Mississippi Geologic Research Papers-1963

EDWARD H. RAINWATER
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THOMAS F. TORRIES

BULLETIN 102

MISSISSIPPI GEOLOGICAL, ECONOMIC AND
TOPOGRAPHICAL SURVEY

FREDERIC FRANCIS MELLEN
DIRECTOR AND STATE GEOLOGIST

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STATE OF MISSISSIPPI

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MISSISSIPPI GEOLOGICAL ECONOMIC AND TOPOGRAPHICAL SURVEY

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ACKNOWLEDGMENT

The sponsorships of the 1963 Geological Research Paper Contest by the following companies and agency have made possible this volume:

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We are deeply grateful for their financial assistance and support of this program. The fact that the number of sponsors has increased in 1963 to 8—from the 1962 total of 6—is, to us, a measure of the success of, and interest in, the Geologic Research Program.

Mississippi Geological, Economic and
Topographical Survey

LETTER OF TRANSMITTAL

Office of the Mississippi Geological Economic and
Topographical Survey
Jackson, Mississippi

January 30, 1964

Mr. Henry N. Toler, Chairman, and
Members of the Board
Mississippi Geological Survey

Gentlemen:

Pursuant to the authority granted by the Board, the Mississippi Geological Survey conducted a Geologic Research Paper Contest for the purpose of stimulating among geologists the development of ideas pertaining to economic geology of Mississippi. The results of the first such contest appeared as Bulletin 97 entitled, "Mississippi Geologic Research Papers—1962."

The winner of our 1963 contest, and the first prize of $500.00, was Mr. E. H. Rainwater, a native of Wayne County, Mississippi, now a resident of Houston, Texas. Mr. Rainwater contributed an outstanding paper to Bulletin 97, and has again submitted a splendid paper which has won for him the first prize in the 1963 contest. This prize winning paper is entitled, "Regional Aspects of the Midway (Paleocene) and Wilcox (lower Eocene) in Mississippi." This paper should be of great value to geologists who are interested in Mississippi in their search for oil and gas in the Wilcox sediments and also to those who may be looking for sands, clays, lignites, iron ores, waters, or other economic mineral substances that can be mined at the surface in the State.

In addition to this paper, Mr. Rainwater has completed and submitted for inclusion in the present bulletin a paper containing the results of his expert and critical study of cores taken from a series of borings along the route of a proposed causeway from Beauvoir to Ship Island. This study should be of considerable scientific, as well as economic, importance to our Coastal area.

The Universities of our State have furnished many fine young geologists to the minerals industries. In their advanced studies they show increasing interest and ability in working out some of the geologic problems assigned to them by their major professors. We have selected for inclusion in this bulletin some studies made by Thomas F. Torries, now working as a geologist for Monsanto Chemical Company in the phosphate fields of Central Tennessee. His paper on the geology of the northeast quarter of the West Point, Mississippi quadrangle, gives the local geologic details of a small area of the State but is reproduced to give other students of Mississippi geology the benefit of the results of his applied use of laboratory techniques in the examination of some of our sediments.

We recommend that the collection of these three papers be published as Bulletin 102 entitled, "Mississippi Geologic Research Papers—1963."

Respectfully submitted,
Frederic F. Mellen
Director and State Geologist

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Regional aspects of Midway and Wilcox (Rainwater)

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REGIONAL STRATIGRAPHY OF THE MIDWAY AND WILCOX IN MISSISSIPPI

E. H. RAINWATER*

ABSTRACT

Midway and Wilcox strata crop out in a broad belt in northeastern Mississippi, and they are known, from wells, to be present under all parts of the State south and west of the outcrop. The exposed sections have received much study during the past hundred years, but little has been written on the formations in the subsurface.

Thickness of the Midway and Wilcox sediments at the outcrop varies from about 500 feet in Tippah County to about 1,200 feet in Kemper County. The section thickens downdip and reaches a maximum of about 5,000 feet in the southwestern corner of the State. Alternating beds of sand, silt and shale comprise almost all of the section.

The late Paleocene and early Eocene were times of major regression when more than 100,000 cubic miles of sediments were transported to the Gulf Coast from the rising interior regions. However, at the beginning of the Tertiary the sea was still over most of the Gulf Coastal Plain and the Mississippi Embayment. A thin open-sea section of glauconitic marl (Clayton) was deposited on marine Upper Cretaceous. The sea became partly restricted and stagnant while a blanket of dark-gray clay (Porters Creek), up to 1,100 feet thick, was spread over most of the Coastal Plain. Open-sea conditions then obtained briefly when the Matthews Landing marl was deposited on the clay. The upper Paleocene (Naheola) was a regressive period during which thick deposits of sand, silt, and clay and several lignite beds were deposited in alluvial and transitional environments.

The early Eocene was also mainly a regressive period with deposits similar to those of the late Paleocene. However, there were two important transgressions of the sea (Nanafalia and Bashi) during the early Eocene. Rapid sedimentation in deltaic environments took place during certain intervals of late Paleocene and early Eocene in southwestern Mississippi and in coastal Louisiana and Texas. Important accumulations of oil and gas are in the deltaic deposits.

The general characteristics of the outcrop and subsurface Midway and Wilcox formations are described and illustrated.

INTRODUCTION

The outcropping Midway and Wilcox formations in Mississippi have received a great amount of study by many eminent geologists for more than 100 years. A review of the studies and

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*Consulting geologist, Tenneco Oil Company, Houston, Texas history of the nomenclature has been published by Murray (24)[1], Hughes (16) and others. Little has been published on the stratigraphy and paleontology of the subsurface Paleocene and lower Eocene which have been penetrated by many wells in Mississippi. The main objective of this paper is to describe briefly the general extent, thickness, lithology and depositional history of each major division of the Midway and Wilcox in Mississippi and adjacent areas. An understanding of the regional stratigraphy is considered important in the scientific exploration for mineral resources such as oil and gas, iron and aluminum ores, and groundwater, all of which occur abundantly in the Midway and Wilcox sediments. Also the regional framework should be useful in interpreting results from detailed studies.

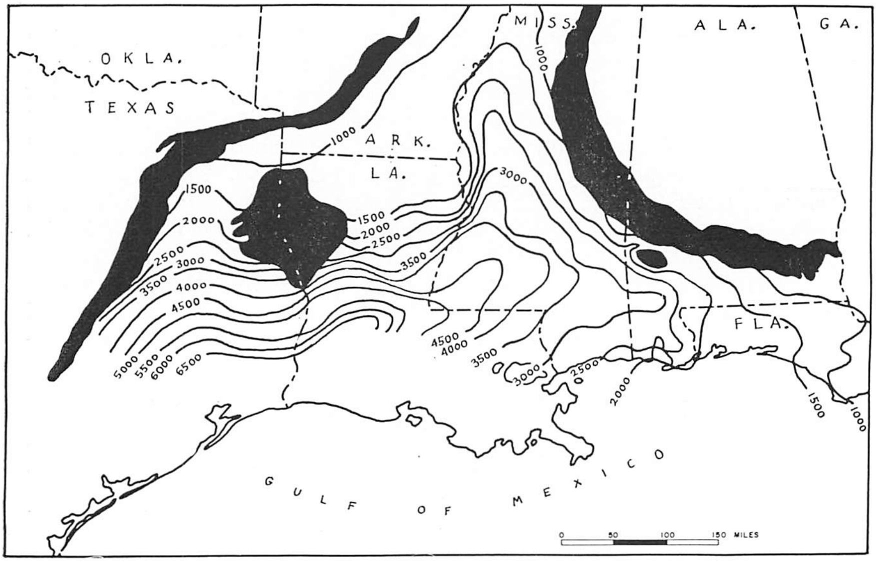

Figure 1.—Thickness of Midway (Paleocene) and Wilcox (lower Eocene). Outcrop of Midway and Wilcox shown in black.

The outcrop section of Midway and Wilcox is about 1,200 feet thick at the Alabama-Mississippi line but only about 500 feet thick at the Mississippi-Tennessee boundary where much of the Wilcox is overlapped by younger sediments. The subsurface section is much thicker and reaches a maximum of about 5,000 feet in the southwestern corner of the state. In coastal Louisiana and Texas,

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[1] Numbers in parentheses refer to selected references at end of paper.

where the rate of subsidence was faster, the subsurface section is much thicker (Figure 1).

The Midway and Wilcox in the central and western coastal Plain are composed almost entirely of terrigenous clastic sediments which were derived from the uplifted interior and were deposited mainly in transitional and alluvial environments. The sea transgressed over the coastal Plain only a few times during this period.

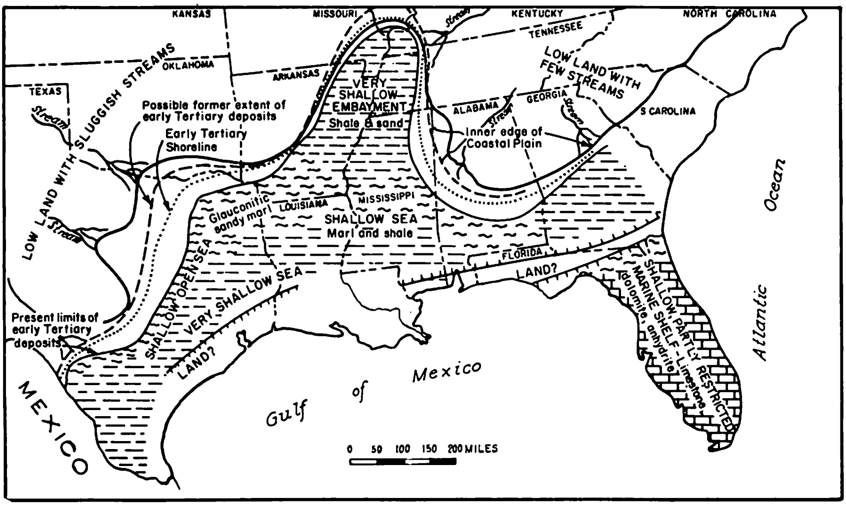

Figure 2.—Paleogeography at beginning of Tertiary deposition.

LOWER AND UPPER BOUNDARIES OF THE MIDWAY AND WILCOX

CRETACEOUS - TERTIARY BOUNDARY

A few feet of basal Midway sediments are open-sea marine, and they lie directly on marine Upper Cretaceous of similar lithology. Yet, the faunal change across the Mesozoic-Tertiary boundary is very sharp, as pointed out by Thompson (32), Rainwater (29, 30), and others. At the outcrop, the large and small fossils have been studied and used to determine the contact. Only the micro-fossils can be studied in most well samples; they also show the marked change and make it possible to determine accurately the Paleocene-Upper Cretaceous boundary in the subsurface. Figure 2 shows general paleogeography at the beginning of Tertiary deposition.

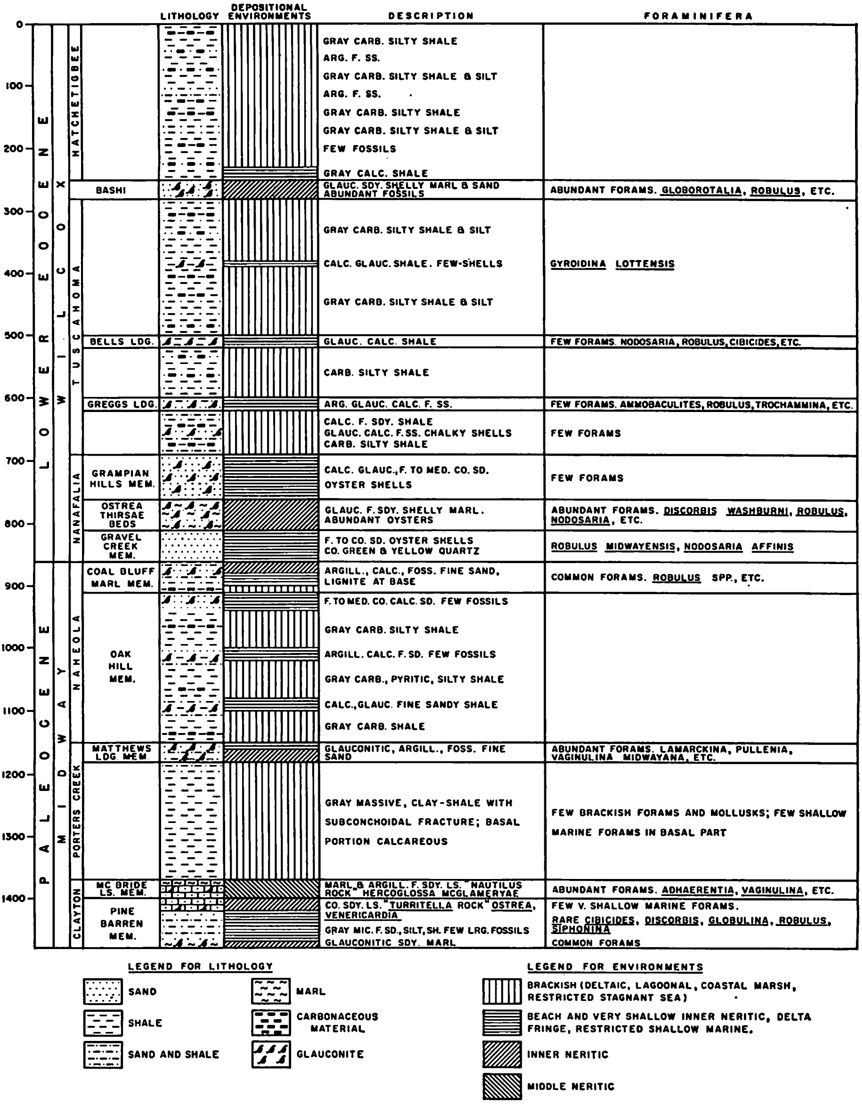

Figure 3.—Representative section of Midway (Paleocene) and Wilcox (lower Eocene) in their type area, west-central Alabama (outcrop and shallow subsurface).

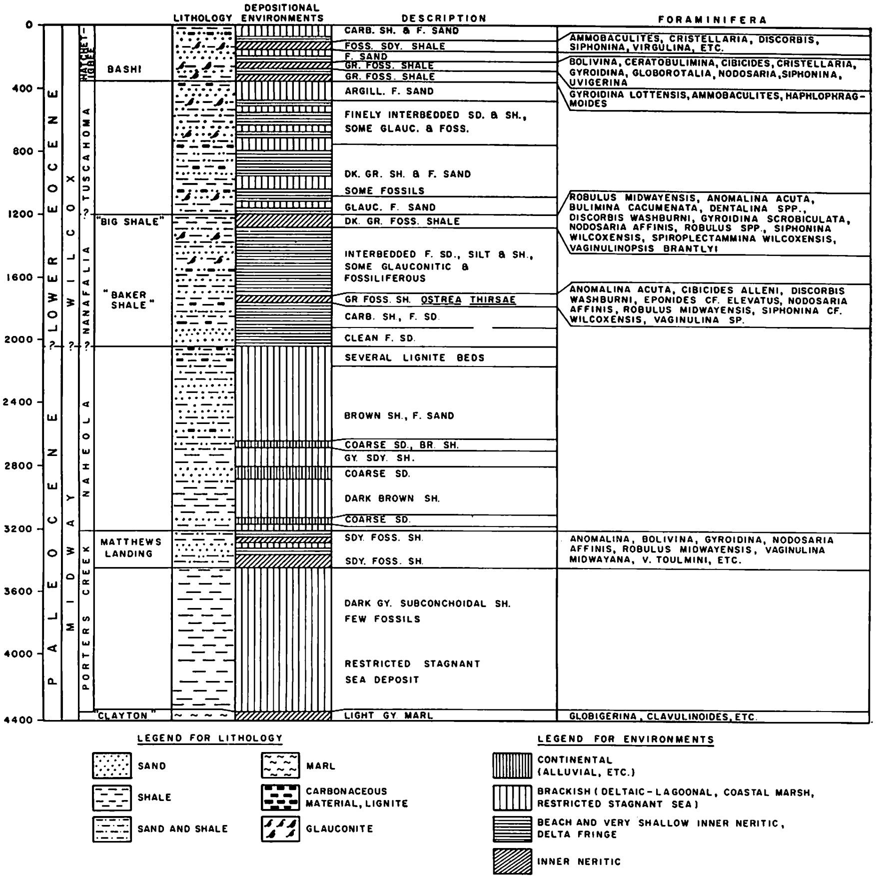

Figure 4.—Representative section of Midway (Paleocene) and Wilcox (lower Eocene), subsurface of southwestern Mississippi.

MIDWAY (PALEOCENE) - WILCOX (LOWER EOCENE) BOUNDARY

At the outcrop in northeastern Mississippi, the Midway-Wilcox boundary is placed in a non-marine sequence of sediments (16, 20, 22, 23). In Wilcox County, Alabama, the type area of the Midway and Wilcox, the base of a coarse sand (Figure 3) is generally accepted as the boundary. The much thicker subsurface lower Eocene and Paleocene sections (Figures 4 and 6) may include stratigraphic units which are not represented by sediments at the outcrop, and it has not been determined where the Wilcox-Midway boundary should be placed.

WILCOX (LOWER EOCENE) - CLAIBORNE (MIDDLE EOCENE) BOUNDARY

Top of the Wilcox is easily determined at the outcrop and in the subsurface where basal Claiborne marine beds lie on non-marine Wilcox. However, where both the upper Wilcox and lower Claiborne are non-marine and composed mainly of sand, as in northeastern Mississippi, there is much disagreement about where the boundary should be placed.

The first sand indicated on electric logs, below Tallahatta claystone, is considered by most petroleum geologists to mark top of the Wilcox. Where the upper Wilcox is composed of shale, which is usually non-marine, the boundary thus determined is incorrect. It is not clear whether the upper Wilcox Bashi-Sabinetown marine beds are present in southern Mississippi. If they are present, the overlying youngest Wilcox (Hatchetigbee) may be very thin as it is on the Hatchetigbee Anticline.

MIDWAY (PALEOCENE)

The Midway at the outcrop and in the subsurface of Mississippi consists of the thin basal open-sea marine Clayton formation which lies on marine Upper Cretaceous; the overlying Porters Creek clay, up to 1,100 feet thick, which was deposited in a large, restricted, stagnant sea; a thin section of open-sea, shallow marine, glauconitic, sandy Matthews Landing "marl"; and, at the top, the thick Naheola formation which is totally non-marine at the outcrop in Mississippi.

Each of the Midway formations is everywhere present downdip from the outcrop except that the Clayton and lower part of the Porters Creek may be absent in parts of southeastern Mississippi.

CLAYTON FORMATION

OUTCROP CLAYTON

A few feet of glauconitic, sandy, fossiliferous marl disconformably overlies the Upper Cretaceous and grades upward into Porters Creek clay. This thin section of Clayton, which is equivalent only to the lower part of type Clayton, has been mapped by Thompson (32) from Houston, Chickasaw County, southeast to Alabama. He recognized five zones in the Clayton, as follows:

5. *Ostrea pulaskensis* limestone, with average thickness of one foot.
4. Thin-bedded, glauconitic, very fossiliferous limestone, with average thickness of about 8 feet.
3. Medium to fine-grained sandstone. Thickness 0 to 5 feet.
2. Conglomerate — composed of rounded pebbles and boulders of the underlying chalk. Discontinuous. Maximum thickness 3-1/2 feet.
1. Basal greensand marl. Discontinuous. Maximum thickness 1 foot.

North of Houston the outcrop Clayton has been described by Priddy (27), Conant (4, 5), MacNeil (20), Bergquist (2), and others.

The present writer mapped much of the outcropping Midway in Mississippi in 1934-1935, collected numerous samples of the Clayton and described and figured—in an unpublished report—more than 100 species of foraminifera.

SUBSURFACE CLAYTON

A thin marl, marly chalk, or calcareous clay represents the Clayton formation in the subsurface of much of the central and western Gulf Coast. The section is generally less than 50 feet thick, and it is included in the Upper Cretaceous by many petroleum geologists. However, it has a foraminiferal fauna similar to that of the outcrop Clayton.

George and Bay (11) reported 35 feet of hard limestone (Clayton) with common foraminifera at depths of 6365-6390 feet in a well in Covington County.

The following species of foraminifera from Clayton or "calcareous Midway" were in ditch samples from depths of 4,364-4,394 feet from a well in Tinsley Field, Yazoo County:

Anomalina midwayensis
Bulimina cf. *arkadelphiana*
Cibicides vulgaris
Gaudryina soldadoensis
Globigerina compressa, G. triloculinoides, and *G.* spp.
Parrella expansa

A well in Pickens Field, Yazoo and Madison Counties, penetrated the Clayton between depths of 3860-3920 feet. *Clavulinoides midwayensis, Alabamina,* and *Parrella* were identified in ditch samples from that interval.

A well in southeastern Lincoln County penetrated about 35 feet of Clayton marl between depths of 8425-8460 feet. *Clavulinoides midwayensis,* abundant *Globigerina* spp., and other foraminifera occur in ditch samples from that interval.

The Clayton may be missing from some wells in Hancock County where the "Wilcox" lies directly on the Upper Cretaceous Austin. Also the Clayton, as well as uppermost Cretaceous and lower Porters Creek, is absent from some wells in southeastern Mississippi and adjacent Alabama, as well as in panhandle Florida. The lowermost Tertiary samples from some of the wells have a foraminifera fauna which includes *Ammodiscus incertus, Bolivinopsis clotho, Glomospira charoides* and *Pelosina complanata.* This assemblage occurs in some outcrop and subsurface sections above the Clayton.

PORTERS CREEK FORMATION

OUTCROP PORTERS CREEK

The Porters Creek is composed mainly of dark-gray massive montmorillonitic clay whose outcrop forms the Flatwoods in northeastern Mississippi. Its thickness at the outcrop varies from about 475 feet in western Kemper County to 250 feet in Tippah County, where some sandy beds are included in the formation.

The Porters Creek clay grades downward into Clayton marl; the clay also grades upward into the marine Matthews Landing marl or, where the marine beds are absent, into the Naheola formation. Fresh exposures of the clay are not numerous, but many outcrop and auger hole sections are described in Mississippi Geological Survey bulletins by Lowe (18), Grim (12), Conant (5), Priddy (27), Bergquist (2), and others. The present writer has studied and sampled many exposed sections of Porters Creek in northeastern Mississippi.

SUBSURFACE PORTERS CREEK

The clay is everywhere present downdip from the outcrop and reaches a maximum thickness of about 1,100 feet in southwestern Mississippi (Figure 5). The formation is only about 200 feet thick over the Jackson uplift and 400 feet thick over the Sharkey platform. In parts of southeastern Mississippi and adjacent Alabama, the lower Paleocene is sandy throughout. Either the Clayton and Porters Creek are missing or they are represented by deltaic sediments which were deposited by a stream draining the uplifted Appalachian region to the northeast. The entire Paleocene thins to about 400 feet in the southeastern corner of Alabama and adjacent panhandle Florida, and it is possible that only the upper Paleocene is represented.

