurities as to melt to a glass at the temperature at which stoneware is burned and are therefore used as natural glazes.

The Tertiary beds of East Texas are largely composed of clays and sands but many of the clays carry too high a percentage of sand, lime or gypsum to be of much importance in the manufacture of clay products. Deposits of excellent clays do occur and are being utilized at many localities.

CLAYS OF THE MIDWAY

While these clays carry a considerable admixture of lime and gypsum there are localities at which they are sufficiently free of these substances to furnish a satisfactory clay for the better grade of brick making Although these clays have not yet been studied the practical tests that have been made are sufficient to warrant further development of them.

These clays are found very well developed in the country around Mexia, southward as far as Groesbeck and northward toward Wortham and whatever uses they may be available for may with equal facility be applied at either or all of these three places. At Mexia the shales are bluish with yellow and brown streaks, but when ground together present a yellowish brown appearance. These clays are quite plastic when wet. As the clays of this formation carry more or less lime and selenite they may be considered a non-refractory or, at best, only semi-refractory.

No tests of these clays looking to their chemical or physical character have been made, so that very little is known regarding their uses, outside the fact that they make a fairly hard pressed brick burning to a bright red.

CLAYS OF THE WILCOX

The Wilcox carries excellent deposits of clays fitted for nearly all uses except perhaps the finer grades of earthenware. Interbedded with the lignites there are beds of shale which are often semi-refractory and clays which, while non-refractory, possess excellent plasticity. In other portions of the beds a red-burning, tough shaly clay is found but the most valuable clays and those which seem to have the widest distribution are the grayish, highly plastic, refractory or semi-refractory clays which occur throughout its entire extent and are opened up at several localities between the Sabine and San Antonio.

These deposits include fire clays, pottery clays and brick clays and are well suited for the manufacture of a great variety of clay products.

FIRE CLAYS

The better grade of fire clays are the grayish clays which seem to belong in the upper half of the Lignitic section. These were first developtd in the vicinity of Athens in Henderson county. The numerous openings show this bed of clay to be of a grayish white color and to have a thickness of from two to twelve feet. It rests upon a bed of white even-grained sand five feet or more in thickness. These sands and clays are found in association at numerous places. While the clay bed at Athens extends over an area of two square miles or more it is probably lenticular and one of several similar deposits as clay of the same character but of somewhat darker color is found at Malakoff, ten miles southwest of Athens, where it is mined and used.

These clays are very refractory, the fusibility of them being those of Seger cones 27 to 30. They are used for the manufacture of fire brick and pressed brick.

While the beds of the Wilcox continue southwestward through Freestone county and it is entirely probable that clays of this character occur in them we have no record of their having been observed there. They are found again in Limestone and Robertson counties and as far south as San Antonio.

Along the line of the Houston and Texas Central Railway these clays are found about a mile east of Denny station in the banks of Grace Spring creek. They lie in a somewhat irregular form in association with a white sand, sometimes apparently underlying the sand, at other places interstratified with the sand, or lying in the form of a large lens within the sand. This clay and sand can be followed for more than a mile along the creek. At no place can this clay be said to have a uniform thickness. It varies from two to ten and sometimes fifteen feet and at one or two localities the clay has a thickness of twenty feet. The clay is white with a very faint pinkish shade. The sands are white, very fine-grained, often indurated and carry numerous small scales of mica. In places it is stained with iron.

South of this at a point five and one-half miles east of Bremond there is an occurrence of similar clay.

While the material is not classed as a high-grade china clay, still it is of a very refractory character. The physical properties of the clay were as follows: Color when moist, whitish gray; soluble salts, 0.09 per cent. The material slakes fast and mixed up with 19.8 per cent of water to a mass of low plasticity and very gritty feel. The air shrinkage was 4 per cent and the average tensile strength 48.5 pounds per square inch with a maximum of 57.3 pounds. In burning it behaves as follows:

Wet-molded Bricklets

Cone	05	03	1	3	5	9	14	33
Fire shrinkage per cent	0.1	0.7	0.3	0.3				
Color	White	White	White	White	White	Whitish	Whitish	
Absorption per cent	13.86	13.46	13.13	12.85	12.93	12.06	11.18	

The material even at cone 14 (2570 F.) was not steel hard and in spite of its low shrinkage its absorption was not high.

This clay was so sandy that the material did not lend itself readily to dry pressing. It does not burn to the pure white necessary for porcelain manufacture. The chemical composition indicates the siliceous character of the clay and cause of its low shrinkage.

	Per cent
Silica	83
Alumina	7.42
Ferric Oxide	0.36
Lime	trace
Magnesia	3.01
Soda	1.26
Potash	0.30
Titanic acid	0.70
Water	3.70
	99.75
Total fluxes	4.93

This is one of the most refractory of the Texas clays tested and is well worthy of careful investigation by fire brick manufacturers.

Very little use has ever been made of this clay. A number of years ago Mr. Denny used it for the manufacture of common jugs and other pottery ware which he burned in a small down draft circular kiln close to the railroad. The ware burned hard and of a grayish color and readily took both the Albany black slip and salt glaze. Although this kiln is still standing, no ware has been made for several years.

In the vicinity of Headville in Robertson county there are several exposures of brownish colored and white clays. The whites are somewhat sandy and in places iron stained by the presence of ferruginous nodules. In places these white clays are overlain by a white sand. The deposits are irregular in thickness, varying from five to fifteen feet. On the J. W. Harper tract the thickness exposed is about five feet, but Mr. Harper says when burning brick in this locality he found the clay to extend downward below fifteen feet. On the Harper farm the white clay is overlain by a reddish sand.

The areal extent of the clay in the Headville region was not ascertained, but from its appearance in a number of small creeks it apparently covers several hundred acres, or at least enough to justify its exploitation.

This material when moist is brownish gray in color and slakes slowly when thrown into water. It has 0.15 per cent soluble salts and some fine grit. When mixed with 19.8 per cent of water it gave a mass which was highly plastic to the feel, but which had a low air shrinkage and tensile strength. The former was 4 per cent and the latter averaged 64 pounds with a maximum of 70 pounds per square inch. In burning the clay behaved as follows:

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	14	30
Fire shrinkage per cent	17	4	6	1.4	2	3		
Color	Whitish	Whitish	Whitish	Whitish	Whitish	Whitish	Light-Buff	Buff
Absorption	17.20	17.18	15.97	15.82	13.83	11.92		10.71

The chemical composition of this clay is:

	Per cent
Silica	70.82
Alumina	18.90
Ferric oxide	0.40
Lime	trace
Magnesia	trace
Soda	0.50
Potash	trace
Titanic acid	2.10
Water	6.80
	99.52
Total Fluxes	0.90

Regarding this clay Ries says: "This is rather an interesting clay and while it is a fair grade of fire clay, it is not highly refractory, due to its high silica percentage, and no doubt also due in part to the high percentage of titanic acid."

