MISSISSIPPI STATE GEOLOGICAL SURVEY

E. N. Lowe, Director

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COASTAL PLAIN STRATIGRAPHY OF MISSISSIPPI

By
Lloyd W. Stephenson, C. Wythe Cooke, and E. N. Lowe

Prepared in Cooperation with the United States Geological Survey

PART FIRST

MIDWAY AND WILCOX GROUPS

By
E. N. LOWE

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LETTER OF TRANSMITTAL

Geological Building,
University, Mississippi,
January 9, 1933

To His Excellency,
Governor Sennett Conner, Chairman, and
Members of the Geological Commission.

Gentlemen:

For a number of years past the State Geological Survey, in co-operation with the United States Geological Survey, has been investigating the stratigraphy of Mississippi and collecting full data on the geology of the state. In the course of this investigation the State Survey has published each year reports on economic resources of value to the state. From the beginning it was expected that this stratigraphic report (which is fundamental to all other geologic studies within the state), would be rather full and voluminous. Hence, since the printing fund of the Geological Survey was at no time adequate to issue the full report, partial reports on various economic resources of the state were published from time to time, the more voluminous stratigraphic report being reserved until an adequate printing fund should become available. In this way, during progress of the cooperation, 23 volumes of Bulletins and 13 Biennial Reports, all dealing with economic resources of value to the people of Mississippi, have been issued.

By prearrangement, the part of the cooperative work on Stratigraphy was to be published by the State Survey, and that on Underground Waters of Mississippi to be published by the United States Geological Survey. The Federal Survey has already published its quota on Underground Waters of Mississippi as Water Supply Paper 576, and the State Survey is now, in spite of short funds, trying to fulfil its part of the agreement by issuing the stratigraphic report, of which the present is the first part. This is done with the consent of the cooperating Federal Department.

The part embraced in this volume is that on the Lower Eocene formations, including only the Midway and Wilcox groups. Other parts will be issued as finances will permit.

Acknowledging the cooperation of Doctors L. W. Stephenson, C. Wythe Cooke, and E. W. Shaw, of the United States Geological Survey, in revision of the manuscript and hoping that the Report will meet your approval, I am

Very respectfully yours,

E. N. LOWE, Director.

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THE EOCENE FORMATIONS BELOW THE JACKSON

By E. N. Lowe

The Tertiary formations in Mississippi range in age from earliest Eocene to Pliocene, and occupy most of the area of the State. They include fresh-water, estuarine, and marine facies and have an aggregate thickness of several thousand feet. The deposits of the Eocene epoch fall into four divisions, which, named in ascending order, are Midway, Wilcox, and Claiborne groups and the Jackson formation. The Midway group as here defined includes the Clayton and Porters Creek ("Flatwoods of Hilgard") formations; the Wilcox group includes the Ackerman, the Holly Springs sand, the Bashi ("Woods Bluff"), Hatchetigbee, and Grenada formations; the Claiborne group includes the Meridian sand member, the Tallahatta, Winona, Lisbon, and Yegua (or "Cockfield") formations. Only the Tertiary divisions that lie stratigraphically below the Jackson formation, the youngest of the Eocene divisions, are considered in this report.

MIDWAY GROUP

NAME AND SUBDIVISIONS

The name Midway was first applied to certain beds of limestone and calcareous marl exposed at Midway Landing, on the Alabama River,[1] but later the name was made to embrace, besides these beds of fossiliferous limestone and marl, the overlying "Black Bluff" or Sucarnochee clay, and the succeeding Naheola ("Matthews Landing") formation.[2] The Porters Creek clay of Safford[3] ("Flatwoods" clay of Hilgard)[4] in Mississippi corresponds to the

[1] Dr. E. A. Smith first used the term "Midway or Pine Barrens section" in Ala. Geol. Survey, Bull. No. 1, 1886, while Aldrich in the same publication called the same beds Midway group. Subsequently ("Sketch of Geology of Alabama," Roberts and Son, Birmingham, Ala., pam. of 36 pp., 1892; also Alabama Geol. Survey Bull. 2, 1892) Smith changed the name of these basal beds to Clayton limestone.

[2] G. D. Harris proposed (Am. Jour. Sci., April, 1894) to use the name Midway for a geological stage or group, to include the "Matthews Landing" (Naheola), "Black Bluff" (Sucarnochee), and "Midway clay and limestone" (Clayton limestone) as substages.

[3] Safford, James M., A Geological Reconnaissance of the State of Tennessee, 1856; Geology of Tennessee, pp. 422-424, 1869.

[4] Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, pp. 110, 273, 1860.

Sucarnochee clay of Alabama. The Naheola formation of Alabama has not heretofore been recognized in Mississippi, but the writer has referred doubtfully to the Naheola horizon a series of beds of sand, glauconitic sandstone, and dark, shaly clay near Walnut, Tippah County. This marine horizon, in the form of unconsolidated glauconitic sands of considerable thickness, has recently been traced by the writer almost continuously from Tippah County to Kemper County. The above inference was drawn by C. Wythe Cooke,[1] and later the identity of the Tippah with the Naheola was reasonably

FIG. 1. A.

A. Ripley formation in cut of St. Louis & San Francisco Railroad, Wallerville, Union County. The top of gray unweathered calcareous sand is marked by the base of the prominent line of vegetation, all above this line is deeply weathered to red and reddish-brown ferruginous sand. Photo by L. W. Stephenson.

well established by the field work of the writer.[2] This reference of the series of beds near Walnut to the Naheola is based upon stratigraphic relations, lithologic character, and the presence of marine fossils which are not found in the immediately overlying or underlying beds. In previous reports[3] the Tippah beds have been treated as a distinct formation overlying the Porters Creek clay, but

1Cooke, C. W., Correlation of the Eocene formations in Mississippi and Alabama. U. S. G. S. Prof. Paper 140-E, p. 4. 1925.

2Lowe, E. N., Field Notes, 1926, 1927, 1928.

3Lowe, E. N. Miss. Geol. Survey, Bull. No. 12, 1915, and Bull. 14, 1919.

as they appear to be represented at the type locality of the Porters Creek formation, and were apparently included in that formation by Safford, they are here treated as a member of the Porters Creek clay.[1]

A study of the Midway in Mississippi reveals an interesting series of changes in physiographic conditions. The basal beds, which consist of limestone of great purity, would seem to indicate that in this region Midway time began with marine conditions—the region was probably covered by a sea in which little sediment was brought from the surrounding land. Upon these beds of limestone were laid down deposits of sandy glauconitic marl that indicate a large intermixture of land-derived sediment with calcium

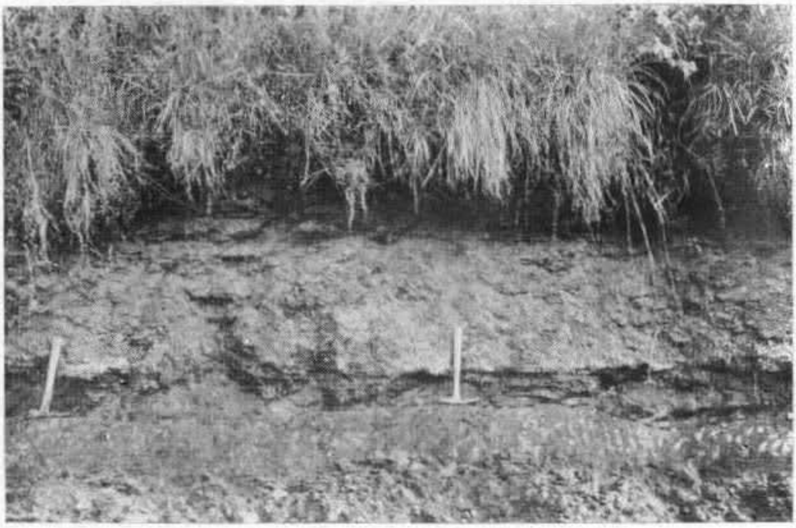

FIG. 1. B.

B. Cretaceous-Eocene contact in cut of St. Louis & San Francisco Railroad, 1¼ miles southeast of New Albany, Union County. The hammers rest on the slightly undulating upper surface of the gray calcareous Ripley sand; the Ripley is overlain by one-half to one foot of yellow ferruginous sand, overlain in turn by 6 feet of hard yellow fossiliferous limestone of the Midway group of the Eocene. Photo by L. W. Stephenson.

[1]Recently in a reexamination of the Walnut area by Lowe and Grim new outcrops of the Porters Creek clay were noted at an elevation of from 60 to 70 feet above the typical fossiliferous Tippah sandstone leading Lowe to express the opinion that the Tippah cannot be a distinct formation, but should be regarded as a member or local phase of the Porters Creek. At numerous localities in Tippah County along the outcrop these distinctly marine beds appear at several different horizons within the Porters Creek. Only in Tippah County does this particular phase appear; elsewhere to the south the outcrop shows yellow and red sands, in places distinctly glauconitic, but rarely, if at all, fossiliferous.

carbonate of marine origin. The overlying beds of clay—Porters Creek formation—are gray and slightly lignitic and contain some impressions of land plants, but they were probably deposited in offshore water at depths below the disturbing influence of waves and currents. The period of quiet clay-depositing water of Porters Creek time was followed in northern Mississippi by a period of shallow, turbulent, swift-flowing water bearing great quantities of coarse sand that formed the Tippah sandstone member of the Porters Creek, which contains an intermixture of glauconite and marine shells.

CLAYTON FORMATION

GENERAL FEATURES

Stratigraphic relations.—The basal formation of the Midway group in Mississippi consists of a series of indurated semi-crystalline, fossiliferous limestones, overlain by greenish-yellow glauconitic and micaceous sands. These beds were originally placed by Hilgard in the uppermost Cretaceous, but later paleontologic investigations have shown that they are Tertiary. They are correlated by means of characteristic fossils with the Clayton formation of Alabama, which is lowermost Eocene. The formation is not well developed in Mississippi, nowhere reaching a thickness approximating that in eastern Alabama.

The Clayton beds lie unconformably upon the blue Owl Creek tongue of the Ripley formation. The relation of the two can be plainly seen in the spring at Chalybeate, 2½ miles east of Walnut, Tippah County. Here 6 feet of Ripley blue marl (Owl Creek tongue) is exposed below the contact between the marl and the overhanging Clayton limestone, the spring flowing out from the plane of contact. Both formations are easily identified by characteristic fossils.

On Owl Creek, 2½ miles northeast of Ripley, the type locality of the Ripley formation, 18 feet of Clayton limestone directly overlies 18 feet of blue Ripley marl. The contact shows an irregular surface indicating a break in the continuity of deposition.

A deep cut on the St. Louis and San Francisco Railroad, a mile southeast of the station at New Albany, in Union County, shows a line of contact between Ripley blue marl below and Clayton limestone above. The limestone here, which contains Tertiary fossils, is only a few feet thick, and is overlain by 18 or 20 feet of red glauconitic sand also belonging to the Clayton formation. The blue marl contains abundant fossils.

In the ravine south of the railroad track between the station at New Albany and the cut just mentioned undoubted Ripley marl outcrops at a level 10 to 15 feet lower than the base of the cut, and a mile east of the cut ledges of Ripley limestone containing characteristic fossils show a dip that would carry them only a few feet below the track level in the cut.

In the great railroad cut half a mile south of Pontotoc 20 feet of Indian red sand of the Clayton overlies somewhat similar sands of the Ripley. The line of division is not well marked, though a zone of clay nodules probably marks an unconformable contact. The sand below the clay nodules contains rather abundant Cretaceous fossils at certain levels, and the red sand of the Clayton has yielded a few specimens of *Enclimatoceras ulrichi*.

The Clayton beds underlie unconformably the Porters Creek clay. The evidence of unconformity between the two formations is not so clear as that between the Clayton and underlying Cretaceous, but an unconformity apparently exists, for the physical features of the two formations are entirely different and sharply marked, and the conditions under which they were deposited were entirely unlike. The best evidence of unconformity may be seen a mile west of Pontotoc on the Toccopola road. Here, at a point where the road passes rather steeply down 10 or 12 feet into a little creek flat, the contact is revealed between 4 or 5 feet of gray Porters Creek clay and the underlying Clayton, a greenish-gray fossiliferous glauconitic marl, weathering yellow-brown. The line of demarcation is sharp, very noticeable, and probably marks an unconformity. A very similar exposure of the contact was noted at a point a quarter of a mile west of Glenfield and 2½ miles west of New Albany, where the characteristic gray clay and "Flatwoods" topography of the Porters Creek clay appears. Within a quarter of a mile west of the eastern edge of the Porters Creek clay a little ravine exposes, beneath 5 or 6 feet of the clay, several feet of the greenish-gray glauconitic sand of the Clayton, and the line of contact is very sharp. The slope on the opposite side of the ravine is occupied by a little farm, and on the lower part of the slope may be seen the red, sandy, glauconitic marly soil of the Clayton. A few feet of the gray, sticky Porters Creek clay caps

A well at Ecru, 8 miles north of Pontotoc, in the eastern edge of the Flatwoods, passed through 18 feet of gray Porters Creek clay, beneath which it penetrated 40 feet of bluish sandy marl before striking solid rock, probably the "*Turritella* rock." The data here give a more definite thickness to this upper sand member of the Clayton than any data collected elsewhere. The 40 feet of bluish sandy marl undoubtedly corresponds to the part of the Clayton formation above the basal limestone.

Three miles north of Scooba, Kemper County, C. Wythe Cooke collected marine fossils from a light gray to white calcareous clay, which he regards as either Clayton or basal Porters Creek. These fossils would seem to indicate that, at this point at least, the conditions gradually changed from those that prevailed when the upper Clayton was laid down to those that brought about the deposition of the Porters Creek. About 15 miles northwest of this locality, at a bridge over a small creek 3 miles north by west of Shuqualak, beds of indurated sandy marl 5 feet thick overlie unconformably Selma limestone. This marl has heretofore been regarded as Ripley, though it is probably Clayton. The outcrop has furnished no fossils.

Distribution and physiographic expression.—Owing to the small area occupied by the Clayton and to the lack of detailed work, no attempt has been made to separate its divisions on the map. The formation constitutes a zone, 3 to 10 miles wide, bordering the Cretaceous outcrop on the west. It enters the State in Tippah County a few miles south of Middleton, Tenn., passes southward through Tippah, Union, Pontotoc, and Chickasaw counties; turns slightly east of south, and passes through a corner of Webster County, through western Clay and Oktibbeha counties, through the northwest corner of Winston, and the southwestern part of Noxubee counties, and thence passes diagonally through Kemper County to the Alabama State line.

The Clayton formation can not be traced continuously throughout this area. It forms the eastern border of the zone continuously from Middleton, Tenn., to Houston, in Chickasaw County. Farther south the outcrop has not been continuously noted, but it appears to be represented by a thin calcareous sandy marl in southern Noxubee and northeastern Kemper counties, and lies unconformably upon the Selma. It maintains a rather uniform width of outcrop of about 3 miles from the Tennessee line to Houston, the western edge being approximately on a line running from half a mile east of

Middleton, Tenn., through Walnut and Ripley 3½ miles east of Blue Mountain; 2½ miles west of New Albany; one-half mile west of Ecru; 1 mile west of Pontotoc, and 1 mile west of Houston.

Four miles north of Houston, one-fourth mile east of the Gulf, Mobile and Northern Railroad, a well was put down for oil in 1922. The well was located on a conspicuous north-south ridge of fossiliferous Clayton limestone, which formed the outcropping bluff edge of the "*Turritella* rock," and dipped sharply toward the west. This rock was penetrated in the well at 250 feet, according to the log of the driller.

The Clayton formation is characterized over much of the area of its outcrop by high, broken hills and ridges, especially in Tippah and parts of Pontotoc counties, where it constitutes the western border of what is known as Pontotoc Ridge. However, large areas of it around Ingomar, Ecru, and Algoma form broad, gently undulating uplands, the red soils of which make fertile fields in a highly prosperous agricultural district.

The water that runs off these uplands drains westward into the Tallahatchie and Yalobusha Rivers or eastward into the Tombigbee and Tennessee Rivers. The removal of the timber from the steeper slopes has caused extensive and destructive erosion over much of the area.

Thickness.—The maximum thickness of the Clayton formation in Mississippi is 65 to 70 feet, unless 250 feet in the well at Houston be correct. It seems excessive. At Ripley, according to Crider, wells that enter the sandy marls of the Clayton at the surface reach the "*Turritella* rock" at a maximum depth of 35 feet; on Ripley Creek, 1½ miles south of Ripley, the Clayton sandy marls are 30 feet thick; in the well at Ecru above mentioned they are 40 feet thick, a figure that is probably the most reliable, because the well undoubtedly passed through the whole thickness of the formation, beginning in the Porters Creek and going to the underlying "*Turritella* rock."

Crider states that the Clayton formation in Mississippi is represented by about 30 to 40 feet of limestone and 30 feet of sandy marl. Hilgard mentions an outcrop "about 30 feet thick, of limestone," but no measurements appear to have been taken. It is now believed that 25 feet may be taken as the maximum thickness, and that 10 to 15 feet is much more common than higher figures.

Dip.—The Clayton beds dip gently westward under the Porters Creek clay. Data for estimating the dip are not abundant. Crider calculated the dip at 15 feet to the mile. The well of J. H. Hattox at Ecru, obtains flowing water beneath blue marl and 18 inches of hard rock at a depth of 85 feet. The gin well of G. H. Horton, 3½ miles west of Ecru, obtains water from the same horizon at a depth of 105 feet. If there is a slight depression of the surface toward the west, making the mouth of the Horton well as much as 16 feet lower than at Ecru, and if the air line distance between the two places is 3 miles (the distance by road being 3½ miles), the dip would be 12 feet to the mile. It is probable that the average dip of the Midway beds does not differ much from that of overlying Tertiary formations, 25 to 30 feet to the mile.

Paleontology.—With a few exceptions the determinable fossils so far found in the Midway of Mississippi belong to the lowest formation, the Clayton. A few marine fossils referred to the clay of the Porters Creek formation have been obtained at two points. A number of rather large marine shells occur in the Tippah sandstone phase of the Porters Creek. The species in the following lists were identified by C. Wythe Cooke from the Clayton formation in Mississippi and Southern Tennessee:

Station 6091.—Clayton formation. Milepost 481, east of Middleton, Tenn. (E. W. Berry, collector)

Mazzalina impressa (Gabb).
Calyptraphorus velatus var. compressus Aldrich.
Turritella saffordi (Gabb).
Turritella 2 sp.
Natica saffordia Harris.
Leda sp.
Ostrea crenulimarginata Gabb.
Meretrix ripleyana (Gabb).
Venericardia planicosta var. smithi Aldrich.
Crassatellites gabbi (Safford).

Station 6495.—Clayton formation. Cut on Southern Railway, 1½ miles east of Middleton, Tenn., 200 feet east of milepost 481. (E. N. Lowe and C. Wythe Cooke, collectors)

Plant fragments.
Foraminifera
Ostracoda
Cylichna sp.
Turris sp.
Plejona rugata var. saffordia (Gabb).
Mazzalina impressa (Gabb).
Pseudoliva cf. P. ostrarupis Harris.
Pseudoliva sp.
Calyptraphorus sp.
Mesalia sp.
Turritella saffordia Gabb.
Turritella 2 sp.
Natica saffordia Harris.
Dentalium mediaviense Harris.
Nucula ovula Lea.
Nucula sp.
Leda sp.
Glycymeris sp.
Cucullaea saffordi Gabb?
Ostrea Crenulimarginata Gabb.
Modiolus saffordi Gabb.
Corbula subcompressa Gabb.
Tellina sp.
Meretrix ripleyana (Gabb).
Meretrix n. sp.
Lucina fortidentalis Harris?
Lucina sp.
Venericardia planicosta var. smithi Aldrich.
Crassatellites gabbi (Safford).

The fossils are associated with obscure plant remains near the base of the cut, in a 6 foot bed of dark gray, glauconitic marl, which is very micaceous in places and includes small crystals of gypsum along the joint planes. This dark marl is overlain by about 10 feet of stratified brown, gray, and yellow sand and sandy clay containing obscure plant remains and casts of shells, apparently of the same species that occur in the underlying bed.

Station 6496. Clayton formation. Bluff on Ripley Creek about 1½ miles south of Ripley, Tippah County, Miss.
(E. N. Lowe and C. Wythe Cooke, collectors)

Bryozoa.
Turritella mortoni Conrad.
Lacunaria alabamensis (Whitfield)?
Leda sp.
Ostrea pulaskensis Harris.
Phacoides (Miltha) clatonia (Harris)?
Venericardia planicosta Lamarck.
Venericardia sp.

The fossils consist of casts in impure semi-crystalline limestone that overlies brown glauconitic sand of the Ripley formation.

Station 6497.—Clayton formation. Bluff on south side of Owl Creek, 2¾ miles northeast of Ripley, Tippah County, Miss., about one-fourth mile east of the Ripley-Troy road. Near base of formation.
(C. Wythe Cooke, collector)

Conopeum damicornis Canu and Bassler.[1]
Nellia midwayanica Canu and Bassler.[1]
Smittipora midwayanica Canu and Bassler.[1]

Shark tooth
Mesalia pumila (Gabb).
Turritella mortoni Conrad.
Turritella sp.
Natica? sp.
Calyptraea sp.
Leda sp.
Cucullaea saffordi (Gabb).
Ostrea pulaskensis Harris.
Ostrea (Gryphaeostrea) vomer (Morton)?
Phacoides (Miltha) clatonia (Harris)?
Venericardia sp.
Venericardia planicosta Lamarck.

The fossils consist of casts in impure limestone overlying the glauconitic sands of the Ripley formation.

Station 5586.—Clayton formation. Ravine just north of Booneville road, 3 miles northeast of Ripley, Miss.
(L. W. Stephenson, collector)

Turritella mortoni Conrad.
Ostrea pulaskensis Harris.

Station 5590.—Clayton formation. About 5 miles south by west of New Albany, Miss., on a small branch of King's Creek, near Gulf, Mobile & Northern Railroad. At a spring coming from a cave in Clayton limestone near the former camp of an Indian chief.
(L. W. Stephenson, collector)

Turritella mortoni Conrad.
Ostrea pulaskensis Harris.

Station 5592.—Clayton formation. Bluff on Owl Creek, 3 miles northeast of Ripley, Miss. Land of William Hill, at spring adjacent to house.
(L. W. Stephenson, collector)

Bryozoa.
Turritella mortoni Conrad.
Arcea? sp.
Venericardia planicosta Lamarck.

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[1]Identified by Canu and Bassler.

Station 5587.—Clayton formation. Cut on Mobile & Kansas City Railroad, about 3 miles north of Houston, Miss.
(L. W. Stephenson, collector)

Ostrea pulaskensis Harris.

Station 6580.—Clayton formation. Macon-DeKalb road, 7 miles south of Macon, Miss. Near base of Eocene, several feet above base of bed No. 2.
(L. W. Stephenson, collector)

Gryphaeostrea vomer (Morton)?

Station 6581.—Clayton formation. Macon-DeKalb road, 7 miles south of Macon, Miss. Bed No. 2, 4 to 6 feet above its base.
(L. W. Stephenson, collector)

Corals
Turritella mortoni Conrad.
Cucullaea saffordi Gabb?
Venericardia alticostata Conrad var. ?

Station 6582.—Clayton formation. Macon-DeKalb road, 7 miles south of Macon, Miss. Bed No. 1.
(L. W. Stephenson, collector)

Coral, probably new sp.
Ostrea pulaskensis Harris.

Station 6566.—Clayton formation. Macon-DeKalb road, 7 miles south of Macon, Miss. Base of bed No. 2. May have been reworked from bed No. 3, but the shells do not appear water-worn.
(L. W. Stephenson, collector)

Ostrea (Gryphaeostrea) vomer (Morton)?

Station 6571.—Clayton formation. From well on place of Mr. Portis, one-fourth mile northeast of post-office at Wahalak, Miss.
(L. W. Stephenson, collector)

Ostrea (Gryphaeostrea) pulaskensis Harris.

Station 6572.—Clayton formation. Bluff of Horse Creek, one-fourth mile north of Benj. Taylor's store, which is about 12 or 13 miles northwest of Macon, Miss., on the northern road from Macon to Louisville.
(L. W. Stephenson, collector)

Coral.
Cylichna? sp., cast.
Turris sp.
Turritella sp.
Natica 2 sp.
Xenophora sp.
Cucullaea saffordi Gabb?
Ostrea pulaskensis Harris.