The uppermost Cretaceous is also missing in parts of an east-west belt across coastal Mississippi, Alabama, and western Florida, and the uplift which caused erosion or nondeposition of late Cretaceous sediments also may have prevented the earliest

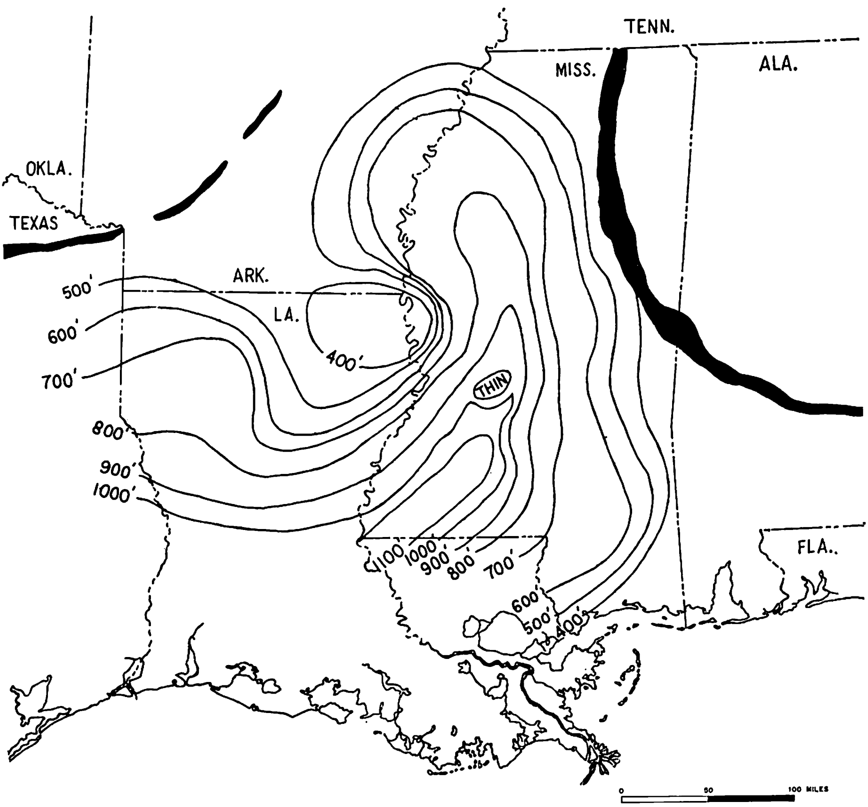

Figure 5.—Thickness of Porters Creek clay (Paleocene). Outcrop of Porters Creek shown in black.

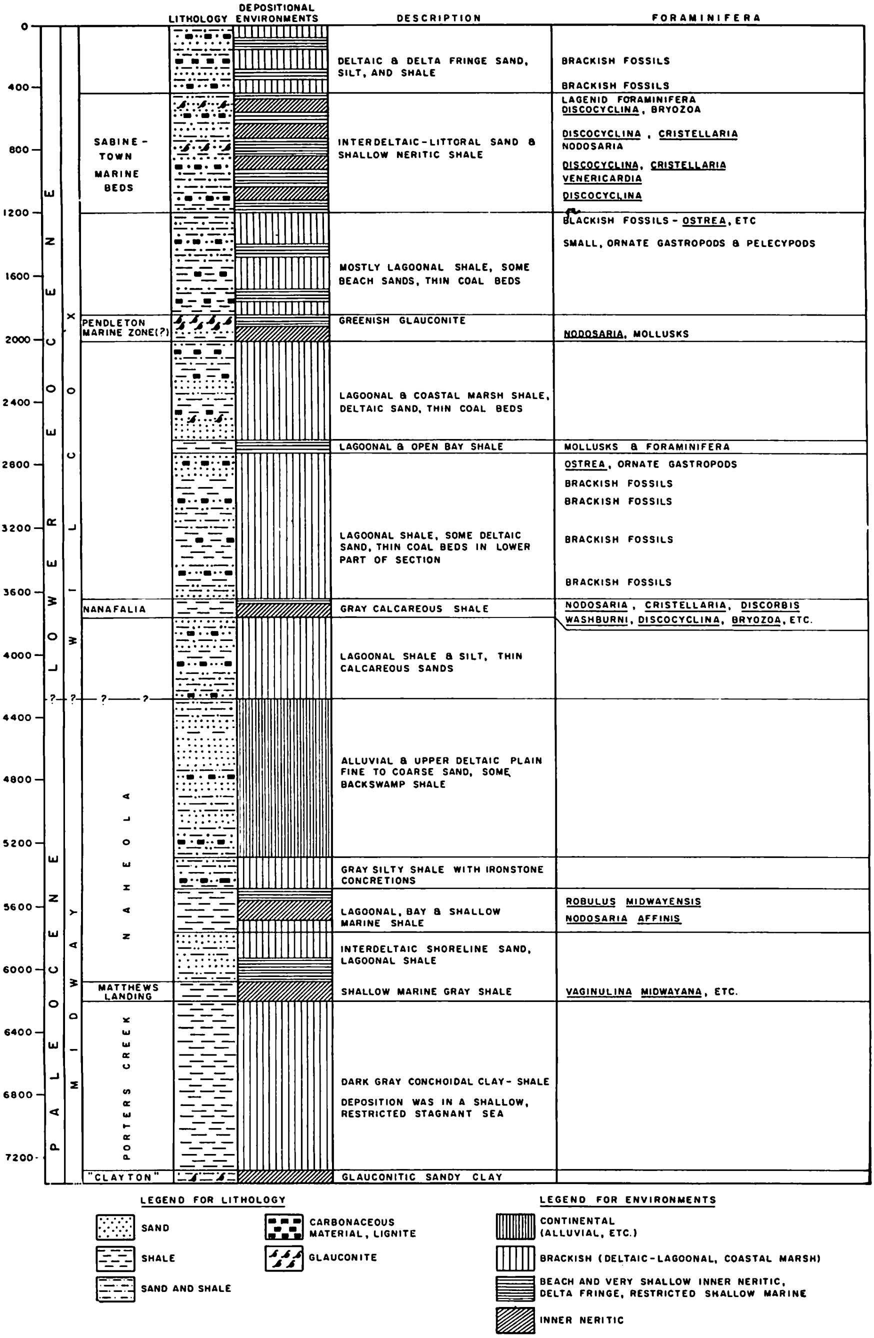

Figure 6.—Representative section of Midway (Paleocene) and Wilcox (lower Eocene), subsurface of southwestern Louisiana.

Paleocene beds from being deposited. The "barrier" (Figure 2) which may have extended, with interruptions, across coastal Louisiana and Texas, did not prevent open-sea marine Clayton from forming throughout most of the Gulf Coast and far up the Mississippi Embayment. But, the barrier became more effective during Porters Creek time when a stagnant sea covered the central Gulf Coast and Mississippi Embayment.

The few fossils (mainly arenaceous foraminifera) which occur in the Porters Creek clay indicate lagoonal to restricted marine environments. The clay was brought to the Mississippi Embayment by streams draining the rising interior regions of late Cretaceous marine clays, and also from the peneplained and weathered Paleozoic rocks of the eastern United States. Only fine-grained material was available, or the low-gradient streams were able to transport only clay and silt. The Porters Creek clay is not the prodelta equivalent of "Wilcox" sands; the clay is present throughout the central and western Gulf Coast beneath the coarser grained "Wilcox".

In eastern Texas the equivalent of Porters Creek is the Wills Point which is similar in lithology but the lower part (Mexia)

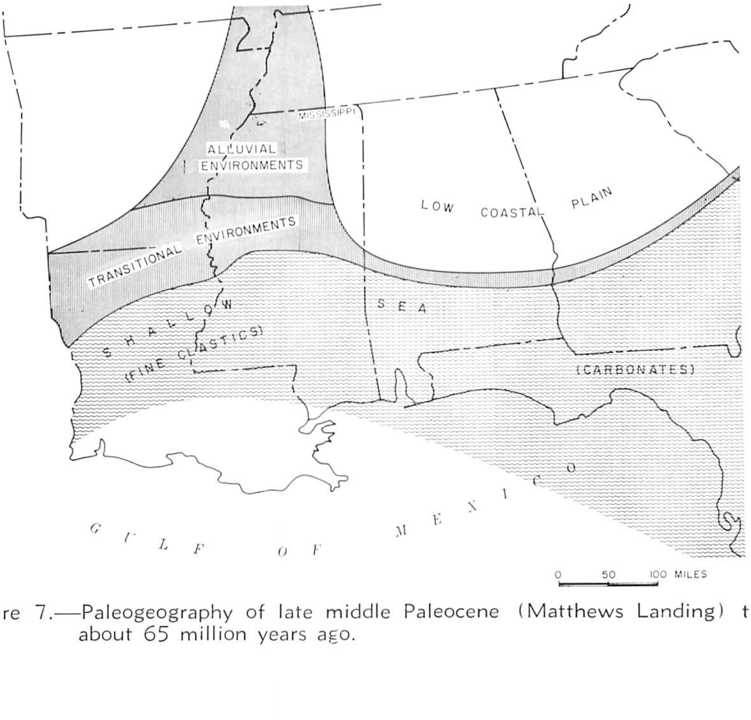

Figure 7.—Paleogeography of late middle Paleocene (Matthews Landing) time, about 65 million years ago.

of which has many open-sea marine fossils (Plummer, 26; Kellough, 17). This region was west of the "restricted" Mississippi Embayment region.

MATTHEWS LANDING MARL

At the end of Porters Creek clay deposition open-sea marine conditions obtained briefly over southern Mississippi (Figure 7) before the important late Paleocene regression began. The Matthews Landing marine beds can be traced at the outcrop across most of Alabama and as far north in Mississippi as Winston County. Even though this fossiliferous, glauconitic section is thin (usually less than 100 feet thick), it can be mapped at the outcrop and in the subsurface, and thus it deserves to have formation status. It appears that the large distinctive foraminifer *Vaginulina midwayana* became extinct near the end of Matthews Landing deposition, and the "top" occurrence of this species can be used to identify the formation in wells. Some other foraminifera identified by the writer from outcrop samples of Matthews Landing in Wilcox County, Alabama, are:

Alabamina wilcoxensis
Anomalina acuta
Ceratobulimina perplexa
Cibicides howelli
Globigerina pseudobulloides
G. triloculinoides
Globorotalia wilcoxensis var. *acuta*
Gyroidina subangulata
Lamarckina naheolensis
Nodosaria affinis
Palmula budensis
Pullenia quinqueloba
Robulus midwayensis
R. pseudomamilligerus
Siphonina prima
Textularia plummerae
Vaginulina longiforma

This assemblage of foraminifera has been noted in samples just above Porters Creek clay from wells in Mississippi, Alabama, Louisiana, and Texas.

NAHEOLA FORMATION

The thick late Paleocene Naheola formation throughout the central and western Gulf Coast is mostly non-marine, and it consists of alternating sand, silt, and clay, and some lignite beds. These deposits in the subsurface are included in the "Wilcox" by petroleum geologists because the lithology is very similar to that of much of the overlying lower Eocene Wilcox. The rising Rocky Mountains, Plains, and Appalachian regions supplied the steep gradient streams with abundant coarse sediments for the first time in the Tertiary, and sedimentation in the Gulf Coast was faster than subsidence. Thus, the Matthews Landing shoreline was pushed far to the south, and alluvial sediments were deposited over the shallow marine Matthews Landing "marl." Alluvial environments dominated throughout much of Naheola time (Figures 4 and 6) as far downdip as wells have penetrated the formation. Doubtless there were depocenters of deltaic sedimentation still further seaward.

The sea advanced in late Paleocene time, and upper Naheola marine deposits (Coal Bluff "marl") are exposed in Wilcox County, Alabama. This transgression apparently did not take place in the lower Mississippi Embayment as the wells in southwestern Mississippi did not penetrate a marine section which can be correlated with the Coal Bluff. However, the fossils and stratigraphic relations of the outcrop Coal Bluff are little known. It may be that sediments deposited during this transgression should be assigned to the lower Eocene.

Top of the Naheola formation is also top of the Midway and top of the Paleocene. However, as stated above, this important boundary is difficult to determine in wells north of the basal Wilcox Nanafalia shoreline. Where the marine Nanafalia is present, the first non-marine beds below it can arbitrarily be taken as top of the Naheola (Paleocene).

It appears very probable that much of the oil and gas credited to the Wilcox, in Mississippi, Louisiana, and Texas, is from sands of upper Paleocene age (Figure 8).

WILCOX (LOWER EOCENE)

OUTCROP WILCOX

The outcrop Wilcox forms an arcuate hilly belt, 20 to 40 miles wide, from Tennessee southeast to Alabama. The formation is about 700 feet thick in Lauderdale County, but it is much thinner in north-central Mississippi. Sand, silt, and shale comprise almost all of the section. The sediments are non-marine

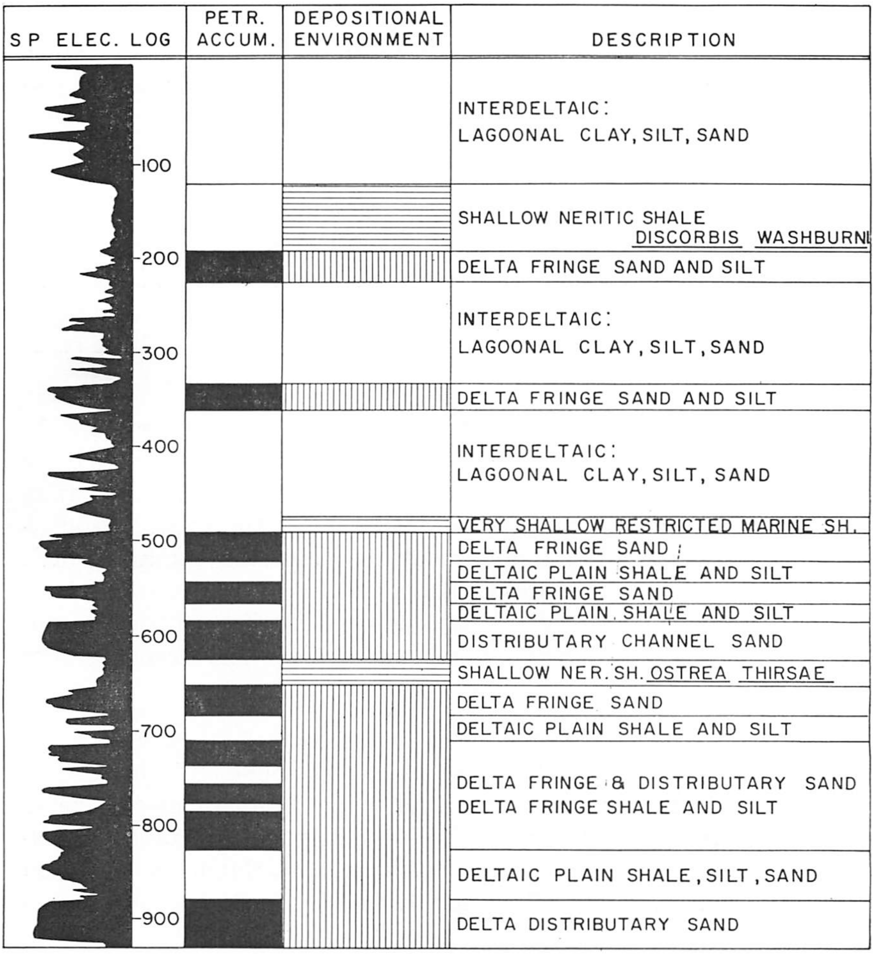

Figure 8.—Section of lower Wilcox (lower Eocene) and upper Midway (Paleocene) in southwestern Mississippi to show petroleum accumulations in deltaic sediments.

except in Lauderdale County, and in the southwestern corner of Kemper County where marine Nanafalia and Bashi crop out. Farther north no marine strata have been reported. Sediment distribution in the Wilcox continental deposits is very complex, and no lithologic units are sufficiently widespread to make possible regional correlation. The detailed studies of outcrop sections by Lowe (18), Grim (12), Mellen (22), MacNeil (20), Foster (8), Conant (4), Priddy (27), Attaya (1), Vestal (35, 36, 37), and others form a basis for interpreting the depositional history of the Wilcox.

The writer pointed out the need for wells to be drilled through the Wilcox just downdip from the outcrop, and for careful study of the well samples to be made. Such wells have been drilled and electrical logs made of the wells (16), but apparently the samples were not studied. Electric logs alone are not sufficient for determining subdivisions of the Wilcox.

It appears that Mississippi subsided uniformly during deposition of the Wilcox sediments so that time-stratigraphic units should not vary greatly in thickness along the outcrop. However, in the Coastal Plain where the sediments were being deposited there were, doubtless, some valleys cut into slightly older sediments and filled with deposits slightly younger than those of the intervalley areas, but no important unconformities should be expected in this alluvial section.

The Wilcox can be subdivided as follows in Lauderdale and Kemper Counties where the marine Nanafalia and Bashi beds crop out:

Hatchetigbee formation. About 200 feet thick. Non-marine.
Bashi "marl". About 20 feet thick. Shallow marine.
Tuscahoma formation. About 400 feet thick. Non-marine.
Nanafalia formation. About 100 feet thick. Shallow marine.

The Meridian sand which overlies the Hatchetigbee appears to be a strandline deposit associated with the lower Claiborne (middle Eocene) transgression. The carbonaceous sand, silt, and shale below the marine Nanafalia belong in the Paleocene Naheola formation.

Fossiliferous Bashi crops out at the base of the "mountain" just south of Meridian and in many places eastward across Alabama. Gee (10) described the Bashi foraminifera in outcrop samples from southeastern Lauderdale County.

The writer has studied Bashi foraminifera from many localities in Alabama, including Hatchetigbee Bluff on the Tombigbee River. The fossiliferous beds near the base of the Bluff are Bashi, not Hatchetigbee, which is non-marine. The inclusion of these very fossiliferous beds in the Hatchetigbee has caused much confusion in upper Wilcox stratigraphy. The Hatchetigbee formation, above Bashi, is about 260 feet thick in Wilcox County, Alabama, but is less than 50 feet thick on the Hatchetigbee Anticline, where the type section of Hatchetigbee formation is exposed.

SUBSURFACE WILCOX

The Wilcox is everywhere present in Mississippi south and west of its outcrop, as proved by numerous wells which penetrated the Tertiary. The section is composed of alternating sands and shales which were transported to the Gulf Coast down the Mississippi Embayment and deposited mainly in alluvial and upper deltaic plain environments. However, two important transgressive periods, Nanafalia and Bashi, are represented by shallow marine shale and marl. Where these marine beds are present, it is possible to subdivide the subsurface Wilcox. Landward of these marine shorelines, the section is mostly undifferentiated because no widespread lithologic units are present. Carbonaceous material is abundant in the sands, silts, and shales, and discontinuous lignite beds occur in most of the stratigraphic units. Pollen and spores are doubtless abundant in the non-marine as well as the marine sediments, and a palynological study of well samples might establish zonation and correlation in this important group of rocks and also indicate where the Paleocene-lower Eocene boundary should be placed.

LOWER WILCOX (NANAFALIA)

The Nanafalia is the most widespread lower Eocene marine formation in the Gulf Coast. It crops out in a narrow belt across Alabama where many fresh exposures have been studied for their large and small fossils. Many of the foraminifera described by Toulmin (34) occur in the subsurface Nanafalia. The writer has identified this fossiliferous section in many wells in Florida, Georgia, Alabama, Mississippi, Louisiana, and Texas. *Ostrea thirsae,* a small marine oyster, is very abundant in many Alabama exposures, and it is also present in the Marthaville formation of the Sabine Uplift. This species occurs in cores of "Baker shale" in some wells in southwestern Mississippi, and also in cores of lower Wilcox from wells in southwestern Louisiana and southeastern Texas. The outcrop section in Texas, which is equivalent to the Nanafalia, has the brackish oyster, *Ostrea duvali,* in some exposures.

Figure 9 shows the approximate extent of the Nanafalia marine transgression. Cores from wells in southwestern Mississippi reveal the presence of two shallow marine sections in the Nanafalia: the "Baker shale" with *Ostrea thirsae,* and common foraminifera; and the "Big shale" with varied and abundant foraminifera (Figure 4). In southwestern Louisiana the marine Nanafalia varies in thickness from 100 to more than 200 feet. Forty species of foraminifera were identified by the writer in well cores from this section. A well in St. Helena Parish, southeastern Louisiana, cored about 500 feet of marine Nanafalia, 1200-1700 feet below top of Wilcox. About 50 species of foraminifera, including the important species *Discorbis washburni, Palmula mcglameryae,* and *Discocyclina blanpiedi,* are present.

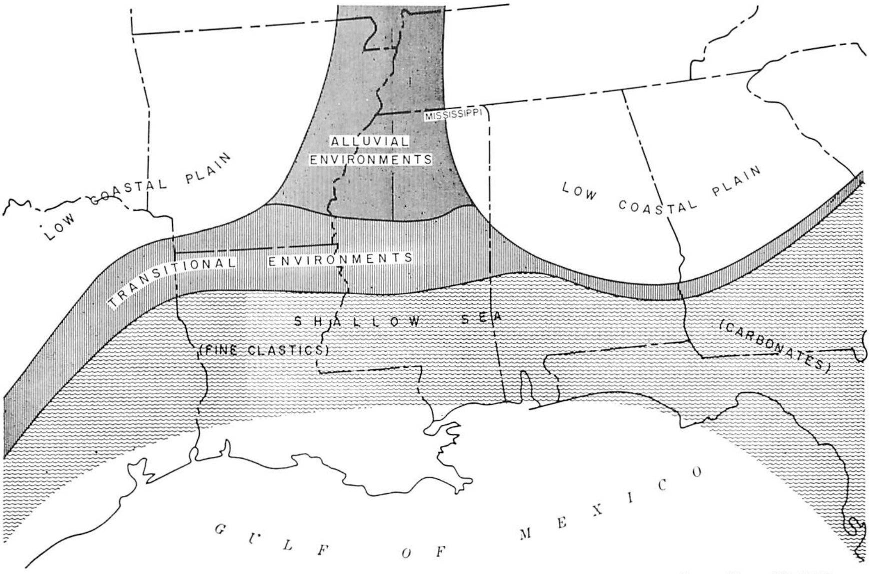

Figure 9.—Paleogeography of early lower Eocene (Nanafalia) time, about 60 million years ago.

The shallow marine Nanafalia has been identified by foraminifera in cores from several wells in central Louisiana. *Discorbis washburni* is probably the most important index species though other calcareous, as well as arenaceous, foraminifera are present.

The Salt Mountain facies (sandy limestone) of the Nanafalia is present as discontinuous layers in southeastern Mississippi, southern Alabama, and western Florida. *Discocyclina* is usually present in this facies.

MIDDLE WILCOX (TUSCAHOMA)

The Tuscahoma can be identified only where it is underlain by marine Nanafalia and overlain by marine Bashi. It is composed of non-marine sands and shales similar to those of the Paleocene Naheola and of the lower Eocene Hatchetigbee. In Alabama at least two thin, very shallow marine sections are known to be present in outcrop Tuscahoma (Figure 3), but no guide fossils have been recognized for identifying the zones in the subsurface.

The middle Wilcox was a period of regression when sedimentation was faster than subsidence in the central and western Gulf Coast. The section in the lower Mississippi Embayment is mostly non-marine as far seaward as wells have penetrated the section (Figure 6).

UPPER WILCOX (BASHI AND HATCHETIGBEE)

Upper Wilcox in the central and western Gulf Coast is represented by the transgressive, shallow marine Bashi marl and the overlying regressive, non-marine Hatchetigbee formation. Middle Wilcox ended with a slowing of deposition. Subsidence continued, and the marine shoreline advanced over the Tuscahoma coastal plain sediments. During Bashi time the sea extended at least as far north in Alabama and east-central Mississippi as the present outcrop of the Wilcox (Figure 10). Equivalent marine deposits (Sabinetown) are exposed on the Sabine uplift along the Texas-Louisiana boundary. Marine conditions obtained only briefly before another pulse of rapid sedimentation pushed the shoreline southward, and the Hatchetigbee sands, silts, shales, and lignites were deposited in coastal plain environments.