The white clay belonging to this region and underlying the brownish gray clays is in many respects similar to the clay found near Denny and belongs to the same horizon. Ries classes it as a very lean sandy clay whose physical properties were as follows: Color, when moist, white; soluble salts 0.08 per cent; water required 17.6 per cent, slakes fast; plasticity low, with much coarse grit. The air shrinkage of the molded bricklets was 3.3 per cent and the average tensile strength 40 pounds, with a maximum of 46 pounds per square inch. In burning it behaves as follows:

Cone:	05	03	1	3	5	9	31	32
Fire shinkage per cent			0.1		0.3	vis.		
Color,	Pinkish white	Pinkish white	Pinkish white	Pinkish white				
Absorption, per cent,	14.71	14.71	14.16	13.06	13.05	12.29		

The chemical composition is:

	Per cent	
Silica	77.4	
Alumina	15.7	
Ferric oxide	0.7	
Lime	trace	
Magensia		
Soda	trace	
Potash	trace	
Titanic acid	0.7	
Water	5.7	100.2
Total Fluxes	0.7	

The clay burns to a good white color, and is very lean and sandy, but if it were to be used for pottery manufacture it would have to be mixed with a denser clay. It is to be classed as a fair grade of fire clay and if some of the sandy matter could be washed out of it, the refractoriness would undoubtedly be increased

This clay, together with the brownish gray clay, was used for pottery and brick making a great many years ago.

It will be noted that all the analyses given are those of the raw clays, that is, the clays just as they came from the mine, without any preparation of any kind. The effects of careful washing or of mixing different clays to obtain material for special industries is practically unknown.

At one time parties interested in the Headville clay made an effort to secure its utilization. Some of the clay was mined and washed and sent to France where it was made into tableware which was apparently of very good quality. At that time, however, the cost of preparation and transportation to potteries proved to be too great to warrant an attempt to open it up commercially.

These clays are well worth a very thorough investigation. Their refractory character is fully established and there is a strong possibility that they can be prepared for use in the manufacture of the better class of white earthenware.

These clays are also found in the Lignitic beds in the eastern portion of the State and may occur in Shelby county. While Walker does not mention the clays he speaks of the beds of white sand five and one-half miles north of Timpson. This would be about the proper horizon and it may be they will be found there.

POTTERY CLAYS.

These include clays suitable for the manufacture of porcelain and white earthenware such as may possibly be found in the beds already described as well as those for stoneware and common red earthenware.

Stoneware clays of excellent quality abound in the Lignitic.

The general character of the stoneware clays is shown in the following descriptions:

On the north side of the railroad track at Saspamco a number of openings have been made in order to obtain clay for the manufacture of sewer pipe for a factory located at this point. The material is similar to that used for stoneware manufacture at Elmendorf, and the formation involves a series of speckled shaly clays interstratified with occasional beds of sandstone and ochreous clay. Owing to the somewhat lenticular character of the clay deposits, new beds have to be opened from time to time as the old ones are worked out. The section in the bank, which was being worked at the time of the writer's visit, was as follows:

1.	Sandy, laminated, iron-stained, surface clay	1 ft.
2.	Chocolate clay	8 ft.
3.	Yellow, ferruginous clay (rejected)	1 ft.
4.	Chocolate clay of dense, tough character	7 ft.

The beds dip gently to the westward and the deposit whose section is here given can be followed for at least 1500 feet to the north, where it dies out. Lying to the northeast and west, respectively, are two other pockets of clay, and one large pocket near the works has been exhausted. The physical properties of the sample taken from the pit in operation were as follows. Clay dense and homogeneous with a few mica scales. Color, when moist, brown; soluble salts, 0.24 per cent. The material slakes slowly and works up with 30.8 per cent of water to a mass of high plasticity and great stickiness, but little grit. The average tensile strength was 257 pounds per square inch, with a maximum of 310 pounds per square inch, but was found difficult to obtain a series of briquettes free from flaws, as the clay cracked some. The behavior of the material in burning was as follows:

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	12	28
Fire shrinkage per cent	1.6	2.7	3.3	5.6	5.7	9.4	Swells	vis.
Color:	Buff	Buff	Buff	Buff	Gray	Gray	Gray	
Absorption per cent	11.44	9.52	6.57	2.35	2.83	0.82	Beyond vit'n.	

Dry-press Bricklets

Cone	1	9
Fire shrinkage, per cent	2.75	8
Color	Buff	Buff
Absorption, per cent	10.20	2

The clay burns steel hard at cone 05, and makes a good hard body of uniform color, which is buff, until cone 9, when it burned gray, due probably to reducing conditions. At cone 12 it swelled somewhat and was slightly blistered. It gives good results when burned in dry press form. The chemical composition is as follows:

Analyses of Pottery Clay from Saspamco, Bexar County:

	Per cent
Silica	64.92
Alumina	22.70
Ferric Oxide	0.80
Lime	0.10
Magnesia	0.74
Soda	0.71
Potash	0.12
Titanic Acid	1.40
Water	7.00
Total	98.49
Total Fluxes	2.47

The material is being used by the San Antonio Sewer Pipe and Manufacturing Company for the manufacture of sewer pipes, conduits and hollow blocks. They also utilize the clay for the manufacture of fire bricks for use at their own works.

Denny, Falls County: The pottery clay used at this locality is obtained from a bed about three and a half miles South of Denny. The clay bed, which has a thickness of 12 feet, is exposed for a distance of several hundred yards up and down the ravine from which the sample was taken, and is underlain by a white clay similar to that described from the vicinity of Bremond. The physical properties of the clay are as follows: The material, when moist, is of light brown color and quite homogeneous in texture. When dry it is very hard and slakes slowly when thrown into water. It shows but little grit, and contains 0.14 per cent of soluble salts. It required 24.2 per cent of water to mix it up to a mass of high plasticity, and had 6.3 per cent air shrinkage. The average tensile strength of the air-dried briquettes was 217 pounds per square inch, with a maximum of 251 pounds per square inch. It behaved as follows in burning:

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	14	28
Fire shrinkage per cent	2	2	4	4.6	5	6.6	Beyond vis.	
Color:	*Light Buff*	*Pink Buff*	*Buff*	*Buff*	*Gray*			
Absorption, per cent	12.51	12.41	9.29	6.73	5.53	1.38		

Dry-press Bricklets

Cone	1
Fire shrinkage, per cent	4
Color	Buff
Absorption, per cent	12.25

This clay is not unlike the regular run of Texas pottery clays. As it will be noticed, it burns buff to cone 9, when it burns gray. At cone 14 it swells and shows slight blistering as well as the development of a few fused specks of iron.

Five miles east of Henderson, in Rusk county, is a pottery clay pit showing the following sections:

1.	Gray sand	1½ ft.
2.	Yellow clay	1½ ft.
3.	Pottery clay	4½ ft.

Parts of the pottery clay show some pockets of sand with slight variations in color. The color of the clay is similar to that used by Mr. Russell, whose pit is some four miles away, but it is not possible to say whether these two pits are different beds or parts of the same one; but the clay here exposed in Mr. Hill's pits is thought to be an extensive deposit.

The physical properties of the material are as follows: Color, when moist, brown; soluble salts, 0.50; water required, 18.7; slaking, slow; plasticity, high; grit, very low; air shrinkage, 6 per cent; average tensile strength, 89.7 pounds per square inch; maximum 110.8 pounds per square inch. In burning it behaved as follows:

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	14	27
Fire shrinkage per cent	2.3	2.4	4	5	5	6.3	7.3	vis.
Color:	Pink	Pink	Light Buff	Light Buff	Buff	Buff	Gray	
Absorption per cent	18.70	18.17	12.22	10.42	9.22	6.34	2.27	

Dry-press Bricklets

Cone	1
Fire shrinkage, per cent	3.33
Color	Pink Buff
Absorption, per cent	14.30

The wet-molded bricklets burn steel hard at cone 1, as did also the dry-press ones. The fire shrinkage of the clay, it will be noticed, is only medium and the clay is to be classed as a low grade fire clay. This clay does not burn to as bright a buff as many of the pottery clays tested. That burned at cone 5 got flashed at one edge and showed a very much deeper color.