Station 6573.—Clayton formation. Cut of St. Louis & San Francisco Railroad, 1 to 1-1/8 miles southeast of New Albany, Miss.
(L. W. Stephenson, collector)

Turitella mortoni Conrad.
Venericardia sp.

Economic products.—No economic use has been made of any of the material in this formation. The glauconitic marls have some value as a fertilizer, for they contain lime and a little phosphorus, but they will never have more than local use. The limestone is in places perhaps pure enough to make good lime, and, where there is enough of it and the outcrops are accessible the rock could be crushed and applied with advantage to acid soils.

LOCAL DETAILS

Middleton, Tenn.—The most northern point examined in the course of the present investigation is on the Southern Railway, 1½ miles east of Middleton, Tenn. About 200 feet east of mile board 481 the following section is exposed in a cut on the south side of the railroad:

Clayton formation:

	Feet
2. Lignitic marly clay, continuous from below, more sandy, thinly laminated, and becoming yellowish from oxidation above, and passing into soil	7
1. Dense dark bluish-gray glauconitic marl (very much like the Owl Creek tongue of Ripley marl at Ripley), micaceous, and having acicular crystals of what appears to be gypsum. Very fossiliferous, containing abundant *Ledas*, *Turritellas*. *Tellinas*, and few *Calyptraphorus*, *Bysonichia* (?) and *Venericardia planicosta;* also some lignitized wood. At base of the exposed excavation the material becomes decidedly clayey and lignitic	7

The absence of Cretaceous fossils and the result of a careful study by C. Wythe Cooke, of fossils collected at this locality (see stations 6091 and 6495) place these marl beds in the Midway. These beds lie stratigraphically between the basal limestone or "*Turritella* rock" and the Porters Creek clay.

Half a mile southeast of Middleton, at the base of the hills just south of the point where the wagon road crosses the railroad track, is the following exposure:

	Feet
2. Gray sandy clay which passes upward into reddish clay soil (Porters Creek?)	Few
1. Yellowish oxidized glauconitic sand, becoming greenish-gray below; exposed to bottom of cut	2

This point seems to mark the contact between the Clayton and the Porters Creek.

In the eastern outskirts of Middleton a cut in the public road exposes Midway materials as follows:

	Feet
4. Soil, perhaps of mixed nature, light, tawny, silty, and with many rounded quartz pebbles, ½ inch to 1 inch in diameter	3-4
Porters Creek clay:	
3. Gray clay, weathering, where exposed, to purplish dark gray clay, somewhat glauconitic and sandy at the bottom	4
Clayton formation:	
2. Light yellowish-gray indurated, highly calcareous bed, separated easily in plates; fossiliferous, and somewhat glauconitic. This bed forms a projecting ledge	2

	Feet
1. Greenish-gray to yellowish-gray sand, speckled with glauconite, weathering to yellowish-brown or deep red, or a lighter red sand; the lighter red material looks very much like some so-called "Lafayette" in the Wilcox area	8

In the above section Nos. 1 and 2 are undoubted Clayton beds, which are exposed in erosion cuts along the road for 2 or 3 miles east of Middleton. The thinness of the Porters Creek clay in this section indicates the immediate proximity of the eastern edge of its outcrop.

Walnut.—At the spring at Chalybeate, 2½ miles east of Walnut, Tippah County, the topography is hilly, and the following section is presented:

	Feet
3. The tops and slopes of the hills are covered by red sands that appear distinctly as if weathered from a glauconitic deposit. All wells sunk on the hills at Chalybeate, after penetrating 8 to 10 feet of red sandy soil, pass through 20 to 30 feet of blue sand before striking the "*Turritella* rock"	35-40
2. Yellowish "*Turritella* limestone," coated with greenish lichenous incrustations	6
1. Blue marl of the Ripley formation showing all its physical characters, and containing numerous characteristic fossils, *Scaphites*, etc.	6

The spring at Chalybeate flows out from under the bed of "*Turritella* limestone," at the contact with the Ripley marl. On the property of Z. H. Hudson, three-fourths of a mile north of Chalybeate, on the hill slope in front of the residence, is the following section:

	Feet
Recent:	
5. Reworked surface material, sandy and pebbly, brownish-red	Few
Eocene—Clayton formation:	
4. Dark-green tough glauconitic marl, fossiliferous, but fossils almost entirely fragmentary	2
3. "*Turritella* rock", only the uppermost foot of which is characteristic; the material in the lower 2½ feet consists of indurated, shelly green marl. Both contain *Venericardia planicosta* Lamarck	3.5
Upper Cretaceous—Ripley formation:	
2. Brighter green glauconitic, highly fossiliferous and friable marl, containing abundant *Baculites* with iridescent shells and *Scaphites*, etc., of the Ripley formation, and at bottom a few rounded pebbles of hard green clay	1
1. Dark-green glauconitic and micaceous marl, tough and tenacious, like that at Ripley; fossils occur only in finely comminuted condition. Exposed to bottom	1

Blue Mountain.—The hill on which Mississippi Heights School is built exposes Porters Creek clay from the bottom to the level of the school buildings. Characteristic gray clay of the Porters Creek forms the surface soil for a distance of 3½ miles east of Blue Mountain; the division line between the Porters Creek clay and sandy marls of the Clayton lies a little east of the Ripley and New Albany road. The surface becomes hilly and broken and the soil a deep red, clayey loam, common in the Pontotoc Ridge. Deep washes reveal the glauconitic sandy marl, with fossils, and show the greenish tint of the Tertiary marl beds. It is impossible to say whether these red soils are derived entirely from Clayton marls or partly from weathered Ripley material. No determinable fossils and no outcrops of "*Turritella* rock" or other hard rock have yet been found in them. Recently, however, a specimen of "*Turritella* limestone" from this vicinity has been examined, and the evidence thus obtained, together with the character of these deposits, which is identical with that of known Clayton deposits, would seem to prove that they are of Clayton age.

The higher hills east of Mississippi Heights Academy are all capped to a thickness of from 25 to 30 feet with reddish and brownish unconsolidated sands. These sands to an even greater thickness overlie the hills west of Blue Mountain College, and were once believed to be Lafayette sands, but are now interpreted to be equivalent to the Naheola of Alabama, and probably of the Tippah sand in the vicinity of Walnut, near the Tennessee line. About four miles to the west of Blue Mountain these sands are intimately associated with the bauxite deposits, which lie just west of the western edge of the Porters Creek from the Tennessee line through Tippah, Benton, Union, and Calhoun counties, and southward to Kemper County. None of these deposits lie within the outcrop of the Porters Creek, but in what the Mississippi Geological Survey has always regarded as basal sands of the Wilcox.

These sands top the ridges half a mile east of Mississippi Heights Academy, lying directly upon Porters Creek clay, which outcrops for at least three miles east of Blue Mountain. East and south of that, the line of contact being a little east of the Ripley and New Albany road (the old road, not the present highway), the surface becomes hilly and broken, and the soil, of a deep red clayey loam, shows everywhere, and washes reveal the glauconitic sandy clay marl, with fossils. This marl on fresh surfaces shows the greenish tints of the

Midway marl beds. This is undoubtedly the glauconitic sandy marl of the underlying Clayton. These red glauconitic deposits are highly developed in the hills and along the creeks forming the headwaters of the Tallahatchie River, five or six miles southeast of Blue Mountain.

New Albany.—A cut on the St. Louis and San Francisco Railroad 1½ miles southeast of New Albany, shows at the base a blue glauconitic micaceous marl which contains Cretaceous fossils and which seems undoubtedly to be Ripley material. About 6 feet of this marl is exposed at the west end of the cut, but only 4 feet toward the east end, and its surface is unconformable with the overlying yellowish-gray, sandy marl. Toward the middle of the cut this yellowish marl becomes changed along the line of contact to a firm, yellowish limestone, which extends through the rest of the cut. The rock is fossiliferous, having a few *Baculites* (mechanically introduced from the Ripley), numerous *Ostrea pulaskensis, Turritella mortoni,* and a species of *Venericardia.* At its thickest part it is 6 feet thick, but it thins toward each end of the cut. Above this rock lies 25 feet of non-fossiliferous yellow and red sands. Three miles south of New Albany, on the New Albany and Pontotoc road, specimens of *Enclimatoceras ulrichi* have been found in these sands, indicating their Midway age.

On all the hillslopes to the south of New Albany, where washes occur on the east side of the Gulf, Mobile & Northern Railroad, the characteristic Indian-red soils of the Pontotoc Ridge are noticeable, but so far as observed the beds are but slightly fossiliferous. This material is probably Midway, for a few specimens of *Enclimatoceras* have been found in it, and it corresponds closely in physical character with that seen east of Blue Mountain, around Chalybeate and Ripley, and, as will be presently shown, around Pontotoc, where it is fossiliferous. Two miles south of New Albany, on the east side of the railroad, a cut exposes for a hundred yards or more several feet of stratified gray, slightly glauconitic, sandy marl, containing *Exogyra* and other fossils. A section at the south end of the cut exposes a thickness of 14 feet of this material, but owing to overlying surface material toward the top the gray marls could not be traced upward into the red soils. Whether the marls and the soils are continuous is thus doubtful, for the soils may possibly have been derived from an overlying terrace whose beds are nowhere exposed. The soil, however, seems to be residual from these beds, which are probably of Ripley age.

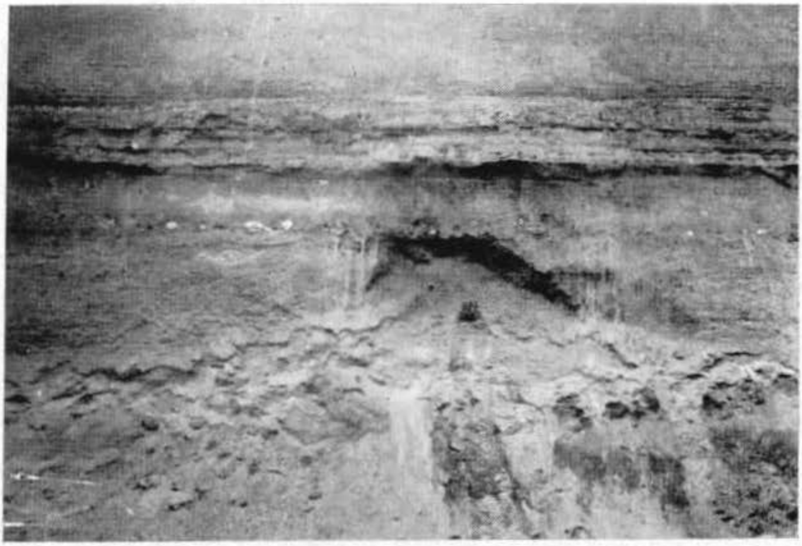

FIG. 2. A.

A. Cretaceous-Eocene contact marked by row of light gray clay pebbles in cut of New Orleans, Mobile & Chicago Railroad, half a mile south of Pontotoc, Pontotoc County. Numerous Ripley fossils, assumed to be present as a mechanical mixture, are contained in the 3 feet of sand just above the clay pebbles. Photo by L. W. Stephenson.

The region between New Albany and Pontotoc shows everywhere broad uplands and ridges with the rich red soils that are characteristic of the marls of the Clayton formation, but affords few exposures of the subsurface material.

Ecru, 8 miles north of Pontotoc, is on the eastern edge of the Flatwoods. A well here belonging to J. H. Hattox gave the following log:

	Feet
4. Gray joint clay	18
3. Blue sandy marl	40
2. Hard rock ("*Turritella* rock")?	1.5
1. Coarse sand (water-bearing)	25.5

This well is 85 feet deep, and overflows at the surface. The well evidently begins in the Porters Creek clay and passes through the upper marl members and a bed of the "*Turritella* rock" of the Clayton formation.

Pontotoc.—The town of Pontotoc is on the Indian-red upland soils that are so prevalent along the Clayton outcrop. Half a mile south of the station is the north end of a railroad cut, which is 265 yards long and 40 feet or more deep. The materials exposed here are horizontally-bedded calcareous sands, with no apparent break in deposition indicated from top to bottom except by an inconspicuous zone of rounded clay boulders.

The beds in the upper part of this section that are referable to the Clayton formation consist mainly of red sands containing an admixture of red clay, whose color is probably due to the weathering of the glauconite which they contain, but toward the base there is a conspicuous layer of laminated sand and clay about 4 feet thick which forms a slightly projecting ledge. Beneath the laminated clay is a 3-foot layer of yellowish glauconitic sand containing numerous very soft Cretaceous shells, which were probably derived from the underlying Ripley formation while they were still hard. The base of the Midway, which is marked by a zone of clay boulders to which reference was made in the preceding paragraph, lies at the base of this layer.

Two specimens of *Enclimatoceras sp.* which had been weathered out of the red sand of the Clayton formation, were found in a gulley on the hill above this cut.

FIG. 2. B.

B. General view of the cut shown in A, taken while excavation was in progress. Photo by L. W. Stephenson.

Two miles southeast of Pontotoc, on the Houston road, at the base of a hill where the road forks, there is exposed a well-defined ledge of limestone several feet thick, showing an abundance of *Exogyra* and *Gryphea*. This limestone is overlain by 10 to 12 feet of stratified gray calcareous clay, which contains the same fossils. Above this clay in apparent unconformity, lies 25 to 30 feet of red clayey sand, doubtless of Clayton age.

A mile west of Pontotoc, on the Toccopola road, at a point where the road passes rather steeply down the east-facing slope (10 or 12 feet) into a small creek flat, the contact between the gray Porters Creek clay and the Clayton glauconitic fossiliferous marl (which weathers yellow-brown with a greenish cast when wet), shows a sharp and probably unconformable division. Some fragments of the limestone and of the yellowish indurated marl lie at the base of the slope. On the east side of the creek the slope shows similar relations between the two formations, but the clay disappears within a few rods and is seen no more toward Pontotoc. A mile north of this locality the road that leads westward toward Lafayette Springs reveals only the glauconitic marl of the Clayton for 2 miles out from Pontotoc. Just west of the residence of Mr. Henry Hardin cuts in the road reveal 3 or 4 feet of light gray Porters Creek clay overlying Clayton marl. For about half a mile to the west yellowish-red Clayton marls outcrop in the lowest places, but are hidden by the Porters Creek clay on the higher levels. Here, too, the line of contact is sharply marked. West of this locality the Clayton sinks beneath the level of the road even in the lowest places, and is seen no more, both the material and the topography being typically Flatwoods.

Houston.—One and one-half miles east of Houston the bluffs along Houlka River present the following exposure:

	Feet
Eocene (Clayton formation):	
3. The highest hills are capped by red sands of the same character as those at Pontotoc, New Albany, Blue Mountain, and Ripley	10-15
Cretaceous (Ripley):	
2. Light-gray sandy marl, passing into slightly more clayey upper layers. Distinctly stratified near upper surface at a point showing gray laminated sand	50
1. Bluish-gray marl, with some grains of glauconite and sand	12

Nos. 1 and 2 are distinctly fossiliferous, with an abundance of *Exogyra* and *Gyphaea*. Smaller fossils, as sea urchins, *Ostrea plumosa*, and shark teeth are plentiful.

All this exposure except the capping of red calcareous sand is Cretaceous. The red sand caps all the ridges and hills between this point and Houston. Three-fourths of a mile east of Houston this sandy marl shows distinct stratification and in places is distinctly but not abundantly fossiliferous. This marl lies unconformably upon the Cretaceous deposits, and seems in all respects identical with what we have already described as Clayton.

On the branch railroad going west from Houston to Calhoun City the material exposed along the track is a slightly glauconitic yellowish clayey sand. No determinable fossils have been found in it, but it is apparently of Clayton age. West of the 1-mile board this material is replaced by the characteristic Porters Creek clay.

Other outcrops.—In an extensive area south of Houston the Clayton beds have not been found. Small outcrops may possibly be found but extensive outcrops will hardly be discovered in this area, and possibly the Porters Creek clay, which here lies in direct contact with the Selma chalk, may have so overlapped the Clayton beds as to cover them entirely.

A few feet of sandy marl overlies unconformably the Selma chalk 3 miles north by west of Shuqualak, in Noxubee County. This outcrop is noticeable at the bridge over a small creek on the Shuqualak and Macon road. At the time of examination the writer regarded this deposit as Ripley material but is now inclined to place it in the Midway. No fossils were seen.

Fossils collected by Dr. C. Wythe Cooke 3 miles north of Scooba, Kemper County, were assigned by him to the Midway. The material containing the fossils was gray calcareous clay and was referred by him to the upper Clayton or basal Porters Creek. It must lie very near the Clayton-Porters Creek contact, and further detailed examination of the area might discover the Clayton under an altered physical aspect.

PORTERS CREEK CLAY

GENERAL FEATURES

Name.—The formation here called Porters Creek clay was called by Hilgard the "Flatwoods clay,"[1] and was placed by him at the base of the so-called "Northern Lignitic formation."

[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, pp. 110, 273. 1860.

Safford[1] later named it Porters Creek, from the type locality near Middleton, Tenn., where the characteristic clay is largely exposed along Porters Creek. It was afterward called in Alabama "Sucarnochee or Black Bluff series."[2] Owing to priority of date over Sucarnochee the name Porters Creek has been adopted by the United States Geological Survey, and because it is a geographic name it replaces Hilgard's name "Flatwoods," which is a descriptive term.

Stratigraphic relations.—As already stated, the Clayton formation underlies the Porters Creek unconformably from the place where it enters Mississippi on the north to the end of Pontotoc Ridge at Houston. The line of contact has been traced in part. At Ripley the contact lies within the northern limits of the town. Hills at the edge of the town, east of the main street, expose in their washed and trenched slopes 5 feet of greenish-gray sand capped by a hard gray stratum of sandstone 4 to 6 inches thick. The rock is thickly speckled with grains of glauconite, so that it looks like a fine-grained diorite. This stratum forms a little projecting ledge which is clearly noticeable all around the hills and makes a parting between the gray sands and an overlying bed of gray clay, which weathers into a darker clay and seems to pass upward into the yellowish soil of the surface. The gray clay is undoubtedly the Porters Creek clay, here 2 or 3 feet thick, but distinctly thicker near the cemetery, and has the characteristic conchoidal fracture. A few hundred feet to the northwest it becomes much thicker.

The sands, which are probably of Clayton age, outcrop east of the cemetery, perhaps 300 yards northeast of the place just described, at a lower level, indicating an irregular contact. They are distinctly glauconitic and laminated but so far as observed are non-fossiliferous.

The outcrop of the gray clay of the Porters Creek is nowhere more than a few miles wide. On its western edge it is in contact with the overlying Wilcox beds, which border it throughout its extent except in Tippah County, where the Tippah sandstone member of the Porters Creek lies between them, but partly lies within the Porters Creek. It is not easy to trace the western boundary of the Porters Creek, for there is no apparent break between it and the overlying Wilcox. The clay of the Porters Creek seems to pass imperceptibly into the basal clay of the Wilcox, so that at many places the dividing

[1]Safford, J. M., Am. Jour. Sci. 2d ser., Vol. 37, p. 368. 1864.

[2]Smith, E. A., Report on the geology of the Coastal Plain of Alabama. p. 186. 1894.

line must be fixed arbitrarily. However, throughout much of the Wilcox outcrop lying immediately west of the Wilcox—Porters Creek contact, a well-marked sand member has been traced with fair accuracy from Kemper County to the Tennessee line. This corresponds to the bauxite belt, and is believed to represent the Naheola of Alabama. In this connection it should be stated that E. W. Berry[1] has presented paleontologic evidence of a notable time break between the Midway and Wilcox groups in Mississippi. The sandy Tippah beds were laid down under different conditions; the transition from the clay of the Porters Creek to the sand of the Tippah is apparently abrupt and noticeable in places, but the two frequently interdigitate in a puzzling way.

Lithology.—The typical material of the Porters Creek formation is a tenacious gray joint clay of distinct conchoidal fracture, which varies from very light gray to lead gray, and on drying becomes much lighter in color and at last almost white. It separates readily along the joint planes into fragments that average about the size of a hen's egg, and that tend to shell off along spherical surfaces and thus assume a nodular appearance. Stratification planes are usually not very evident the more typical material being massive.

The clay varies from this typical character at many places. Locally it becomes highly lignitic and is associated with small deposits of lignite; and in places it becomes sandy and micaceous and thin bedded. These variations occur especially toward the western border of the formation, where, as just stated, the clays merge without break into the lowermost division of the Wilcox. The Tippah sandstone, at the top of the Porters Creek formation in Tippah County, is described below.

The local occurrence of thin beds and lenticular concretions of spathic iron ore in the Porters Creek clay has been noted at some places in northern Mississippi. This iron ore is generally closely associated with beds of lignite or lignitic clays and lies well up toward the contact with the Wilcox. This relation prevails in the iron deposits 4 miles west of Blue Mountain, in the vicinity of Flat Rock Church, which was Hilgard's old locality—Hurley's School House.

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[1]United States Geological Survey Prof. Paper 91, pp. 36-38. 1916; United States Geological Survey Prof. Paper 95-F., p. 32. 1915.

In Kemper County, 3 miles north of Scooba, a deposit of light-gray calcareous clay, which yielded marine fossils, was referred by C. Wythe Cooke, who examined it, to this formation.

The black slaty clay, bearing marine fossils, exposed at Black Bluff, on the Tombigbee River, in Alabama, has not yet been identified in Mississippi, unless it occurs at a point a few miles west of New Albany, where a few impressions of small shells are found in the dark clay, or unless the clay at the locality near Scooba, where the physical aspects of the material are entirely different, is an equivalent.

Tippah Sandstone.—The name Tippah sandstone was given in an earlier bulletin of the Mississippi Geological Survey[1] to designate a series of beds of marine or estuarine sandstone and underlying sands, having a maximum thickness of not less than 100 feet, that are prominently developed in the broken hills and ridges of Tippah County. These deposits were described as overlying the typical gray clay of the Porters Creek and passing beneath the lighter, more variegated, and more distinctly stratified clays of the basal Wilcox. This fossiliferous pepper-and-salt sandstone was noted by Hilgard in his report of 1860,[2] and placed by him in the Claiborne because of its resemblance to a similar Claiborne rock found farther south.

In 1896, G. D. Harris[3] described beds representing apparently the same horizon at Crainsville, Hardeman County, Tennessee. By rule of priority, the name "Crainsville" should probably apply to these beds in Mississippi, but for the fact that Harris did not make clear what was included in his "Crainsville horizon." He apparently recognized no divisions of the Midway, but regarded it as a "stratigraphic and paleontological unit." Two easily identifiable subdivisions of the Midway exist in north Mississippi; and if the Tippah sandstone be regarded as a distinct formation or member, the Midway of Mississippi presents three well-marked aspects.

Later, a re-examination of the type outcrops of the Tippah sandstone (author's Field Notes, 1926, 1927, and 1928) leads to a somewhat different interpretation from that first expressed. A high

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[1]Lowe, E. N., Mississippi: its geology, geography, soils, and mineral resources: Miss. Geol. Survey Bull. No. 12, p. 64. 1915.

[2]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 109, 1860.

[3]Harris, G. D., The Midway Stage, Bull., American Paleontology, Vol. I, No. 4, p. 18 (132). 1896.

dissected plateau half a mile west of the residence of John Wright, (which is four miles west of Walnut, Tippah County), is capped with red and yellow sands 75 feet thick, beneath which undoubted Porters Creek clay of undetermined thickness lies, distinctly unconformable with the sands above. This plateau is cut into a series of hills, called Blake's Hill, Wicker's Hill, Marlow Hill, and others, from all of which ravines lead down into the valleys, and exposures along their flanks show the thick sands overlying unconformably the Porters Creek clay, which has a thickness of at least twenty feet. All of this sand and clay lies above the level of the typical Tippah sandstone as seen at its original site, which is estimated to be 50 feet lower than the outcrops of sand and clay mentioned above.

Examination of numerous other outcrops show not one, but several glauconitic and fossiliferous marl beds of Tippah material at different levels, separated by zones of Porters Creek clay. This situation leads the writer to infer that the so-called Tippah formation is more of the nature of a local phase developed within the Porters Creek at different levels, and not continuous very far southward. It seems to interdigitate into the Porters Creek, especially in the lower half of the formation. This phase probably should not receive a name, unless it be regarded as representing the Naheola formation of Alabama.