BASHI

The thin Bashi sandy glauconitic marl has an abundant fauna (mollusca, foraminifera, ostracoda, corals, etc.) at numerous exposures in Alabama. Seaward of the outcrop, the formation should be equally fossiliferous and easily determined. Yet, the Bashi is little known in the subsurface, where several shallow marine sections are in the upper Wilcox (Figures 4 and 6), but none has the distinctive foraminiferal assemblage of outcrop Bashi. It may be that turbid conditions, in the lower Mississippi Embayment, prevented development of the prolific Bashi fauna. West of the embayment, in southwestern Louisiana and southeastern Texas, the marine water was less turbid and the large foraminifera *Discocyclina* was abundant (Figure 6). Shallow marine mollusks, ostracods, and small foraminifera are in the Sabinetown glauconitic beds exposed in a bluff of the Sabine River, and in shallow wells south of the bluff.

HATCHETIGBEE

The Wilcox ended with deposition of the regressive, non-marine Hatchetigbee formation which is similar lithologically to other non-marine sections of the Wilcox and upper Midway.

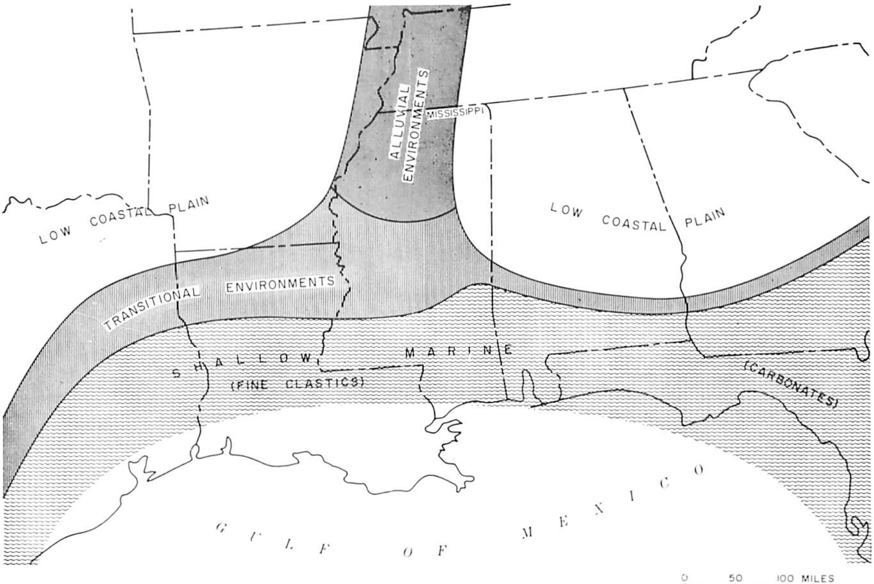

Figure 10.—Paleogeography of late lower Eocene (Bashi) time, about 55 million years ago.

The Bashi marine shoreline was pushed southward at beginning of Hatchetigbee deposition, but the location of Hatchetigbee shorelines is not known. Also the thickness of subsurface Hatchetigbee cannot be determined until the underlying Bashi is identified. Top of the Hatchetigbee is top of the Wilcox, and the criteria for determining the Wilcox-Claiborne boundary were discussed earlier.

The Hatchetigbee sediments were deposited in fresh-water lakes (3) and other coastal plain environments. Downdip from the outcrop are deltaic and lagoonal deposits (Figure 4). Some of the deltaic sands produce oil and gas in southwestern Mississippi.

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LATE PLEISTOCENE AND RECENT HISTORY OF MISSISSIPPI SOUND BETWEEN BEAUVOIR AND SHIP ISLAND

E. H. RAINWATER*

ABSTRACT

Study of 166 samples from 22 borings which penetrated the Recent sediments and into the upper Pleistocene section has made it possible to outline the general depositional history of a portion of Mississippi Sound during that time.

A marine transgression over beach and associated deposits took place in late Pleistocene. The faunas in this transgressive shallow marine section are typical of those now living in the Northern Gulf of Mexico in the inner neritic environment of the interdeltaic province. Mollusks, bryozoa, barnacles, echinoids, ostracods and foraminifera are well represented. Some of the foraminifera, as *Amphistegina* and polymorphinids, indicate that the water was not very turbid.

The transgression ended when the latest Pleistocene continental ice sheets started to form and sea level began to fall. However, subsidence of the area continued, and some of the sediments which were deposited at the retreating shoreline were preserved.

It appears that the shoreline was south of the offshore islands during the last glacial stage, and the area now covered by Mississippi Sound was land that was being eroded and weathered. As sea level rose, due to melting of the ice sheets, the shoreline advanced landward. Formation of the barrier islands (Cat, Ship, Horn, Petit Bois, Dauphin) was initiated during this period, and the islands were built higher as the level of the sea rose. Mississippi Sound was formed by flooding of the coastal area behind the islands, and the lower valleys of the major streams were drowned to form bays (St. Louis, Biloxi, and others). Mississippi Sound and the bays have been brackish bodies of water since their formation because they have been restricted somewhat from the open Gulf by the barrier islands, and there has been large influx of fresh water from many streams which drained to the area.

Sea level reached its present stand about 5,000 years ago. From that time to the Present, the Mississippi Sound has been receiving mostly fine sediments (clay and silt) which have filled more than one half of the originally 30-foot deep body of water.

INTRODUCTION

This report is based on study of 166 core samples from 22 borings in Mississippi Sound along a line from Beauvoir to Ship Island. The borings were drilled by the Eustis Engineering Com-

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*Consulting geologist, Tenneco Oil Company, Houston, Texas

pany, New Orleans, in 1954, for proposed causeway from the mainland to Ship Island. Samples of the cores were obtained from the engineers in charge of the drilling by the late Dr. Olin T. Brown, and his students, Department of Geology, University of Southern Mississippi. Dr. Brown gave small pieces of some of the core samples to the writer who studied them with low power binocular microscope at his home in Jackson, Mississippi in 1954 and 1955.

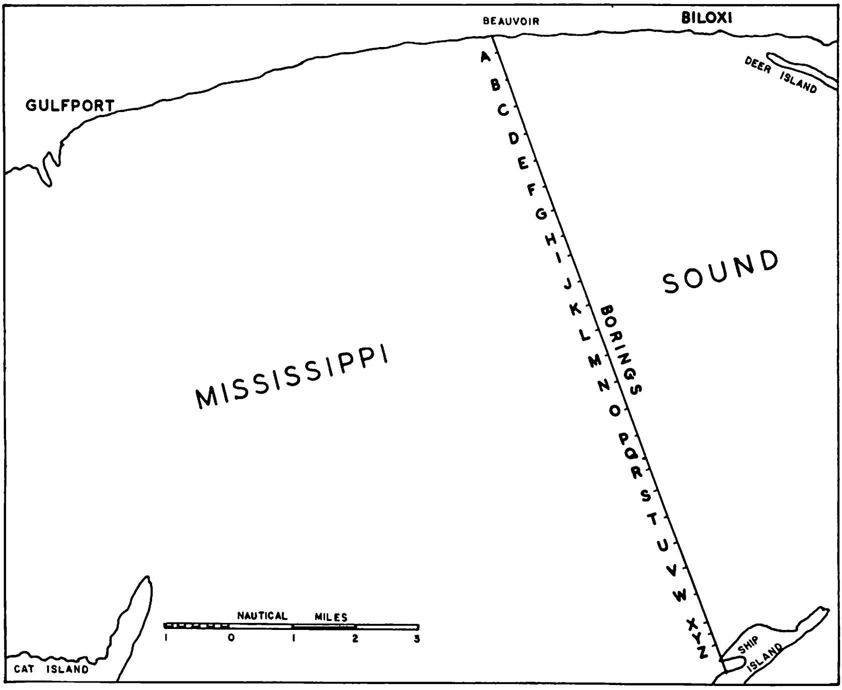


Figure 1.—Location of test borings for proposed causeway to Ship Island.

The general lithology of each sample was described, and residue from washing a portion of each sample over 150- mesh screen was studied for minerals and fossils. The determinations are presented on a chart for each boring, but the graphic lithologic column is largely based on engineers' descriptions.

The borings penetrated the Recent sediments of the Sound and into the late Pleistocene section. The Recent-Pleistocene contact is considered to be in a weathered zone developed when sea level was lower and the shoreline was south of the offshore islands. Sediments above this boundary consist mainly of soft clay and silt which were deposited since sea level rose to its present stand, about five thousand years ago. The clay, silt and sand below the weathered zone are, in general, more compacted than the sediments above.

This brief progress report is presented with the hope that more detailed studies will be made of the minerals and fossils in the core samples. It is important scientifically, as well as economically, that the late geologic history of this region be better understood. The kind and amount of heavy minerals should be determined; ages of the peat beds should be established by radiocarbon analysis; the pollen and spores should be identified as an aid in determining correlation and paleocology; all of the faunal groups represented should be studied by experts who can make comparisons with similar living forms whose habitats are known.

SKETCH OF PRE-PLIOCENE HISTORY OF COASTAL MISSISSIPPI

Coastal and offshore Mississippi are part of a large interdeltaic province of slow subsidence and relatively slow deposition of terrigenous clastic sediments. Similar conditions obtained throughout much of the known geological history of the area though delta-building was important during certain periods of the Lower Cretaceous and early Upper Cretaceous. A shallow epicontinental sea was over the region in middle and late Upper Cretaceous time, and the Gulf of Mexico covered southern Mississippi during the middle and late Eocene and early Oligocene. The Gulf shoreline was mostly south of the present coast during regressive stages of late Paleocene, lower Eocene, and Miocene.

Coastal Louisiana subsided at a faster rate throughout the Tertiary than did coastal Mississippi, and the large ancestral Mississippi River built its deltas, during the regressive stages of the Tertiary, in the more rapidly subsiding segments of the Gulf Coast. The relatively small rivers which emptied into the Gulf in the area of coastal Mississippi were not able to construct large projecting deltas; therefore, there was less fluctuation of the shoreline in this "interdeltaic" area.

PLIOCENE AND EARLY PLEISTOCENE HISTORY OF COASTAL MISSISSIPPI

It is probable that the Pliocene is represented in coastal and adjacent offshore Mississippi by an unconformity and that early Pleistocene sediments lie directly on late Miocene. However, the Pliocene section may be quite thick under the middle and outer continental shelf off Louisiana.

Pleistocene glaciation may have been caused by uplift of the northern hemisphere land areas to greater heights than at any other time in geological history. The mountains were probably much higher than they are now, but the interior and coastal plains were also elevated, so that erosion rather than deposition took place over most of the expanded land areas. The climate changed to colder because of the large uplifted areas, and ice sheets began to form in the northern latitudes. Mountain glaciation became active in the lower latitudes, and enormous quantities of coarse and fine outwash material were supplied to the many large, steep-gradient streams. More coarse sediments (boulders, cobbles, pebbles) were transported from distant sources to the Gulf coastal plain in early Pleistocene than in any other period.

Most of Mississippi was covered with gravel by overloaded steep-gradient streams which were draining much of the interior of the United States. It may be that gravel was brought to the Gulf Coast only once, during the earliest, most severe Pleistocene glaciation, and it was spread as a blanket. Valleys were later cut into and through this blanket, and alluvial terraces were formed during periods of temporary base level. The gravels in these lower and younger terraces were probably derived from the early Pleistocene deposits of the intervalley areas.

The Citronelle formation is considered by the writer to be of Pleistocene age, but the lower terrace deposits mapped as Citronelle in southern Mississippi are younger than those of the type section.

LATE PLEISTOCENE

Each of the borings penetrated late Pleistocene sediments which are composed of sand, silt, and clay, and a few thin beds of impure peat. The oldest sediments were deposited in beach and back-beach environments (Figure 2). Above this non-marine section are sand, silt, and clay which have abundant shallow marine fossils (foraminifera, ostracods, bryozoa, mollusks, echinoids, barnacles, etc.) and some glauconite. This inner neritic section, with maximum thickness under Mississippi Sound of about 15 feet, represents a transgression of the Gulf during the latest Pleistocene interglacial stage.

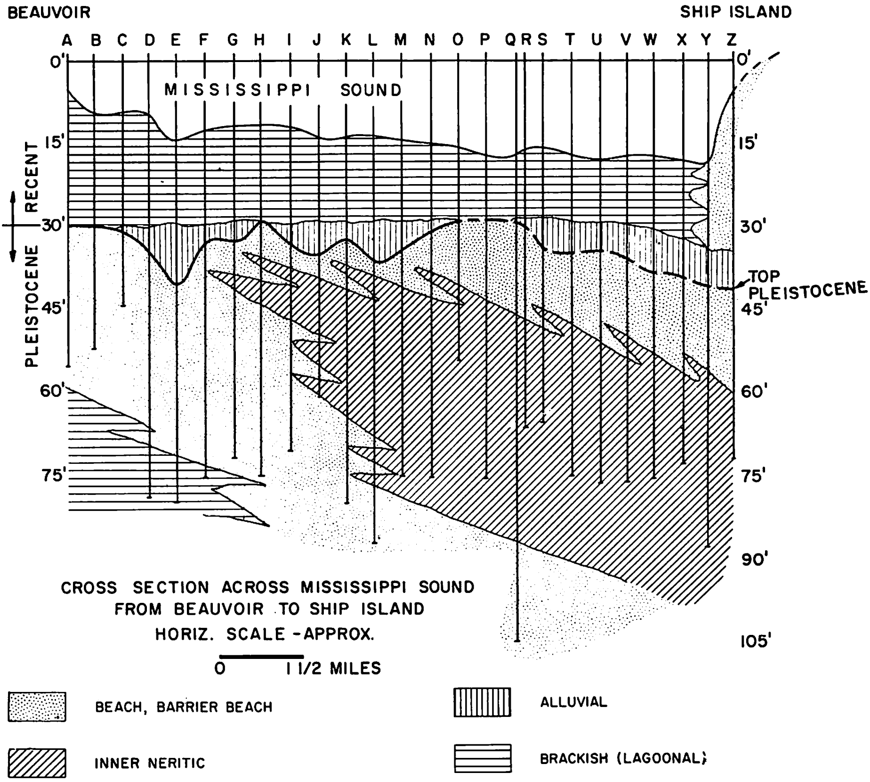


Figure 2.—Late Pleistocene and Recent depositional environments.

Foraminifera are abundant in many of the samples from this section. Miliolids, polymorphinids, *Streblus,* and *Elphidium* are most abundant. This assemblage is characteristic of shallow, near shore, clear water marine environment. Other genera which are present and also indicate non-turbid neritic conditions are *Amphistegnia, Cibicides, Discorbis,* and *Eponides.* It can be concluded that this youngest Pleistocene transgressive marine section was deposited in very shallow, near shore, open sea marine evironment in the interdeltaic province. Deposition was much slower than in coastal and offshore Louisiana where the probable equivalent "Upper Marine" section is several hundred feet thick and is now buried several thousand feet below sea level under the continental shelf.

Beach and associated back-beach deposits accumulated at the same time, and they were penetrated in the northern borings. The old beach ridges just inland from the present coast are probably of this age.

The latest Pleistocene glacial stage caused sea level to be lowered somewhat and the shoreline to retreat. Subsidence of the coastal area continued during this regressive period so that some of the sediments deposited on the newly exposed land were preserved. However, most of the sediment was transported farther seaward to the retreating shoreline. Erosion took place when sea level was lowest.

Sea level began to rise and the shoreline to advance as the continental ice sheets melted, and this ended the Pleistocene Period.

PLEISTOCENE - RECENT BOUNDARY

Base of the Recent is very difficult to determine in areas, such as the outer shelf of the Gulf of Mexico, which have had continuous sedimentation since early Tertiary time. However, where lowering of sea level during the last glacial stage exposed Pleistocene deposits to erosion and weathering, and the final rise of sea level allowed marine or marginal marine deposits to accumulate above the unconformity, it is possible to recognize the unconformity between Pleistocene and Recent.

Figures 2 and 3 show this irregular boundary, which is probably correctly determined in many of the borings even though the lithology is similar above and below the weathered zone. In the more seaward borings the contact is not definite from the samples and descriptions available to the writer.

The sediments below the Pleistocene-Recent boundary are, in general, more compacted than are those above the boundary.

RECENT

Sediments deposited above the Pleistocene are referred to the Recent or Holocene. In areas of rapid subsidence and sedimentation, such as the Mississippi Delta and some intermontane

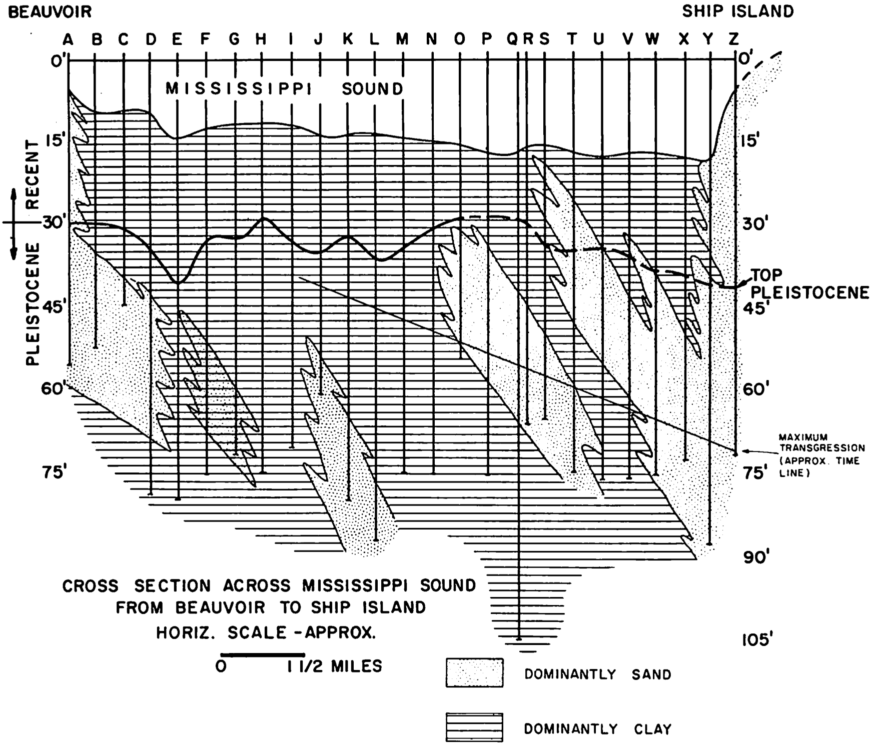


Figure 3.—Distribution of sand and clay in borings.

basins, the Recent sediments may be several hundred feet thick. In Mississippi Sound the Recent sediments have a thickness of about 20 feet, but under the barrier islands of this area the Recent section may be 50 feet thick.

The section is composed mainly of clay, as shown on Figure 3. However, much of the clay is sandy or silty. Pyrite and carbonaceous materials are abundant in many samples from this section.

The earliest Recent sediments were deposited under subaerial conditions (Figure 2), in valleys which were cut when sea level was lower and the shoreline was south of the barrier islands.

Formation of the barrier islands began during the latest rise of sea level. Waves in the advancing sea reworked some of the coastal plain sediments, winnowed the clay and sent it farther seaward. The sand was piled into beach ridges which were built higher as sea level rose. The low coastal plain behind the barriers was inundated to form Mississippi Sound, and the lower valleys of the major streams were flooded to form bays (St. Louis, Biloxi, and others).

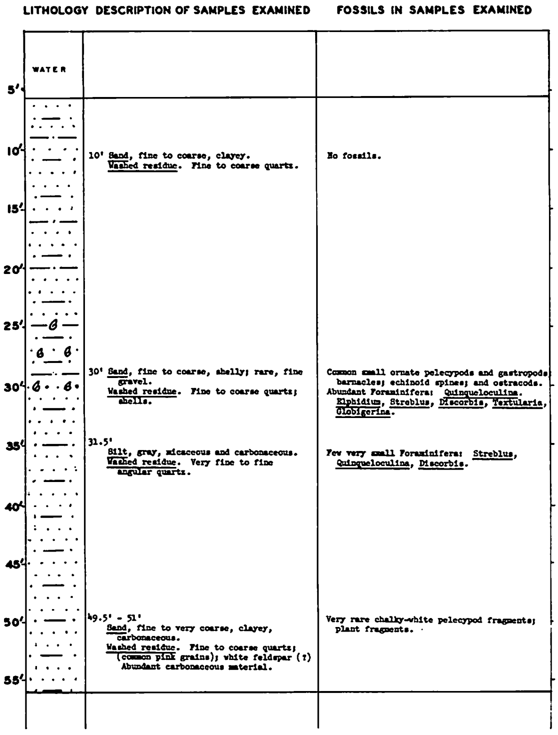
Figure 4.—Eastern part of Ship Island, Harrison County, Mississippi, looking west. The middle ground of the photograph is the approximate south termination of Profile A-Z across Mississippi Sound. The open Gulf lies to the left. Dark, heavy mineral concentrations can be seen along the beach. In the distant upper right Fort Massachusetts on the west end of Ship Island can be faintly discerned. Photo U.S.A.F., courtesy U. S. Bureau of Mines.

After the Sound and bays were formed, most of the coarse sediment of the streams was deposited at the upper end of the bays, and mainly clay and silt reached Mississippi Sound. Brackish faunas, including the foraminifera *Streblus* and *Elphidium,* are present in these fine-grained sediments under Mississippi Sound.

RATE OF SEDIMENTATION IN MISSISSIPPI SOUND

Sediments deposited since sea level rose to its present stand, about five thousand years ago, have filled more than one half of the original 30-foot deep Mississippi Sound between Beauvoir and Ship Island. Sedimentation during that period has been at the rate of about four feet per thousand years. If this rate is maintained, and if there is no significant subsidence or uplift of the area, the Sound should be filled in about three to four thousand years.

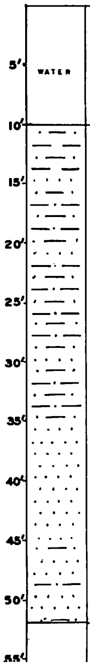
TEST BORING A PROPOSED SHIP ISLAND CAUSEWAY



LITHOLOGY	DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
WATER		
	10' Sand, fine to coarse, clayey. Washed residue. Fine to coarse quartz.	No fossils.
	30' Sand, fine to coarse, shelly; rare, fine gravel. Washed residue. Fine to coarse quartz; shells.	Common small ornate pelecypods and gastropods; barnacles; echinoid spines; and ostracods. Abundant Foraminifera: *Quinqueloculina*. *Elphidium*, *Streblus*, *Discorbis*, *Textularia*, *Globigerina*.
	31.5' Silt, gray, micaceous and carbonaceous. Washed residue. Very fine to fine angular quartz.	Few very small Foraminifera: *Streblus*, *Quinqueloculina*, *Discorbis*.
	49.5' - 51' Sand, fine to very coarse, clayey, carbonaceous. Washed residue. Fine to coarse quartz; (common pink grains); white feldspar (?) Abundant carbonaceous material.	Very rare chalky-white pelecypod fragments; plant fragments.

