MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph. D.
Director

BULLETIN 30

THE EOCENE SEDIMENTS OF MISSISSIPPI

By
RALPH EARLY GRIM, Ph. D.

UNIVERSITY, MISSISSIPPI
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LETTER OF TRANSMITTAL

OFFICE OF THE MISSISSIPPI GEOLOGICAL SURVEY
UNIVERSITY, MISSISSIPPI, OCTOBER 1, 1935.

Dr. A. B. Butts, Chancellor
University, Mississippi

Dear Chancellor Butts:

Of the Midway, Wilcox, Claiborne, and Jackson divisions constituting the Eocene system in Mississippi, the heretofore usual lithologic, stratigraphic, and paleontologic study has provided evidence for a fairly satisfactory interpretation of only the Midway and Jackson geologic history. Because of lithologic variability and paucity of fossil forms, such a study of the Wilcox and Claiborne has not provided like evidence. Accordingly, a new type of investigation of these beds has been initiated. It is a petrographic study of the mineral content of their sediments, which leads, at least in part, to an interpretation of the conditions under which those sediments were deposited, of the source area whence they were derived, and of the physiographic and climatic conditions under which they were developed and were deposited. Although the study is in the field of pure science, no sooner will the results be published than they will become of economic importance "in providing the necessary basic information for determining possible geologic structures which control the underground accumulation of water, gas, and oil."

The study is by Dr. Ralph Early Grim, one of the foremost research students in sedimentary petrography. It is entitled "The Eocene Sediments of Mississippi" and is, by your approval, to be published as Bulletin 30.

Very sincerely and cordially yours,

WILLIAM CLIFFORD MORSE,
Director Mississippi Geological Survey

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THE EOCENE SEDIMENTS OF MISSISSIPPI

BY

RALPH EARLY GRIM, PH.D.

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

All the State of Mississippi, except the extreme northeastern corner, is located about the middle of the eastern half of that portion of the Gulf Coastal Plain physiographic province known as the Mississippi embayment, which includes, besides nearly the whole of Mississippi, the southern end of Illinois, the western parts of Kentucky and Tennessee, and the southern part of Alabama. The Eocene sediments adjoin the western edge of the Upper Cretaceous sediments along a contact line roughly parallel to and from 50 to 100 miles west and south of the inner margin of the embayment, which, at this place, is also the inner margin of the Upper Cretaceous belt. From this nearly north-south line the Eocene sediments extend to the Oligocene contact line which passes roughly east and west through the central part of the state at Jackson. Accordingly, they cover the larger part of the north central portion of the state. The position of the outcrop area of each of the divisions of the Eocene sediments is given in the discussion of that division.

OBJECT OF THE STUDY

The object of this investigation has been to make a detailed study of the Eocene sediments in the State of Mississippi. The investigation includes a determination of the character and composition of the sediments, the location and character of the source area from which they came, their stratigraphic relations, and the conditions under which they were deposited. Aside from their purely scientific value, such determinations are important in evaluating the mineral resources of the large part of Mississippi underlain by these sediments, and in providing the necessary basic information for determining possible geologic structures which control the underground accumulation of water, gas, and oil.

The detailed work embodied in this report has been done in Mississippi and on Mississippi material. The location of the state in the middle of the eastern part of the Mississippi embayment and the close similarity of the Eocene material throughout the whole embayment area make it possible to interpret some of the broader features of the whole eastern part of the embayment from the detailed study in Mississippi. For the sake of clearness and to obtain additional evidence for the larger features, it is necessary to broaden the discussion of some of the characteristics of the Eocene sediments to include this whole region.

Since this report was prepared in 1930, the writer has been away from Mississippi. The urgency of other duties has made it impossible to keep in close touch with all the geologic work on the Eocene in the Mississippi area. For that reason the references to work of the last few years may not be entirely complete.

Table 1.—Classification of the Eocene System in Mississippi

- Jackson formation
    - Yazoo member
    - Moodys member
- Claiborne series
    - Yegua formation
    - Lisbon formation
        - Chickasawhay member
        - Kosciusko member
    - Tallahatta formation
        - Winona member
        - Basic member
        - Meridian member
- Wilcox series
    - Grenada-Hatchetigbee formation
    - Bashi formation
    - Holly Springs formation
    - Ackerman formation
- Midway series
    - Porters Creek formation
    - Clayton formation

FIELD WORK

The field work on which this report is based was done during the summers of 1927, 1928, and 1930 while the writer was a member of the Mississippi Geological Survey. About six weeks of each of the first two summers were spent in the study of the Midway and Wilcox series; two months of the summer of 1930, in the study of the Claiborne series and Jackson formation.

PETROGRAPHIC ANALYSES

OBJECT OF ANALYSES

The lithology, stratigraphy, and paleontology of the Midway and Jackson sediments provide evidence for a satisfactory interpretation of their sedimentary history. Because of lithologic variability and paucity of fossil forms, such is not true of the Wilcox and Claiborne sediments. Therefore, to supplement the field data, petrographic analyses were made of the arenaceous beds of these series.

In addition to providing detailed information as to constitution, petrographic analyses have the important objective of determining the genetic and sedimentary history. Although this objective can not be fully attained in every instance, the attempt is as thoroughly justified as is the petrographic examination of igneous rocks, which does not always determine origin. Only by the gradual accumulation of such analytical data will the complete interpretation of sediments become possible.

In recent years the work of Goldman,[1] Udden,[2] Dake,[3] Kindle,[4] Wentworth,[5] Reed,[6] and many others in this country has served to place the proper emphasis on petrographic studies of sediments. In Europe such studies have been more intensively carried on than in this country. The work of Thoulet,[7] Sudry,[8] Collet,[9] Mohr,[10] Andre,[11] Retgers,[12] Anten,[13] Cayeux,[14] Boswell,[15] Mackie,[16] Gilligan,[17] Milner,[18] and many others has placed this branch of petrography in a more advanced position than has the work of those in this country.

Especially have these studies shown that a careful petrographic analysis of the relative sizing and sorting of the grains may yield evidence as to the conditions of deposition. Such analyses yield further information concerning the detailed mineral composition which, in turn, may aid in determining the conditions of deposition. In addition, the mineral composition may be used in locating the source area from which the sedimentary material was derived, and also in determining the physiographic and climatic conditions at the time of deposition. A further use of correlation was not attempted in these analyses because of the great areal distance between samples.

METHOD OF ANALYSIS

A petrographic analysis of arenaceous sediments usually consists of several parts: a mechanical separation into grade sizes; an identification of mineral constituents; and a determination of shape, character of surface, and other features of the component particles.

In making mechanical analyses, there are several methods by which the material may be separated into arbitrary-sized groups. Analysts have realized that this is an artificial procedure, because the sediment in reality is made up of a continuous gradation of sizes, yet it is valuable in showing the relative sizing of the samples.

For a discussion of the detailed methods of analyses the works of Wentworth,[19] Goldman,[20] Thoulet,[21] Mohr,[22] Baker,[23] Gessner,[23a] and Krumbein[23b] should be consulted.

The analyses of the Wilcox sands were made in 1928 while the writer was a member of the Mississippi Geological Survey. The method used was that of Goldman,[24] because it was well suited to the material to be analyzed, and because it permitted the analyses to be compared with those of Goldman, Thoulet, Sudry, and others.

Wilcox material was separated by the Goldman method into the following size grades:

I.	Coarse Sand	
		.89 mm.
II.	Medium Sand	
		.45 mm.
III.	Fine Sand	
		.26 mm.
IV.	Very Fine Sand	
		.04 mm.
V.	Silt	
VI.	Clay	

The material was separated into sand, silt, and clay fractions by sedimentation. Sand was considered as the material settling in 10 seconds out of a suspension in a 500-cc. beaker two-thirds filled. Silt was designated as the material failing to settle in 10 seconds, but coming down in 30 seconds; clay as that remaining in suspension more than 30 seconds. In this method, the separation of the clay from the silt is not based on any definite size limit, but a microscopic examination of the material showed the limiting size to be about .02 mm.

The analyses of the Claiborne sands were made several years later at the University of Iowa. In the intervening years considerable progress had been made toward a standardization of definite grade sizes. The sizes generally accepted were not those used in making the Wilcox analyses. Hence, arose the problem of separating the Claiborne sands into obsolete size grades to maintain uniformity in the report, or of following the present generally accepted size grades and foregoing uniformity. Chiefly because of the great need for general uniformity in present day methods, it was decided to follow the present size grades in analyzing the Claiborne sands even though it meant that the report would contain two slightly different groups of analyses.

The method used in analyzing the Claiborne sands was developed in the University of Iowa Sedimentation Laboratory.[25] The sands were separated into the following size grades:

I.	Very Coarse Sand	
		1.0 mm.
II.	Coarse Sand	
		.5 mm.
III.	Medium Sand	
		.25 mm.
IV.	Fine Sand	
		.125 mm.
V.	Very Fine Sand	
		.062 mm.
VI.	Coarse Silt	
		.031 mm.
VII.	Medium Silt	
		.015 mm.
VIII.	Fine Silt and Clay	

The quantitative results of the mechanical analyses are shown in the form of the histogram, first used by Udden,[26] later quite independently by Mohr,[27] and more recently by Goldman,[28] Wentworth,[29] and many others.

The Very Fine Sand fraction of all samples was further separated into a "Heavy" and a "Light" fraction with bromoform having a specific gravity of about 2.70. This permits an easier identification of the constituent minerals, and a closer determination of the relative abundance of the minor constituents. This fraction was chosen for separation, because its grade size is well suited for microscopic work. Also as this is neither the largest nor the smallest grade size in these sands, the quantity of the "Heavy" minerals in it provides an approximation of their general abundance in the sample as a whole. The individual minerals in both fractions were identified by means of the petrographic microscope using index of refraction liquids. The other grade sizes were examined with the binocular microscope.

INTERPRETATION OF ANALYSES

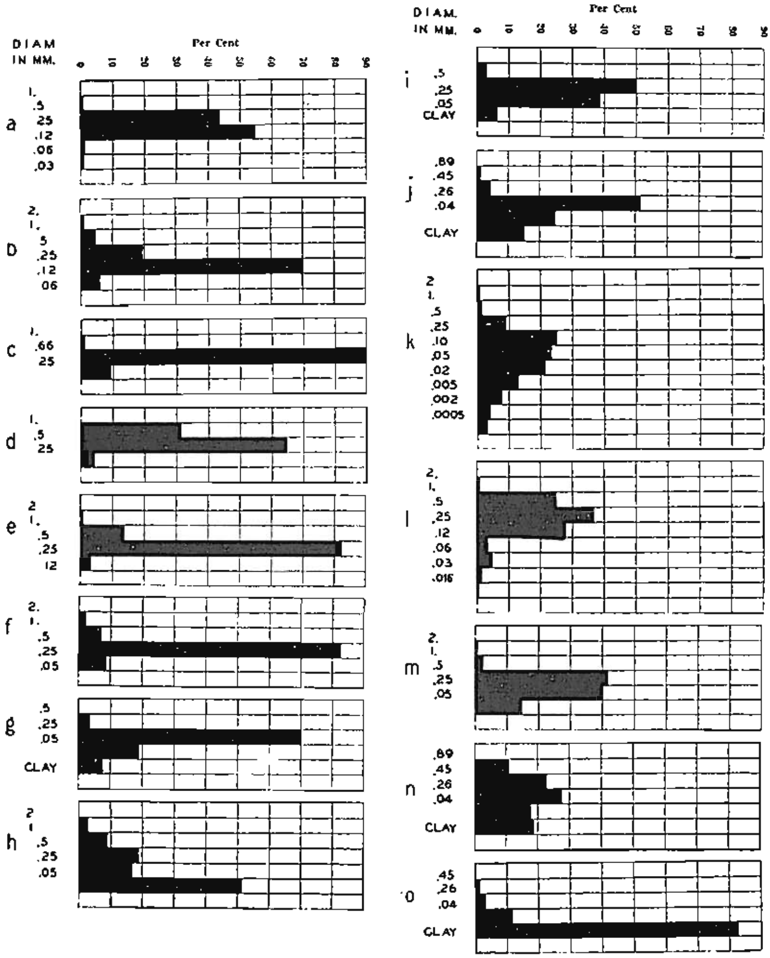
An insufficient number of analyses of modern sediments of known origin have been published to permit the conditions of deposition of ancient sediments to be interpreted completely from their analyses. The character of the histogram may yield evidence for certain environmental conditions and against other conditions of deposition. At the present time, the analytical data represented by the histogram are to be considered as one of the characteristics of a sediment which may be significant in interpreting its history.

Various attempts have been made to correlate certain characteristics of histograms with certain types of sediments. The series of histograms of recent sediments, Histograms a-o, and the following paragraphs will illustrate this point.

These histograms suggest that the most pronounced sorting is usually produced by wind and wave action. Although dune sand and beach sand are likely to show similar histograms, Udden[30] has stated that there are the following significant differences. In many cases wind and wave deposits can be distinguished by their secondary maximum; that is, the size next most abundant to the dominant size. In the wind deposits the quantity of the secondary maximum is usually greater than in water deposits, or in other words the secondary maximum is less pronounced for waves than for wind. Also the grain size of the secondary maximum is apt to be larger for water than for wind. In both cases the secondary maximum is apt to be in a larger grade size than the maximum (Histograms a-f). Goldman[31] has pointed out that an offshore sediment differs from a beach sand in being finer grained and not in the degree of sorting (Histogram g), and also that dune sand from temperate regions may be finer than dune sand from the tropics.

Mohr[32] has pointed out that histograms of river deposits show, in addition to the lack of sorting, an abrupt rise on the coarse side and a more gentle fall on the fine (Histograms k-m). Deposition in a stream is due to a sudden partial checking of the velocity which causes the stream to drop most of the coarse material and less and less of the finer sizes.

Goldman[33] has suggested that delta deposits (Histograms i,j) show the above features of river deposits plus some sorting probably due to the influence of some wave action.



Histograms a-o representing recent sediments

a. Dune sand from Mineral Springs, Indiana.--Wentworth.
b. Dune sand.--Goldman after Udden.
c. Dune sand from the mouth of the Indus River.--Oldham.
d. Dune sand from the Sahara.--Thoulet.
e. Beach sand from Asbury Park, New Jersey.--Wentworth.
f. Beach sand from East Indes.--Mohr.
g. Off-shore sediment from the Gulf of Lyon.--Thoulet.
h. Deeply weathered beach sand from East Indes.--Mohr
i. Sediment from the seaward edge of the delta of the Rhone River. --Thoulet.
j. Deltaic sediment in lagoon.--Sudry.
k. River flood plain deposit from Palembang.--Mohr.
l. River sand from Linwood, Iowa.--Udden.
m. Stream alluvium.--Mohr.
n. Sediment from the lagoon of Thau.--Sudry.
o. Fine lagoonal sediment.--Sudry.

Lagoonal types of deposits, that is, material deposited in shallow bodies of water where there is little opportunity for wave action, are poorly sorted (Histograms n,o).

It must not be considered that the above features are always characteristic of the particular deposits noted. Recent investigation, particularly by Wentworth,[34] has shown a decided variation in recent sediments deposited under the same environmental conditions.

A petrographic analysis is valuable also because the identity and properties of the mineral constituents is important in determining the history of a sediment. Such minerals as glauconite and pyrite may yield definite evidence of the environmental conditions of deposition. Retger[35] has pointed out that the non-quartz minerals in a dune sand are the resistant non-cleavable types. The presence of mica in a well sorted sand may, therefore, be evidence against wind deposition. The work of Milner,[36] Mackie,[37] and others has shown how the mineral composition may be used to interpret the kind and length of transportation. Further, the fact is evident that the mineral composition may lead to the determination of its character and the location of the source area. The feldspar may yield some information concerning the climate of the source area. Mackie[38] has shown, by his work on quartz inclusions and the color of zircons, how detailed properties of the minerals, in addition to their simple presence, are valuable in the location and study of the source area.

METHOD OF COLLECTING SAMPLES FOR ANALYSIS

In collecting samples to be analyzed great care was used to obtain fresh and unweathered material. Because the Wilcox and Claiborne sediments consist of a series of inter-bedded sands and clays, many of which are thin and closely interlaminated, samples were obtained from only the thicker beds which represent the more sustained conditions of deposition.

The samples analyzed were composite of the individual beds, but not of more than one bed even though the distinction between two beds might be very slight. For example, if an outcrop contained a bed of gray sand 10 feet thick underlain by a finer bed of sand 8 feet thick, the sample was a composite of either the upper 10-foot bed or the lower 8-foot bed, but not of both. Since the two beds were probably deposited under slightly different conditions, a composite sample of both would, accordingly, not show the true character of either one, and might lead to an interpretation widely different from that of the actual conditions during the deposition of either sample.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the aid and encouragement in carrying out this study that he received from Professors A.C. Trowbridge and A.C. Tester of the University of Iowa. Doctors Goldman and Ross of the United States Geological Survey were also kind enough to aid in certain of the problems. Finally, the writer wishes to express his indebtedness to Dr. E.N. Lowe, late Director of the Mississippi Geological Survey, without whose assistance and encouragement the problem could never have been attempted, and to Dr. W.C. Morse, the present director for his counsel and aid in preparing the report for publication.

MIDWAY SERIES

NAME

The term Midway, the name of a town in Wilcox County, Alabama, was first used by Smith and Johnson[39] to designate what is now the basal formation of a series of beds subsequently called the Midway series. Previously these authors placed this formation, together with the overlying material now constituting the remainder of the Midway and the whole of the Wilcox series, in a single formation, called Lignitic. Langdon[40] suggested the name Clayton in place of Midway, because of the better exposure at the town of Clayton. Smith and Johnson[41] followed the suggestion of Langdon and used the name Clayton. They also removed it from the Lignitic formation and placed it in a separate division equal in rank to the Lignitic.

Hilgard,[42] in his early work in Mississippi, erroneously placed in the Cretaceous the calcareous material in the basal part of the present Midway. In the same report, he placed the upper part of the present Midway in his Lignitic formation.

Harris,[43] on the basis of paleontologic and stratigraphic studies in much of the coastal plains, redefined the term Midway so as to include: (1) the Clayton limestone of Alabama, (2) the calcareous material in Mississippi previously placed in the Cretaceous, (3) and the beds that had been placed in the base of the Lignitic formation--a procedure followed by all later workers.

STRATIGRAPHIC RELATIONS

According to Stephenson,[44] who has summarized the earlier evidence, the Midway is separated from the Upper Cretaceous by an unconformity of considerable magnitude. Scott[45] has recently advanced evidence to show that the hiatus between the Midway and the Upper Cretaceous is of little importance in the Rio Grande region of Texas.

In an attempt to refute Scott's evidence, Gardner[46] has stated that Scott's reasoning would be more applicable east of the Mississippi River. The final solution of this problem can not be obtained until Paleontologists agree as to correlations with European type sections and also as to the magnitude of faunal differences between the Midway and Upper Cretaceous.

Some evidence has been obtained from Mississippi bearing on the problem. Despite the paucity of good contact sections in a region largely flat and despite the lithologic similarity of the basal Eocene and uppermost Cretaceous material in some areas, a few sections have been found in which there is evidence of an interval of erosion between the Upper Cretaceous and the Midway. Such sections are located at Chalybeate Springs in Tippah County; in a railroad cut of the Frisco one mile east of New Albany; in a railroad cut of the Mobile and Ohio near Houston in Chickasaw County; and along the public road west of Giles in Kemper County. At other localities not only can no evidence of erosion be found, but it is extremely difficult even to draw the line between Eocene and Cretaceous material, as, for example, in the Gulf, Mobile and Northern cut south of Pontotoc in Pontotoc County; and near Starkville in Oktibbeha County. Previous[47] studies of well cores and cuttings have occasionally revealed subsurface evidence of weathering between the Upper Cretaceous and Midway. From both surface and subsurface studies, it seems evident that some erosion took place between the Cretaceous and Midway in Mississippi, but it was not necessarily complete or of long duration.

No evidence has been found of an unconformity between the Midway and the overlying Wilcox in Mississippi, there being a transition from the Midway to the basal Wilcox. Because this transitional material is lithologically more like the Wilcox than the Midway, it has always been included in the Wilcox series.

CLASSIFICATION AND CORRELATION OF THE MIDWAY SERIES

In classification and correlation of the Midway series in the eastern part of the Mississippi embayment (Figure 1), the term Clayton is used, as first defined by Langdon[48] and later by Harris,[49] for the basal calcareous material. The name Porters Creek, first used by Safford,[50] is applied to the dark colored clay making up the bulk of the Midway series. The name Flatwoods was first given to this material by Hilgard,[51] but it has been dropped in favor of the geographic name Porters Creek. The Sucarnoochee formation of Alabama is correlated with the Porters Creek.

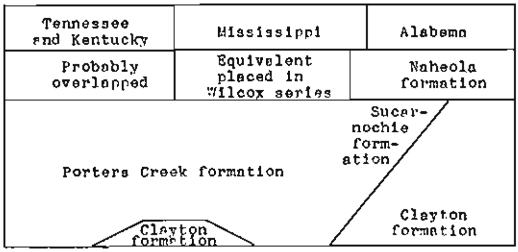


Figure 1.—Classification and correlation of the Midway series.

The term Naheola is applied by the Alabama Geological Survey to the sands, clays, and marls immediately overlying the Clayton and Sucarnoochee formations. The equivalent beds in Mississippi are placed in the Wilcox series, and are believed to be overlapped in Tennessee and Kentucky.

Lowe[52] has suggested that a third formation exists at the top of the Midway series in northern Mississippi which he called the Tippah sand, and which he stated is probably the equivalent of the Crainesville beds of Harris.[53] The Tippah sand is here considered as designating lenticular beds of sand in the Porters Creek and not as a separate formation.

DESCRIPTION AND DISTRIBUTION OF MATERIAL AT THE OUTCROP

CLAYTON FORMATION

The Clayton formation, ranging in thickness from nearly nothing to 60 feet in Mississippi, has a maximum thickness of approximately 400 feet in Alabama.

The Clayton formation in Mississippi and Tennessee is composed typically of semi-crystalline fossiliferous limestone and glauconitic, sandy marl. The limestone which is in the base is yellow in color and develops a rather hard surface on weathering. In Alabama, it is composed of white limestone and white limy sand.

The general distribution of the Clayton and Porters Creek formations in the eastern part of the embayment, and in greater detail in Mississippi, is shown by Figures 2 and 3 respectively. As these figures reveal, the Clayton formation is not everywhere present in the base of the Midway. It is found in two areas in Mississippi separated from each other by a region in the central part of the state in which the Porters Creek clay lies directly on the Upper Cretaceous. Cooke[54] expressed the opinion that the Clayton is here overlapped by the Porters Creek. Deep wells, Borden No. 1, Conway No. 1, McLean No. 1 (Figure 3), at various

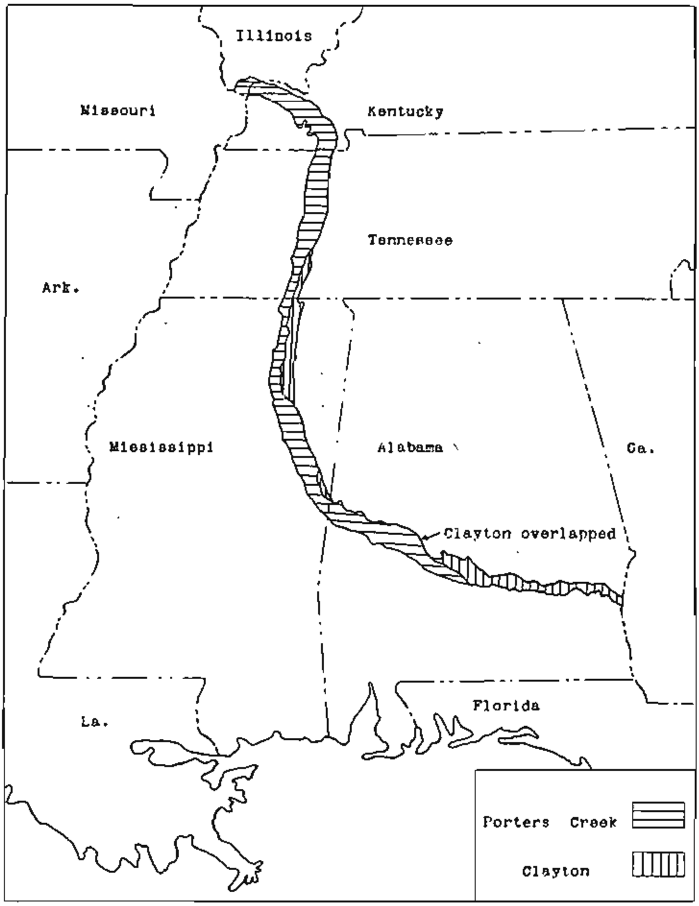


Figure 2.—Sketch map showing the outcrop of the Clayton and Porters Creek formations in the eastern part of the embayment.

distances southwest of the outcrop in this part of the state, passed directly from the Porters Creek into the Upper Cretaceous. The Midway sections of these wells (Figures 4 and 6) show the absence of Clayton material.

It appears, therefore, that there is no Clayton in the basal Midway in this part of the state either at the outcrop or beneath the Porters Creek clay for some distance back from the outcrop. Overlapping is, then, not the explanation. The lower part of the Porters Creek clay in this region is regarded as the lateral equivalent of the Clayton limestone of the north and east. Its absence is, therefore, to be explained by conditions of sedimentation in Midway time rather than by overlapping.

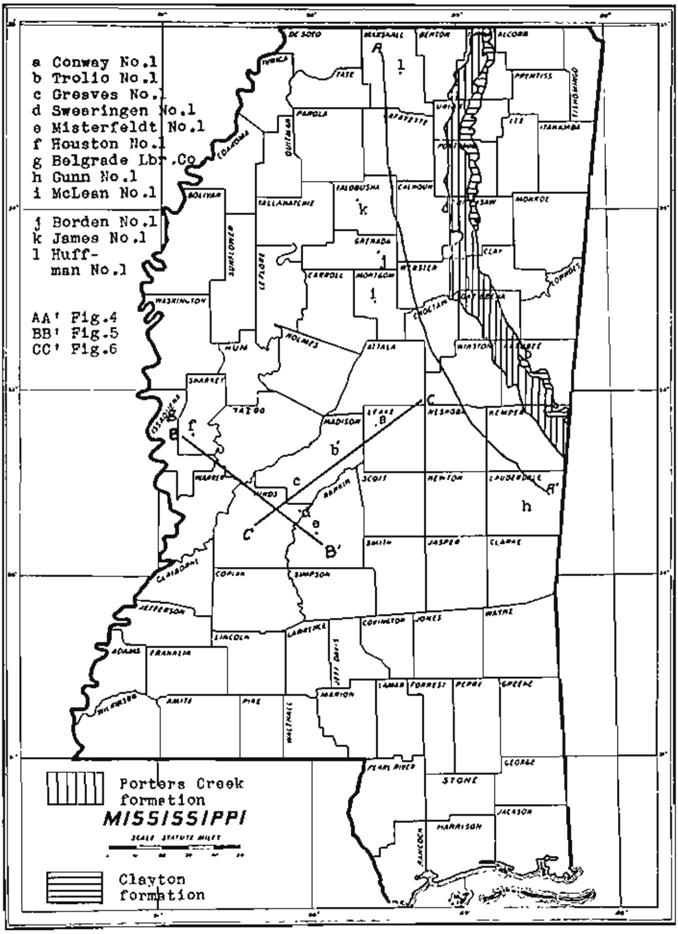


Figure 3.—Sketch map showing the outcrop of the Clayton and Porters Creek formations in Mississippi.

From the northern part of Mississippi the Clayton formation extends, according to Roberts,[55] northward into Tennessee for a distance of about 35 miles and then pinches out. North of this, the Porters Creek clay lies directly on the Upper Cretaceous. The absence of the Clayton here is again regarded as due to conditions of sedimentation and not to overlap.

From the east-central part of Mississippi, the Clayton formation extends into Alabama. It is thicker eastward, reaching, according to Cooke,[56] its maximum thickness in Alabama along the Chattahoochie River.

PORTERS CREEK FORMATION

The Porters Creek varies in thickness from almost nothing in central Alabama to a maximum of about 800 feet in central Mississippi.

It is composed typically of chocolate-brown clay free from grit and is broken by a pronounced conchoidal fracture. The material is not calcareous, and, except for a few plant leaves and foraminifera,[56a] is not fossiliferous. On weathering, it assumes a light brown color. At a few places there are thin streaks of calcareous sandstone in the clay. .

In the southern part of Tennessee the Porters Creek clay contains interstratified beds of glauconitic sand. Lamar and Sutton[57] have reported the existance of lenticular beds of fine glauconitic sand in the basal part of the clay in Illinois and Kentucky.

The contact between the Clayton and the Porters Creek formations at many places is a perfect gradation, because of the interlamination of marl and clay; the following section being an example.

Section one mile north of Ripley, Tippah County, Mississippi

	Feet	Feet
Porters Creek		15
4. Clay, brown soapy (typical Porters Creek)	15	
Transition zone		10
3. Clay, like above, interbedded with sandy marl (like Clayton below)	10	
Clayton		28
2. Marl, light gray glauconitic, sandy	25	
1. Limestone	3	

The name Tippah sand was given by Lowe[58] to "a series of marine or estuarine fossiliferous sandstones and the underlying sands prominently exposed in the broken hills and ridges of Tippah County in northern Mississippi." The sandstone is greenish-gray where fresh, and yellow where weathered. It is cellular in appearance and glauconitic. This material is thinner and thinner from place to place as it is traced southward, being absent about the Tippah-Union County-line.

Lowe[58] first suggested that the sand was on top of the Porters Creek clay, which would make it equivalent to the Naheola of Alabama; accordingly, he considered it a separate formation. Recent field work by Lowe and the writer has shown that there are several beds of marine sand, that they are interstratified with the typical Porters Creek clay, and that they are southward extensions of the sandy layers in the clay interval in Tennessee (See the following section and Figure 7). Except for a slight thickening of the sandy layers toward the top, there is no definite basis for separating them from the Porters Creek. This sand, therefore, does not comprise a separate formation, but rather a member, for which the term Tippah sand should be used.

Section at Blake's Hill, near Walnut, Tippah County, Mississippi

	Feet	Feet
Porters Creek		102
5. Shale, brown soapy; grading below into marl	40	
4. Marl, glauconitic, sandy	2	
3. Sandstone, limy	25	
2. Covered	10	
1. Shale, brown soapy	25	

The Porters Creek--Sucarnoochee formation is continuous from central Mississippi eastward, being thinner and thinner in this direction to middle Alabama, where it is entirely absent. According to Cooke,[59] the contact between the Clayton and the Porters Creek in Alabama is a gradational one, which, in addition to the fact that the Clayton becomes thicker from west to east across the state whereas the Porters Creek becomes thinner in the same direction, suggests that they are, at least in part, lateral equivalents.

North of the northeast central Mississippi region, the Porters Creek formation is thinner, but in the southern part of Tennessee it is thick. This area of reduced thickness coincides with the area in which the Clayton underlies the Porters Creek, and in which the clay section is broken by a series of glauconitic sands.

From a point about 30 miles north of the Mississippi-Tennessee line--that is, from the point where the Clayton is absent beneath the Porters Creek--to the head of the embayment, there is, according to Glenn,[60] an increase in the width of the Porters Creek outcrop from 4 to 6 miles. This increase in width partly reflects a thickening of the formation.

NAHEOLA FORMATION

The Naheola ranges in thickness from 100 to 200 feet.

It consists mainly of pink sands and clays, having a marl bed in the base. According to Cooke,[61] the marl bed contains fossils that have definite Midway affinities. The lateral equivalent of the Naheola in Mississippi has no marine fossils, and has no lithologic characters distinct from the Wilcox, with which series it has of necessity been placed. In Alabama, the lithologic characters of this formation are also more like those of the Wilcox than those of the Midway, but the fossil evidence has placed it in the Midway series.

The Naheola formation has not been traced farther west than Kemper County, Mississippi, where it seems to merge with beds previously placed in the base of the Wilcox. In central and northern Mississippi, there is a transition series of beds from the Porters Creek clay to the basal Wilcox material. This transition material, which contains the bauxite deposits, is probably equivalent to the Naheola of Alabama.

DESCRIPTION OF SUBSURFACE MIDWAY MATERIAL

Drilling operations in Mississippi in recent years have penetrated the Midway in many places bringing to light important information concerning its variation in thickness, lithology, and other features. The following series of sections, although admittedly based on rather incomplete data, strongly emphasize certain features. This evidence, together with the outcrop characteristics just mentioned, point to rather distinctive conditions of sedimentation in the eastern part of the Mississippi embayment in Midway time.

In subsurface correlation the Midway and Wilcox must be separated generally on the basis of lithology. Although the Porters Creek has lithologic characters distinct from the Wilcox, the Naheola equivalent cannot be separated from the Wilcox. Consequently the line between the two series has to be drawn at the top of the Porters Creek.

A series of sections of the Midway extending along a line roughly parallel with the outcrop and about 30 miles west of it is shown in Figure 4. With the exception of the very base of the section in the Huffman No. 1 well, there is no limy material in any of these sections. Seemingly, therefore, in this region the Clayton is generally absent except in the extreme northern part of the state. The sections are composed of clay with the exception of the few beds of sandy material in the McLean No. 1 well. This clay is non-calcareous, soapy to almost waxy, and without grit. It breaks into thin slabs, has a dark gray to black color, and is generally unfossiliferous. The thickening of the Midway in the region of Yalobusha, Grenada, Montgomery, Attala, and Leake counties, shown by this series of sections, is noteworthy.

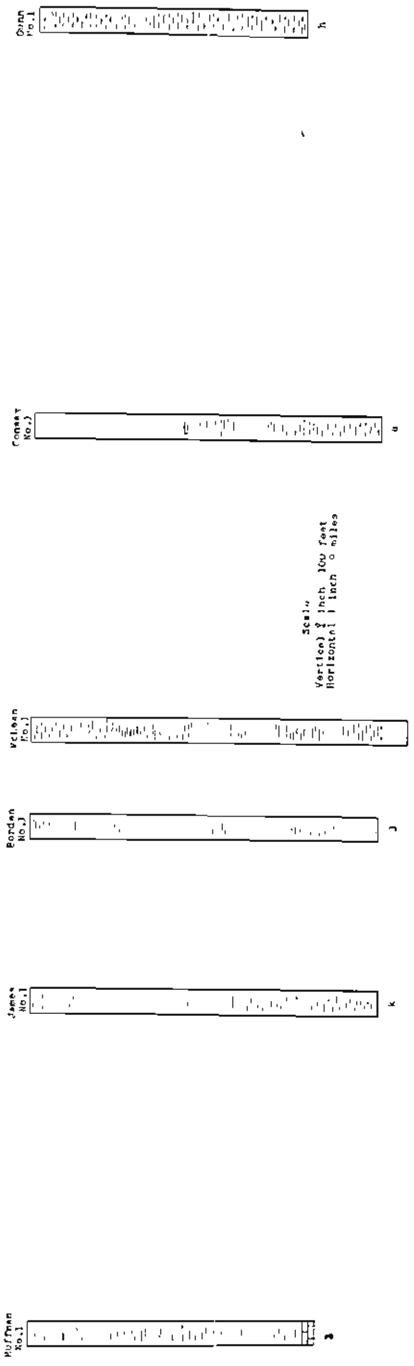


Figure 4.—Sections to show the subsurface Midway along AA' of Figure 3.

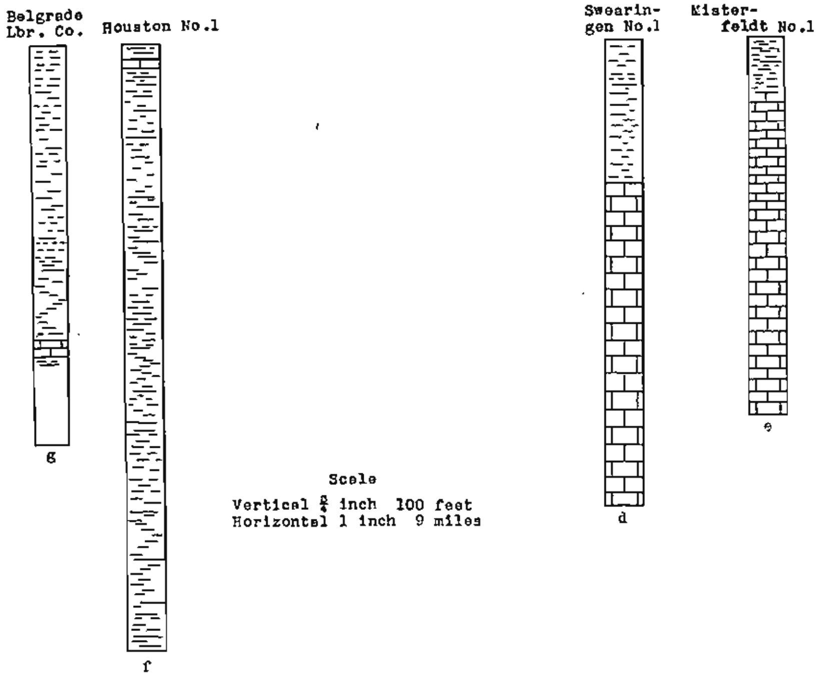


Figure 5.—Sections to show the subsurface Midway along BB' of Figure 3.

A series of sections extending in a northwest and southeast direction from Issaquena to Rankin County is shown in Figure 5. This series, while not exactly parallel to the series of Figure 4, is so nearly so, that it indicates the change in lithology of the Midway to the southwest. The Misterfelt No. 1 well and the Swearingen No. 1 well show an abrupt change in lithology in the vicinity of Hinds and Rankin counties. Here, with the exception of the upper hundred feet which is typical Porters Creek material, the section is composed of pure white crystalline limestone. Fossils are to be found only in a few isolated layers. The great purity of the lime, its crystalline character, and the general absence of fossils suggest chemical rather than clastic deposition of the material. In the Misterfelt well the contact between the clay and the lime is fairly sharp, whereas, in the Swearingen well, although not shown in the section, there is some interlamination of lime and clay. The Houston No. 1 well to the northwest shows the absence of the lime and the thickening of the Midway in that direction. With the exception of the limy beds at the top, it is composed of typical Porters Creek clay.

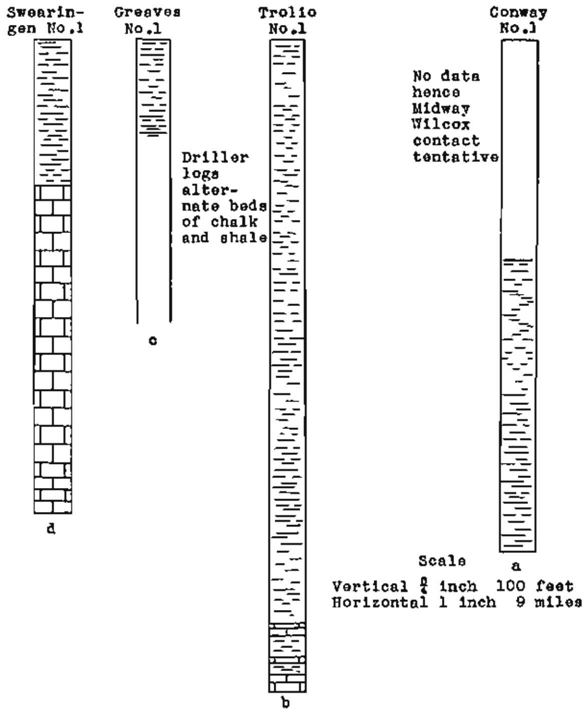


Figure 6.—Sections to show the subsurface Midway along CC' of Figure 3.

The Belgrade Lumber Company well shows an abrupt thinning of the whole Midway; a section of typical Porters Creek clay except for the basal part which is somewhat limy.

A series of sections extending in a northeast-southwest direction, almost at right angles to the strike, from Leake to Rankin counties is presented in Figure 6. These sections show the abrupt change in lithology in this direction; the Trolio No. 1 well section, almost wholly composed of non-calcareous clay, is near the abundantly limy sections in the Greaves and Swearingen wells. These sections also show the thickening of the Midway down the dip to the southwestern part of Madison County where there is an abrupt thinning and where there is an appearance of lime.

SUMMARY OF THE CHARACTERISTICS OF THE MIDWAY

Viewed as a whole, the Midway, with the exception of the Naheola and its equivalent, presents the following general features in the eastern part of the Mississippi embayment (Figure 7).

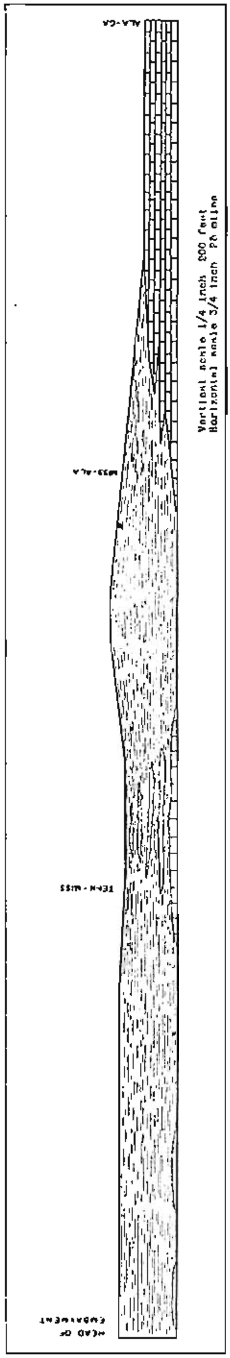


Figure 7.—Section showing the stratigraphic relations of the Clayton and Porters Creek formations.

In the central part of Mississippi, from the outcrop as far to the southwest as Madison County, it is entirely composed of a great thickness of clay. Southwest of Madison County there is a thick calcareous bed at the base of the series.

Eastward from the central Mississippi region, the series is thinner, and limy material (Clayton) is encountered in the base, which becomes thicker across Alabama to the eastern boundary where it makes up the whole Midway. Eastward, the clay becomes thinner as the lime becomes thicker. Unfortunately there is little information available concerning the series at places any distance south of the outcrop in the eastern part of Mississippi.

Northward from the central Mississippi region there is no lime exposed at the outcrop until Chickasaw County is reached, where the Clayton limestone lies at the base of the section. Farther north, in Tippah County, the whole Porters Creek clay section is broken by a series of interstratified marine sands. The Clayton limestone and the interstratified marine sands in the Porters Creek extend northward to near the middle of Tennessee where they are absent. From this point to the head of the embayment the whole Midway series is composed of clay with the exception of small lenticular masses of glauconitic sand near the base.

Northward from the central Mississippi region, the subsurface Midway is shown by well logs to retain the same features as those along the outcrop. As far north as Yalobusha County there is an absence of limy material, and the great thickness of Porters Creek clay is retained. In the Houston No. 1 well in Sharkey County to the southwest this thick uniform clay section is preserved. In the region between Yalobusha and Sharkey counties, the variations are not known for the lack of data. Northwest of the Houston well, in the Belgrade Lumber Company well, the clay becomes thinner, and some basal limy material is present.

North of Yalobusha County in the Huffman No. 1 well, there seems to be an increase of limy material in the subsurface Midway corresponding to the increase in limy material at the outcrop. No cuttings or cores from this well were available for an adequate study of the Midway.

SURFACE UPON WHICH THE MIDWAY MATERIAL WAS DEPOSITED

Before a definite idea can be had of the conditions of deposition that prevailed in the eastern half of the Mississippi embayment during Eocene time, some conception must be obtained of the surface upon which this material was deposited. In Figure 8 contours have been drawn at the base of the Midway, and the general features of this surface have, thereby, been shown. No data were available to extend the contour lines beyond Mississippi, and even in this state the data are so scant that only the larger features are depicted. It is a tentative map to be altered as more information appears.

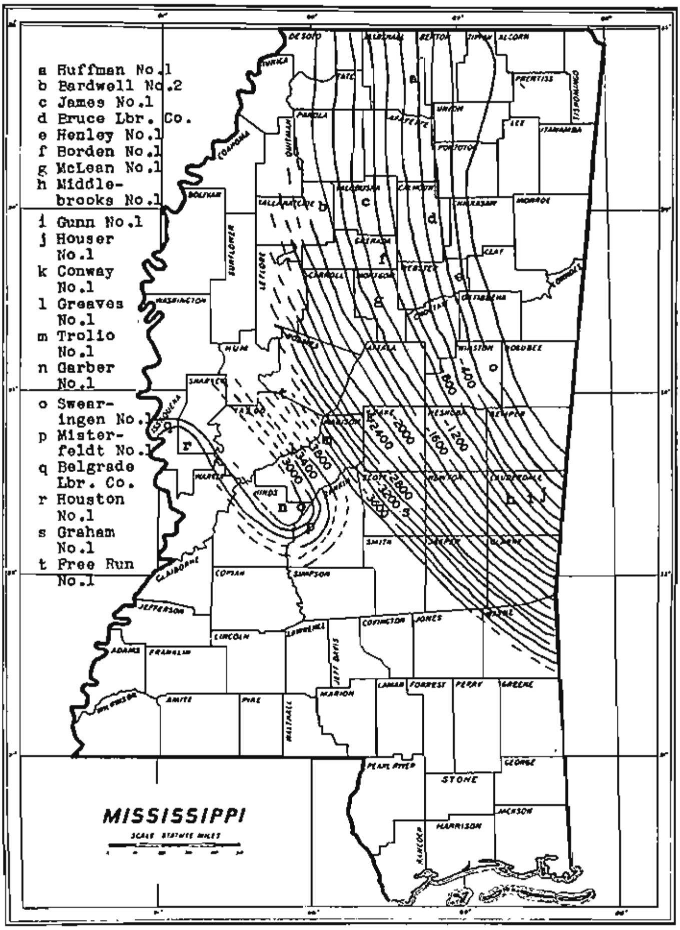


Figure 8.—Sketch map showing contours drawn at the base of the Eocene. Datum: Sea level.

Previously another contour map of this surface was published by the writer.[61a] A comparison of the maps will show slight changes due to information that has become available since the earlier map was published. The method of correlation was the same in both instances.