The paleontology of the Tippah sandstone has not been very fully studied. Hilgard[1] mentions four species (*Venericardia planicosta* Lamarck, *Cardium nicoletti* Conrad, *Trochus sp.* and *Ostrea sp.*) collected by him in Sec. 36, T. 1S, R. 3E, from the fossiliferous "claystone."

Crider collected fossils from the hill at John Wright's old residence, 3½ miles southwest of Walnut. These were examined by Dall, who assigned them to the Eocene. C. Wythe Cooke, in company with E. N. Lowe, collected fossils at a locality on Hurricane Creek near the hill from which Crider had collected, in the autumn of 1912. The collection made was too small to determine the horizon, and no report was made; but the beds were very probably Midway.

Distribution and physiographic expression.—The outcrop of the Porters Creek clay occupies a narrow belt bounded on the east by marine marl of the Clayton as far south as Houston, thence southward by Cretaceous limestone, and on the west by the fresh-water

[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 112. 1860.

Wilcox clay and sand. It ranges in width from 3 to perhaps 10 miles, the average being not much more than 5 miles. The formation enters Mississippi in western Tippah County, and passes southward through its western half, and through west-central Union, Pontotoc, western Chickasaw, Clay, Oktibbeha, northeastern Winston, southwestern Noxubee, and northeastern Kemper counties.

The exact point of contact between the Porters Creek and the Clayton has not been found at Blue Mountain, but was noted about 3½ miles east of the town; and it passes thence southward to the west of Cotton Plant and 2¼ miles west of New Albany. The line of the New Orleans, Mobile & Chicago Railroad lies within a mile or two of the contact, the edge of the Flatwoods making a favorable site for the road bed. The Clayton extends 2 or 3 miles west of Ingomar, Union County; west of Pontotoc, Algoma, and Ecru, in Pontotoc County; and near Houlka and Houston, in Chickasaw County. From Houston southward the Porters Creek lies directly upon the Selma. The line of contact runs southward from Houston, on the east side of the Gulf, Mobile & Northern Railroad, to a point 3 miles north of Woodland, and passes east of Dancy, Webster County; 3 or 4 miles east of Maben, in the northwestern corner of Oktibbeha County; and 2 or 3 miles east of Longview. Thence it passes through southeastern Oktibbeha and western Noxubee counties, a little west of the town of Shuqualak, and 3 miles north of Scooba, in Kemper County, to the Alabama line.

The name "Flatwoods," used by Hilgard to designate this formation, describes the topography of the area of its outcrop. Crider[1] says it "is characterized throughout the State by low, flat land resembling the broad bottom of a large river." This is true for the greater part of the area in Mississippi, yet much of the Porters Creek outcrop is marked by rolling and even decidedly hilly surface. Hilgard mentions hills of 40 feet elevation; Crider[2] mentions measuring 75 feet of Porters Creek clay on a hillslope, 1¼ miles northwest of Ripley. At the type locality, on Porters Creek, near Middleton, Tenn., a hill half a mile south of the 484-mile board on the Southern Railway rises 130 feet above the railroad level. This was examined by C. Wythe Cooke and the writer in 1912, and clay of the Porters Creek formation extends to within 30 feet of the top, or 100 feet

[1]Crider, A. F., Geologic and mineral resources of Mississippi, U. S. Geological Survey Bull. No. 283, p. 23. 1906.
[2]Crider, A. F., Op. Cit., p. 24.

above the railroad level. The upper 30 feet consists of red, yellow, and pinkish sands, probably of the Tippah sandstone member, which is prominently displayed a few miles farther south. The typical Flatwoods topography is well developed farther south, west of Pontotoc, Houston, and Starkville, the hilly phase being not so common in that region as it is toward the northern part of the outcrop in Tippah County.

Structure.—In general the Porters Creek beds strike northward, but toward the southern limit of this area, where they pass into Alabama, they strike eastward. The dip is westward, but in the southern part it veers toward the southwest, keeping, of course, at right angles to the strike.

The angle of dip has not been determined on satisfactory evidence. Crider[1] says that it is 15 feet to the mile; the beds penetrated in the well of J. H. Hattox at Ecru, Pontotoc County, would suggest a lower dip. The Porters Creek is at least 75 feet thick at a point 1¼ miles northwest of Ripley, but at the north edge of that town it is only 2 or 3 feet thick, being a short distance from the eastern edge of its outcrop; and if the elevation of the surface is the same at the two places the angle of dip is much higher than Crider supposed unless the Porters Creek was deposited upon a surface of very considerable relief. At Walnut the outcrop of the formation is 3½ miles wide, at Blue Mountain 7½ miles, and west of Pontotoc 8 miles. At Middleton, Tenn., 1½ miles west of the eastern edge of the Porters Creek outcrop, the hill above mentioned shows 100 feet of clay. Manifestly, then, the angle of dip here must be much greater than 15 feet to the mile.

The thickness of the formation can not be accurately estimated from the data in hand. The clay bed is at least 100 feet thick at Middleton and 75 feet thick at Ripley. If the width of outcrop at Pontotoc is the maximum, and the dip is 15 feet to the mile, the thickness of the beds must be 120 feet. At Blue Mountain 150 feet of Porters Creek beds is exposed 3½ miles west of its eastern outcrop. The writer is very much inclined to the opinion that the dip of these beds coincides closely with that of the Wilcox, and that the thickness is 200 feet or more in the northern part of the state.

Paleontology.—No marine fossils have been found in the Porters Creek formation in Mississippi except at a locality 3 miles north of Scooba, where marine fossils were collected by Cooke, and at a point

[1]Crider, A. F., p. 24. Op. Cit.

5 miles west of New Albany, on the New Albany and Myrtle road, a few obscure impressions of shells were found in dark-gray clays. In the bed of a branch of Porters Creek near Middleton, Tenn., a few marine shells were also obtained from calcareous clays. Notwithstanding the scarcity of fossils the formation is believed to be of marine origin. A few fragmentary plant remains have been found in the formation.

Economic products.—The clays of this formation have been used for making brick. A little lignite and some small deposits of concretionary spathic iron occur here and there, but none of these deposits are of commercial value. That the greenish gray clays of the Porters Creek are bentonitic has been known for several years, the first note of it having been made by E. F. Burchard.[1] While more detailed examination of the Porters Creek bentonite has not yet been made, there seems to be good reason for the belief that commercial deposits of this clay may yet be discovered.

LOCAL DETAILS

Middleton.—The type locality of the Porters Creek clay is along Porters Creek, about 1½ miles west of the station at Middleton, Tenn. The base of the gray clay is exposed a short distance south of the Southern Railway half a mile east of Middleton. This clay is here only a few feet thick and is underlain by the marine marl of the Clayton. The town of Middleton is built upon Porters Creek clay. Half a mile west of the station a wash on the south side of the Southern Railway reveals 6 feet of typical Porters Creek clay. A few hundred yards farther west, at a railroad trestle, 9 to 10 feet of Porters Creek clay is exposed for a distance of 100 yards. Here, at different levels, thin beds of somewhat indurated glauconitic sand from 4 inches to 1 foot thick, are intercalated with the gray clays

At the railroad trestle at mile board 484, a mile west of Middleton, a wash 12 feet deep exposes at the base of the section 2 feet of dark lignitic clay, above which lies 2½ feet of lighter-colored clay. At this level heavy concretionary masses of iron, 2 feet thick, form a parting between the dark clays below and 4 feet of gray laminated clay above. A few feet of tawny clay soil, perhaps derived from the Porters Creek beds, forms the top of the cut. A prominent hill south of this point exposes 100 feet of the Porters Creek gray clays.

[1]Burchard, Ernest F., Bauxite of Northeastern Mississippi, U. S. G. S. Bull. 750-G, p. 108. 1925.

At the eastern edge of the village of Middleton, a cut in the public road exposes Midway materials as follows:

	Feet
4. Soil, perhaps of mixed character, light tawny, silty, and with considerable rounded quartz pebbles, one-half to 1 inch in diameter	3-4
Porters Creek clay:	
3. Gray clay, weathering to purplish dark-gray clay, somewhat sandy and glauconitic at base	4-5
Clayton formation:	
2. Light yellowish-gray, indurated, highly calcareous bed, separating easily into plates; fossiliferous and somewhat glauconitic. Forms projecting ledge	2
1. Greenish-gray to yellowish-gray sand speckled with glauconite and weathering to yellowish-brown, or deep red, or light red sand; in the lighter red looking very much like some so-called "Lafayette" in the Wilcox area. This material is exposed in some erosion cuts along the road 2 or 3 miles east of Middleton	8

In the bed of Porters Creek, about half a mile southwest of Middleton, at the wagon bridge over the creek, there is an exposure that shows a thickness of 3 feet of typical Porters Creek clay at its base, which forms the bottom of the channel. At the west end of the exposure this clay abruptly dips beneath a bed of micaceous sandy clay, light gray but weathering nearly white, and not glauconitic. The clay is fossiliferous and contains specimens of *Ledas,* and perhaps a *Turritella.* The bed is 3 feet thick, but it thins out and disappears toward the east end of the cut. All these beds are overlain by 7 feet of yellowish-gray clayey silt composed of recent alluvium.

The gray clay of this formation outcrops in many places along the Gulf, Mobile & Northern Railroad between Middleton and Walnut in Tippah County. The railroad follows closely the Clayton-Porters Creek contact. Below Brownsfield in Tippah County, red, marly outcrops along the wagon road and in the railroad cuts reveal the presence of the Clayton beds, the contact being just west of the wagon road. About 2½ miles south of Brownsfield a cut on the New Orleans, Mobile & Chicago Railroad shows about 5½ to 6 feet of Porters Creek gray clay at the surface, including the soil. Below the gray clay a thickness of 7 feet of the greenish-gray glauconitic sand of the Clayton is exposed. At the contact is an indurated layer of yellowish-brown material,—a duplicate of that at the eastern edge of Middleton.

Walnut.—Half a mile north of Walnut the Porters Creek is exposed in a deep ravine south of the railroad water tank. Numerous outcrops occur west of Walnut. A mile west-southwest of Walnut a gray, lead-colored clay, like that at Ripley and at the water-tank north of Walnut, is exposed on the steep hillside just south of a little stream flowing eastward, extending to a height of 40 feet above the stream.

The Porters Creek clay is conspicuous in all washed or denuded surfaces west of Walnut above the base of the hills, where the slopes reveal the materials of the Tippah sandstone member. An outcrop of this member in front of John Wright's old residence, at the base of the ridge, exhibits three separated ledges of soft gray sandstone, with sandy partings 2 or 3 feet thick between them. A few rods around the hill southwest of the Wright residence a slump on a small spring branch reveals beds of the Tippah sandstone member, consisting of 8 or 10 feet of laminated gray clayey sand, somewhat glauconitic, dark and lignitic at the base, but weathering yellowish toward the top. The section contains three indurated layers of gray speckled sandstone, each about a foot thick and more or less glauconitic, and these show mottlings of darker gray, with finer texture, due to a larger admixture of clay. The yellow blotches are perhaps due to the oxidation of glauconite. The lowest layer is just above the dark lignitic material at the base.

The sandstone in this cut appears to be identical with that at Wright's residence, which is at the same level, though the outcrop could not be definitely traced between the two places.

On the south bank of Hurricane Creek, a mile northwest of Wright's old residence (1912), a steep bluff that rises about 100 feet above the creek gives the most notable exposure of the Tippah sandstone:

	Feet
3. At top a horizontal ledge of gray sandstone, rather coarse-grained speckled with glauconite, and having large fossils, mostly *Venericardia planicosta*	1 to 1¼
2. Ledge of gray, speckled sandstone, cellular, and stained yellowish, perhaps by the oxidation of glauconite. Somewhat fossiliferous	2
1. White and yellow stratified sand; exposed to a thickness of 10 to 12 feet, but probably much thicker. Below this sand the whole slope is covered to base of bluff	12+

About 250 yards farther down the creek, where the wagon road fords it at the site of an old water mill, the Tippah sandstone is revealed in the lower part of the bluff. The section is as follows:

	Feet
3. Light-gray laminated sandy material, somewhat glauconitic, showing partings similar to those seen in the outcrop at Wright's residence and in that northwest of it. This is about on the same level as that outcrop and the beds are apparently the same. Thickness here	12
2. Dark, bluish-gray sand	8
1. Very dark gray, almost black, shaly lignitic clay. This clay has not the conchoidal fracture nor the lead-gray color of the typical Porters Creek clay	10

A ravine leading down for a distance of 300 yards on the north side of Blake Hill, which has already been mentioned, exposes, at a level at least 30 feet lower than the lowest outcrop of Porters Creek observed in the hill, on property of Oliver Hines, a stratum 8 to 10 inches thick of glauconitic, highly fossiliferous, limy, consolidated marl. It closely resembles, and is probably identical with, a similar bed noted in 1912 as outcropping across the road in front of the home of John Wright.

On land of Herman Keith further down the slope the road bed in front of his residence exposes a few feet of typical Porters Creek clay, immediately beneath which a ledge of fossiliferous gray rock, (Tippah sandstone), is exposed to a thickness of several feet, the exposure being continuous along the valley side for a considerable distance. Below this bed lies a hard, white sandstone, so that a view along the valley side shows a two-fold ledge, each bed being about one foot thick. The whitish underlying sandstone is only partly consolidated, and is rough with nodular excrescences; it becomes several feet thick, and at bottom of the exposure is unconsolidated sand. In the ravine 75 yards east of Keith's residence the same ledge is even thicker, and becomes a hard, grayish-white translucent quartzite. This quartzite was formerly used locally for mill-stones.

These ledges are exposed at the point of a ridge 200 yards north of Keith's residence, and one-quarter of a mile east of this last locality, at the old Jackson residence, all the upper slopes show exposures of undoubted Porters Creek, and at the base outcropping ledges of the Tippah fossiliferous glauconitic rock form a distinct bench along the hillside. For six or seven miles north and south of Wright's numerous exposures of the Tippah fossiliferous sandstone may be seen, with Porters Creek material both above and below.

Tipplersville.—Prominent outcrops of the Tippah sandstone occur on the high ridges around Tipplersville, a few miles south of Walnut. These are perhaps the outcrops mentioned by Hilgard.[1]

"The same rock as No. 2 of the preceding section occurs on a ridge on the east side of Muddy Creek, on Secs. 16 and 17, T. 2S., R. 4E. Here a ledge quite similar to that at Reeves's, but with only here and there an imperfect fossil, appears on the summit of the ridge, jutting out in an abrupt hillock at its northern end, whence it dips southward and crops out on the hillside for a mile, disappearing about 30 feet below the summit of the ridge, which consists of Orange sand. A lower ridge, intervening between the one just mentioned and Muddy Creek, shows bold hilltops, consisting of a tough gray clay soil, underlaid by gray laminated clay."

Blue Mountain.—On the high hills on both sides of the railroad at Blue Mountain a great thickness of clay of the Porters Creek foundation is overlain unconformably with 30 to 50 feet of yellow and red sands, which in places show stratification and on all the high points are more or less cemented into irregular masses, tubes, flutings, and other forms. These sands seem to represent the Tippah member, though no fossiliferous gray sandstone, such as occurs near Walnut and Tipplersville, has been observed.

East of the railroad station on the slope of a conspicuous hill on which the Mississippi Heights Academy stands, the gray clay of the Porters Creek is exposed to an altitude of at least 150 feet, above which there is 25 or 30 feet of red sands (Tippah beds?), forming a level bench upon which the school is built. A few hundred yards east of the school there is an outcrop of the Porters Creek clay, on a level with the school, 150 feet above the railroad track (barometric reading). The red and yellow sands continue above this clay half a mile eastward from the school to the top of a ridge, which is one of the highest points in Mississippi. At the contact of the red sands with the Porters Creek clay, the sands are consolidated into a basal layer of brown sandstone, in places highly ferruginous, and from 3 to 4 feet thick.

East of the high, sand-capped ridges the topography assumes the appearance of the Flatwoods, and the material forming the soil is typical Porters Creek clay for at least 3½ miles east of Blue

[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 112. 1860.

Mountain. The red clayey soil of the Clayton appears just east of the Ripley and New Albany road. The surface becomes hilly and broken, and deep washes reveal the glauconitic sandy clay marl, with fossils, the fresh surfaces, when wet, showing the greenish tints of the unweathered marl. These red oxidized glauconitic deposits are highly developed in the hills and along the creeks forming the headwaters of the Tallahatchie, 5 or 6 miles east of Blue Mountain, and seem to represent the glauconitic sandy Clayton marl. The Porters Creek extends westward from Blue Mountain about 3½ miles, toward Flat Rock Church.

A ledge of claystone somewhat similar to the rock described by Hilgard[1] in the quotation on page 30 outcrops around the hillslope at Flat Rock Church, 4 miles west of Blue Mountain. The ledge is broken and discontinuous, 2 or 3 feet thick, and apparently not fossiliferous. It overlies gray clay, perhaps of the Porters Creek formation, and is overlain by a few inches of red, leaf-bearing shale, above which is 15 to 20 feet of red sand, the shale and red sands being basal Wilcox.

New Albany.—The Tallahatchie River at New Albany, Union County, has developed its flood plain on the Clayton marls, as the red soils show. The gray clays and the Flatwoods topography of the Porters Creek formation show at a point one-fourth of a mile west of Glenfield, which is 2¼ miles west of New Albany. From Glenfield to Myrtle, Union County, a distance of 5 miles, the topography is typical Flatwoods.

Pontotoc.—Ecru, in Pontotoc County, is in the eastern edge of the Flatwoods, which begins a mile west of the town of Pontotoc. From this locality the characteristic Flatwoods topography and the gray tenacious clay extend for a distance of 8 miles to the west. Exposures other than the level gray surface are rare, and are usually very small.

Houston.—The Porters Creek begins a mile west of Houston, in Chickasaw County, and exhibits uniform gray clay flats with slight undulations in a western extent of 6 miles.

Woodland, in Chickasaw County, is 2½ miles west of the eastern edge of the Porters Creek outcrop. This outcrop shows at the surface along the Gulf, Mobile & Northern Railroad as far south as Dancy, in Webster County. West of Starkville, Oktibbeha County,

[1] Hilgard, E. W., Op. Cit., p. 112.

the Porters Creek clay appears 2 or 3 miles east of Longview, and disappears beneath the Wilcox just east of Bradley—an outcrop 7 miles in width. The outcrop of the Porters Creek clay in Noxubee County occupies a belt 10 to 12 miles wide of low, gently rolling topography that passes through the southwest part of the county. In Kemper County the outcrop of the Porters Creek is well-marked, the topography on the western border ascending abruptly into high, broken hills of Wilcox sands, which probably should be referred to the Naheola.

Toward the outcrop of the Selma chalk the line of demarcation is less distinct, as suggested by the Porters Creek deposits near Scooba, which approximate the Cretaceous materials in appearance and carry marine fossils. The outcrop here is 6 or 7 miles wide.

WILCOX GROUP

NAME AND SUBDIVISIONS

The group of Eocene beds of sand, clay, and lignite, several hundred feet in thickness, to which the name Wilcox is now applied, has been variously named by different investigators. It was first described in 1856 by Dr. Safford,[1] then State Geologist of Tennessee, who called it "Orange sand."

Harper,[2] in 1857, adopted the name "Orange sand" from Safford, but used it to designate the Tertiary formations of northern Mississippi, which, however, he regarded as of Miocene age. Hilgard in 1860 applied to these formations the name "Northern Lignitic," using the name "Orange sand" to designate a thin, prevailingly red sand blanket formation of much later age that was believed to overspread the Eocene outcrops in much of northern Mississippi. In a footnote in his "Geology of Tennessee," published in 1869, page 424, Dr. Safford says:

"The name *Orange sand* was originally applied by me (Reconnaissance, 1856) to a series of strata of which the formation now thus designated[3] was the principal member. It then included the Cretaceous beds; these have been excluded, but the name has not

1 Safford, James M., A geological reconnaissance of the State of Tennessee, pp. 148, 162. 1856.

2 Harper, Lewis, Preliminary report on the geology and agriculture of the State of Mississippi, pp. 107-109. 1857.

3 Dr. Safford then used the name "Orange sand" for the series of formations now called Wilcox group. (See Geol. of Tenn., p. 424. 1869.)

been dropped. Since my first use of the name, Drs. Hilgard and Harper, in their respective reports, have applied it to the superficial formation occurring in Mississippi, quite different from anything it was intended to include."

It is a significant fact in the light of the present drift of opinion regarding Hilgard's "Orange sand," or "Lafayette formation," that Safford, in his report issued nine years after Hilgard's report, makes no note of such a blanket formation in Tennessee. On the contrary, he says: "If penetrated to some depth the beds of Orange sand would lose their bright color and become dark or gray;" in other words they would be recognized as Wilcox.

In 1869 Safford[1] called this group the "Orange sand, or Lagrange group." Under the name "Bluff lignite" he described a group of beds of sand, clay, and lignite that outcrop along the bluffs fringing the Mississippi River flood plain. These beds which extend into Mississippi, are descrbed by Hilgard as part of the "Lignitic." In 1913 the writer[2] described these beds as the Grenada, or uppermost division of the Wilcox. In 1895 Dr. Hilgard and Dr. Dall revised the nomenclature used in Hilgard's report, and substituted the name "Chickasaw" to embrace all the original "Lignitic," exclusive of the Porters Creek or "Flatwoods" clay. In 1871 Dr. Hilgard, in a published memoir, recognized Dr. Safford's name Lagrange as synonymous with this "Lignitic" exclusive of the "Flatwoods." Later, following Dr. E. A. Smith, of the Alabama Geological Survey, the Committee on Nomenclature of the United States Geological Survey adopted the name Wilcox, from the county of that name in Alabama, where it is typically exposed.

In Alabama, where the Eocene deposits have been studied very carefully and in detail by the Alabama Geological Survey, four well-marked subdivisions of the Wilcox have been recognized. Each of these subdivisions consists of a considerable thickness of apparently fresh-water beds of sand, clay, and lignite, with which are associated one or more prominent beds of fossiliferous marine marls. These marl beds are used as time markers, because they are very persistent and are easily recognized in outcrops along north-south flowing streams. In Mississippi these beds have not been recognized, because the Alabama subdivisions have not been traced into Mississippi, with

[1]Safford, J. M., Geology of Tennessee, p. 424. 1869.

[2]Lowe, E. N., Preliminary report on the iron ores of Mississippi: Mississippi Geol. Survey Bull. No. 10, pp. 24-25. 1913.

the exception of small outcrops of the Bashi or "Woods Bluff," and the Hatchetigbee formations, which are traceable into Lauderdale County. Nevertheless, recent study in Mississippi has resulted in the subdivision of the Wilcox into four formations.

The Wilcox group in Mississippi is prevailingly fresh water deposits, with the exception of limited deposits of the Bashi and probably of the Naheola, no marine phases having been noted. When it is remembered that the Wilcox of Alabama was laid down in deposits bordering the open gulf, while simultaneous deposits in Mississippi were made in the great bay which was largely filling in by stream flow entering toward the head of the embayment, it is rather to be expected that the formations laid down in Mississippi should be quite different from those of Alabama and eastward. The latter would be expected to show more marine aspects while the former would show more swamp and fresh water aspects. Accordingly, the Wilcox of Mississippi exhibits prevailingly fresh water and swamp deposits, principally sands, clays, and lignites, with local beds and concretionary deposits of spathic iron ore; an occasional limestone or marl deposit indicates temporary transgressions of the sea. Though the deposits show marked irregularity and discontinuity, individual beds being difficult to trace for any considerable distance, the general character of the deposits changes with considerable regularity from one subdivision to another. In general, the lowest division of the Wilcox is characterized by extensive outcrops of gray clay, some sands and lignitic material, and here and there by beds of lignite. The next series of beds consists prevailingly of sand, varicolored at the surface but dark below. Associated with the sand are lenticular beds of clay, generally light in color but not uncommonly lignitic and containing thin beds of lignite. These beds pass upward into dark clay and lignite again, which lie next to the Claiborne in northern Mississippi. But in Lauderdale County, in the eastern part of the State, a considerable thickness of fossiliferous marine calcareous sand, apparently corresponding to the Bashi formation of Alabama, is intercalated between the dark clays and the Claiborne beds. This fourfold division of the Wilcox in Mississippi has been recognized by the present State Geological Survey under the following names: (1) Ackerman formation; (2) Holly Springs sand; (3) Bashi formation; (4) Hatchetigbee formation; and (5) the Grenada formation. Although the same number of subdivisions is recognized in Mississippi as in Alabama, it is not possible to correlate them with the corresponding subdivisions of the Alabama Wilcox, except the Bashi and the overlying Grenada beds which, in part at least, correspond with the Hatchetigbee of Alabama. The Naheola is probably traceable into the State in extensive sand outcrops immediately west of the Porters Creek outcrop.