TEST BORING B PROPOSED SHIP ISLAND CAUSEWAY

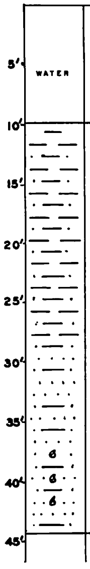
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' Clay, greenish-gray, waxy, sandy, micaceous. Washed residue. Fine to coarse subrounded quartz and common white feldspar(?).	Few Streblus and Elphidium.
24' Clay, greenish-gray, waxy, sandy. Washed residue. Fine to coarse subrounded quartz and common white feldspar(?).	Few Streblus.
30' Sand, fine to coarse, clayey, mottled reddish-brown and light gray, carbonaceous. Washed residue. Fine to coarse quartz; common dark heavy minerals; carbonized plant fragments.	Plant fragments.
34' Clay, greenish-gray, finely sandy; and sand, fine, very argillaceous. Washed residue. Fine angular quartz.	No fossils.
35' - 36.5' Sand, fine to coarse, clayey. Washed residue. Fine to coarse quartz; one pea-size pebble of banded chert.	No fossils.
42' - 43.5' Sand, coarse, white, with brown patches. Washed residue. Fine to coarse quartz; few pink grains.	No fossils.
49' - 50' Sand, white, fine, with streaks of greenish-gray, very sandy clay; carbonized plant fragments. Washed residue. Mostly fine quartz; some coarse grains; abundant carbonized plant fragments.	Plant fragments.

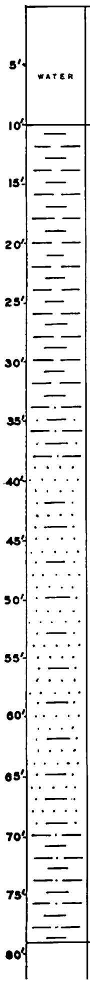
TEST BORING C PROPOSED SHIP ISLAND CAUSEWAY

LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
20' Clay, gray, silty, micaceous, pyritic. Washed residue. Fine quartz.	Streblus (Abundant). Elphidium (Rare).
25' Clay, gray, sandy, pyritic. Washed residue. Fine to coarse quartz.	Streblus (Rare).
30' Sand, fine to coarse, clayey. Washed residue. Fine to coarse quartz.	No Fossils.
33' Sand, fine to coarse. Washed residue. Fine to coarse quartz.	No Fossils.
38' Sand, fine to very coarse, carbonaceous. Washed residue. Fine to very coarse quartz; pyrite.	Common white and gray shell fragments.
41' Sand, fine to coarse, carbonaceous, pyritic. Washed residue. Fine to coarse quartz.	Few white and gray shell fragments.

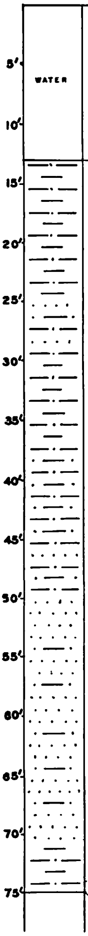
TEST BORING D PROPOSED SHIP ISLAND CAUSEWAY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
25' Clay, gray, silty, micaceous, carbonaceous. Washed residue. Very fine quartz and tiny spherules of pyrite.	*Streblus* (Abundant). *Elphidium* (Abundant).
30' Clay, gray, very silty, pyritic. Washed residue. Very fine quartz and tiny spherules of pyrite.	*Streblus* *Elphidium* Few very small fragments of chalky, white molluscan shells.
34' Clay, mottled white and orange, fine to coarsely sandy. Washed residue. Fine to coarse quartz; some iron-stained; limonitized plant fragments.	Plant fragments.
40' Sand, white, coarse, abundant pink and yellow grains. Washed residue. Mostly coarse, rounded quartz; common white feldspar(?).	No Fossils.
46.5' - 48' Sand, white, fine, micaceous. Washed residue. Fine quartz; abundant pink and yellow grains, dark heavy minerals.	No Fossils.
56' Sand, white with yellowish-brown mottling, fine to coarse, clayey. Washed residue. Fine to coarse quartz; common pink quartz and white feldspar(?); limonite flakes and dark heavy minerals.	No Fossils.
74' Clay, gray, silty. Washed residue. Very fine quartz.	No Fossils.
78' Clay, grayish-white, silty. Washed residue. Very fine quartz.	No Fossils.

TEST BORING F PROPOSED SHIP ISLAND CAUSEWAY

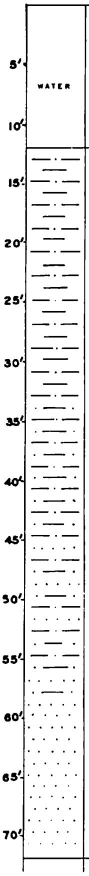
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
13' - 18' Clay, gray, silty, micaceous, carbonaceous. Washed residue. Very fine quartz and spherules of pyrite.	Streblus (Rare).
25' - 28' Sand, fine to coarse, clayey, grayish-white with brown mottling; plant fragments. Washed residue. Fine to coarse quartz; common pink quartz and white feldspar (?).	Plant fragments.
28' - 31' Clay, grayish-white with brown mottling, very sandy. Washed residue. Fine to coarse quartz; many grains iron-stained; ferruginous clay.	No Fossils.
31.5' Sand, fine to coarse, with scattered pellets of white clay. Washed residue. Fine to coarse quartz (common pink grains); rare chert and carbonized plant fragments.	Plant fragments.
48' Sand, fine to coarse with "blebs" of carbonaceous clay. Washed residue. Fine to coarse quartz; common pink quartz and white feldspar(?); dark heavy minerals.	No Fossils.
73' - 75' Clay, grayish-white with faint yellowish-brown mottling, silty. Washed residue. Very fine quartz; pyrite; few very small clusters of siderite pellets; abundant megaspores(?).	Abundant megaspores (?).

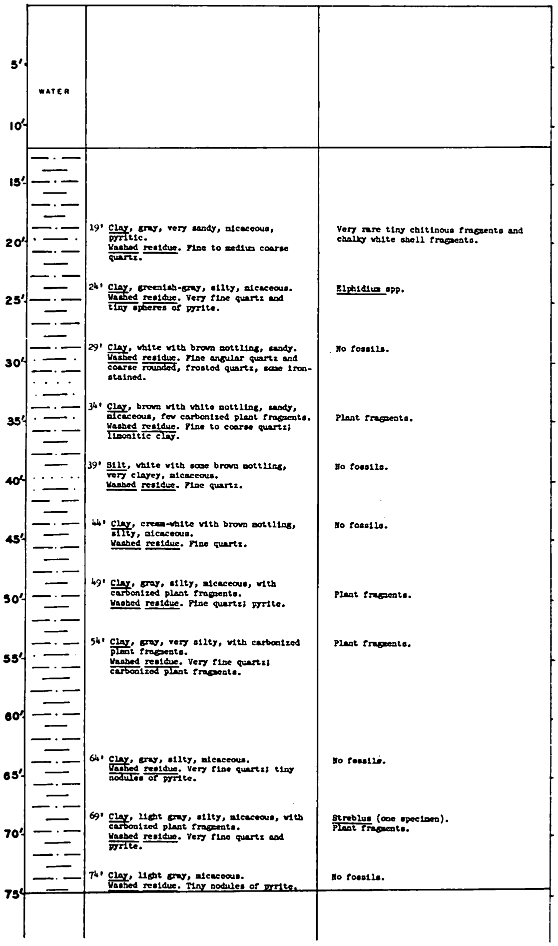
TEST BORING G PROPOSED SHIP ISLAND CAUSEWAY

LITHOLOGY



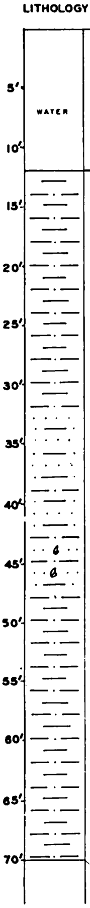
DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
20' Clay, gray, silty, with finely disseminated pyrite. Washed residue. Very fine quartz; abundant tiny spherules of pyrite.	Streblus (Rare). Elphidium (Rare).
35' Clay, grayish-white with brown mottling, very sandy, carbonaceous. Washed residue. Fine to coarse quartz, some grains iron-stained; common pink quartz and white feldspar (?).	No Fossils.
40' Clay, brownish-orange with white mottling, very sandy. Washed residue. Fine to coarse, iron-stained quartz; flakes of brown limonitic clay.	No Fossils.
50' Clay, light gray, silty, finely micaceous and carbonaceous. Washed residue. Fine to medium quartz; common carbonized and pyritized plant fragments.	Plant fragments.
62' Sand, white to yellowish-brown, fine to coarse, with rare pyritized plant fragments. Washed residue. Fine to very coarse rounded quartz; common white and gray chert, pink quartz, white feldspar (?), and dark heavy minerals.	Plant fragments.

TEST BORING H PROPOSED SHIP ISLAND CAUSEWAY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' Clay, gray, very sandy, micaceous, pyritic. Washed residue. Fine to medium coarse quartz.	Very rare tiny chitinous fragments and chalky white shell fragments.
24' Clay, greenish-gray, silty, micaceous. Washed residue. Very fine quartz and tiny spheres of pyrite.	*Elphidium* spp.
29' Clay, white with brown mottling, sandy. Washed residue. Fine angular quartz and coarse rounded, frosted quartz, some iron-stained.	No fossils.
34' Clay, brown with white mottling, sandy, micaceous, few carbonized plant fragments. Washed residue. Fine to coarse quartz; limonitic clay.	Plant fragments.
39' Silt, white with some brown mottling, very clayey, micaceous. Washed residue. Fine quartz.	No fossils.
44' Clay, cream-white with brown mottling, silty, micaceous. Washed residue. Fine quartz.	No fossils.
49' Clay, gray, silty, micaceous, with carbonized plant fragments. Washed residue. Fine quartz; pyrite.	Plant fragments.
54' Clay, gray, very silty, with carbonized plant fragments. Washed residue. Very fine quartz; carbonized plant fragments.	Plant fragments.
64' Clay, gray, silty, micaceous. Washed residue. Very fine quartz; tiny nodules of pyrite.	No fossils.
69' Clay, light gray, silty, micaceous, with carbonized plant fragments. Washed residue. Very fine quartz and pyrite.	*Streblus* (one specimen). Plant fragments.
74' Clay, light gray, micaceous. Washed residue. Tiny nodules of pyrite.	No fossils.

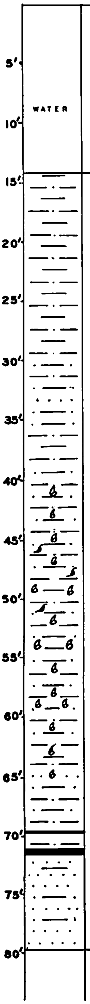
TEST BORING I PROPOSED SHIP ISLAND CAUSEWAY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' Clay, gray, silty, micaceous. Washed residue. Very fine quartz and pyrite nodules.	Streblus (Very rare).
24' Clay, greenish-gray, micaceous. Washed residue. Very fine quartz and pyrite.	Streblus (Common). Elphidium (Common). Few chalky white molluscan fragments.
29' Clay, greenish-gray, carbonaceous, pyritic. Washed residue. Very fine quartz and pyrite nodules.	Streblus (Common). Elphidium (Common). Few chalky-white molluscan fragments.
34' Clay, mottled gray and brown, sandy. Washed residue. Fine to coarse quartz; limonite flakes.	No fossils.
39' Clay, mottled gray and brown, very sandy. Washed residue. Fine to coarse quartz; brownish limonite.	No fossils.
44' Sand, fine to medium, gray, carbonaceous, micaceous, silty. Washed residue. Fine quartz, some coarse grains; dark heavy minerals.	Streblus (Rare). Abundant small fragments of white pelecypod shells.
49' Clay, mottled white and orange-brown, silty. washed residue. Very fine quartz.	No fossils.
54' Clay, light gray, silty, micaceous, carbonaceous. Washed residue. Very fine quartz; some pyrite.	No fossils.
59' Clay, light gray with orange-brown spots, silty, micaceous. Washed residue. Very fine quartz; abundant tiny pyrite nodules and pyritized plant fragments.	Plant fragments.
64' Clay, light gray with brown mottling, silty. Washed residue. Very fine quartz; pyrite.	No fossils.
69' Clay, light gray with brown mottling, silty. ~~Washed residue. Very fine quartz; dark~~ heavy minerals.	Elphidium (Very Rare). One fragment of chalky white pelecypod.

TEST BORING K PROPOSED SHIP ISLAND CAUSEWAY

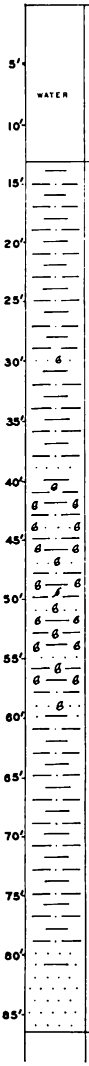
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' Clay, greenish-gray, silty, carbonaceous, micaceous. Washed residue. Very fine quartz; abundant tiny pellets of pyrite.	Streblus (rare). Elphidium (rare).
24' Clay, gray, silty, micaceous, carbonaceous. Washed residue. Very fine quartz.	Streblus (rare). Elphidium (rare). Discorbis (rare). Fragments of chalky white mollusks (rare).
29' Clay, greenish-gray, sandy, micaceous, carbonaceous. Washed residue. Fine quartz.	Streblus (very rare). Fragments of chalky white mollusks (rare).
34' Sand, white and brown mottled, fine. Washed residue. Fine to medium quartz; dark heavy minerals; carbonized plant fragments.	Few carbonized plant fragments.
39' Clay, silty, mottled brown and gray, carbonaceous. Washed residue. Very fine quartz.	Few carbonized plant fragments.
44' Clay, greenish-gray, sandy, very calcareous, carbonaceous. Washed residue. Fine quartz; abundant bronze-colored glauconite; agate and other minerals.	Abundant Foraminifera: Streblus (common), Elphidium (abundant), Quinqueloculina (abundant). Common: Bigenerina, Discorbis, Nonion, Textularia, Uvigerina, etc.
49' Clay, greenish-gray, flaky, very calcareous and fossiliferous. Washed residue. Very fine quartz; shells; some brownish-green glauconite; carbonized plant fragments; pyrite.	Very abundant Foraminifera: Buliminella curta, B. elegantissima, Bolivina, Discorbis, Elphidium, Nonion, Nonionella, Quinqueloculina, Pulvinulinella, Virgulina, etc. Abundant small pelecypods and gastropods, echinoid spines and ostracods, scaphopods.
54' Clay, greenish-gray, with "patches" of fine to coarse sand; very calcareous and fossiliferous. Washed residue. Fine to coarse, dark-stained quartz; shell fragments.	Abundant Streblus and Elphidium. Common Quinqueloculina. Rare Nonion. Common chalky-white shell fragments, few ostracods.
59' Clay, greenish-gray, very sandy, calcareous, with abundant shells. Washed residue. Fine to medium quartz; shells: pyrite.	Streblus (rare). Elphidium (rare). Discorbis (rare).
64' Silt, clayey, carbonaceous, pyritic. Washed residue. Fine quartz; pyrite.	Chalky white pelecypod fragments (rare).
71' Sand, clayey, carbonaceous; and pyritic lignite. Washed residue. Fine to medium quartz; black lignite; pyrite.	Quinqueloculina (very small, very rare).

TEST BORING L PROPOSED SHIP ISLAND CAUSEWAY

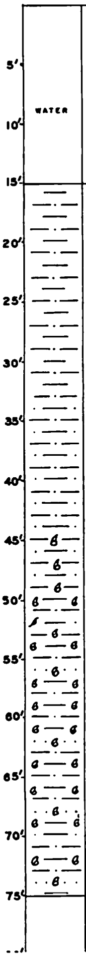
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' *Clay*, greenish-gray, silty, pyritic, micaceous. *Washed residue*. Very fine quartz; pyrite.	No fossils.
24' *Clay*, greenish-gray, pyritic, micaceous; and lenses of silt. *Washed residue*. Very fine quartz; pyrite; dark heavy minerals.	Few very small chitinous fragments; brownish coprolites?
29' *Sand*, fine. *Washed residue*. Fine quartz; dark heavy minerals.	*Streblus* (rare). *Elphidium* (common).
34' *Silt*, clayey, mottled gray and brown. *Washed residue*. Fine quartz and some coarse grains; dark heavy minerals.	No fossils.
39' *Silt*, clayey, mottled gray and brown. *Washed residue*. Fine quartz; dark heavy minerals; pellets of orange clay.	No fossils.
44' *Sand*, fine to coarse, clayey, shelly, *Washed residue*. Fine to coarse quartz; shells; dark heavy minerals.	Abundant mollusks, bryozoa, echinoid fragments, ostracods and Foraminifera. *Streblus*, *Elphidium*, *Discorbis*, *Cibicides*, *Nonionella*, miliolids and polymorphinids.
49' *Clay*, sandy, shelly. *Washed residue*. Shells; fine to coarse quartz; few brown pellets.	Abundant small pelecypods, echinoid spines, and ostracods. Very abundant Foraminifera: miliolids, *Cibicides*, *Textularia*, *Bigenerina*, *Streblus*, *Elphidium*, *Nonionella*, *Globigerina*, *Buliminella elegantissima*, etc.
54' *Clay*, sandy, fossiliferous. *Washed residue*. Shells; fine to coarse quartz.	Very abundant Foraminifera as in sample above. Abundant ostracods, small pelecypods, bryozoa, echinoid fragments.

TEST BORING M PROPOSED SHIP ISLAND CAUSEWAY

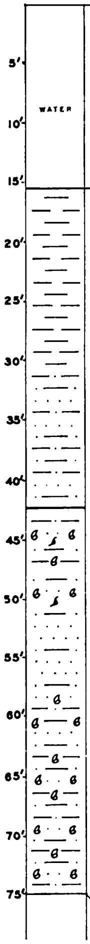
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
16' *Clay*, gray, silty, carbonaceous, micaceous, pyritic. *Washed residue*. Very fine quartz and pyrite pellets.	*Streblus* (rare). *Elphidium* (rare). *Molluscan* fragments (rare).
18' *Clay*, as above. *Washed residue*. Very fine quartz and pyrite pellets.	*Streblus* (common). *Elphidium* (rare). *Molluscan* fragments (common).
30' *Clay*, greenish-gray, sandy, carbonaceous, micaceous, pyritic. *Washed residue*. Fine to coarse quartz; dark heavy minerals; white chalky shell fragments.	*Elphidium* spp. (abundant). *Streblus* (common). *Pelecypod* shell fragments (common).
35' *Sand*, fine to coarse, clayey, mottled gray and brown. *Washed residue*. Fine to coarse, iron-stained quartz.	No fossils.
37' *Sand*, clayey, fine,mottled gray and brown. *Washed Residue*. Fine to coarse quartz; dark heavy minerals.	Rare pyritized plant fragments and chalky white shell fragments.
40' *Silt*, Clayey, mottled white and brown. *Washed residue*. Very fine quartz; dark heavy minerals.	Common plant fragments, partly carbonized.
45' *Clay*, sandy, calcareous, fossiliferous, micaceous. *Washed residue*. Fine quartz; dark heavy minerals.	Common very small pelecypods and gastropods. Abundant echinoid plates and spines; ostracods. *Streblus* and *Elphidium* (abundant), *Discorbis* and *Globigerina* (rare).
48' *Clay*, gray, calcareous, fossiliferous, micaceous, pyritic. *Washed residue*. Fine to medium quartz; pyrite pellets; dark heavy minerals.	Common pelecypod and barnacle shell fragments Abundant echinoid plates and spines, and ostracods. Abundant *Streblus*, *Elphidium*, *Quinqueloculina* Rare *Discorbis*, *Virgulina*, *Nonionella*, *Pulvinulina*.
53' *Clay*, gray, shelly, calcareous, pyritic. *Washed residue*. Fine to coarse quartz; shells; common dark brown glauconite pellets.	Abundant mollusks (worn, "rolled"); barnacles echinoid plates and spines; ostracods. Abundant *Discorbis*, *Hanzawaia*, *Streblus*, *Elphidium*. Common *Globulina*, *Pyrulina*, *Nonionella*, *Buliminella elegantissima*. Rare *Buliminella* cf. *curta*. Few small brownish "pavement" teeth.
65' *Clay*, greenish-gray, sandy, shelly. *Washed residue*. Fine to coarse quartz; plant fragments; pyrite pellets; dark heavy minerals.	*Elphidium* spp. (abundant). *Streblus* (rare). *Cibicides* (common). Few bryozoa and echinoid spines. Abundant partly pyritized and carbonized plant fragments.
75' *Clay*, gray, silty, carbonaceous, micaceous pyritic. *Washed residue*. Very fine quartz; pyrite; dark heavy minerals.	Few carbonized wood fragments.

TEST BORING N PROPOSED SHIP ISLAND CAUSEWAY

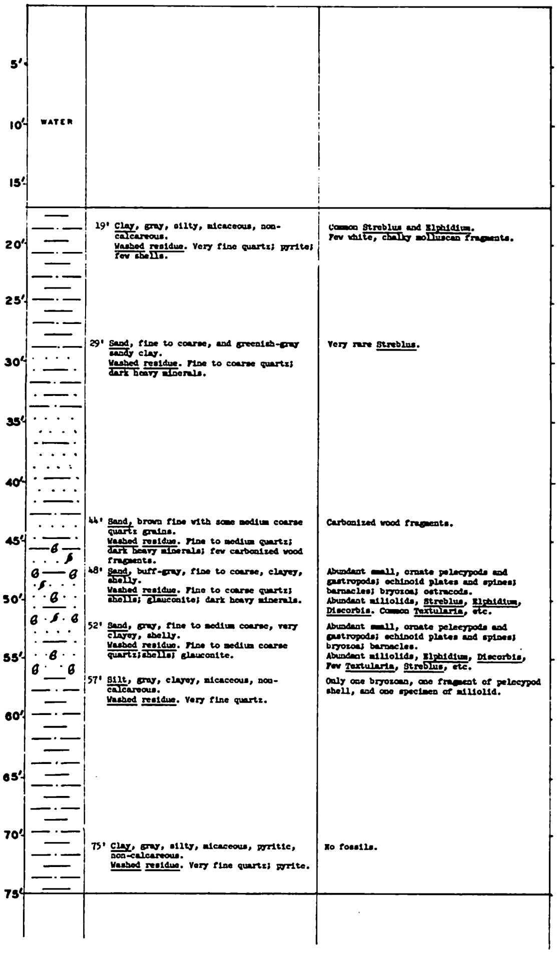
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
30' Sand, fine to coarse, clayey. Washed residue. Fine to coarse quartz; dark heavy minerals.	Few tiny fragments of pelecypod shells.
33' Sand, fine to coarse, clayey, mottled gray and brown. Washed residue. Fine to coarse, iron-stained quartz; dark heavy minerals.	Few pyritized plant fragments.
35' Sand, fine to coarse, clayey, mottled gray and brown. Washed residue. Fine to coarse quartz; some iron-stained; dark heavy minerals.	No fossils.
40' Sand, very fine, silty, with streaks of waxy, very carbonaceous clay. Washed residue. Very fine quartz; dark heavy minerals; carbonized wood fragments.	Carbonized wood fragments (abundant).
45' Sand, fine with some coarse grains; clayey; shelly. Washed residue. Fine to coarse quartz; shells; common brown glauconite pellets.	Abundant small pelecypods and gastropods, and echinoid plates and spines. Common ostracods; rare bryozoa and worm tubes. Abundant miliolids and Elphidium spp. Common Streblus, Cibicides, and Discorbis. Rare Bigenerina, Pyrulina, Textularia.
65' Clay, gray, silty, calcareous, fossiliferous, micaceous. Washed residue. Very fine quartz; some coarse grains; shells; dark brown glauconite pellets.	Abundant very small, ornate pelecypods and gastropods; scaphopods; bryozoa; echinoid plates and spines. Abundant Foraminifera: Amphistegina, Streblus, Elphidium, Discorbis sp., miliolids, Nonionella, Globigerina, Globulina, Pyrulina, Bitubulogenerina, Angulogerina, Buliminella.
75' Silt, gray, clayey, calcareous, fossiliferous, micaceous. Washed residue. Very fine quartz, shells.	Pelecypods, echinoid plates and spines. Abundant Foraminifera: Amphistegina, miliolids, Discorbis, Elphidium, Bolivina, Globigerina, Guttulina, Nonion, Streblus, Textularia.