The most pronounced feature of this surface is the high area extending northwest and southeast in Rankin, Hinds, Yazoo, and Sharkey counties. Wells, recently drilled in this part of the state, such as the Misterfelt No. 1 in Rankin County, the Houston No. 1 in Sharkey County, and the Belgrade Lumber Company No. 1 in Issaquena County, have passed from the Midway directly either into so-called Red Beds, which are non-fossiliferous and at least Tuscaloosa if not older in age, or into igneous rocks. It is evident, therefore, that this area stood as an island, at least in the later Cretaceous seas which flooded the embayment. Whether or not the mass existed as a single island or as a chain of smaller islands is not known. Some idea concerning the variations of this ridge when it was submerged can be obtained from the elevations plotted in Figure 8, although a part of this relief must have been due, as previously determined,[62] to later crustal movements.

Recent magnetometer work by several large oil companies has traced this ridge northwestward toward Arkansas. No evidence is available of any extension to the southeast farther than Rankin County.

The remainder of the map shows the surface upon which the Midway was deposited to have, at present, a gentle west and south slope, becoming somewhat steeper away from the present outcrop. This slope is probably not parallel to the original upon which the Midway material was deposited, because of post-Midway crustal movement. The thickness of the Eocene sediments that accumulated on this surface demands considerable subsidence, and it will be shown later that some seaward tilting, also, was necessary. Shaw,[63] also, has brought forth evidence of seaward tilting, based on a study of late Tertiary erosion surfaces.

The exact relation of the ridge to the general slope can be determined only in the vicinity of Hinds and Madison counties, where the ridge stands out sharply, having a maximum difference in elevation between its surface and the general surface toward the northeast of approximately 1200 feet.

Previously,[64] it was suggested that northwest of Madison County the abruptness of the ridge gradually gives way to a flat terrace-like slope, an inference derived from a study of the Free Run No. 1 well whose cuttings from a depth of 2400 feet suggest Midway material. However, the scantiness and unfossiliferous character of these cuttings, together with some uncertainty as to their validity, make any conclusion drawn from them open to question. Assuming the well record to be authentic, this high area can be explained also as a local high.

Since the determination of the existence of this ridge, numerous magnetometer surveys have been made over it in the area where no other data are available. On top of the ridge the magnetic intensity increases; to the north and east it decidedly decreases; still farther north, in a series of isolated areas, it increases and decreases. These surveys strongly suggest a continuation of the abrupt northeastern slope rather than the terrace-like surface shown in Bulletin 21 of the Mississippi Geological Survey.

The writer[65] has previously emphasized the fact that the ridge was unstable in Tertiary time, and that several means of origin were possible. Recent information suggests volcanic origin, because of the fact that drillings have penetrated igneous rocks on the ridge, that bentonite is known to exist in the Eutaw[66] formation in Mississippi, that angular fragments of scoria and pumice were found in the Eutaw formation in the James No. 1 well in Yalobusha County, and that hot water is pumped from some of the deep wells in the vicinity of the city of Jackson.

CONDITION OF DEPOSITION OF THE MIDWAY SEDIMENTS

The Midway sediments of Mississippi have always been considered marine, for marine material in Tennessee and glauconitic sands at the base of the series in Kentucky and Illinois show that Gulf waters reached the head of the embayment in the beginning of Midway time. Although the material in northeast-central Mississippi is not calcareous and is not fossiliferous, except for a few foraminifera,[66a] it contains calcareous fossiliferous sediments in the region directly to the north in Tennessee. Consequently, the problem is to explain conditions responsible for the deposition of non-calcareous and generally non-fossiliferous material in northeast-central Mississippi and fossiliferous limy sediments northward away from the Gulf source of marine waters.

This material in northeast-central Mississippi is best explained as a delta deposit built out to the southwest by a larger river entering the embayment at this place (Figure 9). The presence of the delta at this place explains, in addition to the lithology and distribution the great thickness of the series in central Mississippi and its thinness northward and eastward (See Figures 7 and 9).

The thick interval of non-limy material comprising the Midway at the extreme head of the embayment in Kentucky and Illinois is also probably to be considered as deltaic material. There is no positive evidence whether it was deposited as one large delta or as a series of

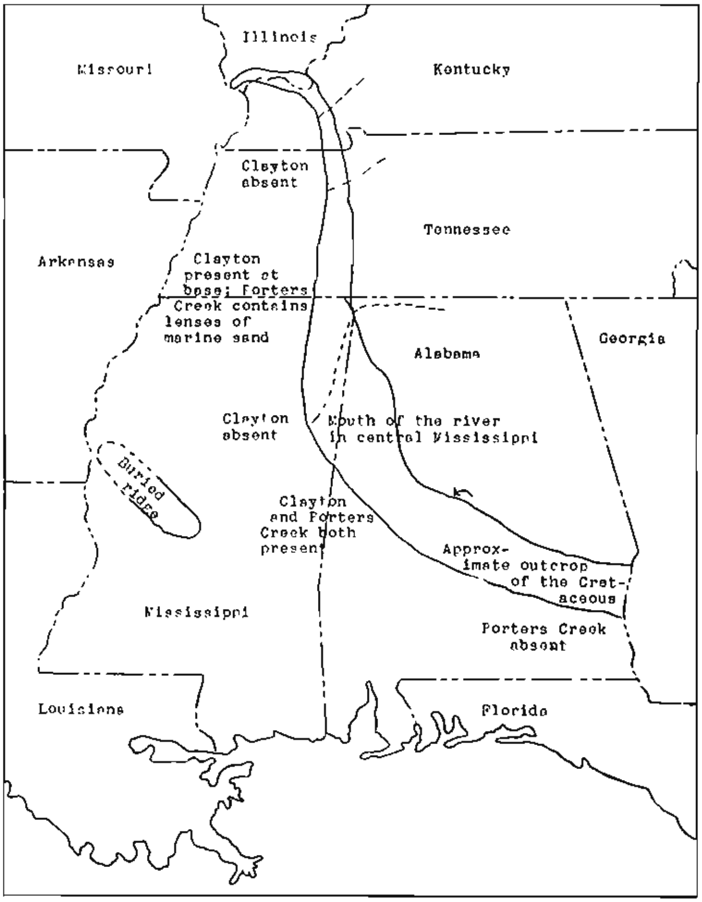


Figure 9.—Sketch map suggesting conditions of deposition of the Midway sediments.

smaller ones, but the fact that the basal part of the Midway varies laterally from non-limy non-fossiliferous clay to glauconitic sands and clays containing marine fossil-casts suggests that many streams entered the head of the embayment, each building a delta.

On the basis of this concept, conditions of deposition in the eastern part of the embayment in Midway time may be reconstructed as follows. A large river entered the embayment in what is now northeast-central Mississippi, and several smaller streams entered the extreme head of the embayment (Figure 9). In early Midway time the deltas of these streams were small, and a region existed in northern Mississippi and southern Tennessee beyond the influence of deltaic deposition where more definitely marine conditions prevailed, permitting the accumulation of calcareous fossiliferous material. In the course of Midway time, the deltas grew in size--the deltas at the head of the embayment southward and the delta in northeast-central Mississippi westward and southward--until they coalesced in the northern Mississippi and southern Tennessee area, spreading muddy delta sediments over earlier limy sediments. The deltas appear to have coalesced intermittently at first, causing alternating marine and deltaic conditions. Such an intermittency explains the sequence of lenticular beds of (1) marine glauconitic partly fossiliferous limy sand and (2) non-fossiliferous non-calcareous clay in this region. The smaller and smaller area covered by the successive marine beds toward the top of the Midway section correlates with a gradual increase in the size of the deltas and their eventual union.

Southward and eastward in Mississippi and Alabama, away from the influence of the delta growing in the northeast-central Mississippi region, limy material was deposited in the Gulf waters in early Midway time. As this epoch advanced and the delta increased in size, the limit of accumulation of lime was pushed farther and farther to the south and east. By the end of Midway time, deposition of deltaic material extended more than half way across the present state of Alabama. This explains the gradual westward replacment of the Clayton limestone by the Porters Creek clay.

The great spread of the deltaic clay eastward in late Midway time is striking. The submerged ridge off the mouth and across the course of the river in central Mississippi may have deflected some of the sediment eastward, and produced deposition of material at a greater distance from the mouth of the stream than would otherwise have been so. An alternative explanation is that other streams, building deltas, entered the embayment in this area. The presence of continuous calcareous material in the basal Midway across Alabama does not suggest the building of deltas into the Gulf by large streams in early Midway time. In discussing the "Source area" later, it will be shown that uplift of the southern Appalachians probably took place in early Eocene time. This may have produced new streams or revived old ones causing them to build deltas in late Midway time. If old streams in this area were smaller than the one in the northeast-central Mississippi region, they would not have been influenced so quickly by the uplift, and would have commenced their delta building later than that stream.

It has been shown recently[66b] that the Porters Creek clay in Illinois is composed essentially of the clay mineral montmorillonite. Since the Porters Creek clay is lithologically uniform in the whole eastern part of the embayment, it is probable that this mineral is the essential constituent elsewhere. It is not known exactly what conditions in the deltaic environment or in the source area are indicated by the dominance of this mineral.

Allen[67] has proved the existence of a few glass shards in the basal Porters Creek in Missouri, and has, therefore, concluded that the formation is a bentonite throughout. The author's examination of numerous thin sections of this material from other localities has failed to produce any evidence of textures indicating a bentonitic origin. Further, the clay reaches a thickness of 800 feet and extends over a very large area, thereby requiring, if it is to be considered a bentonite, an inconceivably large amount of volcanic ash. Local portions of the Porters Creek clay may be bentonitic, because of a slight content of material from volcanic ash; but the distribution and general character of all the Midway material, its thickness, and the absence of evidence of bentonitic textures in much of the clay, make it impossible to accept the idea that the entire Porters Creek is a bentonite.

Another characteristic of the Midway material that must be explained is the considerable thickness of pure basal limestone that overlies the top of the buried ridge in Hinds and Rankin counties. Because this region is so distant from the old shore line, it is reasonable to expect a change in lithology; but the absence of Midway limestone in the wells[68] in Sharkey and Scott counties, which are as far from the old shore line and probably farther from the mouth of the river, shows that distance from the shoreline was not the controlling factor of limestone deposition on top of the ridge.

The lithologic characteristics of this material suggest that it is a chemical precipitate. It may, therefore, be considered as a mass of travertine deposited by springs issuing on the buried ridge during Midway time. This interpretation would also account for the abruptness with which it is met in the Midway section, and the small area in which it is found. The fact that hot water still exists in this area is significant also.

LOCATION OF THE SOURCE AREA

The vast quantity of material deposited and the character of it suggest that the drainage area of the streams entering the head of the embayment must have extended back from the margins of the embayment for considerable distances in all directions. The drainage area of the stream entering the embayment in northeast-central Mississippi must have been northeast of the embayment; namely, in the southern Appalachian region.

PHYSIOGRAPHIC CHARACTER OF THE SOURCE AREA

The uniformity of lithology and the absence of breaks in the Midway series suggest uninterrupted deposition and uniform conditions in the source area. Pronounced variations in climate, which would, in turn, affect the degree of protective vegetable soil-covering and also the amount of oxidation, must not have existed. Sudden crustal movements, which would have influenced the character of weathering and rate of erosion, must not have happened.

A possibility brought out by Barrell[69] is that long transportation tends to produce uniformity of material. In this case, the probable nearness of the area of deposition to the source area tends to eliminate this possibility.

Since the source area was not remote, the fineness of the material, its color, together with the factors just mentioned, suggest a source area in the old age stage of physiographic development. Under conditions of plentiful rainfall, a highly protective vegetable mantle would develop, leading to deep rock decay. Streams coming from regions of this character carry little clastic material but silt, clay, and the finest sands. Intermittent rainfall with floods and droughts would lead to seasonal variations in the sediment deposited. A dryer climate or a more rugged topography would lead to variations in size and color of the material.

RELATION TO THE APPALACHIAN PENEPLAINS

The quantity of material deposited in central Mississippi has lead to the belief that the river was large and, consequently, had a large drainage area, extending over a considerable portion of the southern Appalachian region. It would follow from the above discussion that the southern Appalachian area during early Eocene time was in the old age of physiographic development and had a humid climate.

Hayes,[70] in his physiographic work on the southern Appalachians, recognized the existence of the three peneplains: the Cumberland, the Highland Rim, and the Coosa, respectively of late Cretaceous, Eocene, and Neocene age. More recently Wright[71] has recognized three erosion surfaces in Virginia, the highest of which, the Upland peneplain, is believed to be of Cretaceous or late Jurassic age. In the northern Appalachians, the existence of several erosion surfaces, one of which is believed to be of Cretaceous age, was early pointed out by Davis.[72] Shaw[73] has recently questioned the evidence for the age determination of some of these features. He disputes the conclusion that any of these peneplains could have been formed at such an early date and still remain in existence over the wide area they cover, the opinion being expressed that none of them is older than Tertiary or perhaps mid-Tertiary. The evidence for the past existence of a Cretaceous peneplain is strengthened by the facts gained from a study of the Midway sediments, but this evidence points to its continuation after Cretaceous time on into the early part of the Eocene. Whether or not remnants of this peneplain still remain is another matter.

Perhaps the most satisfactory conception of this source area is as follows: a peneplain developed toward the end of Cretaceous time; it continued into early Eocene time, perhaps undergoing a gradual uplift in Midway time. Along with gradual uplift came increased erosion, tending to strip off the thick soil covering of the country. During this uplift, and before the land became high enough for rapid erosion to expose much bedrock and produce coarser material, the streams draining the area would be heavily laden with fine silts and muds. In this interval the Midway material could have been deposited. The thickness of the Midway clay, and its great areal distribution which increases toward the top of the series, is evidence for the above conception. Further, as the Eocene sediments in this region are traced upward from the Midway, there is a decided increase in the coarseness (See later chapter of this report), which condition points to a continuation of this uplift of the Cretaceous peneplain after Midway time. This conception differs from the prevalent idea of uplift and warping of the peneplain at the end of Cretaceous time, in that it considers this crustal movement as a slow gradual process beginning in early Eocene time and continuing toward middle Eocene time with increasing intensity.

RELATION TO THE "APPALACHIAN RIVER"

Physiographic studies in the southern Appalachian region first led Hayes and Campbell[74] to postulate an ancestral Tennessee River, called the "Appalachian River." This ancient stream was believed by them to have entered the Gulf directly by way of the east Tennessee River and the Coosa River valleys until the uplift of the Cretaceous peneplain. After this, as shown by a series of sketches by Chamberlain and Salisbury[75] (based on the work of Hayes and Campbell), the upper portion of this stream was captured at Chattanooga by a stream flowing westward into the Gulf somewhere in the present state of Mississippi. Later stream capture again took place in northeastern Mississippi, and the present course of the Tennessee River came into being.

Johnson[76] and White[77] critically examined the evidence of capture at Chattanooga and practically disproved the idea. Later, Adams[78] expressed the opinion that the ancestral Tennessee never flowed across Mississippi into the Gulf, and hence there was no stream capture in northeastern Mississippi. The alternative idea is that the Tennessee assumed its course on the Cretaceous peneplain and has maintained it since that time. The evidence that this was the case at Chattanooga seems to be conclusive. However, the present study of the Eocene sediments gives evidence for the existence of a river of considerable size entering the Gulf of Mexico in northeast-central Mississippi in early Eocene time. This stream and the ancestral Tennessee must have been one and the same stream, as it is inconceivable that two large streams could have existed simultaneously so close together and have drained the same area. The conclusion seems correct that, in Midway time, the ancestral Tennessee flowed across northeastern Mississippi directly into the Gulf of Mexico, and that it was responsible for the Midway deposits in much of this part of the Mississippi embayment. As the hypothetical stream has been previously called the "Appalachian River," no new name is warranted now.

WILCOX SERIES

NAME

The name Wilcox was first used in a work (still unpublished) by Eugene A. Smith, late State Geologist of Alabama, for beds exposed at Wilcox in that state. The name was adopted by the United States Geological Survey and used in published reports first by Crider[79] in 1906. Previous to this time, the term Lignitic, first used by Hilgard,[80] was the name generally given to material of this age. As used by Hilgard, the Lignitic included, in addition to the present Wilcox, the Claiborne and possibly younger material. In Tennessee, Safford[81] used the name Lagrange for material of this age. Here again the name included a greater range of material than that now comprising the Wilcox. The work of Harris[82] and of Smith[83] served to limit the Wilcox to its present stratigraphic boundaries. In recent years the United States Geological Survey has raised the name Wilcox from formation to group (series) value in Mississippi.

STRATIGRAPHIC RELATIONS

The Wilcox series in the eastern part of the embayment rests directly on top of the Midway. The contact between these two series in Mississippi is a gradational one, as has been previously described. Berry[84] has suggested that an unconformity exists between the Porters Creek clay and the overlying material in Mississippi, and that this unconformity is marked in many places by beds of lignite. Recent field work has not substantiated this suggestion. The Porters Creek grades through a series of transition beds into the true Wilcox, and these transition beds contain no more lignite than the overlying Wilcox.

In Alabama, the contact, according to Cooke,[85] is not well known, but he believes it to be unconformable. According to Roberts,[86] who bases his correlations chiefly on the paleobotanical work of Berry, the contact in Tennessee is unconformable, because of the overlapping of the lower Wilcox by the upper Wilcox. Cooke[87] and Berry[88] have also suggested this overlapping. Berry[89] has recently pointed out a section in Hardeman County, Tennessee, in which this overlapping can be seen.

CLASSIFICATION AND CORRELATION OF THE WILCOX SERIES

In 1913 Lowe[90] divided the Wilcox in Mississippi, on a lithologic basis, into the Ackerman (lowest), Holly Springs, and Grenada. Two years later,[91] a fourth division was recognized in eastern Mississippi, which is marine and fossiliferous. On the basis of its fauna, this division was correlated with the Bashi of Alabama. In Mississippi, it has only been found in the vicinity of Meridian in Lauderdale County.

The Wilcox series in Alabama contains several marl beds which afford an excellent basis for dividing it. Smith[92] and others divided the series into four formations: Nanafalia (lowest), Tuscahoma, Bashi, and Hatchetigbee.

In Mississippi only the Bashi formation of the Wilcox contains marine fossils, so that a definite correlation of the rest of the series with the beds in Alabama is difficult. The change from the marine to the non-marine facies takes place near the Mississippi-Alabama line. The present conception of the correlation of the Wilcox in the two states is shown in Figure 10. Fossil leaves in the Grenada formation near Meridian and near Grenada have been correlated with the Hatchetigbee.[93] The Bashi formation extends from Alabama into Mississippi in Lauderdale County, being undeveloped beyond that county. From

Alabama, the Tuscahoma can be traced laterally into the Holly Springs formation of Mississippi. The Nanafalia formation of Alabama can also be traced laterally into the Ackerman.

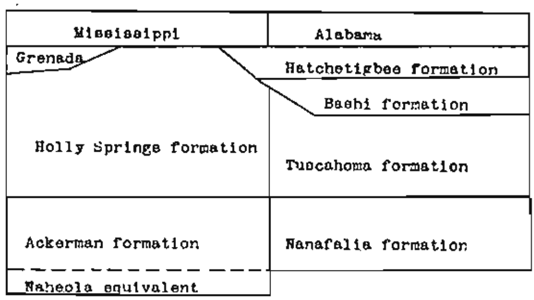


Figure 10.—Classification and correlation of the Wilcox formations in Mississippi and Alabama. Alabama section after Cooke.

The Wilcox in the portion of the embayment north of Mississippi has the same lithologic characters that it possesses in Mississippi. It has been suggested that the Wilcox in this northern area is composed of the equivalent of the Holly Springs and Grenada, the Ackerman being overlapped.

DESCRIPTION AND DISTRIBUTION OF THE MATERIAL AT THE OUTCROP

The Wilcox in Mississippi is an extremely varied assemblage of beds of sand and clay which, except for plant remains are unfossiliferous. The series is not broken by any large unconformities or any abrupt lithologic changes. Any subdivision of the Wilcox is, therefore, purely arbitrary. Some years ago Lowe[94] pointed out the existence of three lithologic zones which he used as a basis for dividing it. The lower part is composed mainly of clay, to which zone the name Ackerman was given. The middle sandy zone is known as the Holly Springs. The upper clayey zone is called the Grenada. The boundaries between these zones are transitional. In the southeastern part of the state, the presence of the marine Bashi formation, extending from the east, complicates the section.

Figure 11 shows the location of the Wilcox outcrop in the eastern part of the embayment; Figure 12, the outcrop in greater detail in Mississippi. As the boundaries between the formations are purely arbitrary, their positions on the map are generalized

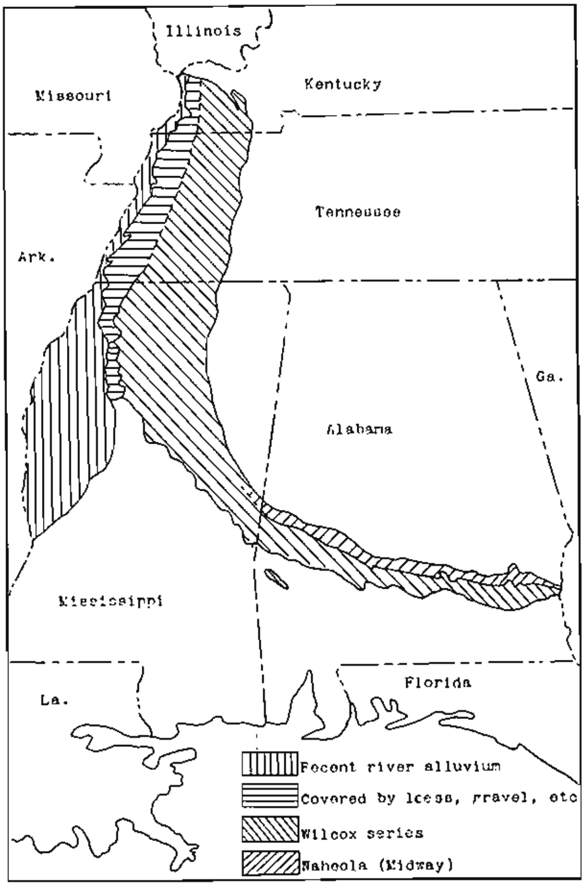


Figure 11.—Sketch map showing the Wilcox outcrop in the eastern part of the embayment.

The series as a whole has a thickness of about 600 feet in Alabama. Traced westward, it is found to average 1200 feet in Mississippi. There appears to be a slighter thickness of the series in the embayment area north of Mississippi.

ACKERMAN FORMATION

The Ackerman, named for the county seat of Choctaw County, Mississippi, near which are excellent exposures, includes all the material from the top of the Porters Creek clay of the Midway series to the Holly Springs sand of mid-Wilcox series. It is divisible into a basal

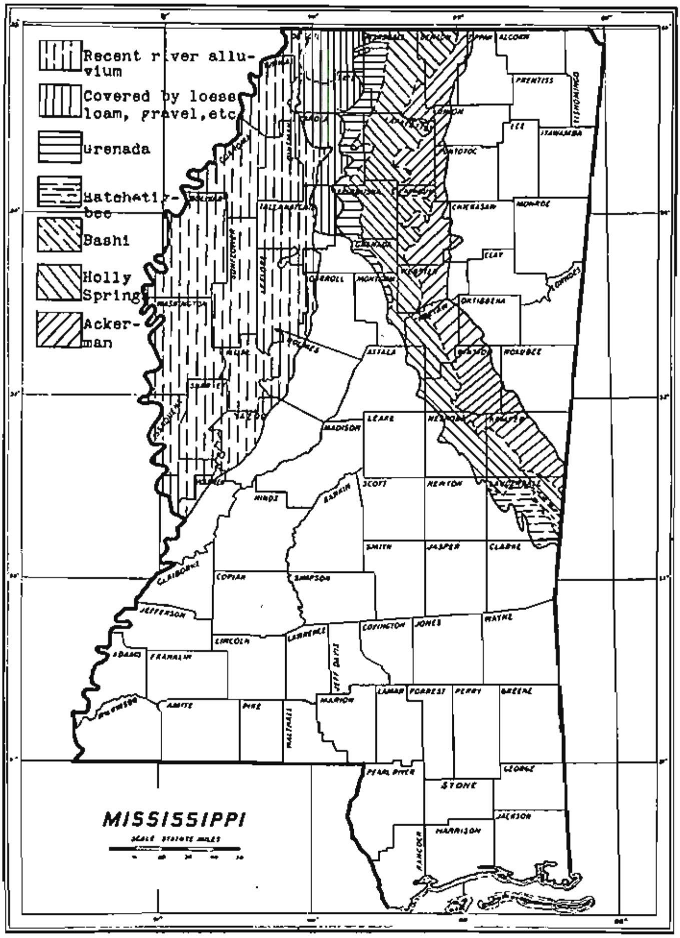


Figure 12.—Sketch map showing the outcrop of the Wilcox formations in Mississippi.

portion, having a thickness of 100 to 200 feet, and an upper portion, averaging about 300 feet. The basal portion of the Ackerman is largely sand which is usually white to gray in color and extremely cross-bedded. In addition to sand, it contains excellent white clays, Fuller's earths, bauxite, and a siliceous material known as Baukite. At the base of this portion of the Ackerman, there is rather abrupt transition to the Porters Creek clay. This zone can be traced laterally into the Naheola beds of Alabama with which it is sometimes correlated. The formations are similar lithologically in the two states.

Section in Blantons Gap on the Illinois Central Railroad 1 1/4 miles east of Ackerman, Choctaw County, Mississippi

	Feet	Feet
Holly Springs formation		30
12. Sand, red	16	
11. Sand, yellow irregularly bedded, grading laterally into yellow clay	14	
Ackerman formation		55
10. Lignite, impure	5	
9. Clay, finely laminated light gray	7	
8. Lignite	1	
7. Clay, blue gray; containing thin streaks and concretions of siderite	20	
6. Sandstone, cemented with limonite	1	
5. Sand, gray massive to laminated (Sample 7)	12	
4. Lignite	1	
3. Clay, bluish gray	1	
2. Clay, yellow sandy	2	
1. Clay, laminated gray	5	

The upper portion of the Ackerman, of which the above section is typical, is composed chiefly of thinly bedded bluish-gray micaceous silty clay and a few interlaminated beds of slightly cross-bedded sand. Lignite is more abundant in this part of the Wilcox than in any other part, some of the beds reaching a thickness of several feet.

There is commonly a gradual change in lithology, rather than a sharp break, between the two divisions of the Ackerman. The Ackerman formation is exposed from the Alabama line on the east to the Tennessee line on the north. Cooke[95] suggested that the Ackerman is overlapped in eastern Mississippi, but since it can be traced continuously into the Nanafalia in this boundary region, any pronounced overlapping is not likely. The Ackerman is believed to be overlapped north of Mississippi.

HOLLY SPRINGS FORMATION

The Holly Springs takes its name from the town of Holly Springs, Marshall County, Mississippi. The formation grades downward into the Ackerman and upward into the Grenada where that formation is present. The Holly Springs has an average thickness of 500 feet. It is composed of cross-bedded lenses of sand and clay, the sand greatly predominating. The lensing is so pronounced that it is extremely difficult to trace any portion of the beds even for short lateral distances. At the outcrop the sand commonly weathers to a deep red color, and the clay varies in color from red to white. Beds of lignite, also, are present. The following section is typical of the Holly Springs.

Section in Illinois Central Railroad cut just south of Oxford

	Feet	Feet
Holly Springs formation		36
4. Sand, gray to white, and interlaminated beds of red sand	20	
3. Clay, white	1	
2. Sand, gray irregularly bedded	3	
1. Sand, dark gray clayey; having purple mottlings	12	

This formation is exposed from eastern Mississippi to the head of the embayment. Its greatest thickness is in central Mississippi; it is thinner toward both the north and the east.

BASHI FORMATION

The Bashi formation was named after Bashi Creek, Clarke County, Alabama. Its relations to the overlying and underlying formations cannot be determined in Mississippi. Its maximum thickness is about 100 feet. The formation consists of fossiliferous yellowish-green glauconitic sand, which contains many large calcareous gray concretions. The Bashi is present only in the eastern part of Lauderdale County, Mississippi.

GRENADA FORMATION

The Grenada, named after the county seat of Grenada County in northern Mississippi, is excellently exposed east of that place. Its average thickness is about 100 feet. The formation is composed chiefly of thinly laminated micaceous pink clay, which is lignitic in the sense that it contains small fragments of lignite. There are a few beds of fine sand interbedded with the clay.

Near Grenada, there is a gradual transition from the typical Grenada clay into the overlying Tallahatta formation of the Claiborne series. This transition zone is a series of interlaminated beds of Grenada-like clay and Tallahatta-like claystone. The clay and claystone become so similar, lithologically, that it is often difficult to distinguish them, except for the fact that the Grenada is lignitic, and the Tallahatta is glauconitic.

Areally the similarity has led to considerable confusion in separating the Wilcox and Claiborne. For example, the following sections, obtained in areas that have been previously mapped as Grenada, clearly contain beds of typical glauconitic Tallahatta material. Stratigraphically, beds of this glauconitic material can be found scattered through the upper half of what has been called Grenada. Whether or not this material of the transition zone is placed in the Wilcox or Claiborne is a matter of opinion. In this report it is placed in the Claiborne. The boundary is thus arbitrarily drawn at the base of the marine material, since the fact that the Wilcox is non-marine and the Claiborne dominantly marine seems to make such a division necessary.

If this division of the Wilcox and Claiborne be accepted, then about half of the beds that have been called Grenada are consequently referred to the Tallahatta. A comparison of older maps with Figure 12, showing the Wilcox outcrop, and Figure 20, showing the Claiborne outcrop, will reveal how this downward shifting changes the outcrop area.

Berry[96] has collected a few fossil plants from a single section along the Bogue River in the Grenada area which he classed as Wilcox. This section contains no glauconitic material, and is approximately 100 feet below the top of the old Grenada. It is now considered to mark about the top of the Grenada; consequently the overlying material is placed in the Claiborne.

Section six miles east of Duck Hill on the Sweatman Road

	Feet	Feet
Transition beds now placed in the Claiborne series		15
1. Shale, thinly bedded drab colored micaceous and lignitic (Grenada-like), interbedded with sand, yellow glauconitic (Claiborne-like)	15	

Section two miles east of Grenada on the Graysport Road

	Feet	Feet
Transition beds now placed in the Claiborne series		30
7. Sand, deeply-weathered red	8	
6. Sand, green glauconitic (Claiborne-like)	4	
5. Sand, white glauconitic; having yellow mottlings	4	
4. Clay, thinly bedded pinkish-brown micaceous, lignitic (Grenada-like)	1	
3. Sand, white to yellow glauconitic (Claiborne-like)	2	
2. Clay, same as No. 4 (Grenada-like)	5	
1. Sand, glauconitic (Claiborne-like)	6	

Section one mile east of Grenada on the Calhoun City Road

	Feet	Feet
Transition beds now placed in the Claiborne series		44
6. Sand, deeply weathered red; containing rounded fragments of claystone	5	
5. Sand, interbedded red, white, and yellow, and a few thin streaks of white clay	20	
4. Clay, thinly laminated pinkish-brown micaceous, lignitic (Grenada-like)	5	
3. Sand, gray-green glauconitic; basal part containing thin beds of lignitic clay	14	
Grenada		14
2. Sand, red, and thin streaks of white shale	4	
1. Clay, pinkish-brown lignitic laminated	10	

Section seven miles southeast of Duck Hill on the road toward Sweatman, Montgomery County

	Feet	Feet
Transition beds now placed in the Claiborne series		40
3. Sand, yellow, cross-bedded	20	
2. Clay, pink lignitic, micaceous laminated (Grenada-like)	10	
1. Claystone, evenly interbedded layers of white; having irregular masses of glauconitic green sand and cross-bedded yellow glauconitic sand	10	

The Grenada and its equivalent, the Hatchetigbee, are present in extreme eastern Mississippi, absent in central Mississippi, and present from north-central Mississippi to the head of the embayment. Cooke[97] has suggested that the Grenada in central Mississippi is overlapped, but no evidence for this could be found in the field or in a study of deep-well material. In this region the Holly Springs ranges in age from the Ackerman to the top of the Wilcox. Consequently, it includes in its upper part the lateral equivalents of the Grenada and the Bashi.

DESCRIPTION OF THE SUBSURFACE WILCOX MATERIAL

In Bulletin 21 of the Mississippi Geological Survey, data concerning the features of the subsurface Wilcox were given. It is not proposed to repeat that discussion in this report, but it is necessary to mention certain of the salient features of that treatment to clarify later discussions in the present report. These features are: first, a pronounced thickening of the Wilcox down the dip to a maximum of perhaps 2000 feet at a considerable distance from the present outcrop; second, the existence of marine beds in the middle part of the Wilcox in the central part of the state (Hinds, Rankin, and Madison counties); third, the impossibility of dividing the subsurface Wilcox or even recognizing lithologic zones, such as characterize the outcrop, the material being a rather uniform gray silty clay; fourth, the total absence of any red color.

The total absence of the red color of the well material indicates that the presence of this color of the material in the outcrop is solely the result of weathering. The intensity of the red color and the abundance of iron hydroxide and iron oxide, causing it, are worthy of note in view of the small quantity of "Heavy" minerals in the sediment, which could act as a source of the iron. Much of the outcrop material appears to contain more iron hydroxide and iron oxide than could be produced by the weathering of the material exposed. For example, in the sand analysed from "Sand Cave", to be discussed later, there can be little doubt that a vastly greater quantity of this ferruginous material is present than could be produced by the weathering of the exceedingly pure quartz sand exposed at the surface. The explanation lies in the conception of the concentration of iron hydroxide and iron oxide by waters seeping downward from beds that have previously existed at the surface, but have since been eroded. Extremely thick beds or beds of another formation need not be postulated to account for this material.

The concentration of this ferruginous material produces a surface phenomenon that has led to considerable confusion in the past. For example, the downward seeping water may encounter a streak of clay whose impervious character prevents further downward migration and causes local deposition of the material. Such concentration, in addition to the normal lenticular form of the beds and the general cross-bedding, may produce a structure closely similar in appearance to an unconformity.

Hilgard[98] and later McGee[99] were of the opinion that the Wilcox was generally mantled by younger material resting on it unconformably. They placed this material in their Lafayette formation of Pliocene age. In recent years, the Lafayette formation has been shown, notably by Shaw,[100] to contain a variety of material of different ages. Berry[101] has shown the existence of Wilcox plants in the type Lafayette section.

Consequently, the concept of the Lafayette formation has been dropped. Much of the material that was thought to mantle the Wilcox is simply weathered Wilcox. The unconformities cited as existing between so-called Lafayette and the underlying Wilcox were not unconformities, but phenomena of the type just described.

Another characteristic effect of such downward migration of iron hydroxide in some beds of sand is the production of a series of layers of dark brown and very light brown sand. Wilcox sections, showing series of fairly regular layers (two inches on the average) of such sand, are common at the outcrop. The difference in the color is due to a slightly greater quantity of iron hydroxide in the darker layers, which are more porous and composed of larger-sized grains than the lighter colored layers. Probably the more porous layers offer easier avenues of movement for the iron hydroxide-bearing waters, and hence more iron is deposited in them. The color difference of the layers is not primary, but it serves to emphasize the primary difference in porosity and coarseness.

The Midway surface upon which the Wilcox material was deposited was closely similar in its general character to that upon which the Midway was deposited. The irregularity in the region of the present city of Jackson still existed, but the deposition of Midway material must have served partly to smooth out this irregularity. The relation of the subsurface Wilcox to this irregularity has been previously[102] discussed. It does not appear that this surface contained irregularities of sufficient magnitude to alter materially the conditions of deposition of the Wilcox sediments.

CONDITIONS OF DEPOSITION SUGGESTED BY THE LITHOLOGY AND DISTRIBUTION OF THE WILCOX SEDIMENTS

Since the Wilcox sediments, as exposed at the outcrop from Mississippi to the head of the embayment, contain lignite and plant remains rather than marine fossils, a non-marine environment of deposition is indicated. In Alabama the variable beds of marine fossiliferous and lignitic material suggest an alternation of marine and non-marine conditions of deposition. These beds, together with the existence of a marine zone in the subsurface Wilcox in Mississippi, show the Mississippi material, at and near the outcrop, to have been deposited adjacent to a marine environment. This marine zone further suggests a northward migration of marine waters in middle Wilcox time, preceded and followed by a retreat southward

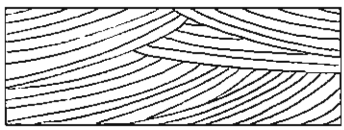
The variable character of the sediments requires environmental conditions and processes capable of considerable variation. The total absence of coarse material indicates an agent of transportation without a high velocity

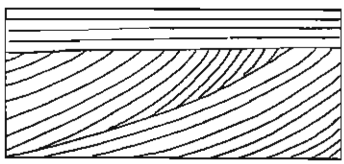
CROSS-BEDDING

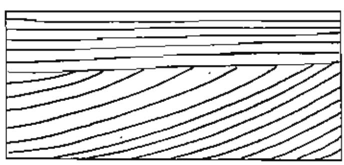
Cross-bedding is such a common feature of the Wilcox sediments that a satisfactory understanding of the conditions under which various types of cross-bedding are formed would provide valuable information for determining the history of the Wilcox. Students are agreed as to the general conditions under which cross-bedding develops, but they are not yet able to correlate a definite type of cross-bedding with a definite set of conditions of deposition. The difficulty appears to be that cross-bedding formed by different agents or in different environments may be so similar to one another that they cannot be differentiated. However, cross-bedding formed by wind action usually has certain characteristics which that formed by water does not have, and hence it is possible to separate cross-bedding into a "wind type" and a "water type".

According to Grabau,[103] eolian cross-bedding shows no uniformity of slope or direction within either the same stratum or successive strata, and the dividing planes are not parallel to each other. Twenhofel[104] has pointed out that this type of cross-bedding shows beds with a direction of inclination varying through all points of the compass. He also states that the bounding planes of the cross-laminated units are such as to make a wedge shape. Cressy[105] has stated that eolian cross-bedding in the sand dunes of the south shore of Lake Michigan shows sweeping curves which slope in various directions and at various angles. The characteristics of the "wind type" of cross-bedding are illustrated in Figure 13.

Grabau[106] lists two types of cross-bedding formed by water action. His first type, called "delta type", is composed essentially of a single bed of diagonal layers bounded above and below by nearly horizontal beds. The second type, characteristic of torrential deposits, is composed of several superimposed strata each one of which consists of diagonal beds sloping in the same direction. The length of the individual beds is less than in the "delta type". As characteristic of cross-bedding formed in (1) deltas, (2) alluvial fans, and (3) the seaward extension of the profile of equilibrum, Twenhofel[107] has noted (1) long foreset beds, (2) a fairly uniform direction of inclination which should usually vary through an arc of less than 180°, and (3) a succession of cross-bedded terranes showing a uniform direction of inclination. According to the same author, cross-bedding formed by the migration of sand bars is apt to be extremely irregular, the length of the foreset beds and the degree and direction of inclination being subject to considerable variation. In river bars the direction of inclination is apt to be more constant than in the shifting of the bars of lakes and of the littoral zone. Cross-bedding of this type cannot always be distinguished from that formed by wind. Gilbert[108] has described such material from the Medina sandstone of New York.







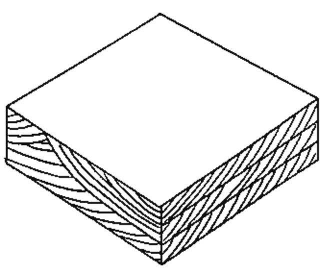


Figure 13.—Wind-type cross bedding.

Figure 14 —Water-type cross bedding.

Figure 15.—Water-type cross bedding.

Figure 16.—Sketch to show how incomplete sections may cause misinterpretation of cross bedding

Ripple marks may also develop cross-bedding, the foreset beds of which are small. This type is, however, of no importance in the Eocene of Mississippi.

In the following description of the Wilcox sediments in Mississippi, the cross-bedding is listed as the "water type" or "wind type", of which the "water type" is far more abundant (Figures 14 and 15). Further, the cross-bedding is of that "water type" more commonly characteristic of deltaic accumulations. Therefore, evidence of cross-bedding suggests water as the chief agent of deposition and the delta as the environment, but this interpretation is a mere suggestion, no more.

It is important to point out the necessity of examining cross-bedding in more than one horizontal direction, for in one direction it may resemble that in Figure 14 or 15; whereas in a second direction, that in Figure 13; a fact illustrated in Figure 16. Fortunately, the gullies and washes which cut the Eocene sections almost invariably permit them to be examined in more than one horizontal direction.

SUMMARY

The characteristics of the Wilcox sediments in Mississippi point strongly to water as the chief agent of deposition and to a somewhat variable non-marine environment adjacent to the sea. Such requirements are met by littoral, deltaic, lagoonal, or palludial conditions in a flat region. Under such conditions wind could have played the minor part suggested for it by the few examples of eolian cross-bedding.

ANALYSES OF THE WILCOX SEDIMENTS AND AN INTERPRETATION OF THE CONDITIONS OF DEPOSITION

After each of the following analyses of the Wilcox sediments, an attempt is made, from these analyses and from the detailed lithologic and stratigraphic characteristics, to interpret the conditions under which the sediments were deposited.

WILCOX SAMPLE 1

LOCATION, POSITION, AND CHARACTER

The sample was collected nine miles west of Pontotoc on the road to Oxford, about 100 feet above the base of the series, in a road cut exposure of approximately 20 feet of white sand (Sample 1), containing nodules of limonite, and of overlying bauxite, the contact between the two being covered. Megascopically, it is a white clayey unconsolidated sand containing streaks of brown sand; microscopically, a poorly sorted white clayey sand containing a considerable quantity of white mica.

Mechanical analysis

The results of the mechanical analysis of Sample 1 are represented by Histogram 1; of the division of the Very Fine Sand, by the table:

Light minerals	98.80 percent
Heavy minerals	1.20 percent

Microscopic examination

I. Coarse Sand: It is composed of a few flakes of white mica, and several grains of well rounded glassy-surfaced quartz.

II. Medium Sand: About 50 percent is composed of flakes of white mica; the remainder, of subangular glassy-surfaced quartz and a few white opaque grains that have a talc-like appearance.

III. Fine Sand: About 75 percent is composed of subangular grains of glassy-surfaced quartz. Except for a few talc-like grains, the rest is made of flakes of white mica.

IV. Very Fine Sand:

A. Light minerals: They are mostly subangular grains of quartz, in which wavy extinction is rare. Inclusions of the Irregular type are fairly common, zircon, tourmaline, and apatite (?) being present. The fraction includes a few grains of chert, a few flakes of white mica, having the properties of muscovite, and a few undeterminable talc-like grains.

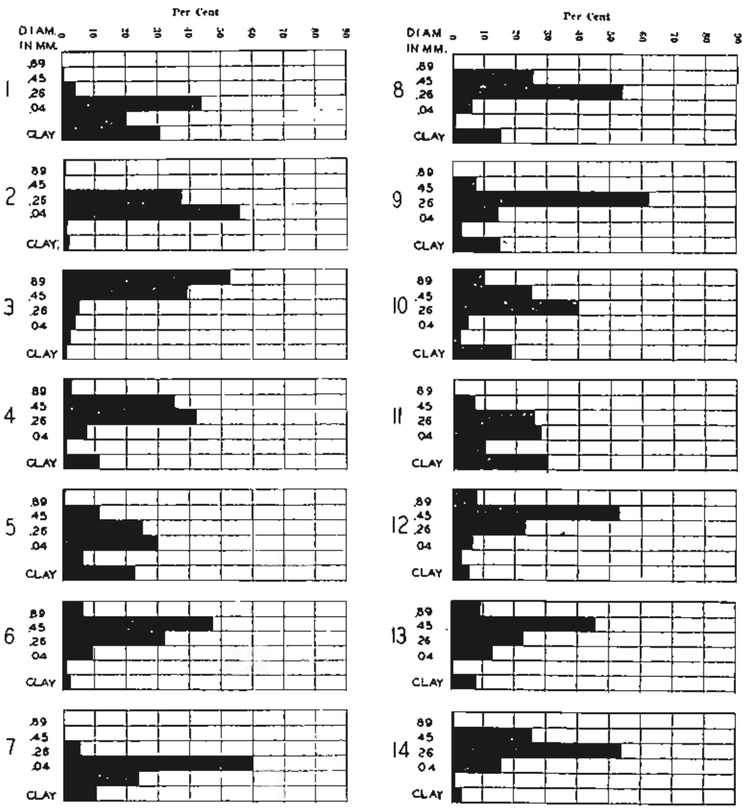
B. Heavy minerals: Kyanite is abundant. Tourmaline, zircon, staurolite, ilmenite, leucoxene are common. Rutile, sillimanite, spinel (?) zoisite, and titanite are rare.

V. Silt: It is composed mainly of angular grains of quartz and few flakes of white mica; subordinately of several grains of a dark mineral.

VI. Clay: It is composed of white aggregates of mottled to opaque clay-like material.

Interpretation

Histogram 1 of Wilcox Sample 1 is very similar to those of the deltaic deposits (Histograms i,j). It resembles especially Histogram j by showing a steep left side, a more gentle right side, and a fair degree of sorting. The similarity of Histogram 1 to those noted would be closer if the right side were smoothed out by the subdivision of the clay. Mohr[109] has shown that a subdivision of the clay will often tend to eliminate a secondary maximum in that grade.



Histograms 1-14.—Histograms representing the results of the mechanical analyses of Wilcox Samples 1-14.

The characteristics of the material at the outcrop yield no positive evidence as to its origin. The histogram, therefore, provides the only suggestion of the condition of deposition of this sample; namely, in a deltaic environment.

WILCOX SAMPLE 2

Location, position, and character

The sample was collected one mile east of Toccopola on the road to Pontotoc, in a cut about 200 feet above the base of the series.

Section of road cut one mile east of Toccopola

	Feet	Feet
Ackerman formation........................		55
2. Sand (Sample 2), white cross-bedded (wind type)	15	
1. Sand, shaly gray cross-bedded (water type).........	40	

Megascopically, it is a fine grained tawny-colored slightly micaceous sand containing very little clay; microscopically, a well sorted quartz sand containing many grains having a faint iron hydroxide coating which produces the tawny color.