ACKERMAN FORMATION

GENERAL FEATURES

Name.—The name Ackerman was applied by the writer to the basal clays of the Wilcox group in 1913,[1] the name being taken from the town of Ackerman, in Choctaw County, 1½ miles northeast of which, at Blanton's Gap, there is the finest exposure of these beds known in the State. The gap is a long cut on the Aberdeen branch of the Illinois Central Railroad at the crest of the dividing ridge between the Big Black and Oaknoxubee drainage basins.

Stratigraphic relations.—The lowest beds of the Ackerman formation are gray clays which appear to pass by easy transition into the underlying Porters Creek clay, with which they lie in contact throughout much of the length of its outcrop, though a zone of red sands and bauxite toward the base is probably to be correlated with the Naheola. E. W. Berry[2] has presented paleontologic evidence of a considerable time break between the Wilcox and Porters Creek. The plane marking the division between the two is physically rather arbitrary than exact. There is no apparent break in deposition from one period to the other, and the separation is marked by a zone from a quarter of a mile to half a mile wide, in which the character of the material and the topography undergo a notable transition. The fossiliferous Tippah sandstone, which lies between the Ackerman formation and the clay of the Porters Creek formation in Tippah County, does not extend southward, but the Naheola red and yellow sands are notable southward.

Between the Ackerman formation and the overlying Holly Springs sand there is no apparent unconformity, although the line of separation is more marked than that between the Ackerman and the underlying Porters Creek. At many places the division is so

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[1]Lowe, E. N. Preliminary report on the iron ores of Mississippi; Mississippi Geol. Survey Bull. No. 10, p. 23. 1913.

[2]Berry, E. W., U. S. G. S. Prof. Paper 91, pp. 36-38. 1916; U. S. G. S. Prof. Paper 95-F, p. 32. 1915.

sharp as to suggest an unconformity between the two, but at others the transition appears to be gradual. The structure of the Holly Springs beds suggests that local unconformities—due, no doubt, to erosion contemporary with deposition—may appear at some localities, but at others nearby perfect continuity of deposition is indicated.

Lithology.—The lowermost beds of the Ackerman are prevailingly clays, the bottom bed differing but little from the clays of the Porters Creek—which shows the same lead-gray color, weathers whitish, is massive, and exhibits local lamination, conchoidal fracture, and jointing. Here and there beds of lignite occur, with associated clays that are sparingly leaf-bearing. Marcasite in considerable quantity is in places associated with the lignite. From the base upward the character of the clay changes, the color becomes more variable, the lignite more common, and the massive structure gives way to distinctly stratified and even finely laminated deposits. Sand and scales of mica become increasingly abundant, until it is often impossible to determine whether a certain stratum is a sandy clay or a clayey sand. Coincident with the change in the constitution of the beds the color in many places becomes variable, ranging from black, where the material is distinctly lignitic in beds composed mainly of clay, to dark gray and bluish or greenish in beds composed mainly of sand. Regularity of deposition and continuity of beds are more noticeable in this than in any other division of the Wilcox. Thin beds of carbonate of iron are at some places associated with the gray and bluish clays and the sandy clay and lignite. These beds are rarely more than a few inches to a foot thick. More commonly the iron occurs in concretionary masses flattened in the direction of the bedding planes. Some of these masses are several feet long and 1 to 2 feet thick. This iron carbonate is homogeneous, dense, and fine-grained, and is sometimes almost chemically pure.

Distribution and physiographic expression.—The area over which the Ackerman beds occur at the surface is more difficult to define on their eastern margin than on their western, because in their physical character the Ackerman beds are much more like those of the Porters Creek clay than they are like those of the Holly Springs sand. The width of the outcrop ranges from 3 to 18 miles and averages 12 or 15 miles. The eastern boundary is described in the discussion of the Porters Creek (pp. 20, 24), and the western boundary runs through Benton County 2 or 3 miles east of Ashland, 2 miles west of Potts Camp, down Tippah River to its mouth, thence southward 6 miles east of Oxford, 6 miles or more east of Water Valley, 10 to 12 miles east of Coffeeville, and 15 or 18 miles east of Grenada, through western Webster County, eastern Choctaw County, a few miles west of Louisville, through the southwestern part of Kemper County, and the northeast corner of Lauderdale County.

The topography of this area is intermediate in character between that of the Porters Creek area and the sandy Holly Springs area. It varies from gently rolling where it borders the Flatwoods to decidedly rolling in the region near the elevated sandy areas toward the west. As the western uplands are 150 to 200 feet higher than the Flatwoods the surface of the Ackerman area rises toward the west and in northern counties is hilly and broken, though less so than the sandy Holly Springs area. In the southern part of the area, in southwestern Noxubee and central Kemper counties, a series of high hills passes abruptly down to the Flatwoods to the east, separating them markedly from the hilly Wilcox area. However, the surface of much of this area in Winston, Choctaw, and Webster counties is comparatively level.

Structure.—The thickness of this lowest formation of the Wilcox group has been estimated rather than measured. Directly east of Oxford the width of the outcrop is 18 miles. With a dip of 15 feet to the mile this width would indicate a thickness of 270 feet. Crider determined from well borings that the westward dip of the strata composing the Holly Springs sand from Oxford to Batesville is 16 feet to the mile; from Batesville to Belen 17 feet, and from Belen to Riverside 18 feet. This determination would give an average dip of 17 feet to the mile. At that dip the Ackerman beds would be 374 feet thick.

The following log of a well at Oxford was furnished by Mr. W. L. Smith, who was city clerk of Oxford at the time the well was bored.

Log of deep well of Oxford Light and Water Plant, put down in 1910-11.

	Feet
Sand and clay	1 to 90
Sand and thin layers of rock	90 to 240
Hard rock	240 to 242
Water-bearing sand	242 to 250
Sand and lignite	250 to 340
Black sand and lignite	350 to 825

Probably the sand and lignite, at 250 to 340 feet, and certainly the black sand and lignite given in the record at 350 to 825 feet, must be the dark and lignitic clays of the Ackerman. The fact that the materials furnished no water and that the well was dry below the water-bearing sand at 242 to 250 feet, suggests that the material must have been prevailingly clay. The well appears to have stopped within the Wilcox; certainly it did not pass beyond the Porters Creek. The whole distance from Oxford to Pontotoc is 30 miles in a straight line, which extends for 24 miles over the outcrop of the Ackerman formation and that of the Porters Creek, and for 6 miles over the Holly Springs sand. As the well stopped at 825 feet in the lowest Wilcox or uppermost Porters Creek the dip of the beds must be 27½ feet to the mile.

A deep well which was sunk a number of years ago at the State University, but of which no record is available, had a similar log. After passing to a depth of 250 or 300 feet it found no more water, and was abandoned at 800 or 900 feet in dry lignitic clay and lignite. A well 700 or 800 feet deep at Holly Springs ended in precisely the same way. A well just within Calhoun County, 3 miles south of Coles Creek and 17 miles east of Grenada, was sunk to a depth of 565 feet. Water was struck at 210 feet in 70 feet of white sand, but as the flow was not sufficient the well was put down to the depth mentioned. Only black shale was encountered below 210 feet, and the well was abandoned. The basal 355 feet of black material was in the Ackerman, the full thickness of which was not penetrated.

This evidence shows that the Ackerman and Porters Creek are much thicker than we have heretofore supposed, and that their rate of dip is much higher. The dip found above, 27½ feet, taken with the outcrop of 20 miles, indicates that the Ackerman beds are 550 feet thick. By the same measurement the Porters Creek would be 220 feet thick.

A slight disturbance of this division in some places has produced gentle undulations of the strata. In the great cut at Blanton's Gap, near Ackerman, Choctaw County, the strata noticeably rise and fall. From the west end of the cut the beds rise gently toward the center, drop steeply down for a short distance, then rise rather abruptly toward the east end. Three miles north of Maben, Oktibbeha County, on the Gulf, Mobile & Northern Railroad, what appears to be two limbs of an anticline are exposed a mile apart, one limb dipping south and the other dipping north. All except the bases of the limbs have been truncated. This apparently structural feature may possibly be the result of heavy cross-bedding; but if so, the result closely simulates that of structural deformation. Two miles east of Hickory Flat, Benton County, a deep cut on the St. Louis & San Francisco Railroad known as the "Blue Cut" exposes a great mass of dark sandy clay, which has been fractured and slightly faulted. East of the fault the cut shows alternating beds of dark-gray sandy clay, thinly laminated, which become rust-colored upward, and shade into the tawny clay loam soil. No fossils have been discovered in these beds. West of the fault the same general succession of strata occurs. The angle of dip of the strata changes noticeably at the fault, which may easily be seen by looking along the edge of outcropping strata. Toward the east end of the cut the strata are bent slightly upward. This cut is 556 yards long and is 25 feet deep at its deepest part.

Paleontology.—All the fossils found in the strata of this formation are impressions of plants. They are not so numerous as might be supposed from the quantity of lignite in the formation. Perhaps the best known locality is that at Flat Rock Church, 4 miles west of Blue Mountain, in Benton County, which is the locality called by Hilgard "Hurley's Schoolhouse." The opportunity for collecting here is not especially good. The material is not plentiful, though the leaves are beautifully preserved in a dense red shale.

The following list shows the fossil plants collected by Berry[1] in 1913 at Flat Rock Church (Hurley's School House, of Hilgard), Benton County, 4 miles west of Blue Mountain.

Asplenium hurleyensis.
Asimina leiocarpa.
Bumelia hurleyensis.
Bumelia pseudotenax.
Combretum ovalis.
Cordia lowii.
Dillenites ovatus.
Dryophyllum morrii.
Eugenia hilgardiana.
Fagara hurleyensis.
Ficus monodon.
Ficus occidentalis.
Ficus puryearensis.
Ficus schimperi.
Gleditsiophyllum hilgardianum.
Lygodium binervatum.
Magnolia leei.
Mespilodaphne eolignitica.
Mimusops eolignitica.
Myrica bentonensis.
Myrica elaenoides.
Nectandra lancifolia.
Nectandra pseudocoriacea.
Oreodaphne obtusifolia.
Oreodaphne puryearensis.
Osmanthus pedatus.
Pisonia chlorophylloides.
Rhamnus marginatus.
Rhamnus marginatus apiculatus.
Terminalia hilgardiana.
Yerminalia lesleyana.

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[1]Berry, E. W., The lower Eocene floras of southeastern North America, U. S. Geol. Survey Prof. Paper No. 91, p. 43. 1916.

Of these 31 species only the following 10 are peculiar to this outcrop:

Asplenium hurleyensis
Asimina leiocarpa.
Bumelia hurleyensis.
Cordia lowii.
Eugenia hilgardiana.
Fagara hurleyensis.
Gleditsiophyllum hilgardianum.
Lygodium binervatum.
Pisonia chlorophylloides.
Rhamnus marginatus spiculatus.

Seventeen species range from the beds near the base to those at the top of the Wilcox.

Hilgard collected fossil plants, which he notes as *Cinnamomum*, *Sabal*, *Quercus*, and *Ficus*, from the clays of this division of the Wilcox at Ragland's Branch, in Sec. 9, T. 10S., R. 2W., in eastern Lafayette County.[1]

Slumping has obscured the original collecting ground, and a re-examination of the locality in recent years has yielded no recognizable material.

THE LIGNITE DEPOSITS

True bituminous coal is not found in Mississippi. The terranes that underlie the coal measures of Alabama extend into the extreme northeast corner of Mississippi, but the coal beds do not extend as far as the State line. Lignite, however, which is coal in process of formation, occurs in more than twenty counties of the State, and in some of the northern counties it is fairly abundant. Some of this lignite occurs in the Cretaceous beds but the largest deposits are found in the Wilcox. In the upper Wilcox (Grenada formation) which outcrops in the bluffs along the Mississippi flood plain, beds of lignite are common, but those in the basal Wilcox (Ackerman formation) are thicker, more numerous, and purer.

Lignite is a fuel intermediate in heating value between peat and bituminous coal. According to tests made on 33 Mississippi lignites, their heating value ranges from 8,022 British thermal units in the lowest grade, to 10,071 British thermal units in the highest grade, and averages 9,012 British thermal units. By excluding ten tests of lignites from the uppermost Wilcox and Claiborne, which show considerably lower values than the average given, the average of the lower Wilcox lignites becomes 9,315 British thermal units. These lower Wilcox lignites of Mississippi are but little inferior to

[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 115. 1860.

the brown lignites of North Dakota, which average about 9,500 British thermal units. The lignites of Texas average no better than those of Mississippi. Black lignites from Colorado, Montana, and Wyoming, however, average about 10,500 British thermal units, which is not far below the heating value of ordinary bituminous coal. The lignites of Mississippi have a very high content of water as they come from the mine, the quantity running as high as 35 to 50 per cent. This large content of water lowers the fuel value of the lignite, for a large quantity of heat is consumed in driving off the water. It is therefore improbable that these lignites will ever be used extensively as a fuel directly as they come from the ground.

In Europe, and to a less extent in this country, experiments have been made in briquetting lignite. By this method of treatment the lignite is first ground to a fine powder, the excess of moisture is driven off, and small quantities of some bonding material, such as pitch, are thoroughly mixed with the powder, which is then compressed under high pressure into "briquets."

E. A. Smith says, in a private letter, that specimens of Texas brown lignite were sent by Dumble[1] to Europe to be tested for briquets. The results were unsatisfactory where pressure alone was used but were entirely satisfactory when bond was used. A sample of lignite from Pike County, Ala., was sent to a briquetting syndicate in Germany and molded into satisfactory briquets. Some of these briquets, which look much like anthracite coal, may be seen at Tuscaloosa, Ala.

Experiments made by the United States Geological Survey in briquetting the lignites of Colorado, Wyoming, North Dakota, and New Mexico, were in part successful, the black lignites of Colorado and Wyoming giving the best results.[2] No briquetting tests have been made on the lignites of Mississippi, but as tests made on those of Alabama, which are of the same age and in no way superior, gave satisfactory results, the Mississippi product would probably give equally good results.

During recent years the United States Geological Survey and the United States Bureau of Mines have made interesting and valuable experiments with lignite in making producer gas. Although

[1]Dumble, E. T., Brown Coal and Lignite of Texas, p. 223. 1892.
[2]Brown, Calvin S., Lignite of Mississippi, Miss. Geol. Survey Bull. No. 3, p. 62. 1907.

no lignites from Mississippi were used in these tests, the brown lignites used were of no better quality than the brown lignites of Mississippi. The report of the committee in charge of these tests says:[1]

> "Probably the most important of the results accomplished has been the demonstration that bituminous coals and lignites can be used in the manufacture of producer gas and that this gas may be consumed in internal-combustion engines for the development of power, with a fuel economy of over 50 per cent. The use of producer gas made from anthracite coal, from coke, or from charcoal, for power purposes, and of producer gas from bituminous coal in steel works, etc., is no new story; but the demonstration of the possibility of utilizing bituminous coal and lignite in the gas engine is a decided advance in the economical combustion of coal for power. * * * "
>
> "Of scarcely less importance are the results obtained in the use of lignite in the gas-producer plant. It has been shown that a gas of higher quality can be obtained from lignite than from high-grade bituminous coals, and that one ton of lignite used in a gas-producer plant will yield as much power as the best Pennsylvania or West Virginia bituminous coals used under boilers. It appears, in fact, that as coals decline in value when measured by their steam-raising power, they increase in value comparatively as a fuel for the gas-producer. The brown lignites on which tests were made at the coal testing plant were from North Dakota and Texas, and the unexpectedly high power-producing qualities developed by them in the gas-producer and gas engine give promise of large future developments in these and other States in the far West, where extensive but almost untouched beds of lignite are known to exist."

Within recent years another method of using lignite as a fuel has been tried in Texas, apparently with good success. The lignite is ground into a fine powder and blown into the furnace by hot air blast. The powdered lignite immediately ignites in the heated furnace, flashing into flame like a gas, and the result is much as if a gas were being used. While this method has not been experimented with in the use of Mississippi lignite, it offers promise of success. However, the discovery of gas fields in the state will tend to retard development of the lignite resources as a fuel.

The chief lignite deposits of lower Wilcox (Ackerman) age are in the counties of Benton and Lafayette, parts of Calhoun, Webster, and Choctaw; the east half of Winston; a broad belt running diagonally northwest and southeast through Kemper, and the half of Lauderdale lying north and east of a line passing through the county from its northwest to its southeast corner. Of course some lignite is found beyond the boundaries given, but only scattering deposits.

[1]Report of the operations of the Coal-Testing Plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904, by Edward W. Baker, Joseph A. Holmes, Marion R. Campbell, Committee in charge, U. S. G. S. Prof. Paper No. 48, Part I, pp. 29-30. 1906

So far as we know, the lignite beds of Mississippi are nowhere so thick as those in some of the Western States. A thickness of 5 or 6 feet is rare, a thickness of 1 to 3 feet in this State is much more common, and the deposits are small in areal extent. They seem to have been laid down in numerous small swamps or bogs rather than in one or more larger areas, but in spite of this fact, many of the lignites are very pure, the proportion of ash in some of them being hardly more than would be furnished by the vegetable matter entering into their composition.

THE IRON ORES

As already noted, nodular masses and even beds, 1 or 2 feet thick, of iron carbonate ore are rather common in the Ackerman formation. These ores are in many places quite pure. In certain areas their quality and extent has attracted some attention, and in 1913 a developing company erected a 10-ton furnace on the ore bodies in Benton County, but the venture was not a success.

FIG. 3. A.

A. 125 Tons of pig iron made of Winborn, Benton County ore Winborn, Benton County.

Scattered deposits of brown ore, or limonite, have long been known in different parts of the State, especially in the northern counties. In 1912 the writer collected samples of these ores from several places, and at two points—Ackerman, in Choctaw County, and near Oxford, in Lafayette County—it was noted that large flattened, nodular masses, oxidized on the outside, when broken open showed a light gray interior, very dense and fine-grained, indicating the presence of iron carbonate. This discovery was surprising, because heretofore this fact seemed to have escaped notice. Though Hilgard spoke frequently of iron in his report, he seemed always to refer to the brown oxide, which he usually associated with the "Lafayette." At both the places just mentioned the carbonate ore was associated with lignitic clay or with lignite and gray and lignitic clay of Ackerman age. Further investigation revealed the ore in numerous places along the zone marking the outcrop of the Ackerman beds, at some of them in quantities so great as to justify development on a small scale. Investigations have so far failed to discover this ore in the Holly Springs sand or in the Grenada formation. It is always associated with the gray and lignitic clays and constitutes a very fair time marker, for it is not found except sparingly in the other formations of the Wilcox, and only rarely in the Porters Creek clay, where it is found near the Wilcox contact.

Where these carbonate ores are exposed at the surface for a long time the carbonate is oxidized to limonite, a fact that explains the constant reference by the older writers to the common occurrence of the brown oxide ore strewn over the hillslopes in this part of the State. A fresh slump, a railroad cut, or a well dug in the iron-bearing area shows that the brown ore is derived from the carbonate beds.

The purity of the ores seems to have a definite relation to the constitution of the embedding clay. If the clay is free from sand the ore is rather pure, but if the clay is sandy the carbonate ore is highly siliceous. This relation leads the investigator to expect the best ores generally below the transition zone of rather sandy clay in which the Ackerman or lowest formation of the Wilcox group passes into the sandy Holly Springs or middle Wilcox beds.

With few exceptions, these spathic ores are remarkably free from deleterious impurities, such as silica, phosphorus, and sulphur. The limonite deposits, which were derived by weathering from the spathic ores, are equally free from these harmful ingredients, but they are generally a little more siliceous. As might be expected, beds capping the hills or lying near the surface become completely oxidized, as do also the exposed edges of the deep-lying beds. That these were originally also carbonate deposits has been proved beyond question. In places the oxide ore passes directly into deeply covered carbonate beds. At one place, in Lafayette County, a surface deposit of large masses of limonite that showed concretionary structure appeared to be completely oxidized, and yet after numerous concretions were broken open a hollow shell was at last found that contained a small quantity of loose, light-gray powder, which on analysis proved to be amost pure iron carbonate.

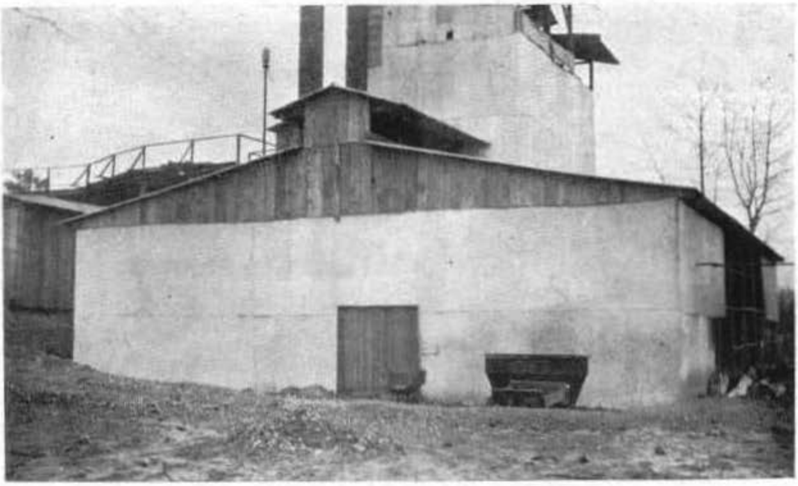

FIG. 3. B.
B. Charcoal Furnace at Winborn, Benton County.

The carbonate or spathic iron ores of the Ackerman formation occur in two forms, as continuous stratified beds and as large and small "kidney" concretions. The stratified beds appear to be sedimentary, and as they are distinct, though generally thin beds of uniform thickness, are interstratified with beds of lignitic or gray clays or lignite and show the same continuity that is found in the accompanying sedimentary beds, these iron deposits are almost certainly of mechanical origin. All the concretionary ore, which constitutes the greater part of these iron deposits, is evidently of chemical origin, having been accumulated by the segregation of the iron in solution and its redisposition in concretionary form. The mechanically deposited beds, if they were indeed so deposited, are almost certainly contemporaneous with the inclosing clay beds. The age of the concretionary carbonate deposits is more problematic, though they were probably deposited during Eocene time, but after the iron-bearing stratified beds were laid down.

During early Wilcox time much of the land of the present Ackerman area, together with a large area not now exposed, was low, and was occupied by peat swamps. In these swamps pure peat was at times deposited, but at other times they received less vegetable matter but considerable quantities of mechanical sediments, principally clay, silt, and fine sand, and in this way alternating bodies of lignite, lignitic clays, and sandy clays were laid down. The surrounding lands that furnished these sediments to the peat swamps contained more or less iron which has been disseminated through the rocks as a coloring matter or cement. The fineness of the sediments suggests low relief of the land, and the complete oxidation and solution of the iron contained in the material was probably the result of weathering. The iron was brought into the swamps in solution, probably as the protoxide, which impregnated the clay beds as they were deposited in the low swampy areas. The same beds received from the swamps solutions containing products of vegetable decay, and the iron protoxide was converted to the iron carbonate while deposition was still going on. The iron was probably segregated in concretionary masses and beds synchronously with the conversion of the protoxide to the carbonate, for distinct impressions of leaves here and there are embedded in the carbonate concretions. However, the carbonate in solution might have been slowly deposited from a concentrated solution by a gradual loss of water on account of the uplift of the region into higher and drier land, or through the filling of these low areas by clay and peat saturated with iron solutions simultaneously with the lowering of the general surface drainage, or by a combination of these operations.

The most notable outcrops of these iron ores are in the northern counties of the State. On the St. Louis & San Francisco Railroad, in the vicinity of Potts Camp, Winborn and Hickory Flat, in Benton County, these ores have been prospected more fully than elsewhere and were found extensive enough to lead to the erection at one place of a small charcoal furnace. This zone of ore is 8 to 10 miles wide and extends northward to the Tennessee line and southward through several counties. Except in a few localities the ore seems to be scattered in small deposits.