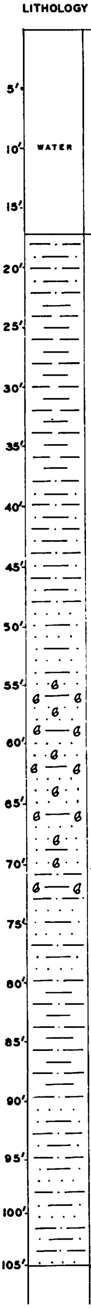
TEST BORING P PROPOSED SHIP ISLAND CAUSEWAY

LITHOLOGY



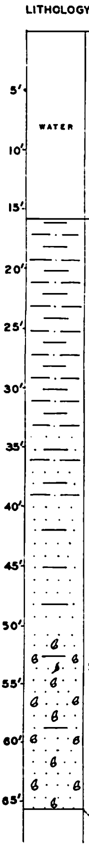
DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19' Clay, gray, silty, micaceous, non-calcareous. Washed residue. Very fine quartz; pyrite; few shells.	Common Streblus and Elphidium. Few white, chalky molluscan fragments.
29' Sand, fine to coarse, and greenish-gray sandy clay. Washed residue. Fine to coarse quartz; dark heavy minerals.	Very rare Streblus.
44' Sand, brown fine with some medium coarse quartz grains. Washed residue. Fine to medium quartz; dark heavy minerals; few carbonized wood fragments.	Carbonized wood fragments.
48' Sand, buff-gray, fine to coarse, clayey, shelly. Washed residue. Fine to coarse quartz; shells; glauconite; dark heavy minerals.	Abundant small, ornate pelecypods and gastropods; echinoid plates and spines; barnacles; bryozoa; ostracods. Abundant miliolids, Streblus, Elphidium, Discorbis. Common Textularia, etc.
52' Sand, gray, fine to medium coarse, very clayey, shelly. Washed residue. Fine to medium coarse quartz; shells; glauconite.	Abundant small, ornate pelecypods and gastropods; echinoid plates and spines; bryozoa; barnacles. Abundant miliolids, Elphidium, Discorbis, Few Textularia, Streblus, etc.
57' Silt, gray, clayey, micaceous, non-calcareous. Washed residue. Very fine quartz.	Only one bryozoan, one fragment of pelecypod shell, and one specimen of miliolid.
75' Clay, gray, silty, micaceous, pyritic, non-calcareous. Washed residue. Very fine quartz; pyrite.	No fossils.

TEST BORING Q PROPOSED SHIP ISLAND CAUSEWAY



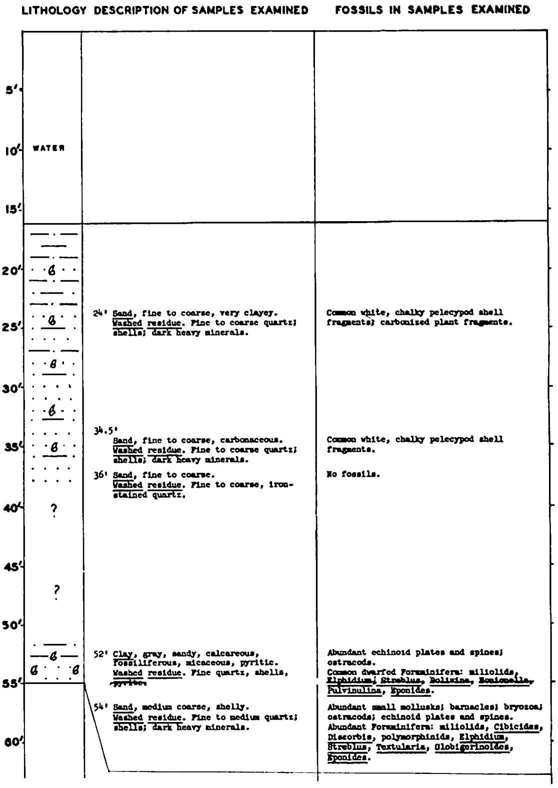
DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
19.5' Clay, gray, silty, micaceous, pyritic. Washed residue. Very fine quartz.	Few pelecypod shell fragments, Streblus, Elphidium.
38' Clay, gray, fine to coarsely sandy, micaceous, pyritic. Washed residue. Fine to coarse quartz; pyrite.	Few white pelecypod shell fragments.
46.5' Clay, brown, waxy, sandy, carbonaceous. Washed residue. Fine quartz, some coarse grains; brown plant fragments.	Few pelecypod shell fragments.
54.5' Sand, fine with some coarse grains, shelly. Washed residue. Fine quartz; some coarse quartz, pyrite; dark heavy minerals, abundant shells.	Gray oyster shells; white, chalky pelecypods; barnacles; echinoid fragments; very rare bryozoa. Abundant miliolids and Cibicides; few Elphidium, Nonion, Textularia, etc.
71.5' Clay, greenish-gray, finely sandy, very carbonaceous and fossiliferous, pyritic, calcareous. Washed residue. Very fine quartz; pyrite; dark heavy minerals; abundant shells.	Abundant small, thin-shelled pelecypods; gastropods; echinoid fragments; abundant ostracods. Abundant Elphidium, Streblus, Discorbis, Cibicides. Common Nonionella, Virgulina. Rare Bigenerina, Bolivina, Cancris, Globigerina, Globulina, etc.
72' Clay, light gray, sandy micaceous. Washed residue. Fine to medium quartz.	No fossils.
89' Sand, gray with orange mottling, fine to coarse. Washed residue. Fine quartz and some coarse frosted grains; pyrite; dark heavy minerals.	Few very small chalky white shell fragments.
94' Clay, greenish-gray, sandy, micaceous, pyritic. Washed residue. Fine to medium quartz, pyrite.	No fossils.
99' Clay, gray and black, sandy, very carbonaceous, pyritic. Washed residue. Fine quartz; carbonaceous material.	Abundant carbonized plant fragments.
104' Clay, greenish-gray, very sandy and carbonaceous. pyritic, micaceous. Washed residue. Very fine quartz; pyrite; peaty plant fragments.	Abundant plant fragments.

TEST BORING R PROPOSED SHIP ISLAND CAUSEWAY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
23' Clay, gray, sandy. Washed residue. Fine quartz.	Few very small white, chalky pelecypod shell fragments.
29' Clay, gray, sandy, micaceous. Washed residue. Fine to coarse quartz; dark heavy minerals.	No fossils.
34' Clay and Sand. Washed residue. Very fine to medium quartz; very small pyrite pellets; dark heavy minerals.	No fossils.
39' Sand, brown, fine to coarse, very clayey and carbonaceous. Washed residue. Fine to coarse quartz; partly lignitized plant fragments.	Abundant plant fragments.
54.5' Sand, fine to medium, shelly. Washed residue. Fine to medium quartz; shells; dark green glauconite.	Very abundant small mollusks; barnacles; bryozoa; echinoid plates. Abundant miliolids, *Elphidium*, *Discorbis*, *Cibicides*; few *Textularia*, etc.
63' Sand, fine to medium, carbonaceous. Washed residue. Fine to medium quartz; shells; dark heavy minerals.	Common small, worn pelecypods and gastropods; echinoid plates.
64' Sand, fine to coarse. carbonaceous. Washed residue. Fine to coarse quartz; shells.	Few mollusks. echinoid spines, miliolids.

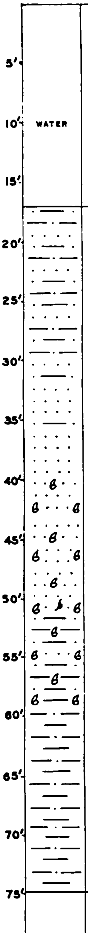
TEST BORING S PROPOSED SHIP ISLAND CAUSEWAY



LITHOLOGY	DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
24'	Sand, fine to coarse, very clayey. Washed residue. Fine to coarse quartz; shells; dark heavy minerals.	Common white, chalky pelecypod shell fragments; carbonized plant fragments.
34.5'	Sand, fine to coarse, carbonaceous. Washed residue. Fine to coarse quartz; shells; dark heavy minerals.	Common white, chalky pelecypod shell fragments.
36'	Sand, fine to coarse. Washed residue. Fine to coarse, iron-stained quartz.	No fossils.
52'	Clay, gray, sandy, calcareous, fossiliferous, micaceous, pyritic. Washed residue. Fine quartz, shells, ~~pyrite.~~	Abundant echinoid plates and spines; ostracods. Common dwarfed Foraminifera: miliolids, Elphidium, Streblus, Bolivina, Nonionella, Pulvinulina, Eponides.
54'	Sand, medium coarse, shelly. Washed residue. Fine to medium quartz; shells; dark heavy minerals.	Abundant small mollusks; barnacles; bryozoa; ostracods; echinoid plates and spines. Abundant Foraminifera: miliolids, Cibicides, Discorbis, polymorphinids, Elphidium, Streblus, Textularia, Globigerinoides, Eponides.

TEST BORING T PROPOSED SHIP ISLAND CAUSEWAY

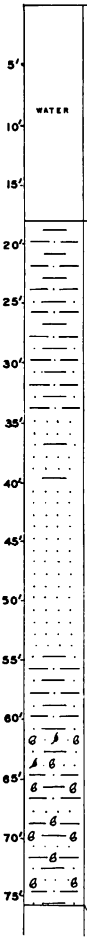
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
23' Clay, gray, sandy, carbonaceous. Washed residue. Very fine to medium quartz; pyrite; dark heavy minerals; shells.	Common white, chalky pelecypod shell fragments. Few Elphidium and Streblus.
25' Sand, fine to medium, very clayey, carbonaceous. Washed residue. Fine to medium quartz; shells, carbonized plant fragments; dark heavy minerals.	Common plant fragments. Few fish scales, Streblus, Quinqueloculina.
31' Sand, fine to medium, very clayey, carbonaceous. Washed residue. Fine to coarse, dark-stained quartz; dark heavy minerals.	Few white chalky pelecypod fragments.
35.5' Sand, fine to coarse, carbonaceous. Washed residue. Fine to coarse, dark-stained quartz.	No fossils.
45' Sand, fine to coarse, clayey, shelly. Washed residue. Fine to coarse quartz; shells.	Abundant gray and white, worn pelecypod and gastropod shell fragments. Common Streblus and Elphidium. Rare Cibicides and Quinqueloculina.
51' Sand, Fine to coarse, shelly, carbonaceous Washed residue. Fine to coarse, dark-stained quartz; black glauconite; dark heavy minerals; shells.	Abundant gray and white mollusk shell fragments; echinoid plates and spines; barnacles; bryozoa. Few miliolids, Cibicides, Elphidium, Textularia.
72' Clay, gray with brown mottling, sandy, micaceous. Washed residue. Fine to medium quartz.	Few carbonized plant fragments. Rare echinoid spines. Very rare Streblus.

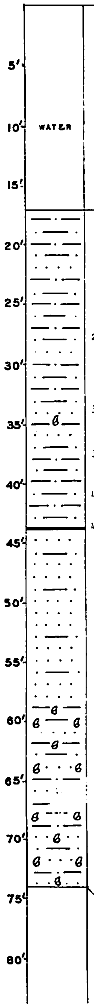
TEST BORING U PROPOSED SHIP ISLAND CAUSEWAY

LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
23' Clay, gray, sandy, micaceous, pyritic. Washed residue. Fine quartz; dark heavy minerals; pyrite.	Few Streblus and Elphidium.
29' Clay, gray, very sandy, micaceous, pyritic. Washed residue. Fine quartz; dark heavy minerals; pyrite.	Few carbonized plant fragments.
35' Sand, white and brown mottled, medium coarse, carbonaceous. Washed residue. Fine to medium iron-stained quartz (pink quartz abundant); brown sandy limonite; dark heavy minerals.	One fragment of white, chalky, pelecypod shell. One fragment of limonitized wood.
61' Sand, fine to medium, shelly; abundant greenish-gray clay. Washed residue. Fine to medium quartz; shells; glauconite; dark heavy minerals.	Abundant small ornate pelecypods and gastropods; common bryozoa, echinoid fragments; Dentalium. Few otoliths and barnacles. Abundant foraminifera; milioids, polymorphinids, Cibicides, Discorbis, Elphidium, Textularia, Nonionella, Globigerina, Planulina, Bigenerina, Streblus, Buliminella elegantissima.
73' Clay, greenish-gray, sandy, shelly. Washed residue. Fine to medium quartz; shells; dark heavy minerals; pyrite.	Abundant white, thin-shelled pelecypods; echinoid fragments; ostracods. Few worn Dentalium and barnacles. Abundant Foraminifera: miliolids, polymorphinids, Amphistegina, Elphidium, Textularia, Cibicides, Discorbis, Nonion, Streblus.

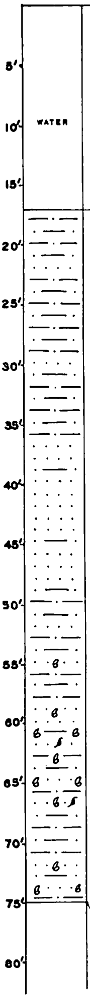
TEST BORING V PROPOSED SHIP ISLAND CAUSEWAY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
28' **Clay**, greenish-gray, silty, micaceous, pyritic. **Washed residue**. Fine quartz; dark heavy minerals; pyrite.	Very rare pelecypod and echinoid fragments. Few *Elphidium*, *Nonionella*.
34' **Silt**, gray, clayey, micaceous, pyritic. **Washed residue**. Fine quartz; dark heavy minerals; shells; some pyrite.	Common echinoid plates and spines, and white chalky pelecypod shell fragments. Common Foraminifera: *Streblus*, *Elphidium*, *Quinqueloculina*.
36' **Sand**, gray, fine to medium, and greenish-gray, carbonaceous clay. **Washed residue**. Fine to medium quartz; dark heavy minerals; pyrite.	Few very small fragments of white chalky pelecypod shells.
40' **Clay**, light gray, very sandy, micaceous. **Washed residue**. Fine to medium, frosted quartz; dark heavy minerals.	Common carbonized plant fragments.
44' **Peat**, dark brown to black, sandy. **Washed residue**. Partly carbonized marsh grass?; fine to medium quartz.	Plant fragments.
55' - 56.5' **Sand**, white, very fine, carbonaceous. **Washed residue**. Fine quartz; plant fragments; dark heavy minerals.	Plant fragments.
62' **Clay**, buff with brown patches, silty, shelly. **Washed residue**. Mostly shells; fine quartz.	Very abundant small thin-shelled pelecypods. Few gastropods, bryozoa, echinoid spines. Common small, thin-shelled, smooth ostracods. Abundant Foraminifera: miliolids, *Elphidium*, *Streblus*, *Discorbis*, *Nonionella*, *Textularia*.
65' **Clay**, greenish-gray, very sandy, calcareous. **Washed residue**. Fine to medium quartz; shells; dark heavy minerals.	Abundant small ornate pelecypods; echinoid plates. Common gastropods; *Dentalium*; few bryozoa. Abundant and varied ostracods. Abundant Foraminifera: miliolids, *Elphidium*, *Streblus*, *Discorbis*, *Textularia*, *Guttulina*, *Globulina*.
74' **Sand**, fine to medium, and greenish-gray ~~clay~~. **Washed residue**. Fine to medium quartz; shells; dark heavy minerals; pyrite.	Abundant mollusks, echinoid fragments, barnacles. Few ostracods; otoliths. Abundant Foraminifera: miliolids, *Elphidium*, *Streblus*, *Amphistegina*, *Discorbis*, *Nonionella*, *Bolivina*, *Globigerina*, *Textularia*, *Buliminella bassendorfensis*, *B. elegantissima*.

TEST BORING W PROPOSED SHIP ISLAND CAUSEWAY

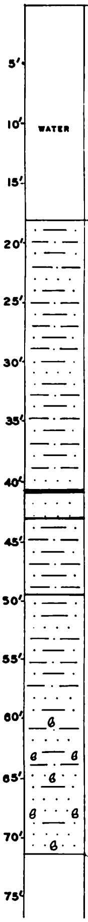
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
30' Sand, gray with brown mottling, clayey, fine to medium. Washed residue. Fine to medium quartz; dark heavy minerals.	Very rare shell fragments. One worn specimen of *Quinqueloculina*.
44' Sand, fine to medium, and greenish, waxy clay. Washed residue. Fine to medium quartz; dark heavy minerals.	Few ostracods and molluscan shell fragments. Rare *Cibicides* and *Quinqueloculina*.
54' Clay, light gray, very calcareous, micaceous. Washed residue. Fossils; some pyrite.	Abundant echinoid spines. Common Foraminifera: *Streblus*, *Elphidium*, *Miliammina*.
62' Sand, fine to coarse, shelly. Washed residue. Fine to coarse quartz; glauconite; shells; dark heavy minerals.	Abundant small ornate pelecypods and gastropods; echinoid plates; barnacles; worm tubes?. Few bryozoa and ostracods. Abundant Foraminifera: miliolids, polymorphinids, *Elphidium*, *Cibicides*, *Discorbis* *Eponides*, *Streblus*, *Globigerina*, *Bigenerina*, *Textularia*.
66' Sand, light buff, fine to coarse, shelly. Washed residue. Fine to coarse quartz; shells; dark heavy minerals; black glauconite.	Abundant small ornate pelecypods and gastropods, and echinoid fragments. Common bryozoa, barnacles, worm tubes?. Abundant Foraminifera: miliolids, *Elphidium*, *Streblus*, *Amphistegina*, *Bolivina*, *Nonionella*, *Textularia*, *Guttulina*.
74' Sand, fine, fossiliferous; and greenish-gray clay. Washed residue. Fine quartz; some coarse grains; shells; dark heavy minerals.	Abundant small ornate pelecypods, gastropods, ostracods, echinoid plates and spines, and barnacles. Abundant Foraminifera, as above.

TEST BORING X PROPOSED SHIP ISLAND CAUSEWAY

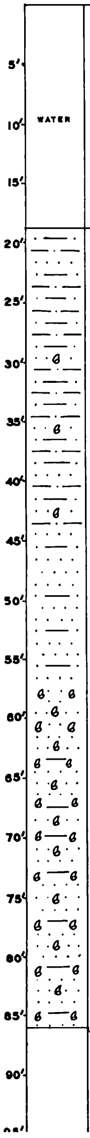
LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
29' Clay, greenish-gray, sandy, pyritic, micaceous. Washed residue. Fine to coarse quartz; pyrite.	Very rare Streblus, Elphidium, Virgulina.
34' Clay, gray, silty, pyritic, micaceous. Washed residue. Fine to medium quartz; pyrite.	Very rare Elphidium and white chalky pelecypod fragments.
39' Sand, fine to medium, clayey, carbonaceous. Washed residue. Very fine to medium quartz, some grains iron-stained; dark heavy minerals.	No fossils.
44' Clay, gray, sandy, very carbonaceous, pyritic, micaceous. Washed residue. Fine to medium quartz; partly carbonized and pyritized plant fragments; dark heavy minerals.	Plant fragments.
53' Sand, fine, clayey, very carbonaceous, micaceous. Washed residue. Fine quartz, some medium coarse grains; plant fragments; dark heavy minerals.	Partly carbonized plant fragments.
59' Clay, gray, carbonaceous, micaceous, pyritic. Washed residue. Rare fine quartz; pyrite.	Common Echinoid spines.
64' Sand, fine to coarse, fossiliferous. Washed residue. Fine to coarse quartz; shells; dark heavy minerals.	Abundant small ornate pelecypods; gastropods; echinoid spines and plates. Common bryozoa, barnacles, worm tubes?, Dentalium. Abundant Foraminifera: miliolids, Elphidium, Cibicides, Discorbis, Amphistegina, Streblus, Textularia, Bigenerina, Nonion, Globigerina, etc.
70' Sand, fine, fossiliferous.	Common white chalky molluscan shell fragments; ~~bryozoa; echinoid plates and spines;~~ barnacles, ostracods. Abundant Amphistegina and Elphidium.

TEST BORING Y PROPOSED SHIP ISLAND CAUSEWAY

LITHOLOGY



DESCRIPTION OF SAMPLES EXAMINED	FOSSILS IN SAMPLES EXAMINED
29' Clay, gray, sandy, micaceous, carbonaceous Washed residue. Fine to medium quartz; pyrite; dark heavy minerals; shells; plant fragments.	Common white chalky pelecypod shell fragments; echinoid plates and spines; carbonized plant fragments. Rare Foraminifera: *Streblus*, *Elphidium*, *Nonion*, *Quinqueloculina*.
39' Clay, gray, sandy, and fine to coarse sand. Washed residue. Fine to coarse quartz; pyrite; dark heavy minerals.	Rare *Streblus* and white chalky shell fragments.
43' Sand, fine to coarse, carbonaceous, pyritic. Washed residue. Fine to coarse quartz; partly carbonized and pyritized plant fragments.	Small ornate gastropods; white chalky pelecypod fragments; echinoid spines; plant fragments. Very rare worn *Cibicides*.
58' Sand, fine to coarse, shelly. Washed residue. Fine to coarse quartz; shells.	Abundant small pelecypods and echinoid fragments. Few small gastropods. Common Foraminifera: *Streblus*, *Elphidium*. Most of fossils worn.
68' Sand, fine to coarse, clayey, shelly. Washed residue. Fine to coarse, carbonaceous stained quartz; shells.	Abundant pelecypods, gastropods, echinoid fragments. Common barnacles, *Dentalium*, worm tubes (?). Abundant Foraminifera: miliolids, polymorphinids, *Elphidium*, *Cibicides*, *Eponides*, *Streblus*, *Asterigerina*, *Amphistegina*, *Nonion*, *Bigenerina*.
80' Sand, fine to coarse, shelly. Washed residue. Fine to coarse quartz; worn shells; dark heavy minerals.	Abundant worn mollusks, echinoid fragments, barnacles, *Dentalium*. Common bryozoa, ostracods. Abundant Foraminifera: miliolids, *Elphidium*, *Amphistegina*, *Cibicides*, *Eponides*, *Globulina*, *Ehrenbergina*, *Streblus*.
84.5' Sand, fine to coarse, shelly. Washed residue. Fine to coarse quartz; shells; dark heavy minerals.	Abundant small ornate pelecypods and gastropods; barnacles; echinoid fragments; ostracods; bryozoa; *Dentalium*. Abundant Foraminifera: *Amphistegina*, *Elphidium*, *Discorbis*, *Cibicides*, *Textularia*, etc.

GEOLOGY OF THE NORTHEAST QUARTER OF THE WEST POINT, MISSISSIPPI QUADRANGLE, AND RELATED BENTONITES*

THOMAS F. TORRIES**

ABSTRACT

The purposes of this investigation were to describe the areal geology in the northeast quarter of the West Point, Mississippi Quadrangle, to map the units within the area, and to investigate the related bentonites.