Mechanical analysis

The results of the mechanical analysis of Sample 2 are represented by Histogram 2; of the division of the Very Fine Sand, by the table:

Light minerals	99.03 percent
Heavy minerals	0.97 percent

Microscopic examination

I. Coarse Sand: It is composed of well-rounded grains of glassy-surfaced quartz and a few flakes of white mica.

II. Medium Sand: It is composed mostly of subangular grains of glassy-surfaced quartz; subordinately of a few grains of a dark mineral, a few aggregates of clay, and a few flakes of white mica.

III. Fine Sand: The content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular grains of glassy-surfaced quartz in which wavy extinction is uncommon. Inclusions are very common. The Irregular type--tourmaline, zircon, and apatite are identifiable--is most abundant, and in some grains a definite linear alignment is shown. The Acicular type is common. The Regular type is rare. The fraction includes a few grains of chert, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite and tourmaline are abundant; sillimanite, staurolite, ilmenite, and leucoxene are common; and zircon, rutile, xenotime, and epidote are rare.

V. Silt: It is composed mainly of angular grains of quartz. Dark minerals are present in more abundance than in the coarser grades. They are more rounded than the quartz grains. A few white clay aggregates are also present.

VI. Clay: It is composed of brown flakey mottled to opaque clayey material studded with a few quartz grains and mica flakes.

Interpretation

Histogram 2 seems definitely to suggest wind deposition. Its similarity to Histogram a is striking. Although it does not show the very high degree of sorting usually produced by wind, the position of the size next in abundance to the maximum is in accordance with Udden's generalization for wind deposits. Udden[110] has also stated that in material deposited by wind over 90 percent is made up of grains varying in size from 0.5 to 0.125 mm. in diameter. In this sample well over 90 percent is between these grade-sizes. The very small quantity of clay, silt, and mica and the cross-bedded character of the material also suggest wind deposition.

On the other hand, a frosted surface of the grains would be anticipated if wind action had been important. Wave action is capable of yielding well-sorted sediments in which there is an absence of clay and silt and frosted grains, but less able to eliminate mica or to produce the type of cross-bedding visable at the outcrop. A compromise explanation is that wave action first rounded and partly sorted the grains, and that wind action followed later for a relatively short period, finally sorting and depositing them. Such conditions might prevail along a shore line that was receding so that more and more beach sand would be permanently abandoned by the waves to the action of the wind.

WILCOX SAMPLE 3

Location, position, and character

The sample was collected 10 miles east of Oxford on the New Albany Road, from the lower part of the Holly Springs formation, in a road cut of 20 feet of white cross-bedded (water type) sand (Sample 3). Megascopically, it is a coarse white to tawny sand containing quartz pebbles up to 6 mm. in diameter, locally cemented with limonite; microscopically, a quartz sand containing some grains of chert. Some of the grains are coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 3 are represented by Histogram 3; of the division of the Very Fine Sand, by the table:

Light minerals	97.26 percent
Heavy minerals	2.74 percent

Microscopic examination

I. Coarse Sand: It is composed of well rounded grains of quartz having a maximum diameter of 6 mm. Many of the grains are thoroughly fractured. About half of them have a frosted surface; the remainder, a glassy surface. Some of the frosted grains have a suggestion of a dreikanter shape. Some of the larger grains are composed of chert.

II. Medium Sand: It is composed mostly of subangular grains of glassy-surfaced quartz; subordinately of a few grains of frosty-surfaced quartz, several grains of milky quartz, and a few grains of a dark mineral.

III. Fine Sand: The content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mainly subangular grains of quartz, commonly showing wavy extinction. Inclusions of the Irregular type are fairly common; of the other types, rare. There are also a few grains of chert and a few flakes of white mica having the properties of muscovite. No feldspar could be positively identified. A few grains having indices of refraction below 1.540 may be orthoclase.

B. Heavy minerals: Kyanite and staurolite are common; zircon, tourmaline, rutile, topaz, monazite, xenotime, titanite, and epidote, rare.

V. Silt: It is composed mostly of grains of quartz; subordinately of a few grains of a dark mineral, a few flakes of white mica, and a few yellow nodules of clay.

VI. Clay: About 25 percent of the fraction is composed of dark mineral grains; the rest, of cream colored clayey material.

Interpretation

A division of the maximum grade size would slightly flatten Histogram 3, but not enough to change the grade size position. However, the small quantity of fine material and the fair degree of sorting suggest wave or wind action. The large size of the grains and the type of bedding favor deposition by water rather than by wind although the frosted grains indicate that wind action was not entirely absent. One interpretation of this material is, therefore, that it was deposited in a littoral environment. Several alternative interpretations suggest themselves. The material may have been deposited by a stream where slight checking of the velocity would cause only the coarse material to be dropped. The material could also have been deposited in a deltaic environment by a stream carrying coarse material. It is not possible definitely to eliminate any of these proposed interpretations, but the general absence of other characteristics suggesting a marine origin, and the presence of general characters favoring the existence of a deltaic environment in this region when the Wilcox was deposited make the deltaic suggestion most probable.

WILCOX SAMPLE 4

LOCATION, POSITION, AND CHARACTER

The sample was collected five miles east of Oxford on the New Albany Road, from the Holly Springs formation.

Section of gully five miles east of Oxford

	Feet	Feet
Holly Springs formation		60
3. Sand, red, having limonite concretions	10	
2. Sand, cross-bedded (water type); containing pebbles of clay	20	
1. Sand (Sample 4), variably colored cross-bedded (water type)	30	

Megascopically, the sand is thinly bedded white, tawny, and green and contains grains ranging up to 2 mm. in diameter; microscopically, a quartz sand in which many grains are coated by white clay and a few by iron hydroxide.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 4 are represented by Histogram 4; of the division of the Very Fine Sand, by the table:

Light minerals	96.70 percent
Heavy minerals	3.30 percent

MICROSCOPIC EXAMINATION

I. Coarse Sand: It is composed of well rounded grains of glassy-surfaced quartz and a few flakes of white mica.

II. Medium Sand: It is composed of the same material as the Coarse Sand and a few talc-like grains.

III. Fine Sand: It is composed of subangular grains of glassy-surfaced quartz and a few flakes of white mica, a few dark mineral grains, and a few talc-like grains.

IV. Very Fine Sand:

A. Light minerals: They are mostly subangular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are abundant; the other types are rare. Zircon is the only mineral inclusion identifiable. There are also a few grains of chert, a few somewhat altered grains of orthoclase and sodic plagioclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, staurolite, tourmaline, and zircon are abundant; rutile and sillimanite, common; and ilmenite, leucoxene, epidote, and corundum, rare.

V. Silt: It is composed mainly of angular quartz grains; subordinately of a few dark mineral grains, a few flakes of white mica, and a few clay aggregates.

VI. Clay: It is composed of yellow, mottled to opaque clayey material studded with a few distinct grains.

Interpretation

Histogram 4 possesses little similarity to any of those Histograms a-o. The sediment is fairly well sorted, but has a rather large quantity of fine material to suggest a strong sorting agent such as waves or wind.

The character of the bedding, the presence of mica, and the non-frosted character of the quartz grains indicate deposition by water rather than by wind. The cross-bedding indicates current action. This material could have accumulated in a littoral, deltaic, or fluvial environment. None of these possibilities can be definitely eliminated, but the lack of pronounced sorting and the absence of any other indications of marine conditions render the littoral interpretation least probable. Fluvial deposits are apt to be less sorted than this material. Hence, accumulation as a deltaic material is the most likely interpretation.

WILCOX SAMPLE 5

Location, position, and character

The sample was collected one-half mile south of Oxford where an Illinois Central Railroad cut exposes a part of the Holly Springs formation, consisting of 15 feet of red to tawny sand interstratified with red and white clay (Sample 5 is a composite of the sand bed about the middle of the section). Megascopically, it is an unconsolidated red clayey sand; microscopically, a fine grained clayey, quartz sand, many of the grains of which are coated with limonite.

Mechanical analysis

The results of the mechanical analysis of Sample 5 are represented by Histogram 5; of the division of the Very Fine Sand, by the table:

Light minerals	96.50 percent
Heavy minerals	3.50 percent

Microscopic examination

I. Coarse Sand: It is composed of well rounded grains of glassy-surfaced quartz and a few flakes of white mica.

II. Medium Sand: It consists of the same material as the Coarse Sand except that the quartz grains are subangular.

III. Fine Sand: It is composed mainly of angular glassy-surfaced quartz grains, and subordinately of a few well rounded frosted quartz grains, a few dark mineral grains, and a few white mica flakes.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular grains of glassy-surfaced quartz, in which wavy extinction is rare. Irregular inclusions, many of which show a linear arrangement, are abundant. Other types are rare. Zircon and tourmaline inclusions are identifiable. There are also a few grains of chert and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, rutile are abundant; tourmaline, staurolite, sillimanite, monazite, ilmenite, leucoxene, epidote, xenotime, rare.

V. Silt: It is composed of angular grains of quartz, a few dark mineral grains, and a few flakes of white mica.

VI. Clay: It is composed of yellow clay studded with a few grains of quartz and dark minerals.

Interpretation

Histogram 5 is closely similar to the one from the Lagoon of Thau (Histogram n). Deposition in a lagoon is one possible interpretation of this sample. The unsorted character of the material, the abundance of fine sediment, and the even bedding indicate deposition in an environment of little current action and little sorting power. Such conditions could exist in a lacustrine environment, and in parts of the fluvial environment such as on a flood plain, in a lagoon, and on various parts of a growing delta. None of these possible interpretations can be eliminated, but, because of the general characteristics of the Wilcox sediments in this area, the deltaic interpretation is preferable.

WILCOX SAMPLE 6

Location, position, and character

The sample was collected three miles west of Oxford on the Batesville Road, from the upper part of the Holly Springs formation.

Section of road cut three miles west of Oxford

	Feet	Feet
Holly Springs formation		18
2. Sand (Sample 6), massively bedded white; containing limonite concretions	8	
1. Clay, massively bedded grayish-white	10	

Megascopically, it is an unconsolidated fine grained somewhat clayey sand; microscopically, a fairly pure quartz sand in which many of the grains are very slightly coated with limonite.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 6 are represented by Histogram 6; of the division of the Very Fine Sand, by the table:

Light minerals	97.41 percent
Heavy minerals	2.59 percent

MICROSCOPIC EXAMINATION

I. Coarse Sand: It is composed entirely of subangular glassy-surfaced quartz grains.

II. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, a few dark mineral grains, and a few flakes of white mica.

III. Fine Sand: The content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are almost entirely angular grains of glassy-surfaced quartz having straight extinction. Inclusions of the Irregular type are common and many have a linear arrangement. The other types are rare. Zircon, tourmaline, apatite, and staurolite can be identified as mineral inclusions. There are also a few grains of chert, a few flakes of white mica having the properties of muscovite, and a very few grains of highly altered orthoclase.

B. Heavy minerals: Kyanite, staurolite, and sillimanite are common; epidote, rutile, zircon, tourmaline, ilmenite, and leucoxene, rare.

V. Silt: It is composed chiefly of angular grains of quartz, and subordinately of dark mineral grains, a few flakes of white mica, and a few white clay aggregates.

VI. Clay: It is composed of yellow, mottled to opaque, clayey material studded with a considerable number of quartz grains.

Interpretation

Histogram 6 is very similar to those of the deltaic deposits (Histograms i, j). It shows the steep left side, the more gentle right side and the fair degree of sorting that have been suggested as characteristic of these deposits. The sediment is not well enough sorted to suggest a beach or wind deposit, and it has none of the characteristics of a marine deposit. Conditions under which material such as this is apt to be deposited exist in certain parts of the fluvial environment, as, for example, in and near the channel and the delta. Lacustrine, lagoonal, and alluvial flat deposits would probably be less well sorted, and contain more fine material. Accordingly, the nature of the material suggests deltaic deposition.

WILCOX SAMPLE 7

Location, position, and character

The sample was collected one mile northeast of Ackerman where the Blantons Gap cut of the Illinois Central Railroad exposes the Ackerman formation, a section of which is given under the description of the Ackerman formation. Megascopically, it is a massively bedded unconsolidated gray sand; microscopically, a fine grained quartz sand speckled by a few grains that are stained by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 7 are represented by Histogram 7; of the division of the Very Fine Sand, by the table:

Light minerals	98.90 percent
Heavy minerals	1.10 percent

Microscopic examination

I. Coarse Sand: It is composed entirely of aggregates of silt-sized grains of quartz, biotite, and other dark minerals, and yellow clay. This material is calculated with the silt.

II. Medium Sand: The content is the same as that of the Coarse Sand.

III. Fine Sand: It is composed mostly of angular grains of glassy-surfaced quartz, and subordinately of a considerable number of dark mineral grains, flakes of biotite, flakes of white mica, and talc-like grains.

IV. Very Fine Sand:

A. Light minerals: About 50 percent of the fraction is made up of grains of talc-like material. The rest is composed chiefly of angular grains of quartz having straight extinction, and subordinately of a few grains of chert, a few grains of altered orthoclase and microcline, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Biotite, topaz, and tourmaline are abundant; zircon, andalusite, and staurolite, common; kyanite, garnet, epidote, sillimanite, and titanite, rare.

V. Silt: It is composed chiefly of angular grains of quartz most of which are partly coated with white clay; subordinately of mineral grains, flakes of white mica, and white clay aggregates.

VI. Clay: About 70 percent of the fraction is composed of distinct grains, chiefly quartz, the rest, of flakey white clay.

Interpretation

Histogram 7 is very similar to those of deltaic deposits (Histograms i, j). The other characteristics of the material are in harmony with this interpretation. The considerable quantity of fine material and the presence of lignite in the outcrop are evidence against deposition in a marine or a wind environment. This sand is rather highly sorted for a lacustrine, palludial, or alluvial flat deposit, although the presence of lignite shows that the environment of accumulation was such that peat could form from time to time.

WILCOX SAMPLE 8

Location, position, and character

The sample was collected one-fourth mile north of Williamson Station on the Gulf Mobile and Northern Railroad, from the Ackerman formation.

Section of cut one-fourth mile north of Williamson

	Feet	Feet
Ackerman formation		41
3. Sand (Sample 8), massively-bedded red	30	
2. Lignite	3	
1. Shale, thinly bedded gray	8	

Megascopically, it is a red fairly clayey sand; microscopically, a medium grained quartz sand in which the grains are coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 8 are represented by Histogram 8; of the division of the Very Fine Sand, by the table:

Light minerals	94.47 percent
Heavy minerals	5.53 percent

Microscopic examination

I. Coarse Sand: It is composed of flakes of white mica and a few subangular grains of glassy-surfaced quartz.

II. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, white mica flakes, and a few dark mineral grains.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are angular glassy-surfaced quartz grains in which wavy extinction is rare. Although inclusions of any type are uncommon, the Irregular type is most abundant and the others are very rare. There are also a few grains of chert, a few flakes of white mica having the properties of muscovite, and several grains of light green glauconite.

B. Heavy minerals: Kyanite and zircon are abundant; staurolite, rutile, hypersthene?, leucoxene, and ilmenite are common; and tourmaline and sillimanite are rare.

V. Silt: It is composed of angular grains of quartz, a few aggregates of yellow clay, and grains of a dark mineral.

VI. Clay: It is composed of red opaque flakes of clay in which a few grains of quartz can be recognized.

Interpretation

Histogram 8 shows no definite similarity to any of Histograms a to o. The degree of sorting suggests wave or wind action although the sediment may not be so well sorted nor so free from clay as most beach or wind deposits. The lack of frosting of the grains and the character of the bedding do not suggest wind deposition. The degree of sorting is rather high for palludial, lagoonal, lacustrine, or river alluvial flat deposits, although the presence of lignite in the outcrop section shows that accumulation took place under conditions which could change without interruption to those permitting peat to form. Glauconite indicates marine conditions, but it is not present in sufficient quantities to make certain the conclusion that it is not detrital. Consequently, a deltaic environment is believed most likely to have produced this sediment.

WILCOX SAMPLE 9

Location, position, and character

The sample was collected two miles north of Sherwood on the road to Ackerman, from the upper part of the Ackerman formation, in a road cut that shows a series of thinly-bedded red and white clayey sands, a few beds of gray-white sand (Sample 9 includes all these beds), and a clay conglomerate interstratified near the base of the section. Megascopically, it is a yellow-gray clayey, slightly limonitic partly consolidated sand containing streaks of concentrated dark minerals; microscopically, a fine grained quartz sand in which a few grains are coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 9 are represented by Histogram 9; of the division of the Very Fine Sand, by the table:

Light minerals	96.99 percent
Heavy minerals	3.01 percent

Microscopic examination

I. Coarse Sand: It is composed of several grains of well rounded glassy-surfaced quartz and a few flakes of white mica.

II. Medium Sand: It is composed of angular grains of quartz, a few dark mineral grains, and a few flakes of white mica.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: About 30 percent of the fraction is made up of grains of highly altered orthoclase and albite; the remainder, of angular glassy-surfaced quartz grains. Wavy extinction is rare. The Irregular type of inclusions is fairly common. A small percentage consists of a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, epidote, garnet, ilmenite, and leucoxene are common; kyanite, tourmaline, tremolite?, and staurolite, rare.

V. Silt: It consists of angular grains of quartz, a few aggregates of brown clay, a few dark mineral grains, a few highly altered feldspars, and a few flakes of white mica.

VI. Clay: It is composed of minute opaque-appearing clay-coated grains of quartz and a few uncoated grains.

Interpretation

Histogram 9 is similar to those of beach sands (Histograms e,f), although beach sands are apt to be better sorted than this material and to contain a smaller quantity of clay. The histogram also has some features that have been suggested as characteristic of deltaic deposits although the degree of sorting may be high for deltaic material. A probable interpretation is that deposition took place near shore under the influence of wave action and also under the influence of a nearby small stream or a distant large river.

The thin-bedded character of the material and the clay conglomerate are not in agreement with this interpretation. Characters such as these suggest deltaic or flood plain deposition.

WILCOX SAMPLE 10

Location, position, and character

The sample was collected two miles east of Eupora on the road to Maben, from the Holly Springs formation, in a road cut showing thick, massive beds of red sand and white clay interstratified (Sample 10, middle sand bed). Megascopically, it is a fine-grained red to pink sand, the color resulting from the iron hydroxide coating of the sand grains. The red and white sands are irregularly bedded on a small scale. Microscopically, it is a clayey quartz sand having unusually abundant dark mineral grains.

Mechanical analysis

The results of the mechanical analysis of Sample 10 are represented by Histogram 10; of the division of the Very Fine Sand, by the table:

Light minerals	90.93 percent
Heavy minerals	9.07 percent

Microscopic examination

I. Coarse Sand: It consists of well rounded glassy-surfaced grains of quartz and a few grains of milky quartz.

II. Medium Sand: It is composed of subangular glassy-surfaced quartz grains and a few dark colored mineral grains.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are chiefly angular glassy-surfaced quartz grains. Wavy extinction is rare. Inclusions of the Irregular type are abundant; of the others, common. Zircon and apatite are identifiable as inclusions. The fraction consists also of a few grains of chert, a few grains of altered sodic feldspar, and a very few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite is abundant; tourmaline, staurolite, sillimanite, ilmenite, leucoxene, and rutile are rare.

V. Silt: It is composed of angular quartz grains, a few white mica flakes, a few dark mineral grains, and a few yellow clay aggregates.

VI. Clay: It consists of somewhat opaque flakey material that is brown to black and studded with a few transparent grains.

Interpretation

Histogram 10 shows little resemblance to Histograms a-o. The degree of sorting and the quantity of fine material do not suggest the action of waves or wind. There are no characters that indicate deposition in a marine environment. Deposition of this material could have taken place in a fluvial, deltaic, lacustrine, or palludial environment, although the massive bedding does not suggest lacustrine material, and the absence of plant remains is not greatly in harmony with accumulation under palludial conditions. Deposition in a fluvial or deltaic environment, therefore, seems most likely. The slight degree of sorting may favor the probability of deltaic deposition rather than the fluvial.

WILCOX SAMPLE 11

Location, position, and character

The sample was collected four miles west of Eupora on the road to Kilmichael, from the Holly Springs formation, in a road cut which shows several thin seams of lignite, interbedded shales, and sands of variegated colors (Sample 11, thick sand in middle of section). Megascopically, it is a partly consolidated clayey sand made up of thin streaks and small patches of brown sand in white sand. Microscopically, it is a clayey, quartz sand in which most of the grains are somewhat coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 11 are represented by Histogram 11; of the division of the Very Fine Sand, by the table:

Light minerals	96.75 percent
Heavy minerals	3.25 percent

Microscopic examination

I. Coarse Sand: It consists of angular glassy-surfaced quartz grains.

II. Medium Sand: It is made up mostly of angular glassy-surfaced quartz grains and subordinately of a few dark mineral grains and a few white mica flakes.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are almost entirely angular glassy-surfaced quartz grains having straight extinction. The Irregular type of inclusion is abundant. The other types are rare. Zircon is an identifiable inclusion. The fraction includes a few grains of chert.

B. Heavy minerals: Kyanite and zircon are abundant; tourmaline, staurolite, rutile, ilmenite, leucoxene, sillimanite, epidote, and xenotime, rare.

V. Silt: It is composed of angular grains of quartz, a few dark mineral grains, a few flakes of white mica, and a few white clay aggregates.

VI. Clay: It consists of yellow clayey material, of grains of quartz, and of a few grains of a dark mineral.

Interpretation

Histogram 11 bears a striking resemblance to Histogram n. Deposition in a lagoon is, therefore, one of several possible interpretations. The lack of sorting, the abundance of clay, and the presence of lignite in the outcrop suggest that the sediment did not accumulate in the sea, in a river channel, or in an eolian environment. On the other hand it may have accumulated in a lake, on a river flood plain, or on the subaereal part of a delta. The even bedding indicates an environment in which there was no pronounced current action. None of these possible interpretations can be eliminated, but the general characteristics of the Wilcox suggest deltaic conditions.

WILCOX SAMPLE 12

Location, position, and character

The sample was collected one mile east of Stewart on the road to Eupora, from the Holly Springs formation, in a road cut section which shows thick beds of red sand (Sample 12) interbedded with gray lignitic, sandy clay. Megascopically, it is a red to yellow coarse sand partly cemented with iron hydroxide. Microscopically, it is composed of iron hydroxide-coated quartz grains, a few flakes of white mica, and a few fragments of lignite.

Mechanical analysis

The results of the mechanical analysis of Sample 12 are represented by Histogram 12; of the division of the Very Fine Sand, by the table:

Light minerals	97.21 percent
Heavy minerals	2.79 percent

Microscopic examination

I. Coarse Sand: It is made up of well rounded glassy-surfaced quartz grains.

II. Medium Sand: It consists entirely of quartz grains, most of which are subangular and glassy-surfaced, but some of which are well rounded and frosted.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are angular grains of quartz coated with iron hydroxide.

B. Heavy minerals: The coating of iron hydroxide prevents a satisfactory identification of the minerals.

V. Silt: It is composed of iron hydroxide-coated grains and aggregates of iron hydroxide.

VI. Clay: It consists of red opaque flakey clay, through which a considerable number of quartz grains are scattered.

Interpretation

The rather high degree of sorting and the small quantity of fine material suggest wave or wind action. The absence of cross-bedding and the fair quantity of fine constituents do not favor wind action, but the frosted surface of 40 percent of the grains does. Along a flat sandy shore, waves and wind may work together and may form a sediment that would show the influence of both.

The sediment is lignitic in the sense that it contains fragments of detrital lignite, which, since they otherwise could not have been preserved, must have accumulated in water or have been buried rapidly.

Deposition in a littoral environment seems to be the most plausible interpretation. However, accumulation in a river channel or on various parts of a delta cannot be definitely eliminated.

WILCOX SAMPLE 13

Location, position, and character

The sample was collected six miles east of Kilmichael on the Eupora Road, from the Holly Springs formation, in the middle of a road cut exposure of lignitic clay at the base and of thick beds of sand (Sample 13) interlaminated with gray shale above. Megascopically, it is an unconsolidated tawny, brown sand showing distinct bedding due to variations in the size of the grains; microscopically, it is a rather pure quartz sand in which some of the grains are slightly coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 13 are represented by Histogram 13; of the division of the Very Fine Sand, by the table:

Light minerals	97.85 percent
Heavy minerals	2.15 percent

Microscopic examination

I. Coarse Sand: It is composed entirely of well rounded glassy-surfaced quartz grains.

II. Medium Sand: It consists of subangular glassy-surfaced quartz grains and a few dark mineral grains.

III. Fine Sand: Its content is the same as that of Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains. Wavy extinction is rare. Irregular inclusions are abundant; Regular inclusions are common of which zircon, tourmaline, and apatite are identifiable. The Acicular type is rare. The fraction includes a few grains of chert.

B. Heavy minerals: Kyanite, tourmaline, zircon are abundant; staurolite, rutile, ilmenite, leucoxene, common; sillimanite, epidote, rare.

V. Silt: Angular quartz grains, a few dark mineral grains, and a few white clay aggregates make up this fraction.

VI. Clay: It is composed of brown, opaque, clayey material.

Interpretation

The histogram and the other characteristics of this sample are so similar to Histogram 6 that a similar interpretation is suggested for it.

WILCOX SAMPLE 14

Location, position, and character

The sample was collected one mile west of Kilmichael, from near the top of the Wilcox, where a road cut exposes thinly bedded red sand (Sample 14). Megascopically, it is a buff-red unconsolidated sand containing irregularly scattered masses of white sand; microscopically, a fairly pure quartz sand, a few of the grains of which are slightly coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 14 are represented by Histogram 14; of the division of the Very Fine Sand, by the table:

Light minerals	95.92 percent
Heavy minerals	4.08 percent

Microscopic examination

I. Coarse Sand: It consists of subangular glassy-surfaced quartz grains, a few flakes of white mica, and a very few grains of light green glauconite.

II. Medium Sand: It is composed mostly of angular glassy-surfaced quartz grains and subordinately of a few flakes of white mica, a few dark mineral grains, and a few dark green grains of glauconite.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains. Inclusions of the Irregular type are common. The other types are rare. Zircon and tourmaline are the only mineral inclusions identifiable. A fair abundance of talc-like grains, a few altered grains of microcline, and a few flakes of white mica having the properties of muscovite constitute a minor part.

B. Heavy minerals: Kyanite, zircon, tourmaline, rutile are abundant; epidote, staurolite, ilmenite, leucoxene, rare.

V. Silt: It is composed of approximately 80 percent aggregates of buff colored clay and nearly 20 percent angular grains of quartz.

VI. Clay: It consists of opaque cream colored clayey material through which a few distinct grains are scattered.

Interpretation

The degree of sorting and the scarcity of clay and silt point to the action of a strong sorting agent such as waves or wind in the environment of deposition. The glassy surface of the quartz grains, the presence of mica, and the regular bedding suggest wave action rather than wind. This would lead to the interpretation that the sediment accumulated in a littoral or neritic environment. The presence of glauconite would at first appear to strengthen this interpretation, but it is not abundant enough to eliminate a possible detrital source. Other possible interpretations such as deposition in a river channel or on a delta cannot be excluded.

WILCOX SAMPLE 15

Location, position, and character

The sample was collected two miles east of Grenada on the Graysport Road, from the transition zone between the Grenada (Wilcox) and Tallahatta (Claiborne), in a road cut exposing several massive beds of sand, 10 to 15 feet thick (Sample 15 from middle bed), separated from one another by thin beds of pink micaceous, lignitic clay. Megascopically, it is a gray mottled green and yellow unconsolidated sand; microscopically, it is a slightly glauconitic, quartz sand, a few of the quartz grains of which are coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 15 are represented by Histogram 15; of the division of the Very Fine Sand, by the table:

Light minerals	97.57 percent
Heavy minerals	2.43 percent

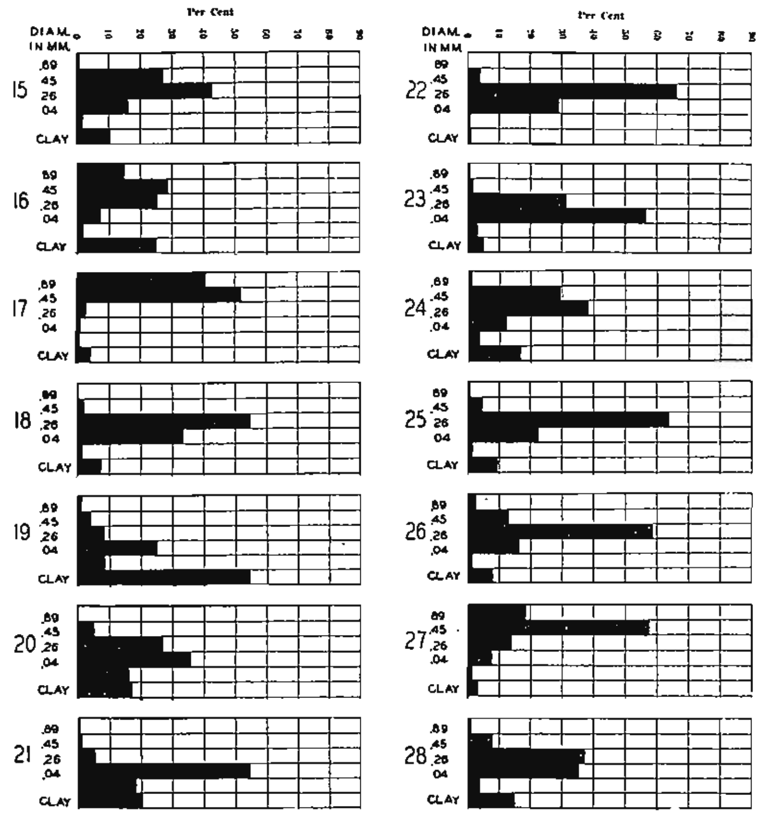
Microscopic examination

I. Coarse Sand: It is composed entirely of angular grains of quartz.

II. Medium Sand: It consists of angular grains of quartz and a few light colored grains of glauconite.

III. Fine Sand: Its content is the same as that of the Medium Sand plus a few flakes of white mica and a few dark mineral grains.

IV. Very Fine Sand:



Histograms 15-28.—Histograms representing the results of the mechanical analyses of Wilcox Samples 15-28.

A. Light minerals: Angular glassy-surfaced grains of quartz are the dominant constituent. Wavy extinction is rare. The Irregular type inclusion is abundant. The other types are rare. Zircon is the only inclusion identifiable. A few grains of chert, a very few grains of microcline, a few unaltered light green grains of glauconite, and a few flakes of white mica having the properties of muscovite are the minor constituents.

B. Heavy minerals: Kyanite, tourmaline, zircon, staurolite are abundant; rutile, sillimanite, biotite, epidote, monazite, ilmenite, leucoxene, rare.

V. Silt: It is composed of angular grains of quartz and aggregates of yellow clay.

VI. Clay: It consists of greenish-yellow opaque clayey material studded with a few distinct grains.

Interpretation

The fair abundance of glauconite in this sample indicates a marine environment of deposition. The existence of lignitic clays in the outcrop section indicates a near shore environment where oscillations from a marine to a non-marine condition were possible. The histogram shows the sand to be poorly sorted, which suggests accumulation where wave action was not strong or where material accumulation was too rapid to permit the waves to sort it effectively. Such conditions would best be fulfilled in a littoral region near the mouth of a river.

WILCOX SAMPLE 16

Location, position, and character

The sample was collected one mile west of DeKalb on the road to Union, from the Ackerman formation about 125 feet above the top of the Porters Creek, where a road cut shows about 25 feet of red massively bedded pebbly sand (Sample 16 composite). Megascopically, it is a red sand containing pebbles of clay and quartz up to 15 mm. in diameter. Iron hydroxide acts as a partial cement. Microscopically, it is a quartz sand containing little clay except the clay pebbles. The sand grains are coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 16 are represented by Histogram 16; of the division of the Very Fine Sand, by the table:

Light minerals	93.59 percent
Heavy minerals	6.41 percent

Microscopic examination

I. Coarse Sand: Except for a few flakes of white mica this grade size is composed of well rounded glassy-surfaced quartz grains.

II. Medium Sand: It consists of subangular glassy-surfaced quartz grains, a few flakes of white mica, and a few dark mineral grains.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mainly angular glassy-surfaced quartz grains having straight extinction. Inclusions are rare. The Irregular type is most common. The Regular type is very rare; zircon alone can be identified. A few grains of chert, a few grains of microcline, and a few flakes of white mica having the properties of muscovite compose the smaller part.

B. Heavy minerals: Kyanite, staurolite are abundant; rutile, zircon, tourmaline, sillimanite, titanite, ilmenite, leucoxene, epidote, xenotime, rare.

V. Silt: It is composed chiefly of angular glassy-surfaced quartz grains and flakes of white mica; subordinately of a few dark mineral grains and a few yellow clay aggregates.

VI. Clay: It consists of brown clayey material studded with a few grains of quartz.

Interpretation

The unsorted character of this sediment and the presence of clay pebbles indicate that the material was not deposited in an environment where there was continuous sorting action. The coarseness of the material does not indicate deposition in a lacustrine or palludial environment, and there is no evidence for a marine origin. The characteristics of this material indicate that it was deposited in a fluvial or deltaic environment. Gardner[111] and Patton[112] have shown the development of clay pebbles on flood plains. However, the coarseness of this sample would seem to favor channel deposition. A comparison of Histogram 16 with the Histograms k-m of the river sands shows considerable similarity between them.

WILCOX SAMPLE 17

Location, position, and character

The sample was collected 23 miles east of Union on the DeKalb Road, from the Ackerman formation, where a road cut shows massive beds of red to pink cross-bedded (water type) sand (Sample 17 composite). Megascopically, it is a coarse grained uncemented sand; microscopically, a fairly pure quartz sand in which the grains are coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 17 are represented by Histogram 17; of the division of the Very Fine Sand, by the table:

Light minerals	96.69 percent
Heavy minerals	3.31 percent

MICROSCOPIC EXAMINATION

I. Coarse Sand: It is composed entirely of well rounded glassy-surfaced quartz grains.

II. Medium Sand: It consists of subangular glassy-surfaced quartz grains.

III. Fine Sand: It is composed of angular glassy-surfaced quartz grains, a few talc-like grains, a few flakes of white mica, and a few dark mineral grains.

IV. Very Fine Sand:

A. Light minerals: They are principally angular glassy-surfaced quartz grains. Wavy extinction is rare. The Irregular inclusions are abundant. The other types are rare. Zircon alone can be identified. A considerable number of altered grains of microcline, a few grains of chert, and a few flakes of white mica having the properties of muscovite compose the smaller quantity.

B. Heavy minerals: Kyanite is abundant; staurolite is common; and sillimanite, zircon, rutile, ilmenite, leucoxene, are rare.

V. Silt: It is composed of angular grains of quartz, a few flakes of white mica, a few dark mineral grains, and a few clay aggregates.

VI. Clay: It consists of brown opaque clayey material studded with a few distinct mineral grains.

INTERPRETATION

The well sorted character of this sediment together with the very small quantity of material finer than medium sand strongly suggests the presence of a strong sorting agent, such as waves or wind in the environment of deposition. The position and size of the secondary maximum indicate wind rather than wave action, according to the generalization of Udden.[113] The character of the bedding, the large size of the grains, the presence of mica, and the glassy surface of the quartz grains are stronger evidences against wind deposition. Therefore, the most plausible interpretation of this sand appears to be that it accumulated in a littoral environment where wave action was strong enough to remove material smaller than the medium sand.

WILCOX SAMPLE 18

LOCATION, POSITION, AND CHARACTER

The sample was collected 15 miles east of Union on the road to DeKalb, from the Holly Springs formation, where a road cut shows massively bedded red and yellow sand (Sample 18 composite). Megascopically, it is a fine grained unconsolidated yellow sand containing a few flakes of white mica. Microscopically, it is a quartz sand in which the grains are partly coated with iron hydroxide. There seems to be little silt or clay.

Mechanical analysis

The results of the mechanical analysis of Sample 18 are represented by Histogram 18; of the division of the Very Fine Sand, by the table:

Light minerals	99.21 percent
Heavy minerals	.79 percent

Microscopic examination

I. Coarse Sand: It consists of flakes of white mica and a few well rounded quartz grains.

II. Medium Sand: About 50 percent of the fraction is composed of flakes of white mica. The remainder is made up of well rounded grains of glassy-surfaced quartz and a few unaltered light green grains of glauconite.

III. Fine Sand: It consists of subangular glassy-surfaced quartz grains, a few flakes of white mica, and a few dark mineral grains.

IV. Very Fine Sand:

A. Light minerals: They are almost entirely angular glassy-surfaced quartz grains. Straight extinction is most common. Inclusions of the Irregular and Acicular types are common. The Regular type is rare; zircon alone can be identified. A few grains of chert and a few flakes of white mica having the properties of muscovite compose a small number.

B. Heavy minerals: Kyanite, tourmaline, zircon, sillimanite, ilmenite are common; staurolite, leucoxene, epidote, rare.

V. Silt: It is composed of angular quartz grains, a few flakes of white mica, a few dark mineral grains, and a very few grains of glauconite.

VI. Clay: It consists of a large quantity of minute distinct mineral grains and a very slight quantity of clayey material.

Interpretation

The histogram of this sample does not accurately reflect the high degree of sorting undergone by the sand. An examination of the Fine Sand shows it to be composed chiefly of grains near the lower limit of the grade size. A similar examination of the Very Fine Sand shows it to be composed mainly of grains near the upper limit of this grade size. Therefore, this sand is composed chiefly of material having a diameter of about .25 mm. The analysis separating the sand at .25 mm. artificially divides this uniform material into two grade sizes.

The high degree of sorting and the small quantity of silt and clay suggest the action of waves or wind. The abundant mica, the character of the bedding, and the glassy surface of the quartz grains favor waves rather than wind as the sorting agent. Therefore, deposition in a littoral or neritic environment where there was considerable wave sorting action seems to be the most plausible interpretation of this sample. The rare glauconite adds further weight to this suggestion although it is not present in sufficient abundance to permit a positive determination that it is not detrital.

WILCOX SAMPLE 19

Location, position, and character

The sample was collected eight miles east of Union on the road to DeKalb, from the Holly Springs formation about 200 feet below the base of the Claiborne series, where a road cut shows a series of thinly interbedded red and gray clayey sands (Sample 19 composite). Megascopically, it is composed of thin beds of unconsolidated red and gray clayey sand. The light colored beds appear to be more clayey than the dark colored beds. Microscopically, it is a clayey quartz sand in which the grains are coated by variable amounts of iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 19 are represented by Histogram 19; of the division of the Very Fine Sand, by the table:

Light minerals	99.60 percent
Heavy minerals	.40 percent

Microscopic examination

I. Coarse Sand: The fraction is composed of well rounded glassy-surfaced quartz grains and a very few dark mineral grains.

II. Medium Sand: It consists of subangular glassy-surfaced quartz grains, a few flakes of white mica, and a few dark mineral grains.

III. Fine Sand: Its content is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mainly angular grains of quartz. Wavy extinction is rare. Inclusions are rather abundant. The Irregular type is most abundant. The other types are rare. The mineral inclusions except zircon are too small for identification. A few grains of chert, a few light green unaltered grains of glauconite, a few grains of microcline, and a few flakes of white mica having the properties of muscovite compose the minor part.

B. Heavy minerals: Kyanite, tourmaline, zircon are abundant; ilmenite is common; and rutile, staurolite, sillimanite, andalusite, titanite, epidote, leucoxene are rare.

V. Silt: It is composed of angular grains of quartz, a few white clay aggregates, a few flakes of white mica, and a few dark mineral grains.

VI. Clay: It consists of yellowish-brown flakey opaque clayey material studded with a few distinct mineral grains.

Interpretation

The great quantity of clay and the even character of the bedding suggest an environment of deposition where there was little wave or wind action and little current activity. Such conditions might exist in a lagoon, in a lake, on the flood plain of a river, or on various parts of a delta. Although glauconite is not present in sufficient quantities to eliminate a possible detrital origin, it favors accumulation in a marine or perhaps subaqueous deltaic environment. Histogram 19 is similar to those of lagoonal deposits (Histograms n,o).

On the basis of all the foregoing data, the most likely interpretation appears to be that of deposition in a littoral environment where there was little wave action, such as in a lagoon, or a place where material was being brought to the site of deposition faster than the waves could sort it.

WILCOX SAMPLE 20

Location, position, and character

The sample was collected three miles south of Philadelphia at Blue Mountain, from a bed which lies about 100 feet below the base of the Tallahatta, and which, although separated from that formation by slumped material, is so similar to unquestionable Wilcox sand at a lower level as to suggest Wilcox age. It came from a road cut which shows massively interbedded red, gray, and yellow sand and a very few thin lenses of clay (Sample 20 is a composite of a yellow sand bed about the middle of the section). Megascopically, it is a poorly sorted clayey, micaceous slightly cemented sandstone; microscopically, a fine grained quartz sand in which the grains are slightly coated by iron hydroxide and cemented with it.

Mechanical analysis

The results of the mechanical analysis of Sample 20 are represented by Histogram 20; of the division of the Very Fine Sand, by the table:

Light minerals	97.34 percent
Heavy minerals	2.66 percent

Microscopic examination

I. Coarse Sand: No coarse sand.

II. Medium Sand: It consists of angular glassy-surfaced quartz grains, a few flakes of white mica, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: Most of this fraction is composed of angular grains of quartz most of which have wavy extinction. Inclusions of the Irregular type are common; of the other types, rare. Some of the fraction consists of a few flakes of white mica having the properties of muscovite and a few grains of highly altered albite and orthoclase.

B. Heavy minerals: Kyanite, tourmaline, ilmenite are common; leucoxene, zircon, staurolite, rutile, sillimanite, rare.

V. Silt: About 80 percent of the material is composed of angular grains of quartz; and about 20 percent, of gray clay aggregates.

VI. Clay: It is composed of red clayey material studded with many distinct mineral grains.

Interpretation

The considerable quantity of fine material and the small amount of sorting indicate deposition in an environment which did not possess a strong sorting agent. The even bedding seems to exclude pronounced current action. The material has no features indicative of a marine origin. The absence of associated lignite is evidence against accumulation in a palludial environment. Conditions permitting such deposition might have existed in lakes, on flood plains, on various parts of deltas, or in lagoons. A comparison of Histogram 20 with Histograms n,o of lagoonal deposits shows decided similarities, which favor this interpretation over the other possible ones.

WILCOX SAMPLE 21

Location, position, and character

The sample was collected six miles north of Lauderdale on the Macon Road, from the Ackerman formation about 100 feet above the top of the Porters Creek, where a road cut shows thinly bedded and cross-bedded (water type) red sand (Sample 21 composite). Megascopically, it is a fine grained buff colored micaceous, clayey sand; microscopically, a quartz sand containing distinct zones in which the dark minerals are concentrated, and in which mica seems to be less abundant. The quartz grains are faintly coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 21 are represented by Histogram 21; of the division of the Very Fine Sand, by the table:

Light minerals	97.54 percent
Heavy minerals	2.46 percent

Microscopic examination

I. Coarse Sand: It is composed of approximately equal amounts of well rounded glassy-surfaced quartz grains and white mica flakes.

II. Medium Sand: It consists of flakes of white mica, grains of talc-like material, and a few grains of subangular glassy-surfaced quartz.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand.

A. Light minerals: Approximately 30 percent of this fraction is composed of flakes of white mica having the properties of muscovite; about 15 percent of grains of talc-like material; and about 5 percent of highly altered sodic feldspar. The rest is composed of angular glassy-surfaced quartz grains. Wavy extinction is rare. The Irregular type of inclusion is most common, many showing a definite linear arrangement. The other types are rare. Zircon and apatite are identifiable inclusions. A small amount consists of grains of chert.

B. Heavy minerals: Zircon, kyanite, rutile, tourmaline are common; leucoxene, ilmenite, epidote, sillimanite, xenotime, rare.

V. Silt: It is composed of angular quartz grains and a few white clay aggregates.

VI. Clay: It consists of flakey translucent clayey material studded with a few distinct grains.

Interpretation

The considerable quantity of clay in this sand suggests that a strong sorting agent did not influence its deposition. On the other hand the concentration of over half the sample in one grade size and the existence of "pay streaks" of Heavy minerals indicates some sorting action. The character of the bedding, the glassy surface of the quartz grains, the abundance of mica, and the abundance of fine material favor waves rather than wind as the sorting agent. Suitable conditions for the accumulation of this material could be found around the margins of a delta where fine material was being carried at a more rapid rate than would permit removal by the waves, in a littoral area where wave action was feeble, or in a river channel. The fact that "pay streaks" are known to develop under surf action, as Kennedy[114] has shown, favors the littoral interpretation.

WILCOX SAMPLE 22

Location, position, and character

The sample was collected two miles north of Lockhart on the Macon Road, from the lower part of the Midway-Wilcox transition zone, where a road cut shows massive beds of cross-bedded (water type) brown sand (Sample 22 composite). Megascopically, it is a fine grained well sorted unconsolidated sand containing little clay or silt; microscopically, a fairly pure quartz sand in which the grains are slightly coated with iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 22 are represented by Histogram 22; of the division of the Very Fine Sand, by the table:

Light minerals..	99.08 percent
Heavy minerals	.92 percent

Microscopic examination

I. Coarse Sand: About 75 percent is well rounded glassy-surfaced quartz grains; and about 25 percent, flakes of white mica.

II. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, a few well rounded frosted-surfaced quartz grains, a few flakes of white mica, a few talc-like grains, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: Angular glassy-surfaced quartz grains are the dominant constituent. Wavy extinction is rare. Inclusions of the Irregular type are abundant; of the Regular type, common; and of the Acicular type, rare. A few grains of chert, a few grains of highly altered albite and orthoclase, and a few flakes of white mica having the properties of muscovite are less abundant.

B. Heavy minerals: Kyanite, tourmaline, staurolite are abundant; zircon, topaz, sillimanite, rutile, ilmenite, leucoxene, rare.

V. Silt: It is composed of angular quartz grains, a few dark mineral grains, and a few yellow clay aggregates.

VI. Clay: It consists of yellow semi-transparent clayey material studded with many distinct mineral grains.

Interpretation

The high degree of sorting and the small quantity of silt and clay indicate strong sorting agents. The character of the bedding, the presence of mica, and the glassy surface of the quartz grains favor wave rather than wind action. Deposition in a littoral environment where there was considerable wave action, therefore, seems to be the most likely interpretation of this sample.