Along the Tippah River 2 miles west of Potts Camp there are rather extensive outcrops of beds and surface masses of brown oxide ore, the ore thickly strewn over the hill slopes. Lower down the slopes there are outcrops of gray carbonate ore, from a few inches to 1 or 2 feet thick. These ores are found in considerable quantities in all the hills north and south of the railroad from Tippah River to Hickory Flat, about 8 or 9 miles. All the wells in this region strike the gray carbonate ore under the surface at depths ranging from a few feet to 15 to 25 feet.

The quality of these ores compares favorably with ores of the same kind found elsewhere in the country. The Mississippi Geological Survey has analyzed five specimens of average brown oxide ore from the region immediately north and south of the St. Louis & San Francisco Railroad between Tippah River and Hickory Flat. A summary of these analyses follows:

Metallic iron	49.53
Manganese	8.69
Sulphur	1.38
Phosphorus	0.057
Silica	18.88

The percentage of silica is rather high, mainly because the ores from the vicinity of Winborn are more highly siliceous than those elsewhere in the area. The average content of silica in the oxide ores from the outcrop at Potts Camp and on the Morehead property at Hickory Flat is 7.81 per cent, which is probably nearer the general average than the figure given above.

Four carbonate ores from the same region after calcination showed the following composition:

Metallic iron	62.15
Manganese	5.77
Phosphorus	0.122
Sulphur	0.87
Silica	13.345

The average composition of 17 ores from the same region, including oxides and carbonate ores calcined, is given in the table below:

Metallic iron	55.07
Manganese	4.072
Phosphorus	0.079
Sulphur	1.15
Silica	13.12

One of the most interesting outcrops of carbonate ore so far discovered in the State occurs on the land of J. Q. Hunter, in Sec. 16, T. 5S., R. 2E., nearly a mile southeast of Flat Rock Church, in Tippah County.

"In the same ditch a short distance from the skirting hills at its head, and at a somewhat higher level than the ore bed, is exposed what appears to be a log 20 inches in diameter, spanning the ditch, a distance of 14 feet, and passing into the bank on either side; how much longer it is has not been determined. It is 5 feet underground, lies embedded at each end in the gray clay, and has what appears to be remnants of concentric layers of bark, which is absent from the trunk except near the two ends, where they are partly protected by the clay in which they are embedded. The interesting feature about this apparent tree trunk is the fact that the whole trunk is of red carbonate ore of very good grade."

A sample taken gave on analysis after calcination more than 50 per cent of iron.

"In spite of the fact that this apparent tree trunk shows the tapering columnar shape of a tree and concentric layers of bark, it is very doubtful if it was ever really a tree. It is most probably an interesting columnar concretion of iron carbonate; no vegetable tissue or structure is visible to the eye, there is no branching so far as exposed, and the so-called bark may be only the concentric shells of superficial oxidation, such as we so often see encrusting concretionary masses of carbonate iron ore.[1]

The same belt of iron-bearing lower Wilcox clay, with ores of the same kind passes through eastern Lafayette County, though the known deposits are less extensive and more scattered. They begin about 6 miles southeast of Oxford in Lafayette County, and extend 10 to 12 miles eastward. The largest deposits south of this area are found in Choctaw County, though deposits are found in all the intervening counties in greater or less abundance. No deposits south of the St. Louis & San Francisco Railroad have been developed.

THE CLAY DEPOSITS

The Ackerman formation is rich in clay of different grades, which undoubtedly will eventually be developed. Brick and tile clays are abundant; stoneware and pottery clays are not uncommon, though not so common in this as in the overlying Holly Springs sand; and fire clay is doubtless abundant, though it has nowhere been exploited. White brick are made at one or two places. Unfortunately for the development of the clay resources of the Ackerman beds, much of this outcrop lies too far from transportation

[1]Lowe, E. N., Preliminary report on Iron Ores of Miss., Miss. Geol. Survey Bull. No. 10, p. 40. 1913.

lines. With better transportation facilities through this area it will probably become one of the richest clay manufacturing regions in the State.

LOCAL DETAILS

Blue Mountain.—The materials of the lowest Wilcox (Ackerman) beds and those of the uppermost Porters Creek are so nearly similar that the line of division between these formations can not be drawn with exactness. West of Blue Mountain, in Tippah County, the characteristic Porters Creek ("Flatwoods") clay is exposed along the road from the railroad station across the low flat just beyond the edge of the town. Less than 2 miles west of the town the road climbs up into more elevated and broken country in which the gray clay of the Porters Creek formation is visible in all the washes and ravines.

About 3 miles west of Blue Mountain a deep ravine on the north side of the road exposes beds 25 to 30 feet in thickness, which appear to consist entirely of gray sands with thin, lighter gray clay partings. These sands probably represent the Tippah or Naheola. No Porters Creek clayey material is seen at this exposure, yet a mile farther southwest the gray nodular Porters Creek clay is seen in gullies south of the road. Less than half a mile northwest of Flat Rock Church, which is about 4 miles west of Blue Mountain, there are outcrops of white Wilcox clays. This church stands exactly on the site of the old Hurley's schoolhouse, of Hilgard's report. The old schoolhouse has been gone for many years, but the tumulus left by the decay of the chimney is still plainly visible at the rear end of the church. The church stands on an eminence, the top of which, to a depth of 12 to 14 feet, consists of rather coarse red sand that seems to be indistinctly stratified. Below this sand lies a thin deposit of hard red shale, which is in places thinly laminated and which, when parted along the laminated planes, is seen to contain beautifully preserved impressions of leaves. This shale differs entirely from the coarse-grained ferruginous plates generally associated with the coarse sand of the Holly Springs formation. This fossiliferous shale which is not well exposed is apparently not over 6 inches thick Below this shale is an indurated bed that appears to be a ledge of gray, fine-grained aluminous rock, full of stemlike impressions that traverse it in all directions. The size of the masses indicate that this ledge must be 2 feet or more in thickness. Below this rock gray clayey sand seems to constitute the hill to the base, about 25 feet below.

A mile west of the church, on land of T. M. Gadd, in Sec. 8, T. 5S., R. 2E., Ocklimita Creek has exposed on its west bank 16 feet of dark-gray slightly sandy and micaceous clay that shows horizontal bedding. At the bottom of this cut a ledge of good quality of iron carbonate ore 6 inches thick is exposed. From the top of the cut the slope recedes gently and is underlain by the clay, which weathers to a tawny clayey loam soil.

The material at this exposure and those at Flat Rock Church are probably all Wilcox. The leaves from the red shale were assigned by E. W. Berry to the lower Wilcox, or Ackerman. Half a mile east of the church a ditch on the place of Hugh Jackson reveals two beds of carbonate iron ore embedded in typical nodular gray Porters Creek clay. The line of division between the Porters Creek and the Ackerman beds should therefore porbably be drawn not more than half a mile east of Flat Rock Church.

In August, 1927, the Flat Rock Church region was re-examined by the writer and R. E. Grim. One mile north of the church on property of J. M. Gunter, in the slopes and bottom of a small creek back of Mr. Gunter's residence, considerable deposits of bauxite were noted. This deposit, as exposed at this point, is 6 feet thick, and highly siliceous, having more the character of a deposit noted by H. Mace Payne near Louisville, Winston County, which he called baukite.

Beneath this deposit was exposed a thick deposit of white clay remarkably free from grit, very plastic, and apparently of excellent quality. The bauxite was highly siliceous and not plastic. Most of it was not pisolitic, but of light buff color, quite firm, and lying in the deposit in angular blocks, separated from each other by joint fissures. The writer's field notes say: "This, I think, is what Payne calls *Baukite*; it is manifestly a high silica bauxite." Analysis of this bauxite by the state chemist, Dr. W. F. Hand, is given below:

Analysis of Bauxite from land of J. M. Gunter, Blue Mountain, Miss., located in SW¼ in NE corner of S. 9, T. 5, R. 2E., one mile north of Flat Rock Church:

Moisture	0.30
Ignition Loss	17.94
Silica (SiO_2)	30.40
Non-volatile with H. F.	1.44
Iron Oxide (Fe_2O_3)	2.55
Aluminum Oxide (Al_2O_3)	45.95

Very pure masses of iron carbonate were picked up here, apparently in place immediately above the bauxite. The outcrops at this locality seem quite surely the Wilcox bauxitic horizon noted elsewhere, representing probably the Naheola, the Porters Creek contact being, as before determined, a short distance east of Flat Rock Church.

Hickory Flat.—At the east end of the wagon bridge over Ocklimita Creek at Old Hickory Flat, Benton County, a long hill slope, probably the one referred to by Hilgard in his report (page 112), exhibits the following section of lower Ackerman beds:

	Feet	Inches
10. Red ("Lafayette?") sand and loam, with a few small quartz pebbles	6	
9. Light-gray clay, weathering red and yellow	5	
8. Dark-gray clay, very tenacious and slightly lignitic at top	5	
7. Greenish-gray sand weathering yellow in bands near bottom, passes into next bed	6	
6. Gray laminated clay	1	2
5. Greenish-gray sand	2	
4. Dark-gray clay (jointed)	2	6
	Feet	Inches
3. Greenish-gray sand with a lignite parting 4 inches thick near the base	4	6
2. Dark-gray clay, weathering shaly and almost white	2	2
1. Greenish-gray sand with lignitic streaks; weathers yellow	7	

The "Blue Cut" on the St. Louis & San Francisco Railroad 2 miles east of Hickory Flat, which has been already referred to, exhibits materials similar to those in the above section and is undoubtedly near the base of the Ackerman. The typical Porters Creek clay and Flatwoods topography appear only a short distance east of this cut. A slump on the banks of Ocklimita Creek ½ mile due south of Hickory Flat station shows a bluff 20 to 25 feet high of gray stratified Wilcox clay. Three miles southwest of Hickory Flat the Ocklimita swings over to the base of the hills bordering its valley on the south side. On the land of J. H. Morehead, Sec. 30, T. 5S., R. 1E., the wagon road rises by a steep grade to the point of the hill, the north slope of which shows the following exposure:

	Feet	
8. Soil, red clay	3	
7. Lignitic clay	2	
6. Shelly sandy iron carbonate	0	3 to 4
5. Gray sandy clay	2	
4. Iron carbonate in large masses	0	12 to 14
3. Lignite	0	6
2. Gray clay	12	
1. Lignitic clay	6	

The fringe of hills and ridges half a mile west of Tippah River reveal the most westerly exposure of the Ackerman beds. All the region lying between these hills and Holly Springs exhibits the outcrop of the sandy Holly Springs formation.

Lafayette County in general.—In Lafayette County no exposures of lignitic and iron-bearing beds of the Ackerman are found west of a line running from the mouth of Tippah River southward through the county. The two westward flowing streams, the Tallahatchie and Yocona, at the northern and southern boundaries of the county respectively, have cut their valleys deep in the uplands, exposing the beds of the Ackerman formation at points considerably farther west than in the intervening territory.

The uplands of Lafayette County stand in general about 500 feet above sea level. These uplands are trenched by the valleys of the Tallahatchie and Yocona to a depth of 200 feet. The prevailingly red and yellow sands of the middle or Holly Springs division of the Wilcox overlie all the uplands deeply, but these two streams have cut their valleys down into the lower division, which, however, sinks below the valley floor to the west of the Illinois Central Railroad. This thickness of the Holly Springs sands on the uplands has caused a good deal of confusion with regard to the "Lafayette formation" of this region. The gray and lignitic clays that are characteristic of the Ackerman or lower Wilcox formation are seen at the surface all over the eastern third of Lafayette and the western part of Pontotoc counties. In the regions around Lafayette Springs, Paris, Delay, and Tula the Ackerman clay caps the hills as well as forms the slopes. Sand beds occur at some places but they dip distinctly beneath the clay, notably at three places, one a mile south of Delay, on the hill slope just north of the residence of Lee Davis; another on the Toccopola road 4 miles east of Tula; and a third on the Toccopola and Pontotoc road half a mile southeast of Toccopola.

In northeastern Lafayette County the gray clays of the Ackerman formation are well developed. The broken hills around Bluff Springs are capped by red and yellow sands to a thickness of 30 feet (probably the eastern edge of the Holly Springs formation), beneath which throughout the region outcrop heavy gray clays of the Ackerman. On the Oxford to New Albany road on the east slope of Puscus Creek about 15 miles northeast of Oxford, beginning of the Ackerman gray clays, lignite and lignitic sandy clays are in evidence. Large sandy clay concretions of iron carbonate ore showed gray carbonate in the center, but covered with concentric shells of iron oxide. Some of these are very large, weighing at least a ton, rounded in outline, and flattened in the direction of stratification. These concretions are associated with the sandy clay strata of the Ackerman formation. For several miles along this road toward Etta red sands and gray sandy clays alternate, the latter showing the iron carbonate concretions so noticeable in the Ackerman. The gray sandy clay which forms the prevailing bed rock formation in this region, and which contains these large concretions, while gray in its unweathered condition, weathers to a sticky, red sandy clay, which undoubtedly was formerly interpreted as being the Lafayette. For 3 or 4 miles south of the Tallahatchie bottom the gray clay is replaced in the hills by red banks, which again suggest a sandy member interstratified with the clays. After traversing the Tallahatchie lowland a mile or more the road climbs a ridge which shows outcrops of the gray and somewhat lignitic clay with some iron carbonate concretions. The writer's notes say: "I am impressed with the belief that this road passes over successive outcrops of gray clay and reddish and yellowish stratified sands, all of lower Wilcox age." This ridge is just a little less than 17 miles northeast of Oxford according to the mile board. From here to the rock hill near Etta, 3 or 4 miles, gray clay seems to underlie everywhere the surface soil. At the rock hill gray sandy clay underlies the great flat masses of sandstone. This sandstone is nearly all white, rather fine-grained, and almost of quartzitic hardness. Similar sandstone outcrops for 2 or 3 miles north of Etta. All this material is basal Wilcox, and the sands and sandstones probably represent the Naheola or Tippah sandstone.

Six miles southwest of New Albany, along the highway, a thin stratum 8 inches thick of hard, glauconitic, fossiliferous marl outcrops along the roadside on the east slope of Mud Creek, on property of W. H. Hall. This marl bed is interstratified with Porters Creek clay, and the exposure is of undoubted Midway age.

Ramey's Chapel.—Six miles southeast of Oxford, on the Delay road, in the vicinity of Ramey's Chapel, is exposed the following section:

	Feet
5. Brown loam	2 to 4
4. Red, indistinctly stratified micaceous sand	15
3. Gray sandy laminated micaceous clay	5
2. Pure gray joint clay	3
1. Gray sandy laminated clay, becoming less sandy toward the bottom; exhibits nearly midway large masses of brown oxide ore and near the bottom one seam of iron carbonate a few inches thick	17

All below No. 4 is Ackerman. No. 4 might be regarded as the thinned-out edge of the Holly Springs sand but is more probably Ackerman. The line of division is rather sharp. The hill slopes east of this exposure all show the same kind of materials.

Pumpkin Creek.—On the south side of Pumpkin Creek, on the land of Mr. W. D. Porter, in Sec 20, T. 9S., R. 2W., the old course of the Oxford and Delay road lay along a steep slope leading up from the creek bottom, where the following strata are exposed:

	Feet	Inches
12. Sandy clay, reddish soil	1 to 4	
11. Sandy oxidized shelly iron ore	1	
10. Gray sandy clay, weathering yellowish	7	
9. Iron carbonate with thin oxidized outer crust in places, the bed thinning to a mere film but averaging about	0	4 or 5
8. Gray clay	7	
7. Iron carbonate in lenticular flattened masses, light gray and dense, with a thin oxidized crust	0	5
6. Gray clay, slightly sandy	10	
5. Iron carbonate masses, soon pinching out	0	4
4. Gray clay	4	
3. Iron carbonate in discontinuous lenticular masses, quite pure, exterior oxidized, as in No. 7	0	7
2. Gray clay	4.5	
1. Gray carbonate ore, like No. 3	0	5

On the same side of the creek where the above interesting section is exposed, and 200 yards farther up, in a slump that shows a fresh face of 16 feet, the following strata appear:

	Feet
3. Laminated sandy gray clay to top of slump, the hill slopes back from the slump rising 25 to 30 feet higher but beds all covered	?
2. Lignite (rather sandy), showing in places flattened tree trunks. This bed a short distance upstream is replaced laterally by lignitic clay and sand	1.5
1. Dark lignitic clay to water's edge	6

Yocona River.—One and one-half miles south of the above exposure a face in the south bank of Yocona River at Rocky Ford, in Sec. 30, T. 9S., R. 2W., exposes the following beds:

	Feet
6. Red silty clay soil, residual from No. 5	3
5. Rather heavy bedded lignitic clay	4
4. Bed of lignite, apparently pure	2
3. Bluish sandy laminated clay, the upper 3 feet purer clay, more massive and highly lignitic	10
2. Bed of dense fine-grained gray iron carbonate, continuous along base of bluff	1.3
1. Bluish sandy clay	1

Two miles farther down the Yocona a great slump on the south side of the river exposed a face of 30 feet of light-gray sandy clay containing here and there a flat concretion of carbonate of iron. The most westerly exposure of the Ackerman beds along the Yocona is at Chandler Springs, 2½ miles east of Taylor, on the Illinois Central Railroad. The spring is at the base of a bluff which, when visited by the writer, showed recent slumping. The hill rises above the spring on the east side about 35 feet, the lower 18 feet showing the fresh surface of the slump. The formations revealed in this hill are slightly sandy gray clay at the base for a height of 10 feet above the spring, and just above this clay a bed of siliceous iron ore 6 inches thick. This ore is oxidized dark brown on the surface, but when broken, the oxidized exterior shells off in layers and reveals within whitish-gray carbonate ore. The bed dips 5° to the southwest. Above this bed the formation becomes much more sandy, is laminated, and is oxidized to a yellowish color. A thickness of 12 to 14 feet of this material overlies the iron ledge and is in turn overlain by a higher bed of iron ore about 8 inches thick, which seems to be wholly oxidized. This ore bed dips parallel to the lower beds. Above this ore the hill is topped with the orange-red sands that are so abundantly developed in all this section, a thin veneering of brown loam making the surface soil to a depth of 3 to 4 feet.

Tula.—The sand layers outcropping on the slopes 4 miles east of Tula probably furnish the water in wells at Delay and southwestward. A long slope shows the following exposure:

	Feet
2. Grayish clayey sand	15
1. Light yellow coarse sand	15

The next hill 200 yards farther east shows:

	Feet
8. Red clayey soil, residual from No. 7	4
7. Yellowish-gray sand, separated from No. 6 by iron nodules of moderate size. More clayey toward the top	4.5
6. Light-gray clay	0.5
5. Yellowish-gray sand with indistinct laminae	12
4. Light-gray sandy clay with wavy laminae	4.5
3. Yellowish-gray laminated sand, becoming more iron-stained above, perhaps because of greater oxidation	5
2. Same as No. 1, passing in a short distance into gray clayey sand, thinly laminated and dipping strongly toward the east with an iron-stained parting near the middle. Clay becomes light-gray above	4.5
1. Yellowish-brown sand, thinly laminated, the laminae dipping eastward	5

These sandy beds occur in a region of clay outcrops, and the clayey beds both overlie and underlie them, so that they are very well placed to form aquifers to regions beneath which they dip. The eastward dip of the laminae is doubtless only a local feature, the general dip of the beds being toward the west and southwest.

Delay.—The sawmill well at Delay, on the flat of a little creek below the store, furnishes a supply of good water, which rises to a level within 30 feet of the top. The depth of the well is about 185 feet.

Approximate log of sawmill well at Delay, Lafayette County.

	Feet
Yellowish sand and clay	20
Gray sand, with water	2 to 3
Black dirt (lignitic clay or lignite)	Few
Stiff blue clay, about	159
Water-bearing sand	Few

Log of well of N. P. Eskridge, at Delay, on hill by the store.

	Feet
Reddish clay	20
Sand, blue-gray, coarse	20
Clay, gray, brown and black, alternating	160
Sand, white and clean (water)	Several
Clay, gray, brown, and black, alternating to the bottom, and stopped without water	328

Log of well on Thweatt place, 5 miles southwest of Delay.

	Feet
Red clay	9
Coarse yellow sand	34
Hard sand rock, dark gray	2
White sand, water-bearing	2
Gray-blue clay	121
White quicksand, with water. (Drill lost in quicksand by suction)	3 or 4

Depth of well, 72 feet; located on hill; does not flow.

Wells on the Yocona bottom in this vicinity strike flowing water at 125 to 170 feet depth. This water-bearing stratum has been struck in the Light & Water Plant well at Oxford, at a depth of 340 feet. Two public wells at Oxford get their water from this source, unless there is an error in determining the horizon. Water at a higher horizon is struck at a depth of 240 feet in the Oxford wells, which probably marks about the contact of the Holly Springs sand and the Ackerman formation. The University wells, 1 mile west of Oxford, get their water, apparently from the upper horizon, at a depth of 175 feet. The deeper water-bearing stratum is not reached by the present wells, but about 15 years ago a boring made to a depth of more than 700 feet failed to strike it.

Wells at Oxford.—The wells at the University at Oxford show the following sections:

Log of University Well No. 1, at the Power House:

	Feet
Red sand	30
White and light-colored sand with a little clay the rest of the depth. Stopped on hard rock. Good water struck at 100 feet and 175 feet	157

Well No. 2, 100 yards southeast of No. 1:

	Feet
Red sand, about	30
White and light-colored sand	70
Blue lignitic sandy clay. Boring stopped in the lignitic material; water above it	25

Log of well of Oxford Light and Water Plant:

	Feet
Sand and clay, red toward top, becoming white below	1 to 90
Light-colored sand and thin layers of rock	90 to 240
Hard rock	240 to 242
Sand, water-bearing	242 to 250
Sand and lignite	250 to 340
Black lignitic sandy clay	350 to 825

The black lignitic sandy clay referred to in the last log is almost certainly the buried westward extension of the somewhat sandy dark-gray clay (Ackerman) that outcrops in the eastern part of the county. The significant fact about this well is that no water was encountered below the depth of 350 feet. The well was stopped in barren lignitic clay at a depth of 825 feet. The same was true of the old well bored on the University campus 25 years ago, as referred to above. A well was put down at Holly Springs several years ago with the same result. Below a depth of 250 feet only dark lignitic material was penetrated to the bottom of the boring, about 900 feet deep.

These well records and the record of the 328-foot well of N. P. Eskridge at Delay (see p. 56) all indicate that except for local and rather thin beds of sand, which outcrop in the eastern part of Lafayette and adjacent counties, the Ackerman formation of the Wilcox group consists prevailingly of gray and lignitic clay devoid of water.

Yalobusha County.—Most of the surface of Yalobusha County is covered by the outcrop of the Holly Springs sand and the Grenada formation but along the Scuna and Otuckalofa valleys in the eastern part of the county some outcrops of the lower Ackerman occur.

Calhoun County.—At Pine Valley, 10 miles east of Water Valley, the characteristic deposits of iron carbonate, partly oxidized, indicate the presence in this region of the Ackerman formation of the Wilcox. The more subdued topography toward Pine Valley suggests the change to the Ackerman from the sandy Holly Springs which lies between Pine Valley and Water Valley in broken hills of red sand. Half a mile west of Pine Valley post office the Wilcox outcrops noticeably on a hillside by the road, the exposure being about 16 feet in thickness, as follows:

	Feet
2. Gray to white clay, quite pure, in laminae from 1 to 5 inches thick	4
1. Whitish aluminous sand, showing iron mottlings	12

The sand at the contact with the overlying clay becomes cemented into a tolerably firm white sandstone. This outcrop seems to lie rather close to the contact between the Ackerman and Holly Springs formations.

Calhoun County lies mostly within the outcrop of the Ackerman formation of the Wilcox. Going from Houston west to Calhoun City, one passes from the Flatwoods into the more rolling topography of the Ackerman about a mile east of the little settlement, Ellzey, which is 2 miles north of Vardaman. The soil here becomes a yellowish loam, silty and lighter than that in the Flatwoods but residual from a gray clay. This material is regarded as Wilcox, though there is no evidence of a break between the Wilcox and the Porters Creek of the Flatwoods.

Half a mile west of Ellzey, on the west slope of Cane Creek, the gray clay is weathered red, and shows part way up the slope concretions of iron with carbonate interior. These concretions are so common in the Ackerman formation of Lafayette and Benton counties that they have come to be associated always with that formation.

From Ellzey to Derma the topography is rolling, the soil is manifestly residual from the gray clay, and numerous iron carbonate concretions are seen at intervals along the road.