Six geologic units belonging to the Cretaceous and Quaternary systems can be differentiated and mapped on the basis of lithology and stratigraphic position. The Cretaceous units include, in ascending order, the Tombigbee sand member of the Eutaw formation, the Mooreville formation and its Arcola limestone member, and the Demopolis formation. Pleistocene and Recent stream terrace deposits and Recent alluvium veneer the Cretaceous sediments.

Samples taken from the formations and the bentonites were studied in detail utilizing x-ray, optical microscopic, electron microscopic, chemical, mineralogical, and particle size analyses.

The structure in the area is relatively simple. The Cretaceous units dip gently to the southwest 30 to 40 feet per mile with minor variations. Based on the regional dip, the calculated thickness of the Tombigbee sand in the northeastern portion of the area is abnormally high, and could be due to a reduction of the dip or to faulting.

Streams in the area are entrenched below their flood plains. This is especially evident in the southeast portion of the quadrangle.

The bentonites are variable in thickness, and although conforming to the regional strike, they may differ from the regional dip by dipping 10 to 25 feet per mile. The presence of marine fossils, abundant montmorillonite clays, occasional glass shards, biotite crystals, structure, and texture suggest that the bentonites are the products of water-deposited, altered volcanic ash.

INTRODUCTION

Bentonite was first discovered in Mississippi in 1927 in an area south of Aberdeen, Monroe County. Since this initial discovery, the nature, occurrence, and the genesis of the bentonite

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*Submitted to the Faculty of Mississippi State University in partial fulfillment of the requirements for the Degree of Master of Science in the Department of Geology and Geography. Degree of M. Sc. awarded 1963.

**Geologist, Monsanto Chemical Company, 2017 Westwood Drive, Columbia, Tennessee.

have been investigated by several workers. Stephenson and Monroe (1940) described the area and the bentonites in their description of the Upper Cretaceous deposits of Mississippi. Monroe and Clay Counties have been described and mapped on a reconnaissance basis by Vestal (Vestal and McCutcheon, 1943), and Bergquist (Bergquist, McCutcheon, and Kline, 1943), respectively. No detailed study of the stratigraphic positions of the bentonite occurrences is present in available literature.

The purposes of this investigation were: (1) to describe the areal geology of the region; and (2) to describe the bentonites south of Aberdeen and the surrounding formations in an effort to determine their mineralogy, stratigraphic position, attitude, and genesis.

LOCATION OF AREA

The investigation was conducted in a region 65 square miles in area, which lies almost entirely within the northeast quarter of the West Point, Mississippi, Quadrangle. The topography was mapped by the United States Geological Survey in 1959. The area, which includes portions of Monroe and Clay Counties, lies between latitudes 33° 37.5′ N. to 33° 45.0′ N. and longitudes 88° 30.0′ W. to 88° 37.5′ W. An unmapped area one mile wide which extends two miles northward in Monroe County toward Aberdeen from the northeastern corner of the West Point Quadrangle is included in the investigation because of the bentonite occurrences. This unmapped area consists of portions of Sections 13, 14, 23, 24, 25, and 26, R. 7 E., T. 15 S.

GEOLOGIC UNITS

Six geologic units of Cretaceous and Quaternary age are present at the surface in the area. The outcropping rocks of the Cretaceous system are represented by the Tombigbee sand member of the Eutaw formation, and that part of the Selma group known as the Mooreville formation with its Arcola limestone member and the overlying Demopolis formation. Pleistocene and Recent stream terraces and Recent alluvium veneer the Cretaceous sediments in many places. The bentonite found in the area of investigation occurs as beds in the Tombigbee sand member of the Eutaw formation.

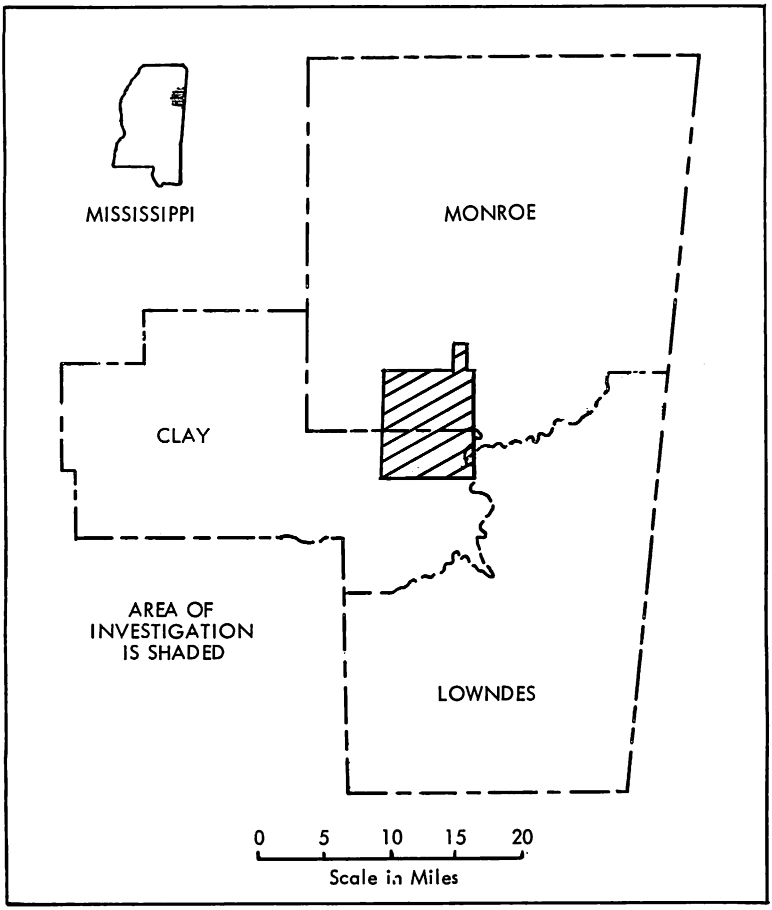


Figure 1.—Location of area studied.

METHODS OF INVESTIGATION

Several methods of investigation were used to describe the physiography of the area and the lithology, structure, composition, and fauna of the units involved. The areal geology was studied during the months of January, February, and March, 1963. The area was mapped and the local units were described. Representative samples of the individual formations and the bentonite beds were studied in detail utilizing x-ray, optical microscopic, electron microscopic, chemical, mineralogical, and particle size analyses techniques. Subsurface data was incorporated where information was available.

Relatively unweathered samples of the Mooreville formation were obtained by digging into fresh outcrops. Samples of Tombigbee sand and the Panther Creek and Little Panther Creek bentonites were taken from fresh exposures in the bentonite pits some 70 feet below the weathered zone. The bentonites in the vicinity of Richardson Lake and the Cane Creek bentonites were sampled, but completely unweathered material was unavailable. Each sampling locality was assigned a number which is used in all figures and charts. The sample numbers and their locations are listed in Table 1.

The following sample numbers are used for the sampling localities in the charts and tables presented. All of the sampling localities are fully described in the text.

Sample No.	Lithology	Unit	Location
1	bentonite	Ket*	Little Panther Creek, Sec. 13, T. 15 S., R. 7 E.
2	bentonite "ball'	Ket	Little Panther Creek, Sec. 13, T. 15 S., R. 7 E.
3	bentonite	Ket	Panther Creek, Sec. 25 and 26, T. 15 S., R. 7 E.
4	bentonite	Ket	Near Richardson Lake, Sec. 7, T. 16 S., R. 8 E.
5	bentonite	Ket	Cane Creek, Sec. 13, T. 16 S., R. 7 E.
6	sand	Ket	Little Panther Creek, Sec. 13, T. 15 S., R. 7 E.
7	marl	Km**	Town Creek, Sec. 29, T. 16 S., R. 7 E.
8	marl	Km	Town Creek, Sec. 33, T. 16 S., R. 7 E.

*Tombigbee sand member of the Eutaw formation, Cretaceous system.
**Mooreville formation, Cretaceous system.

Table 1. Sample Number and Location Key

OPTICAL MICROSCOPIC AND HEAVY MINERAL ANALYSES

Heavy mineral analyses were conducted on samples from all collecting localities. The bromoform technique, as outlined by Krumbein and Pettijohn (1938), was used to separate the minerals. A portion of each heavy mineral separate was mounted on glass slides for microscopic observation. The slide was partitioned into small areas by a marking pencil and all minerals within an area were identified and counted. Over 200 mineral grains were identified in each slide. In some cases high percentages of muscovite or opaque minerals necessitated a larger count to insure a representative sampling of the entire suit of heavy minerals. The light fraction was mounted and studied in a similar manner. Thin sections were made and studied in order to observe the fabric of the specimens.

CARBONATE AND SIZE ANALYSES

The carbonate percentage was computed from a 25 gram portion of each sample which was acidized in 2 Normal HCl, washed, dried, and reweighed. The insoluble residue from the carbonate determination was then used to determine the percentage of sand, silt, and clay by Boupouco's method (1936). A 10 per cent solution of "Calgon" (a brand of detergent composed of sodium hexametaphosphate), adjusted to a pH of 8.5 by the addition of sodium carbonate was used as the dispersing agent. Hydrometer readings were taken at .5, 1, 10, 30, 90, 360, and 540 minutes. All computations were based on a temperature of 22° C, and it was assumed that all particles had an average specific gravity of 2.65 and were spherical. Triangular diagrams showing sand, silt, clay, and carbonate percentages were plotted for each sample and are shown in Figure 4.

X-RAY ANALYSES

The clay particles from the less than 2 micron size fraction of: (1) Tombigbee sand; (2) the bentonites; and (3) the Mooreville formation were studied by x-ray diffraction. A Phillips x-ray diffractometer set at 35 kV, 18 ma, using a time constant of 2° per minute, a scale factor of 8, and copper K_a radiation was used to make all x-ray patterns.

The technique of specimen preparation outlined by Jackson (1956, p. 31) was used in this study. This technique allows one to obtain potassium- or magnesium-saturated specimens which are glycerated and allowed to settle on glass slides. This preparation technique produces basally oriented clay particles which are structurally unaltered and are free from calcium and magnesium salts.

The potassium-saturated and the magnesium-saturated samples were x-rayed before heating using a 30° scan in order to obtain control patterns and good reflections from the minerals present. The potassium-saturated samples were then heated for 4 hours at 100° C, at 300° C, and 500° C, with x-ray patterns being made between each heating. By noting the collapse or destruction of certain clay structures with increased heating, the clay minerals were identified. A 15° scan was used for all of the heated specimens. To minimize resorption, the specimens were immediately placed in a dessicator after removal from the furnace.

ELECTRON MICROSCOPIC ANALYSES

For electron microscopic investigation, only the portion of the specimens less than 20 microns in diameter were used. About 10 grams of a representative portion of each sample was air dried and then placed in a 100 ml beaker with distilled water. After the particles were dispersed, the mixture was stirred and then allowed to settle for three minutes. A small portion of the suspension was drawn from the top of the mixture and placed in 12 ml tubes. This mixture was diluted with distilled water to approximately a 1% concentration. A drop of the 1% suspension was placed on a previously prepared colloidion film mounted on a 200 mesh copper screen. Once the screen had dried, no further preparation was necessary. A Norelco EM 75C electron microscope capable of 30 Angstrom resolution was used to observe and photograph the specimens.

PHYSIOGRAPHY

The area of investigation encompasses parts of two physiographic districts, the Tennessee-Tombigbee River Hills District to the east and the Black Prairie District to the west. Seven southeast flowing streams drain the area and empty into the Tombigbee River to the east.

The Tennessee-Tombigbee River Hills District, whose western edge is underlain by the Tombigbee sand member of the Eutaw formation, comprises the eastern one-third of the area and consists of a well-dissected upland exhibiting a relief in places slightly greater than 150 feet. Flood plains of the streams that head in the eastern and more rugged portion of the district are very narrow, whereas those in the less rugged portion are almost invariably broader. Valleys of small streams developed in the Tombigbee sand are normally symmetrical in cross-sectional profile and exhibit steeply sloping valley walls.

The east-facing cut bank of the Tombigbee River, which borders the eastern margin of the district, forms in many places nearly vertical cliffs which exceed 100 feet in height. The eastern walls of Dry Creek and Spring Creek valleys are covered in places by a thin mantle of terrace material. The dissected uplands have concordant upper levels which conform with the regional rise of the land to the northeast where the maximum elevation is 350 feet. Immediately to the east the surface descends to its minimum elevation of 160 feet along the Tombigbee River.

In the north central portion of the area the Tombigbee sand is capped by a thin veneer of Mooreville chalk preserving remnants of Black Prairie topography. The hills, in turn, are surrounded by rugged dissected valleys cut into the underlying sand.

BLACK PRAIRIE DISTRICT

The remainder of the area lies within the Black Prairie District and is underlain by the Mooreville and Demopolis formations of the Selma chalk group. Dark clayey soils have developed on these gently rolling surfaces of little relief. The thin Arcola limestone member of the Mooreville formation crops out in the western portion of the area and forms eastward facing assymetrical ridges in some places.

Flood plains in all of the larger streams in the district are well-developed and may be up to one mile in width. A general westward migration of the streams is evidenced in this District by the assymetrical valleys. The western cut banks are appreciably steeper than the eastern slip-off slopes. Uplands formed on the chalk are gently undulating surfaces which rise gradually to the northeast.

CRETACEOUS DEPOSITS

The Upper Cretaceous deposits exposed in the area of investigation have a total thickness of about 300 feet. The Tombigbee sand member of the Eutaw formation and the overlying Mooreville formation comprise the majority of the Cretaceous deposits. Only the lower 30 feet of the Demopolis formation is present.

EUTAW FORMATION, TYPICAL

The name Eutaw was first used by Hilgard (1860) in describing all of the strata between the Paleozoic rocks and his Tombigbee sand group. Smith and Johnson (1887) separated the underlying Tuscaloosa formation from the Eutaw and included the Tombigbee sand as the upper member of the Eutaw formation.

The lower or "typical" Eutaw is not present on the surface in the area of investigation, but crops out farther to the east. According to Stephenson and Monroe (1940), this lower part consists of fine, glauconitic, micaceous sand with numerous thin clay laminae and thicker clay layers. Crossbedding of the sand is common. The sands are white, gray, and greenish gray when fresh, and weather to yellow, red, purple, and brown. Lignite and plant fossils are sometimes associated with the clays.

EUTAW FORMATION, TOMBIGBEE SAND MEMBER

The oldest unit that crops out within the area of investigation is the Tombigbee sand member of the Eutaw formation. In most areas of Mississippi and Alabama where the Eutaw is present, the Tombigbee sand constitutes the upper 100 feet of the formation.

NOMENCLATURE

Hilgard (1860) first described the Tombigbee sand as the group of beds between the Eutaw formation and the Selma chalk. Smith and Johnson (1887) later included the Tombigbee sand in the Eutaw formation as a member.

AREAL GEOLOGY

A north-south strip approximately 2½ miles wide extending along the eastern margin of the area represents the outcrop of the Tombigbee sand member. The Mooreville chalk lies west of the Tombigbee sand, but in a strip approximately 1½ miles wide, streams have cut through the Mooreville chalk exposing Tombigbee sand. The eastern extent of exposure of the Tombigbee sand is covered by Tombigbee River flood plain deposits.

An almost continuous section of Tombigbee sand is exposed in the cuts along the gravel road that runs northwest-southeast across Secs. 1 and 12, T. 16 S., R. 7 E., and Sec. 7, T. 16 S., R. 8 E. Over 175 feet of Tombigbee sand can be seen in the cuts of another branch of this road which runs northeast-southwest across Secs. 35 and 36, T. 15 S., R. 8 E.

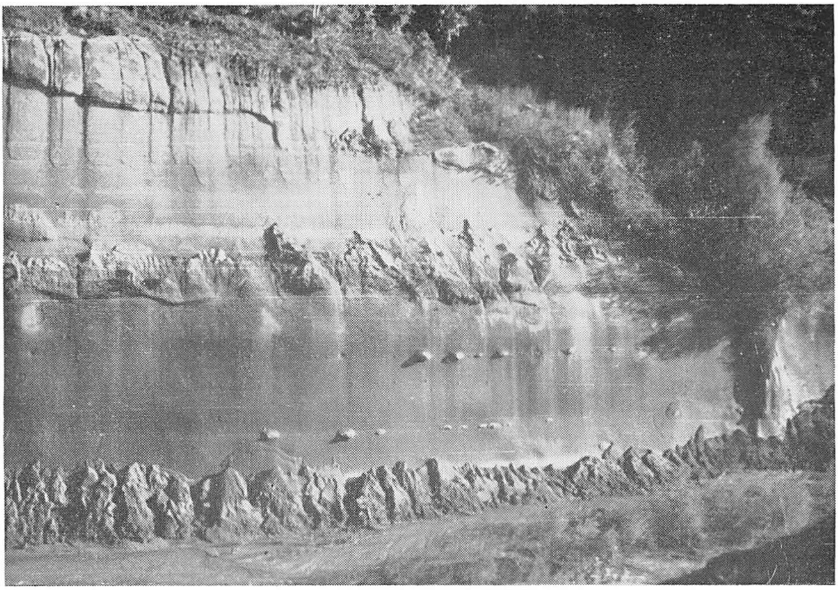


Figure 2.—Vertical cut exposing 70 feet of Tombigbee sand with typical concretionary ledges in the Panther Creek bentonite pit.

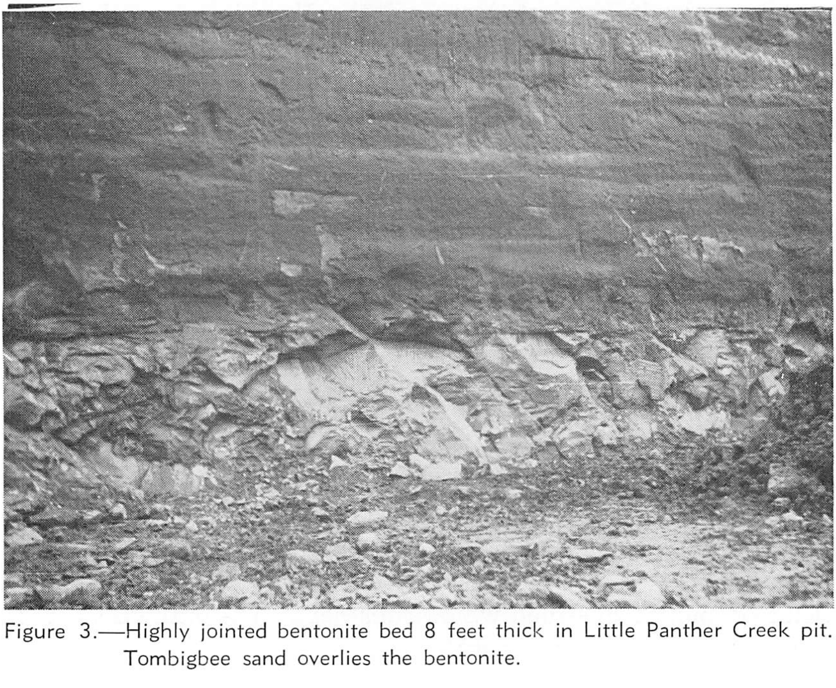


Figure 3.—Highly jointed bentonite bed 8 feet thick in Little Panther Creek pit. Tombigbee sand overlies the bentonite.

LITHOLOGY AND MINERALOGY

The Tombigbee sand member is a massive glauconitic and micaceous sand with occasional layers of indurated sand and concretionary masses. Figure 2 shows an excellent exposure of the sand in the Panther Creek bentonite pit. Unweathered sand is usually gray, but weathers to tan to buff-colored, and occasionally, to red. Steep walls form along the cut banks of the streams where concretionary layers are best observed, and in numerous road cuts.

Bentonite is present in the Tombigbee sand as beds of varying thicknesses which appear to occur 105 to 175 feet below the Tombigbee sand-Mooreville contact. The bentonite is gray, micaceous, massive, and very brittle.

Heavy minerals, carbonate, and clay minerals together comprise less than 10% of the constituents of the Tombigbee sand. Most of the particles are sand-sized and consist of quartz, glauconite, a lesser amount of muscovite, and a small percentage of heavy minerals. The quartz grains are fine, well-sorted, and very angular to subangular. The angular grains are flake and tabular shaped, whereas the subangular grains are more spherical. Most of the more rounded grains have frosted surfaces, but occasionally angular grains exhibit one or more frosted surfaces.

Glauconite grains are also fine, well-sorted, and, except when broken, are well-rounded. Two types of glauconite may be differentiated on the basis of shape and color. Globular shaped grains predominate and are of a solid green color. Spheroidal grains, which are less common, exhibit a layered appearance caused by alternating dark and light green layers.

Thin muscovite flakes, larger in diameter than the quartz grains, are well-rounded in plan form. Many flakes show alteration on the edges. Larger polished spheroidal grains of brown collophane are also present.

Less than 2% of the sand consists of heavy minerals, of which about 35% is pyrite. Pyrite occurs as spherical crystalline aggregates and is, in some cases, associated with glauconite. Most of the heavy minerals occur as angular fragments, but euhedral twinned biotite crystals are also present. The individual percentages of the heavy minerals are given in Table 2.

Montmorillonite, interstratified mica and a mineral with properties similar to vermiculite are the three most abundant clay minerals in the Tombigbee sand. X-ray diffractograms are shown in Figure 8. Electron microscopy revealed the presence of small quantities of highly crystalline halloysite and kaolin. Another clay mineral which occurs as bundles of fibers was also observed but could not be identified. Coccoliths 2 to 20 microns in diameter are abundant enough to account for the 3% carbonate in the Tombigbee sand. Quartz is present in the minus 2 micron fraction in minor amounts.

STRUCTURE

The Tombigbee sand member dips at about 40 feet per mile in a direction South 76° West. Total thickness of the Tombigbee sand could not be measured because in no place in the area of investigation could the base of the sand be found. The thickness of the outcropping Tombigbee sand, based on regional dip, increases from 130 feet in the southern portion of the area to over 170 feet in the northern portion.

The Tombigbee sand is generally massive, but exhibits bedding wherever the clay content increases. The indurated layers of sand, concretionary masses, and fossil shell reef appear to be bedding plane deposits. Jointing is very evident wherever the sand has enough clay content to preserve the structure. The numerous joints in the bentonite beds are described later in the discussion of the bentonites.

FAUNA

Fossil marine vertebrates and invertebrates are common within the member. A layer of sharks' teeth associated with lignite is present in Section 7, T. 15 S., R. 7 E., and is described in Section 5. A reef-like accumulation of *Pecten* species and very large *Exogyra ponderosa* is present in the banks of Town Creek, Section 33, T. 16 S., R. 7 E., and is described in Section 1 below. The *Exogyra ponderosa* Roemer may possess a maximum shell diameter of 10 inches. In no other locality within the area was this reef observed.

Smaller *Exogyra ponderosa* Roemer are present in great numbers in the bottom of Hang Kettle Creek in Section 8, T. 16 S., R. 7 E. North of this location fewer fossils are found at the Eutaw-Mooreville contact.

Exogyra ponderosa Roemer, *Exogyra ponderosa erraticostata* Stephenson, *Pecten* species, *Hamulus squamosus* Gabb, and *Mortoniceras* species are among the most common fossils.