WILCOX SAMPLE 23

Location, position, and character

The sample was collected one mile north of Keewanee on the road to Lauderdale, from the Holly Springs formation, where a road cut shows thin regular beds of white and brown sand (Sample 23 composite). Megascopically, it is an alternate series of white and brown sands, similar except for the difference in color and the presence of more dark minerals in the brown sand. Microscopically, it is an unconsolidated slightly micaceous quartz sand in which the grains are slightly coated by iron hydroxide. The dark minerals are uniformly small in size.

Mechanical analysis

The results of the mechanical analysis of Sample 23 are represented by Histogram 23; of the division of the Very Fine Sand, by the table:

Light minerals	98.00 percent
Heavy minerals	2.00 percent

Microscopic examination

I. Coarse Sand: It is composed of flakes of white mica and a few well rounded grains of glassy-surfaced quartz.

II. Medium Sand: Its composition is the same as that of the Coarse Sand.

III. Fine Sand: About 70 percent of this fraction is composed of angular glassy-surfaced quartz grains. The remainder is made up of flakes of white mica, grains of talc-like material, a few dark mineral grains, and a very few grains of glauconite.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains. Extinction is usually straight. Inclusions are uncommon, the most numerous being of the Irregular type, some of which have a definite linear arrangement. Among the inclusions, zircon and apatite alone are identifiable. There are a few highly altered grains of albite and orthoclase.

B. Heavy minerals: Kyanite is abundant; staurolite, zircon, rutile, tourmaline are common; and sillimanite, ilmenite, leucoxene, titanite, topaz are rare.

V. Silt: It is composed of angular quartz grains, a few white clay aggregates, and a few dark mineral grains.

VI. Clay: It consists of translucent cream colored clayey material studded with many distinct mineral grains.

Interpretation

Histogram 23, like Histogram 18, does not accurately reflect the high degree of sorting possessed by the sand. The small quantity of clay and silt and the high degree of sorting indicate a strong sorting agent, such as waves or winds. The size and position of the secondary maximum, according to the generalization of Udden,[115] favor wind rather than wave action. Other features, such as the bedding, the glassy surface of the quartz grains, and the presence of mica afford stronger evidence for deposition in water. The most plausible interpretation, therefore, seems to be that of deposition in a littoral environment where there was strong surf action. Although the glauconite is not present in sufficient quantities to eliminate a possible detrital origin, it further suggests this interpretation.

WILCOX SAMPLE 24

Location, Position, and Character

This sample was collected eight miles east of Meridian on the road to Toomsuba, from the Holly Springs formation, where a road cut shows massively bedded gray sand (Sample 24) overlain by thinly laminated brown shale. Megascopically, it is a medium to fine grained unconsolidated gray sand containing patches of red sand which produce a mottled appearance. It contains a few thin streaks of clay. Microscopically, it is a fairly pure quartz sand in which the grains are coated by variable amounts of iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 24 are represented by Histogram 24; of the division of the Very Fine Sand, by the table:

Light minerals	98.77 percent
Heavy minerals	1.23 percent

Microscopic examination

I. Coarse Sand: It consists of subangular glassy-surfaced quartz grains and a few flakes of white mica.

II. Medium Sand: It is composed of angular glassy-surfaced quartz grains, a few well rounded frosted quartz grains, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly glassy-surfaced quartz grains. Extinction is usually straight. Inclusions of the Irregular type are abundant, and many show a linear arrangement. The other types are rare. Zircon alone is identifiable as an inclusion. The minerals include a few grains of chert, a few grains of highly altered albite, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Tourmaline, zircon, kyanite are common; rutile, ilmenite, staurolite, sillimanite, topaz, leucoxene, rare.

V. Silt: It consists of angular quartz grains, a few dark mineral grains, and a few yellow clay aggregates.

VI. Clay: It is composed of about equal parts of cream colored flakey clay and minute distinct mineral grains.

Interpretation

Histogram 24, indicating little sorting and a considerable quantity of fine material, suggests the absence of a strong sorting agent in the environment of deposition. The bedding also favors the absence of appreciable current action. The sediment has none of the features characteristic of a marine origin. Also there are no characters suggestive of a palludial environment of accumulation. Material such as this could accumulate in a lake, on a flood plain, on various parts of a delta, in a lagoon, or portions of the littoral environment protected from strong surf action. A comparison of Histogram 24 with Histograms a-o shows that it most closely resembles those of lagoonal deposits; consequently, lagoonal origin is favored.

WILCOX SAMPLE 25

Location, position, and character

The sample was collected from the bottom of Sand Cave, two miles northeast of Marion Station on the Mobile & Ohio Railroad, Lauderdale County, from the Holly Springs formation, where the Sand Cave is a series of washes showing 160 feet of sand overlying brown shale. The sand varies from massively bedded to cross-bedded (water type). Where fresh it is white throughout; where weathered, a light yellow. The sand at the top of the wash is reddish-brown and contains more iron hydroxide than could be produced by the weathering of a quartz sand of this purity. The suggestion is, therefore, that the iron hydroxide has been concentrated by downward migration from previously overlying beds. Sample 25 is a composite of the lower ten feet of sand. Megascopically, it is a fine grained unconsolidated sand containing little clay or mica; microscopically, a pure quartz sand in which the grains are slightly coated with white clay.

Mechanical analysis

The results of the mechanical analysis of Sample 25 are represented by Histogram 25; of the division of the Very Fine Sand, by the table:

Light minerals	98.47 percent
Heavy minerals	1.53 percent

Microscopic examination

I. Coarse Sand: It is composed of quartz grains, most of which are subangular and glassy-surfaced, but some of which are well rounded and frosted, and a few flakes of white mica.

II. Medium Sand: Its composition is the same as that of the Coarse Sand.

III. Fine Sand: It is composed of the same material as the Coarse Sand plus a few dark mineral grains.

IV. Very Fine Sand:

A. Light minerals: They are angular grains of quartz having straight extinction. Inclusions of the Irregular type, a few of which have a linear arrangement, are common; of the Regular type, rare; and of the Acicular type, very rare. The fraction includes a few grains of chert, a few light green grains of glauconite, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, tourmaline, staurolite, zircon, rutile are common; topaz, enstatite, ilmenite, epidote, andalusite, sillimanite, leucoxene, monazite, anatase, xenotime, rare.

V. Silt: It is composed almost entirely of angular quartz grains, although slightly of a few dark mineral grains.

VI. Clay: It consists of cream colored flakey translucent material studded with a few distinct mineral grains.

Interpretation

The high degree of sorting and the small quantity of silt and clay suggest the action of waves or wind in the environment of deposition. The type of bedding and the glassy surface of the quartz grains favor deposition by water rather than by wind. Accordingly, a littoral or neritic environment of accumulation is suggested. The frosted grains are not present in sufficient abundance to be considered of any origin other than that of having been blown or washed in from some nearby area.

WILCOX SAMPLE 26

Location, position, and character

The location, position, and character of the material from which Sample 26 was collected are the same as those of the material from which Sample 25 was taken, except that Sample 26 is a composite sample of the interval from 50 to 60 feet above the base of the sand. Megascopically, it is an unconsolidated buff colored fine grained sand containing a small amount of clay; microscopically, a quartz sand in which the grains are slightly coated by iron hydroxide and cream colored clay.

Mechanical analysis

The results of the mechanical analysis of Sample 26 are represented by Histogram 26; of the division of the Very Fine Sand, by the table:

Light minerals	98.70 percent
Heavy minerals	1.30 percent

Microscopic examination

I. Coarse Sand: It is composed entirely of quartz grains. Most of them are subangular and glassy-surfaced but some are well rounded and frosted.

II. Medium Sand: It consists of quartz grains, similar to those in the Coarse Sand, a few flakes of white mica, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are angular quartz grains, most of which have straight extinction. Inclusions of the Irregular type are common; of the Regular type, fairly common; and of the Acicular type, very rare. Zircon is the only identifiable mineral inclusion. The minerals include a few grains of chert and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, tourmaline, staurolite, rutile are common; zircon, sillimanite, leucoxene, epidote, ilmenite, rare.

V. Silt: It is composed of angular grains of quartz, a few flakes of white mica, a few dark mineral grains, and a few yellow clay aggregates.

VI. Clay: It consists of cream colored flakey translucent material studded with a few distinct mineral grains.

Interpretation

The histogram of this sample and the other characteristics of this sand are so similar to those of Sample 25 that a like interpretation is warranted. This sand contains slightly more medium and coarse material than does the sand of the previous sample indicating a slight change in the character of material brought to the environment of accumulation.

WILCOX SAMPLE 27

Location, position, and character

The location, position, and character of the material from which Sample 27 was collected are the same as those of Sample 25, except that Sample 27 is a composite of the interval from 100 to 110 feet above the base of the sand. Megascopically, it is an unconsolidated buff colored sand containing little clay; microscopically, a quartz sand in which the grains are slightly coated by iron hydroxide and clay.

Mechanical analysis

The results of the mechanical analysis of Sample 27 are represented by Histogram 27; of the division of the Very Fine Sand, by the table:

Light minerals	98.07 percent
Heavy minerals	1.93 percent

Microscopic examination

I. Coarse Sand: It is composed entirely of well rounded quartz grains, most of which have a glassy surface, but a few of which are frosted.

II. Medium Sand: It consists of quartz grains similar to those in the Coarse Sand, a few flakes of white mica, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium Sand except that its quartz grains are more angular.

IV. Very Fine Sand:

A. Light minerals: They are chiefly subangular grains of quartz, about half of which have wavy extinction. The Irregular type of inclusion is common; the other types are rare. The minerals include a few flakes of white mica having the properties of muscovite and a few light green glauconite grains.

B. Heavy minerals: Kyanite, zircon, tourmaline are abundant; biotite, staurolite, ilmenite, rutile, common; andalusite, leucoxene, sillimanite, epidote, titanite, rare.

V. Silt: It is composed of angular grains of quartz, a few dark mineral grains, and a few clay aggregates.

VI. Clay: It consists of cream colored flakey translucent material studded with a few distinct mineral grains.

Interpretation

The characteristics oi this sample are so like those of Samples 25 and 26 that a similar interpretation is indicated. This sand differs from the previous two sands in the general coarseness of the material and the concentration of the sand in the medium rather than in the fine grade size. This suggests, either that coarser material was provided to the environment when the material of this sample was deposited or that wave action was stronger, removing more of the fine and very fine sand.

WILCOX SAMPLE 28

Location, position, and character

The sample was collected in Purdues cut, one mile south of Meridian near the old road to Enterprise, from the Bashi formation, where a Mobile & Ohio Railroad cut shows 40 feet of massively bedded gray sand (Sample 28 composite of middle 15 feet) containing concretions of fossiliferous sand cemented by calcite, which reach 10 feet in diameter. Megascopically, it is a gray fine grained sand containing considerable clay and silt; microscopically, a micaceous, glauconitic, quartz sand, in which the quartz grains are slightly coated by iron hydroxide.

Mechanical analysis

The results of the mechanical analysis of Sample 28 are represented by Histogram 28; of the division of the Very Fine Sand, by the table:

Light minerals	98.65 percent
Heavy minerals	1.35 percent

Microscopic examination

I. Coarse Sand: It is composed of well rounded glassy-surfaced quartz grains, a few dark green glauconite grains, and a few dark mineral grains.

II. Medium Sand: It is composed of subangular quartz grains, some of which are frosted, a few dark green glauconite grains, a few dark mineral grains, and a few white mica flakes.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains in which wavy extinction is rare. The Irregular type of inclusion is common; the other types are rare. The fraction includes a few flakes of white mica having the properties of muscovite, a few light green glauconite grains, and a few highly altered microcline grains.

B. Heavy minerals: Kyanite, tourmaline, zircon, staurolite are abundant; rutile, sillimanite, ilmenite, topaz, garnet, epidote, rare.

V. Silt: It is composed of aggregates of yellow clay and a few distinct mineral grains, chiefly quartz.

VI. Clay: It consists of yellow clayey material studded with a few distinct mineral grains.

Interpretation

The marine fossils and the abundant glauconite in this sand indicate a marine origin. The unsorted character of the material and the considerable quantity of clay suggest accumulation in a neritic environment where wave sorting action was not very effective. This condition may have existed at a considerable distance from the shore, in an area where the configuration of the shore prohibited strong surf action, or where material was provided faster than the waves could sort it.

SUMMARY OF CONDITIONS OF DEPOSITION SUGGESTED BY THE ANALYSES

The samples, the analyses of which have just been described, were collected across the outcrop of the Wilcox in four different areas: Samples 1 to 6 in the northern part; Samples 7 to 15 in the middle part; Samples 16 to 20 in the southeastern part; Samples 21 to 28 in the extreme southeastern part. It was hoped that analyses of such samples would show changes from the bottom to the top of the Wilcox series and also any lateral variations in the material.

In the northern part of the state it was impossible to collect samples positively known to be from the upper Wilcox along its outcrop, because the surface is partly covered by younger loess, loam, and gravel which mask the true Wilcox in many places. In the deposition of this younger material there has been some reworking of the Wilcox. In addition to these difficulties, it is impossible to separate the Wilcox from younger Eocene sediments which may possibly exist in this area. Berry,[116] for example, has reported Jackson material in the embayment north of Mississippi.

In addition to the location of the samples analysed, the conditions of deposition suggested by the histograms and the lithological character of the material are shown in Figure 17. It is recognized that the present status of sedimentation permits these interpretations to be presented only as suggestions. However, it is believed that any satisfactory explanation of Wilcox deposition should be in harmony with the conditions indicated by these analytical and lithological data.

Samples 1, 2, 3, 4, 5, and 6 from the northern part of the state have been interpreted as a series of deltaic and wind deposits; Samples 7, 8, 9, 10, 11, 12, 13, 14, and 15 from nearer the middle of the belt, as a series of deltaic and littoral accumulations; the remaining samples, from the southeastern part of the belt, as mainly littoral deposits and subordinately other types.

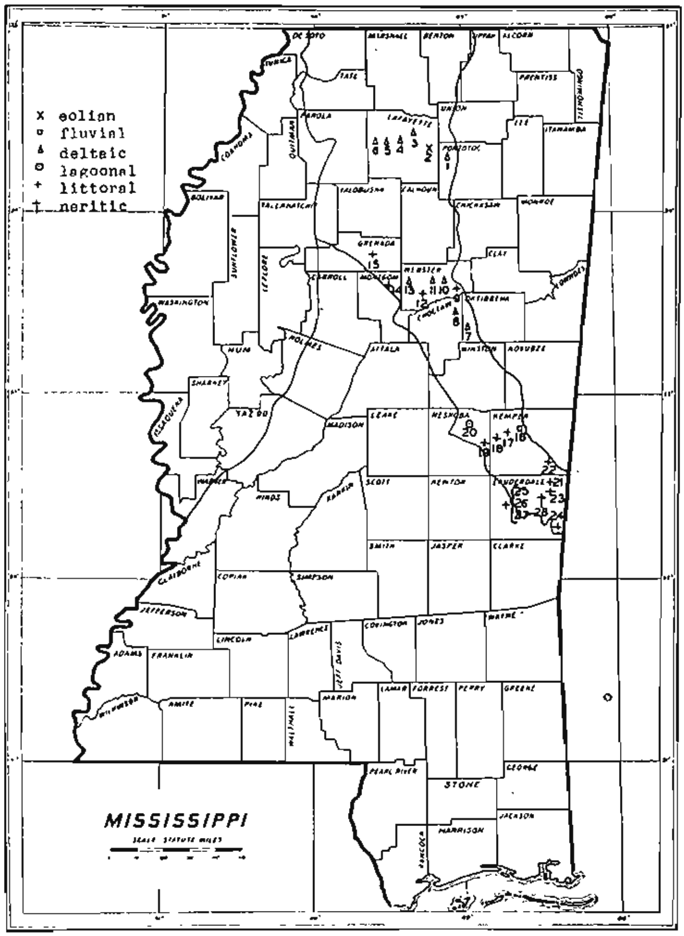


Figure 17.—Location and suggested interpretation of each Wilcox sample analysed.

In general these interpretations point to several broad conclusions. Littoral conditions are suggested for the deposition of the Wilcox in the southeastern part of the belt and for the uppermost Wilcox in the middle part of the belt. Deltaic conditions are suggested for the Wilcox in the northern part of the state and for all but the uppermost material in the middle part of the belt. These interpretations suggest that the Wilcox material in central Mississippi was deposited as a huge delta built out to the southwest from the northeast-central part of the state. The littoral deposits in eastern Mississippi may have been local on the delta, but more probably mark the general limit of the delta in that direction.

The littoral deposits in the uppermost Wilcox in the middle of the belt suggest a thick transition zone from the non-marine Wilcox sands to the marine Claiborne sand (See Claiborne chapter). The interpretation suggests that conditions which were destined to become dominant in the Claiborne began back in the upper Wilcox.

Objection may be raised against these conclusions on the ground that they are founded in part on analytical data which can not yet be completely evaluated. Thus, other interpretations than the ones suggested cannot be entirely eliminated. The deltaic deposits of the northern part of the state might also be interpreted as lagoonal, lacustrine, or fluvial. An examination of the other possible interpretations for these samples shows that even if the suggested interpretation is false and the other possibilities are true, the general conclusion remains about the same.

The littoral deposits in eastern Mississippi and the marine beds in Alabama show definitely that the middle and northern parts of Mississippi were adjacent to a marine environment in Wilcox time. Assuming for the moment that the alternative interpretations are correct and the suggested ones false, the most logical conclusion is that the interbedded and interlensed series of deltaic, lagoonal, lacustrine, or fluvial deposits grading laterally into littoral deposits, were formed under general deltaic conditions. The absence of breaks between these beds, as well as their interlensing and interbedding, shows that there were no continuous distinct lagoonal, fluvial, or lacustrine environments, but rather a general environment in which conditions varied locally from time to time. If the general environment were littoral rather than deltaic, there should be littoral material scattered through the section, which is not true in the northern and middle parts of the belt. If the environment were continental, at least local breaks should appear in the section, which also is not true.

MINERAL COMPOSITION

LIGHT MINERALS

Quartz is the dominant constituent of all the samples. Most of the grains are of the colorless variety, but some grains are smoky, milky, or chalcedonic. They are usually somewhat rounded; the larger sized grains showing the greatest degree of rounding; successively smaller grains, more angularity; and very small grains, almost no rounding. When such small grains are rounded, they show a frosted surface suggesting wind rather than water action. Anderson,"[7] on the basis of some experimental work, has concluded that rounding is a very slow process, and that more than one cycle of transportation and deposition is probably necessary to produce well rounded grains. As he offers no quantitative basis for comparison, it cannot be determined whether or not the present quartz grains suggest more than one cycle.

Every sample contains many quartz grains having straight extinction and some having wavy extinction. In most samples quartz having straight extinction reaches about 80 percent, but in a few, quartz having wavy extinction reaches more than 50 percent. Usually the grains having wavy extinction were somewhat fractured and possessed fewer inclusions than the others. As most metamorphic rocks would probably yield normal unstrained quartz, the character of the extinction provides little evidence as to the character of the rocks in the source area.

Many of the quartz grains are so thoroughly fractured that they appear opaque. In general, the larger sized grains are fractured to the greatest degree, seemingly the result of the greater pounding to which the larger grains were subjected.

Most of the quartz grains possess inclusions of some kind. According to Mackie's[118] classification, *the inclusions of the Irregular type are by far the most abundant, although those of the other types are found in nearly every sample. Most individual inclusions of the Irregular type are small, but some of them are of fair size. Some grains have these inclusions arranged in a definite linear pattern. The number of individual inclusions in a single grain ranges between wide limits, but, in most of the grains the number is considerable.

According to Mackie, the Acicular and Irregular types of inclusions are found preeminently in the quartz of acid igneous rocks, whereas the Regular type is more characteristic of the quartz of gneiss and of the younger schistose rocks. If this statement is correct, the inclusions in these Wilcox samples indicate an ultimate source area chiefly composed of acid igneous rocks and a very minor quantity of metamorphic rocks.

Most of the samples contain a few grains of chert. Although these grains are never abundant, a careful search will usually reveal a few of them.

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* I. Regular—Minerals of good crystal form,
II. Irregular—Glass, fluid, gas, and cavity inclusions, and those too fine for determination,
III. Acicular—Acicular crystals, chiefly rutile,
IV. Negative—Without inclusions or Irregular type too small to be noticed.

Glauconite was found in abundance only in Sample 28. In several other samples a few grains were found, but not in sufficient quantities to indicate that the mineral is not detrital. The grains are generally light green in color and unaltered.

Feldspar is present in extremely small quantities in the Wilcox, this fact being perhaps the most conspicuous feature of its mineralogy. Many samples contain none and but few samples contain more than a little. The feldspar is mainly in the form of microcline. Some few grains of albite and orthoclase are also noted. All of the feldspar is highly altered

Mackie[119] has pointed out the possible use of feldspar as an indicator of contemporary climate. He noted that microcline was the most resistant feldspar, and that orthoclase was more resistant than plagioclase. In the plagioclase feldspars, the resistance to weathering decreases as the calcium increases

The scarcity of feldspar and the presence of only the most resistant varieties point to a source area lacking feldspar, or to climatic conditions favoring rapid decomposition during erosion, transportation, and deposition of this material, or to conditions causing slow decomposition during slow erosion, transportation, and deposition, which would permit thorough decay.

The extreme scarcity of feldspar probably calls for more than one of the above conditions. It suggests that the Wilcox material was derived from an area where sedimentary rocks having little feldspar were dominant, and where the climate was so warm and moist as to eliminate by thorough chemical decomposition all but a few of the most resistant feldspars. From other evidence, the conditions of the source area seem not to have been such that erosion would have proceeded slowly enough to produce the elimination of the feldspar under less effective climatic conditions

Talc-like material is present in several of the samples and is so designated because of its appearance. It is white, soft, soapy, flakey, and isotropic or faintly anisotropic. The material is in regularly outlined grains, or it is on the surface of altered feldspar grains in such a way as to suggest that it has been formed by the alteration of that mineral. In many samples containing this talc-like material, there is no feldspar present, and hence the material must have had another origin, or else all the feldspar has been completely altered. The distribution and physical appearance of the material suggest that it is a kaolinitic mineral.

It is not so designated because X-ray and chemical data essential for a positive identification could not be obtained due to the absence of the necessary facilities. The possibility that this material is nothing but aggregates of clay suggests itself, but the general regularity of the grains is not compatible with this view.

That this material resulted from the alteration of feldspar seems most probable. Because of the softness of the material, the alteration must have taken place after deposition, and hence some of the sediments must have had somewhat larger quantities of feldspar when first deposited than they now possess. In collecting representative samples, great care was used to obtain fresh material. Seemingly alteration has advanced so far downward from the surface that, in many places, samples of unaltered material are not obtainable at the outcrop.

Muscovite, or a white mica that has the properties of muscovite, is a common constituent of most of the sands analysed. It is most abundant in the larger grade sizes of the sediments. The individual flakes are usually larger than the largest quartz grains in the same sample. The explanation probably lies in the fact that the cleavage of the mineral makes thin flakes which are easily transportable in suspension.

HEAVY MINERALS

In Table 2 opposite each sample number, the Heavy minerals of the Very Fine Sand are listed in the order of their abundance. The characteristics of the more important species of these minerals are described in the following pages.

Table 2.—The Heavy minerals of the Very Fine Sand of the Wilcox, arranged in the order of their abundance opposite each sample number.

1. Kyanite, tourmaline, zircon, staurolite, ilmenite, leucoxene, rutile, sillimanite, spinel?, zoisite, titanite.
2. Kyanite, tourmaline, sillimanite, staurolite, ilmenite, leucoxene, zircon, rutile, xenotime, epidote.
3. Kyanite, staurolite, zircon, tourmaline, rutile, topaz, monazite, xenotime, titanite, epidote.
4. Kyanite, staurolite, tourmaline, zircon, rutile, sillimanite, ilmenite, leucoxene, epidote, corundum.
5. Kyanite, zircon, rutile, tourmaline, staurolite, sillimanite, monazite, ilmenite, leucoxene, epidote, xenotime.
6. Kyanite, staurolite, sillimanite, epidote, rutile, zircon, tourmaline, ilmenite, leucoxene.

7. Biotite, topaz, tourmaline, zircon, andalusite, staurolite, kyanite, garnet, epidote, sillimanite, titanite.
8. Kyanite, zircon, staurolite, rutile, hypersthene?, leucoxene, ilmenite, tourmaline, sillimanite.
9. Zircon, epidote, garnet, ilmenite, leucoxene, kyanite, tourmaline, tremolite?, staurolite.
10. Kyanite, tourmaline, staurolite, sillimanite, ilmenite, leucoxene, rutile.
11. Kyanite, zircon, tourmaline, staurolite, rutile, ilmenite, leucoxene, sillimanite, epidote, xenotime.
12. Not identifiable (see analytical data).
13. Kyanite, tourmaline, zircon, staurolite, rutile, ilmenite, leucoxene, sillimanite, epidote.
14. Kyanite, zircon, tourmaline, rutile, epidote, staurolite, ilmenite, leucoxene.
15. Kyanite, tourmaline, zircon, staurolite, rutile, sillimanite, biotite, epidote, monazite, ilmenite, leucoxene.
16. Kyanite, staurolite, rutile, zircon, tourmaline, sillimanite, titanite, ilmenite, leucoxene, epidote, xenotime.
17. Kyanite, staurolite, sillimanite, zircon, rutile, ilmenite, leucoxene.
18. Kyanite, tourmaline, zircon, sillimanite, ilmenite, staurolite, leucoxene, epidote.
19. Kyanite, zircon, tourmaline, ilmenite, rutile, staurolite, sillimanite, andalusite, titanite, epidote, leucoxene.
20. Kyanite, tourmaline, ilmenite, leucoxene, zircon, staurolite, rutile, sillimanite.
21. Zircon, kyanite, rutile, tourmaline, leucoxene, ilmenite, epidote, sillimanite, xenotime.
22. Kyanite, tourmaline, staurolite, zircon, topaz, sillimanite, rutile, ilmenite, leucoxene.
23. Kyanite, tourmaline, staurolite, zircon, topaz, sillimanite, ilmenite, leucoxene, titanite, topaz.
24. Tourmaline, zircon, kyanite, rutile, ilmenite, staurolite, sillimanite, topaz, leucoxene.
25. Kyanite, tourmaline, staurolite, zircon, rutile, topaz, enstatite, ilmenite, epidote, andalusite, sillimanite, monazite, anatase.
26. Kyanite, tourmaline, staurolite, rutile, zircon, sillimanite, leucoxene, epidote, ilmenite.

27. Kyanite, zircon, tourmaline, biotite, staurolite, ilmenite, rutile, andalusite, leucoxene, sillimanite, epidote, titanite.
28. Kyanite, tourmaline, zircon, staurolite, rutile, sillimanite, ilmenite, topaz, garnet, epidote.

Kyanite was found in all the samples, in most of the sands of which it is the dominant mineral. In almost every sample there are two types of kyanite: one type is fresh and angular; the other is well rounded and shows grayish alteration material along the cleavage planes.

Staurolite, although not abundant, was found in all but one of the samples. In most of them it is of two types: a well rounded type, and a fresh angular type.

Tourmaline is present in all samples except one, the number of grains ranging between wide limits. Tourmaline also exists in two types in most samples: one type is well rounded, whereas the other is angular, showing crystal outlines.

Zircon was found in all samples but one, usually in considerable abundance. Every sample in which zircon is present in fair abundance contains, in addition to the normal variety, another which has grains of a purplish tint. Mackie[120] has suggested that colored zircons lose their color during metamorphism, and hence a non-metamorphic source is to be postulated for the purple variety. Mackie also pointed out that the quantity of zircons present in igneous rocks tends to decrease as basicity increases. The abundance of zircons, therefore, suggest the existence of considerable acid igneous rock in the ultimate source area. Zircon, like kyanite and the other minerals, is present in grains which show two distinct degrees of rounding. The grains of purple zircons are usually angular.

Rutile is present in small quantities in most of the samples. The grains are fresh and show a variable degree of rounding. The mineral is not present in sufficient abundance to determine the existence of the two degrees of rounding.

Ilmenite is present in small quantities in most of the samples, usually partly altered to leucoxene.

Sillimanite, in angular fresh grains, is found in most of the sands.

Leucoxene is found in more than half of the samples as an alteration product of ilmenite. Other grains, having the same appearance as leucoxene but not associated with ilmenite, are probably leucoxene, although a definite determination is impossible.

The other minerals are present as rare constituents in a few of the samples. Usually there were enough individuals in the sample to make the identification certain. In most cases these minerals are decidedly less resistant than the abundant species. Therefore, they do not necessarily indicate a scarcity in the ultimate source area. Those present probably owe their existence to fortunate conditions which served to protect them from the fate of the remainder.

The two distinct degrees of rounding of some of the grains is best explained as follows. The angular fresh grains were derived directly from igneous and metamorphic rocks in the source area. The rounded, commonly somewhat altered type, has passed through more than one cycle of erosion, transportation, and deposition. An attempt was made to determine the proportions of the two types of grains of the various minerals, but different samples showed such extreme variations that no satisfactory results could be obtained. On the whole the conclusion is that the immediate source area of the Wilcox was composed of igneous, metamorphic, and sedimentary rocks. The high degree of angularity of the angular type suggests that more than one cycle is necessary for any considerable degree of rounding of these Heavy minerals (Plate 1).

No pronounced difference in degree of rounding could be determined in the quartz grains. Whether this means that the principal source of the quartz was sedimentary rocks or that quartz is more easily rounded than the Heavy minerals is not known.

Stratigraphic Distribution of the Heavy Minerals

There is no pronounced lateral or vertical variation in the mineralogy of the Wilcox sand in Mississippi. The only variations are in the rare constituents, and the fact that they are rare would cause them to be detected in some samples and not in others. This uniformity suggests that a single source area supplied the Wilcox material, and throws doubt on the possible value of mineralogy for correlation purposes.

There is a slight relation between the abundance of Heavy minerals and the areal distribution of the samples. These minerals are generally most abundant in the samples from the middle part of the belt although they are almost as abundant in the samples from the northern part. The concomitant variation between the interpreted conditions of deposition of the sediment in these areas and the quantity of Heavy minerals suggests that there may be some correlation between them.

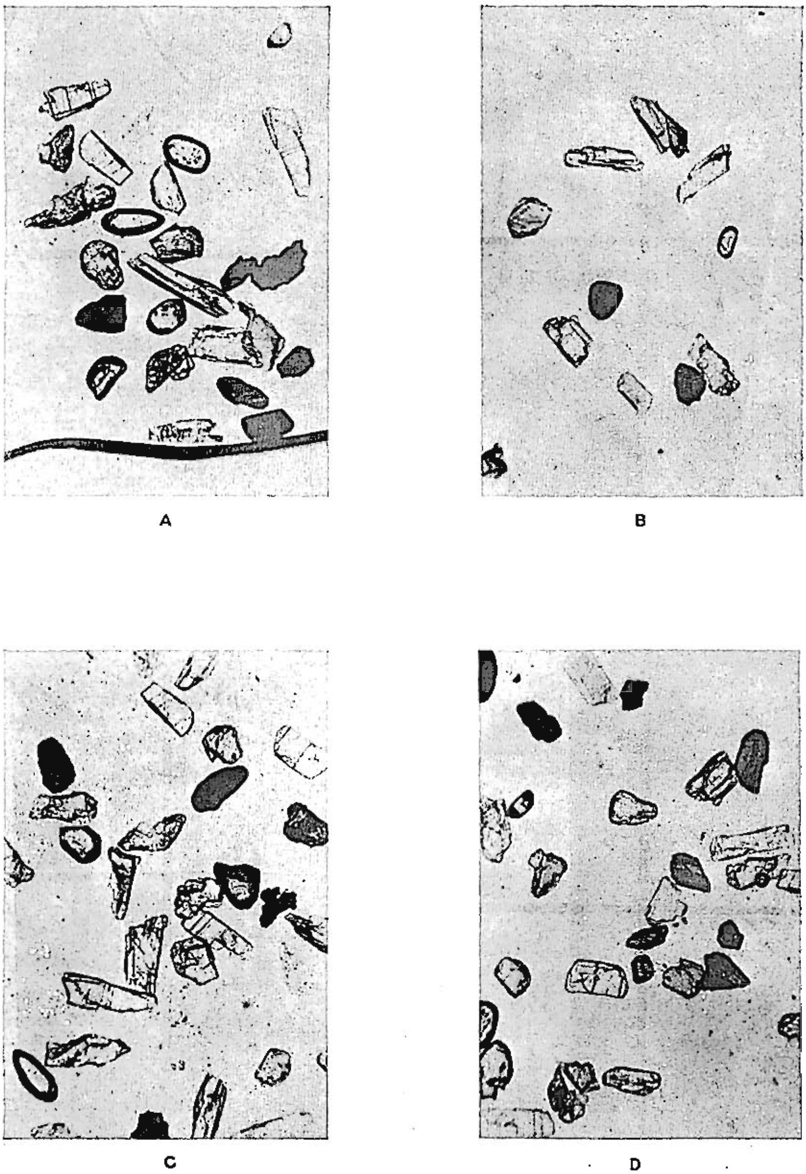


Plate 1.—Heavy minerals from Wilcox sands showing the rounded character of some grains and the angular character of others.

A. Sample 4 B. Sample 9

C. Sample 20 D. Sample 26

Table 3.—The relative abundance of Heavy minerals and Light minerals in the Very Fine Sand of the Wilcox samples and the postulated conditions of deposition.

Sample	1	Light	98.80	Heavy	1.20	Deltaic
"	2	"	99.03	"	.97	Eolian
"	3	"	97.26	"	2.74	Deltaic
"	4	"	96.70	"	3.30	Deltaic
"	5	"	96.50	"	3.50	Deltaic
"	6	"	97.41	"	2.59	Deltaic
"	7	"	98.90	"	1.10	Deltaic
"	8	"	94.47	"	5.53	Deltaic
"	9	"	96.99	"	3.01	Littoral
"	10	"	90.93	"	9.07	Deltaic
"	11	"	96.75	"	3.25	Deltaic
"	12	"	97.21	"	2.79	Littoral
"	13	"	97.85	"	2.15	Deltaic
"	14	"	95.92	"	4.08	Littoral
"	15	"	97.57	"	2.43	Littoral
"	16	"	93.59	"	6.41	Fluvial
"	17	"	96.69	"	3.31	Littoral
"	18	"	99.21	"	.79	Littoral
"	19	"	99.60	"	.40	Littoral
"	20	"	97.34	"	2.66	Lagoonal
"	21	"	97.54	"	2.46	Littoral
"	22	"	99.08	"	.92	Littoral
"	23	"	98.00	"	2.00	Littoral
"	24	"	98.77	"	1.23	Littoral
"	25	"	98.47	"	1.53	Littoral
"	26	"	98.70	"	1.30	Littoral
"	27	"	98.07	"	1.93	Littoral
"	28	"	98.65	"	1.35	Neritic

Relation of the Quantity of Heavy Minerals to the Coarseness of the Sediment and to Conditions of Deposition

In Table 3 the percentages of Light and Heavy minerals in the Very Fine Sand are given together with the suggested interpretation of the environment of deposition for each sample. The percentages of Heavy minerals range from 0.40 to 9.07, the average being 2.64. This great range raises the question as to whether there is not some relation between the quantity of Heavy minerals and the other characteristics of the sand.

Boswell[121] has shown that under fluvial, littoral, and shallow water conditions, wind and wave currents, often accompanied by contemporaneous erosion, may cause local concentrations of Heavy minerals. These exceptionally rich streaks he has called "pay streaks." Boswell also brings out that although such streaks are rich in quantity, they are commonly deficient in variety. Kennedy[122] has shown the formation and existence of zones rich in Heavy minerals in modern littoral deposits. He explains the origin on the basis of a natural panning process. Observation of the outcrops from which the samples were collected did not reveal the presence of any "pay streaks" except in Sample 9. No doubt action tending toward concentration of Heavy minerals is not always strong enough or operative long enough to cause definite streaks to form, although there may still be some concentration of these minerals. Such concentrations would not necessarily be very conspicuous. It is possible that some such process as this may have caused the variation in Heavy minerals, although there is no definite proof of it.

Boswell[123] has pointed out that there is usually a relation between the abundance of Heavy minerals and the mechanical composition of the sediment. In the samples analysed, the abundance of Heavy minerals generally increased as the size decreased. In other words, in a given sample the medium-sized sand was apt to have a greater proportion of Heavy minerals than the coarse sand, the fine sand a greater proportion than the medium sand, and so on. This is apparently the result of the greater specific gravity of the Heavy minerals. Where the sand is sorted, there is a concentration in the grade-size next smaller than that carrying the maximum quantity of sand. Water or wind, having transportative power sufficient to carry coarse-sized grains of quartz and feldspar, could carry only medium-sized grains of Heavy minerals, unless the individual minerals possessed certain characters, such as cleavage which would increase their transportability.

There is no consistant relation between the abundance of Heavy minerals and the general coarseness or fineness of a sample. For example, Sample 1 contains 1.20 percent of Heavy minerals in the Very Fine Sand and contains 51 percent of silt and clay. Sample 14 contains 4.08 percent of Heavy minerals in the Very Fine Sand and contains 4.40 percent of silt and clay. These percentages only represent the quantity of Heavy minerals in one fraction, but they serve to show the general abundance in the sediment as a whole. Since the sand of coarse-sized, medium-sized, and fine-sized fractions would probably possess a less quantity of these minerals than the Very Fine Sand; and the silt and clay, a greater quantity, the Very Fine Sand fraction is probably most representative of the content of these minerals in the whole sample.

The quantity of Heavy minerals does not depend on whether a sample is composed mainly of large-sized or small-sized material, but the proportion of Heavy minerals in a single sample does increase as the grain-size decreases. An exception exists in the well sorted sands where the Heavy minerals are usually concentrated in the next size smaller than that carrying the maximum quantity of material.

If it be granted that the proportion of Heavy minerals in the Very Fine Sand is representative of their general abundance in the sample as a whole, there appears to be a relation between the abundance of these minerals and the type of deposit. Littoral deposits show a percentage range from 0.79 to 4.08 and an average of about 2.00. Delta deposits show a range from 1.10 to 9.07 and an average of 3.00 to 4.00. The stating of this relation is another way of presenting the fact that the abundance of Heavy minerals increases as the sorting decreases. Further, there appears to be a wider fluctuation in quantity as the sorting decreases. Whether this is simply a fortuitous condition in this series of analyses or a generalization holding elsewhere cannot be determined.

An explanation for this relationship may be as follows: The processes that tend to concentrate Heavy minerals in zones operate in environments where the tendency is to produce well sorted sediments. Therefore, in a well sorted sand the total quantity of these minerals in the whole sand bed might be the same as that in an unsorted sand, but in the well sorted sand the Heavy minerals will be concentrated in definite streaks scattered through sand relatively poor in these minerals. It follows from this that a sample of well sorted sand should usually contain an abundance of Heavy minerals or few of them. As the horizons containing the small quantity of Heavy minerals would no doubt be most common, they would be most apt to be sampled for analysis. A small section might not show the "pay streaks." Analysis of Sample 48 of a Claiborne sand reveals one of these "pay streaks" carrying over 60 percent of Heavy minerals.

A comparison of Tables 2 and 3 shows that there is no relation between the quantity of Heavy minerals and the variety or identity of the minerals, except a slight tendency toward a deficiency in variety where the Heavy minerals are most abundant.

LOCATION OF THE SOURCE AREA

The work of Gilligan,[124] Mackie,[125] and others has emphasized the way in which the source area of a sediment may be determined by a study of its mineral composition. For such correlations, accurate petrographic information concerning the older rocks is necessary. Where such data are scanty, the determination of the source area is difficult. In the samples analysed, no very unusual minerals, except xenotime and monazite, nor any minerals having decidedly unusual properties were found that could be directly correlated with minerals in possible source areas. The difficulty is not that the sediments do not contain minerals whose properties are distinctive, but rather that the possible source areas are large and extremely varied, and comparatively little detailed petrographic information is available concerning them. However, by determining the type of rocks from which the minerals found in the Wilcox are likely to have come, some evidence concerning their ultimate source area can be obtained. Milner[126] has listed the probable source areas of detrital minerals, and the following data are taken from his work. In Table 4, the probable type of source rock of each of the Heavy detrital minerals is listed, as is also the general stability of the mineral.

Table 4.—Probable types of source rocks supplying the Heavy minerals in the Wilcox samples.

Kyanite--Metamorphic rocks, especially certain mica schists and gneisses. Stable.

Tourmaline--Acid igneous rocks, pegmatites, schists, gneisses, and phyllites. Stable.

Zircon--Acid and intermediate igneous rocks, less commonly crystalline schists and limestone. Stable.

Staurolite--Crystalline schists and contact metamorphic rocks. Stable.

Rutile--Acid igneous rocks and crystalline metamorphic rocks. Stable.

Sillimanite--Crystalline metamorphic rocks. Stable.

Ilmenite--Igneous rocks, especially basic types. Moderately stable.

Topaz--Granite and contact metamorphic rocks. Stable.

Spinel--Metamorphic limestone and crystalline schists. Stable.

Zoisite--Crystalline schists and metamorphosed basic igneous rocks. Stable.

Andalusite--Granite and metamorphic rocks. Moderately stable.

Garnet--Igneous and metamorphic rocks, particularly crystalline schists and gneisses. Stable.

Epidote--Crystalline metamorphic rocks, especially impure limestone; also highly altered igneous rocks. Stable.

Tremolite--Metamorphic rocks and also altered basic igneous rocks. Moderately stable.

Biotite--Igneous and metamorphic rocks. Moderately stable.

Titanite--Intermediate igneous rocks and metamorphic rocks. Stable.

Enstatite--Basic igneous rocks and metamorphic rocks. Moderately stable.

Hypersthene--Basic and ultra-basic igneous rocks. Moderately stable.

Leucoxene--Derived essentially from ilmenite in situ. Stable.

Monazite--Acid igneous rocks. Stable.

Xenotime--Acid igneous rocks and pegmatites. Stable.

Anatase--Usually secondary after ilmenite. Stable.

This list shows that all the dominant minerals are of the stable varieties, that most of the minor minerals are also of the stable varieties, and that the others are of the moderately stable varieties. Such an assemblage of dominant types suggests more than one cycle of erosion, transportation and deposition.

With the exception of the ilmenite, which is the least important of the dominant types, the most important minerals all suggest a source area composed of metamorphic rocks, such as schists and gneisses and acid igneous intrusive rocks. The minor minerals mainly point to the same conclusion. Only a few of the rare constituents suggest basic igneous rocks or types other than those indicated above. The mineralogy, therefore, strongly points to an ultimate source area composed mainly of crystalline metamorphic rocks such as schists and gneisses and some acid igneous rocks. Basic igneous rocks were of minor importance.

The testimony of the inclusions in the quartz, as previously noted, is for a source area composed mainly of granitic rocks and some metamorphic rocks. This evidence serves to change the conception of the ultimate source area only in giving a more important place to the acid igneous intrusive rocks.

The required conditions of the ultimate source area are very perfectly met by the Piedmont Plateau region of the southern Appalachians. This region is composed chiefly of crystalline metamorphic rocks containing a variety of schists and gneisses, and some acid igneous intrusive rocks. In addition, smaller masses of basic igneous rocks are present. The literature[127] reveals that all the minerals found in the Wilcox exist in these ancient rocks. The Roan gneiss, Bakersville gabbro, Cranberry granite, the Carolina gneiss of Pre-Cambrian age, and the Great Smokey conglomerate of Cambrian age are examples of the rocks carrying the minerals found in the Heavy fraction of the Wilcox. Unfortunately the petrographic descriptions of them do not give sufficient details to permit a definite correlation of individual minerals, with the possible exception of monazite and xenotime. Monazite is a mineral of considerable rarity. In North America, it is found most commonly in North Carolina, in the area just noted as the most probable ultimate source area of the Wilcox sediments. Other places noted by Pratt[128] are in Maine, New Hampshire, Rhode Island, Massachusetts, Connecticut, New York, Virginia, South Carolina, Georgia, Indiana, South Dakota, Montana, Nevada, Utah, Washington, Wyoming, Colorado, Oregon, California, Arizona, and New Mexico. With a few exceptions these states are outside of the possible source areas of the Wilcox sediments, a fact which strongly suggests that the source area of the monazite was in the southern Appalachian area.

The mineral xenotime adds further evidence as to this ultimate source area. Dana[129] records the existence of this mineral in McDowell, Burke, Henderson, Mitchell, and Alexander counties of North Carolina and near Clarksville, Georgia. The only other locality in North America that he records is near Pikes Peak, Colorado. Unless there be still other places where this mineral may be found, the ultimate source area must have been in the Piedmont Plateau area.

One other possible ultimate source area suggests itself, and that is the Pre-Cambrian area of the Great Lakes region. This region contains great masses of rocks of the crystalline metamorphic, acid intrusive, and basic intrusive and extrusive types. The basic rocks are present in sufficient quantity to supply considerable numbers of distinctive minerals in any derived sediment. Therefore, in the Wilcox, the scant quantity of distinctive minerals derived from such rocks is decided evidence against the Great Lakes region as a possible source.

Additional evidence against this possible northern source is furnished by the recent work of Ockerman[130] and Graham[131] on the Cambrian sands of Wisconsin and Minnesota. Ockerman lists garnet, zircon, and tourmaline as dominant, epidote and rutile as common, and staurolite, kyanite, and anatase as extremely rare in these rocks in southern Wisconsin. Graham lists garnet, tourmaline, and zircon as dominant, rutile, anatase, brookite, augite, and monazite as rare to very rare in these rocks in Minnesota. The difference between this assemblage of minerals and that characteristic of the Wilcox shows that neither these rocks nor their source was the source of the Wilcox sediments.

The degree of rounding of the quartz grains, the absence of appreciable feldspar, and the rounding of some of the Heavy minerals all suggest that much of the material composing the Wilcox had experienced more than one cycle of erosion, transportation, and deposition. The immediate source area of the Wilcox sediments is believed to have been the southern Appalachians and the older part of the Coastal Plains. The Cretaceous rocks of the Coastal Plains, the Paleozoic rocks of the southern Appalachians, and the ancient rocks of the Piedmont Plateau are the immediate source rocks of these sediments. The location of the ultimate source area, namely, in the southern Appalachian region, and the conditions of deposition of the Wilcox sediments further indicate this immediate source area.