Pottery clay is dug on the Henderson and Marshall dirt road, four and a half miles northeast of Henderson. The beds are at least 6 feet thick, but the base has not been exposed. The upper 1½ feet is of reddish clay, but has considerable iron stain, which is pink when dry and blue when wet. Nothing definite can be stated regarding its extent.

The physical qualities are as follows: The material is a hard, homogeneous clay, with a conchoidal fracture and some mica scales. It contains 0.06 per cent of soluble salts, and when thrown into water slakes slowly. With 29.7 per cent of water it works up to a mass of good plasticity containing a little fine grit. Its air shrinkage is 7 per cent and the average tensile strength 148 pounds per square inch, with a maximum of 177 pounds per square inch. In burning the material behaved as follows:

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	14	27
Fire shrinkage per cent	1.7	2.6	4.3	4.7	6	6	6.6	vis.
Color:	Pink Buff	Pink Buff	Pink Buff	Pink Buff	Pink Buff	Pink Buff	Gray	
	05	03	1	3	5	9	14	
Absorption, per cent	15.53	12.59	11.16	9.82	5.41	4.83	3.11	

Dry-press Bricklets

Cone:	1	9
Fire shrinkage	1.33	3.33
Color	Pink	Pink
Absorption, per cent	7.53	...

The wet-molded-bricklets burned steel hard at cone 1. In its general features this clay closely resembles the Athens and the Denton pottery clays. The chemical composition is as follows:

Aanlysis of Pottery Clay from near Henderson, Rusk county

	Per cent
Silica	67.84
Alumina	21.80
Ferric Oxide	1.00
Lime	trace
Magnesia	trace
Soda	1.11
Potash	0.39
Titanic Acid	1.48
Water	7.37
	100.99
Total Fluxes	2.50

In the neighborhood of Evansville, Leon county, clays of economic value are found in association with the lignite deposits. At various localities on the Connelly league and Rejon grant blue and gray clays occur which are of a refractory or semi-refractory nature and compare favorably with the clays used at Saspamco for the manufacture of sewer-pipe and drain-tile. These Evansville clays would take the necessary glaze.

The Lignitic area of eastern Nacogdoches county, Shelby county, and the northern portions of San Augustine and Sabine will probably yield clays of similar character.

The fact that certain clays are grouped here under the head of stoneware clays is not to be regarded as indicating that they can be used for this purpose alone, but the term is to be regarded as an index of certain physical qualities characteristic of stoneware clays.

The most important use of stoneware clays is for the manufacture of terra cotta, buff brick, floor tile, retorts, fire brick, in short, as an ingredient of many kinds of ware in which a refractory, plastic, more or less dense burning clay of good bonding power is required.

Their value is never sufficiently high to permit of their shipment to distant markets, and consequently, they must be worked up near the point of production.

The Texas stoneware clays have not, by any means, been developed to their full capacity, for at present they are utilized in the most limited manner by small potteries scattered here and there over the State. The wares now being produced show that they can not only be made to yield a good stoneware body, but will also take either a slip, salt or Bristol glaze-ware with good results.

CLAYS OF THE MARINE

The Marine is prevailingly sandy but carries some clays of economic importance. As has been stated previously, beds of lignite occur in it ocasionsially and these are accompanied by clays or clay shales of good quality, some of which are refractory and others, while not sufficiently refractory to be classed as fire clays, are well adapted for the manufacture of buff brick. The deposits occurring at Minera in Webb county in connection with the cannel coal of that region are of this latter class. The deposits worked near Nacogdoches are of the former.

A stoneware clay is dug near Carmichael's pottery six miles south of Nacogdoches. The material is a dark brown, finely gritty clay, containing 0.10 per cent soluble salts. It slacks slowly, but with 25.3 per cent water, works up to a mass of high plasticity whose air shrinkage was 9.6 per cent. The average tensile strength was 302 pounds per square inch, with a maximum of 374 pounds per square inch. In burning it behave as follows.

Wet-molded Bricklets

Cone:	05	03	1	3	5	9	14
Fire shrinkage, per cent	03	1	2.6	3	4	5.7	vis.
Color:	Buff	Dark Buff	Deep Buff	Deep Buff	Gray Buff	Gray Buff	Gray
Absorption, per cent	10.35	8.63	5.68	5.32	3.30	4.00	

Dry-press Bricklets

Cone:	1	9
Fire shrinkage, per cent	2.33	6
Color	Buff	Light Gray
Absorption, per cent	14.50	4.86

The clay burned steel hard at cone 9, but was nearly so at cone 3; its fire shrinkage is low and it burns to a good dense body. The slight increase in absorption of the wet molded bricklet at once 9 is due to a slight blistering of the ware.

The chemical composition of the sample tested is:

Analysis of Pottery Clay from Nacogdoches, Nacogdoches County

	Per cent
Silica	75.33
Alumina	14.73
Ferric Oxide	1.10
Lime	0.05
Magnesia	1.61
Soda	0.10
Potash	0.64
Titanic Acid	1.27
Water	4.50
Total	99.33
Total Fluxes	3.50

This clay is at present used for making common stoneware. It burns to a deeper buff than the Athens stoneware clay. It is not sufficiently refractory to be used for fire brick manufacture, but could profitably be utilized for making buff brick, terra cotta, or at least for the backing of encaustic tile.

CLAYS OF FAYETTE AND YEGUA

These formations both carry numerous beds of clay. Some of the clays of the Fayette are white in color and are of good plasticity. They have been called kaolins but are probably not entitled to such classification. They vary very much in character and the specimens analyzed by Ries supposedly from these beds are not thought to be of especial value.

A sample of the so-called kaolin was tested from the property of Mr. Lytenburg, southeast of Lena. This material is whitish in color, but contains heavy limonite stains on all of the joint and fracture surfaces. It slakes very slowly when thrown into water and forms a gummy mass of very low plasticity, but practically free from grit. Its tensile strength is so low that it was difficult to test the briquettes made from the clay. The material was so lean and cracked so when drying that no wet-mud bricklets were tested and the sample burned were all molded dry-press. When burned at cone 9 a sample ground to 60 mesh showed a fire shrinkage of 8 per cent and absorption of 9.44 per cent. Another sample ground to 100 mesh and burned at this cone showed a fire shrinkage of 12 per cent. A third sample ground to 60 mesh and burned at cone 12 showed a fire shrinkage of 13.33 and an absorption of .61. The clay burned steel hard at cone 9, and although its general color was whitish, all of the samples burned showed small black specks.

The material is not a fire clay for at cone 27 it fuses to a clear glass. Its chemical composition was as follows:

	Per cent
Silica	73.00
Alumina	15.79
Ferric Oxide	63
Lime	1.29
Magnesia	1.53

Soda	.16
Potash	trace
Titanic Acid	.10
Manganese Dioxide	trace
Water	5.76
Total	98.69
Total Fluxes	3.71

This is the only test of which we have record, and it should not be taken as characteristic of all Fayette deposits, for among them will be found clays of better grade than this.

In the region under consideration the Fayette outcrop at Homer in Angelina county may repay examination.