	PERCENT PRESENT							
LOCATION	1	2	3	4	5	6	7	8
MINERAL								
Muscovite	30.0	62.4	13.0	45.0	15.0	10.0	37.2	1.3
Rutile	3.5	1.0	2.0	2.1	1.6	1.4	-	4.7
Zircon	4.0	2.8	4.0	1.8	0.3	4.3	2.2	4.0
Biotite (Total)	13.7	3.3	14.1	9.8	29.7	5.7	9.8	13.9
Biotite (Opaque)	6.0	2.0	2.8	8.2	1.9	1.4	2.2	10.6
Hornblende	0.7	0.5	1.2	0.5	0.3	-	-	-
Epidote	7.6	2.0	4.0	-	0.3	-	-	-
Staurolite	3.3	0.8	2.0	8.0	2.5	8.6	1.9	8.0
Titanite	0.7	3.3	3.2	0.8	1.0	-	0.9	-
Kyanite	7.1	2.0	6.5	9.3	1.9	4.3	1.5	4.0
Tourmaline	4.1	3.1	4.4	2.1	4.8	1.4	0.9	2.8
Orthoclase	0.5	-	0.8	-	0.3	-	.3	-
Hypersthene	4.7	2.0	2.8	2.4	0.3	-	-	-
Garnet	1.6	0.3	2.0	2.4	0.6	2.8	1.9	10.0
Leucoxene	5.0	2.0	10.0	6.4	37.3	4.3	28.8	28.6
Ilmenite	1.3	2.3	8.9	2.7	1.9	5.7	2.5	15.3
Pyrite	10.0	6.2	15.0	1.1	-	35.6	9.0	2.0
Glauconite	1.0	0.3	0.4	1.1	-	14.2	0.9	-
Limonite	1.6	-	-	1.6	1.3	-	0.9	-
Hematite	0.5	-	-	-	-	-	-	-
Pyroxene	-	-	-	-	0.6	-	-	-
Spores	4.0	2.8	4.4	-	-	-	0.9	-
Other	1.1	0.8	0.8	3.0	1.0	-	-	-
TOTAL	99.6	98.1	99.5	100.2	100.7	98.3	99.6	100.5

Table 2.—Heavy mineral analyses.

CONTACT RELATIONSHIPS

The lower contact of the Tombigbee sand member with the "typical" Eutaw is not exposed in the area of investigation. According to Vestal (Vestal and McCutcheon, 1943) the contact between the two is gradational and consists of a transitional zone of cross-bedded and laminated clay.

The nature of the upper contact of the Tombigbee sand with the overlying Mooreville formation is gradational. The contact can be seen in several locations, the best of which is exposed in the side of Town Creek, Section 33, T. 16 S., R. 7 E. This exposure is described in the section below.

Section 1. Town Creek, NE/4, SE/4, Sec. 33, T. 15 S., R. 7 E.

Formation	Thickness (feet)
Recent	
8. Alluvium	1.0
Cretaceous System	
Mooreville formation	
7. Brown mottled clay grading into unweathered chalk	8.0+
6. Greenish gray, micaceous, highly fossiliferous, jointed chalk. Occasional biotite fragments. Pyrite nodules	3.0
5. *Exogyra ponderosa* Roemer reef. Average diameter about 3 inches	0.5
4. Gray, micaceous, fossiliferous chalk becoming sandy at bottom. Euhedral biotite books 1 to 2 mm. in diameter	2.0
Eutaw formation (Tombigbee sand member)	
3. Greenish gray, calcareous glauconitic and micaceous sand. Fossiliferous. Internal gastropod molds and *Inoceramus* common. As sand increases downward, biotite decreases.	3.0
2. Buff-colored, indurated, resistant sand layer. Worm borings and *Pecten* species common	2.0
1. Blue gray sand. Very irregular accumulation of very large *Exogyra ponderosa* Roemer, and many *Pecten* species	5.0+
Total	24.5+

Just below the transitional contact between the Eutaw and the Mooreville formations there is a large "reef-like" accumulation of *Exogyra ponderosa* Roemer and other fossil shells along what appears to be a very irregular surface. In verticle profile, the reef undulates in a scalloped fashion exhibiting as much as three feet vertical relief in one foot horizontal distance. The bottoms of the depressions appear to have a common lower level. The shells are randomly oriented and occur in the bottoms and sides of the depressions as if they were dumped into holes. Few of the shells have attached butt plates. No difference in the sand above and below the reef could be discerned and no traces of bedding could be seen. *Pectens* are abundant within the reef and in the sands above. In no other location within the area was this reef observed.

A resistant ledge of indurated sand is present immediately above the reef. Above this ledge the glauconitic sand grades into the Mooreville chalk in a zone of about three feet. Internal molds of gastropods are present in this transition zone.

MOOREVILLE FORMATION

The Mooreville formation is the lower unit of the Selma chalk group. Typically, the formation is a marl, but in northern Mississippi the Mooreville becomes more sandy and grades into the Coffee sands in Itawamba and Lee Counties (Stephenson and Monroe, 1940).

NOMENCLATURE

The name Selma was first used by Smith, Johnson, and Langdon (1894) as a formational name. The Selma has since been divided into a number of subdivisions and tongues. The Mooreville was first described by Stephenson (1917) as the basal tongue of the Selma chalk. In 1945 the Selma was raised to group rank, necessitating the elevation of the members to formational rank. At present, the units which constitute the Selma group are the Mooreville formation with the Arcola limestone member at its top, the Demopolis formation with the Bluffport marl member at its top, the Ripley formation, and the Prairie Bluff formation. O'Quinn (1961) described in some detail the Mooreville formation of the Tibbee Creek area in Clay and Lowndes Counties, Mississippi.

AREAL GEOLOGY

Almost 43% of the area of investigation is underlain by the Mooreville formation of the Selma group. The area of outcrop is a strip roughly two to three miles wide which extends in a north-south direction over the west-central portion of the area. Outliers of the Mooreville formation are present in the northeastern portion of the area and overlie the Tombigbee sand.

The Arcola limestone member of the Mooreville formation occurs as the uppermost unit of the formation and forms a convenient boundary between the Mooreville and the overlying Demopolis formation.

LITHOLOGY AND MINERALOGY

The material composing the Mooreville formation is chiefly hard, brittle, blue to blue-gray, micaceous, arenaceous, and glauconitic chalk or marl. Sand content increases both at the top and the bottom of the formation (O'Quinn, 1961).

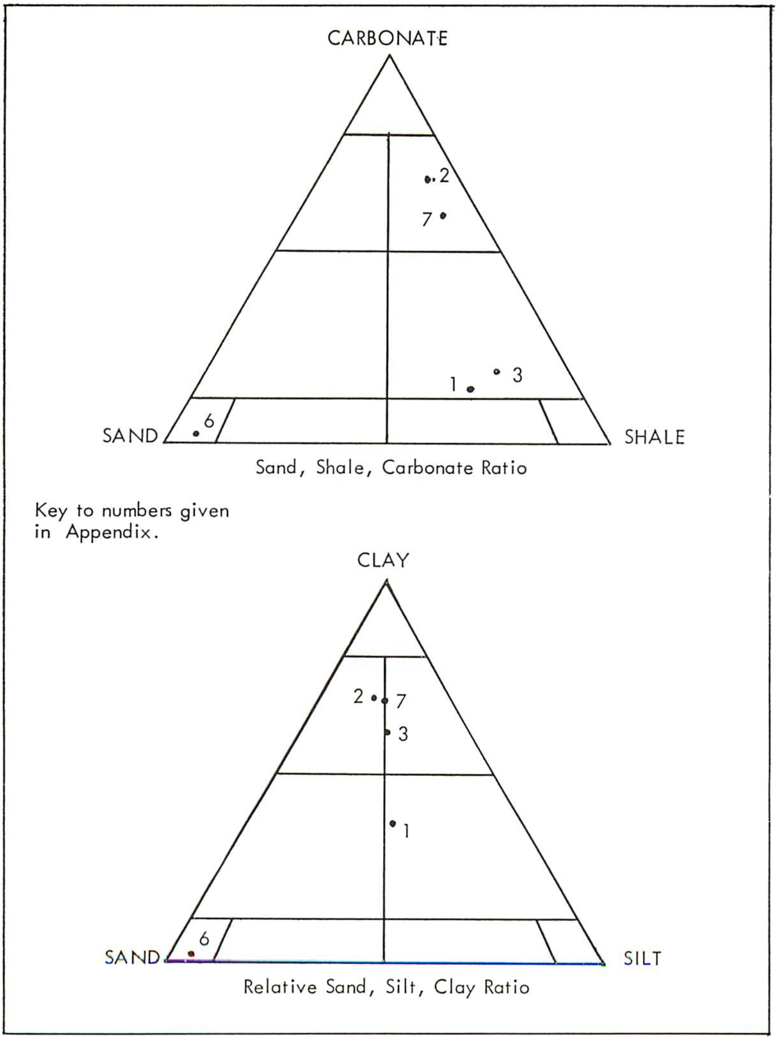
The chalk weathers readily to a brown or mottled red and gray clay which may further develop into dark clayey soils. An irregular but very sharp contact divides the weathered from the unweathered portion of the chalk. Well-developed jointing and pyrite nodules aid in the weathering process. One such weathering profile is well exhibited in the side of Town Creek, Sec. 29, T. 16 S., R. 7 E.

Section 2. Town Creek NE. Cor. Sec. 29, T. 16 S., R. 7 E.

Formation	Thickness (feet)
Cretaceous system	
Mooreville formation	
3. Black clayey and limy soil grading into mottled red and gray clay	2.0+
2. Mottled red and blue-gray clay with occasional spherical concentrations of blue-gray clay. Sharp but undulating contact with lower unweathered chalk	5.0+
1. Hard, brittle, fossiliferous, blue-gray, slightly micaceous, arenaceous chalk. Jointing well-developed. Pyrite nodules. Limonitic clays in vacancies left by weathered pyrite	6.0+
Total	13.0+

Although the composition of the Mooreville is variable, it generally consists of calcium carbonate, clay minerals, and sand, in that order of abundance.

The calcium carbonate is present in the form of foraminifera, coccoliths, and fine calcium carbonate cement. Inorganic calcium carbonate appears to comprise only a small per cent of the total carbonate.



Sand, Shale, Carbonate Ratio

Key to numbers given in Appendix.

Relative Sand, Silt, Clay Ratio

Figure 4.—Triangular diagrams showing carbonate to clastic ratios and size ratios.

Montmorillonite is the dominant clay mineral but highly crystalline kaolin is also common. Interstratified micas are present in smaller amounts. Only a very small percentage of quartz is present in clay sized particles.

Quartz, muscovite, biotite, varying amounts of glauconite, and the heavy minerals comprise the sand sized portion. The characteristics exhibited by these minerals vary with their positions within the formation.

In the middle portion of the Mooreville formation the quartz is present as angular to subangular, spherical to tabular, fine to very fine grains. The more rounded particles have frosted surfaces. In the lower portion of the formation subhedral quartz crystals are present.

Muscovite is present as fine angular flakes. Biotite is present as angular flakes but is more often in the form of euhedral books and crystals. Perfect unaltered biotite crystals are especially abundant near the Tombigbee sand contact. O'Quinn (1961) described two zones of biotite mica within the lower middle portion of the Mooreville in the Tibbee Creek area of Clay County, but did not mention a basal accumulation.

The majority of the glauconite is rounded to sub-rounded, ellipsoidal-shaped, green grains with very distinctive laminae. Globular-shaped particles are much less common.

Larger rounded particles of leucoxene are common in the middle of the formation.

The majority of the heavy minerals are angular to subangular and are extremely fine and well sorted. Fine rounded to spherical crystal aggregates of pyrite which may be altered to limonite comprise the majority of the heavy minerals. Pseudomorphs of limonite after biotite are also present.

A few fragile glass fragments are present in the lower Mooreville formation. The glass is brown, vesicular, contains inclusions, and generally has very irregular and angular forms.

Larger pyrite concretions 3 to 6 cm. in diameter are present throughout the Mooreville formation. Pseudomorphs of limonite after pyrite are common near the weathered surface.

STRUCTURE

Dip and strike of the strata were determined by descriptive geometry from information obtained by surface mapping. The Mooreville-Eutaw contact strikes N. 14° W. and dips 40 feet per mile to the southwest, whereas the Arcola limestone at the top of the Mooreville strikes N. 11° W. and dips approximately 30 feet per mile to the southwest. Converging dips and strikes suggest a northward thinning of the Mooreville formation. In the southern portion of the area the formation is little over 140 feet thick, but 8 miles to the north it thins to less than 110 feet.

Bedding is generally not apparent in the Mooreville except in thin sections where the muscovite flakes can be seen to be horizontally oriented. Joint sets are common wherever fresh exposures of chalk are present.

FAUNA

Fossils occur throughout the formation, but concentrations are present in the form of faunal zones or reefs. *Ostrea falcata* Morton, *Exogyra ponderosa* Roemer, *Exogyra ponderosa erraticostata* Stephenson, *Ostrea plumosa* Morton, *Anomia argentaria* Morton, fish scales and micro fossils are among the most common fossils found.

A zone ½ inch thick of indurated *Ostrea falcata* Morton can be traced for at least seven miles in the southwestern portion of the area and may be continuous throughout the formation. Stephenson and Monroe (1940) mention the presence of this zone in the eastward facing cut bank of Town Creek in the northeastern corner of Sec. 5, T. 17 S., R. 7 E. A good exposure of the zone is present in a cut on the south side of the east-west road to Vinton in Sec. 8, T. 16 S., R. 7 E. The road cuts through the east cut bank of Fuller Creek. The zone occurs 60 to 70 feet below the Arcola limestone member throughout the area.

At the base of the Mooreville a thin uniform layer of *Exogyra ponderosa* Roemer forms a distinctive reef which can be seen in the sides of Town Creek, Sec. 33, T. 16 S., R. 7 E. This exposure is described in Section 1. In no other location is this reef observed, although O'Quinn (1961) described a similar reef in Tibbee Creek, Clay County.

MOOREVILLE FORMATION, ARCOLA LIMESTONE MEMBER

To the north and to the south of the area the Arcola limestone member forms a distinctive unit at the top of the Mooreville formation, but in the area of investigation the Arcola is very thin and apparently discontinuous. The Arcola limestone was first described by Smith, Johnson, and Langdon (1894) as a unit of the Selma in Alabama.

The Arcola supports, at least partially, the ridges to the west of Town Creek and Fuller Creek and is seen only on the east facing banks of these streams. On top of the cut bank of Town Creek a thin layer of weathered limestone fragments is present in the side of the east-west road to Vinton that forms the southern boundary of Sec. 20, T. 16 S., R. 6 E. In a cut of a secondary road that leads to Strong Cemetery, a 6-inch thick zone of weathered limestone fragments is present in Sec. 13, T. 16 S., R. 6 E.

Limestone fragments derived from the Arcola limestone member are brownish-gray in color, rather dense, and commonly solution pitted on the surface. Numerous "borings" are present in the fragments. In Sec. 13, T. 16 S., R. 6 E., a 2-inch layer of finely micaceous and fossiliferous, buff colored, arenaceous limestone is associated with the typical limestone fragments. This buff limestone is composed of almost 20% fine quartz sand, numerous small *Ostrea* species, and calcium carbonate matrix.

Although the Arcola limestone is very thin and does not offer any good exposures in the northeastern portion of the area, it makes a good key bed for use in the study of the structure wherever the limestone is present. The Arcola itself dips steadily 30 feet per mile in a direction South 79° West.

The nature of the contact with the overlying Demopolis formation could not be definitely determined because of the highly weathered nature of the outcrops. No phosphatic nodules or molds of fossils were observed.

DEMOPOLIS FORMATION

The youngest Cretaceous rocks that crop out within the area belong to the Demopolis formation of the Selma group. Smith (1888) was the first to use the term Demopolis and later (1903) reclassified the unit as a member of the Selma chalk. In 1945 the

Selma was elevated to group rank and the Demopolis was correspondingly raised to formational rank.

The Demopolis crops out in the western portion of the area and is generally seen only on the tops of assymetrical ridges which are supported by the resistant Arcola limestone.

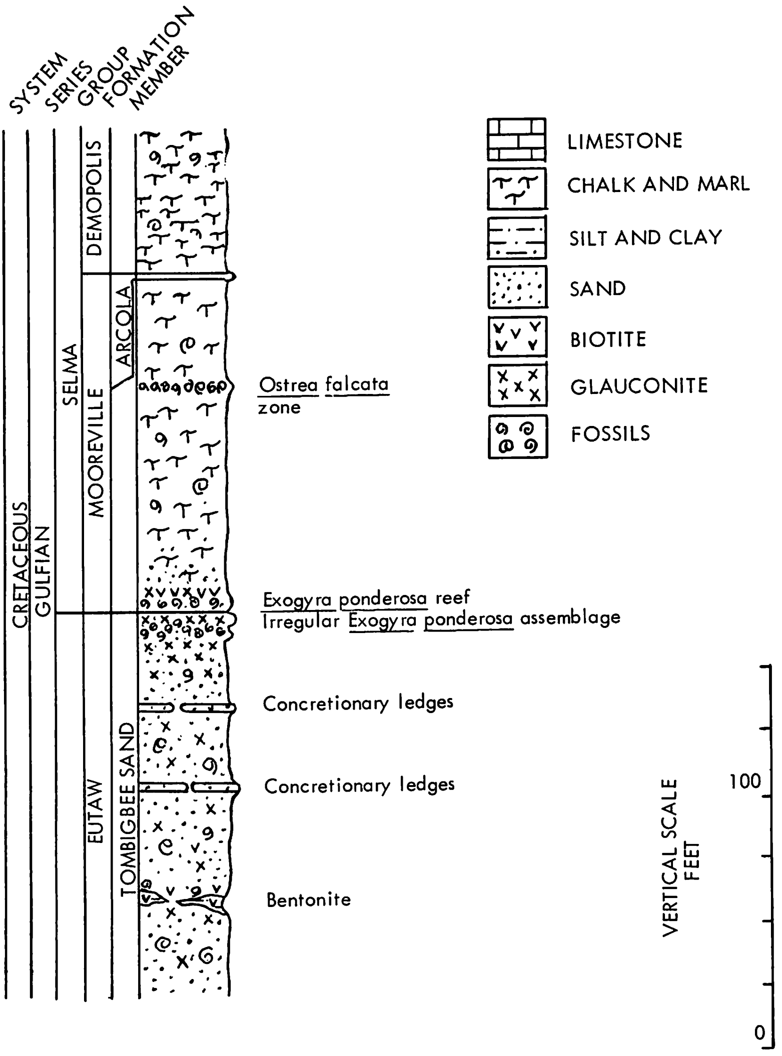


Figure 5.—Generalized columnar section of the area of investigation.

The Demopolis chalk in the area of investigation has the same appearance as the underlying Mooreville formation. The chalk is usually hard, brittle, fossiliferous, blue-gray, micaceous, and arenaceous and weathers to dark clayey soils. Vestal (Vestal and McCutcheon, 1943) states that the calcium carbonate is predominately in the form of cocoliths and to a lesser amount as foraminifera. Quartz, ilmenite, and leucoxene are the predominant sand particles. According to Carson (1961), the major clay mineral of the gray chalk is montmorillonite.

Keady (1962) states that the apparent thickness of the Demopolis formation in Clay County is about 447 feet, but only the lower 60 feet are present within the area of this investigation. On the basis of attitude of the underlying Arcola limestone member of the Mooreville formation, the Demopolis formation dips 30 feet per mile to the S. 80° W. Joint sets are well developed and abundant. No bedding is evident.

PLEISTOCENE AND RECENT DEPOSITS

Pleistocene and Recent deposits in the area owe their origin to stream deposition of sand and clay reworked from the Cretaceous sediments. Although the deposits are generally not over 15 feet thick, they cover over 50% of the surface of the area of investigation.

TERRACES

The streams have been migrating to the west, cutting progressively lower, and leaving remnants of flood plain material on the east slopes of the valleys. These remnants, or terraces, rest unconformably on the underlying Cretaceous beds. The terrace deposits of the east valley wall of Town Creek are very well developed and appear to have a maximum thickness of 10 to 15 feet. The other streams are smaller and their terraces are not as extensive. The terrace deposits, which are composed of unsorted fine to medium grained quartz sand and varying amounts of clay, are generally brown becoming reddish with increased age.

ALLUVIUM

Flood plain alluvium represents the most recent deposition in the area. All the major streams which drain the area have flood plains of varying degrees of development and thickness. In the southeastern portion of the area, Town Creek and the lower portion of its two tributaries, Fuller Creek and Hang Kettle Creek, are now entrenched 20 feet below their flood plains. Although the flood plain of Town Creek is extensively developed, little alluvium now remains and the underlying formations commonly crop out at the flood plain surface. The alluvium in the flood plains gradually thickens to the north up the stream valleys until a maximum thickness of about 10 feet is present in the larger streams. In the extreme eastern portion of the area the alluvium deposited in the Tombigbee River flood plain may be as much as 40 feet thick, according to Boswell (1962). The alluvium consists of gray to brownish gray unsorted medium to fine quartz sand and varying amounts of clay.

BENTONITES

Bentonite is a type of clay formed from the decomposition of volcanic material and is composed largely of montmorillonite. The name bentonite was first used by Knight (1897) in describing a clay found at Rock Creek, Wyoming. The parent volcanic material is usually ash, or tuff, composed chiefly of acidic glass fragments.

OCCURRENCES

Although bentonite occurs in many places in northeastern Mississippi, it crops out in only four places within the area of investigation. Two of the occurrences, the Panther Creek and the Little Panther Creek bentonites, are presently being mined. The largest bentonite pit in the area, which also has the distinction of being the first bentonite to be discovered in Mississippi, is the Panther Creek mine of the American Colloid Company, located 6.8 miles south of Aberdeen in Sections 25 and 26, T. 15 S., R. 7 E. The late Mr. N. W. Dahlem discovered the bentonite in 1927. The Little Panther Creek bentonite, located 5.5 miles south of Aberdeen, Section 13, T. 15 S., R. 7 E., is being mined by the International Mineral and Chemical Corporation.

The Panther and Little Panther Creek deposits were first described by Grim (1928) and later by Morse (1934), Bay (1935), and Vestal (1936). Dr. Poole Maynard (1935), a consulting geologist from Atlanta, Georgia, constructed preliminary maps of the deposits of Panther Creek.

Grim (1928) reported two bentonite beds at Panther Creek, each 4 to 7 feet thick. During the course of this investigation, only one bed was observed. The bentonite varies in thickness from 2 to over 10 feet with an average thickness of about 7 feet. The overburden consists of up to 100 feet of Tombigbee sand, however, the relief of the area and the unconsolidated character of the sand make open pit mining feasible. The exposure in the American Colloid pit is given in the following section.

Section 3. Panther Creek Pit 6.8 Miles South of Aberdeen.

Formation	Thickness (feet)
Cretaceous system	
Eutaw formation (Tombigbee sand member)	
3. Greenish gray glauconitic and finely micaceous sand with layers of indurated sandy concretions. Worm borings present.	100.0±
2. Transition zone of glauconitic sand grading into dark gray, micaceous, jointed bentonite. Blocky appearance on weathered surface. Worm borings conspicuous.	2.0
1. Gray, finely micaceous and slightly silty bentonite. Very tough and brittle. Curved joints filled with fibrous calcite. Calcareous "balls" 3 to 18 inches in diameter common.	2.0+
Total	104.0±

The northernmost bentonite occurrence in the area is the Little Panther Creek deposit located 5.5 miles south of Aberdeen in Sec. 13, T. 15 S., R. 7 E. The clay occurs 15 to 40 feet beneath an old flood plain of the Tombigbee River. The bentonite bed is about 5 feet thick with an additional overlying transition zone 2 feet thick. Figure 3 shows the appearance of this bentonite bed. This occurrence is described in Section 4.

Section 4. Little Panther Creek Pit 5.5 Miles South of Aberdeen.