PREVIOUS EXPLANATIONS OF THE CONDITIONS OF DEPOSITION OF THE WILCOX SEDIMENTS

All the students of the Tertiary in Mississippi have advanced more or less satisfactory descriptions of the conditions under which the Wilcox beds were deposited. Hilgard[132] considered the portion of his Lignitic that is now known as the Wilcox Series to have been deposited in portions of the embayment inaccessible to the sea. His conception is not perfectly clear, but apparently he had in mind lagoonal or deltaic conditions. Later Harris[133] interpreted the Wilcox as being deposited under lagoonal or brackish water conditions. Glenn[134] considered his Lagrange material which included the present Wilcox as a brackish water deposit. Berry,[135] partly on the basis of floral evidence, interpreted the Wilcox material as deposited upon and along a broad flat coastal plain containing lagoons, estuaries, and barrier beaches, over which rivers building flood plains and deltas meandered from the northeast. Burchard,[136] in discussing the bauxite of northeastern Mississippi, considered the Ackerman formation as a fresh water lagoonal deposit. Lowe[137] has interpreted the Wilcox as a sediment deposited under fresh water and swamp conditions.

SUMMARY OF THE CONDITIONS OF DEPOSITION OF THE WILCOX SEDIMENTS

The Wilcox sediments in Mississippi are believed to have been deposited as a huge delta by a stream flowing from the northeast and entering the embayment in northeast-central Mississippi. Local conditions on the delta varied, permitting the deposition of subaerial deposits at one place and subaqueous at another. Toward the southeast, away from the delta, the conditions were more marine, permitting the deposition of unfossiliferous near-shore material. In Alabama, at a still greater distance from the area of deltaic deposition, fossiliferous marine marls were deposited.

The lithologic character, distribution, and analyses point to such a conception of deposition. Other evidence can also be marshalled. The study of Midway material indicated the existence of a river entering the embayment in this area, and there is no reason to doubt that it continued to exist after Midway time. In fact the continuous series of sediments from the Midway into the Wilcox in this region when compared to the interruption in deposition indicated by unconformities in other parts of the embayment show that the river did continue to exist. Another line of evidence is the mineral composition of the Wilcox sediments which has shown the source area to be in the southern Appalachian region.

The close similarity of the Wilcox sediments in Tennessee and Kentucky to those in Mississippi suggests that they were deposited under similar conditions. It seems doubtful, because of the distance from the probable delta center in Mississippi, that the material was all deposited by the same river. A more logical conclusion would be that these sediments were deposited by another stream or other streams. This deltaic material was of such magnitude as to coalesce with that deposited in Mississippi, and to prevent the extention of marine conditions into the area. Whether one stream or several streams are responsible for these sediments is not clear, but the suggested existence of several streams in Midway time points likewise to several in Wilcox time.

The thickness of the Wilcox sediments indicates a gradually subsiding area during Wilcox deposition. Throughout this interval the crustal movement in the region of the present Wilcox outcrop in Mississippi did not usually keep pace with deposition, so that the area became filled and general non-marine conditions were maintained. In extreme eastern Mississippi and in Alabama, there were intervals when subsidence was more rapid than deposition during which intervals marine beds accumulated, and also intervals when deposition was relatively more rapid than subsidence temporarily filling the area of accumulation and developing non-marine conditions. It appears unnecessary, therefore, to postulate subsidence and uplift to explain this series of marine and non-marine beds. Periodic subsidence is sufficient.

Berry[138] has presented evidence to show that mid-Wilcox time was marked by a landward migration of the Gulf waters, preceded and followed by a southward retreat. The existence of marine beds in the middle of the subsurface Wilcox in central Mississippi is further evidence of this migration. The continuous series of beds in central Mississippi show that these migrations were of slight intensity--not sufficient to stop deposition. Also the transition from Wilcox non-marine material to Claiborne marine material in this same area indicates that the Wilcox ended and the Claiborne began with a rapid advance of the Gulf waters without an interval of erosion between. These changes can also be explained by simple subsidence without uplift, if the subsidence is considered to have been periodic.

As the Wilcox and Midway sediments were deposited under much the same conditions, some explanation must be found for the decided difference in their lithology. It cannot be explained solely on the basis that the Midway was deposited under subaqueous conditions and the Wilcox under subaerial conditions, because in eastern Mississippi where conditions were certainly subaqueous to marine in Wilcox time, the material deposited was sand, whereas in Midway time the material deposited was clay. The explanation, therefore, lies in variations in the source area.

The lithologic change in the Wilcox from the base to the top is also to be explained by variations in the source area. Omitting the Midway-Wilcox transition zone, the basal Wilcox or Ackerman contains slightly more clay than sand, the upper Wilcox or Holly Springs contains slightly more sand than clay. There is then a gradual increase in the coarseness of the Wilcox material from the bottom to the top. This points to a source area supplying increasing proportions of coarser material throughout Wilcox time. The thin Grenada clay zone at the top of the Wilcox is not generally present and is only of local importance.

Berry[139] has suggested several oscillations of the shore line in Wilcox time as an explanation of the lithologic changes in the section. Periodic subsidences undoubtedly caused some shifts of the shore line, but it appears doubtful if they can entirely explain the variations in lithology. A simpler and more satisfactory explanation lies in the condition of the source area.

PHYSIOGRAPHIC CHARACTER OF THE IMMEDIATE SOURCE AREA

Several possible reasons appear for the change in lithology of the Midway and Wilcox sediments which must in general be accredited to variations in the source area. In the first place, an uplift of the region may have so increased the rate of erosion that coarser material was produced. As already pointed out, the Appalachian area is believed to have been gradually uplifted throughout Midway time during which the deep residual material produced during the long preceding stage of peneplaination was gradually swept off. Toward the end of Midway time increasing uplift of the area would increase the power of the agents of erosion and cause coarser material to be produced. This increased activity of the erosive agents found the residual material already gone, and a rather sudden change to coarse material would be expected. Another possible explanation is a change in the climate. Barrell[140] has pointed out that a change in the climate may yield results similar to those yielded by crustal movement. A change to more arid conditions in the Appalachian area tending to remove the protective vegetable surface covering and to lower the water table would have served to quicken erosion and to produce coarser material. Berry[141] has shown that the Midway flora is made up entirely of forms whose modern representatives flourish in warm humid climates. According to him, the Wilcox flora also points to warm moist conditions. The absence of evidence of a change in the climate of the Coastal Plains from Midway to Wilcox time does not prove that there was no change in climate in the nearby Appalachian region at the same time. However, it does throw doubt on climatic change as the cause of the difference between Midway and Wilcox lithology.

The available evidence then points to the southern Appalachian area as a peneplained region being uplifted throughout Midway and Wilcox time. The uplift beginning in Midway time continued with increasing intensity into Wilcox time. No further explanation is necessary to account for the difference in lithology between the Midway and Wilcox, and for the gradual increase in coarseness of the Wilcox sediments.

RELATION TO THE APPALACHIAN PENEPLAINS

If the above interpretation be correct, a peneplain was probably developed in the southern Appalachian region by the beginning of Eocene time. The uplift of this peneplain took place not at the end of Cretaceous time, but in early Eocene time--beginning gradually in Midway time and continuing throughout Wilcox time. A youthful stage of physiographic development is, therefore, suggested for this area in Wilcox time.

RELATION TO THE "APPALACHIAN RIVER"

In discussing the Midway material, the reason was pointed out for believing that the river responsible for that deltaic deposit was the Appalachian River. The Wilcox material indicates the building of a delta in the same place as that proposed for the Midway and a similar source area. The conclusion is, therefore, that the same stream is responsible for the Wilcox deposits. The Appalachian River then continued to flow southwestward across northeastern Mississippi in Wilcox time.

CLAIBORNE SERIES

NAME

The Claiborne series takes its name from the village of Claiborne, Alabama. Fossils from this place were studied by Conrad,[142] who first applied the name. The section at Claiborne shows beds belonging to the upper part of the present Claiborne series only, and, as first used, the name was applied solely to these beds. Tuomey[143] continued the use of the term Claiborne as defined by Conrad, and suggested the term Buhrstone for the lower part of the present Claiborne. Later Hilgard[144] working in Mississippi redefined the term, and included in it all the material between his Lignitic and Jackson formations. This is the present Claiborne interval. Hilgard in the same report divided the Claiborne into a lower "Siliceous" and an upper "Calcareous Claiborne" corresponding approximately to Tuomey's Buhrstone and Claiborne. This usage of Claiborne was continued by Hilgard[145] is his later papers on the geology of Mississippi.

Smith and Johnson[146] in Alabama continued the usage of Tuomey applying the terms Buhrstone and Claiborne. Later, Harris[147] in Louisiana and Crider[148] in Mississippi followed Hilgard's definition.

STRATIGRAPHIC RELATIONS

The Wilcox-Claiborne contact in western Mississippi was shown, in the discussion of the Wilcox series, to be conformable. The arbitrary line separating the two series is drawn at the first appearance of marine material in the transition section.

Berry[149] has suggested that an unconformity exists in eastern Mississippi between these two series. Recent field work has thrown doubt on the existence of such an unconformity.

Sections can be found in eastern Mississippi which appear to show an unconformity between the marine sand at the base of the Claiborne and the underlying lignitic Wilcox shale. Such sections may be seen at Seymours Hill 1 1/2 miles south of Meridian, on the Meridian and Basic Road 1 1/4 miles north of the town of Basic, at Lost Gap on the Alabama and Vicksburg Railroad, on the road from Suqualena to Meehan Junction two miles south of Suqualena, and on the Kosciusko and Louisville Road 18 miles east of Kosciusko.

Sections can also be found in eastern Mississippi in which the lignitic material is conformably interbedded with the marine glauconitic sand. Considerable field work has shown that these sections are as abundant as those suggesting unconformities. Some of the sections in which this conformable relationship is evident are located as follows: along a secondary road in Sec. 10, T. 5 N., R. 15 E., Lauderdale County; in a railroad cut one-fourth mile east of the overhead bridge at Longview Church, Lauderdale County; seven miles southeast of Ethel on the road to Rural Hill, Attala County; along a local road just south of the main Kosciusko and Louisville Road 18 miles east of Kosciusko.

Many of the sections show breaks within the basal Claiborne sand, as for example at Lost Gap and at Seymours Hill. These breaks seem to be as large as the break between the Claiborne and Wilcox series shown by the previously noted sections. It appears, therefore, that the Wilcox and Claiborne series in eastern Mississippi are separated by local breaks, but that there is no large widespread unconformity between them.

Exposures of the Jackson-Claiborne contact in Mississippi are very scant and poor, because the Jackson outcrop is marked by a series of prairies, and the upper Claiborne also outcrops in a topographically flat region. The available data suggest that the contact is a conformable one.

According to Cooke,[150] the contact between the Wilcox and Claiborne in Alabama is unconformable, and the contact between the Claiborne and Jackson in the same state is conformable.

CLASSIFICATION AND CORRELATION OF THE CLAIBORNE SERIES

The Claiborne series in Mississippi is divided into three formations: the Tallahatta (base), the Lisbon, and the Yegua (Figure 18).

Yegua formation		
Lisbon formation	Chickasawhay member	Cutrea sellaeformis
	Kosciusko member	
Tallahatta formation	Winona member	
	Basic member	
	Meridian member	

Figure 18.—Classification of the Claiborne series.

The Tallahatta formation is divided into three members which grade vertically into one another, and are in part lateral equivalents. The name Meridian, originally suggested by Lowe,[151] is here applied to the beds of glauconitic sand below the typical claystone of the Tallahatta in eastern Mississippi. The name Basic is here used for the typical claystone of the Tallahatta formation in Mississippi; the term, taken from the town of Basic in Clarke County, was first applied by Lowe.[152] The name Winona is here applied to the deeply weathered glauconitic sands and marls immediately overlying the Basic claystone. Winona is used in the way defined by Cooke[153] except that Cooke places this member in the Lisbon formation rather than in the Tallahatta. The Winona everywhere grades downward into the Basic, whereas it is separated from the overlying material by a rather distinct brown, locally lignitic, shale. In addition, the Winona contains interstratified beds of typical claystone. It would seem, then, that this material belongs in the Tallahatta rather than in the Lisbon. The term was first used by Lowe[154] for this same material, but he erroneously suggested that it was below rather than above the Basic claystone. The Winona, as here used, includes the Enterprise marl of Lowe[155] which can be traced into it.

The Lisbon formation in Mississippi is divided into two parts. The lower part, called the Kosciusko member, includes beds of loose gray to white sand, traceable all the way across the state. This name suggested by Cooke[156] is here used as he defined it. Lowe[157] originally suggested the name Decatur for these beds, but this term is preoccupied.

For the upper part of the Lisbon, to which no name has previously been given, the name Chichasawhay is here proposed. This name is taken from the Chickasawhay River in eastern Mississippi along which good exposures can be found. This member carries the typical fossiliferous Lisbon marl in a zone about the middle of the section. This zone in turn contains a distinct shell bed of *Ostrea sellaeformis*. Lowe[158] applied the name Wautubbee marl to this fossiliferous zone.

The term Yegua is here used for the beds of lignitic shales and sands overlying the Lisbon, and underlying the Jackson formation. Lowe[159] applied the name Cockfield to these beds, but this term has been dropped because of the earlier usage of Yegua.

The Claiborne series in Alabama is divided into three formations; namely, Tallahatta, Lisbon, and Gosport. According to Cooke,[160] these formations are equivalent respectively to the Tallahatta, Lisbon, and Yegua in Mississippi.

DESCRIPTION AND DISTRIBUTION OF THE MATERIAL AT THE OUTCROP

TALLAHATTA FORMATION

THICKNESS

The Meridian sand member ranges in thickness from almost nothing in western Mississippi to approximately 75 feet in the eastern part of the state. The thickness of the Basic member ranges from 50 feet in western Mississippi to 100 feet in the eastern part of the state. The Winona member ranges in thickness from less than 100 feet in eastern Mississippi to about 275 feet in the western and central parts of the state.

LITHOLOGY

The Meridian member is composed typically of beds of greenish yellow to white glauconitic sand that ranges from medium-grained to coarse. The glauconite is extremely abundant at the top of the section becoming rare toward the base. The lower beds are highly cross-bedded, whereas the upper beds are slightly cross-bedded. In some sections there seems to be a break between the very evenly bedded glauconitic sand above, and the scantily glauconitic cross-bedded sand below, but at other places they intergrade. The upper glauconitic material contains streaks and irregular nodular masses of claystone. By the increase of this claystone material there is a gradation into the overlying Basic member. No fossils have been found in the Meridian.

The Basic member is composed of firm brittle siltstone locally ranging from coarse siliceous sandstone to fine siliceous claystone. It varies in color from grayish-yellow to grayish-green. Some sections show interbedded zones, several feet in thickness, of chocolate-brown micaceous thinly bedded shale. Thin irregular pipe-like masses of fine sand are another rather common characteristic of the Basic. Where the Basic rests on the Meridian sand, the lower part of the section contains streaks and irregular masses of glauconitic sand. In western Mississippi where the Basic grades into the Wilcox Grenada shale, there is little glauconitic sand in the lower part of the section. The upper part of the claystone also contains streaks and irregular masses of glauconitic sand, and it is by the increase of this material that the transition to the Winona member takes place. A few molds of marine shells have been found in the claystone in the central and eastern part of the state.

The Winona member is composed of evenly bedded glauconitic sands and marls. The material at the outcrop is deeply weathered to a distinctive blood red color. The marl beds are fossiliferous, but the thorough weathering has left only imperfect molds and casts of the original shells. Winona marl fresh enough to permit the satisfactory collecting of fossils can be found at only one place in Mississippi, so far as the writer knows; namely, along the banks of the Chickasawhay River at Enterprise in Clarke County. Concretionary masses and streaks of limonite are constant characteristics of the Winona. The top of the Winona is marked all the way across the state by beds of brown thinly bedded micaceous shale, in a few places lignitic. Some of this shale weathers similarly to the Basic claystone, and can be easily confused with it in the field.

The Winona in some places contains beds of glauconitic shale, and in others, beds of claystone identical with those in the Basic member. Extending from the region between the towns of Kosciusko and Vaiden westward is a distinct wedge of medium grained grayish-yellow sand in the Winona member. This wedge becomes thicker toward the west, and divides this member into two parts as shown in Figure 19.

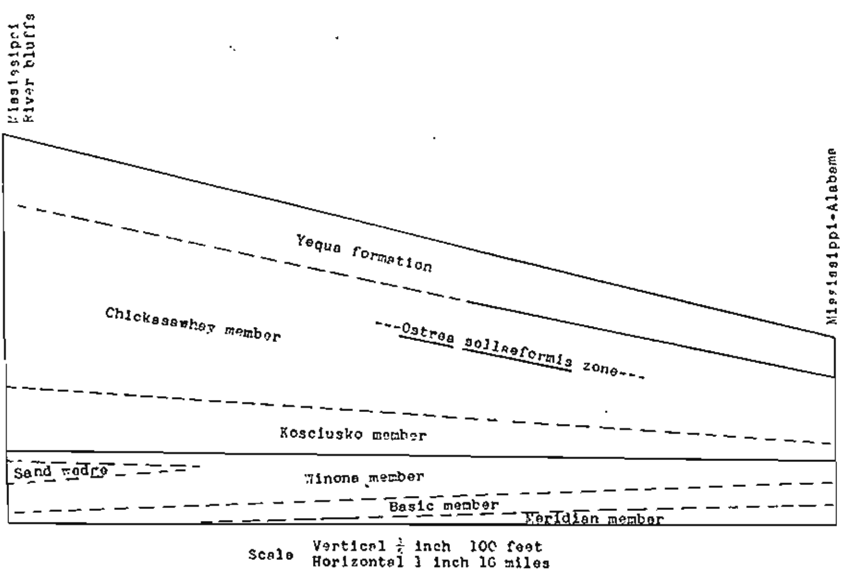


Figure 19.—Generalized section of the Claiborne series across Mississippi.

DISTRIBUTION

The Meridian sand can be traced from eastern Mississippi to the central part of the state where it pinches out. The Basic and Winona members are traceable all the way across Mississippi.

DETAILED SECTIONS

The following series of sections illustrate the characteristics and relationships of the members of the Tallahatta formation. Several of the sections also show the relation between the Claiborne and the Wilcox in eastern Mississippi. Sections to show the contact in western Mississippi have been given previously.

Section of cut on the Kosciusko and Louisville Road, 10 miles east of Kosciusko

	Feet	Feet
Tallahatta formation		20
Winona member		10
2. Marl, glauconitic, sandy; having streaks of limonite	10	
Basic member		10
1. Claystone, yellowish-brown	10	

Section of cut on the Meridian and Enterprise Highway 1 1/2 miles south of the town of Basic

	Feet	Feet
Tallahatta formation		63
Winona member		33
4. Shale, brown glauconitic, and irregular masses of glauconitic sand	15	
3. Sand, coarse grained red weathered glauconitic	6	
2. Marl, weathered red sandy	12	
Basic member		30
1. Sand, gray, and gray siltstone; interbedded with irregular masses of glauconitic sand. This material grades into the overlying marl	30	

Section along secondary road near the center of Sec. 11, T. 5 N., R. 15 E., Lauderdale County

	Feet	Feet
Tallahatta formation		93
Basic member		58
6. Claystone and irregular masses of glauconitic sand	50	
5. Shale, greenish-gray claystone-like, and irregular masses of glauconitic sand	8	
Meridian member		35
4. Sand, irregularly bedded white; grading into the overlying material	35	

	Feet	Feet
Hatchetigbee formation (Wilcox)		14
3. Shale, red sandy; conformable below No. 4	2	
2. Shale, thinly laminated gray	10	
1. Sand, white fine grained silty	2	

Section of cut 1 1/2 miles north of the town of Basic on the Meridian and Enterprise Highway

	Feet	Feet
Tallahatta formation		41
Basic member		25
4. Claystone, massive to thin bedded yellowish-green, and irregular masses of glauconitic sand	25	
Meridian member		16
3. Sand, gray massive; containing streaks of claystone	12	
2. Sand, purple, yellow-streaked	4	
Hatchetigbee formation (Wilcox)		8
1. Shale, bluish-brown lignitic thinly laminated; unconformably underlying No. 2	8	

Section at the Lost Gap tunnel on the Alabama and Vicksburg Railroad

	Feet	Feet
Tallahatta formation		68
Basic member		33
4. Claystone, greenish-gray (Sample 37); and irregular streaks and masses of glauconitic sand	25	
3. Shale, grayish-green, and interbedded coarse glauconitic sand; the sand becoming dominant toward the base. This material locally grades into No. 2, whereas at other places it is discordantly separated from it	8	
Meridian member		35
2. Sand, irregularly bedded white	35	
Hatchetigbee formation (Wilcox)		10
1. Shale, thinly bedded lignitic, sandy. The contact with No. 2 is poorly exposed, but it appears to be unconformable	10	

Section of cut along Meridian and Paulding Road three miles south of the point where this road leaves the Meridian and Jackson Highway

	Feet	Feet
Tallahatta formation		205
Winona member		101
9. Sand, massively bedded red deeply weathered	40	
8. Marl, coarse glauconitic, sandy; weathering to a deep red color and having streaks of limonite	25	
7. Shale, gray, and coarse glauconitic interbedded sand	25	
6. Covered	3	
5. Sand, white to brown slightly glauconitic; grading below into No. 4 (Sample 39)	8	
Basic member		75
4. Claystone, greenish-gray, and irregular masses of glauconitic sand grading below into No. 3	75	
Meridian member		29
3. Sand, coarse glauconitic; having nodules of claystone	5	
2. Sand, white to gray glauconitic	4	
1. Sand, white irregularly bedded micaceous	20	

Section of Railroad cut one-fourth mile east of overhead bridge near Longview Church, Lauderdale County

	Feet	Feet
Wilcox-Claiborne transition beds		20
2. Shale, thinly bedded gray lignitic. This material is like typical Wilcox	10	
1. Sand, gray green massive glauconitic. This material is typical Meridian. Other sections of Meridian sand nearby further indicate that it is Meridian	10	

Section of gully along the Meridian and Paulding Road, seven miles south of the fork with the Meridian and Jackson Highway

	Feet	Feet
Lisbon formation		40
Kosciusko member		40
9. Sand, cross-bedded white	35	
8. Covered	2	
7. Sand, massively bedded gray	2	
6. Covered	1	
Tallahatta formation		21
Winona member		21
5. Shale, brown lignitic; having pyrite nodules	6	
4. Covered	2	
3. Shale, thinly bedded brown	2	
2. Sand, red glauconitic fossiliferous	6	
1. Shale, brown claystone-like	5	

Section of cut on the secondary road between Rural Hill and Ethel, seven miles southeast of Ethel, Attala County

	Feet	Feet
Tallahatta formation		35
Basic member		25
4. Claystone, yellowish-gray, and interbedded brown shale and irregular masses of glauconitic sand	25	
Meridian member		10
3. Sand, yellow glauconitic, and interbedded gray shale	4	
2. Shale, thinly bedded lignitic	3	
1. Claystone, gray and irregular masses of yellow glauconitic sand (Nos. 3, 2, and 1 are conformable)	3	

LISBON FORMATION

Thickness

The Kosciusko member ranges in thickness from 100 feet in the eastern part of the state to approximately 250 feet in the western part. The Chickasawhay member ranges in thickness from 250 feet in eastern Mississippi to approximately 750 feet in the western part of the state.

Lithology

The Kosciusko is composed of medium grained loose sand which varies in color from white to yellow, brown, purple, or red. The type of bedding is not constant. In local sections the sand may be massively bedded, thinly bedded, or cross-bedded. Locally in the southeastern part of Attala County and near the town of Hoffman in Holmes County, the sand in the upper part of the section has been silicified into hard sandstone. The upper limit of this member is fairly definite in eastern Mississippi where the Chickasawhay is composed dominantly of glauconitic shales and sands. In the western part of the state where the Chickasawhay is mainly sand, the upper limit of the Kosciusko member is indefinite.

The Chickasawhay member in eastern Mississippi is composed of beds of glauconitic sand and shale. These materials crop out generally in a low flat region having few good exposures; consequently, it is impossible to trace the individual beds. As this member as a whole is traced from east toward the west, the marl beds disappear, so that in the western part of the state, the whole upper part of the Lisbon contains only beds of sand, clay and lignite. The Chickasawhay in Clarke County in eastern Mississippi is composed almost entirely of glauconitic sands and shales. In Newton County to the west the section includes interbedded glauconitic sands and shales and non-glauconitic material. In Leake County still farther west the glauconitic material, although present, is not abundant. In Holmes County and Carroll County in the extreme western part of the belt the non-glauconitic and lignitic sands and shales seem to comprise the whole member. Near the top of the Chickasawhay a distinct fossiliferous marl zone can be traced from the Alabama boundary as far west as Newton County beyond where it is not developed. In this zone a thin shell bed of *Ostrea sellaeformis* greatly aids in tracing it. Fossils are scanty or absent from the remainder of the Lisbon material in Mississippi.

The boundary between the Lisbon and the Yegua in Mississippi is an arbitrary line. Because the Yegua contains lignitic material all the way across the state, the boundary can be drawn in extreme eastern Mississippi at the base of the lignitic material, but no satisfactory dividing line can be drawn in the western part of the state where both formations are lignitic. In this area the Claiborne series above the Tallahatta is really one continuous unit, and any division is arbitrarily drawn. In Alabama the Yegua equivalent, the Gosport sand, is fossiliferous providing a faunal basis for separating it from the Lisbon.

Distribution

Both members of the Lisbon formation can be traced continuously across Mississippi.

Detailed Sections

The following sections illustrate the characteristics of this formation.

Section of gully along the secondary road in the northern part of Sec. 1, T. 4 N., R. 15 E., Lauderdale County

	Feet	Feet
Lisbon formation		61
Kosciusko member		61
6. Sand, evenly bedded red fine grained	15	
5. Shale, white, and yellow interbedded sand	5	
4. Sand, cross-bedded yellow and thin streaks of white shale	10	
3. Sand, irregularly bedded yellow and white	3	
2. Shale, yellow streaked, gray silty	3	
1. Sand, cross-bedded white	25	

Section of cut along the Quitman and Carmichael Road, four miles southeast of Quitman

	Feet	Feet
Lisbon formation		91
Chickasawhay member		91
5. Shale, grayish-green calcareous; containing irregular calcite masses and a few fossils	40	
4. Marl, fossiliferous glauconitic sandy	6	
3. Sand, deeply weathered red glauconitic shaley; having a few fossil casts and molds	20	
2. Sand, irregularly bedded yellow (Sample 51)	10	
1. Shale, gray; sand, yellow; and sand, white evenly interbedded	15	

Section along Chickasawhay River, two miles south of Quitman, Clarke County

	Feet	Feet
Lisbon formation		36
Chickasawhay member		36
4. Marl, gray fossiliferous glauconitic, sandy	5	
3. Marl, light green very fossiliferous sandy	15	
2. Shell bed of *Ostrea sellaeformis*	1	
1. Marl, light green fossiliferous sandy	15	

Section of cut along the Newton and Doolittle Road, one mile north of Newton, Newton County

	Feet	Feet
Lisbon formation		86
Chickasawhay member		86
7. Sand, massively bedded red and white	20	
6. Clay, yellow sandy	2	
5. Shale, grayish-brown slightly glauconitic	22	
4. Sand, glauconitic green	2	
3. Shale, brown, and irregular masses of glauconitic sand	3	
2. Sand, sparingly fossiliferous brown glauconitic	2	
1. Marl, grayish-green fossiliferous sandy; containing a shell bed of *Ostrea sellaeformis* about 1 foot thick near the middle	35	

Section of cut along the Walnut Grove and Sebastapool Road, 4 1/2 miles east of Walnut Grove

	Feet	Feet
Lisbon formation		37
Chickasawhay member		37
4. Shale and sand, gray interbedded	6	
3. Sand, yellow glauconitic (Sample 54)	15	
2. Shale, brown	5	
1. Shale, grayish-green glauconitic sandy	11	

Section of Illinois Central Railroad cut at West Hill, five miles west of Durant

	Feet	Feet
Lisbon formation		45
Chickasawhay member		45
4. Sand, irregularly bedded yellowish-white	35	
3. Covered	2	
2. Shale, black lignitic, and gray interbedded sand	5	
1. Shale, grayish-black lignitic	3	

Section of cut six miles northeast of Kosciusko on the road to West

	Feet	Feet
Lisbon formation		45.0
Kosciusko member		45.0
6. Sand, deeply weathered red massively bedded	45.0	
Tallahatta formation		51.5
Winona member		51.5
5. Shale, grayish-brown, and irregular masses of glauconitic sand	25.0	
4. Sand, fine glauconitic	.5	
3. Shale, grayish-brown silty, and irregular masses of glauconitic sand	15.0	
2. Shale, grayish-brown	5.0	
1. Sand, deeply weathered red glauconitic	6.0	

Section in gully just north of the Vaiden and Blackhawk Road, 1 1/2 miles west of Vaiden

	Feet	Feet
Lisbon formation		70
Chickasawhay member		70
3. Sand, red, and gray interbedded shale	20	
2. Shale, grayish-brown lignitic; containing crystals of calcite in irregular scattered masses	25	
1. Sand, irregularly bedded pink. This sand and the overlying beds show a reversal of dip; that is, toward the northeast instead of the normal southwest dip	25	

YEGUA FORMATION

Thickness

The Yegua formation ranges in thickness from approximately 175 feet in eastern Mississippi to about 300 feet in the western part of the state.

Lithology

The Yegua outcrop in Mississippi has but few exposures, most of which are poor, because of the general flatness of the country. In addition, the overlying Citronelle (Pliocene) gravel and sand blanket the surface and conceal the underlying material in some places. Therefore, it is impossible to do more than to determine the general character of the Yegua across the state. It is composed typically of a series of non-marine lignitic shales and sands and a few beds of marine glauconitic sand. In the eastern part of the state the glauconitic sands and lignitic material seem to be about equally abundant. As the formation is traced westward, the lignitic material increases and the glauconitic material decreases.

Distribution

The Yegua formation is traceable continuously across Mississippi.

Detailed Sections

The following series of sections illustrate the characteristics of this formation in Mississippi.

Section of cut one mile south of Wautubbee on the road to Pachuta

	Feet	Feet
Yegua formation		20
3. Shale, gray, and gray interlaminated sand	6	
2. Sand, slightly glauconitic gray	4	
1. Shale, brown lignitic, and gray interbedded sand	10	

Section along local road in the southeastern part of the town of Newton

	Feet	Feet
Yegua formation		14.5
5. Shale, gray sandy	3.0	
4. Sand, green to black fine micaceous, glauconitic	1.5	
3. Sand, grayish-green glauconitic	2.0	
2. Shale, thinly laminated black lignitic	5.0	
1. Shale, thinly laminated gray brown	3.0	

Section of gully one-fourth mile east of the Pickens and Durant Highway just south of the Big Black River

	Feet	Feet
Yegua formation		70
2. Sand, deeply weathered red slightly glauconitic	10	
1. Shale, grayish-white, and fine to medium irregularly interbedded sand (Sample 63 composite of sand bed about the middle of this interval)	60	

SUMMARY

Figure 19 shows the range in thickness of the Claiborne formations and members and their relation to one another. It emphasizes the partial equivalence of the Meridian sand and the Basic claystone, and also of the Basic claystone and the Winona sand. It further emphasizes the fact that the Tallahatta formation, which is a fairly uniform marine unit all the way across the state, has a rather constant thickness. On the other hand, the portion of the Claiborne above the Tallahatta formation which loses its marine character from east to west greatly increases in thickness as it is traced westward.

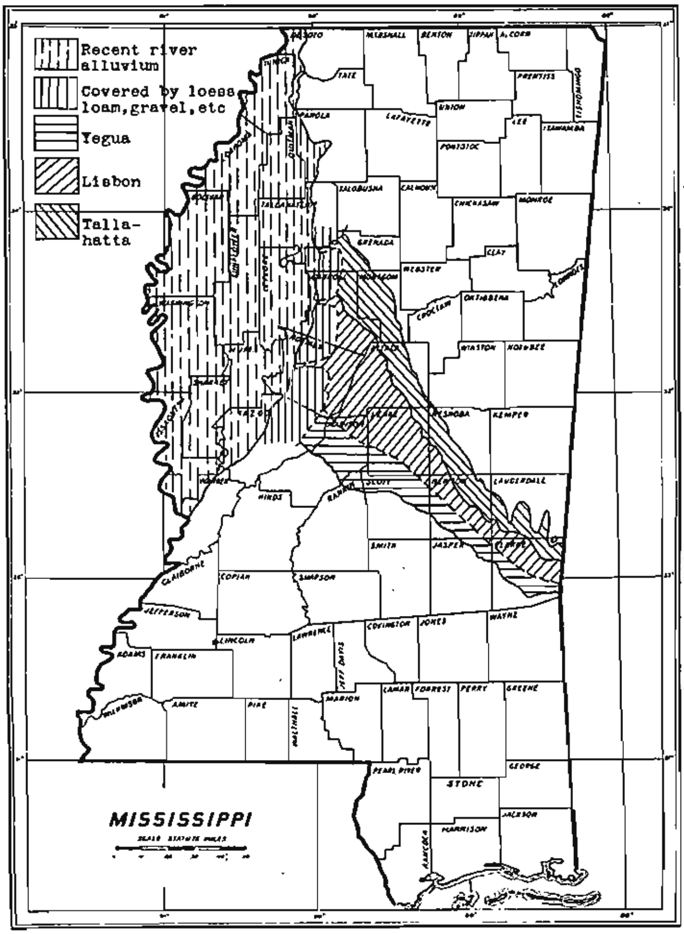


Figure 20.—Sketch map showing the outcrop of the Claiborne formations in Mississippi.

The outcrop area of the Claiborne formation in Mississippi, and in the eastern part of the Mississippi embayment are shown in Figures 20 and 21 respectively. A comparison of these maps with earlier maps of the Claiborne, such as the one in Water-Supply Paper 576 of the U. S. Geological Survey shows several notable changes. The Tallahatta-Lisbon contact has been changed by the placing of the Winona member in the Tallahatta rather than in the Lisbon. Perhaps the most important change is in the location of the Claiborne-Wilcox contact which is much in error in the earlier maps. Sections have already been presented to show that typical Basic claystone exists in the vicinity of the town of Grenada east of the contact as previously mapped. Considerable field work

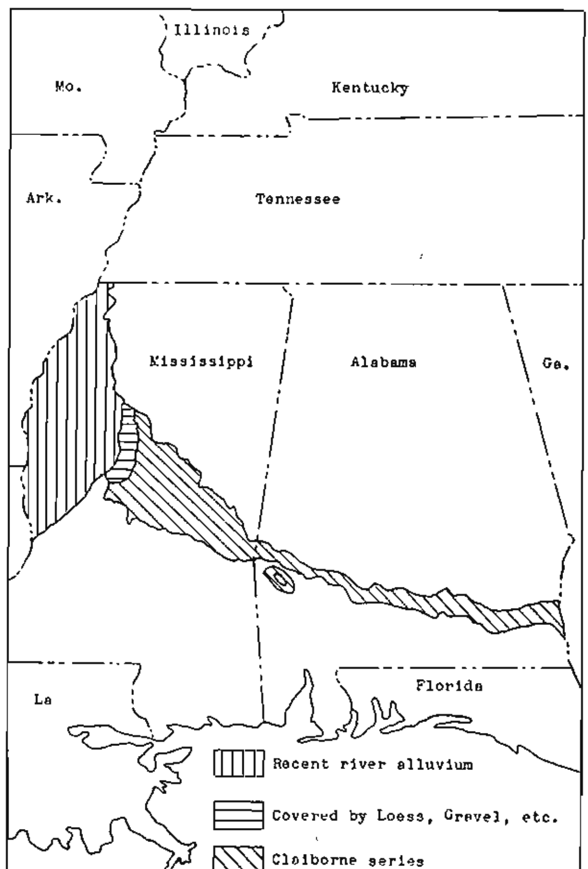


Figure 21.—Sketch map showing the outcrop of the Claiborne series in the eastern part of the embayment.

in the Grenada area revealed that much of the material there mapped as Wilcox Grenada was in reality Basic.

Other errors in placing the Wilcox-Claiborne contact were the result of confusing claystone-like material in the Winona with the Basic member. For example, the shale material that marks the top of the Winona member crops out along the banks of the Pearl River at the town of Edinburg. It has been mapped as Basic, and the Claiborne-Wilcox contact has been erroneously mapped on that basis. Winona marl can be found under this material, and the true Basic crops out about eight miles to the east. Also along the Chunky River in eastern Mississippi and the Yockahockany and the Big Black Rivers in central Mississippi, claystone-like material in the Winona has been mistaken for Basic claystone which error resulted in the placing of the Claiborne-Wilcox contact from three to eight miles west of its actual position.

DESCRIPTION OF THE SUBSURFACE CLAIBORNE MATERIAL

Recent wells have brought to light several characters of the subsurface Claiborne that are of importance. In the first place, the series thickens to more than 2000 feet down dip in the central and western parts of the state. There is a notable exception to this thickening on the high area in the vicinity of the city of Jackson. Secondly, in a general way the subsurface Claiborne seems to have the same stratigraphic relations as the surface material. However, insufficient trustworthy well data are available to permit a definite determination of this point. Finally, there is a total absence of red, the prevailing color being green or gray. The red must then be entirely the result of weathering at the outcrop.

CONDITIONS OF DEPOSITION SUGGESTED BY THE LITHOLOGY AND DISTRIBUTION OF THE CLAIBORNE SEDIMENTS

TALLAHATTA FORMATION

The glauconite of the Meridian sand suggests that this member was deposited in a marine environment. The cross-bedding is of the water type indicating shallow water and some current action. The interbedded lignitic shale suggests littoral, lagoonal, or deltaic environments and oscillations from marine to non-marine conditions.

The Basic member contains glauconite and molds of marine shells together with cross-bedded sands of the water type and interbedded lignitic material, all of which suggest an environment approximately similar to that in Meridian time.

The Winona member also possesses marine fossils, glauconite, and the water type of cross-bedding. The absence of interbedded lignitic material indicates either that the changing conditions of the previous times ceased, or that the marine waters migrated so far landward that oscillations were not felt in this area. The lignitic material at the top of the Winona indicates not an interruption of deposition, but a temporary change to non-marine conditions at the end of Winona time. Except for the wedge of sand in the section in the western part of Mississippi, the Winona member is laterally uniform in character. The wedge of sand indicates a temporary local variation from the otherwise uniform conditions of the Winona.

The beginning of the Tallahatta marked a change from the non-marine conditions of the Wilcox to marine conditions. There is evidence that this interval was marked by local interruptions of deposition, but the absence of a large continuous unconformity argues against a widespread interruption. The Tallahatta-Lisbon interval is marked by a temporary change to non-marine conditions seemingly without any interruption in deposition.

LISBON FORMATION

The Kosciusko sand yields no positive evidence as to conditions of deposition except that the water type cross-bedding shows it to be of aqueous origin. The laterally and vertically uniform character of the material suggests that the conditions were uniform across the state throughout Kosciusko time.

The Chickasawhay, containing marine fossils and glauconite, is dominantly marine in the eastern part of the state. Cross-bedded sands of the water type and interbedded lignitic shale indicate shallow water and some oscillation of marine and non-marine conditions. In the western part of the state similar conditions existed, except that here the change from marine to non-marine conditions was more frequent, and non-marine conditions were prevalent.

YEGUA FORMATION

There is no evidence of an interruption of deposition between Lisbon and Yegua time. The Yegua series of interbedded glauconitic sands and lignitic shales in eastern Mississippi indicate a series of oscillations from near shore marine conditions to non-marine. In the western part of the state conditions were similar, except that marine conditions were of minor importance.

ANALYSES OF THE CLAIBORNE SEDIMENTS AND AN INTERPRETATION OF THE CONDITIONS OF DEPOSITION

After each of the following analyses of samples of the various members of the Claiborne formations, an attempt is made, from these analyses and from detailed lithologic and stratigraphic characteristics, to interpret the conditions under which the sediments were deposited. The plan of presentation is the same as that for the Wilcox material.

CLAIBORNE SAMPLE 29

Location, Position, and Character

The sample was collected at Seymours Hill, one mile south of Meridian, from the middle part of the Meridian member.

Section of sand quarry at Seymours Hill

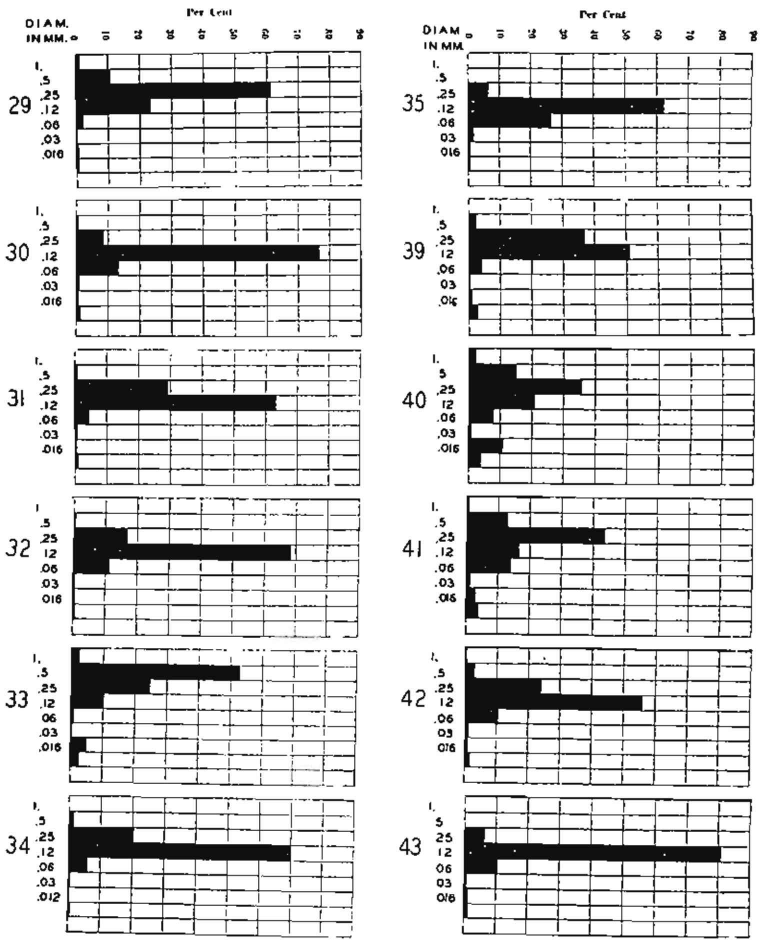
	Feet	Feet
Basic member		48.0
6. Claystone having irregular masses of glauconitic sand	35.0	
5. Sandstone, coarse glauconitic	1.5	
4. Claystone	2.0	
3. Sandstone, coarse glauconitic	0.5	
2. Claystone having irregular masses of glauconitic sand	9.0	
Meridian member		40.0
1. Sand (Sample 29 composite of middle 10 feet), cross-bedded (water type) white; containing streaks of gray claystone-like shale	40.0	

Megascopically, the sample is a white unconsolidated quartz sand; microscopically, a fairly well sorted medium grained quartz sand, in which non-quartz constituents are rare.

Mechanical Analysis

The results of the mechanical analysis of Sample 29 are represented by Histogram 29; of the division of the Very Fine Sand, by the table:

Light minerals	97.9 percent
Heavy minerals	2.1 percent



Histograms 29-35, 39-43.—Histograms representing the results of the mechanical analyses of Claiborne Samples 29-35, 39-43.

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: It is composed of subangular quartz grains, most of which have a frosted surface.

II. Coarse Sand: It is composed of quartz grains, most of which are subangular and glassy-surfaced, but some of which are well rounded and frosted; and a few grains of talc-like material.

III. Medium Sand: Its composition is the same as that of the Coarse Sand, except for the presence of a few dark minerals and a few flakes of white mica.

IV. Fine Sand: Its composition and character are the same as the Medium Sand, except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, many linearally arranged, are abundant; of other types, rare. There are also a few flakes of white mica having the properties of muscovite and a few grains of altered plagioclase.

B. Heavy minerals: Kyanite, zircon, staurolite, tourmaline, ilmenite, are common; leucoxene, rutile, rare; and spinel, garnet, epidote, xenotime, very rare.

VI. Coarse Silt: It is composed of angular glassy-surfaced quartz grains, a few flakes of white mica, a few dark minerals, and a few white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream colored clayey material studded with a few distinct mineral grains.

Interpretation

The high degree of sorting and the extremely small quantity of clay and silt of this sand suggest the action of either waves or wind. The very small quantity of mica may favor wind action. The frosted surfaces of some of the grains are also indicative of wind action, but the large number of non-frosted grains and the character of the cross-bedding suggest that wind activity played only a minor part in the deposition of this material.

The outcrop shows that the sand is conformably overlain by glauconitic sand and marine claystone. This sand was deposited in an environment which could, without interruption, change into one permitting the accumulation of definitely marine material. It appears probable, therefore, that this sediment was deposited under littoral conditions which changed to neritic when the overlying material accumulated. The littoral environment must have been such that wave action was an important factor. Under these conditions, wind-rounded and frosted grains, produced on nearby land areas, could easily have been included in the resulting sediments.

CLAIBORNE SAMPLE 30

Location, Position, and Character

The sample was collected two miles south of Philadelphia on the road to Union, from the upper part of the Meridian member.

Section of road cut two miles south of Philadelphia

	Feet	Feet
Basic member		32
4. Claystone having irregular masses of glauconitic sand	25	
3. Sand, glauconitic; interbedded with gray claystone	4	
2. Claystone having irregular masses of glauconitic sand	3	
Meridian member		15
1. Sand, irregularly bedded loose white (Sample 30 composite)	15	

Megascopically, the sample is an unconsolidated cream colored micaceous sand, in which dark minerals produce a speckled appearance; microscopically, a well sorted fine grained quartz sand containing a few grains of glauconite, white mica, and dark minerals.

Mechanical Analysis

The results of the mechanical analysis of Sample 30 are represented by Histogram 30; of the division of the Very Fine Sand, by the table:

Light minerals	94.3 percent
Heavy minerals	5.7 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: Most of the fraction is composed of flakes of white mica; the remainder, of grains of quartz either sub-angular and glassy or well rounded and frosted, and of a few grains of a dark mineral and grains of talc-like material.

III. Medium Sand: Its composition is the same as that of the Coarse Sand, except that the quartz grains are more abundant.