This bed of clay is white to cream-colored, sometimes grayish when damp. It is hard, compact, fine-grained and breaks with a conchoidal fracture. Sections of four to five feet were found with bottom not seen. It appears to be a lenticular deposit with an east-west diameter of 2,000 feet or more. A commercial analysis gave the percentages of silica 64.85, alumina 17.01, with about 6 per cent of fluxing material.

The shales and clays accompanying the lignites of the Yegua should yield some fair beds of plastic or semi-refractory clays but so far they have not been studied nor are there any localities within the area at which they have been utilized.

CLAYS OF THE JACKSON

While we have no analyses of clays belonging to the Jackson, there are beds occurring in the Caddell series which are apparently of good quality for the manufacture of bricks and common earthenware. Among the clays of the upper portion of the Jackson some of those which have been derived from the alteration of the sediments of volcanic origin will furnish good slip clay material and this is also true of similar clays in the Corrigan. Ries gives the analyses of one of these.

Two miles southeast of Carmona and 8 miles east of Corrigan clay is found outcropping for a distance of some five hundred feet on the bank of Bull Creek on the property of the Cameron Lumber Company. The thickness exposed is at least six feet but the base of the bed is hidden. The clay, when moist, is of a sky blue tint and very uniform color, but when dried is almost white. It appears to be slightly granular in texture, but is soft and can be easily crushed between the fingers. A sample of this clay was tested with the following results: Soluble salts, 0.06 per cent; water required, 36.3 per cent; slaking fast; plasticity, low; texture, sandy. The air shrinkage is 1.3 per cent and the average tensile strength 61 pounds, with a maximum of 62 pounds per square inch.

Analysis of Clay from Carmona, Polk County:

	Per cent
Silica	68.34
Alumina	15.28
Ferric Oxide	3.44
Lime	1.20
Magnesia	0.88
Soda	3.55
Potash	2.47
Titanic Acid	0.52
Water	4.70
Total	100.38
Total Fluxes	11.54

Among the peculiar physical characteristics which the clay shows are its low air shrinkage and its remarkably high fire shrinkage, which at cone 1 is 16 per cent. It has no value whatever as a brick clay and its chief use would be as a slip clay for decorating pottery.

Clays of this character are rather common in both the Jackson and Corrigan of our area and they also occur in the Fayette west of the Colorado.

Kennedy says of a clay of this character from Grimes county: An extensive deposit of a good clay occurs in the neighborhood of Piedmont Springs. In structure it is thinly stratified and breaks with a sub-conchoidal fracture. Thin streaks or stains of iron occur at places throughout the partings, but in general the clay is milky white. An analysis in the laboratory of the Survey shows:

	Per cent	
Silica	58.50	
Alumina	18.39	76.89
Ferric oxide	3.21	
Lime	2.34	
Magnesia	1.61	
Potash	2.70	
Soda	4.93	
Sulphuric acid	trace	14.79
Water and loss	8.70	8.70
Specific gravity, 1.5		100.38

The high percentage of the alkalies, iron, lime and magnesia contained in this clay places it in the anomalous position of midway between the grade of a good pottery clay and a "slip" clay. It might probably, with care, be utilized for certain grades of earthenware. In composition the Piedmont clay resembles the "Albany" slip so much used among the pottery manufacturers for glazing purposes.

CLAYS OF THE FLEMING

The prevalence of calcareous material in the Fleming clays is against their use as fictile material but there are occasional deposits of value.

A sample of clay from the land of U. R. Shine, Hortense, Polk County, had the following physical properties: Color, pink-brown; soluble salts, 0.15 per cent. It contains very little grit and works up with 30 per cent of water to a mass of high plasticity, whose air shrinkage is 8.1 per cent. The average tensile strength of the air-dried briquettes was 248.5 pounds with a maximum of 269.5 pounds per square inch. Its burning qualities were as follows:

Wet-molded Bricklets

Cone:	05	1	3	5	9
Fire shrinkage, per cent	2.6	4.3	5.3	6.7	8
Color:	Pink	Pink	Gray Brown	Gray Brown	Gray
Absorption, per cent	12.37	9.35	7.96	4.25	2.33

Its chemical composition was as follows:
Analysis of Clay from Hortense, Polk County:

	Per cent
Silica	70.00
Alumina	18.60
Ferric Oxide	4.50
Lime	trace
Magnesia	trace
Soda	0.90
Potash	trace
Titanic Acid	0.60
Water	6.10
Total	100.70
Total Fluxes	5.40

Although this is a rather siliceous clay, as shown by the physical properties and the chemical analysis, still it burns to a rather dense body and becomes steel hard even at cone 1.

At the present time it is not being worked for any purpose, but would, no doubt, lend itself to the manufacture of common brick, or even, perhaps, dry-press brick, and is less siliceous than some clays which are being used in the State for molding in dry-press machines.

There is a possibility that some of the more highly calcareous clays of the Fleming would furnish material for the manufacture of natural cement.

An analysis of clay of this character from near Courtney in Grimes county shows:

	Per Cent
Silica	40.69
Alumina	12.68
Ferric Oxide	3.90
Lime	18.12
Carbonic acid gas and water	18.91
Alkalies by difference	1.14
Magnesia	.92
Manganese	trace
Water at 100 degrees C	3.64
	100.00

At many localities within this area there are deposits of clays suitable for the manufacture of red brick and pressed brick some of which are being utilized by local brick yards.

Taken all together, therefore, the clay resources of the area appear to be ample for a great production of common brick, pressed brick and fire brick, common red earthenware and stoneware, sewer-pipe, drain-tile, encaustic tile and, in short, practically all clay products below the grade of white earthenware with a possibility of some clays suited for that use.

CHAPTER XVI.

FULLER'S EARTH, VOLCANIC ASH, GLASS SAND

FULLERS EARTH

Fuller's earth is a material having a chemical constitution similar to that of clay, but differing from ordinary clays in some of its physical properties. It possesses a high absorbent power for certain substances and by reason of this is very useful as a decolorizing agent. Its chief use is for filtering, bleaching and clarifying fats, greases and oils. The value of any deposit for these purposes cannot be determined by chemical analyses, but must be ascertained by practical test. To be of commercial importance, the fuller's earth must not only bleach the substance treated, but it must leave no disagreeable taste or odor, must not absorb too much oil, must filter well and without clogging filter press.

Fuller's earth that gives excellent results with one class of fats or oils may be far less satisfactory with others, and that which is used for bleaching petroleum oils is seldom the best bleaching and clarifying agent for use with vegetable and animal oils.

To fit fuller's earth for use it must be prepared by drying and grinding to the size best suited to that use.

In preceding chapters attention was called to the prevalence of volcanic ash or tuff and fuller's earth in the upper portion of the Jackson and the Corrigan throughout the region between the Neches and the Brazos. The deposits are at times very closely associated and constitute a considerable portion of the deposits of the formations named. It is probable that the fuller's earth is simply altered portions of the ash or tuff.

The relations of the volcanic ash or tuff and fuller's earth are shown by the occurrence on Lucas creek north of San Antonio, where there is a bluff 18 feet in height, of which the lower 8 feet are fuller's earth and the upper 10 feet rhyolitic tuff or ash. There is a little selenite near the border line between the two. Similar occurrences were noted south of Corrigan, the fuller's earth being found in one or two instances overlying the ash instead of beneath it.

In color, the fuller's earth of this region varies from a creamy white to yellow, brown and gray.

Some typical exposures of fuller's earth occur in the vicinity of Corrigan and Moscow.