Webster County.—In Webster County, 3½ miles north of Maben, on the Gulf, Mobile & Northern Railroad, a cut 150 feet long reveals the following characteristic Ackerman materials:

	Feet
Recent:	
3. Yellowish-red soil (residual), a sandy clay loam	3.5
Ackerman formation:	
2. Thinly laminated gray clay and sand, highly micaceous, becoming yellow and reddish from oxidation, especially toward the top	10+
1. Dark greenish-gray lignitic sandy clay, weathering almost black; highly micaceous, especially the lamination partings	10

The upper beds dip 4° north, the lignitic beds dipping at a lower angle in the same direction. This cut reveals what appears to be the north limb of an anticline; the south limb is shown in the next cut nearly a mile farther south, where the following exposure occurs:

	Feet
2. Above, gray and yellow laminated micaceous sand and clay, redder toward top, owing to oxidation, giving rise to a few feet of red sandy clay soil	10
1. Below these beds lies a dark-gray lignitic sandy clay 2½ feet to 3 feet thick near the north end of the cut, and at the bottom, which is in sight only at the north end of the cut, gray clay of unknown thickness is exposed. These beds dip S. 20° east at an angle of 4°	2½ to 3

A few nodular iron masses occur in the gray clay, somewhat like those seen in the gray clay of Lafayette and Benton counties.

Ackerman, Choctaw County.—The type locality of the Ackerman formation of the Wilcox group is at Ackerman, in Choctaw County, on the dividing ridge between the drainage basins of the Tombigbee and Pearl rivers. A mile and a quarter east of the station at Ackerman the Illinois Central Railroad cuts through the prominent rim of the divide in what is known as Blanton's gap

FIG. 4. A.

A. Exposure of Ackerman formation toward east end of the great cut on the Aberdeen branch of the Illinois Central Railroad at Blanton's Gap, one and one-fourth miles northeast of Ackerman, Choctaw County. The beds here consist of gray and lignitic clays, lignite, and thin beds of iron carbonate, all distinctly stratified, and showing slight undulations. Photo by E. N. Lowe.

The length of this cut is 275 yards, and the total vertical exposure is 88½ feet. This depth is not reached in the cut, but some strata are exposed at the east end which disappear beneath overlying beds toward the west. The section exposed is as follows:

	Feet
12. Red sand and sandrock, possibly distinct from underlying strata though not plainly so	15 to 18
11. Yellow sands, micaceous, variously cross-bedded, apparently passing laterally into light-gray and yellowish clay	14
10. Earthy lignite	5½
9. Light-gray clay, finely laminated	7
8. Lignite	5/6
7. Gray lignitic clay with two thin seams of iron largely in concretions (4 to 10 inches thick)	20
6. Sandy rock containing iron	5/6
5. Gray clay with iron-stained joints, lower 5 feet massive, upper part laminated	12
4. Lignite	1
3. Gray clay	1
2. Iron-stained laminated sandy clay	2
1. Stratified gray clay with iron-stained joints	5

This cut exhibits one of the most remarkable exposures of the Wilcox in Mississippi. The beds are characteristically Ackerman. All of them near the west end of the cut dip gently westward, but those near the middle dip distinctly in the opposite direction and then rise again with equal distinctness. The beds thus clearly undulate, but the crest of the ridge seems to be the crest of a gentle anticlinal uplift. One of the iron seams in bed No. 7 of the above section, near the west end of the cut, is 5½ feet above the track; 100 yards from the east end it is at track level; thence it rises again in 100 yards to a height of 10 feet above the track.

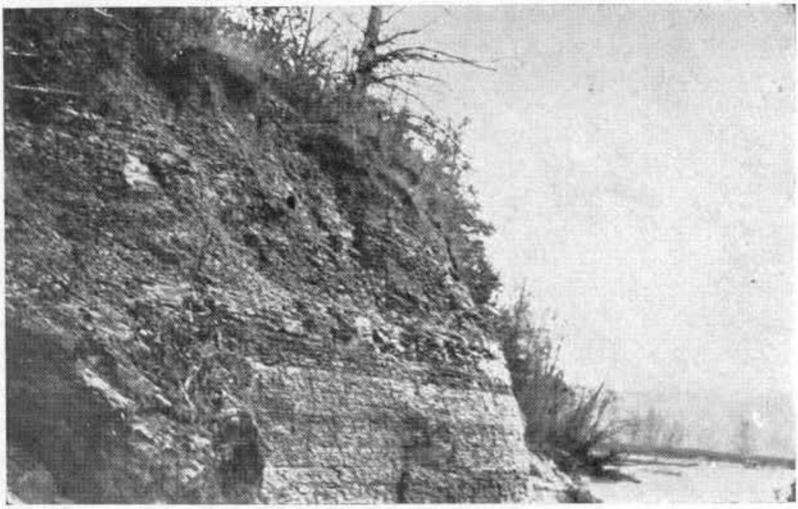

FIG. 4. B.

B. Exposure of gray and pinkish leaf-bearing clays of uppermost Wilcox, or Grenada formation on the right bank of the Bogue, one mile east of Grenada and half-a-mile up the creek from the wagon bridge. The beds are thinly laminated and sandy above, .becoming less sandy, thicker-bedded, and micaceous below. The best leaf impressions are found almost midway between the top and bottom of the exposure. Photo by E. N. Lowe.

The iron concretions seen in the cut are the typical concretions of iron carbonate, large, flattened, light gray, and very dense, which seem to characterize this division of the Wilcox wherever it is found.

A recent very careful re-examination of the red and yellow sands that cap the section at Blanton's Gap, which were formerly called "Lafayette," has led the writer to put them in the Wilcox. These sands seem to pass into the lighter colored clays without break. They are irregularly stratified and cross-bedded, and contain large irregular masses of ferruginous rock of coarse texture—angular, fluted, and tubular—such as are usually associated with the so-called "Lafayette," but at the west end of the exposure a bench, about 60 feet back from the railroad inner cut, is composed mainly of horizontally bedded gray clay, that shows lignitic bands. This clay passes without break into the darker clay near the base of the cut and grades upward into the overlying sands by a gradual admixture of the sand and clay, the clay consisting largely of "clay balls." Farther east the sands appear to pass down into sandy clays without break and to merge laterally into the upper clay beds. If the name "Lafayette" had not been applied formerly to all such deposits, no one would place these sands in a formation separated by a long time interval from the Wilcox.

At the east end of Blanton's Gap the track turns north, and 300 yards farther north another smaller cut shows the following beds:

	Feet
5. Gray clay, lower part thinly laminated, and upper part lighter and sandy, weathering into a red and yellow loam soil to top of cut	10
4. Thinly laminated earthy lignite	1
3. Gray stratified clay, upper part more sandy and thinly laminated	5
2. Lignite, distinctly jointed, red on joints, and very firm, 6 inches in thickness; passes below imperceptibly into gray lignitic sandy clay, 6 inches in thickness, which is jointed and breaks off with the lignite	1
1. Greenish-gray sandy clay	5

This cut shows lateral and vertical passage of the darker material into the red and yellow sandy loam soils, which, though looking like "Lafayette" soils, are evidently residual.

As typical lower Wilcox material is exposed in the great cut near Ackerman, the writer named this division of the Wilcox the Ackerman beds, or formation.[1]

Crider gives the following section, which is exposed 1 mile north of Ackerman on the Gulf, Mobile & Northern Railroad:

	Feet
3. Lafayette sand	2
2. Cross-bedded sandy gray clay, alternating with bands of yellow clayey sand	15
1. Dark-gray sandy clay, containing fragments of leaves and lignitic material	10

"Along the Mobile, Jackson & Kansas City Railroad, (now Gulf, Mobile & Northern), in the vicinity of Maben, there are numerous cuts which show a dark blue, highly micaceous, plastic clay containing small lenses of sand."[2]

[1]Lowe, E. N., Preliminary report on the iron ores of Mississippi: Mississippi Geol. Survey Bull. No. 10, p. 23. 1913.

[2]Crider, A. F., Geology and mineral resources of Mississippi, U S. Geol. Survey Bull. No. 283, p. 26. 1906.

At Reform and between Reform and Ackerman the topography is broken hills, exposures being largely sandy, but sand and clay outcrops alternate. Lignite has been mined at Reform. It is probable that these outcrops are all lower Wilcox, and that the notable sandy phase is to be referred to the Naheola.

Williams.—A deep cut on the Gulf, Mobile & Northern Railroad just north of the little station of Williams exposes the following section:

	Feet
4. Red indistinctly stratified yellowish sand, maximum	25
3. Hard brown sandstone at bottom of sands	6 to 8 inches
2. Lignite and lignitic clay	3
1. Gray clay to base of cut	12

The contact between the sand (3 and 4) and the clay is quite irregular and undoubtedly marks an unconformity, and the clay has apparently been faulted, the northern block having dropped 5 or 6 feet.

Five miles west of Mashulaville and 16 east of Louisville the Porters Creek outcrop expressed in low flat topography, gives place westward to a region of hills making the outcrop of basal Wilcox. Lignite is of frequent occurrence in this region, and high grade iron carbonate concretions together with bauxite outcrops around the hills determining the horizon to be approximately the same as the bauxite zone farther north. Large sand deposits on and for a few miles west of Hashuqua Creek associated with lignite and lignitic clay at Fearn Springs, and with the siliceous bauxite called by Henry Mace Payne *baukite*, identify this horizon as Ackerman Wilcox and associated sands and bauxite of the Naheola.

In Kemper County high ridges both north and south of DeKalb mark the outcrops of oxidized and indurated sands, the age of which has not been definitely determined but is believed to represent the Naheola. Conspicuous ledges of rock of this character in sec. 27, T. 11N., R. 16E., were described by Harper[1] as coarse-grained sandstone cemented by iron oxide, and as varying in color from yellow through dark red to purple. This sandstone may be a sandy indurated facies of the Ackerman formation or it may be a southern representative of the Tippah sandstone member of the Porters Creek clay, probably the Naheola.

[1]Harper, L., Preliminary report on the geology and agriculture of the State of Mississippi, p. 210. 1857.

HOLLY SPRINGS SAND

GENERAL FEATURES

Name.—The name Holly Springs sand was applied by the writer in 1913[1] to a great thickness of sand of Wilcox age that overlies the Ackerman formation. In northern Mississippi these beds of sand constitute that part of the Wilcox group which lies between the Ackerman formation, and about 150 feet of lignitic clays and lignite at the top, to which the name Grenada formation has been given. Doubtless the great thickness of these beds of middle Wilcox sand and their excessive outcrop were the impressive features that caused Dr. Safford[2] to use the name "Orange Sand" to designate the beds that are now included in the Wilcox, though he tentatively excluded the so-called "Bluff Lignite," which in 1913, in the bulletin cited above[3] was called the Grenada beds.

Stratigraphic relations.—These beds of vari-colored sand lie at the surface, or just beneath the surface, over a greater breadth of territory in northern Mississippi than either of the other divisions of the Wilcox. They overlie immediately the clay beds of the Ackerman formation, and the division between the two is generally rather sharp, though at some places it is marked by a gradual transition from clay to sand.

The relations of this formation to the underlying clay beds as seen in Lafayette County are characteristic of the whole line of contact between the two formations.

Along the line of bluffs that fringe the Mississippi River flood plain are exposed the edges of the Grenada, the uppermost formation of the Wilcox, which here consists of beds of gray clay, brown clay and lignite. These beds overlie the Holly Springs sand, though the actual contact between the two formations is seldom visible owing to overlapping later formations. Artesian wells of the "bluff" region obtain water from the Holly Springs sand after penetrating 150 to 250 feet of the overlying beds.

1Lowe, E. N., Preliminary report on the iron ores of Mississippi; Mississippi Geol. Survey Bull. No. 10, p. 24. 1913.

2Safford, James M., A geological reconnaissance of the State of Tennessee, pp. 148, 162. 1856.

3Lowe, E. N., Preliminary report on iron ores of Mississippi; Mississippi Geol. Survey Bull. No. 10. p, 24. 1913, Over a large part of the upland that marks the outcrop of the Holly Springs sand a thin deposit of Pleistocene yellowish-brown silt loam covers the sand. This blanket is intimately associated with the loess, from which it is probably derived. The loam is from 6 to 10 feet thick near the bluffs and thins eastward for 30 or 40 miles, where it is only from 2 to 4 feet thick.

In the broken and eroded hills the Holly Springs sand is almost everywhere exposed by the rapid denudation of the overlying blanket of loam. In the vicinity of the "bluffs" terrace sand and gravel generally lie between the loam and the Wilcox beds.

Lithology.—The Holly Springs formation consists largely of rather coarse-grained sand, generally very micaceous and, where it is exposed in outcrops, varying in color from white to yellow, red, and purple. The prevailing tints at and near the surface are red and yellow, due to the oxidation by weathering of the iron in the beds; in the deeper parts of the formation the color becomes more subdued, and bluish, greenish, or grayish tints are produced by the iron protoxide that forms the coloring matter.

The sand shows cross-bedding and other irregularities of stratification that suggest deposition from strong currents of water that rapidly vary in direction. That the water was fresh, and perhaps fluviatile, seems probable from the character and arrangement of the materials, from the leaf-bearing clay associated with the sand, and from the lignite, which occurs in small deposits throughout the formation.

Clay forms a relatively small part of this formation. Most commonly it occurs in a zone about the middle of the series, which extends through the center of several of the northern counties, notably Marshall, Lafayette, Yalobusha, and Grenada. The clay is usually light gray to white or pink in color, highly plastic, and at a few places it is used for making stoneware. The deposits form small lenses, which are surrounded with sands. Some of these clay lenses have yielded an abundance of beautiful leaf impressions.

The irregular and complex structure of the beds of sand and the coarseness of the material justify the inference that deposition was rapid, and that often erosion was taking place while deposition was going on in the immediate vicinity. Doubtless much of the material was deposited, shifted, and reworked many times before it finally came to rest. Local erosional unconformities, which are evidently intraformational, are common. How clay deposits so pure as some of those that are embedded within this formation could have had their origin is problematical. Many of the clay lenses are overlain unconformably by red sand, as if a quiet, disconnected basin in which weak, clay-laden streams had been gradually depositing, had suddenly become deluged with swift currents overloaded with sand. Strong and varying currents, such as must have prevailed during middle Wilcox time, would probably produce erratic structure. The Ackerman beds exhibit so much regularity of structure and contain so much material of the uniformly fine texture indicative of quiet waters that we may say almost with certainty that middle Wilcox time was an epoch of turbulent water with erosion and deposition, in which what was built up yesterday was torn down today and then again rebuilt on its ruins.

FIG. 5. A.

A. Large Pothole in Wilcox clay at the end of the inner gorge of Isom Ravine, Oxford, Lafayette County. The clay is here becoming thinly laminated and sandy and is no longer fossiliferous. Note the thin lamination at the bottom of the clay exposure next to the water surface. Photo by E. N. Lowe.

The sand is generally coarse-grained, and the grains are fairly well rounded. Rather uncommonly sand that is rusty-red or yellow at the surface passes downward into white sand. The coloring matter of the sand consists of films of iron, which envelop the grains. In the sand at and near the surface these films of iron become oxidized red by atmospheric action, but in the sand that lies deeper the iron is in the form of protoxide, which has a bluish or grayish tint; or descending surface water may have leached out the iron while it was soluble, leaving the sand white.

A common and noticeable structural feature of the Holly Springs beds is the "clabber," or curdled milk appearance, which is due to the clay balls embedded in the sands of the formation. These clay balls are generally rounded or subangular, light gray, white, or pinkish, and in some localities contain distinct impressions of fossil plants. The balls may be scattered sparsely through the sands or they may be so numerous as to constitute the bulk of the deposit over a small area. Some of these clay balls weigh 100 pounds or more; most of them are much smaller, ranging in weight from a few ounces to about 5 pounds. The large masses are generally angular, as if they originated by slumping. The clabber-like deposits are very common in the vicinity of Oxford and all of them seem to be closely associated with the lenses of clay that abound in that part of Lafayette County. This peculiar material irresistibly suggests slump material. During middle Wilcox time sand-bearing currents of water probably reworked some of the clay deposits, and perhaps, by cutting into

FIG. 5. B.

B. View in Isom Ravine just below the Pothole shown in A. The clay is here thinly laminated and very sandy so that in the Ravine below this point only slopes of sand with occasional thin clay partings are exposed. The clay lens passes into sands both laterally and vertically, as shown by the various exposures. Photo by E. N. Lowe.

them, caused slumping. The slumped material may then have been transported short distances and redeposited as clay balls in the sands. The reworking of these clays and their deposition as clay balls in the sands are clearly intraformational, and are associated with local unconformities; the work was not accomplished at a later epoch, as has heretofore been the prevailing opinion.

Although lignite is not prominent in this division of the Wilcox, it does occur in small deposits, especially in association with the larger clay lenses that are most numerous near the middle of the formation. Many of the large clay lenses are distinctly lignitic, but beds of lignite a foot thick are not common.

In many places the iron contained in the sands of this formation segregates in small quantities and forms a firm cement about the sand grains, so that a very hard ferruginous sandstone is formed. This rock is dark brown and some of it is so highly ferruginous that a freshly broken surface presents almost a metallic luster. It occurs in angular blocks and masses of irregular shapes, and rather commonly presents the appearance of flutings or tubular concretions. These blocks of sandstone range in weight from a few pounds to several tons, and generally cap the hills of the regions where they occur. This rock is evidently formed from iron-bearing sands that lie within the zone of weathering, where the soluble iron is changed to insoluble oxide, which firmly cements the grains into masses of rock. These masses, which resist erosion better than the surrounding unconsolidated sands, protect the underlying soft materials and cause the development of hills.

In most of its exposures especially those in the northern part of the State, in a belt 15 to 25 miles wide and 75 miles long, the formation consists typically of red sand, in most places unstratified, which lies immediately beneath the loam, and passes downward into lighter-colored sand. The surface sand for some distance down is red or brown, from the oxidation of the iron it contains, and the stratification has probably been largely obliterated by processes of weathering. In many places the unstratified red sand is doubtless the result of slope wash and creep of the oxidized surface material. That these changes may be brought about by weathering is shown by the evidence of unbroken series of strata that pass by gradual transition from lighter colored stratified sands toward the bottom of exposures into red unstratified sands at the top. At many places also a vertical face in a hill may show distinct stratification toward the center, which is lost as the surface is approached toward either side.

The clay shows similar relations. The clays toward the bottom of Isom Ravine at Oxford are much darker and firmer and less plastic than those toward the top, so that the upper beds of clay appear to be more recent than the basal beds. This change in character has seemed at times to offer a real stumbling block to the interpretation of the relations, but it is not difficult to explain. Where the clay lies in thin beds between pervious layers of sand or in small lenses surrounded by loose sand, surface waters that carry oxygen and various acids penetrate and soften or mellow the clay, making it more plastic, and oxidize to the peroxide state any protoxide or sulphide of iron, so that the color is changed from gray or bluish to pinkish, reddish, or purplish, as is so often seen in these small lenses. The same oxidation would remove the organic matter, which so often makes these clays dark in their unchanged condition, and would thus cause the clay to become white. When the lenses are thick, large, and dense, like the lens in Isom Ravine, the oxidation does not penetrate very deep; hence the bulk of the clay mass, especially toward the base, where the material is farthest removed from oxidation, remains dense, shale-like, dark, and lignitic, and retains distinct, highly carbonaceous, black, impressions of fossil plants, which are either lost entirely through weathering or are oxidized to impressions of pink and red iron oxide in small lenses, like those seen at the "nose," where Berry collected specimens near the railroad station at Oxford. At the Holly Springs clay pits the whitish clay shows little evidence of fossils, but in places it passes down into lignitic clay, the dark parts of which contain beautiful impressions of leaves.

Where the clay is distinctly stratified and shows a dark lignitic appearance and a shale-like firmness, and contains impressions of plants it is at once recognized as Wilcox, but where it has been bleached of its lignitic material by weathering, has lost its firmness and its impressions of fossil plants, and especially where by slumping its changed aspect raises a doubt as to its identity, the red and yellow ochers, brown hematite, and other materials which Dr. Hilgard described as common in the "Lafayette" of northern Mississippi, seem all to be oxidation products associated with the weathered red sand outcrops of the middle Wilcox. There seems no longer reason

FIG. 6. A.

A. Typical stratified Wilcox clay exposed in Isom Ravine, inner gorge, just north of the Public School building, Oxford, Lafayette County. The clay is dark-gray, very firm, heavy-bedded, and abundantly fossiliferous, the leaf impressions being black and carbonaceous. This is interpreted to be a large clay lens embedded in the Holly Springs Sand. Photo by E. N. Lowe.

to doubt that the rather extensive deposits of white pottery clay in the northern counties consist of Wilcox clay, which, because of the small size of the lenses and their being interbedded with loose sand that permits it to be attacked by oxidizing waters and leaching acids, has now become white and plastic and fit for the potter's wheel. They were not originally so, however, as may be seen at many places where they pass down into stratified lignitic beds of fossiliferous clay.

The degree and the sharpness of these changes necessarily depend upon several factors, among which are size and thickness of the clay deposit, the thickness of its beds, its depth below the surface, the permeability of the surrounding sands to water, and the dissolved contents of the water. Hilgard[1] recognized the process by which these changes in the clays were brought about, as he shows in a diagram and in the accompanying description, but he evidently did not attach sufficient importance to it, for it is the key to some of the knotty difficulties that arise in the study of the so-called "Lafayette" phase of the Holly Springs sand in this area.

Distribution.—In the northern counties of Mississippi the outcrop of the Holly Springs sand has a width from east to west of 25 miles or more. Its width diminishes somewhat farther south. Toward the middle counties and southeastward toward the Alabama line it narrows in such a way as to suggest the partial covering of the formation by the overlapping Claiborne. Further evidence of such an overlap is furnished by the more or less extensive outliers of Claiborne quartzite entirely surrounded by Wilcox sands that cap the hills of several of those counties some miles to the east of the Claiborne outcrop. Still further evidence of an overlap lies in the apparent absence of the uppermost Wilcox beds (the lignitic clays of the Grenada and Hatchetigbee formations), which are here probably covered by the overlapping edge of the Claiborne, and reappear in Lauderdale County and eastward.

The eastern edge of the Holly Springs sand has been indicated in the description already given of the western limits of the Ackerman beds, to which reference may be made. Owing to the deposit of loess that envelops the region bordering the Mississippi River bluffs the contact between the Holly Springs and the Grenada beds

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[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 16. 1860.

has not been accurately made out. In DeSoto County 2 miles west of Pleasant Hill and about 10 miles east of the river bluffs there is an outcrop of lignite and clay underlying about 25 feet of terrace sand and gravel. At the cotton gin of Dan F. Smith, 6 miles east of Sardis, undoubted Wilcox is exposed beneath the superficial deposits.

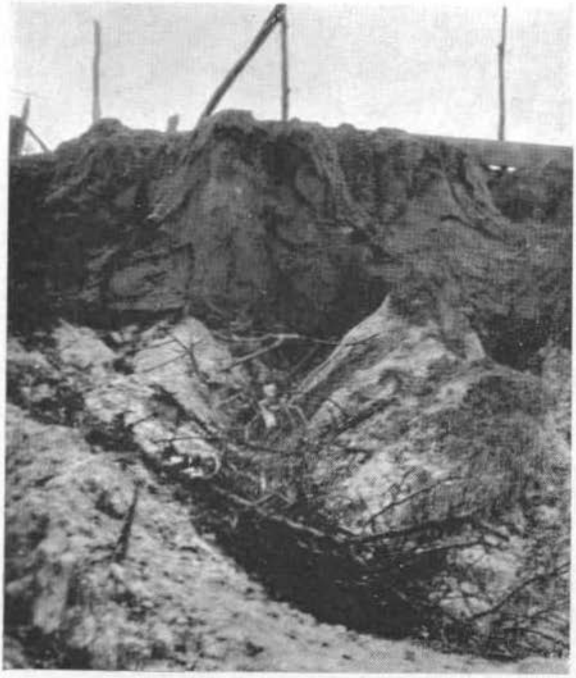

FIG. 6. B.

B. Isom Ravine, Oxford, upper slope facing north, showing light-colored stratified sands and sandy clays below, red unstratified sand and loam soil at the top. The division between the red sands and underlying lighter sands is sharp, and may represent an unconformity. The red sands are regarded by some as "Lafayette."
Photo by E. N. Lowe.