IV. Fine Sand: It is composed principally of angular glassy-surfaced quartz grains; subordinately of flakes of white mica, a few dark minerals, a few grains of talc-like material, and a few grains of light green glauconite.

V. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, a few linearally arranged, are most common; of the Regular type, rare, among which zircon and tourmaline can be identified; of the Acicular type, very rare. About 5 percent of the sample is composed of slightly altered light green grains of glauconite; a less amount, of a few grains of chert, a few grains of altered albite, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, kyanite, staurolite, tourmaline, rutile, ilmenite are common; leucoxene, xenotime, rare; and sillimanite is very rare.

VI. Coarse Silt: Its composition is 80 percent angular grains of quartz, 10 percent dark mineral grains, 10 percent white mica, and a small amount of light green glauconitic grains and a few yellow clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of yellow clay-like material studded with a few distinct mineral grains.

Interpretation

The high degree of sorting and the very small quantity of clay and silt suggest wave or wind action at the time of deposition. The abundance of mica, the presence of glauconite, the dominance of glassy rather than frosted quartz grains, and the conformably overlying marine claystone points to wave rather than wind action.

The environment of deposition suggested by the above characteristics is, therefore, a littoral or neritic one where wave action was important. Wind activity on nearby beaches would adequately account for the few grains having a frosted surface.

CLAIBORNE SAMPLE 31

Location, Position, and Character

The sample was collected five miles east of Zama on the Noxapater Road, from the upper part of the Meridian member.

Section of road cut five miles east of Zama

	Feet	Feet
Basic member		30
4. Claystone having irregular masses of glauconitic sand	30	

	Feet	Feet
Meridian member		15
3. Sand, evenly bedded glauconitic (Sample 31 composite)	3	
2. Sand, glauconitic white, and brown inter-bedded shale	4	
1. Sand, cross-bedded (water type) white (Sample 32 composite)	8	

Megascopically, the sample is a greenish-yellow glauconitic sand, locally cemented by iron hydroxide; microscopically, a well sorted glauconitic quartz sand. The light green glauconite composing about 10 percent of the sample varies in shape from round to discoidal or mammalary, and ranges in size to a greater degree than the quartz grains. Some of the glauconite is altered to yellow clayey material.

Mechanical Analysis

The results of the mechanical analysis of Sample 31 are represented by Histogram 31; of the division of the Very Fine Sand, by the table:

Light minerals	91.5 percent
Heavy minerals	8.5 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed principally of grains of quartz, of which most are angular and glassy-surfaced, and a few are well rounded and frosted; subordinately of fresh light green round to mammalary or discoidal glauconite grains, a few flakes of white mica, and a few dark mineral grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Coarse Sand except that the glauconite is more abundant.

V. Very Fine Sand:

A. Light minerals: About 35 percent is composed of fresh light green glauconite, of which the indices of refraction range from approximately 1.55 to 1.60. The remainder is composed of glassy-surfaced angular quartz grains having straight extinction. Inclusions of the Irregular type are common; of the other types, rare. It further consists of a very few grains of chert and microcline and a very few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, staurolite, rutile, monazite, are common; tourmaline, ilmenite, rare; and xenotime, leucoxene, hornblende, very rare.

VI. Coarse Silt: In composition it is about 75 percent quartz grains, 25 percent light green glauconitic material, and a few white mica flakes, and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is a green clayey material studded with a few distinct mineral grains.

Interpretation

The high degree of sorting in this sample and the very small quantity of clay and silt suggest the action of waves or wind. The size and position of the secondary maximum, according to the generalization of Udden,[161] is indicative of wind rather than wave action. It was shown in discussing the Wilcox sediments that this generalization does not always hold, and in this sample other characteristics point definitely to the action of waves rather than wind.

The abundance of glauconite, the even bedding, and the conformably overlying marine claystone suggest that this sand was deposited in a neritic environment where there was considerable wave action. The few grains of quartz having a frosted surface can be accounted for by wind activity along nearby beaches.

CLAIBORNE SAMPLE 32

Location, Position, and Character

As the previous section of the road cut five miles east of Zama shows, sample 32, as well as sample 31, was collected at that place from the middle of the Meridian member. Megascopically, it is a green unconsolidated glauconitic, quartz sand; microscopically, a fine grained quartz sand in which glauconite composes about 5 percent of the material. The glauconite is round, discoidal, or mammalary, light green, and fresh. The grains vary in size over a larger range than do the quartz grains.

Mechanical Analysis

The results of the mechanical analysis of Sample 32 are represented by Histogram 32; of the division of the Very Fine Sand, by the table:

Light minerals	99.0 percent
Heavy minerals	1.0 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: In composition it is 90 percent white mica flakes and 10 percent glassy-surfaced subangular quartz grains.

III. Medium Sand: It is composed principally of subangular glassy-surfaced quartz grains and a few well rounded and frosted grains, and subordinately of a large number of white mica flakes, a few light green unaltered glauconite grains, a few dark mineral grains, and a few grains of talc-like material.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular and the glauconite is more abundant.

V. Very Fine Sand:

A. Light minerals: The fraction is composed principally of angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, a few of which are definitely arranged, are common; of the other types, rare. Zircon and tourmaline inclusions are identifiable. About 10 percent is composed of light green unaltered grains of glauconite; a smaller amount, of a few altered grains of microcline, orthoclase, and albite, a few grains of chert, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, staurolite, tourmaline, ilmenite are common; rutile, leucoxene, rare; and sillimanite, monazite, garnet, very rare.

VI. Coarse Silt: It is composed of light green glauconitic material and quartz grains, a few dark mineral grains, and a few mica flakes.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt except that the glauconitic material is more abundant.

VIII. Fine Silt and Clay: The fraction is composed of yellowish-green clayey material, a few flakes of white mica, and a few quartz grains.

Interpretation

Wave or wind action is indicated by the high degree of sorting and the very small quantity of clay and silt. The abundance of glauconite, the abundance of mica, and the character of the cross-bedding favor waves rather than wind as the sorting agent.

The environment of deposition suggested by the above characters is, therefore, a neritic one which had considerable wave activity. A few grains of frosted quartz would be expected in sand accumulating in such an environment if beaches existed nearby from which such material could be obtained.

CLAIBORNE SAMPLE 33

Location, Position, and Character

The sample was collected one mile southeast of the fork of the Louisville and Kosciusko Highway, 18 miles east of Kosciusko, from the upper part of the Meridian member.

Section of the road cut one mile southeast of the Louisville and Kosciusko fork

	Feet	Feet
Winona member		50
5. Marl, deeply weathered red glauconitic, sandy	40	
4. Covered	10	
Basic member		20
3. Claystone having irregular masses of glauconitic sand	20	
Meridian member		22
2. Sand, coarse glauconitic; discordantly separated from the underlying material (Sample 33 composite)	5	
1. Sand, irregularly bedded (water type)	17	

Megascopically, the sample is an unconsolidated brown quartz sand containing a few nodules of clay; microscopically, a slightly glauconitic quartz sand in which many of the grains are coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 33 are represented by Histogram 33; of the division of the Very Fine Sand, by the table:

Light minerals	96.5 percent
Heavy minerals	3.5 percent

Microscopic Examination

I. Very Coarse Sand: It is composed of rounded glassy-surfaced quartz grains and well rounded frosty-surfaced quartz grains in about equal proportions.

II. Coarse Sand: It is composed of subangular glassy-surfaced quartz grains, a few well rounded and frosted quartz grains, and a few dark mineral grains.

III. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, a few dark minerals, a few light green unaltered glauconite grains, several white mica flakes, and a few talc-like grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: About 65 percent of this fraction is composed of light green glauconitic grains, in which the indices of refraction range from 1.54 to about 1.60. The remainder is composed of angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type are common; of the other types, rare. The remainder is composed further of a few flakes of white mica having the properties of muscovite, several grains of altered albite, and a few grains of chert.

B. Heavy minerals: Kyanite, zircon, tourmaline, staurolite are common; rutile, ilmenite, rare; monazite, spinel, leucoxene, very rare.

VI. Coarse Silt: About half is composed of glauconite and material having an opaline appearance; the rest, of quartz grains, yellow clay aggregates, a few dark minerals, and a few flakes of white mica.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of yellowish-green clayey material.

Interpretation

This sand contains rounded nodules of clay which disintegrated in analysing, yielding a considerable quantity of the clay and silt, as shown in the histogram.

The abundance of glauconite indicates a marine environment, but the histogram shows less sorting than would be anticipated from strong wave action. The above characteristics together with the size of the grains and the presence of clay granules suggest deposition under neritic conditions in an area where material was supplied slightly faster than the waves could thoroughly sort it. Such an environment would be close to the mouth of a stream, on the margin of a delta, or in a protected coastal area where the waves operated with diminished intensity. A region of stronger wave action would probably have yielded a better sorted product free from clay granules.

CLAIBORNE SAMPLE 34

Location, Position, and Character

The sample was collected 19 miles east of Kosciusko on the Louisville Road, from the upper part of the Meridian member.

Section of the road cut 19 miles east of Kosciusko

	Feet	Feet
Winona member		15
4. Sand, deeply weathered red	15	
Basic member		40
3. Claystone and irregular masses of glauconitic sand	30	
2. Covered	10	
Meridian member		20
1. Sand, irregularly bedded (water type) white (Sample 34 composite)	20	

Megascopically, the sample is an unconsolidated cream colored sand; microscopically, a fine grained, slightly micaceous, quartz sand, about half of the grains of which are partly coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 34 are represented by Histogram 34; of the division of the Very Fine Sand, by the table:

Light minerals	98.3 percent
Heavy minerals	1.7 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of slightly rounded glassy-surfaced quartz grains, a few well rounded frosty-surfaced quartz grains, a few white mica flakes, a few dark mineral grains, and a biotite flake.

III. Medium Sand: Its composition is the same as that of the Coarse Sand, except for the addition of a few talc-like grains and a few dark green unaltered glauconite grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are principally angular glassy-surfaced quartz grains having straight extinction. Inclusions of the Irregular type are very common, a few having a definite linear arrangement; of the Regular type, of which zircon and apatite? are identifiable, common; of the Acicular type, very rare. A few grains of chert, a few grains of slightly altered albite and orthoclase, a few grains of dark green glauconite slightly altered to limonite, and a few flakes of white mica having the properties of muscovite are also present.

B. Heavy minerals: Zircon, kyanite, staurolite, tourmaline, rutile are common; leucoxene, ilmenite, rare; xenotime, andalusite, fluorite, monazite, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, dark mineral grains, light green glauconite grains, talc-like grains, white mica flakes, and limonitic aggregates.

VII. Medium Silt: It is composed of yellow, green clayey material, limonitic aggregates, quartz grains, and a few white mica flakes.

VIII. Fine Silt and Clay: In composition the fraction is the same as that of the Medium Silt.

Interpretation

The very small quantity of clay and silt and the high degree of sorting suggest a strong sorting agent. The position of the size next in abundance to the maximum indicates, according to Udden's[163] generalization, the action of wind rather than waves. Other characteristics of the sample, such as the presence of glauconite, the existence of considerable white mica, and the type of cross-bedding point more positively to a marine environment in which wave action was the sorting agent. The probable environment of deposition was, therefore, either littoral or neritic. The few frosted grains of the sample could easily have been developed on nearby beaches, and then washed or blown into the area of deposition.

CLAIBORNE SAMPLE 35

Location, Position, and Character

The sample was collected seven miles southeast of Duck Hill on the road to Sweatman, Montgomery County, from transition beds between the Wilcox and Claiborne.

Section of road cut seven miles southeast of Duck Hill

	Feet	Feet
Transition beds		40
2. Sand, irregularly bedded (water type) brown (Sample 35 composite)	20	
1. Claystone having irregular masses of glauconitic sand, cross-bedded glauconitic sand, and thinly laminated lignitic shale, interbedded	20	

Megascopically, the sample is a brown sand locally cemented with iron hydroxide; microscopically, a well sorted slightly micaceous, quartz sand in which the grains are slightly coated with iron hydroxide.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 35 are represented by Histogram 35; of the division of the Very Fine Sand, by the table:

Light minerals	97.2 percent
Heavy minerals	2.8 percent

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of about equal proportions of well rounded frosty-surfaced quartz grains and flakes of white mica.

III. Medium Sand: It is composed principally of subangular glassy-surfaced quartz grains and a few well rounded frosty-surfaced quartz grains, and subordinately of a few dark mineral grains, a few talc-like grains, and a very few unaltered dark green glauconite grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They consist principally of angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, a few of which have a linear arrangement, are common; of the Regular type, in which zircon and tourmaline are identifiable, rare. They consist subordinately of a few grains of chert, several slightly altered grains of albite and orthoclase, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite and zircon are abundant; staurolite, rutile, tourmaline, ilmenite, leucoxene, common; monazite, sillimanite, corundum, xenotime, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, yellow clay aggregates, dark mineral grains, white mica flakes, and talc-like grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of flakes of white mica, grains of quartz, and aggregates of yellow clay.

Interpretation

The high degree of sorting and the small quantity of clay and silt suggest the action of a strong sorting agent such as surf or wind in the deposition of this material. The type of cross-bedding, the presence of glauconite, and the abundance of white mica favor wave action rather than wind. It appears probable, therefore, that this sediment was deposited in a littoral or neritic environment where wave action was an important factor. Frosted grains could be present in such material in the same manner as noted for Sample 34. This interpretation is in harmony with the conditions under which the underlying interbedded glauconitic sands and lignitic clays of the outcrop were deposited; namely, an environment where successive alternations from marine to non-marine conditions were possible.

CLAIBORNE SAMPLE 36

Location, Position, and Character

The sample was collected just east of the Meridian and Quitman Highway three miles south of Meridian, from the upper part of the Basic member.

Section of the road cut east of the Meridian and Quitman Highway

	Feet	Feet
Kosciusko member		15
8. Sand, irregularly bedded (water type) white	15	
Winona member		99
7 Covered	25	
6. Sand, deeply weathered massive red	45	
5. Sandstone, yellow; cemented by limonite	1	
4. Shale, gray, which weathers red	2	
3. Sand, massively bedded medium grained red	18	
2. Shale, gray; grading into the underlying material	8	

	Feet	Feet
Basic member		45
1. Claystone; upper and lower parts of this zone contain irregular masses of glauconitic sand (Sample 36 from the upper part)	45	

Megascopically, the sample is composed of dense, hard gray clay-like material and irregular masses of coarse glauconitic sandstone. The clay-like masses are locally pure and give the rock a conglomeratic appearance, but they usually have sand grains scattered through them. A few small molds of molluscs are present.

Microscopic Examination of Thin Section

Because this material could not be disaggregated, the type of analysis used for the other Claiborne members could not be followed. Consequently, the material was studied in thin sections. Microscopically, this thin section (08131) showed a matted matrix of extremely fine grained partly isotropic material, which with high magnification can be resolved into organic remains, chiefly diatoms, and structures that may be organic or volcanic. Such structures are minute elongate, circular, oval, or U-shaped masses of isotropic material. Laths of white mica and a considerable number of quartz grains are present in the matrix. The grains do not touch one another and have sharp boundaries

Figure 22.—Photomicrograph of thin section 08131 of the Basic material. 200X

with the matrix or grade abruptly into it, indicating some alteration of the detrital quartz. Likewise the several scattered grains of glauconite have sharp boundaries or grade into the matrix. Some of them are broken and are penetrated by the matrix; others are concentrically encrusted by the matrix. Staurolite, tourmaline, and biotite are rare constituents.

Interpretation

The fossil remains and the glauconite indicate a marine environment of deposition. These characters and the features of the outcrop suggest a neritic environment.

CLAIBORNE SAMPLE 37

Location, Position, and Character

The sample was collected at the Lost Gap Tunnel on the Alabama and Vicksburg Railroad west of Meridian, from the middle part of the Basic member. Megascopically, it is a light, hard, dense gray massive clay-like material possessing a distinct conchoidal fracture.

Microscopic Examination of Thin Section

Microscopically, this thin section (08132) is composed entirely of the same material as that of which the previous section (08131) is composed.

Interpretation

The same conditions of deposition are suggested for Sample 37 as were indicated for Sample 36.

CLAIBORNE SAMPLE 38

Location, Position, and Character

The sample was collected four miles west of Philadelphia on the road to Carthage, from the upper part of the Basic member.

Section of road cut four miles west of Philadelphia

	Feet	Feet
Basic member		58
2. Claystone, massive to laminated silty; having streaks and irregular masses of glauconitic sand	50	
1. Shale, grayish-green, and glauconitic sand interbedded	8	

Megascopically, this specimen is hard, dense drab-gray siltstone, that varies from a massive to a laminated structure and that has a conchoidal fracture. The laminated structure is accentuated in weathering by the yellow color of some of the laminae. Irregular masses and streaks of dense hard claystone are scattered through the siltstone.

Microscopic Examination of Thin Section

Microscopically, this thin section (08133) shows matrix material similar to that described in the previous thin sections (08131 and 08132). A few small grains of quartz and glauconite are scattered through this matrix. These minerals either have sharp boundaries or grade into the matrix. Many small, lath-shaped grains of white mica possessing a crude parallel arrangement are also present. Another thin section (08134) of this sample differs from the previous thin section (08133) in possessing more distinct mineral grains. Most of the laths of mica are larger than the quartz grains, which suggests a non-detrital origin. The lamination is the result of the parallel arrangement of the mica and the greater abundance of the quartz grains in some zones than in others.

Interpretation

The interpretation suggested for Sample 38 is the same as that suggested for Samples 36 and 37.

CLAIBORNE SAMPLE 39

Location, Position, and Character

The sample was collected along the Meridian and Paulding Road, three miles south of the fork with the Meridian and Jackson Highway, from the lower part of the Winona member (See stratigraphic section of road cut along Meridian and Paulding Road). Megascopically, it is an unconsolidated yellow sand locally cemented by iron hydroxide; microscopically, a well sorted fine grained slightly micaceous, quartz sand in which many of the grains are faintly coated by iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 39 are represented by Histogram 39; of the division of the Very Fine Sand, by the table:

Light minerals	94.7 percent
Heavy minerals	5.3 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed principally of subangular glassy-surfaced quartz grains and a few grains having frosted surfaces and a higher degree of rounding; subordinately of several flakes of white mica.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: It is composed principally of grains of quartz like those in the Medium Sand; and subordinately of several dark mineral grains, a few white mica flakes, a very few dark green unaltered glauconite grains, and a few talc-like grains.

V. Very Fine Sand:

A. Light minerals: They consist of angular glassy-surfaced quartz grains, in which wavy extinction and inclusions are rare, and of a few grains of chert, orthoclase, unaltered light green glauconite, and of several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, staurolite, zircon, tourmaline are abundant; rutile, leucoxene, ilmenite, common; monazite, sillimanite, rare.

VI. Coarse Silt: It is composed of 90 percent angular grains of quartz, about 10 percent glauconitic material, a few flakes of white mica, and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt, except that the non-quartz material is more abundant.

VIII. Fine Silt and Clay: The fraction is composed of greenish-yellow clay studded with a few distinct mineral grains.

Interpretation

The high degree of sorting and the small amount of clay and silt suggest the activity of a strong sorting agent such as waves or wind. Histogram 39 is similar to Histograms a-d of the dune sands. Wind action is further suggested by the position of the secondary maximum according to the generalization of Udden,[164] and by the frosted surface of some of the grains. However, other characteristics of the sand indicate definitely that wind action was not the dominant agent in the deposition of this sediment.

The presence of glauconite and the relation of this sand to the underlying Basic marine material into which it grades indicate a neritic or littoral environment of deposition in which waves were the sorting agent. The presence of some mica may also be evidence against wind action. A few frosted grains are to be expected in a sediment deposited under such conditions if wind is active on nearby beaches.

CLAIBORNE SAMPLE 40

Location, Position, and Character

The sample was collected one-fourth mile east of Union on the road to DeKalb, from the middle part of the Winona member, in a road cut which shows 30 feet of red glauconitic, sandy marl containing molds and casts of marine shells and streaks of limonite (Sample 40 composite). Megascopically, it is a reddish-brown glauconitic sand locally cemented by iron hydroxide; microscopically, a poorly sorted sand composed of approximately equal parts of glauconite and quartz. The glauconite varies in shape from round to discoidal or mammalary; in color from light to dark green. The grains are altered in two distinct ways: some to red limonitic material, others to a white clay-like material. Weathering has proceeded inward from fractures. In partly altered individuals, green residual areas are bounded by either white or red material. Some dark green grains seemingly are in the process of altering to light green.

Mechanical Analysis

The results of the mechanical analysis of Sample 40 are represented by Histogram 40; of the division of the Very Fine Sand, by the table:

Light minerals	99.6 percent
Heavy minerals	0.4 percent

Microscopic Examination

I. Very Coarse Sand: About 60 percent is composed of grains of subangular quartz, most of which are well rounded and have a frosted surface; the remainder is composed of glauconite.

II. Coarse Sand: Its composition is the same as that of the Very Coarse Sand.

III. Medium Sand: It is composed of approximately equal parts of angular glassy-surfaced quartz grains and glauconite.

IV. Very Fine Sand:

A. Light minerals: About 50 percent is composed of grains of glauconite in which the indices of refraction range from 1.55 to about 1.60; the remainder is composed of angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are common; of the other types, rare. Zircon is the only inclusion identifiable. It is composed also of several grains of chert, and altered albite.

B. Heavy minerals: Ilmenite, kyanite, staurolite, zircon, are common; rutile, tourmaline, rare; sillimanite, epidote, xenotime, spinel, topaz, clinozoisite, very rare.

VI. Coarse Silt: It is composed of greenish glauconitic material, angular grains of quartz, a few white mica flakes, and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: They are composed of yellowish-green clay material.

Interpretation

The molds and casts of marine forms and the abundance of glauconite show that the sand was deposited in a neritic environment. The considerable quantity of silt and clay and the lack of sorting indicate deposition where wave action was feeble, or where more material was supplied to the sea than the waves could sort.

Such feeble wave action would be possible in an area protected from the full force of normal wave action, and the excess material would exist near the mouth of a stream. Another possibility is that the marine area of deposition was subsiding at a rate which lowered the accumulating material below the zone of wave action before the waves could effectively sort it.

The frosted grains can be accounted for in the same manner as for Sample 39.

CLAIBORNE SAMPLE 41

Location, Position, and Character

The sample was collected one-fourth mile east of Zama on the road to Noxapater, from the middle part of the Winona member, where a road cut exposes 15 feet of regularly interbedded red glauconitic sand and grayish-brown shale (Sample 41 composite of the sand bed about the middle of the section). Megascopically, it is a yellowish-brown, green speckled glauconitic sand locally consolidated with gray clay; microscopically, a poorly sorted quartz sand containing about 5 percent of glauconite, which has the same features as those described in the analysis of Sample 40. The sand is slightly clayey and slightly micaceous.

Mechanical Analysis

The results of the mechanical analysis of Sample 41 are represented by Histogram 41; of the division of the Very Fine Sand, by the table:

Light minerals	98.9 percent
Heavy minerals	1.1 percent

Microscopic Examination

I. Very Coarse Sand: It is composed principally of sub-angular glassy-surfaced quartz grains; subordinately of a few quartz grains that are well rounded and frosted, and a few grains of glauconite that have properties similar to those noted in the analysis of Sample 40.

II. Coarse Sand: Its composition is the same as that of the Very Coarse Sand except for the addition of a few flakes of white mica.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the glauconite is more abundant and the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: About 25 percent is composed of glauconite, having indices of refraction ranging from about 1.55 to 1.60; the remainder, of angular grains of quartz, in which wavy extinction is rare and in which inclusions of the Irregular type are abundant and of the other types, rare. It is composed further of a few grains of chert and albite and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, staurolite are abundant; tourmaline, ilmenite, rutile, common; topaz, monazite, sillimanite, xenotime, very rare.

VI. Coarse Silt: It is composed of approximately equal parts of quartz grains and yellow clay aggregates, also of a few white mica flakes and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: They are composed of yellow clay aggregates and a few distinct mineral grains.

Interpretation

The characteristics of this sample are so similar to those of Sample 40 that similar conditions of deposition are suggested. Sample 41, however, differs from the previous one in that it shows slightly more sorting and decidedly fewer fossils, suggesting an environment where waves were more active or had more opportunity to influence the material delivered to them.

CLAIBORNE SAMPLE 42

Location, Position, and Character

The sample was collected 23 miles north of Kosciusko on the Vaiden Road, from the upper part of the Winona member.

Section of a road cut 23 miles north of Kosciusko

	Feet	Feet
Winona member		31
2. Sand, red coarse grained glauconitic (Sample 42 composite)	30	
1. Shale, grayish-brown	1	

Megascopically, the sample is a greenish-gray glauconitic sand, locally cemented by iron hydroxide and clay; microscopically, a fairly well sorted fine grained quartz sand containing about 10 percent of glauconite which varies in color from light to dark green and shows little alteration. Some of the grains appear to be alternate bands of light and dark green material. The glauconite is round, mammalary, or discoidal.

Mechanical Analysis

The results of the mechanical analysis of Sample 42 are represented by Histogram 42; of the division of the Very Fine Sand, by the table:

Light minerals	98.9 percent
Heavy minerals	1.1 percent

Microscopic Examination

I. Very Coarse Sand: It is composed of a few grains of slightly rounded glassy-surfaced quartz and of abundant grains of glauconite similar to those in Sample 40.

II. Coarse Sand: About 50 percent is composed of subangular glassy-surfaced quartz grains, of which a few are well rounded and frosted; the remainder, except for a few flakes of white mica, is composed of glauconite of the type noted above.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of Medium Sand, except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: About half of the fraction is composed of light and dark green glauconite whose indices of refraction range from about 1.55 to about 1.60; the remainder is composed of angular grains of quartz in which wavy extinction is rare. Inclusions of the Irregular type are common; of the Regular type, in which zircon, tourmaline, and apatite? are identifiable, fairly common; and of the Acicular type, very rare. In addition there are several grains of chert, a few grains of microcline, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, staurolite are abundant; tourmaline, rutile, leucoxene, ilmenite, common; xenotime, zoisite, monazite, andalusite, very rare. Some of these grains are concentrically coated with glauconitic material.

VI. Coarse Silt: It is composed of yellowish-green clay aggregates, a few quartz grains, a few dark mineral grains, and a few white mica flakes.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The composition is the same as that of the Medium Silt.

Interpretation

The small quantity of clay and silt and the rather high degree of sorting indicate a strong sorting agent. According to Udden's[165] generalization, the position of the secondary maximum suggests that the sorting agent was wind.

Facts in favor of surf action rather than wind are the abundance of glauconite and the concentric coating of some of the grains neither of which condition could have been produced out of water. The most probable interpretation is, therefore, deposition in a neritic environment where wave action produced considerable sorting. The few frosted grains were undoubtedly blown or washed in from nearby land areas.

CLAIBORNE SAMPLE 43

Location, Position, and Character

The sample was collected along a secondary road toward Poplar Creek, five miles north of the Kosciusko and Vaiden Road, from approximately the eastern limit of the "sand wedge" in the middle part of the Winona member, where a road cut exposes 20 feet of interbedded yellow sand (Sample 43 composite of a sand bed near middle of section) and white clay which resembles the Basic claystone. Megascopically, it is a yellow micaceous, quartz sand locally cemented by iron hydroxide; microscopically, a slightly glauconitic fine grained sand. The glauconite is unaltered and ranges from light to dark green.

Mechanical Analysis

The results of the mechanical analysis of Sample 43 are represented by Histogram 43; of the division of the Very Fine Sand, by the table:

Light minerals	96.9 percent
Heavy minerals	3.1 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of flakes of white mica and a few grains of unaltered light green glauconite.

III. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, a few well rounded and frosted quartz grains, several white mica flakes, a few light green glauconite grains, and a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the quartz grains are more angular and the white mica is less abundant.

V. Very Fine Sand:

A. Light minerals: About 90 percent is composed of angular glassy-surfaced quartz grains, having straight extinction. Inclusions of the Irregular type are abundant, many being definitely arranged; of the Acicular type, common; of the Regular type, rare, zircon and tourmaline being identifiable. About 10 percent is composed of flakes of white mica similar to muscovite, slightly altered grains of orthoclase and albite, a few grains of chert, and a few grains of unaltered light green glauconite.

B. Heavy minerals: Kyanite, zircon, tourmaline, staurolite are abundant; rutile, ilmenite, leucoxene, common; xenotime, monazite, epidote, very rare.

VI. Coarse Silt: Its composition is about 75 percent angular quartz grains and 25 percent yellowish-green clay-like material, a few dark mineral grains, and a few flakes of white mica.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of yellow clayey material studded with a few distinct mineral grains.

Interpretation

The high degree of sorting and the small amount of clay and silt suggest a strong sorting agent, such as waves or wind. The abundance of white mica may be evidence against wind action; the presence of glauconite definitely indicates a marine environment. The most probable environment of deposition was, therefore, a littoral or neritic area where wave action was strong enough and operated long enough to produce a high degree of sorting. The few quartz grains having frosted surfaces may be accounted for in the same manner as those described in previous samples.

CLAIBORNE SAMPLE 44

Location, Position, and Character

The sample was collected three miles west of Winona and one-fourth mile north of the Winona and Carrollton Road from near the middle of the sand wedge in the Winona member.

Section of a gully three miles west of Winona

	Feet	Feet
Winona member		30
2. Sand, irregularly bedded (water type) white micaceous; containing streaks of white clay	15	
1. Sand, massively bedded white (Sample 44 composite)	15	

Megascopically, the sample is an unconsolidated white quartz sand; microscopically, a slightly micaceous, quartz sand in which many of the quartz grains are coated by white clay.

Mechanical Analysis

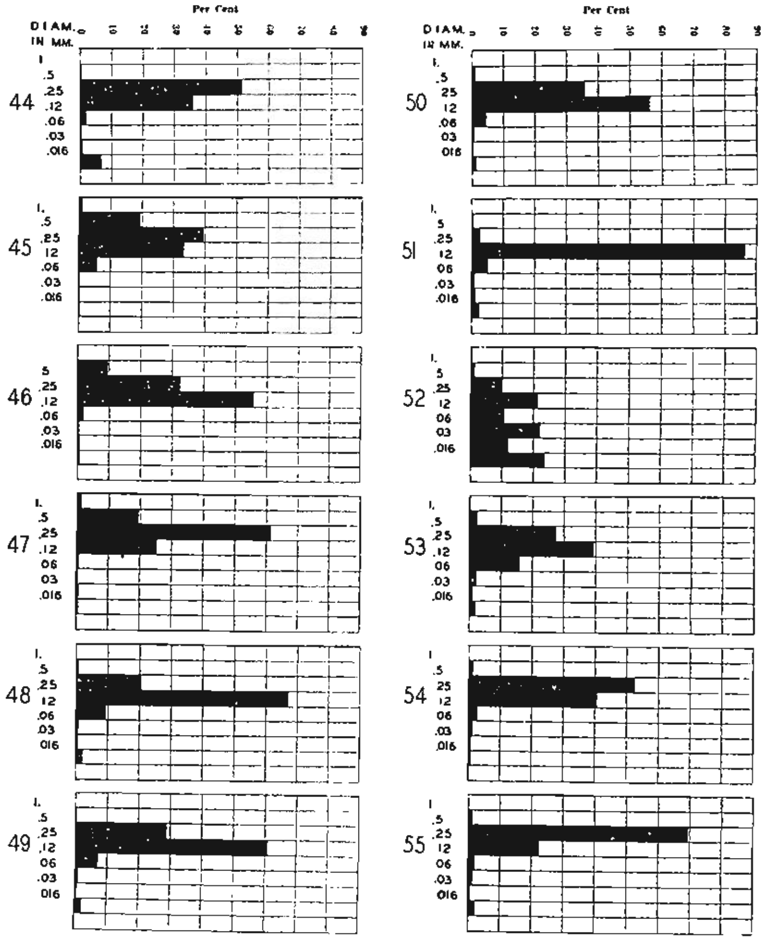
The results of the mechanical analysis of Sample 44 are represented by Histogram 44; of the division of the Very Fine Sand, by the table:

Light minerals	99.0 percent
Heavy minerals	1.0 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: Except for a few flakes of white mica, this fraction is composed of subangular glassy-surfaced quartz grains and well rounded frosty-surfaced quartz grains.



Histograms 44-55.—Histograms representing the results of the mechanical analyses of Claiborne Samples 44-55.

III. Medium Sand: It is composed of quartz grains like those in the Coarse Sand, several grains of talc-like material, a few dark mineral grains, and a few light green glauconite grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: They are subordinately a few grains of light to dark green glauconite whose indices of refraction range from approximately 1.55 to 1.60, a few grains of chert, and several flakes of white mica having the properties of muscovite. They are mostly angular quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type are abundant, many having a linear arrangement; and of the other types are rare.

B. Heavy minerals: Zircon, kyanite, staurolite, rutile, tourmaline are common; epidote, leucoxene, ilmenite, rare; sillimanite, monazite, garnet, andalusite, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, white clay aggregates, white mica flakes, and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of white clayey material studded with a few distinct mineral grains.

Interpretation

The histogram of this sand shows that 88 percent of it belongs in the medium and fine grade-sizes. This does not give a true conception of the degree of sorting it possesses, since an examination of the medium sand shows it to be almost wholly near the lower size limit, and an examination of the fine sand shows it to be almost wholly near the upper size limit. Therefore, the predominant grade size of the sample ranges from slightly above 0.25 mm. to slightly below that size.

The degree of sorting indicates the action of either surf or wind. The small quantity of mica may favor the action of wind. A few of the grains have a frosted surface, but most of them have a smooth glassy surface, suggesting that wind played a minor part in the deposition of the sand. Wind action sufficient to produce such a high degree of sorting would probably produce irregular bedding and rather general frosting of the grains.

The evidence is not sufficient to permit a definite decision between wind and wave action, but the evidence appears to favor wave action. A littoral or neritic environment of deposition is, therefore, suggested.

CLAIBORNE SAMPLE 45

Location, Position, and Character

The sample was collected 15 miles east of Quitman on the road to Butler, Alabama, from the middle of the Kosciusko member, where a road cut exposes 15 feet of regularly bedded yellow streaked, white sand (Sample 45 composite). Megascopically, it is an unconsolidated yellow sand, locally cemented by iron hydroxide; microscopically, a quartz sand in which many of the grains are partly coated by iron hydroxide.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 45 are represented by Histogram 45; of the division of the Very Fine Sand, by the table:

Light minerals	99.6 percent
Heavy minerals	0.4 percent

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: Except for a very few flakes of white mica, this fraction is composed of subangular glassy-surfaced quartz grains and well rounded frosty-surfaced quartz grains.

II. Coarse Sand: It is composed of quartz grains like those in the Very Coarse Sand, a few white mica flakes, and a few dark mineral grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, many having a linear arrangement are common; of the other types, rare, zircon, tourmaline, apatite ?, and staurolite ? being noted. They also include several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Sillimanite, kyanite, tourmaline, staurolite, zircon are common; rutile, leucoxene, ilmenite, rare; xenotime, tremolite, very rare.

VI. Coarse Silt: It is composed principally of angular quartz grains, subordinately of a few white mica flakes, several cream-colored clay aggregates, and a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studed with a few distinct mineral grains.

Interpretation

The small amount of clay and silt in this sand is its most significant feature. The sediment shows little sorting in the sand grade sizes. These characteristics favor the action of waves or wind as a sorting agent in an environment where material ranging in size through all sand grades was being brought to the sorting agent. Sorting by waves or wind is performed largely by removing the finer grades and leaving the remainder behind. The absence of clay and silt is probably more decisive evidence of wave or wind action than the concentration of material in one grade size. This latter characteristic would largely depend on the material supplied to the sorting agent, the time available to perform the sorting, and the strength of the agent.

Histogram e of a river sand is similar to the histogram of this sample. A partial checking of the velocity of a stream will cause it to drop its coarse load and permit it to continue to carry its finer material. A sediment showing a variety of coarser sizes without much finer material would result. However, it is believed that a river sediment would usually show more clay and silt than this sample.

The evidence seems to indicate that this sand is the result of wave or wind action. There is no decisive evidence as to which of these agents was the more important. The general glassy character of the surface suggests wave action, although the few frosted grains indicate at least some wind action. A probable interpretation of this sand is that of deposition in a littoral or neritic environment where wave action was able to remove only the clay and silt from the material provided.

CLAIBORNE SAMPLE 46

Location, Position, and Character

The sample was collected two miles south of Enterprise on the Wautubbee Road, from the upper part of the Kosciusko member, where a road cut exposes 20 feet of irregularly bedded (water type) yellow sand (Sample 46 composite). Megascopically, it is an unconsolidated cream colored sand; microscopically, a slightly glauconitic, slightly micaceous, quartz sand. The glauconite is light green and shows some alteration to limonitic material.

Mechanical Analysis

The results of the mechanical analysis of Sample 46 are represented by Histogram 46; of the division of the Very Fine Sand, by the table:

Light minerals..............................	99.0 percent
Heavy minerals..............................	1.0 percent

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is almost entirely composed of subangular glassy-surfaced quartz grains, a few well rounded frosty-surfaced quartz grains, a few white mica flakes, a few light green glauconite grains, a few talc-like grains, and a few dark mineral grains. The glauconite is round, mammalary, or discoidal in shape.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are mainly angular quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are most common, many showing a linear arrangement; and of the other types, rare. About 20 percent is composed of equal parts of slightly altered albite, microcline, and albite, and light green glauconite whose indices of refraction range from about 1.55 to 1.60. A smaller quantity consists of a few grains of chert, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, sillimanite, zircon, staurolite, tourmaline are common; rutile, monazite, leucoxene, ilmenite are rare; and anatase is very rare.

VI. Coarse Silt: It is composed of angular quartz grains, of yellowish-green clay-like grains, of white mica flakes, and of a few dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studded with a few flakes of white mica and grains of quartz.

INTERPRETATION

The extremely small quantity of clay and silt and the rather high degree of sorting suggest wave or wind action. The position of the secondary maximum and the scant quantity of mica favor wind action, but the presence of glauconite, the character of the bedding, and the dominant glassy surface of the quartz grains is stronger evidence in favor of wave action.

The strongest evidence points to waves as the sorting agent in a littoral or neritic environment. The few grains having a frosted surface can be accounted for in the manner noted in previous samples.

CLAIBORNE SAMPLE 47

Location, Position, and Character

The sample was collected just south of the Paulding and Meridian Road, five miles south of its fork with the Meridian and Jackson Road, from the lower part of the Kosciusko member.

Section of the gully just south of the Paulding and Meridian Road

	Feet	Feet
Kosciusko member		75
3. Sand, irregularly bedded (water type) white (Sample 47 composite of middle 35 feet)	70	
2. Covered	5	
Winona member		10
1. Sand, green glauconitic silty	10	

Megascopically, the sample is an unconsolidated pinkish-white quartz sand in which the color is produced by a slight iron hydroxide coat; microscopically, a fairly pure quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 47 are represented by Histogram 47; of the division of the Very Fine Sand, by the table:

Light minerals	97.2 percent
Heavy minerals	2.8 percent

Microscopic Examination

I. Very Coarse Sand: It is composed of grains of quartz, most of which are partly rounded and glassy-surfaced, but a few of which are well rounded and frosted.

II. Coarse Sand: Its composition is the same as that of the Very Coarse Sand except for the addition of a few dark mineral grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand except that the quartz grains are more angular and that it includes a few talc-like grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: They are principally angular grains of glassy-surfaced quartz, in which wavy extinction is rare. Inclusions of the Irregular type are abundant; of the Regular type, in which zircon alone can be identified, common; of the Acicular type, very rare. There are also several grains of chert, a few grains of light green glauconite, and a few grains of highly altered orthoclase.

B. Heavy minerals: Zircon, kyanite, rutile, staurolite, tourmaline are common; andalusite, sillimanite, leucoxene, ilmenite, rare; monazite, xenotime, epidote, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, a few dark mineral grains, and a few yellowish-green clay-like grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of yellow clay.

Interpretation

The very small quantity of clay and silt and the considerable degree of sorting suggest the action of waves or wind in the environment of deposition. The absence of mica may favor wind rather than wave action, but the type of bedding and the predominance of glassy-surfaced quartz grains are stronger evidences against wind action.

A littoral or neritic environment in which waves acted as the sorting agent was the most probable condition. The presence of but few grains of glauconite are in agreement with this interpretation, although these grains are too few to eliminate the possibility of a detrital origin. The few frosted grains can be accounted for by considering them to have been blown in or washed in from a neighboring area.

CLAIBORNE SAMPLE 48

Location, Position, and Character

The sample was collected one-half mile south of Decatur on the road to Newton, from the upper part of the Kosciusko member, where a road cut exposes 20 feet of evenly bedded white sand (Sample 48 composite). Megascopically, it is an unconsolidated sand having the appearance of "salt and pepper," because of the abundance of dark minerals; microscopically, a fine grained sand in which some of the quartz grains are coated slightly with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 48 are represented by Histogram 48; of the division of the Very Fine Sand, by the table:

Light minerals	33.1 percent
Heavy minerals	66.9 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of well rounded quartz grains, most of which have a frosted surface.

III. Medium Sand: It is composed principally of subangular glassy-surfaced quartz grains; subordinately of a few well rounded frosted quartz grains and a few dark minerals.

IV. Fine Sand: Its composition is the same as that of the Medium Sand, except that the dark minerals are more abundant.

V. Very Fine Sand:

A. Light minerals: They are chiefly glassy-surfaced angular quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, many of which have a linear arrangement, are common; of the other types, rare. There are also a few grains of light green glauconite.

B. Heavy minerals: Kyanite, sillimanite, zircon, tourmaline, rutile are common; staurolite, leucoxene, ilmenite, rare; and epidote, clinozoisite, very rare.

VI. Coarse Silt: It is composed of dark mineral grains, a few quartz grains, and white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of gray clay studded with dark mineral grains and quartz grains.

Interpretation

The characteristics of this sand are so similar to those of Sample 47 that a similar interpretation of its origin seems warranted. In this sand the greatest quantity exists in the fine grade size, whereas in the previous sample it is in the medium grade size. The sand of Sample 47 also shows more sorting. These differences suggest a difference in the strength of the sorting agent, or a difference in the character of material brought to the environment of deposition.

CLAIBORNE SAMPLE 49

Location, Position, and Character

The sample was collected in the Illinois Central Railroad cut just south of Kosciusko, from the middle part of the Kosciusko member, consisting here of 25 feet of irregularly bedded (water type) white to pink sand containing lenses of gray shale (Sample 49 composite of sand about middle of section). Megascopically, it is an unconsolidated cream-colored sand; microscopically, a fine grained quartz sand in which the grains are slightly coated by iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 49 are represented by Histogram 49; of the division of the Very Fine Sand, by the table:

Light minerals............................	97.4 percent
Heavy minerals..........................	2.6 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed principally of subangular glassy-surfaced quartz grains; subordinately of a few well rounded frosted quartz grains, a few white mica flakes, a few talc-like grains, and a few dark mineral grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are mostly angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, many of which have a linear arrangement, are common; of the Regular type, in which zircon and apatite? can be identified, fairly common; of the Acicular type, very rare. They are subordinately several grains of chert, a few grains of highly altered plagioclase, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, kyanite, tourmaline, staurolite, rutile are common; sillimanite, leucoxene, ilmenite, rare; and xenotime, monazite, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, of several dark mineral grains, of clay aggregates, and of white mica flakes.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studded with a small number of mineral grains.

Interpretation

The high degree of sorting and the small quantity of silt and clay favor the activity of a strong sorting agent such as waves or wind. The position and quantity of the grade next in abundance to the maximum is suggestive, according to the generalization of Udden,[166] of wind rather than water. Evidence against this conclusion is afforded by the character of the bedding and the glassy surface of the quartz grains. The interbedded lenses of gray clay in the outcrop are more compatible with water than with wind action, but do not yield decisive evidence for either one.

The evidence seems to favor an interpretation of littoral or neritic environmental conditions where there was considerable wave action.

CLAIBORNE SAMPLE 50

Location, Position, and Character

The sample was collected 12 miles west of Kosciusko on the road to West from the upper part of the Kosciusko member, where a road cut exposes 25 feet of irregularly bedded (water type) white sand (Sample 50 composite). Megascopically, it is an unconsolidated cream-colored sand; microscopically, a fairly pure fine-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 50 are represented by Histogram 50; of the division of the Very Fine Sand, by the table:

Light minerals	97.0 percent
Heavy minerals	3.0 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed chiefly of subangular glassy-surfaced quartz grains; subordinately of a few well rounded frosted quartz grains, several white mica flakes, and a few talc-like grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are mostly angular quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are most abundant; of the other types, rare. There are also a few grains of chert, a few altered grains of sodic plagioclase, and a considerable number of flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, kyanite, staurolite, tourmaline, rutile are common; sillimanite, leucoxene, ilmenite, rare; and monazite, epidote, corundum, very rare.

VI. Coarse Silt: About 75 percent of the fraction is composed of angular grains of quartz; the rest, of dark minerals, flakes of white mica, and white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of white clay studded with a considerable number of distinct mineral grains.

Interpretation

The characteristics of this sample are similar to those of Sample 49. The interpretation suggested for that sample is, therefore, favored for this sand also.

CLAIBORNE SAMPLE 51

Location, Position, and Character

The sample was collected four miles southeast of Quitman on the Carmichael Road, from 10 feet of sand in the upper part of the Chickasawhay member, where a road cut exposes more than 90 feet of this member (Second Section under Lisbon formation). Megascopically, it is an unconsolidated yellow sand locally cemented with iron hydroxide; microscopically, a fine grained quartz sand in which some grains are partly coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 51 are represented by Histogram 51; of the division of the Very Fine Sand, by the table:

Light minerals	96.1 percent
Heavy minerals	3.9 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of subangular glassy-surfaced quartz grains and a few flakes of white mica.

III. Medium Sand: It is composed principally of quartz grains, most of which are subangular and glassy, but a few of which are well-rounded and have a frosty surface; subordinately, of white mica flakes and a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except for the presence of a few grains of light green glauconite.

V. Very Fine Sand:

A. Light minerals: About 10 percent is light to dark green glauconite grains whose indices of refraction range from about 1.55 to about 1.60. In less amounts are several slightly altered grains of orthoclase and albite, and a few flakes of white mica having the properties of muscovite.