About 1½ miles southwest of Corrigan along Bear Creek, there is exposed a bed of fuller's earth. The section along the creek is as follows:

1.	Light-brown or drab colored plastic fuller's earth. Thin-bedded	4½ ft.
2.	White, fine-grained volcanic ash made up of minute white grains	3 in.
3.	Greenish brown, structureless gypsiferous clays, weathering yellow	3½ ft.

If this fuller's earth proves to be of good quality, the deposit could be easily worked.

A hill section one-fourth mile west of Moscow Station on the Trinity road shows fine, loose, imperfectly laminated clay, light to dark cream colored on surface exposures, but grayish to greenish-drab underneath. The layers which show the laminations are creamy white, non-plastic, clay and may possibly be fuller's earth. The following is the section from bottom up:

1.	Light gray to light green drab clay	3 ft.
2.	Creamy white non-gritty laminated fuller's earth	1½ ft.
3.	Clay like No. 1	½ ft.
4.	Fine and laminated cross-bedded light yellow clayey sand weathering whitish to light-blue and with very thin seams of whitish clay	3½ ft.
5.	Fuller's earth like No. 2, becoming more gritty towards the top where it has white limestone nodules	10 ft.
6.	Light green clay with large and small calcareous nodules.	

A number of other occurrences are noted in the description of the stratigraphy of the Jackson, Corrigan and Fleming

We have no record of any of these earths having been utilized commercially to any extent, but with the great number of refineries so near them it would seem advisable to have the various localities studied and the material carefully tested.

VOLCANIC ASH

Volcanic ash is used as a polishing powder and in the manufacture of scouring soaps.

Deposits of this material of considerable thickness are found throughout the region between the Neches and the Brazos in the Jackson and Corrigan and probably in the Fleming.

In the Jackson there are two or more beds which are traceable for a long distance and which are excellent horizon markers.

In the other formations the deposits are more local in their nature, but taken as a whole form a considerable part of the sediments composing them.

Many of these occurrences have been referred to in the description of the stratigraphy of the region.

Some of the other localities mentioned by Baker and Suman are Sulphur Springs, five miles north of Chester in Tyler county, where there is a six foot bed of white volcanic ash; Chalk Bluff, northeastern Polk county, where there is an exposure of 8 feet of thin-bedded, medium grained volcanic ash.

Around Potomac, Polk county, there are deposits of volcanic ash five feet and more in thickness. The ash is pure white in color and of very fine even grain.

It also occurs at Groveton, where it contains pellets of cream-colored, non-plastic clay, probably fuller's earth. This bed of ash is cream-colored and pink.

Kennedy, under the term "siliceous sinter," describes the various deposits of ash of the Piedmont Springs area in Grimes county:

"In Grimes county these deposits are best developed in the neighborhood of Piedmont Springs. Small outcrops of sinter occur at Kellum Springs and on Mr. S. Smith's land, about two miles east of Union Hill. In the Piedmont Springs area the deposits consist of light gray sands, with great quantities of beautifully opalized wood, sandy clays, white thinly laminated fine-grained clay, and extensive irregularly shaped deposits of siliceous sinter. A section close to the springs shows:

1.	Light gray sand	5 ft.
2.	Light gray or pinkish gray sandy clay	2 ft.

On the C. O. Edwards headright, and about a mile northeast of the springs, another section shows:

1.	Gray sand	1 ft.
2.	Thinly laminated yellow and brown sands	5 ft.
3.	Fine-grained laminated white clay	4 ft.

The surface of the country in this region is covered with grayish white or light gray sands, containing bowlders of coarse-grained flaky siliceous sinter and great quantities of opalized wood of different colors. While the greater portion of the pieces of opalized wood are small, many of them measure from four to eight feet in length and from one to three feet in diameter. These large trunks are very easily broken, and break with a glassy fracture, although longitudinal sections of from two to four feet are easily obtained.

Two miles west of the springs, deposits of a very fine-grained siliceous sinter occur upon the southwest corner of the James Tuttle league and on the W. P. Zuber headright. A section on the Tuttle league shows:

1.	Coarse gravel	Scattering.
2.	Dark gray sandy soil	1½ ft.
3.	Siliceous sinter	4 to 5 ft.

This deposit of sinter underlies an area of from twenty-five to thirty acres.

On the west side of the same league, and about a mile farther west of this deposit, the bank of a small creek running into Dry branch shows a section of:

1.	Gray surface sand with small quantities of pebbles	4 ft.
2.	Soft fine-grained sand	10 ft.
3.	Broken laminated bluish gray clay	3 ft.
4.	Lignite	3 ft.

Southwest of the siliceous sinter deposits of the Tuttle league there is another deposit of the same class of material on the W. P. Zuber headright. The sinter in this area occurs in all the creeks and washouts along the east side of the headright, and is overlain by a light gray sand and gravel made up of pebbles of quartz and jasper, and underlain by a gray sand, as seen in the following section:

1. Light gray sand and gravel, the gravel scattering........2 to 5 ft.
2. Siliceous sinter ....4 to 5 ft.
3. Gray sand, visible ....2 to 6 ft.

Two miles east of Piedmont Springs a cutting on the east side of Sandy creek shows a section of:

1. Gray-sand with white opalized wood ....3 to 5 ft.
2. Thinly laminated gray sandy clay ....2 to 6 ft.

Going northward to Kellum Springs deposits of siliceous sinter occur on the Wm. Fitzgibbon league, and one mile west of the spring the following section occurs in Chalk branch, a small stream tributary to Gibbon's creek:

1. Gray sand ....1 ft.
2. Lignitic sands and clays ....5 to 12 ft.
3. Siliceous sinter ....2 ft.
4. White sand ....1 ft.
5. Brown lignitic sandy clay.

In this region the sinter lies in thin strata or seams between deposits of a coarse white sand, which rests upon a laminated brown sand. The section shown for nearly a mile southward along the creek is a succession of lignitic sands and clays, alternately dipping southeast and northwest. These lignitic deposits overlie the siliceous deposits.

This siliceous sinter, which is locally known as chalk, is reported as occurring in small quantities at other places in this region and in the area between Piedmont and Kellum Springs.

Five miles northeast of Kellum Springs, on a Mr. S. Smith's land, near Union Hill church, there is an isolated deposit of siliceous sinter covering an area of nearly ten acres and having a thickness of over twenty feet. The greater portion of this deposit is covered by a dark gray sandy soil, and gray sands form the prevailing characteristic of the surface of the whole surrounding country.

Nowhere throughout the area occupied by these beds can the thickness of the deposits belonging to the Piedmont Springs group exceed thirty feet. On the northeastern border the gray sands and sinters either rest upon or are interstratified with the lignitic deposits; and toward the southwest, in the neighborhood of Piedmont, where they attain their greatest thickness, wells dug to a depth of thirty feet pass completely through these beds and enter blue clays containing thin seams of an earthy brown coal.

The siliceous sinter found in these deposits is a very fine-grained, soft, pulverulent, snow-white mass, amorphous in places and showing lines of stratification in others. It has a specific gravity of 2. Under the microscope the grains are small, rounded, and angular, generally flattened and scaly, and all translucent, some of them being perfectly transparent. Many of the scales are striated and marked in such a manner as to resemble thin sections of the opalized wood.

GLASS SANDS

Sands for the manufacture of glass, especially that of higher grade, must be practically free of impurities. Iron oxide, even in small quantities, colors the glass green and any admixture of clay tends to cloud it. Even sands of pure white color are sometimes not sufficiently pure for this use without washing.