Formation	Thickness (feet)
Cretaceous system	
Eutaw formation (Tombigbee sand member)	
3. Massive, micaceous, buff to gray colored glauconitic, fine, and well sorted quartz sand. Worm borings and shell fragments.	60.0

2. Transition zone grading from massive, gray, micaceous, fossiliferous, glauconitic, clayey sand to a darker, gray massive, micaceous, and fossiliferous sandy clay. Weathered surface hackly. Worm borings conspicuous.	2.0
1. Gray, micaceous, highly jointed bentonite. Very tough and brittle. Conchoidal fracture on fresh surface. Weathers into rounded blocks 1 to 2 inches in diameter. Shell fragments, echinoids, and lignite abundant near top. Calcareous "balls" 3 to 18 inches in diameter common. Fibrous calcite-filled curved joints.	5.0
Total	67.0

Several occurrences of bentonite are present in the bottom of Cane Creek in Sections 12 and 13, T. 15 S., R. 7 E. As was noted by Vestal (Vestal and McCutcheon, 1943), each of the occurrences are only a few inches thick and are interstratified with sand. The best exposure in the location is described in the section below.

Section 5. Cane Creek, Sec. 13, T. 15 S., R. 7 E.

Formation	Thickness (feet)
Cretaceous system	
Eutaw formation (Tombigbee sand member)	
4. Gray glauconitic and finely micaceous coarse sand with occasional quartz pebbles. Bottom contact very sharp.	1.0
3. Dark gray, sandy, micaceous clay. Jointing conspicuous. Much shell material.	1.0
2. Gray bentonite exhibiting conchoidal fracture. Weathers to brown concentric shells.	0.2
1. Dark gray sandy, micaceous, jointed clay.	1.0
Total	3.2

In the vicinity of Richardson Lake, two small layers of bentonite are present in the east facing slope of the Tombigbee River cut bank. This occurrence, which is described in the section below, is very well exposed along an old road which leads down into the Tombigbee River flood plain.

Section 6. Road Cut in NE/4, SW/4, Sec. 7, T. 15 S., R. 7 E., 800 Feet SE. of Richardson Lake.

Formation	Thickness (feet)
Cretaceous system	
Eutaw formation (Tombigbee sand member)	
8. Tan, glauconitic and slightly micaceous, massive sand.	3.0+
7. Covered zone.	3.0
6. Highly weathered, buff to tan, very sandy and micaceous, massive bentonite. Occasional dark gray clay blebs. Jointing decreases with increasing sand content. Blocky appearance on weathered surface. Bottom contact sharp.	3.0
5. Dark gray, clayey, glauconitic, sand. Jointing continuous from overlying clay. Worm borings present.	9.0
4. Buff, glauconitic, slightly micaceous sand with little clay. Upper contact gradational within 2 inches. Worm borings.	5.0
3. Covered zone.	2.0
2. Buff colored, highly weathered and jointed micaceous, sandy bentonite. Parting and clay blebs along bedding plane. Bottom contact with sand sharp but wavy.	3.0
1. Buff, glauconitic, slightly micaceous sand. Worm borings. Layer of shark teeth and lignite. (Prospect pit dug 15 feet into the sand.)	14.0
Total	42.0+

Vestal (Vestal and McCutcheon, 1943) mentioned a stratum of bluish-gray to greenish bentonite 4 feet thick along the west bank of the Tombigbee River. The clay is described by Vestal (Vestal and McCutcheon, 1943) as being hard, tough, silty, and micaceous, and breaking with a pronounced conchoidal fracture. This clay could not be found during this investigation possibly because the area is now covered with alluvium and very thick vegetation.

CHEMICAL COMPOSITION

Chemical analyses have been made of the bentonites in northeastern Mississippi by various agencies. Analyses of the Panther Creek bentonite and a Cane Creek bentonite are given in Table 3. For comparison, bentonites from Amory, Mississippi, and Clay Spur, Wyoming, are also given.

Location	Cane Creek NW 1/4, Sec. 12 T. 15 S., R. 7 E Monroe Co. Miss.	Panther Creek, Monroe Co. Miss.	Amory, Itawamba Co., Miss.	Clay Spur, Wyoming
SiO_2	58.64	55.45	51.52	60.96
Al_2O_3	21.50	17.68	17.15	18.27
Fe_2O_3	4.40	6.82	5.65	2.83
FeO	-	-	0.32	0.14
MgO	1.90	2.63	2.80	2.96
CaO	1.30	1.43	1.72	0.10
Na_2O	0.31	-	0.15	1.44
K_2O		-	0.85	0.31
TiO_2	0.59	-	0.48	0.08
H_2O	-	-	19.77	13.34
Ignition	9.16	16.08	-	-
TOTAL	97.80	100.09	100.41	100.43
Source:	Vestal (1943)	Vestal (1943) from Poole Maynard	Reference Clay	Minerals (1951)
Analysis made by:	B. F. Mandebaum	Burrow-Agee Lab, Memphis, Tenn.	Ledoux and Co.	New York, N. Y.

Table 3.—Chemical Analyses of bentonites.

Although the chemical compositions of all these bentonites are similar, small differences in composition cause large differences in their physical properties. Because of the differences in sodium and calcium content and their relative tendency to swell with the addition of water, the Wyoming bentonites are known as swelling or sodium bentonites, while the Monroe County bentonites are known as non-swelling or calcium bentonites. The relative abundance of sodium and calcium is an important factor in causing the clay to be swelling or non-swelling. According to Foster (1955) the kind and extent of isomorphous replacement of magnesium and ferrous iron for aluminum in the octahedral layer and, to a lesser degree, the replacement of aluminum for silica in the tetrahedral layer also influence the swelling properties of the clays.

MINERALOGY AND LITHOLOGY

The minerals present are similar in all of the bentonite occurrences, however, the relative percentages and characteristics of the individual minerals are different in each clay occurrence. Typically, the bentonite is composed of clay with calcium carbonate and sand in varying amounts.

X-ray analyses and electron microscopy suggest that well ordered montmorillonite is the major clay mineral. Varying amounts of interstratified mica, and small amounts of a mineral with 14 A° d spacing with some of the characteristics of vermiculite, and quartz are also present. A few euhedral crystals of kaolin and halloysite were observed in the clay by the use of the

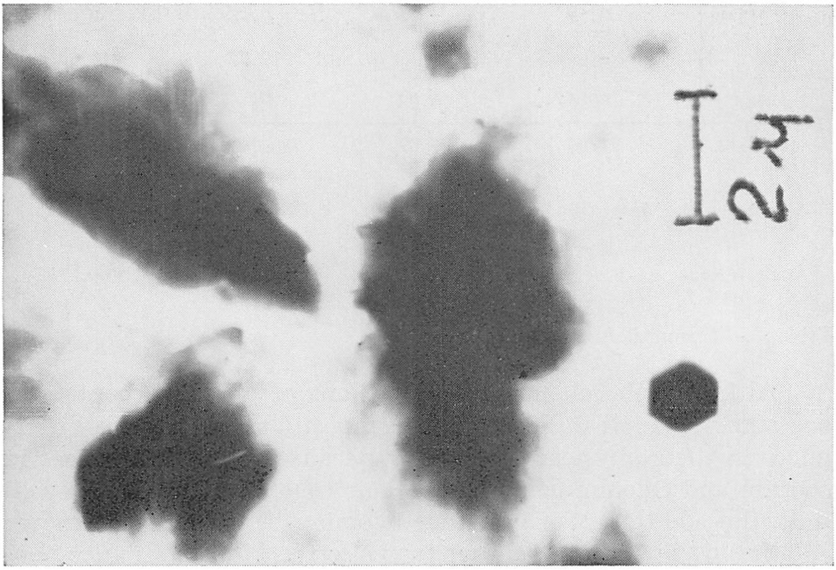


Figure 6.—Electron micrograph of Little Panther Creek bentonite showing mica (center and lower left), montmorillonite and kaolin (lower right).

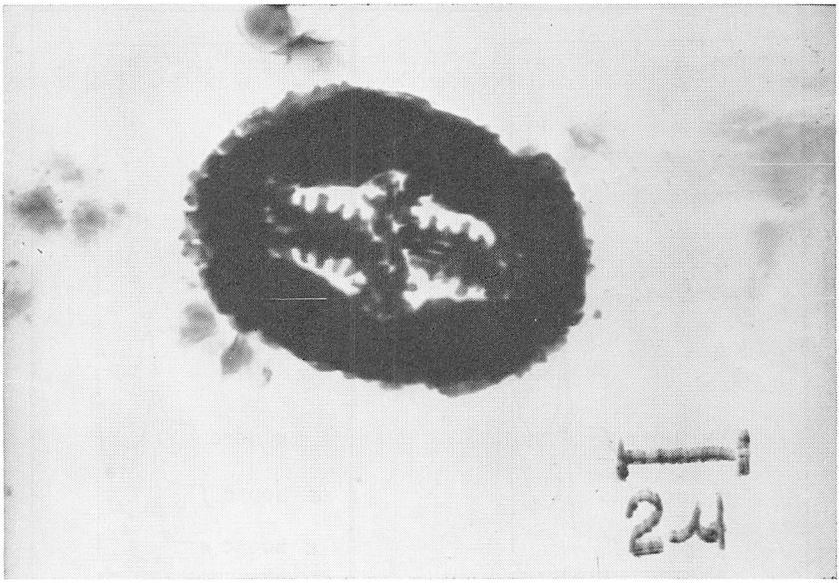


Figure 7.—Electron micrograph of a coccolith in bentonite from Cane Creek, Sec. 13, T. 16 S., R. 7 E., Monroe County.

electron microscope. Coccoliths are present and are more plentiful in some bentonites than in others.

The electron microscope also revealed the presence of bundles of unidentified radiate fibers. Similar fibers have been observed by Sudo (1954) in altered volcanic glass in Japan. Large, almost transparent (to the electron beam) sheets, presumably of mica, and many other small opaque particles are also present. These small particles, which are irregular, spherical, or cubic-shaped, settled at the same velocity as the larger particles and could represent the heavier minerals.

According to Gruener (1940), cristobalite, which is usually associated with montmorillonite, can be detected in quantities as little as 5% by x-ray diffraction. No cristobalite was detected in any of the bentonite in the area by the use of this technique.

Quartz, mica, glauconite, and the heavy minerals constitute the majority of the sand sized particles. The quartz grains are angular, spherical to flake-shaped particles. The majority of the quartz grains are very fine but occasional larger grains which are typical of the Tombigbee sand are present.

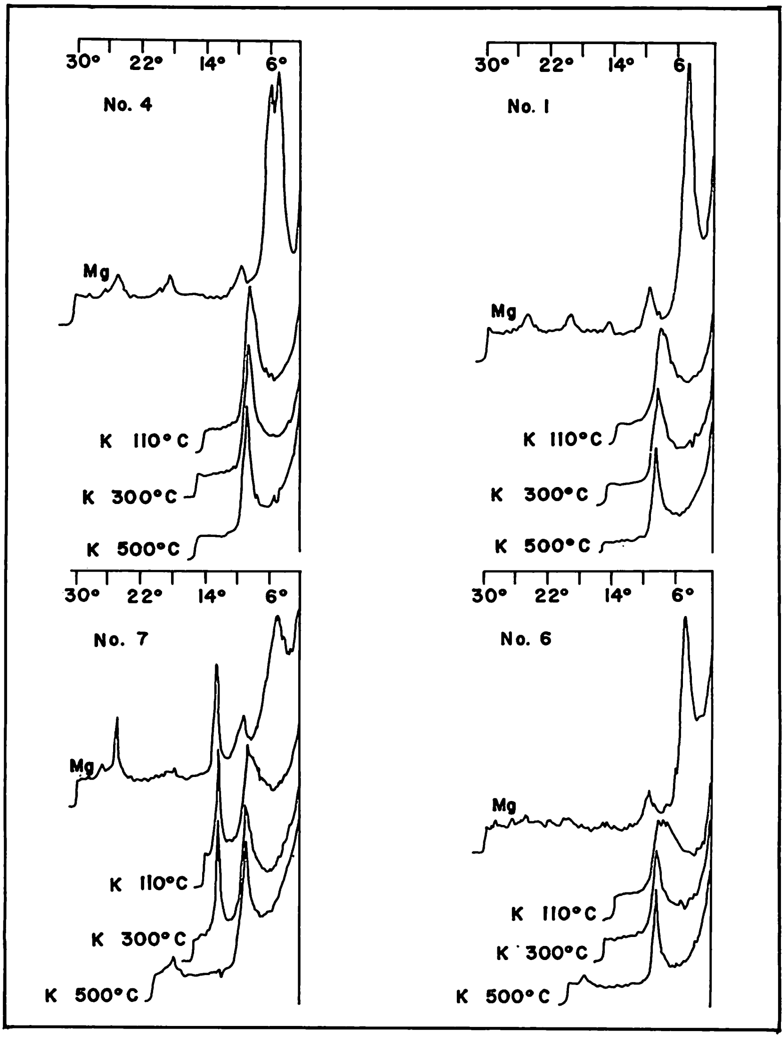


Figure 8.—X-ray diffractiongrams.

Most of the mica flakes are very fine and angular. A few small euhedral biotite flakes and biotite crystals are present. Many of the biotite flakes exhibit hexagonal voids. Euhedral biotite inclusions are sometimes present in what appears to be muscovite. The muscovite flakes often show degrees of alteration on their surfaces. Many biotite flakes are completely altered to glauconite, and many other flakes exhibit varying degrees of alteration. All layered glauconite observed was angular, but globular-shaped glauconite is present as very fine, well rounded particles.

Mica, pyrite, ilmenite, and leucoxene are the most common heavy minerals. Pyrite is present as radiating crystal aggregates and is commonly partially altered to limonite.

A few small, brown, irregular-shaped angular glass shards are present in the bentonites. The shards are commonly very thin, curved, and contain inclusions.

Dense, spherical, calcium carbonate "balls" of about 3 to 18 inches in diameter are present in the Panther Creek and Little Panther Creek deposits. The "balls" analysed were composed of about 66% calcium carbonate, 25% clay and silt, and the remainder of sand. One or more concentric shells of pyrite around the "balls" may be present. The centers of the "balls" are more arenaceous than are the outer layers. The calcium carbonate "balls" contain minerals similar to those that occur in the surrounding bentonite.

STRUCTURE

The attitude of the bentonite occurrences relative to the surrounding formations is not clear. The many prospect pits and test holes that have been drilled in the Panther and Little Panther Creek area suggest that these two bentonite deposits may be continuous in the subsurface. The other two occurrences of bentonite in the area are not continuous in the subsurface with the Panther Creek bentonite.

The Panther Creek bentonite, according to Poole Maynard's map (1935), dips about 25 feet per mile almost due west. Mr. E. G. Birkholz, manager of the American Colloid bentonite plant at Aberdeen, stated in a personal interview that the dip may be as little as 10 feet per mile.

Irregularity of the bentonite beds both vertically and horizontally is pronounced. According to the survey conducted by Maynard (1935), the Panther Creek bentonite in places thins from 9 to 2 feet thick in a horizontal distance of 100 feet.

Bedding is generally absent in the bentonites and is only poorly developed when present. In thin sections, bedding is evidenced by the horizontal orientation of the muscovite flakes. The calcareous concretions that are present in the Panther Creek bentonites and the concentric clay shells present in the Cane Creek bentonite exhibit concentric spherical orientation of the particles both microscopically and macroscopically.

All of the bentonites are highly jointed, but the structure is best seen in the two bentonite pits of Panther and Little Panther Creeks. Two types of joints appear to be present. Large nearly straight parallel joints dipping about 45° to the northeast are present whenever the clay content of the Tombigbee sand is appreciably increased. Smaller conical shaped joints with the apex pointing downward are very abundant. Slickensides and fibrous calcite are present in both types of joints.

FAUNA

Small echinoids, worm borings, and lignite fragments are very abundant near the top of the bentonite bed in the Little Panther Creek deposit. Worm borings and lignite are common in all of the bentonites but in no other locality were echinoids observed. Coccoliths are present in all of the bentonites, but in varying amounts.

CONTACT RELATIONSHIPS

In all bentonite occurrences within the area, the bottom contact of the bentonite with the sand is very sharp. The upper contact, where seen, is gradational within a few inches to two feet. In Figure 3, the dark layer above the bentonite represents the transition from bentonite to sand.

SUMMARY AND CONCLUSIONS

Six mappable units in the area can be differentiated on the basis of lithology and stratigraphic positions. These units are, in ascending order, the Tombigbee sand member of the Eutaw formation, the Mooreville formation, the Arcola limestone member of the Mooreville formation, the Demopolis formation, the terrace deposits, and the alluvium.

On the basis of surface mapping, the Tombigbee sand member appears to be abnormally thick in the northeastern portion of the area. This increase in outcrop width could be caused by the reduction of the dip of the formation. Faulting could also cause such an apparent thickening, but no evidence of faulting was observed in any portion of the area. The Tombigbee sand member of the Eutaw formation and the Mooreville formation strike N. 20°W. and dip 30 to 40 feet per mile.

At one location in Town Creek, the contact between the Tombigbee sand member and the Mooreville formation appears to be unconformable. In all other locations the contact appears to be gradational and conformable.

The streams are entrenched below their flood plain surfaces, especially in the southeastern quarter of the area. Removal of the vegetation in the area in preparing the land for agricultural use would allow more rapid runoff of the surface water, thereby effectively rejuvenating the streams.

The clay minerals present in the sediments are mainly montmorillonite, a lesser amount of illite, and minor amounts of kaolin, and halloysite. The predominant sand-sized mineral in the sediments is quartz. Mica, glauconite, and the heavy minerals comprise the remainder.

Euhedral biotite crystals, subhedral quartz crystals, and glass fragments in the sand-sized particles at the base of the Mooreville formation are indicative of a volcanic origin for a portion of the sediments. No bentonites were found in any units other than the Tombigbee sand member.

The bentonites in the area appear to be altered waterlaid volcanic ash. This conclusion is supported by the presence of euhedral biotite, biotite inclusions in what appears to be muscovite, the relative percentages of the heavy minerals, a few glass shards, and the presence of marine fossils within the bentonites. The glass shards found were few in number but were very distinctive. Whether or not the ash or bentonite was water transported before final deposition could not be determined from the information available. The bentonites are discontinuous in the subsurface, but may lie in a single zone of deposition within the Tombigbee sand member.

The bentonites conform to the regional strike of the formations in the area, but may differ from the regional dip by dipping 10 to 20 feet per mile.

ACKNOWLEDGMENTS

I dedicate this work to my parents, Mr. and Mrs. Felix Torries, and to my wife, Joanne Saucier Torries, whose sacrifices and encouragements made my education possible.

I also wish to express my sincere appreciation for the ideas and guidance given to me by Professor Ernest E. Russell during the preparation of this thesis. I am deeply grateful for the innumerable suggestions given to me by Dr. Troy Laswell and Dr. Spenst M. Hansen.

I am also indebted to the Department of Ceramic Engineering and to the Department of Agronomy, Mississippi State University, for the use of their laboratories and equipment.

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MISSISSIPPI GEOLOGICAL, ECONOMIC AND TOPOGRAPHICAL SURVEY
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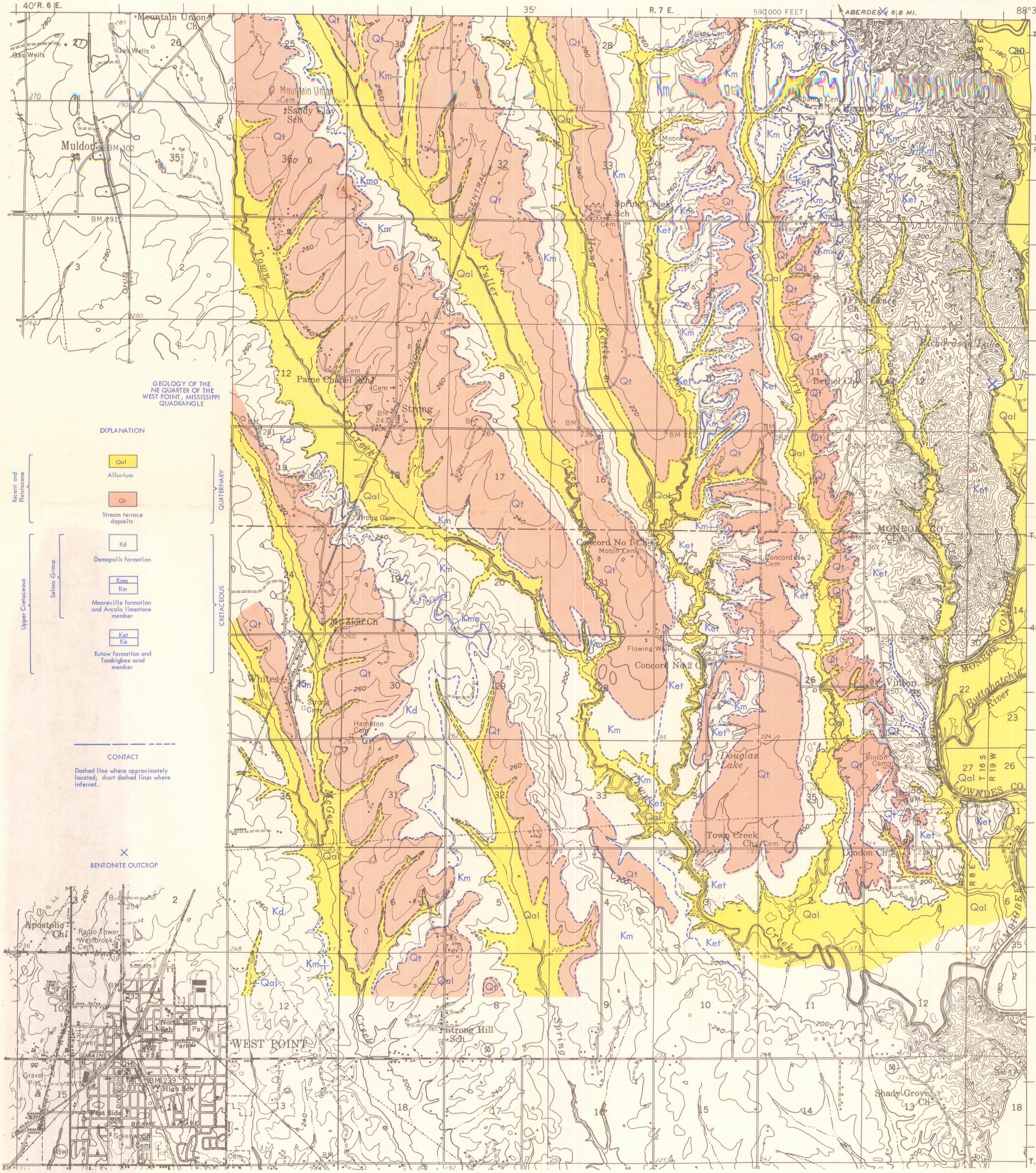
BULLETIN 102
PLATE 1



Base map by Geological Survey.
Control by USGS, USC&GS, and USCE.
Topography from aerial photographs and planetable surveys 1959.
Polyconic projection.

TRUE NORTH
MAG. NORTH
5°
APPROXIMATE MEAN DECLINATION, 1959

SCALE 1:62,500
1 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

CONTOUR INTERVAL 20 FEET

Datum Is Mean Sea Level

MISS.
AREA LOCATION

GEOLOGY OF THE NORTHEAST QUARTER OF THE WEST POINT, MISSISSIPPI, QUADRANGLE

By

THOMAS F. TORRIES

1963