They are mainly angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are common; of the Regular type, in which zircon, tourmaline, and apatite? are identifiable, rare; of the Acicular type, rare.

B. Heavy minerals: Kyanite, sillimanite, zircon, staurolite, rutile are common; tourmaline, leucoxene, ilmenite, rare; and epidote, xenotime, andalusite, very rare. Some of these minerals are concentrically coated by glauconitic material.

VI. Coarse Silt: It is composed chiefly of brown clay aggregates; subordinately of a few quartz grains, white mica flakes, and dark mineral grains.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of brown clay studded with a few distinct mineral grains.

Interpretation

The great concentration of the sand in one grade size and the small quantity of silt and clay indicate the action of a strong sorting agent such as waves or wind.

The presence of glauconite, the gradation of this sand into the overlying marine beds, and the general glassy surface of the quartz grains indicate deposition in a marine environment in which waves were the sorting agent. Deposition in a littoral or neritic environment is, therefore, the most likely interpretation of this sand. The few frosted grains are to be accounted for as they have been in previous samples.

CLAIBORNE SAMPLE 52

Location, Position, and Character

The sample was collected 1 1/2 miles north of Stonewall along the banks of the Chickasawhay River, from the lower part of the Chickasawhay member.

Section 1 1/2 miles north of Stonewall

	Feet	Feet
Chickasawhay member		7
2. Sand, brown shale, and irregular masses of glauconite	3	
1. Sand, massively-bedded glauconitic (Sample 52 composite)	4	

Megascopically, the sample is an unconsolidated grayish-green silty glauconitic sand; microscopically, a poorly sorted sand containing considerable clay and silt. The glauconite ranges from light to dark green and shows the two types of alteration described in the analysis of Sample 40.

Mechanical Analysis

The results of the mechanical analysis of Sample 52 are represented by Histogram 52; of the division of the Very Fine Sand, by the table:

Light minerals	97.1 percent
Heavy minerals	2.9 percent

Microscopic Examination

I. Very Coarse Sand: It is composed of subangular, glassy-surfaced quartz grains, a few mica flakes, and a few dark mineral grains.

II. Coarse Sand: About 75 percent is composed of quartz grains. Most of them are subangular and glassy-surfaced, but a few are well-rounded and frosted. The rest is mainly made up of light to dark green glauconite that varies in shape from round to mammalary or discoidal. A very few glauconite grains have the shape of foraminifera. A still smaller amount is composed of a few aggregates of pyrite and a few flakes of white mica.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: About 45 percent of this fraction is composed of glauconite whose indices of refraction range from approximately 1.54 to 1.60. About 50 percent is angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are common; of the other types, rare. Some of the quartz grains are concentrically coated with glauconitic material. A small amount consists of a few grains of altered albite and orthoclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Pyrite, zircon, kyanite, tourmaline, staurolite are common; rutile is rare; and monazite, xenotime, ilmenite are very rare. Some of these minerals are concentrically coated by glauconitic material.

VI. Coarse Silt: It is composed chiefly of angular quartz grains; scantily of grains of glauconite, fragments of translucent yellow clayey material, flakes of white mica, and grains of a dark mineral.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of green clayey material studded with a few distinct mineral grains.

Interpretation

The histogram of this sand yields no evidence of the conditions under which it was deposited.

The abundant glauconite is indicative of a marine environment of accumulation. The absence of sorting suggests that the marine environment was located beyond the influence of strong wave action. Such conditions would be fulfilled in a part of the neritic environment protected from wave action, where material was supplied faster than it could be sorted by the surf, or in water too deep for effective sorting. The few frosted grains are to be accounted for in the manner noted for previous samples.

CLAIBORNE SAMPLE 53

Location, Position, and Character

The sample was collected four miles north of Newton on the road to Doolittle, from the middle part of the Chickasawhay member.

Section four miles north of Newton

	Feet	Feet
Chickasawhay member		25
3. Shale, grayish-brown, and irregularly interbedded fossiliferous glauconitic sand	6	
2. Sand, yellowish-white glauconitic (Sample 53 composite)	4	
1. Marl, fossiliferous glauconitic, sandy	15	

Megascopically, the sample is an unconsolidated yellow sand; microscopically, a poorly sorted fine-grained glauconitic sand. Some of the quartz grains are stained by limonite. The glauconite is similar in its characteristics to that described in the previous sample.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 53 are represented by Histogram 53; of the division of the Very Fine Sand, by the table:

Light minerals	99.7 percent
Heavy minerals	.3 percent

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: It is composed of grains of well-rounded, glassy-surfaced quartz.

II. Coarse Sand: It is composed principally of subangular glassy-surfaced quartz grains, and subordinately of glauconite similar to that just described.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are mainly angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions are common; the Irregular type, most common; the other types, rare. About 15 percent is composed of glauconite having indices of refraction ranging from 1.55 to 1.60. Slightly altered albite and orthoclase make up about 5 percent of this fraction. A few grains of chert and several flakes of white mica having the properties of muscovite are also present.

B. Heavy minerals: Kyanite, tourmaline, staurolite, zircon are common; sillimanite, rutile, leucoxene, ilmenite, rare; and xenotime, zoisite, monazite, very rare. Some of these minerals are concentrically coated with glauconite.

VI. Coarse Silt: It is composed of quartz grains, grains of yellow clay-like mineral, a few dark minerals, and flakes of white mica.

VII. Medium Silt: It is composed of yellow clay-like grains and a few quartz grains.

VIII. Fine Silt and Clay: The composition is the same as that of the Medium Silt.

Interpretation

The sand is underlain and overlain by marine fossiliferous marl. The sand itself possesses considerable glauconite. These facts point to a marine environment of deposition. The histogram shows a fair degree of sorting and a small amount of clay and silt. The suggested interpretation is, therefore, that of deposition in a neritic environment under the influence of some sorting action. Since this sand is only fairly sorted, suitable conditions for its accumulation would be found where wave action was not very strong, or where more material and of a larger size was supplied to the sea than the waves could effectively sort.

CLAIBORNE SAMPLE 54

Location, Position, and Character

The sample was collected 4 1/2 miles east of Walnut Grove on the road to Sebastapool, from the middle part of the Chickasawhay member, as a section of a road cut at that place, presented under the Lisbon formation, shows. Megascopically, it is an unconsolidated "salt and pepper" glauconitic sand; microscopically, a medium-grained glauconitic, quartz sand. A few of the quartz grains are coated with iron hydroxide. The glauconite ranges from light to dark green and is altered in the two ways described in the analysis of Sample 40.

Mechanical Analysis

The results of the mechanical analysis of Sample 54 are represented by Histogram 54; of the division of the Very Fine Sand, by the table:

Light minerals	96.7 percent
Heavy minerals	3.3 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed principally of quartz grains, most of which are subangular and glassy-surfaced, but a few of which are well-rounded and frosted; subordinately of a few glauconite grains of the types just noted.

III. Medium Sand: Its composition is the same as that of the Coarse Sand, except for the addition of a few flakes of white mica and a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: About half of the fraction is composed of glauconite having indices of refraction ranging from approximately 1.55 to approximately 1.60. The rest is composed of angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, many of which have a linear arrangement, are rare; of the other types, very rare. And still a small amount is composed of several flakes of white mica having the properties of muscovite and several altered grains of albite, orthoclase, and microcline.

B. Heavy minerals: Kyanite, zircon, staurolite, sillimanite are abundant; rutile, tourmaline, leucoxene, ilmenite, common; epidote, monazite, xenotime, titanite, very rare.

VI. Coarse Silt: About half of the fraction is composed of grains of quartz and half of yellow clay material; a small amount of a few dark mineral grains and a few white mica flakes.

VII. Medium Silt: It is composed of yellow clayey material having a few angular quartz grains.

VIII. Fine Silt and Clay: The composition is the same as that of the Medium Silt.

Interpretation

The histogram of this sand shows that over 90 percent of the material is in the medium and fine grades. An examination of the medium grade size showed it to be largely near the lower limit, and an examination of the fine grade size showed it to be mainly near the upper size limit. The dominant grade of this sand is, therefore, about .25 mm.; consequently the histogram does not accurately show its high degree of sorting.

The high degree of sorting and the small amount of silt and clay in the sediment suggest the action of a strong sorting agent such as waves or wind. The presence of glauconite and the predominance of glassy-surfaced quartz grains indicate a marine environment of deposition. The probable interpretation of this sand is a neritic environment of deposition where effective sorting by waves was possible.

CLAIBORNE SAMPLE 55

Location, Position, and Character

The sample was collected four miles north of Carthage on the Renefro Road, from the lower part of the Chickasawhay member, where a road cut exposes 15 feet of irregularly bedded (water type) yellow sand (Sample 55 composite). Megascopically, it is an unconsolidated yellow quartz sand; microscopically, a fairly pure medium-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 55 are represented by Histogram 55; of the division of the Very Fine Sand, by the table:

Light minerals	98.1 percent
Heavy minerals	1.9 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of subangular glassy-surfaced quartz grains, a few well-rounded frosty-surfaced quartz grains, a few light green glauconite grains, a few talc-like grains, a few white mica flakes, and a few dark minerals.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are principally angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type are abundant; of the other types, rare. Zircon and tourmaline are the only mineral inclusions identifiable. They are subordinately a very few flakes of white mica having the properties of muscovite, a few light green grains of glauconite, several altered grains of albite and orthoclase, and a few grains of chert.

B. Heavy minerals: Zircon, kyanite, rutile, staurolite, tourmaline are common; sillimanite, leucoxene, ilmenite, rare; and monazite, xenotime, andalusite, very rare.

VI. Coarse Silt: It is composed of grains of quartz, a few white clay aggregates, a few flakes of white mica, and a few dark minerals.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studded with a few distinct mineral grains.

Interpretation

A strong sorting agent such as waves or wind is indicated by the high degree of sorting and the small amount of silt and clay. The type of bedding and the predominance of glassy-surfaced quartz grains are suggestive of water rather than wind as the agent of deposition. The absence of mica may be evidence of some wind action. Glauconite is present, but in a quantity too small to eliminate the possibility of detrital origin. The most probable interpretation seems to be that of deposition in a littoral or neritic environment where wave action was effective.

CLAIBORNE SAMPLE 56

Location, Position, and Character

The sample was collected at Dossville on the Carthage and Kosciusko Road, from the lower part of the Chickasawhay member, where a road cut exposes 10 feet of irregularly bedded (water type) yellow sand (Sample 56 composite). Megascopically, it is an unconsolidated yellow quartz sand; microscopically, a fairly pure medium-grained quartz sand in which some of the grains are coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 56 are represented by Histogram 56; of the division of the Very Fine Sand, by the table:

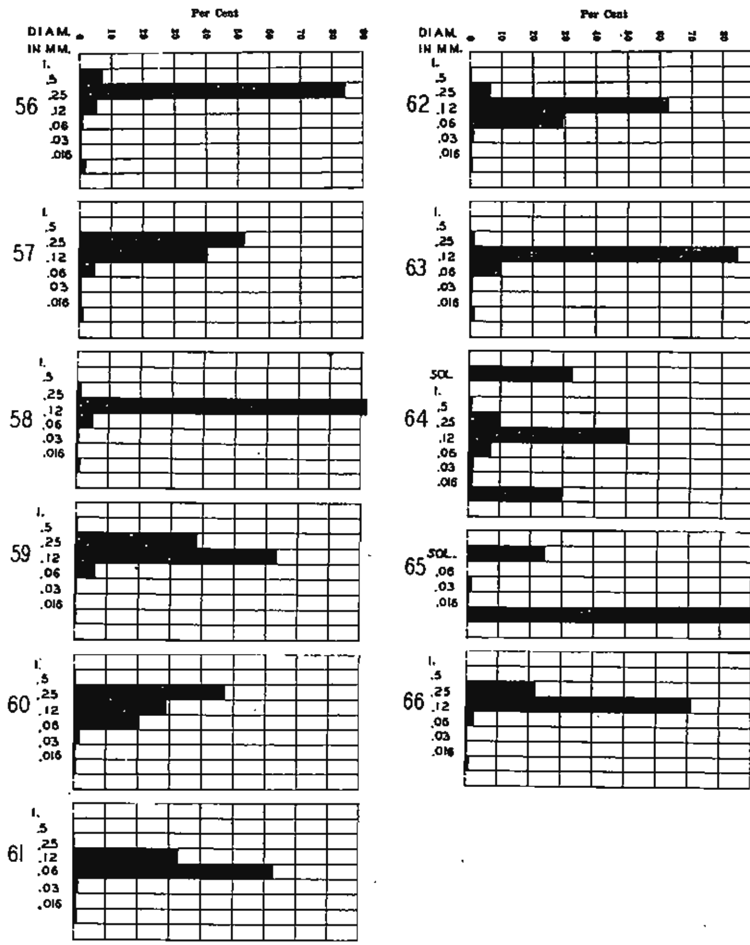
Light minerals	97.9 percent
Heavy minerals	2.1 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of subangular glassy-surfaced quartz grains, a few talc-like grains, and a few dark mineral grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand.



Histograms 56-63.—Histograms representing Claiborne Samples 56-63.
Histograms 64-66.—Histograms representing Jackson Samples 64-66.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: About 90 percent is composed of angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, a few of which show a linear arrangement, are common; of the other types, rare. About 5 percent is composed of flakes of white mica that have the properties of muscovite; 5 percent, of altered grains of albite, orthoclase, and microcline; and a less amount, of several grains of chert.

B. Heavy minerals: Kyanite, zircon are abundant; rutile, staurolite, sillimanite, leucoxene, ilmenite, common; tourmaline, epidote, rare.

VI. Coarse Silt: It is composed of grains of quartz, a few grains of a dark mineral, a few flakes of white mica, and a few grains of talc-like material.

VII. Medium Silt: It is composed of cream-colored clayey material and a few mineral grains.

VIII. Fine Silt and Clay: The composition is the same as that of the Medium Silt.

Interpretation

Histogram 56 shows the sand to be very well sorted. This character together with the small quantity of clay and silt suggests the action of a strong sorting agent.

The type of bedding, the considerable quantity of mica, and the non-frosted surface of the quartz grains indicate deposition by water rather than by wind. Accumulation of this sand in a littoral or neritic environment where effective wave sorting was possible is the interpretation favored.

CLAIBORNE SAMPLE 57

Location, Position, and Character

The sample was collected seven miles southwest of Thomastown on the Ofahoma Road, from the middle part of the Chickasawhay member, where a gully section shows 30 feet of regularly bedded red and white sand (Sample 57 from sand bed about the middle of the section) and thin interbedded lenses of purple clay. Megascopically, it is an unconsolidated cream-colored quartz sand locally cemented by iron hydroxide; microscopically, a fairly pure medium-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 57 are represented by Histogram 57; of the division of the Very Fine Sand, by the table:

Light minerals	97.3 percent
Heavy minerals	2.7 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed mainly of subangular glassy-surfaced quartz grains and a few well-rounded frosty-surfaced quartz grains. The remainder consists of flakes of white mica.

III. Medium Sand: It is composed of quartz grains like those in the Coarse Sand, a few white mica flakes, a few dark mineral grains, and a few talc-like grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are chiefly angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type are abundant; of the other types, rare. They are subordinately a few grains of chert, a few grains of altered orthoclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, staurolite, rutile, tourmaline are common; sillimanite, leucoxene, ilmenite, rare; and xenotime, garnet, monazite, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, a few dark minerals, and a few flakes of white mica.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studded with a few distinct mineral grains.

Interpretation

This sand is similar to Sample 54 in that over 90 percent of the material is concentrated in two adjoining grade sizes. As was shown in discussing that sample, the sand is better sorted than the histogram indicates. The same discussion holds for this sample.

The action of wind or waves is suggested by the high degree of sorting and the small quantity of silt and clay. Deposition by water rather than by wind is favored by the glassy surface of the quartz grains, the fair abundance of mica, and the character of the bedding. A littoral or neritic environment similar to that suggested for the previous sand was the probable site of deposition of this sediment.

CLAIBORNE SAMPLE 58

Location, Position, and Character

The sample was collected along the banks of the Big Black River at the Kosciusko-Durant Highway bridge, from the middle part of the Chickasawhay member, in an outcrop of 50 feet of white, slightly yellow streaked sand (Sample 58 composite). Megascopically, it is an unconsolidated quartz sand containing a sufficient number of iron hydroxide coated grains to produce a yellow color; microscopically, a fairly pure fine-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 58 are represented by Histogram 58; of the division of the Very Fine Sand, by the table:

Light minerals	97.7 percent
Heavy minerals	2.3 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of a few grains of well-rounded frosted quartz, a few grains of subangular glassy-surfaced quartz, and a few flakes of white mica.

III. Medium Sand: It is composed of subangular glassy quartz grains, a few well-rounded frosty-surfaced quartz grains, several talc-like grains, a few flakes of white mica, and a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: They are chiefly angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, many of which have a linear arrangement, are abundant; of the other types, common, zircon, tourmaline, apatite? being identifiable. There are also several grains of chert, a few grains of altered orthoclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon are abundant; staurolite, rutile, tourmaline, ilmenite, leucoxene, common; sillimanite, xenotime, epidote, monazite, garnet, very rare.

VI. Coarse Silt: It is composed chiefly of angular quartz grains, also of dark mineral grains, flakes of white mica, and yellow clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of yellow clay and a few mineral grains.

Interpretation

The characteristics of this sand are so similar to those of Sample 56 that similar conditions of deposition are suggested. The concentration of the material in the fine grade size in this sand in contrast to its concentration in the medium grade size in Sample 56 indicates a slight difference in the character of the material provided for the waves to sort and the strength of the surf action. For this sand, wave action only sufficient to remove clay, silt, and very fine sand is implied, whereas in Sample 56 it had to remove the fine sand also. This sand shows practically no material larger than the medium sand, whereas Sample 56 shows some coarse sand which indicates a difference in the character of the material brought to the two environments of deposition. Any coarse material like that represented by Sample 56 would have remained because of the feeble strength of the waves.

CLAIBORNE SAMPLE 59

Location, Position, and Character

The sample was collected along Fielders Creek, four miles east of Lexington, from the upper part of the Chickasawhay member, where the creek bank exposes 20 feet of irregularly bedded (water type) white sand having thin shale streaks parallel to the bedding (Sample 59 composite of sand). Megascopically, it is an unconsolidated white quartz sand; microscopically, a fairly pure medium-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 59 are represented by Histogram 59; of the division of the Very Fine Sand, by the table:

Light minerals	95.8 percent
Heavy minerals	4.2 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of many well-rounded glassy quartz grains and a few frosted quartz grains.

III. Medium Sand: It is composed of quartz grains like those in the Coarse Sand, a few flakes of white mica, a few talc-like grains, and several dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Coarse Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are chiefly angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, of which many have a linear arrangement, are abundant; of the other types, rare. They are subordinately a few grains of chert, a few altered grains of albite and orthoclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, kyanite, staurolite, xenotime, rutile, tourmaline are common; sillimanite, monazite, leucoxene. ilmenite, rare; and epidote, andalusite, very rare.

VI. Coarse Silt: It is composed of angular quartz grains, several dark mineral grains, a few white mica flakes, and a few white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of gray clay, a few quartz grains, and a few mica flakes.

Interpretation

The characteristics of this sample are so like those of the sand represented by Sample 57 that a similar littoral or neritic environment of deposition is suggested.

CLAIBORNE SAMPLE 60

Location, Position, and Character

The sample was collected 11 miles west of Vaiden on the Blackhawk Road, from the lower part of the Chickasawhay member, in a gully exposing 26 feet of irregularly bedded (water type) variably colored sand (Sample 60 composite). Megascopically, it is, except where locally cemented by iron hydroxide, an unconsolidated cream-colored sand in which a few grains are coated with that compound; microscopically, a fairly pure medium-grained quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 60 are represented by Histogram 60; of the division of the Very Fine Sand, by the table:

Light minerals	99.7 percent
Heavy minerals	.3 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: Except for a few grains of talc-like material, the entire fraction is composed of well-rounded glassy-surfaced quartz grains.

III. Medium Sand: Its composition is the same as that of the Coarse Sand except for the addition of a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand except that the quartz grains are more angular.

V. Very Fine Sand:

A. Light minerals: They are chiefly glassy-surfaced angular quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, of which many have a linear arrangement, are common; of the Regular type, in which zircon and tourmaline are identifiable, common; of the Acicular type, rare. There are also a few grains of chert, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon, kyanite are abundant; rutile, staurolite, tourmaline, ilmenite, leucoxene, common; xenotime, sillimanite, zoisite, very rare.

VI. Coarse Silt: It is composed of angular grains of quartz, a few flakes of white mica, several dark mineral grains, and a few white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of cream-colored clay studded with a few distinct mineral grains.

Interpretation

Several possible conditions of deposition are suggested by the characteristics of this sand. Histogram 60 is similar to the Histograms i, j of deltaic deposits. However, an objection to this interpretation is that such deposits might be expected to contain more clay and silt. The same objection can be raised to its interpretation as a fluvial sand. The almost complete absence of silt and clay suggests an effective sorting agent such as waves or wind. The general character of the bedding and the non-frosted surface of the quartz grains point to deposition by water rather than by the wind. The most plausible interpretation of this sand appears to be that of deposition in a littoral or neritic environment where wave action was sufficient to remove the clay and silt from the sand.

CLAIBORNE SAMPLE 61

Location, Position, and Character

The sample was collected two miles south of Newton on the road to Roberts, from the middle part of the Yegua formation.

Section of a road cut two miles south of Newton

	Feet	Feet
Yegua formation		20
3. Sand, irregularly bedded (water type) white; streaked with white clay (Sample 61 composite of sand)	5	
2. Covered	10	
1. Shale, massive gray sandy	5	

Megascopically, the sample is an unconsolidated cream-colored sand; microscopically, a fairly pure fine-grained quartz sand, a few grains of which are coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 61 are represented by Histogram 61; of the division of the Very Fine Sand, by the table:

Light minerals	98.9 percent
Heavy minerals	1.1 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of flakes of white mica, grains of subangular glassy-surfaced quartz, and a few grains of well-rounded frosty-surfaced quartz.

III. Medium Sand: About half of this fraction is composed of quartz grains, most of which are subangular and glassy-surfaced, but a few are well-rounded and frosted. The rest is composed of flakes of white mica and a few talc-like grains.

IV. Fine Sand: It is composed chiefly of grains of quartz similar to those in the Medium Sand; subordinately of a few talc-like grains, a few flakes of white mica, and a few dark mineral grains.

V. Very Fine Sand:

A. Light minerals: They are chiefly angular glassy-surfaced quartz grains in which wavy extinction is rare. Inclusions of the Irregular type, of which many have a linear arrangement, are common; of the other types, rare. They are subordinately a few grains of chert, several grains of altered albite, orthoclase, and microcline, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, sillimanite, staurolite are abundant; rutile, zircon, tourmaline, ilmenite, leucoxene, common; xenotime, monazite, epidote, zoisite, garnet, very rare.

VI. Coarse Silt: About 75 percent is composed of angular grains of quartz; the rest, of dark mineral grains, flakes of white mica, and white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of gray clay studded with a few mineral grains.

Interpretation

The condition of deposition suggested for this sand is a littoral or neritic environment where wave action was only sufficient to remove the clay and silt, and where practically no material coarser than fine sand was supplied to the environment of deposition. This conclusion appears warranted from the following evidence. The very small quantity of clay and silt and the great uniformity of grain size are suggestive of a strong sorting agent. The non-frosted surface of the quartz grains, the character of the bedding, and the considerable quantity of mica are evidences against an eolian origin. The explanation previously suggested for a few frosted grains in deposits of this origin could also apply here.

CLAIBORNE SAMPLE 62

Location, Position, and Character

The sample was collected one-half mile north of Harperville on the Walnut Grove Road, from the middle part of the Yegua formation.

Section of a road cut one-half mile north of Harperville

	Feet	Feet
Yegua formation		10
2. Sand, yellow, and interbedded gray shale	4	
1. Sand, massively bedded white (Sample 62 composite)	6	

Megascopically, the sample is an unconsolidated white quartz sand; microscopically, a slightly micaceous fine-grained quartz sand containing few other constituents.

MECHANICAL ANALYSIS

The results of the mechanical analysis of Sample 62 are represented by Histogram 62; of the division of the Very Fine Sand, by the table:

Light minerals	97.9 percent
Heavy minerals	2.1 percent

MICROSCOPIC EXAMINATION

I. Very Coarse Sand: No fraction.

II. Coarse Sand: About half of this fraction is composed of subangular grains of glassy quartz. The remainder is made up of flakes of white mica and a very few dark mineral grains.

III. Medium Sand: It is composed chiefly of angular glassy-surfaced quartz grains and subordinately of several flakes of white mica, a few dark mineral grains, and a few talc-like grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: They are principally glassy-surfaced angular quartz grains in which wavy extinction is rare. Inclusions of the Irregular type are abundant; of the other types, rare. They are subordinately several chert grains, several grains of altered orthoclase, and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite, zircon, sillimanite are abundant; staurolite, rutile, tourmaline, ilmenite, leucoxene, common; monazite, garnet, xenotime, andalusite, very rare.

VI. Coarse Silt: About 75 percent is composed of angular grains of quartz; the rest, of dark mineral grains, flakes of white mica, and white clay aggregates.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of white clay studded with a few aggregates of distinct minerals.

Interpretation

The small quantity of medium-sized sand is the only manner in which the sample differs from the previous sample. A similar environment of deposition is, therefore, suggested for this sand. To this neritic or littoral environment more medium sized sand was supplied than to the site of deposition of the previous sand.

CLAIBORNE SAMPLE 63

Location, Position, and Character

The sample was collected one-fourth mile east of the Pickens and Canton Highway just south of the Big Black River, from the lower part of the Yegua formation, as the section of a gully at that place, presented under the Yegua formation, shows. Megascopically, it is an unconsolidated yellow quartz sand; microscopically, a fairly pure fine-grained quartz sand, a few grains of which are coated with iron hydroxide.

Mechanical Analysis

The results of the mechanical analysis of Sample 63 are represented by Histogram 63; of the division of the Very Fine Sand, by the table:

Light minerals	97.2 percent
Heavy minerals	2.8 percent

Microscopic Examination

I. Very Coarse Sand: No fraction.

II. Coarse Sand: It is composed of flakes of white mica.

III. Medium Sand: It is composed principally of grains of quartz, most of which are subangular and glassy-surfaced, but a few of which are well-rounded and frosted; subordinately of several grains of talc-like material, a few flakes of white mica, and a few dark mineral grains.

IV. Fine Sand: Its composition is the same as that of the Medium Sand.

V. Very Fine Sand:

A. Light minerals: They are angular glassy-surfaced quartz grains, in which wavy extinction is rare. Inclusions of the Irregular type, a few of which have a linear arrangement, are abundant; of the other types, rare. They are also a few grains of chert, several grains of altered albite and orthoclase, and several flakes of white mica having the properties of muscovite.

B. Heavy minerals: Kyanite and zircon are abundant; rutile, staurolite, tourmaline, ilmenite, leucoxene, common; sillimanite, monazite, rare; and xenotime, epidote, andalusite, very rare.

VI. Coarse Silt: It is composed of angular grains of quartz, a few dark minerals, several flakes of white mica, and several white grains of clay.

VII. Medium Silt: Its composition is the same as that of the Coarse Silt.

VIII. Fine Silt and Clay: The fraction is composed of gray clay studded with a few distinct mineral grains.

Interpretation

The histogram of this sample shows it to have a small quantity of clay and silt and a great concentration of sand in one grade size, which suggests the action of a strong sorting agent in the environment of deposition. The general glassy surface of the quartz, the character of the bedding, and the presence of considerable mica suggest deposition in water rather than in the air. Thus a littoral or neritic environment seems most probable as the site of deposition. Added weight to this conclusion is furnished by the overlying beds of glauconitic sand.

The outcrop section, showing that this sand is interbedded with silty shale, points to an environment where conditions were not constant. Such material could be deposited in a littoral environment where the influx of material was variable, where shore currents were changeable, or where wave activity was not constant.

SUMMARY OF CONDITIONS OF DEPOSITION SUGGESTED BY THE ANALYSES

MERIDIAN MEMBER

All of the analyses of the Meridian member were interpreted as indicating near shore marine deposition where there was sufficient wave action to perform considerable sorting. Whether deposition took place in the littoral or neritic part of the marine environment was not determinable from most samples.

Analyses of all the sands showed extremely small quantities of silt and clay, and analyses of all but one showed the dominant grade size to be medium or fine sand. Since the sands came from outcrops scattered laterally across the state and vertically through the section, this uniformity suggests that there was no pronounced variation in the character or size of material brought to the environment of deposition in different parts of the area throughout Meridian time, and that wave activity varied little from east to west across the state or in the course of Meridian time.

BASIC MEMBER

The fossil fragments in the Basic sediments show that the environment was marine, probably neritic. The character of the material as shown by thin sections suggests that the sea floor on which these sediments accumulated was covered by a gelatinous mass of material at least in part derived from the solution of siliceous organic remains. Considerable quantities of glauconite and detrital material were deposited with the basal and upper portions of this siliceous material, but practically none in the middle part. Many grains of glauconite were somewhat silicified, but the detrital quartz seems to have remained mostly unchanged.

The presence of fragments of this siliceous material scattered through the sand of the transition zones from the Basic member to overlying and underlying sands indicates that consolidation must have taken place soon after deposition.

WINONA MEMBER

Analyses suggest that these sediments were deposited in a littoral or neritic environment. Samples 39, 40, 41, and 42 from the typical Winona indicate a neritic rather than a littoral environment. The differences in the degree of sorting and the abundance of silt and clay suggest some slight variation in the conditions under which this material accumulated. These variations may have been in the strength of wave action, in the rate at which material was brought to the environment of deposition, in the depth of water, or in the rate of subsidence of the area of accumulation.

Samples 43 and 44 from the "sand wedge" indicate that it was deposited in a littoral environment where there was pronounced sorting action by the waves. If this interpretation be correct, the "sand wedge" indicates a temporary local interval of littoral conditions in the general neritic environment of Winona time.

KOSCIUSKO MEMBER

The analyses of the material from the Kosciusko member all suggest a littoral or neritic environment of deposition where there was considerable sorting by waves. All the samples show very small amounts of clay and silt, the dominant grade size in the fine or medium sand, no material larger than very coarse sand, and very small quantities of material larger than the medium or coarse sand. This pronounced similarity of material indicates uniformity in the environment of deposition and in the material supplied to the environment in Kosciusko time.

CHICKASAWHAY MEMBER

The analyses of the samples suggest a marine environment. Samples 51, 52, 53, and 54 from the eastern part of the state further suggest that the material accumulated in a neritic part of the marine environment where the detailed conditions of deposition, such as the rate at which material was supplied, the effectiveness of wave action, the depth of the water, and the rate of subsidence, were subject to some variation.

The remainder of the samples from the central and western parts of the state can be interpreted as either neritic or littoral sediments. These samples show decided uniformity of composition, pointing toward rather constant environmental conditions during their interval of accumulation.

One character common to all samples is the absence of any appreciable amount of material larger than the medium sand grade. This indicates a constancy in the size of material brought to the area of accumulation.

YEGUA FORMATION

The interpretations suggested for all of the Yegua samples are that they were deposited in a littoral or neritic environment where wave action was sufficient to remove the clay and silt. Also the uniform composition of the sands is probably indicative of uniform conditions in the area of deposition and a uniform supply of material.

MINERAL COMPOSITION

LIGHT MINERALS

Quartz is the dominant mineral constituent of the Claiborne sands. With the exception of a few grains of the smoky, amethystine, and milky varieties, the quartz is colorless and transparent. Most of the grains possess a smooth glassy surface; a few, a well-rounded frosty-surface. These frosted grains are more conspicuous in the larger grain sizes, but are not limited to those grades. There seems to be no difference between the degree of rounding of the Claiborne quartz grains and the Wilcox quartz grains. This rounding may suggest that the immediate source area of the Claiborne sands, like that of the Wilcox sand, was composed of sedimentary rock.

Most of the quartz grains show straight rather than wavy extinction. The relative abundance of strained and unstrained grains is the same as in the Wilcox sand. Every sample contains some grains, usually in the coarser grade sizes, that are well fractured, which causes many of these grains to appear opaque.

Inclusions in the quartz grains are fairly abundant. Most of the grains have some inclusions, and a few have sufficient numbers to produce a dirty appearance. Of the three types recognized by Mackie,[167] the Irregular type is by far the most abundant, the Regular type is common, and the Acicular type is rare. Except for a few specimens in which cavity or gas inclusions could be determined, the individual Irregular type inclusions are too small for identification. In grains possessing a considerable number of inclusions of this type, many of the individuals have a linear arrangement.

The Regular inclusions were commonly too small for identification. Zircon was the only common mineral inclusion. The inclusions of the Acicular type could not be positively identified, but they appeared to be needles of rutile.

The inclusions suggest, according to Mackie's classification,[168] that the ultimate source area of the Claiborne quartz was composed principally of acid igneous rocks.

Glauconite, in the unbroken state in the Claiborne sands is round, mammalary, discoidal, or flattened. Many of the grains have a saucer-shape as if they had been squeezed out, and only a very few have the shape of foraminifera. Two distinct types of alteration were very common: (1) all stages from fresh dark green individuals to masses of brown limonitic material; and (2) all stages from dark green glauconite to light green individuals, and thence to white clay-like material. Both types of alteration seem to have started along fractures, so that many grains show residual areas surrounded by partly or thoroughly altered material. Some samples contained both light and dark green grains without any gradation between them. There is no evidence that all light colored grains were derived from those of a darker color although this is commonly true. These alteration characteristics were observed in unanalyzed material so that they are not the result of any bleaching or leaching by acid during the process of analysis.

As the two types of weathering took place in the same horizon seemingly under the same conditions, the reason for the two must be a difference in the initial glauconite. The chemical composition of glauconite is known to be variable. If a decided variation in the iron content is postulated, glauconite having very little iron might weather to a white or very light green material; and the glauconite having considerable iron, to a red material. Since all recorded analyses of glauconite, so far as the writer knows, show appreciable iron this explanation finds little support. An alternative explanation is that the iron is removed from some grains as fast as it is liberated by weathering, thus lightening the color but not producing any associated iron hydroxide. In other grains the iron remains with the grains as the oxide or hydroxide after it has been liberated. Neither explanation is very satisfactory; consequently it is not clear how the original character of the grains determined the type of weathering.

Goldman[169] has shown that the glauconite associated with stratigraphic breaks in the Bend series of North-central Texas is usually more abundant, coarser, more irregular, and of deeper color than that elsewhere in the series. This generalization cannot be applied to the Claiborne series. The fact that one color may be formed secondarily from the other makes it manifestly impossible to apply color generally as a criterion for the location of stratigraphic breaks.

It is not proposed to enter here into a discussion of the various ideas concerning the origin of glauconite beyond stating the evidence afforded by the Claiborne glauconite. Previous explanations can be obtained from the works of Collet,[170] Murray and Renard,[171] Goldman,[172] and Takahasi and Jagi.[173]

The almost complete absence of foraminiferal casts or of any other apparent organic remains associated with much of the Claiborne glauconite suggests that organic material is not necessary in the formation of the mineral as has been suggested by Collet[174] and Murray and Renard.[175]

The weathering of the glauconite suggests that in some of the grains the iron is easily removed. Microscopic examination showed decided variation in the index of refraction which probably is to be explained by a variation in the iron content. These features and the consideration of the glauconite-coated Heavy minerals have led to the conception that glauconite may form from siliceous material by the gradual adsorption of iron and potassium followed by recrystallization rather than from an initial clay of ferric hydroxide stage as has been suggested.

Feldspar, with one or two exceptions, is in very small quantities in the Claiborne sands. The grains usually show some alteration. Albite, microcline, and orthoclase, in about equal abundance, were the most common varieties. A few samples contained slightly more calcic varieties of plagioclase.

In the variety and quantity of feldspar the Claiborne sands are like the Wilcox sands. The possible explanation developed in discussing the scantiness of the feldspar in that material will also hold here; that is, an immediate source area generally lacking in feldspar, or conditions of erosion, transportation, and deposition tending to eliminate the mineral, or both.

Talc-like material in the Claiborne sands is identical with that found in the Wilcox sediments. Like that material, it is probably kaolinitic resulting from the thorough alteration of feldspar.

Muscovite in the different samples is in small and variable quantities. The mineral seems to be unaltered.

HEAVY MINERALS

In Table 5 are listed the minerals of the Heavy fraction of the Very Fine Sand of each sample in the approximate order of their abundance. On the pages following the table are listed the characteristics of the more important of these minerals.

Table 5.—Heavy minerals of each Claiborne sand sample arranged in order of their abundance

Meridian member

29. Kyanite, zircon, staurolite, tourmaline, ilmenite, leucoxene, rutile, spinel, garnet (grossularite), epidote, xenotime.
30. Zircon, kyanite, staurolite, tourmaline, rutile, ilmenite, leucoxene, xenotime, sillimanite.
31. Kyanite, zircon, staurolite, rutile, monazite, tourmaline, ilmenite, xenotime, leucoxene, hornblende.
32. Kyanite, zircon, staurolite, tourmaline, ilmenite, rutile, leucoxene, sillimanite, monazite, garnet (grossularite).
33. Kyanite, zircon, tourmaline, staurolite, rutile, ilmenite, monazite, spinel, leucoxene.
34. Zircon, kyanite, staurolite, tourmaline, rutile, leucoxene, ilmenite, xenotime, andalusite, flourite, monazite.
35. Kyanite, zircon, staurolite, rutile, tourmaline, ilmenite, leucoxene, monazite, sillimanite, corundum, xenotime.

Winona member

39. Kyanite, staurolite, zircon, tourmaline, rutile, leucoxene, ilmenite, monazite, sillimanite.
40. Ilmenite, kyanite, staurolite, zircon, rutile, tourmaline, sillimanite, epidote, xenotime, spinel, topaz, clinozoisite.
41. Kyanite, zircon, staurolite, tourmaline, ilmenite, rutile, topaz, monazite, sillimanite, xenotime.

42. Kyanite, zircon, staurolite, tourmaline, rutile, leucoxene, ilmenite, xenotime, zoisite, monazite, andalusite.
43. Kyanite, zircon, tourmaline, staurolite, rutile, ilmenite, leucoxene, xenotime, monazite, epidote.
44. Zircon, kyanite, staurolite, rutile, tourmaline, epidote, leucoxene, ilmenite, sillimanite, garnet (grossularite), andalusite.

Kosciusko member

45. Sillimanite, kyanite, tourmaline, staurolite, zircon, rutile, leucoxene, ilmenite, xenotime, tremolite?.
46. Kyanite, sillimanite, zircon, staurolite, tourmaline, rutile, monazite, leucoxene, ilmenite, anatase.
47. Zircon, kyanite, rutile, staurolite, tourmaline, andalusite, sillimanite, leucoxene, ilmenite, monazite, xenotime, epidote.
48. Kyanite, sillimanite, zircon, tourmaline, rutile, staurolite, leucoxene, ilmenite, epidote, clinozoisite.
49. Zircon, kyanite, tourmaline, staurolite, rutile, sillimanite, leucoxene, ilmenite, xenotime, monazite.
50. Zircon, kyanite, staurolite, tourmaline, rutile, sillimanite, leucoxene, ilmenite, monazite, epidote, corundum.

Chickasawhay member

51. Kyanite, sillimanite, zircon, staurolite, rutile, tourmaline, leucoxene, ilmenite, epidote, xenotime, andalusite.
52. Pyrite, zircon, kyanite, tourmaline, staurolite, rutile, monazite, xenotime, ilmenite.
53. Kyanite, tourmaline, staurolite, zircon, sillimanite, rutile, leucoxene, ilmenite, xenotime, zoisite, monazite.
54. Kyanite, zircon, staurolite, sillimanite, rutile, tourmaline, leucoxene, ilmenite, epidote, monazite, xenotime, titanite.
55. Zircon, kyanite, rutile, staurolite, tourmaline, sillimanite, leucoxene, ilmenite, monazite, xenotime, andalusite.
56. Kyanite, zircon, rutile, staurolite, sillimanite, leucoxene, ilmenite, tourmaline, epidote.
57. Kyanite, zircon, staurolite, rutile tourmaline, sillimanite, leucoxene, ilmenite, xenotime, garnet (grossularite), monazite.
58. Kyanite, zircon, staurolite, rutile, tourmaline, ilmenite, leucoxene, sillimanite, xenotime, epidote, monazite, garnet (grossularite).

59. Zircon, kyanite, staurolite, xenotime, rutile, tourmaline, sillimanite, monazite, leucoxene, ilmenite, epidote, andalusite.
60. Zircon, kyanite, rutile, staurolite, tourmaline, ilmenite, leucoxene, xenotime, sillimanite, zoisite.

Yegua formation

61. Kyanite, sillimanite, staurolite, rutile, zircon, tourmaline, ilmenite, leucoxene, xenotime. monazite, epidote, zoisite, garnet (grossularite?).
62. Kyanite, zircon, sillimanite, staurolite, rutile, tourmaline, ilmenite, leucoxene, monazite, garnet (grossularite), xenotime, andalusite.
63. Kyanite, zircon, rutile, staurolite, tourmaline, ilmenite, leucoxene, sillimanite, monazite, xenotime, epidote, andalusite.

Kyanite is present in considerable abundance in every sample. A slight development of gray secondary material on the surface and in the cleavage cracks is the only indication of any alteration. The grains are all rounded, but to a variable degree.

Zircon is present in all of the samples in considerable abundance. The individual grains are well rounded and show no alteration. Most of the grains are colorless, but a few of them are of the purple variety. Some of the grains show very perfect zoning. According to the work of Mackie,[176] the presence of purple zircon and the abundance of the mineral suggest the existence of a considerable amount of acidic igneous rock in the ultimate source area.

Staurolite is also found in every sample, but not so abundantly as kyanite or zircon. The individual grains, which vary in color from reddish-brown to yellowish-brown, are slightly rounded.

Tourmaline is present in small quantities in every sample. The individual lath-shaped or irregular grains are fairly well rounded, and are unaltered. Most of the tourmaline is of the yellowish-brown variety, but a few grains are of the blue variety.

Rutile is found in all the samples in about the same degree of abundance as tourmaline. The grains are irregular in shape, unaltered, and somewhat rounded. They vary from yellow to deep blood-red.

Ilmenite is probably present in every sample, but its determination was definite only in those samples showing partial leucoxene alteration. In a few others, however, grains that show no alteration but are otherwise identical with ilmenite are probably this mineral. All the grains are rounded. The quantity of ilmenite in different samples varies widely.

Leucoxene in widely ranging amounts is present in all but three of the samples. It is an alteration product of ilmenite definitely in most samples.

Sillimanite is found in small quantities in about two thirds of the samples. Most of the grains are fresh, but a few show a surface coating of a secondary gray material. All are somewhat rounded.

Xenotime is a rare constituent in about two-thirds of the samples. The grains are unaltered and somewhat rounded.

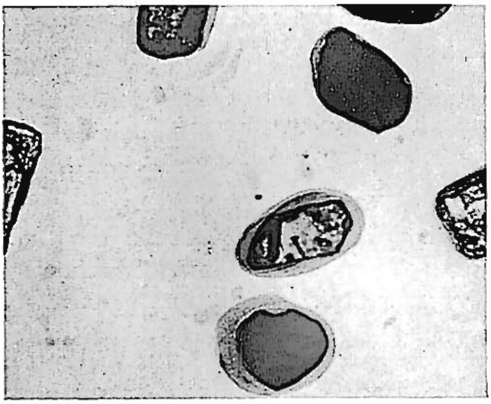
Monazite is a rare constituent in about two-thirds of the sands analysed. The individual grains are unaltered and well rounded.

The other mineral constituents are present in very small quantities in a few of the sands analysed. The individual grains are rounded. They are in general less resistant types than those abundantly present. They do not necessarily indicate a scarcity in the ultimate source area, since their existence may be due to fortuitous conditions which served to protect them from the fate of the remainder.

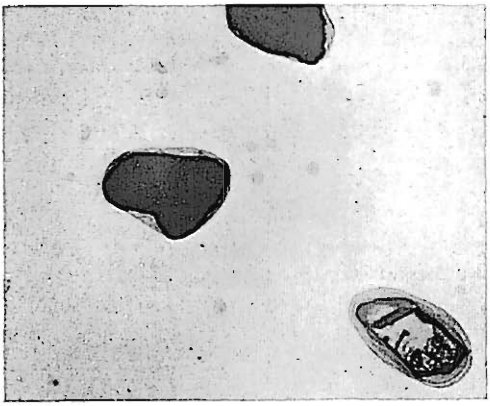
Glauconite-coated minerals were noted in several of the samples (Plate 2). Grains of zircon, tourmaline, staurolite, kyanite, and ilmenite partly altered to leucoxene were found so coated. But an extended search revealed only a few quartz grains thus coated. The index of refraction of the glauconite coating ranges from about 1.55 to about 1.60. Many of the grains show a very perfect concentric development of the coating.

The reason this material coated the non-quartz grains rather than the quartz grains is not clear. No similar structures have, so far as the writer knows, been described, but this may be due to the scantiness of petrographic work on sedimentary rocks. Consequently, it does not necessarily follow that they are unusual and that unusual conditions must be postulated for their origin. The fact that such grains are not confined to one bed, but are found in the Claiborne in all beds containing glauconite suggests that unusual conditions are not required for their development.

The coating is too fragile to have withstood transportation after it was once developed. The completeness of the concentric coating eliminates the possibility that it was formed by circulating waters



A



B

Plate 2.—Glauconite-coated heavy minerals from the Claiborne sands.
A. Sample 42 B. Sample 52

after deposition. Further, the sand is loose and unconsolidated. The coating must, therefore, have developed at the time of deposition, and probably before the mineral reached the sea floor.

Obviously this glauconite could not have passed through an initial clay stage unless it be postulated that the grains were coated with clay which then changed to glauconite, or that, after forming, the glauconite was dissolved and redeposited around the grains. The perfection of the coating makes such origins extremely unlikely. A more satisfactory explanation is that these grains were coated by siliceous material as they were deposited, and that the siliceous material was gradually altered to glauconite. Obviously, too, this glauconite has no direct relation to organic remains.