The glass sands of East Texas are found in two horizons. The lower, geologically, are the white sands that come in connection with the gray refractory clays occurring above the middle of the Lignitic, and these have been reported both from the eastern and western portions of this area. The upper deposits are of Pleistocene age and occur in the drainage areas of Trinity and San Jacinto rivers. The Pleistocene sands are derived from the disintegration of the rice sands of the Corrigan.

SANDS OF THE LIGNITIC

In Shelby county, Walker calls attention to a pure white sandstone at Cave Spring 5½ miles north of Timpson. This is a soft friable sandstone, in places stained with iron, but when washed as in the neighborhood of the spring, of pure white color and apparently well suited for glass making.

Similar sands were noted at several localities to the north of this in Panola county, among which were a creek crossing one and one half miles northwest of Beckville on the Harmony road and Grand Bluff on the Sabine river.

This sand is also found three miles north of Jacksonville in Cherokee county as a pure white siliceous sand.

Along the lines of the Houston and Texas Central Railroad sands of the same character are found from Dennys to Headville and with small preparation will yield glass sands of excellent quality.

SANDS OF PLEISTOCENE

In the drainage valleys of the Trinity and San Jacinto rivers south of the belt occupied by the deposits of the Corrigan there are numerous bars and banks of a pure white sand derived from the disintegration of the rice sands of that formation. These are good glass sands and can be had in abundance at or near the railway crossings on these streams.

Chapter XVII

BUILDING STONE AND GRAVEL

STONE

Building stone is relatively scarce in our East Texas area and the only stone of value is sandstone, of which there are two classes.

Brown sandstones which are altered glauconitic sands or sands cemented by ferruginous cement.

Gray sandstones with calcareous or siliceous cement.

The brown sandstones are found almost entirely in connection with the Marine beds. In some places the altered greensands are of sufficient hardness to be quarried and are used occasionally where other rock is scarce for building foundations and chimneys. At other places the sand beds have been cemented by ferruginous solutions and hardened into good beds of sandstone.

The gray sandstones are by far the most abundant and are found in Fayette, Jackson and Corrigan. Some of them have a calcareous cement, but probably the greater part have a siliceous matrix.

No limestones suitable for building are known in the area.

SANDSTONE OF THE MARINE—BROWN SANDSTONE

The most important of these sandstones are a series of local and limited deposits formed by the action of ferruginous solutions on the original loose sands. This varies from a comparatively soft friable mass to a compact hard and flinty rock; from yellow to very dark brown in color, and from one to twenty feet thick. Such rocks are found everywhere throughout the East Texas region, and are often used for foundations and chimneys. They occur plentifully in the bluffs of the Angelina at the mouth of Walker creek, and on the Neches river west of Gent, in the shape of a soft friable sandstone. The State Penitentiary at Rusk is built of a soft yellow sandstone, containing specks of altered glauconite and a few casts of fossils. This was obtained from a bed ten feet thick immediately underlying the main iron-bearing greensand bed. It is soft and easily cut with a saw. A rock very similar to this is found capping Cook's Mountain, three miles west of Crockett, in Houston county. It is friable sandstone, and composed of siliceous sand with specks of glauconite and mica, is of a yellow color, contains many fossil casts in places, and shows considerable cross-bedding.

The greensand bed which directly underlies the brown laminated iron ore stratum has often become yellow and hardened to a sufficient degree to be utilized as a building stone. In the region where it occurs it is very extensively used for fireplaces and such small structures. It is of a chalky or waxy consistency, dense and compact in structure, and easily shaped into the desired form by an ax or saw. On account of the ease with which it can be cut, and also a certain toughness which it preserves in spite of its softness depends its universal use wherever it can be found. The greensand bed varies from thirty to forty feet thick, but it is only in parts of it that he hardening process has gone on to a sufficient extent to make it available for building purposes. These indurated places vary from one to ten feet thick. Sometimes the greensand has become hardened without losing its green color, and in such cases we have a green rock of very similar nature to the yellow one just described. Such material is found in Doyle's Gap and on the slope of the Mount Selman iron range, in Cherokee county. The glauconite in this green rock is generally mixed with a large amount of clay of the same color, and in some places the clay almost entirely replaces that mineral. This presence of clay probably accounts for the hardening of the bed as it has acted as a cement in indurating the glauconite. Sometimes, also, finely disseminated carbonate of lime is the cementing material in such rock.

These sandstones, although soft when first quarried, have a tendency to harden when exposed to the weather and are very durable, although they will not admit of fine dressing.

The building stones of Robertson county are wholly of brown sandstone, and occur in many locations along the ridges extending across the country from the Houston and Texas Central Railway eastward. They are rather coarse-grained, and contain frequent streaks or pockets of coarse sand or fine gravel in the form of a conglomerate.

The sandstones found along the top of the ridge on the Denver Jones headright form a bed from two to four feet in thickness and have been quarried for railway purposes, having been used as piers and abutments of bridges on the line of the Houston and Texas Central Railway.

In the neighborhood of Franklin the hills near the town and surrounding Racetrack prairie contain soft brown sandstones, which may be utilized for building purposes They also occur to the west of the town, and at several other places in the central portion of the county. These sandstones are quarried only as needed and no regular quarries have been opened in them.

SANDSTONE OF THE FAYETTE

Southeast of Alto in Cherokee county a hill at Huston Park 75 feet in height has in the upper 60 feet a hard cream colored sandstone. It is fine-grained and in places approaches a quartzite in texture. It weathers irregularly with fretted forms. The outcrop of this rock extends a mile east of Huston Park and as far to the south. Penrose states that properly quarried it will be a valuable stone.

The Fayette areas along the Houston, East and West Texas Railway north of Burke show similar sandstone. It is all fine-grained, some of it is laminated and it varies in hardness.

A fine grade of light gray sandstone of medium grain occurs east of Blix on Jack creek in the Lavinge survey, Angelina county. It is of medium hardness and in layers of about one foot in thickness. To the west of the creek it outcrops in a ridge ten to twenty feet high and a well fifty feet deep was in sandstone throughout.

In the Fayette at Huntington a small hill on the Renfro place is composed of a very hard sandstone, almost a pure quartzite in places, breaking with splintery fracture.

Similar sandstones occur near Homer where it was formerly quarried and used for lining walls and building chimneys and foundations. The quantity however is small as it is at Huntington.

SANDSTONES OF THE JACKSON

Sandstones of good quality are found in places in the Jackson area. No attempt will be made to enumerate them but of some those which came more directly under our notice will be described.

On the sides and top of the low hill ¼ mile east of Manning is found a coarse-grained medium-hard, light gray sandstone in layers averaging about one foot in thickness. The cement is whitish and granular. The sandstone overlies the flaggy shaly beds which outcrop in the town of Manning. This stone could be readily dressed.

Three miles south of Manning, east and west of the Carter-Kelly lumber tram there outcrops along the tops of the lower ridges and in the middle slopes of the higher hills, a white, fine-grained, well indurated and rather heavy bedded sandstone. Several holes have been blasted in the vicinity. The rock is of good quality, but its thickness could not be determined. The harder rock is underlain by soft sandstones and arenaceous clays.

About three and one-half miles slightly north of east of Potomac, near the southern line of the W. B. Hardin Survey, on the farm of Mr. Barch, is a ridge trending in a general east-west direction, capped by a hard dark gray quartzite outcropping in rough irregular blocks. This rock has a splintery to conchoidal fracture and should be admirably adapted for use as crushed rock in concrete work. The ridge was followed for ⅜ of a mile with continuous outcrop of sandstone. The thickness was indeterminable.