Structure and thickness.—Well records at Oxford show that the Holly Springs sand ranges in thickness there from 175 to 240 feet. The underlying Ackerman clay which contains concretions of spathic iron crops out 8 miles east of the town. If the dip is uniform and the thickness is 175 feet, the rate of dip would be 22 feet to the mile; if the thickness is 240 feet the dip would be 30 feet to the mile. A similar calculation based upon well records from Holly Springs shows a dip of 21 feet to the mile. At Grenada well records give approximately a dip of 22 feet to the mile.

In the calculations given above which are based upon the depth at which the top of the Ackerman is reached, it is assumed that the Holly Springs and Ackerman formations are conformable, or at any rate that there is no angular divergence between them. If the interpretation of these well records is correct, the average dip of the formation should be about 24 feet to the mile toward the west and somewhat less toward the south. This figure is believed to represent more nearly the actual dip than the smaller figure given in earlier reports, because it is calculated from the records of numerous wells sunk between Holly Springs and Grenada and furthermore because it coincides very well with the general dip of the Eocene formations in Mississippi. According to this rate of dip and the width of outcrop of the Holly Springs formation its thickness in the latitude of Oxford would be 576 feet; in the latitude of Water Valley, Yalobusha County, 588 feet; in the latitude of Grenada, Grenada County, 360 feet; and in the latitude of Ackerman, Choctaw County, 288 feet. Near Marion, Lauderdale County, if the overlying Bashi formation is assumed to be 70 feet thick, and if the clays exposed in the bottom of the great "sand cave" belong to the Ackerman formation, the thickness of the Holly Springs sand would be 160 feet, or the exposure in the great "sand cave" would represent the full thickness of the formation.

A flattening of the dip westward, suggested by Crider[1] as probable in the northern part of the outcrop, would reduce these thicknesses. Disturbances accompanied by bending or breaking of the strata, and consequent change in the angle of dip, would also modify the results of the calculations, but the evidence thus far discovered shows only local disturbances in the region under consideration.

Physiographic expression.—The region in which the Holly Springs sand crops out is characterized by high, broken sand hills. The streams have broad valleys, and during each season the smaller ones carry down from their bordering steep hillslopes great quanti-

[1]Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. No. 283, p. 61. 1906.

ties of loose sand. In those parts of the region that have been denuded of forests erosion is rapid and great chasms and gullies often develop to a destructive extent within a few years. In this region soil erosion is a positive menace, and reforestation of the steep slopes should be seriously considered.

The average elevation of the uplands is 150 to 250 feet above the streams, and 450 to 625 feet above sea level. The region in which the weathered sand outcrops is 150 to 200 feet higher than the adjacent regions in which clay outcrops. This rise in altitude, together with the exposure in the channels of the larger streams in Lafayette and adjoining counties, of the gray clay and lignite of the Ackerman, no doubt gave a basis for the belief that the weathered sand represented a later and distinct formation deposited upon the Wilcox. The close study of the geology of Mississippi, however, clearly shows that the weathering and erosion of alternating deposits of sand and clay, develops a topography marked by lowlands underlain by clay and uplands consisting of ridges of sand. Sandy formations invariably stand up in high, broken hills, whereas clayey formations form low regions of gentle relief. This fact has undoubtedly contributed to a misinterpretation of much of the so-called "Lafayette" of northern Mississippi, which in most places seems to consist of the weathered and oxidized outcrops of underlying sandy formations in conspicuous ridges and hills. Often the transition can easily be made out.

Economic products.—The sand of this formation furnishes excellent building material along most of the outcrop, the coarse sand especially being admirably adapted to the making of mortar and concrete. In some localities the sand is useful in road making. In many places where it contains a proper admixture of clay and iron it makes an excellent molding sand.

In the narrow zone in which lenses of white and pinkish clay occur along this outcrop in northern Mississippi the clay forms a very good ball and stoneware clay and offers opportunities for its commercial use. Small potteries are located on clay lenses of this formation at Holly Springs.

Paleontology.—The deposits of sand which make up the greater part of the Holly Springs formation are nonfossiliferous and were undoubtedly laid down in fresh water. Only in the clay lenses, which are most numerous and extensive in the middle of the series, have fossil leaves been found in abundance. Collections have been made and examined by E. W. Berry from several localities in northern Mississippi. Where the clay is dark and lignitic the impressions are shining, black, and very striking. In localities where the clay has been oxidized the organic matter of the leaves has been lost, and iron oxide generally stains the impressions a handsome pink tint. At Holly Springs the same clay pit showed both types of impressions; the deeper unoxidized dark clays showed the black impressions.

No fossils other than leaf impressions have been found, and the formation consists probably of fresh-water deposits throughout.

The following sections together with their flora have been furnished by Prof. E. W. Berry,[1] of Johns Hopkins University:

"Early Grove is situated in northeastern Marshall County, Mississippi, at an elevation of between 450 and 500 feet, less than 15 miles directly along the strike north of the plant locality at Holly Springs. The exact locality is at Wellborns, about 1 mile southeast of the town and just east of the public road, where extensive gullies have been eroded in the upland. The following section is exposed:

"Section of Holly Springs sand at Early Grove, Mississippi:

	Feet
1. Orange, brown, yellow, and gray compact coarse cross-bedded sand grading downward into No. 2	15
2. Gray, more or less ferruginous stratified sand; thin iron crust at base	15
3. Gray, pinkish, and white arenaceous laminated clay, containing in places thin iron crusts and poorly preserved impressions of leaves grading downward into No. 4	8
4. Brownish-drab, rather pure clay, thickly laminated, and containing thin films of fine, light sand, with well-preserved leaf impressions exposed	4 to 5

"A small collection was made here in 1889 by L. C. Johnson from No. 4, and three specimens from No. 3 were collected by W J McGee shortly afterward. McGee's specimens are *Cassia eolignitica* Berry, *Engelhardtia* (*Oreomunnea*) *mississippiensis* Berry, and *Sapindus mississippiensis* Berry. I visited this locality in 1910 and 1913 and made considerable collections from the lower member. A study of this collection and that made by Johnson furnishes the following list of species:

[1] U. S. Geol. Survey Prof. Paper No. 91, pp. 38-44. 1916.

Antholithus marshallensis:
Avicennia nitidaformis.
Bumelia pseudotenax.
Bumelia wilcoxiana.
Caesalpinia wilcoxiana.
Canavalia acuminata.
Capparis eocenica.
Cassia eolignitica.
Cassia glenni.
Cassia marshallensis.
Cassia tennesseensis.
Cedrela mississippiensis.
Celastrus eolignitica.
Celastrus veatchi.
Engelhardtia ettingshausensi.
Engelhardtia mississippiensis.
Euonymus splendens.
Exostema pseudocaribaeum.
Ficus myrtifolius
Glyptostrobus europaeus.
Heterocalyx saportana.
Ilex vomitoriafolia.
Inga mississippiensis.
Lycopodites (?) eolignitiicus.
Mimosites variabilis.
Paliurus mississippiensis.
Sapindus linearifolius.
Sapindus mississippiensis.

"Both the potteries at Holly Springs obtain their clay from nearby exposures in the same hill about 1½ miles east of the town. The small opening on the south slope of this hill shows the following sequence of materials:

Section of Holly Springs sand at Holly Springs, Mississippi:

	Feet
1. Brownish sandy loam, about	5
2. Gray sandy clay becoming purer, more distinctly bedded, and darker, toward the base, where it carries finely preserved impressions of leaves exposed	10

"The leaf-bearing portion is 1 to 2 feet thick and is underlain by more sandy materials. The following species occur here:

Ficus sp.
Ficus myrtifolius.
Gleditsiophyllum entadaformis.
Gleditsiophyllum fructuosum.
Guettarda ellipticifolia.
Laguncularia preracemosa.
Nectandra pseudocoriacea.
Oreodaphne mississippiensis.
Oreodaphne obtusifolia.
Paliurus angustus.
Paliurus mississippiensis.
Reynosia praenuntia.
Sabalites grayanus
Sapindus formosus.
Sapindus linearifolius.
Solanites saportana.
Sophora wilcoxiana.
Anacardites marshallensis
Bumelia lanuginosafolia.
Caesalpinia wilcoxiana.
Caesalpinites mississippiensis.
Canavalia eocenica.
Capparis eocenica.
Cassia emarginata.
Cassia fayettensis.
Cassia wilcoxiana.
Cedrela wilcoxiana.
Cinnamomum obovatus.
Cinnamomum vera.
Citharexylon eoligniticum.
Dillenites serratus.
Dryophyllum tennesseensis.
Drypetes prelateriflora.
Engelhardtia ettingshauseni.

"The larger opening on the north slope shows 3 to 5 feet of brownish argillaceous sand underlain by about 20 feet of gray stratified clay in beds that are alternately of different degrees of purity or sandiness. At the base of the exposure in a nearby ravine the following species were collected:

Dodonaea wilcoxiana.
Dryophyllum tennesseensis.
Ilex eolignitica.
Paliurus angustus.
Cinnamomum vera.
Cassia emarginata.
Cedrela wilcoxiana.
Celastrus bruckmannifolia.
Celastrus minor.

"Section in ravine at Oxford commencing at the top about 200 yards north of the courthouse, (Isom Ravine):

	Feet
1. Brown loam	0 to 1
2. Loam grading into reddish compact, rather fine sand with a few scattered pieces of limonite (probably not a primary feature); the sands become looser and of a buff color toward the base	9 to 10
3. Similar stratified sands, lighter in color and more argillaceous than material No. 2; carrying small clay pellets at the base; about	5
4. Grayish sandy clay, more or less ferruginous stained and with some scattered thin iron crusts	3 to 4
5. Brownish stratified sand similar to that of No. 2, containing layers of gray laminated clay grading into brownish or bluish laminated clay	5 to 6
6. Laminated clays passing gradually into darker, more massive, and somewhat more micaceous clays, in places very arenaceous and containing numerous leaves of plants	20

"Bed No. 6 grades horizontally into the lighter sandy laminated clays exposed along the railroad immediately south of the first section and are at the same level as the lower sands in that section. The massive argillaceous beds in the ravine are somewhat bluish in color, but on drying become brownish-banded ringing clays. The gray films of sand in the laminated clays contain much brownish comminuted vegetable matter, but apparently no leaves have been found in them possibly because they do not lend themselves to exploitation. The leaf remains are not especially abundant but are rather generally distributed through the more massive clays and represent a considerable flora. Palm leaves are especially abundant and large, some being several feet in diameter, but they are very difficult to collect."

"The following species occur here:

Railroad Cut.

Sabalites grayanus.
Sapindus oxfordensis.
Oreopanax oxfordensis.
Apocynophyllum tabellarum.
Ficus vaughani.

Ravine.

Glyptostrobus eoropaeus.
Myrcia bentonensis.
Myrcia vera.
Nectandra lowii.
Nectandra pseudocoriacea.
Oreopanax oxfordensis.
Palaeodendron americanum.
Pithecolobium oxfordensis.
Sabalites grayanus.
Zizyphus meigsii."
Ficus cinnamomoides.
Acacia wilcoxensis.
Apocynophyllum wilcoxense.
Caenomyces laurinea.
Caenomyces myrtae.
Caenomyces pestalozzites.
Caenomyces sapotae.
Canna eocenica.
Cinnamomum mississippiensis.
Cinnamomum vera.
Dryophyllum tennesseensis.

LOCAL DETAILS

Grand Junction, Tenn.—A few miles north of the State line, in the vicinity of Grand Junction, Tenn., numerous deep washes give characteristic exposures of the structure of the Holly Springs sand. One of the most notable cuts is on the Illinois Central Railroad a mile south of the station at Grand Junction. The cut is 28 or 30 feet deep and exposes the following strata on its east side:

	Feet
3. Brown loam (at top)	6
2. Red sand, with more or less reworked white clay	12 to 18
1. Stratified light-gray clay, becoming sandy toward the bottom of the cut	14 to 16

A distinct erosional unconformity separates bed No. 2 from bed No. 1, the line of contact being quite irregular.

In the wash a few steps east of the cut, the erosional unconformity between the red sand and the gray and pinkish clay is shown even better than in the cut, the two being separated by a thin partition, and finally coming together. On this side, however, more reworked clay is seen toward the bottom of the sands, and the clay member, which corresponds to No. 1 of the section, rests without break upon beds of stratified grayish-white sand. Furthermore, at

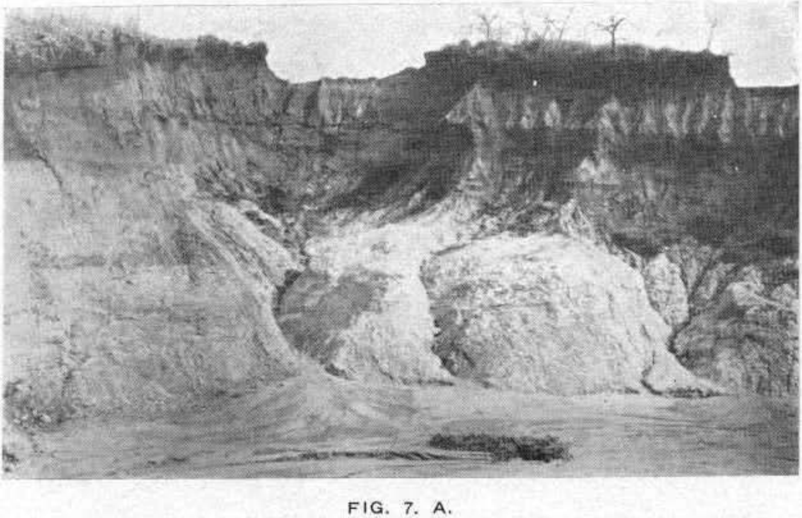

FIG. 7. A.

A. Exposure of Holly Springs sand one-half mile west of Lamar, Marshall County. The material consists of red quartz sand grains rounded and rather coarse, passing into pinkish-white clays and sands below. A capping of 3 or 4 feet of brown loam (loessal) soil removed bp erosion from the gap seen in the middle of the picture. Photo by E. N. Lowe.

the head of this wash the evidence of unconformity between the red sand and the underlying beds disappears, and the clay passes without break into the overlying sand.

These sections are duplicated at many places around Grand Junction but at most of these places the clay consists of lenses embedded in the sand, the unconformity that is commonly noted between the overlying sand and the clay lens being entirely local.

All the railroad cuts on the Southern Railway for several miles east and west of Grand Junction exhibit the sands of this formation. Along the Illinois Central Railroad this formation is exposed from Grand Junction southward as far as Grenada. On the St. Louis & San Francisco Railroad southeast of Holly Springs to the crossing of the Tippah River, about 10 miles in a straight line, great thicknesses of these beds are exposed. The extensive and characteristic development of this formation in the vicinity of Holly Springs has given the name of that place to the formation in this report and in a previous report by the writer.[1]

Around Hudsonville and Holly Springs the white ball clays of that part of the Holly Springs formation are found in considerable quantity, and at Holly Springs they are used for the manufacture of stoneware.

Lamar.—Lamar is about midway between Grand Junction, Tenn., and Holly Springs, and lies within the zone of white clays so prominently developed in the middle of the Holly Springs sand from Grand Junction and Lagrange to Holly Springs and Oxford. Nearly all the washed hillslopes in the vicinity of Lamar reveal in greater or less purity the white ball clays associated with the red sands.

On the hillslope half a mile west of Lamar, on the south side of the Lamar and Mount Pleasant road, interesting sections are exposed in a group of deep washes. The most easterly exposure examined is a small amphitheater which shows at the bottom 6 feet of stratified white sand. Overlying this sand without break is a remnant, 6 feet thick, of a yellowish-white sandy stratified clay lens, in which the strata curve downward toward the southeast. This clay passes upward into yellowish-white, then into red clay, and finally into red sand, 5 or 6 feet in thickness. Brown loam 4 to 5

[1]Lowe, E. N., Preliminary report on the iron ores of Mississippi: Mississippi Geol. Survey Bull. No. 10, p. 24. 1913.

FIG. 7. B.

B. Cut in ravine at head of old lake Lumpkin's Mill, Watersford, Marshall County, exposing from top to bottom sands of the Holly Springs formation. These sands are deep rusty red above, passing by easy gradation into lighter yellowish-gray sands and clays toward the middle, which in turn show a gradual transition toward the bottom into yellowish-gray sands. Note how the unstratified red sands at the top pass imperceptibly into stratified materials of lighter color. Photo by E. N. Lowe.

feet in thickness lies at the top. To the right and left, as one faces the above exposure, other interesting exposures appear. To the left there is exposed a wall 15 feet high, all of light-colored sands, except a few feet of red sands and loam at the top. To the right the beds consist of light-colored material, sandy, but with considerable clay. These exposures show the differing character of the materials of this formation, even within small areas. The topmost red sands of these sections pass down into the lighter clayey material in such a way as to force the conclusion that all the beds form one deposit.

A few rods up the main wash, on the east side, there is a good exposure of the following beds:

	Feet
4. Brown loam	A few
3. Red sands, showing some stratification below	5 to 6
2. Sands, slightly clayey, light-colored below but becoming red above, without any evidence of break	4.5
1. Gray sandy clay, showing very irregular, wavy lamination; the lamination planes are red and purplish	7

Less than 25 feet to the south of this section the clay has almost entirely disappeared from the basal part of the exposure, and in its place are light grayish sands with pink partings to the bottom of the exposure.

About 75 yards farther up this wash the north wall of the ravine is practically vertical and 18 feet high. The lower 10 feet of this vertical face consists of whitish sandy clay with a rather sharp upper surface, covered by 8 feet of red sand and brown loam at the surface. The parting between the clay and sand is not only sharp but curved downward toward the west end of the exposure, showing an unconformity between them. An exposure in the south wall of the ravine 30 feet distant shows no such break, but here gray clayey sand with purplish streaks underlies conformably the red sand and brown loam.

The section just described as showing unconformity between the red sand and whitish sandy clay forms the south face of a narrow partition between washes. On the north side the beds of light-colored clay are not so thick and are underlain by 4 feet of brown sand.

The lenticular character of these white clay deposits is very evident in this group of exposures. No one exposure reveals this fact so well as the whole series of exposures. Furthermore, the variations are so pronounced and sudden that any two exposures, even within a few feet of each other, may show entirely different materials and structure.

At a little bridge over a wash in the public road a few rods north of the gullied area just described the following beds are exposed:

	Feet
5. A few feet of brown loam at the surface.	
4. Light-gray clay, indistinctly stratified, somewhat sandy and micaceous	5 to 6
3. Bed No. 4 passes down into purplish stratified clay	5 to 5.5
2. Thinly laminated, yellowish-brown sandy clay	2
1. Light-gray clay with purplish mottlings	1

The hills half a mile to the west rise 75 feet higher, and nearly all the deep washes, which are numerous, reveal the white clay beneath the red sand, but the white clay does not always extend to the bottom of the sections. In many places a bluish-gray sand underlies the clay which is 3 to 5 feet thick, to the bottom of the cut, and the two are commonly separated by a thin purplish shell of sandstone.

East and south of Lamar the association of the white clay with the red sand is as common as it is west of the town. Very pure ball clay occurs in considerable quantity on the old Judge A. M. Clayton estate, 2 or 3 miles southeast of Lamar.

Holly Springs.—The Allison clay pit, a mile east of the town, in a decidedly rolling region, has been opened to a depth of 16 feet on a hillslope where a length of 40 feet of clay is exposed. The following section is presented:

	Feet
3. Brown loam soil (at surface)	2 to 4
2. Red unstratified sand	6 to 8
1. White clay, horizontally stratified, slightly lignitic, and bearing beautiful leaf impressions toward base	10

A distinct erosional unconformity exists between No. 2 and No. 1. The full thickness of No. 1 has not been exposed in this pit. Wherever fragments of this clay have been dumped out and become mixed with the red sand, the resulting dump surface, after it has been exposed to the weather, for some time, presents the "clabber" appearance already mentioned, an appearance frequently seen in exposures in the vicinity of Oxford.

Hull's clay pit, 300 feet west of Allison's pit, has a vertical exposure of 45 to 50 feet and 250 feet in length. Here the following exposure occurs:

	Feet
3. Loam and red sand (at surface)	3 to 10
2. Stratified clay, mottled white and purple, of irregular thickness	6 to 20
1. Sand, light yellow to pinkish, with numerous small purplish iron balls near base of the clay; cross-bedded and dips eastward	15 to 35

In both these pits the topmost red sand lies unconformably upon the clay. This relation is common where sand overlies a lens of clay, and to it is very largely due the past misconceptions with regard to these formations.

On the north side of the Hernando road, 1½ miles west of Holly Springs, a long hillslope is deeply trenched by a wash that exposes 10 feet of what appears to be brown loam which overlies 12 feet of deep red unstratified sand and is separated from it by a layer of fragments of iron-cemented sand. These fragments lie at all angles, and were evidently not formed in their present position, but their angularity shows that they must have been transported only a very short distance. Less than 200 yards away the layer of iron crusts leaves the supposed contact of the loam and the red sand and passes gradually to a level that is distinctly within the red sand, 2 or 3 feet below the loam. Fifty yards still farther east, all the material seen in the exposure from the top to the bottom, a distance of 18 to 20 feet is of the character of so-called orange sand, or loam, it is impossible to say which.

The significance of this exposure lies in the fact that there seems to have been a slight local shifting of material here by slope wash. E. W. Shaw[1] has expressed the opinion, based upon exposures in Lafayette County similar to the one here presented, that much of the surficial deposits of red sand so common to this region is due to slope wash. The evidence in favor of this view is cumulative, and it explains satisfactorily many heretofore enigmatical problems of this formation. Today slope wash is depositing in many places materials that in the past have been regarded as typically "Lafayette." There is abundant evidence everywhere in this region that many seeming unconformities of the red sand with the underlying formations are really due to slope wash.

Waterford.—Interesting sections of the Holly Springs sand occur at Waterford, 6 miles south of Holly Springs. All the cuts on the Illinois Central Railroad for a mile or more north of Waterford expose typical Holly Springs sand, chiefly red, but varying in color from red to yellow, white, and purple. Many exposures show white sand below that pass by gradual transition to the common red sand at the surface. This transition is especially noticeable in the first cut north of Waterford. The red sand is usually micaceous, commonly cross-bedded, and in many places shows thin laminae or linearly placed flecks of white clay along the oblique division planes.

A deep wash on the east side of the track 1¼ miles north of Waterford shows 18 to 20 feet of white sand with purplish lamination planes, cross-bedded and intricately laminated. This sand becomes distinctly red along lamination planes upward and finally passes into red beds at the top without a break in continuity.

A deep cut 250 yards north shows a distinct unconformity between the red and yellow sand deposit which measures 15 feet in the thickest part, and an underlying deposit of gray clay with purplish streaks. The clay is exposed to the bottom of the cut at track level, a thickness of 20 feet, but most of the lower part is concealed by slump. This exposure is on the east side of the track.

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[1]Oral communication.

On the west side the overlying sand has been artificially removed, leaving a considerable amphitheater, perhaps an acre or two in extent, with a floor of gray clay. At many places in this amphitheater small remnants of the red sand a few inches thick lie on the clay, but the geologist's hammer, in a few strokes, easily reveals the sharp line of division between the sand and the clay. Toward the westernmost edge of this amphitheater, however, beds of red sand distinctly underlie a few feet of gray clay, suggesting strongly that, in spite of the unconformable contact at the railroad cut and over most of the adjacent area, the red sand and gray clay seem to be interstratified as if both are of one formation. The unconformity may be intraformational, for this is not an uncommon feature of this formation throughout its outcrop.

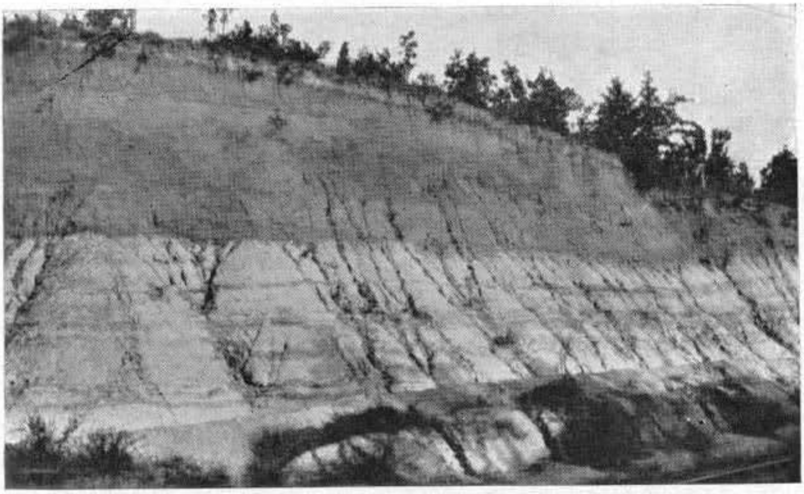

FIG. 8. A.