Another possibility is that iron hydroxide was deposited around the grains and that it was later altered to glauconite by the addition of silica and potassium. Although the conception of such an origin cannot be disproved, yet the postulate of an initial siliceous stage is favored, for reasons given in the discussion of the origin of glauconite.

Relation Between the Degree of Rounding of Wilcox and Claiborne Heavy Minerals

It was pointed out in discussing the Heavy minerals of the Wilcox series that the species of minerals present in some abundance showed two distinct degrees of rounding. In explanation it was suggested that the highly angular grains were derived directly from the parent source rocks, whereas the distinctly rounded grains were derived from sedimentary rocks; the angular grains being so because they had passed through but one cycle of sedimentation; and the rounded grains being so because they had passed through more than one cycle of sedimentation.

In the discussion of the Claiborne Heavy minerals all were shown to be rounded, although the actual amount of rounding varied. It follows that the Heavy minerals of the Claiborne sands passed through more than one cycle of sedimentation. This means that if the Wilcox and Claiborne sediments had about the same immediate source area, it was changed at the end of Wilcox time by the removal of the outcrop area of the igneous and metamorphic rocks. A comparison of Plates 1 and 3 will illustrate this difference between the Wilcox and Claiborne Heavy minerals.

Stratigraphic Distribution of the Heavy Minerals

The Heavy mineral composition of all the Claiborne sands is remarkably constant. The abundant minerals are uniformly present laterally across the state and vertically through the section. The only appreciable variation is in the rare constituents, and their very rareness is an adequate explanation of their presence in some samples and their absence in others.

The detailed characteristics of the individual mineral species are also constant across the state and through the section.

It seems safe to conclude on the basis of these facts that all the Claiborne material in Mississippi had the same ultimate source area, and about the same immediate source area.

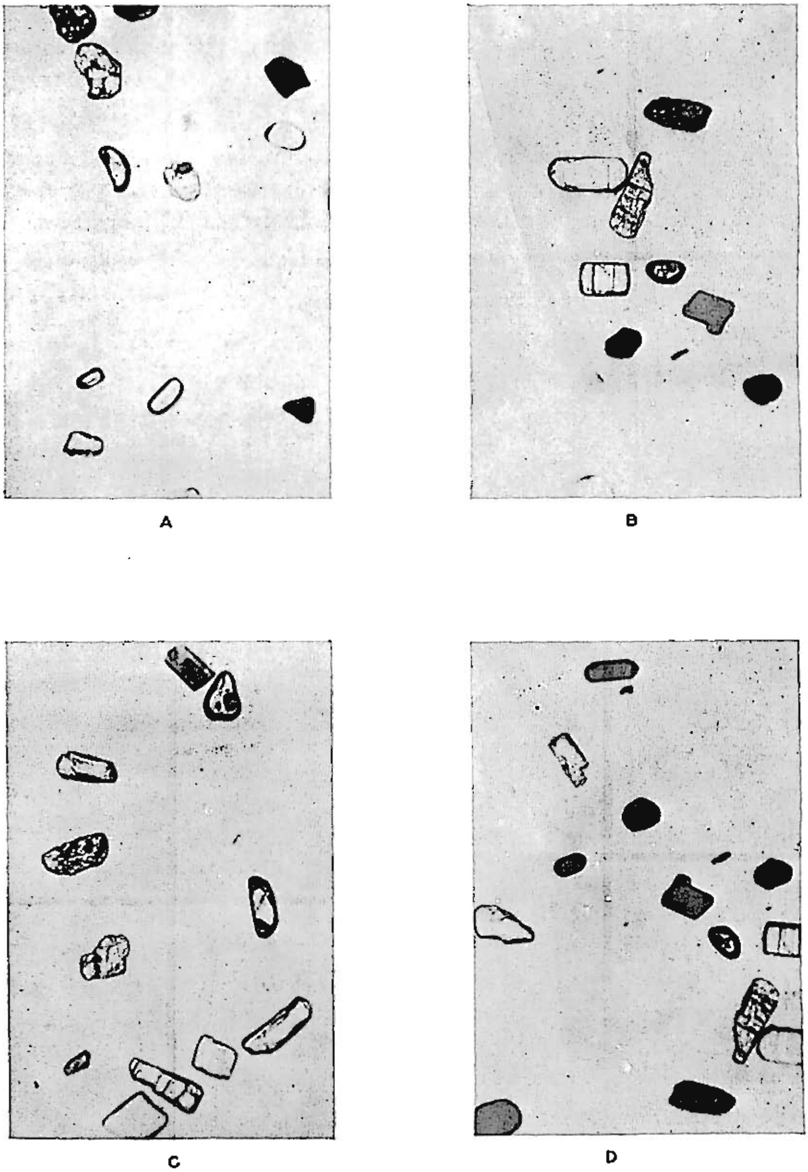


Plate 3.—Heavy minerals from the Claiborne sands showing the rounded character of the grains.

A. Sample 30 B. Sample 41
C. Sample 46 D. Sample 55

RELATION OF THE QUANTITY OF HEAVY MINERALS TO THE COARSENESS OF THE SEDIMENT AND TO CONDITIONS OF DEPOSITION

In Table 6 are listed the proportions of Heavy minerals and Light minerals in the Very Fine Sand of each sample and the suggested interpretation of the environment of deposition.

Table 6.—The relative abundance of the Heavy minerals and the Light minerals in the Very Fine Sand of the Claiborne samples and the postulated conditions of deposition.

Meridian member						
Sample	29	Light	97.9	Heavy	2.1	Littoral or Neritic
”	30	”	94.3	”	5.7	Littoral or Neritic
”	31	”	91.5	”	8.5	Neritic
”	32	”	99.0	”	1.0	Neritic
”	33	”	96.5	”	3.5	Neritic
”	34	”	98.3	”	1.7	Littoral or Neritic
”	35	”	97.2	”	2.8	Littoral or Neritic
Winona member						
Sample	39	Light	94.7	Heavy	5.3	Neritic or Littoral
”	40	”	99.6	”	0.4	Neritic
”	41	”	98.9	”	1.1	Neritic
”	42	”	98.9	”	1.1	Neritic
”	43	”	96.9	”	3.1	Littoral or Neritic
”	44	”	99.0	”	1.0	Littoral
Kosciusko member						
Sample	45	Light	99.6	Heavy	0.4	Littoral or Neritic
”	46	”	99.0	”	1.0	Littoral or Neritic
”	47	”	97.2	”	2.8	Littoral or Neritic
”	48	”	33.1	”	66.9	Littoral or Neritic
”	49	”	97.4	”	2.6	Littoral or Neritic
”	50	”	97.0	”	3.0	Littoral or Neritic
Chickasawhay member						
Sample	51	Light	96.1	Heavy	3.9	Littoral or Neritic
”	52	”	97.1	”	2.9	Neritic
”	53	”	99.7	”	0.3	Neritic
”	54	”	96.7	”	3.3	Neritic
”	55	”	98.1	”	1.9	Littoral or Neritic
”	56	”	97.9	”	2.1	Littoral or Neritic
”	57	”	97.3	”	2.7	Littoral or Neritic
”	58	”	97.7	”	2.3	Littoral or Neritic
”	59	”	95.8	”	4.2	Littoral or Neritic
”	60	”	99.7	”	0.3	Littoral or Neritic

Yegua formation

Sample	61	Light	98.9	Heavy	1.1	Littoral or Neritic
"	62	"	97.9	"	2.1	Littoral or Neritic
"	63	"	97.2	"	2.8	Littoral or Neritic

Sample 48, about two-thirds of which was composed of Heavy minerals, was collected from a "pay streak" or zone rich in such minerals. It cannot, therefore, be included in a general discussion of the Heavy minerals in the Claiborne sands. Kennedy[177] and later Boswell[178] described such "pay streaks." The natural panning process described by Kennedy as operating in modern littoral environments is the most satisfactory explanation of the manner of their formation. The similarity of the other characteristics of this sample, including its histogram, to those of other Claiborne sands deposited under the same conditions shows that the causes of "pay streaks" can operate without materially changing the other characters of a sand.

The samples, with the exception of Sample 48, show a range from 0.3 percent to 8.5 percent of Heavy minerals in the Very Fine Sand. Since 26 of the 31 samples show not more than 3.5 percent of Heavy minerals in this grade size, the abundance of these constituents seems to be rather constant.

Individual samples of the Claiborne sand, like those of the Wilcox, show an increase in abundance of Heavy minerals as the grain size decreases. In some of the samples there seemed to be a slight concentration of the Heavy minerals in the size next smaller than the dominant grade. If Heavy minerals supplied to the sorting agent were fairly abundant, if their specific gravity was fairly constant, and if they were not given added transportability by a characteristic such as the ability to break into thin flakes, a concentration would be expected in a quartz sand in a grade size smaller than the dominant grade because of their greater specific gravity. Probably because of the small quantity of Heavy minerals, this concentration is not evident in all of the Claiborne sands.

For the same reasons mentioned in discussing the Wilcox mineralogy, it is believed that the percentage of Heavy and Light minerals in the Very Fine Sand shows the relative abundance of these constituents in the whole sample. Detailed examinations of several samples show that this is true.

The abundance of Heavy minerals bears no evident relationship to the general coarseness or fineness of the individual samples; however, all the material is so nearly of the same grade size that no relation of this kind is apt to be pronounced.

It was noted in discussing the Wilcox sands that their Heavy minerals decreased in abundance as sorting increased. Thus the sediments interpreted as being deposited in a littoral environment where there was considerable sorting showed the least variation in the abundance of these minerals, and the lowest average quantities (0.79 percent to 3.31 percent and an average of from 1 percent to 2 percent). The less sorted sediments showed greater variations and a higher average abundance. The Claiborne sands are, in general, well sorted and were probably deposited in littoral or neritic environments. The abundance and variation in the Heavy minerals in these sands is similar to the abundance and variation in those of the Wilcox sands which were interpreted in the same way (84 percent of the samples contain from 0.3 percent to 3.5 percent of Heavy minerals). This suggests that the generalization reached for the Wilcox mineralogy may be widely applicable.

A comparison of Table 5 with Table 6 shows no apparent relation between the abundance of Heavy minerals and the individual species present.

LOCATION OF THE SOURCE AREA

A comparison of the mineralogy of the Wilcox and Claiborne sands shows that the same species are present in both sands. Further, the minerals have similar detailed characteristics and are about equally abundant in the two sands. Of all the minerals found in the Wilcox, only two (enstatite and hypersthene) were not found in the Claiborne. Five of the minerals (hornblende, flourite, corundum, clinozoisite, and anatase) found in the Claiborne have not been found in the Wilcox. In every case these minerals were rare or very rare, and were found in only a few samples. The extremely slight difference in mineralogy does not suggest any difference in source areas, since minerals as scantily present as these are certain to be present in some samples and not in others. Also these rare species are mainly less stable than the others; hence their preservation probably depends on some fortuitous events tending to protect them in the cycle of sedimentation.

This almost complete uniformity of minerals in the Wilcox and Claiborne sands must mean that the material came from the same ultimate source area. The suggested ultimate source area of the Wilcox sediments and also of the Claiborne sediments is the complex of ancient rocks located in the present Piedmont Plateau. The suggested immediate source area of the Wilcox sediments was the southern part of the Appalachian mountain area including the Piedmont Plateau and the older part of the Coastal Plains. The mineralogy suggests the same immediate source area for the Claiborne except that the Piedmont Plateau area is no longer to be included. This conclusion follows from a comparison of the Heavy minerals of the Wilcox with those of the Claiborne sands with respect to the degree of rounding (see previous pages).

PREVIOUS EXPLANATIONS OF CONDITIONS OF DEPOSITION

The Claiborne sediments in the eastern part of the Mississippi embayment area have always been considered to have accumulated under dominantly marine conditions. Hilgard[179] in his early work advanced this view, but erroneously interpreted the Claiborne sediments as the marine equivalent of his Lignitic material. Crider[180] and more recently Lowe[181] have followed Hilgard, in considering the Claiborne of Mississippi to be dominantly of marine origin.

Harris[182] suggested that the lower part of the Claiborne in the western part of the embayment area was of marine origin; whereas the upper part, probably corresponding to the present Yegua, was chiefly deposited under lagoonal and swamp conditions. Harris also suggested, as did Veatch[183] later, that conditions in the central and northern part of the Mississippi embayment throughout all of Claiborne time were decidedly less marine than those found elsewhere. They thought it probable that marine waters never extended into this area.

Tuomey[184] in his early work in Alabama showed the Claiborne to be marine in that state. Later Smith[185] and his associates pointed out the condition of deposition in greater detail. Lignitic time, according to them, ended not with an emergence, but with a seaward tilting of the land and a consequent increase in the depth of the off-shore water. These conditions induced the invasion of a deep sea fauna, the entombment of whose remains in littoral deposits gave rise to the Buhrstone. They further stated that the accumulation of Buhrstone material ended with the cessation of seaward tilting, and that the other beds now placed in the Claiborne were deposited in shallow marine water during a concomitant depression of the area.

According to Berry,[186] an emergence marked the end of Wilcox time; later the Gulf waters advanced northward permitting the deposition of the Tallahatta formation. The early Lisbon was marked by a slight initial retreat; the late Lisbon by the maximum advance of the Gulf waters in Claiborne time. The end of Lisbon time was again marked by a retreat of the Gulf waters. During Yegua time there was a slight advance of the sea followed at the end of the Claiborne by a withdrawal to the south. The Yegua is considered to have accumulated in an environment which included estuarine, littoral, and continental conditions.

SUMMARY OF THE CONDITIONS OF DEPOSITION OF THE CLAIBORNE SEDIMENTS

MERIDIAN MEMBER

As Wilcox time ended and Claiborne time began, the Gulf waters began a gradual northward migration caused by a relative subsidence of the land which was probably accompanied by some tilting of the portion being submerged. This caused a gradual change, with only local interpretations of deposition, from the non-marine conditions of the Wilcox to the littoral conditions at the initiation of Meridian time. As the Meridian progressed, subsidence and tilting continued, changing the environment from littoral to neritic. The depression of the area of accumulation was not uniformly continuous throughout this time as is shown by the occasional interbedded layers of lignitic shale. The presence of these beds does not necessarily mean that actual uplifts of the land took place as the sea receded southward; it is more probable that the failure of subsidence to keep ahead of deposition allowed the shore line to be pushed southward by accumulation. Later subsidence would bring the marine environment north again. Subsidence did not lag sufficiently behind accumulation to produce intervals of erosion, but simply altered the environment temporarily.

When this environment was in its marine stages, waves were rather uniformly and continuously active. Material was being carried to this environment from a single source area at a rate not too rapid to prevent sorting by wave action. There is no evidence of appreciably larger quantities of materials being supplied locally to the area of accumulation. This suggests that the material was being carried to the area of deposition by many small streams rather than by one or a few large ones.

In the western part of the State, the interbedded lignitic shales and glauconitic sands indicate that the alternation of non-marine and marine conditions was particularly pronounced.

BASIC MEMBER

The environmental conditions during the Basic interval were marine and probably neritic. The presence of glauconite, the character of the organic remains, and the absence of any indication of surf action are evidence for this conclusion. However, the presence of interbedded layers of lignitic material shows that non-marine conditions existed temporarily, and that the marine water was not very deep. The unusual material deposited during this time indicates that this neritic environment must have been unusual in some of its characteristics. Several possible explanations may be suggested to account for the presence of this unusual material.

Smith[187] and his early associates in Alabama stated that the beginning of this interval was marked by a pronounced seaward tilting of the land and a consequent increase in the depth of the off-shore water. According to them, these conditions induced the invasion of a deep sea fauna and the entombment of its remains in near-shore deposits. They regarded the siliceous material as being entirely composed of organic remains. Against this explanation can be raised the objection that there is no evidence of any entombing clastic material in much of the Basic sediment. Furthermore, the existence of fragments of Diatoms and probable Radiolarians in the material, which originally suggested this idea, does not necessarily indicate a deep sea fauna as the authors of this explanation believed. In fact the molluscan fossils in the sediment suggest that it is not of deep sea origin.

Another possible explanation is that in Basic time a rather sudden relative depression of the land took place, permitting a considerable northward migration of the shore line. The siliceous material then accumulated from an organic source at a distance from the shore line which could not be reached by clastic material from the land and in water too deep for effective wave action. Several objections can be raised to this explanation. The presence of interbedded lignitic shales, which would seem to indicate alternations between marine and non-marine conditions, make it improbable that any Basic material accumulated a long distance from the strand line. Furthermore, there is no evidence that any of the Claiborne formations ever extended appreciably farther landward than they do now.

Another explanation--the one favored by the writer--is that from time to time during the Basic great quantities of volcanic ash fell. According to this hypothesis, the matrix of the claystone material would be slightly silicified volcanic ash. The entombed organic remains and the absence of clastic detrital material in some horizons could follow naturally from such an origin. The interbedded layers of other types of sediments, such as lignitic shale, glauconitic sand, and the like are also easily explained by this conception. Successive ash falls would also account for thin streaks of this material in the higher Winona member. Variation in the rapidity of accumulation and in the quantity of ash would explain the absence of detrital grains at some stratigraphic positions and their abundance at others. If, however, the Basic claystone had a volcanic origin, distinctive structures should be present. Such structures could not be positively identified by the writer and others.[188] Facilities were not available to obtain chemical data which would aid in solving this problem.

Whatever the conditions under which this material accumulated, they extended all the way across Mississippi into Alabama.

WINONA MEMBER

As Basic time gradually changed into Winona time, conditions of deposition became neritic. From time to time in the early part of the Winona interval conditions reverted to those characteristic of the Basic interval, and layers of claystone-like material were deposited. Except for these changes and those responsible for the "sand wedge," conditions were generally uniform throughout Winona time all the way across Mississippi. There is no suggestion of stronger wave action at one place than at another or of any decided local variation in the supply of material. It would seem from the latter fact that many small streams rather than a few large ones brought the material to the area of accumulation.

The accumulation of this material indicates some subsidence and probably some tilting of the area of deposition. If this crustal movement all took place at the beginning of Winona time, the kind of material being deposited would have gradually changed from bottom to top along with the change in environment. As this is not the case, a gradual subsidence maintaining general uniform conditions appears most likely. A slight exception to the above statement is made necessary by the "sand wedge" in the western part of the state. Probably because more material was being brought to this region than elsewhere, subsidence did not keep sufficiently ahead of deposition to maintain uniform neritic conditions. As the area of accumulation became filled, conditions of deposition changed from neritic to littoral about middle Winona time. Later subsidence increased, and conditions reverted to neritic for the remainder of Winona time. The alternative explanation of less subsidence in this area is not compatible with the greater thickness of Winona material.

The Winona ended with a brief fairly general shift to non-marine conditions, permitting the deposition of lignitic shales.

KOSCIUSKO MEMBER

Environmental conditions during this time were dominantly shallow neritic or littoral. Since the bulk of the Kosciusko is well sorted sand, generally prevalent wave action is indicated. Such conditions seem to have existed entirely across Mississippi throughout this time. The uniformity of material suggests a uniform supply and deposition throughout Kosciusko time. As suggested for previous members, small streams rather than one or two large ones probably supplied the material.

For reasons similar to those developed in discussing the previous member, gradual subsidence and tilting are believed to have recurred in the area of accumulation during Kosciusko time. The greater thickness of the Kosciusko section in the west probably indicates greater subsidence in this region than in the east. As the character of the material is the same where the section is thicker, the amount or rate of subsidence could not have been great enough to change the environment. An alternative postulate for this greater thickness of sediment is that of an increase in the supply of material in this area. If an increased supply of material were the only explanation, changes in lithology would be expected, due to the filling of the original area of deposition and the altering of the environment. Such changes in lithology are not present; therefore, this explanation is not satisfactory. It follows that in an original environment of this kind, the thickness of uniformly lithologic beds along the strike is determined largely by the amount of subsidence rather than by the supply of material.

CHICKASAWHAY MEMBER

In the interval during which the Chickasawhay accumulated, environmental conditions varied from neritic to littoral or non-marine. To account for the lateral variations in thickness and lithologic variations of the material, non-uniform subsidence and probable tilting of the area of accumulation are postulated.

In the eastern part of the state subsidence was, in relation to the supply of material, usually rapid enough to maintain marine conditions. Periodic subsidence would provide, just after a lowering of the area, intervals favorable to accumulation in deep water during which rather unsorted glauconitic material would be deposited. Following this as the area of accumulation was filled and brought within reach of wave action well sorted sands would be deposited. Still later when filling further increased, non-marine conditions would develop. The series of marls, well sorted sands, and lignitic sands and clays which compose the Chickasawhay section in eastern Mississippi indicate such environmental conditions.

In the western part of Mississippi subsidence in relation to the supply of material was not rapid enough to maintain the prevailing marine conditions. The increased thickness of the section in this region shows that there was more actual subsidence than there was toward the east. To account for the less general marine conditions indicated by the lithology of the sediments, therefore, a greater supply of material must be postulated, which would keep the area of deposition so filled that marine conditions could not be common.

YEGUA FORMATION

The Yegua section all the way across Mississippi is similar to the section of the Chickasawhay member in the western part of the state. The conditions sketched as existing in that area at that time continued to exist throughout Yegua time. In the eastern part of the state Yegua conditions differed from those of Chickasawhay time in having a less prevalent marine environment. There is no suggestion of an interpretation of deposition between Lisbon and Yegua time.

This concept of only periodic and variable subsidence of Claiborne environmental conditions of deposition differs from previous explanations which postulated both up and down movements of the land. It seems to the writer that the facts to be explained, namely, the alternation of littoral, neritic, and non-marine conditions, can be accounted for without any upward movement. The thick accumulation of sediments unquestionably indicates subsidence, and if this subsidence is considered to be periodic and variable no other explanation is needed. This concept, in addition to its simplicity, is supported by the evidence of continuous deposition and vertical gradation of beds of one environment into those of another. The writer is inclined to the idea that subsidence is a major control in the accumulation of material in environments such as those outlined for the Claiborne.

Many factors may operate in environments such as these which would cause variations in the lithology of accumulating sediments. Among such factors are configurations of the shore line, variation in intensity of wave action, and lateral abundance of material being supplied. It has been suggested by Trowbridge[189] that a temporary shift in the general direction of the wind would cause local variations.

In the discussion of the Claiborne sediments some tilting of the area of accumulation was postulated along with subsidence. Subsidence without tilting would cause the shore line to migrate farther landward with each submergence, unless sedimentary material was accumulating landward from the shore line as well as seaward. Such landward accumulations would permit the shore line to be maintained at one place by subsidence only. It follows from this that with subsidence and no tilting and with or without migration of the shore line, there must have been accumulations landward from the present Claiborne outcrop. Since there is no evidence that appreciable quantities of Claiborne material ever existed in this area, strong evidence is derived for the tilting.

An alternative explanation is that the crustal movement affected only the area of accumulation and not the area landward from it. This would necessitate faulting for which there is no known evidence.

Sufficient data are not available to discuss conditions of deposition of the subsurface material.

RELATION TO THE "APPALACHIAN RIVER"

The discussion of the Midway and Wilcox sediments led to the conclusion that a large river, here called the "Appalachian River," entered, during Midway and Wilcox time, the Mississippi embayment in what is now the northeast-central part of the State of Mississippi and that it built a huge delta out into the embayment

The Claiborne sediments have been interpreted as of littoral or neritic origin. These sediments, extending wholly across the previous site of the mouth of the "Appalachian River" in Mississippi, do not show any characteristics which suggest that a large river entered this part of the embayment area during Claiborne time. In fact they indicate that many streams rather than one supplied the Claiborne material. A stream comparable in size to the postulated "Appalachian River" would manifest its existence in the nature of the sediments particularly since its influence during Midway and Wilcox time was so pronounced.

There are several possible explanations for the seeming disappearance of the "Appalachian River." It may have continued to exist with a drainage area so lowered that large quantities of detrital material were not transported. The uniform sandiness of the Claiborne which indicates streams capable of bringing sand to the embayment is not in agreement with this explanation.

Another possible explanation is that, in Claiborne time, the shore line was northeast of the present outcrop, and that, at and near the shoreline, the "Appalachian River" built into the Gulf a delta which since has been removed by erosion. Opposed to this conception is the lack of evidence of the previous existence of any considerable amount of Claiborne material landward from the present outcrop. Further, the character of the Claiborne material suggests that it was deposited near the shore line. Otherwise, oscillations of the shore line must have been unusually large.

Another explanation--and the one favored by the writer-- is that stream capture took place approximately at the beginning of Claiborne time, so that after Wilcox time the "Appalachian River" no longer entered the embayment in the Mississippi region. Evidence for this conclusion is provided by a comparison of the immediate source areas of the Wilcox and Claiborne sediments (See previous pages). This idea of stream capture is not new. Physiographic studies early led Hayes and Campbell[190] to postulate stream capture in northeastern Mississippi. The evidence here presented serves to place the time of capture at the beginning of the Claiborne.

PHYSIOGRAPHIC CHARACTER OF THE IMMEDIATE SOURCE AREA

The change in lithology from the Midway to the Wilcox was interpreted as indicating an uplift of the source area beginning gradually in Midway time and continuing throughout Wilcox time, the area being in the youthful stage of physiographic development in Wilcox time. The character of the material derived from this region in late Wilcox time was sandy; and, in Claiborne time was likewise sandy. The conclusion would follow, therefore, that the immediate source area remained in the youthful stage or perhaps reached the early mature stage during Claiborne time.

RELATION TO THE APPALACHIAN PENEPLAINS

A consideration of the source area of the Midway and Wilcox sediments led to the conclusion that a peneplained area was uplifted in the southern Appalachian area in early Eocene time. The conclusion just reached regarding the physiographic character of the immediate source area of the Claiborne sediments would mean that erosion had developed the portion of the uplifted peneplain still remaining in the source area (See Location of Source Area) into the youthful or early mature stage in Claiborne time.

JACKSON FORMATION

NAME

The term Jackson was first used by Conrad[191] for beds of fossiliferous marl that crop out near the city of Jackson, Mississippi. Conrad correctly determined the age of this material to be late Eocene, and he placed it between the Claiborne and Vicksburg series. Wailes[192] had previously illustrated fossils from this same locality without naming the beds. All later workers in this state have continued Conrad's usage of the term.

The Jackson formation and the overlying Vicksburg series in much of Alabama are similar lithologically and paleontologically. As a result, earlier workers grouped them under the name St. Stephen white limestone. Recently Cooke[193] has divided the St. Stephen into Jackson and Vicksburg equivalents and has shown that the Ocala limestone of Florida can be correlated with the Jackson portion of the St. Stephen.

STRATIGRAPHIC RELATIONS

As previously pointed out, the Claiborne and Jackson contact is conformable in both Mississippi and Alabama.

The Jackson formation in Mississippi is overlain conformably by the Vicksburg series. In the western part of the state the contact is marked by non-marine transition sands and clays. In the eastern part of the state the Yazoo member of the Jackson is conformably overlain by the Vicksburg Red Bluff.

According to Cooke,[194] the contact between the Jackson and the Vicksburg in Alabama is also conformable.

CLASSIFICATION AND CORRELATION OF THE JACKSON FORMATION

The classification of the Jackson formation in the eastern part of the Mississippi embayment is shown in Figure 23. The term Moodys Branch is here applied, as defined by Lowe,[195] to the basal glauconitic, sandy marl member characteristically exposed in Moodys Branch in Jackson, Mississippi. The term Yazoo is applied, as defined by Lowe,[196] to the clay beds that overlie the Moodys Branch marl in good exposures near Yazoo City, Mississippi. The term Forest Hill is used for the beds of sand and clay that form a transition between the Jackson and Vicksburg in western and central Mississippi, for which Lowe[197] originally suggested the name Madison. Because this term was preoccupied, Cooke[198] advanced the term Forest Hill from the village of that name in Mississippi.

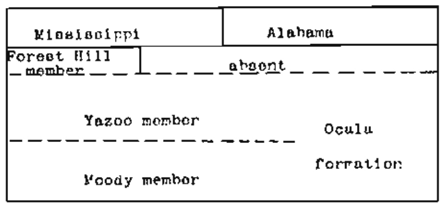


Figure 23.—Classification and correlation of the Jackson formation in Mississippi and Alabama.

The Forest Hill beds were placed in the Jackson formation by Lowe. Later Cooke suggested that they are of Vicksburg age and the equivalent of the Red Bluff beds in eastern Mississippi. The Forest Hill beds have no marine fossils and their floral remains are too poor for identification; hence, a paleontological correlation is impossible. Because the Red Bluff beds exist only in eastern Mississippi, the Forest Hill beds only in western Mississippi, and neither in the intervening area, it is impossible to prove or disprove Cooke's suggestion. However, these beds as exposed at many places between Jackson and Vicksburg are definitely transitional, grading down into the Jackson and up into the Vicksburg. Since they grade very gradually into the Jackson and abruptly into the Vicksburg, their Jackson age is favored in this report. The material is also lithologically more like the Jackson than the Vicksburg.

DESCRIPTION AND DISTRIBUTION OF THE MATERIAL AT THE OUTCROP

MOODYS BRANCH MEMBER

The Moodys Branch member has an average thickness of approximately 200 feet. Wherever found, it is very uniform in lithology being composed of dark green very fossiliferous calcareous, sandy marl.

This member can be traced from the bluffs along the Mississippi River to the Tombigbee River in Alabama where it grades into the lower part of the Ocala limestone.

The distribution of the Jackson formation is shown on Figures 24 and 25. The few and poor exposures of this and of the other members of the formation make it impossible to map them accurately. Accordingly, the separate members are not so shown.

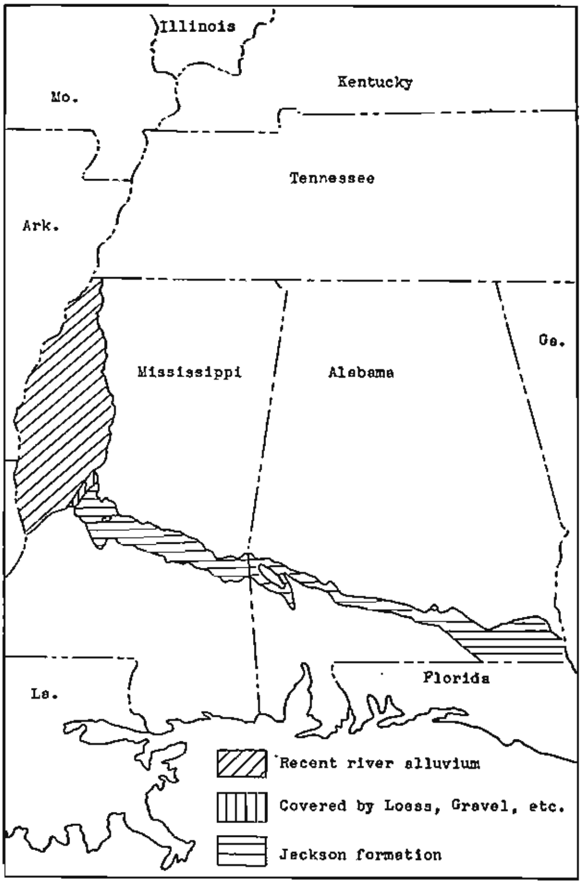


Figure 24.—Sketch map showing the Jackson outcrop in the eastern part of the embayment.

YAZOO MEMBER

In western Mississippi the Yazoo member has an average thickness of approximately 500 feet. As it is traced eastward its thickness becomes less and less. It is composed of massively-bedded yellow to green calcareous clay. In the western part of Mississippi thin beds of lignitic clay are interbedded with the calcareous material. The calcareous clay locally contains small fossils. The Yazoo contains also the "Zeuglodon bed" in which remains of the huge whale-like mammal, *Basilosaurus cetoides*, have been found. This member can be traced from the bluffs along the Mississippi River to the Tombigbee River in Alabama where it grades into the upper part of the Ocala limestone.

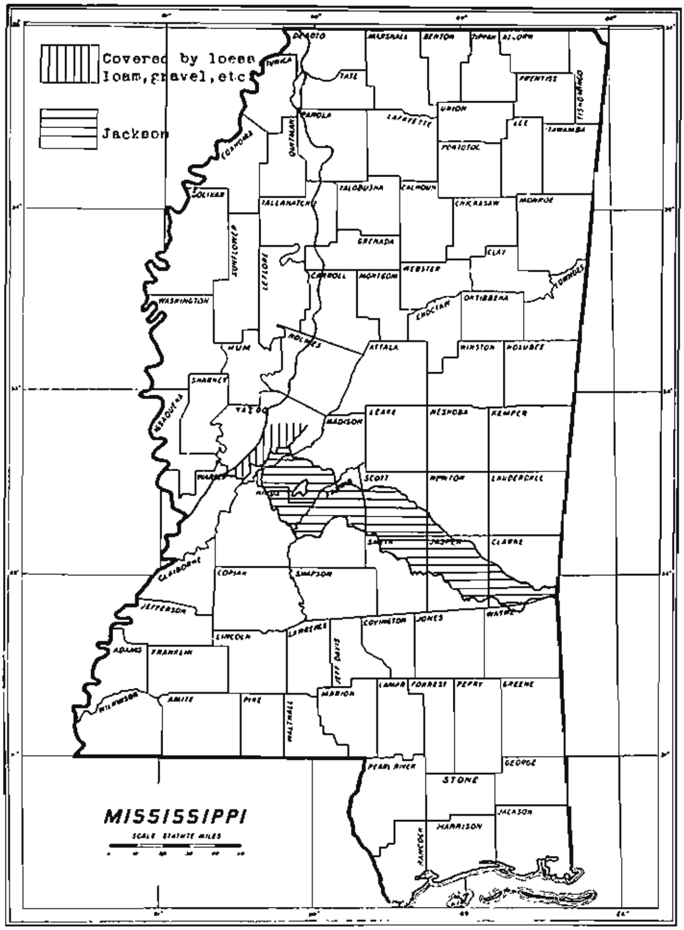


Figure 25.—Sketch map showing the outcrop of the Jackson formation in Mississippi.

FOREST HILL MEMBER

In western Mississippi the Forest Hill member has a maximum thickness of about 75 feet. As it is traced eastward its thickness becomes less and less until in the central part of the state the member is not developed at all. The Forest Hill member consists of a series of stratified beds of non-calcareous sand and clay, which contain no fossils other than poor plant remains. In western Mississippi, from Rankin County to the Mississippi River bluffs, the Yazoo clay gradually grades upward into a series of gray non-calcareous shales. These shales in turn grade upward into a series of stratified sands which are conformably overlain by the hard Vicksburg limestone.

ANALYSES OF JACKSON SEDIMENTS

The following are analyses of typical samples of the members of the Jackson formation.

JACKSON SAMPLE 64

Location, Position, and Character

The sample was collected on Moodys Branch back of the Kennington home in the city of Jackson, from the Moodys Branch member. Megascopically, it is a massive unconsolidated grayish-green glauconitic, sandy marl containing many broken shells; microscopically, a clayey, glauconitic, sandy marl in which the quartz grains are usually coated by white clay. The glauconite shows the two types of alteration noted in Sample 40.

Mechanical Analysis

The results of the mechanical analysis of Sample 64 are represented by Histogram 64; of the division of the Very Fine Sand, by the table:

Light minerals	95.76 percent
Heavy minerals	4.24 percent

Microscopic Examination

I. Coarse Sand: About 75 percent is composed of rounded broken discoidal fibrous or flakey glauconite. The mineral varies from dark to light green and shows the types of alteration previously noted. The remainder is composed of well-rounded to subangular grains of quartz. The well-rounded grains have a frosted surface.

II. Medium Sand: It is composed of subangular glassy-surfaced quartz grains, glauconitic grains, and a few dark mineral grains.

III. Fine Sand: Its composition is the same as that of the Medium sand.

IV. Very Fine Sand:

A. Light minerals: About 5 percent is composed of glauconite whose indices of refraction range from about 1.55 to about 1.60. Most of the fraction is composed of angular glassy-surfaced quartz grains, in which wavy extinction is rare. All types of inclusions are present. The Irregular type is most common. The fraction includes a few grains of chert and a few flakes of white mica having the properties of muscovite.

B. Heavy minerals: Zircon is abundant; kyanite, staurolite, tourmaline, leucoxene, ilmenite, sillimanite, garnet, epidote, rutile are common; and xenotime is rare.

V. Very Coarse Silt: It is composed of about equal proportions of angular quartz grains and light green glauconitic grains. It includes a few limonite aggregates and a few dark minerals.

VI. Medium Silt: Its composition is the same as that of the Very Coarse Silt.

VII. Fine Silt and Clay: The fraction is composed of olive green clayey material.

JACKSON SAMPLE 65

Location, Position, and Character

The sample was collected along the road 1000 feet north of the south line of Sec. 17, T. 5 N., R. 1 E., Hinds County, from the Yazoo member. Megascopically, it is a yellowish-green massive clay containing very little grit, and possessing an uneven fracture; microscopically, a waxy clay containing a few small fossils.

Mechanical Analysis

The results of the mechanical analysis of Sample 65 are represented by Histogram 65.

Microscopic Examination

I. Coarse Silt: It is composed of angular grains of quartz, a few flakes of white mica, a few dark minerals, and a few white opaque masses of clay.

II. Medium Silt: Its composition is the same as that of the Coarse Silt.

III. Fine Silt and Clay: The fraction is drab gray semi-transparent clay.

JACKSON SAMPLE 66

Location, Position, and Character

The sample was collected at Forest Hill School 5 1/4 miles southwest of Jackson from the Forest Hill member.

Section at Forest Hill School

	Feet	Feet
Vicksburg series		6.0
13. Limestone, pure white	3.0	
12. Limestone or marl containing nodules of marine shells	3.0	

	Feet	Feet
Forest Hill member of the Jackson formation		68.3
11. Clay, sandy non-fossiliferous; having lime nodules	4.0	
10. Sand, pure quartz	3.0	
9. Chalk, white	0.1	
8. Sand and clay, gray laminated	4.0	
7. Lignite, earthy	0.2	
6. Clay, drab sandy	0.5	
5. Sand, having ferruginous, clayey layers	6.5	
4. Sand and clay, laminated	2.0	
3. Sand, cross-bedded; having clay laminae (Sample 66)	12.5	
2. Sand, green; weathering yellow	25.5	
1. Clay, drab sandy; grading below into the Yazoo clay	10.0	

Megascopically, the sample is an unconsolidated yellowish-brown quartz sand; microscopically, a fairly pure quartz sand.

Mechanical Analysis

The results of the mechanical analysis of Sample 66 are represented by Histogram 66; of the division of the Very Fine Sand, by the table:

Light minerals	94.1 percent
Heavy minerals	5.9 percent

Microscopic Examination

I. Coarse Sand: Except for a few flakes of white mica, the whole fraction is composed of well-rounded grains of quartz possessing either a frosted or glassy surface.

II. Medium Sand: It is composed mostly of grains of sub-angular glassy-surfaced quartz; subordinately of a few grains having a frosted surface, of a few dark minerals, and of a few flakes of white mica.

III. Fine Sand: Its composition is the same as that of the Medium Sand.

IV. Very Fine Sand:

A. Light minerals: They are mostly angular quartz grains. Wavy extinction is rare. Inclusions are common. The Irregular type is most common. The fraction includes a considerable number of grains of chert and unaltered microcline.

B. Heavy minerals: Zircon is abundant; kyanite, tourmaline, rutile, xenotime, staurolite, sillimanite, ilmenite, leucoxene are common; and andalusite is very rare.

V. Coarse Silt: It is composed of angular grains of quartz and a few dark mineral grains.

VI. Medium Silt: Its composition is the same as that of the Coarse Silt.

VII. Fine Silt and Clay: The fraction is composed of yellow clayey material studded with many distinct grains.

CONDITIONS OF DEPOSITION IN JACKSON TIME

MOODYS BRANCH

The fossil content and the lithologic character of the Moodys Branch member favor deposition in a near shore marine environment. The absence of a break between the Yegua and Moodys Branch sediments indicates a gradual change from the non-marine and littoral environments of Yegua time to the neritic environment of Jackson time. Thus, at the initiation of Jackson time the area of accumulation was either submerged with the attendant landward migration of the shore line or submerged and tilted. The absence of any definite overlapping by the Jackson suggests the latter possibility.

The uniformity of this material all the way across Mississippi points to uniformity in the neritic environmental conditions and also to general uniformity in the amount and character of material supplied.

YAZOO

The Yazoo clay, by its fossil content and lithology, also indicates near shore marine conditions. The clayey character of the Yazoo in contrast to the sandy character of the Moodys Branch means either a change in the character of the material supplied to the area or deposition farther from the shore line. The existence of lignitic beds in the Yazoo clay in western Mississippi favors the first suggestion.

The uniformity of the Yazoo clay across the state again indicates uniformity of the environmental conditions and of material supplied. An exception to this uniformity is the lignitic material in western

Mississippi. Here, because of an increased supply of material, the area of accumulation was filled occasionally causing local non-marine conditions. The increased thickness of the Yazoo in this area shows that actual subsidence was greater here than to the east so that the non-marine material cannot be explained as the result of a decrease in subsidence. The continuous series of beds does not suggest uplift of the land as a cause of the variation in lithology.

FOREST HILL

In eastern Mississippi the Yazoo clay conformably underlies the Vicksburg series indicating that the environmental conditions of the Yazoo continued to the end of Jackson time. The Forest Hill beds show that toward the end of Jackson time the supply of material in western Mississippi so kept ahead of subsidence that littoral and non-marine conditions became general. The increased thickness of the Jackson in this area suggests that subsidence was actually greater here than to the east. Therefore, the supply of material must have been greater than to the east. If this were not true, a littoral or neritic environment would have resulted.

Following the lines of reasoning in the discussion of the Claiborne sediments, there appears to be no evidence for uplift throughout Jackson time. Subsidence alone is adequate to account for the Jackson material.

RELATION TO THE "APPALACHIAN RIVER" AND THE APPALACHIAN PENEPLAINS

The existence of marine conditions across Mississippi in Moodys Branch and Yazoo times without any suggestion of deltaic deposition agrees with the evidence of the Claiborne in showing that the "Appalachian River" was not a controlling depositional factor in this area during and after Claiborne time.

The mineral composition of the Jackson is about the same as that of the Claiborne, showing that they had the same immediate source area; that is, the southern part of the Appalachian mountain area and the older part of the Coastal Plains. If the change from sandy accumulations in early Jackson time to clayey accumulations in late Jackson time is interpreted as indicative of a change in material supplied and the source area of the Jackson remained the same as that of the Claiborne, the suggestion follows that by the end of Eocene time this area was reduced to the physiographic stage where only fine material was produced. In other words, the portion of the uplifted Eocene peneplain remaining in the source area was reduced to late maturity or early old age by the end of Eocene time.

GENERAL SUMMARY

The object of this investigation has been to determine the stratigraphic relations of the Eocene sediments in Mississippi, their character and composition, the location and characteristics of the source area from which they came, and the conditions under which they were deposited. The investigation included a study of the material in the field and in the laboratory. It embraced petrographic analyses, made tc determine the characteristics of the sediments in greater detail and to obtain additional evidence for their interpretation.

The Eocene sediments are divided into the Midway series, the Wilcox series, the Claiborne series, and the Jackson formation. These sediments from a conformable system except for local unconformities between the Wilcox and Claiborne series in eastern Mississippi.

The Midway series is divided into the Clayton formation below and the Porters Creek formation above. The Clayton is marine, and the Porters Creek is generally non-marine. They are partially equivalent to each other. The Clayton is present in northern Mississippi, absent in central Mississippi, and present in eastern Mississippi. The Porters Creek formation is continuous across the state.

The Wilcox series consists of an assemblage of generally lenticular beds of non-marine sand and clay, the sand becoming more important toward the top. This series is divided into four formations on the basis of lithologic differences: Ackerman, Holly Springs, Bashi, and Grenada. The Ackerman and Holly Springs formations are continuous across Mississippi. The Bashi is present only in eastern Mississippi, and the Grenada is present only in western and northern Mississippi.

The Claiborne series is composed of an assemblage of near shore marine deposits. It is divided into three formations: Tallahatta, Lisbon, and Yegua. The Tallahatta is divided into the Meridian, Basic, and Winona members. The Lisbon is divided into the Kosciusko and Chickasawhay members. Non-marine material, local throughout this series, is most important in the upper part of the series and in the western part of the state. With the exception of the Meridian member, which is limited to the eastern two thirds of the state, the entire Claiborne can be traced continuously across Mississippi.

The Moodys Branch and Yazoo members of the Jackson formation consists of near-shore marine fossiliferous deposits. In the western part of the state, the upper part of the Jackson, the Forest Hill member, contains an assemblage of non-marine beds.

The following conditions of deposition are indicated by the stratigraphic relations, lithology, distribution, and petrographic analyses of these sediments. The Midway and Wilcox series, except the Midway Clayton formation, were deposited as huge deltas by a river, known as the "Appalachian River," which entered the Mississippi embayment in what is now northeast-central Mississippi. Around the edge of the area of delta accumulation there was marine sedimentation. At the beginning of Claiborne time the "Appalachian River" is believed to have been eliminated, probably by stream capture, as a factor in the deposition of material in the Mississippi embayment. The Claiborne and Jackson sediments were deposited in a littoral or neritic environment locally varying to non-marine. Considerable quantities of volcanic ash appear to have fallen into the eastern part of the embayment at various intervals during Tallahatta time.

Subsidence accompanied by tilting took place in the area of accumulation during the deposition of these sediments. Upward crustal movement, to account for the features of the Eocene sediments, probably did not take place.

The mineral composition of these sediments and the distribution of them have led to the determination of their source area as in the southern Appalachian region. This source area is believed to have been in the old age stage of physiographic development at the beginning of Eocene time. During Midway and Wilcox time it was gradually uplifted so that by Wilcox time the youthful stage was reached. In Claiborne time that portion of this region remaining in the source area after the elimination of the "Appalachian River" had progressed to the stage of late youth or early maturity. By Jackson time it was again reduced to conditions of late maturity or early old age.

The study of the mineral composition of these sediments has shown that the abundance of Heavy minerals decreases as sorting increases. The characteristics of the glauconite have shown that the mineral may alter to limonitic material, or by lightening in color to a white clay-like substance. Consequently it is impossible to use always the character of glauconite as a criterion for the determination of stratigraphic breaks. The characteristics of this mineral favor the idea that it forms from an initial siliceous stage by the gradual addition of iron and potassium, rather than from an initial clay stage or ferric hydroxide stage.

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