Near the line between Section 40, International & Great Northern Railroad land and the Rains Survey, some two miles west of the Houston, East and West Texas Railway is an outcrop of fine-grained, fairly resistant sandstone. There is a thickness of 12 feet along a hillside and quarrying here would be a very simple matter. While this rock might possibly be a little soft for building purposes, it might be of use for ballast.

A hill seventy feet in height with a summit area of two and one-half to three acres is found in the bottom of Dean Creek, Trinity county. The creek bows along the northern and northeastern base of this hill. In the bed and banks of the creek is found the following section, detailed from the base upwards:

1. Base, dark brown carbonaceous clay, total thickness unknown.
2. Lignite, poor in quality. .... 1 ft.
3. Dark brown carbonaceous clay, gradually becoming lighter with a lessening in the amount of carbonaceous matter toward the top .... 1 ft.
4. (a) At the north along the creek banks is exposed 10 feet of thinly laminated light-brown to drab sandy clay carrying plant fragments. The bedding is not very regular and the individual beds are not of uniform thickness. At the easternmost locality examined the beds dipped 3½° to the southward, 50 yards south the dip is 8° to the southward, while 100 yards south of the latter locality, the dip is apparently 4 or 5° to the westward, but this apparent dip may have been caused by slumping.
4. (b) At the south, directly under the northeast base of the hill, there is 12 feet of thinly laminated brownish to buff sand carrying thin streaks of brown carbonaceous material, but becoming sandier and thicker bedded towards the top. The bedding here is also slightly irregular.

Above the bed 4 (b) the surface of the hillside is strewn with blocks of sandstone. A rim of sandstone in place surrounding the top of the hill is in places a massive bed three to four feet thick. Locally these sandstone blocks are quartzitic; in places they exhibit imperfect lamination and break in blocks thick enough to be suitable for dimension stone. The rock last described splits readily along the bedding planes and could easily be shaped into rectangular blocks. In texture the sandstone is medium-grained. It contains thin flakes of selenite and much of it case-hardens on the surface on exposure to air. This property of case-hardening is a valuable one in building stone of this kind, since the stone in the quarry is soft enough to be readily cut and shaped, and it becomes harder after removal from the quarry. All of the rock seen is suitable for crushed stone of a very fair quality.

Near the east corner of the John Veatch grant, approximately two miles north of Groveton, the sandstone outcrops on the northwest side of a hill. There is a vertical thickness of 30 feet in which the rock is found. At the base of this thirty feet, hard rock is found in place in layers varying from six inches to a foot in thickness. Above this outcrop hard sandstone blocks are found on the side and top of the hill, although no other exposures of rock actually in place were noted, save that mentioned above. The sandstone as a whole varies in degree of hardness from a fairly hard rock, breaking with clean fracture, to a hard gray-blue silica-cemented rock which is really a quartzite. This quartzite is hard, compact, and brittle, and breaks into angular fragments. The softer varieties of rock vary from light brown to buff in color. Some of the rock is irregularly stained a brownish color with limonite. The rock contains small irregular flakes of selenite. All of the rock seen in this hill is suitable for crushed rock and some of it which lies in layers of ten inches and upwards in thickness is suitable for building stone. The blue-gray quartzite, with its pleasing color and great crushing strength would be especially suitable for building stone.

West of the Trinity the sandstones of the Welborn division will probably furnish some good building material.

In Grimes county, the hard, semi-quartzitic and close-grained sandstones occur only in the north central portion of the county, where they appear as a narrow belt, extending from the L. J. F. Mammel headright northeasterly to the northwest corner of the Biggam White headright, and from this latter thin beds extend north and easterly to within a few miles south of Bedias postoffice, on the D. S. Stone headright. They are best developed on the Biggam White headright, where they are repesented by a ledge from fifteen to twenty feet high. The rocks forming this ledge are stratified and lie in strata from six to eighteen inches in thicness, and change fom a soft gray colored to a hard gray and brownish gray colored sandstone, with occasional blocks showing the characteristic texture of quartzite. Some of the beds are very much broken and tilted in places, and lie mostly in the shape of boulders or blocks, many of them measuring from eight to ten feet in length and nearly as many feet in width. On the Mammel headright the same class of rocks occur along the northern edge of the Gibbons creek bottom lands. Here they lie in a very similar condition to that on the Biggam White land although the blocks are more irregularly formed and much smaller and are of less value as a building material.

Intermediate between these exposures the rocks belonging to this group are white and grayish white, evenly bedded, close-grained sandstones. This class occurs in quantities along the upper division of Rock creek on the John Bowman headright. Another deposit is found in the Francis Holland headright, about a mile south of Anderson, on the Anderson and Navasota public road. These rocks lie close to and appear on the surface in many places. They have been quarried both on Rock creek and in the neighborhood of Anderson, and from the smoothness of their grain and closeness of texture admit of being dressed in a fairly good condition, although somewhat limited as to size. The stone finishings of the court house at Anderson are from the quarry south of that place.

The building stones of Brazos county are almost altogether confined to the hard gray sandstones of the Wellborn beds. Small deposits of a coarse, soft, brown colored sandstone occur on the McMillan and Williams headright, about four miles west of Bryan, but these deposits are of comparatively little value.

Isolated patches of gray sandstone occur on the James Hope league, and on the Sam Davidson league much larger deposits occur. These have been quarried in the neighborhood of Wellborn and Minter Springs for building purposes.

In the Rock prairie region, on the Stephenson and Robertson leagues, as well as on the N. Clampett headright, deposits of a close-grained, firm sandstone occur, which can be obtained in blocks of large size and admit of fine dressing. A quarry on the N. Clampett headright supplied the foundation stones for some of the Agricultural and Mechanical College buildings a number of years ago.

SANDSTONE OF THE CORRIGAN

These are the beds best known of all the East Texas sandstones as they furnished much of the material for the harbor improvements at Galveston and Sabine Pass and are now being worked to supply crushed rock for concrete work throughout South Texas.

These sandstones are of various degrees of hardness, many of them being hard compact quartzites but the degree of induration varies very much locally. Some strongly indurated sandstones have a white porcellaneous matrix while in others, which are less indurated, the cementing material, while white, is not lustrous.

The deposits of the Neches river drainage, southern Angelina and northern Polk, Tyler and Jasper counties, are those which have received most attention.

Two miles west of Aldridge in northern Jasper county Kyle's Quarry in the Conn league has been opened on a deposit of the Corrigan sandstone.

This quarry is in the quartzitic phase of the Corrigan with local lenses of greenish clay. The main layer quarried is from 35 to 40 feet thick, but the superficial 10 feet is not indurated enough to produce crushed rock. The rock worked has hackly fracture with sharp edges. It is suitable only for rough masonry or for crushed rock. There is 10 to 12 feet of Lafayette overburden to be removed.

The hard rock is very light gray or gray blue in color. It contains angular fragments of hard whitish and greenish clays. The rock is made up mainly of quartz and chert, sometimes coarse enough to be conglomeratic, with a porcellaneous to translucent cement. Some specimens show an outside film of porcellaneous cement which is about ¼ inch thick, the interior of the rock being quartzitic, suggesting that the porcellaneous surface film may possibly be an alteration of the quartzitic interior. The interbedded lenticular clays are sulphurous.

About two miles southwest of Rockland there outcrops on the sides of a large hill a porcellaneous-cemented sandstone showing a high degree of induration, and in places being a fine quartzite. A vertical thickness of 10 feet was exposed. The same rock again outcrops about ¼ mile west of this place.

To the west of the point where the Carter-Kelley Lumber Company tram crosses the Neches river, along the southern bank, a series of high bluffs rise above the river. They exposed at the top and well down the sides a medium to coarse-grained sandstone having a porcellaneous matrix. Underlying is a white, somewhat arenaceous claystone of various degrees of induration. The sandstone is in places indurated to a quartzite and would make a good rock for concrete work.

Near Mt. Hope church, some 2½ miles north of Chester an exceedingly well indurated fine-grained sandstone, showing a splintery fracture wherever broken into, outcrops over an area approximately eight to ten acres, and along a bluff overlooking Russell creek. This quartzite is at least eighteen feet thick, as shown in outcrop along the public road. It is underlain by a clay, weathering cream colored.

At Griswold, three quarters of a mile west of Stryker on the Missouri, Kansas and Texas Railroad, a spur turns off south for the quarry of the Texas Grading Company. A ridge of sandstone commences near the Missouri, Kansas and Texas track and continues south along McManus Creek for nearly a mile. The rock in the northern end of the quarry is a soft to medium hard coarse-grained, gray to light brown sandstone, for the most part massive but locally showing up as cross-bedded. The matrix is in places porcellaneous, but in other places it is fine granular. In the center of the area over which quarrying operations have been carried on there outcrops fifteen feet of a hard, medium-grained, sandstone, massive in structure, and of a good quality for jetty work, riprap, etc. In the extreme southern end of the quarry where operations are being carried on at present, there is a ledge of very hard, almost quartzitic sandstone, bluish-gray in color and made up of fine rounded quartz grains set in a porcellaneous matrix. In the eastern side of the quarry, the section is as follows from bottom up:

1.	Blue-colored massive arenaceous claystone, contains nodules of marcasite, not fit for quarrying	3 ft.
2.	Bluish gray fine-grained sandstone, almost a quartzite, massive; has a splintery fracture and is very hard	2 ft.
3.	Fairly hard sandstone, grayish white in color and grading into thin bedded at top	4 ft.
4.	Gray sand, overburden to be stripped	8 ft. 10 in.

In the southwestern end of the quarry there is ten feet of extremely hard, fine-grained, bluish-gray sandstone with porcellaneous cement and splintery fracture overlain by twelve feet of loose clayey sand. The sandstone everywhere contains many rounded drab to gray clay balls and the coarser sandstone always contains abundant well preserved leaf impressions, reeds and palmetto leaves being predominant. Silicified wood fragments are also common.

A quarry one-half mile north of Corrigan and one-quarter mile east of the Houston, East and West Texas Railroad shows at the western end a medium to fine-grained, medium hard, white to gray and yellowish brown, sandstone. This is for the most part massive, but exhibits some cross-bedding. Locally the sandstone contains hard rounded clay balls. In the eastern end of the quarry the hard sandstone grades into a thin-bedded softer rock. The rock in the western end of the quarry appears very well adapted for rip-rap and ballast, but in the eastern end it is too soft for these purposes. A graded spur connects this quarry with the Houston, East and West Texas Railroad.

About one mile southwest of Corrigan there is a hill of porcellaneous sandstone. There is a thickness of fully thirty-five feet of this sandstone exposed, but only half of it is said to be valuable. There are locally fragments of clay, some of which were rounded. The quartz grains of the sandstone are remarkable for their clearness, large size and angularity. Locally the rock is quartzitic.

West of the Trinity no quarries have as yet been opened in the Corrigan quartzites in our area, but there has been some quarrying for local use of the sandstone occurring in the upper portion of the Corrigan and the base of the Fleming. Kennedy says of the beds in Grimes county: These sandstones are usually thinly bedded, rarely exceeding six inches in thickness, show a rough surface, and in quarrying break into irregular masses or slabs. Their texture is soft and coarse-grained, in places strongly calcareous, and often inclose small nodules or fragments of white clay. In color they vary from a soft gray to a white or creamy yellow. They are irregularly distributed in the beds, changing frequently from the consolidated sandstone to an unconsolidated mass of grayish yellow sand, and in this condition form a continuously alternating series of lenticular masses of sandstone and sand. The sections exposed in the several quarries are made up of alternate strata of sand and sandstone.

Exposures of these rocks occur at numerous places throughout the southern central portion of Grimes county and in the neighborhood of Navasota. The exposures seen near this place form a ridge extending from near the Navasota river in a northerly direction, skirting the river bottom to Holland creek, a distance of about four miles. This same ridge then passes up the south side of Holland creek to the crossing of the Navasota and Anderson public road, where the sandstones are exposed over an area of several hundred acres. These rocks also appear on Grimes prairie and near White Hall post-office and several other points along the northern side of the prairie.

Sandstones in the neighborhood of Navasota belonging to this group have been quarried for building purposes for a great number of years. They were used in Navasota as building material almost exclusively.

GRAVELS

All of the gravel of this area which is of any commercial value comes in connection with deposits of Lafayette age. It is frequently mixed with sand or with clay and the workable deposits are limited in number.

At Urbana a mile or two south of the Houston, East and West Texas Ry. Company's bridge over the Trinity river a gravel pit has been opened.

The pit lies in a flat area bordering the river bottom proper and lies at a slight elevation above it in an area not subject to overflow, the same constituting what might be termed the "second bottom." The gravel has been found by boring, to cover an area of from seventy to one hundred acres and the depth of the gravel ranges from twenty-two feet in the west side to thirty-three feet in the east side. This is practically all workable gravel, as there is only a surface covering of from eighteen to twenty-four inches of fine gray sand. The pebbles in the gravel are rounded and up to two and a half inches in diameter, but they probably average about half an inch. The deposit runs about 40 per cent gravel, considering everything as gravel that remains on a one-eighth inch screen. The remaining 60 per cent is a coarse-grained sand having angular grains. The gravel as loaded into the cars weighs 3,000 pounds per cubic yard.

West of the Houston, East and West Texas Railway there are gravel deposits on a ridge which strikes west from near Willard, in Polk county. At the Watts place on the John Lindsey league a well was dug for water. At four feet they entered a red sandy clay containing the gravel and went out of the same at 22½ feet. Mr. Watts also had a prospect hole dug to the depth of seven feet and the material from this hole was examined. The gravel was about one-half flint pebbles and the other half a stiff sandy clay, which when it gets dried out is very hard to pick into. The flint pebbles in the gravel vary in size from two inches to half an inch in diameter, averaging about one inch. This material would make an excellent ballast although it contains too much clay to admit of being economically washed for use in concrete construction work.

Similar gravel occurs northwest on the Hood farm in northwest corner of Cartwright league. Here there is a hill covering some five or six acres, the surface of which is covered with a gravel consisting mostly of rounded flint and jasper pebbles averaging three-fourths to an inch in diameter. At Mr. Hood's house a well was dug some thirty-six feet deep and it is reported gravel was encountered all the way down, but that it became more clayey toward the bottom.

There are probably other deposits on the interstream areas where the Lafayette overlies the Fleming.

Between the Trinity and the Brazos gravel deposits are found in the Lafayette and will doubtless prove to be of importance locally but they will probably not be as extensive as those west of the Brazos.

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