A. Cut one mile north of Oxford on the Illinois Central Road, showing exposure of Holly Springs formation. The material above is red sands, the lighter-colored below is clay and sandy clay thinly laminated. The stratification is more regular than usual in this formation, and beds are conformable from top to bottom. Photo by E. W. Shaw.

A mile west of the above exposure and 25 or 30 feet lower is the old Lumpkin mill and pond. At the upper end of this pond, on its west side, there is a series of very deep washes. It would seem that the gray clay exposed at the railroad cut ought certainly to occur here, but it could not be found. No clay at all corresponding to that at the railroad is exposed in these ravines, which suggests that the clay deposit is lens like.

A deep wash just west of the upper end of the pond shows at the opening near the lake the following conformable strata:

	Feet
3. This bed passes gradually into red sand at top	A few
2. Yellowish-gray horizontally stratified sandy beds, somewhat clayey	12 to 14
1. Whitish cross-bedded sand, with purplish partings	15

Toward the head of this wash the cut is 35 feet deep. The lower part consists of whitish sand that passes up into tawny yellowish sand, horizontally bedded, and somewhat clayey toward the top, showing a distinct whitish clayey zone 1 to 2 feet thick. These beds pass upward without break into 12 to 14 feet of red stratified sand capped with a few feet of loam.

The other washes in this vicinity reveal materials of about the same general character; red sand at the surface passes downward into lighter or even white sand. Half a mile down the wagon road toward Waterford a deep wash on the east side of the road, which leads down to the upper end of the lower lake, exposes red sand from top to bottom to a depth of 30 feet except that about halfway down there is a zone of grayish mottled sandy clay, 12 to 14 inches thick. The beds of red sand below this zone are like those above but show stratification more plainly and are apparently more compact.

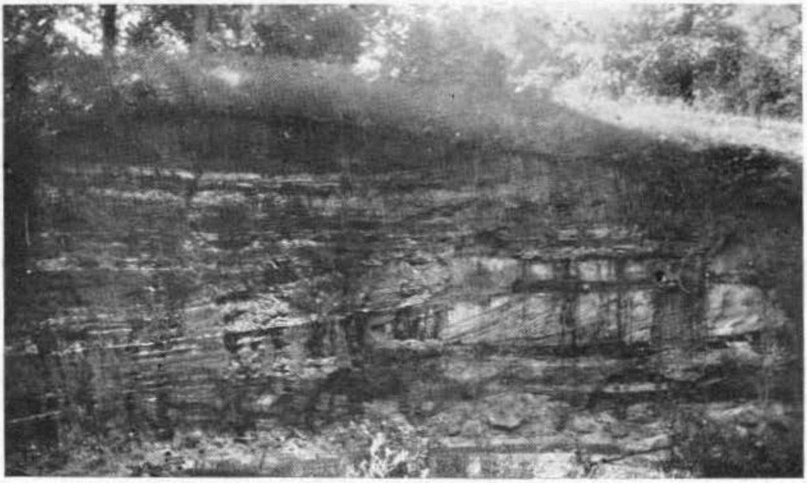

FIG. 8. B.

B. Cross-bedding in the Holly Springs sand at Bailey's Spring ravine just south of Oxford, Lafayette County. The sands here show an unusual variety of coloration. Photo by E. W. Shaw.

The uplands around Waterford form distinctly rolling, in places rather rough, topography and have a general elevation of 500 to 520 feet above sea level.

Oxford.—Some of the most interesting exposures of the Holly Springs Sand occur around Oxford, in Lafayette County. Since Hilgard's day Oxford has been classic ground for the geologist, because it was regarded by him as the type locality of the "Lafayette formation." His "Lafayette"[1] included at least 200 feet of sand, the upper 35 or 40 feet of which are exposed in the railroad cuts just south of the station, as well as in numerous ravines in the vicinity of Oxford and the State University. There seems always to have been some question about the age of these exposures. Safford[2] in 1869 recognized no formation in Tennessee corresponding to Hilgard's "Lafayette." In 1891 a number of geologists met at Oxford, went over the ground, and finally seem to have accepted the "Lafayette." Mabry,[3] who later occupied the chair of geology at the University of Mississippi, followed Hilgard in his interpretation of the exposures around Oxford.

Crider and Johnson first questioned[4] Hilgard's interpretation of the exposures in Marshall and Lafayette counties. They say, "In northern Mississippi, particularly in Marshall and Lafayette counties, where the formation was first described and named, the Lafayette, when present at all, is only a few feet thick, but in many places it is wanting."

Brown more specifically puts the thickness of the "Lafayette" at Oxford at 2 to 8 feet.[5] Neither Crider nor Brown regarded the lower parts of the railroad cuts at the University Bridge as "Lafayette."

In 1910 E. W. Berry made a collection of fossil plants from the railroad cut just north of the station at Oxford. These plants proved to be of Wilcox age, and Berry therefore expressed the

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[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, pp. 5-29. 1860; Am. Geologist, Vol. 8, pp.129-131. 1891.

[2]Safford, J. M., Geology of Tennessee, pp. 424-426. 1869.

[3]Mabry, T. O., Brown and yellow loam of north Mississippi, and its relation to the northern drift; Jour. Geology, Vol. 6, pp. 273-302. 1898.

[4]Crider, A. F., and Johnson, L. C., Summary of the underground water resources of Mississippi: U. S. Geol. Survey Water Supply Paper No. 159, p. 12. 1906.

[5]Brown, Calvin S., Lignites of Mississippi, Miss. Geological Survey Bulletin, No. 3, p. 18. 1907.

opinion that the type exposures of so-called "Lafayette" materials were Eocene.[1] The publication of Berry's article renewed interest in the study of the "Lafayette" at the type locality. Unfortunately the leaf-bearing clays examined by Berry were very much broken up and disturbed, so that the evidence obtained was not convincing, and the correctness of conclusions as to the age of the type exposures of so-called "Lafayette" at Oxford was therefore questioned.

In 1911, after Berry had made his first examination, the writer discovered in a deep ravine 200 yards north of the public school at Oxford undoubted undisturbed fossiliferous Wilcox beds. This discovery has given the investigation of this much disputed question a definite and certain starting point. All who have examined the locality acknowledge unhesitatingly that the basal beds exposed in the Isom Ravine (a name suggested by Dr. E. A. Smith, who examined this ravine with the writer in 1911) are of Wilcox age. Strange to say, until 1911 no geologist had apparently examined this ravine, for if it had been examined before it could hardly have escaped mention. After these undoubted Wilcox beds had been discovered the only open question left was, What is their relation to the overlying sands?

To determine this point as well as to re-examine the type exposures of the "Lafayette" in the vicinity of Oxford, in October, 1913, a number of geologists, consisting of T. Wayland Vaughan, E. W. Shaw, and George C. Matson, of the United States Geological Survey, E. A. Smith, State Geologist of Alabama, W. L. Kennon, of the University of Mississippi, and E. N. Lowe, State Geologist of Mississippi, met in Oxford and studied critically the numerous outcrops of so-called typical "Lafayette." In the autumn of 1914, E. W. Shaw and the writer spent a week studying jointly throughout Lafayette and Panola counties the evidences bearing upon the "Lafayette formation" of that region. The writer individually studied the exposures of Wilcox in Lafayette and adjacent counties for several years. Although the result of these several examinations has not been an entire unanimity of opinion with regard to

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[1]Berry, E. W., Age of the type exposures of the Lafayette formation: Jour. Geology, Vol. 19, pp. 249-256. 1911.

the so-called "Lafayette" exposures, the great majority of observers have come to regard the beds exposed as of middle Wilcox age, and the presence of "Lafayette" as not proved at Oxford or in Lafayette County.

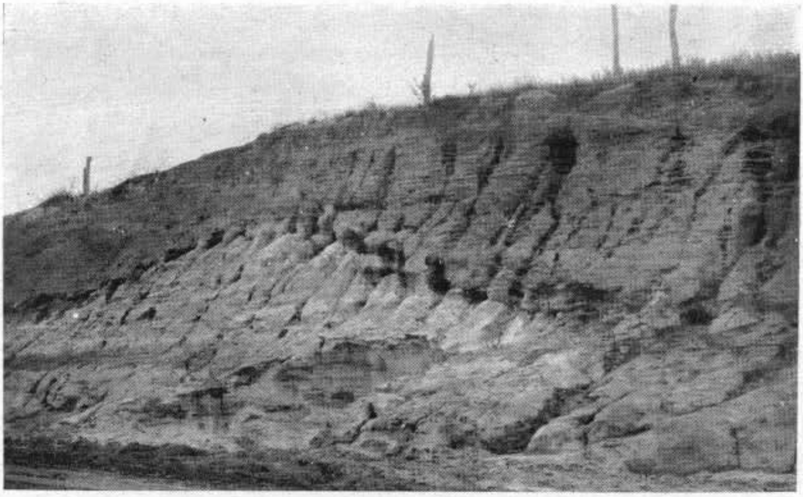

FIG. 9. A.

A. Unconformity at top of hill one-half mile east of Oxford, between stratified reddish sand and white clay of the Holly Springs formation. As will be seen, the clay passes below into light-colored sand, which weathers to different colors. This is a clay lens in the formation, and the unconformity is intra-formational. The red sand above the unconformity is what some still regard as "Lafayette." Photo by E. W. Shaw.

The most interesting, though by no means the most typical, exposure of the Holly Springs division of the Wilcox in the vicinity of Oxford is that just mentioned, in the Isom ravine, just north of the Oxford public school building. A narrow, vertical-walled inner gorge shows the following strata:

	Feet
6. Red unstratified sand (Crider's and Brown's "Lafayette") lie upon bed No. 5 with a sharp line of division—apparently an unconformity—separating the two—capped by 2 or 3 feet of loam	12
5. Sand with clay laminae passing upward into reddish sand that contains abundant whitish clay balls, producing a "clabber" or curdled milk effect, due apparently to the reworking of the clay by currents of sand-bearing waters, but all intraformational, showing no evidence of a break	4
4. Clay which toward the top becomes somewhat sandy and passes into light-colored, slightly mottled sandy clay; thin partings of sand appear and become more pronounced; these partings of sand pass above into yellowish-red sand with numerous thin laminae of pale clay. No break apparent	12 to 14

3.	Lighter-colored clay, slightly variegated and plastic as a result of weathering; exposed in gentle slope	5
2.	Above No. 1 the ravine walls slope rather gently back from the top of the inner gorge; a little side ravine exposes the dark, heavy-bedded clay above the top of the inner gorge	6
1.	Walls of dark brownish-gray, slightly lignitic clay, heavy-bedded, fossiliferous, with abundant black and carbonaceous impressions of leaves. Clay, pinkish on drying, slightly micaceous (firm like shale) rings under the hammer	6

It will thus be seen that there is no break in the series from the bottom of the gorge to the base of the 12 feet of red sand, (No. 6), where there is a probable break.

The bottom of the gorge gradually deepens toward the west for 100 yards or more, exposing at least 5 feet more of the basal leaf-bearing clay beds. Toward the lower end of the gorge there is a decided vertical drop, below which there is a large pothole several feet in depth, partly filled with water. At the lower end of the gorge, just below the pothole, the walls widen out into a more open ravine with sloping sides. On both sides of the ravine the walls show at the base thinly laminated gray, sandy, micaceous clay, which becomes more sandy downward. On the north side the wall shows thinly laminated and highly siliceous clay from bottom

FIG. 9. B.

B. Exposure at same point as seen in A, from opposite side of road. The lighter-colored material below the red sands is white and tawny sands with thin clay partings. The whole exposure is probably Wilcox. Photo by E. N. Lowe.

to top, whereas on the south side only the lower 5 feet is thinly laminated and sandy and passes gradually upward into the more heavy-bedded and purer fossiliferous pinkish clay.

This deposit of clay thus becomes distinctly sandy both above and below and even passes into well-marked beds of sand. There is evidence that it passes laterally also into sand. It is not struck in the town wells 250 yards southeast and southwest. Just beyond the pothole the ravine turns toward the north for 100 yards. Only sand is found in that direction. All the evidence indicates that in this locality a large clay lens is embedded in the Wilcox sand. The clay lenses so common in this mid-zone of the Holly Springs sand are usually much smaller than the one just described and the clay is lighter in color. These beds were described by Hilgard as deposits within the "Lafayette or Orange sand" formation. Crider and Brown referred them to the Wilcox, and all late observers concur in this interpretation. Crider and Brown regarded the surficial deposits of a few feet of unstratified red sand, such as that seen at the top of the section in the Isom Ravine as distinct from the underlying material and as of "Lafayette" age. If there is any "Lafayette" in the numerous exposures around Oxford these beds of sand are correctly referred to it, but after a careful and critical study of exposures in Marshall, Benton, Lafayette, and adjacent counties, the writer is forced to the conclusion that all these surficial beds of sand are, where undisturbed, of Wilcox age and that numerous so-called "Lafayette" deposits are reworked Wilcox sand due to recent slope wash, as suggested by Shaw.[1]

Not more than 250 yards west of the pothole in the Isom Ravine an exposure on the Illinois Central Railroad just opposite the Stone residence shows 4 feet of horizontally laminated gray sandy and micaceous clay. This material is about on a level with material of the same kind at the pothole and is probably a continuation of the same deposit, though the physical aspects of this formation are so variable that the character of its material might change several times within that distance.

Two or three hundred yards south of this cut and less than that distance north of the station at Oxford a vertical bank rises 25 feet above the railroad track on the east side. The track here is at the same level as at the last exposure, so that this section

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[1]Oral communication.

rises at least 20 feet above the top of the other. In the lower half of this cut balls of whitish and pinkish clay are embedded in yellow sand, producing the same "clabber" or curdled milk effect already mentioned, and in the upper half beds of yellow and red sand are interstratified to the top. The deposit appears to be a unit from top to bottom. A few rods farther north in the same exposure 10 to 12 feet of unstratified red sand overlies without apparent break the bed of whitish sand and clay balls. Toward the south the unstratified red sand passes laterally into distinctly stratified red and yellow sand. A rod farther north the "clay ball" deposit is underlain by stratified red sand and overlain by similar sand unstratified, and still a little farther north the "clay ball" deposit comes to the top of the cut, underlain by the red sand, which here becomes pink and light purple.

The "clay ball" deposit in the Isom Ravine is plainly a part of the Wilcox and gives no suggestion of a break between the typical Wilcox clay and these sand and clay deposits. The sections already described offer very good proof that they pass without break into the red sand that overlies them. A section 1 mile north of the station and just west of the railroad track, opposite the mile-board marked on the south face C 571, is exhibited in a maze of deep gullies. At the north end of the section, where the material exposed is 25 feet deep, the strata consist entirely of white and purplish sand, intricately cross-bedded toward the bottom, passing upward by insensible transition into yellow and red stratified sand and toward the top into red unstratified sand, which is covered by a veneer of surface loam. In the same exposure a few rods to the south the whitish "clay ball" effect is very marked, and this material occupies the position in the section which the white and purple sands occupy at the north end of the section. It passes laterally by easy transition into the sand, which, as stated, passes without break into the surficial unstratified red sand.

These detailed descriptions are given to show the relation of the subsurface deposits of unstratified red sand to the undoubted Wilcox sand, for the reason that their red color and unstratified condition have been regarded as diagnostic features of the "Lafayette" formation. At innumerable outcrops around Oxford and throughout the middle Wilcox area the unstratified red sand passes downward by easy gradations into stratified deposits of sand of various colors. The only break seen in the series exposed in Isom

Ravine is that between the uppermost red sand and the underlying sand and "clay ball" deposit. As the "clay ball" deposit in that ravine is of Wilcox age, and as the same "clay ball" deposit in the outcrop west of the railroad track described above grades without break into white and purple stratified sand, which in turn passes upward into unstratified red sand at the top of the section, the conclusion is inevitable that the red sand belongs to the same geologic unit as the underlying material. Furthermore, in the section in Isom Ravine this deposit is obviously in perfect conformity with unquestioned Wilcox beds.

A few rods north of the Stone residence, half a mile north of the station at Oxford, on the east side of the railroad track, is the "nose" from which Berry collected his first fossil plants from this locality, though he afterward collected from Isom Ravine. The section follows:

	Feet
4. Brown loam, forming the soil	2 to 5
3. Red unstratified sand	2 to 4
2. Clay and sand, with pinkish, plastic leaf-bearing clay nodules. In places the clay occurs in large, rather distinctly stratified masses that lie with the stratification planes at all angles, some of them practically vertical. The larger masses are angular and more like slump than water-transported material	7
1. Cross-bedded yellowish, reddish, brownish, and purplish coarse sand with large angular blocks of ferruginous sandstone, which are distinctly in place	10

These materials merge laterally into one another, so that, except for the surface brown loam, they apparently are included in one formation.

The sand and "clay ball" deposits are seen in nearly all the cuts around Oxford, associated with red sand in all sorts of relations, in places overlying them, in other places underlying them, and in still others sandwiched between them or merging laterally into them. There can be no doubt that both belong to the same formation.

The red unstratified sands usually found at the tops of the exposures immediately in contact with the brown loam (where that material is present), are obviously vertically continuous with underlying stratified red sand, which in turn continues downward into yellow and white sand that all recent observers consider Wilcox.

Crider[1] and Brown[2] both placed in the Wilcox the 35 feet of beds exposed at the wagon bridge over the railroad cut south of the station at Oxford, except the brown loam at the top and about 6 feet of red unstratified sand immediately below the loam. No one who has examined this noted cut in recent years thinks of placing the basal portion in the "Lafayette."

The following section is exposed on the west side of the railroad track a few rods north of the bridge:

	Feet
4. Gray to white sand, with thin intercalated beds of reddish sand. The red sand is of "Lafayette" type, but is plainly weathered and oxidized sand of lighter color. The color gradually changes toward the top from white with reddish partings to more conspicuous red bands between the white, which becomes yellowish and finally by easy gradations passes into the typical unstratified red "Lafayette" sand. No break is apparent in the series	20
3. Below No. 4 and just above No. 2 there are thin, more distinctly clayey partings, which form slightly protruding shelves	½ to 2/3
2. The material of No. 1 passes above into somewhat lighter gray sand, rather coarse-grained	3
1. From track level up to No. 2 the material is gray, clayey sand, distinctly and regularly stratified, which shows pinkish and purplish mottlings	10 to 12

On the east side of the track, just north of the bridge, a small amphitheater with vertical or slightly overhanging walls has been formed by caving after recent heavy rains. The lower half of the face of the cave is concealed beneath slump, but the upper half gives a good exposure. Considerable cross-bedding of the sands was noted here, especially in the material at the base of the exposure, which is less clayey than that on the west side of the track. The color is yellowish, grayish, and brownish, and the deposit shows small, thin, inconspicuous pinkish clay partings and lenses. The thickness of the beds exposed is 5 feet.

Above the basal beds 3½ feet of whitish sands, markedly cross-bedded, with reddish bands, very conspicuous and irregular are exposed.

Above the whitish sand, to the top of the exposure, lie yellowish-red sand, rather distinctly stratified and cross-bedded below but uniformly red and unstratified toward the top. The upper

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[1]Crider, A. F., Geology and Mineral Resources of Mississippi: U. S. Geol. Survey Bull. No. 283, p. 64. 1906. Also oral communication.

[2]Brown, C. S., Lignite of Mississippi: State Geol. Survey Bull. No. 3, p. 21. 1907.

third of the section shows entire absence of stratification or lamination. The only suggestion of a break in this section is at the line of contact between the uppermost red sand and the middle whitish cross-bedded sand. At the south end of the section an apparent unconformity is marked by a thin ferruginous sandrock parting a quarter of an inch thick. This line of contact shows small angular irregularities, but the apparent break marked by the iron laminae disappears within 10 feet, and the north half of the exposure shows no sign of a division, presenting an unbroken wall of unstratified, structureless red sand.

On the south side of the bridge the exposures repeat the features that are shown all along the exposures north of the bridge—a gradual transition without break from basal material, now universally regarded as Wilcox, into the structureless red sand toward the top, which have been regarded as "Lafayette."

The great cuts on the railroad, 1¼ mile north of the station at Oxford, repeat the same evidence. They contain considerably more clay in regular, thin beds interstratified with the sand, generally showing light colors at the base of the cut but becoming yellow and more sandy upward and finally passing without break into the red sand at the top. This red sand passes laterally by gradual change from a stratified to an unstratified condition. In the northernmost great cut, 200 or 300 yards from the cut last mentioned, the gray clay beds, which are weathered reddish, are interfingered with beds of the red overlying sands in such a way as to leave no doubt that they are all parts of one formation, from bottom to top.

One and one-half miles south of the courthouse at Oxford, in Dr. B. F. Linder's pasture, a southfacing slope shows numerous deep washes. The whole slope for 200 yards is deeply dissected by erosion, presenting a striking picture of "badland" topography on a small scale. The washes radiate from the upland surface to the south, southeast, and east. The formations here include a few feet of brown loam, which overlies and apparently merges into red unstratified sands which attain a maximum thickness of 10 feet and below which lie gray stratified and white and yellowish-gray sands, mostly cross-bedded.

The most easterly wash of the series which runs almost due east and west is the largest, and it exposes the following beds in its nearly vertical walls:

	Feet
5. Brown loam (at top)	3 or 4
4. Deep-red unstratified sand, which seems to merge into bed No. 5 as if one deposit	10
3. A ferruginous cross-bedded plate rock at bottom of bed No. 4, formed by deposition of iron at its base	1/12 to 1/6
2. Gray clay with brownish joints; unconformity indicated with bed No. 3 by an uneven surface	4
1. Beds of medium fine sand, brightly and variously colored at the head of the wash, but rather uniformly light-gray lower down the ravine. Thinly stratified and cross-bedded	12

In this wash everything is conformable below the red sand (No. 4), which lies unconformably upon the clay.

The wash immediately west of the one just described, and almost connected with it by the erosion of the separating wall, shows the same materials and the same relations. Here, however, the red sand is only about 3 feet thick and overlies unconformably the gray clay. The lowermost gray sand of both these sections is highly micaceous.

The most westerly but one of this series of washes shows the same materials as the others, but here the red sand, which is 12 feet thick, contains thin laminae of white clay, and is noticeably cross-bedded. The narrow gorge that leads up from the large wash cuts through the red sand into the clay, showing that the upper surface of the clay slopes decidedly toward the south. In the next wash, a few yards to the west, the upper surface of the gray clay slopes down at a sharp angle to the north, which strongly suggests that the clay is a lens. As a thin bed of whitish clay similar to that in the lower mass appears near the top of the red sand toward the head of the wash, and as all the sand is cross-bedded and shows white clay laminae, it is probable that all the beds exposed in these washes (except the surface loam) are of middle Wilcox (Holly Springs) age.

About a mile east of Oxford, on the Lafayette Springs road, a few rods south of the residence of A. B. Burt, a deep wash reveals the following beds:

	Feet
3. Brown loam (at top)	2 to 3
2. Red sand, indistinctly stratified	8 to 10
1. Gray clay that contains pinkish streaks and sand variously stratified and cross-bedded; locally a 12-inch bed of lignite is exposed. Total thickness of the gray clay, clayey sand, lignite, and other materials	18

The towns of Lamar, Holly Springs, and Oxford are built on beds that lie near the middle of the Holly Springs division of the Wilcox, within the zone of pottery and ball clays. The foregoing sections for the most part show more clay than the exposures a few miles east or west. For example, 4 or 5 miles east of Oxford deep exposures reveal much less clay than those in the vicinity of Oxford. The same is true both east and west of Holly Springs. On the road to Burgess, 3 miles west of Oxford, an eastward-sloping hill shows the following beds:

	Feet
3. Brown loam (at top)	2½ to 3
2. Reddish-yellow sand, partly cross-bedded, with a lens of white clay about the middle that is 2 feet thick at the maximum but thins eastward, and finally pinches out; the sand weathers to red on the east slope of the hill. Total thickness	20
1. White to purplish cross-bedded sand to bottom of hill	20

Aylesville.—A long hillslope at Aylesville, 5 miles west of Oxford, exposes only red sand. In all the region towards Burgess, 7 miles west of Oxford, the hill slopes show red, yellow, and white sand but very little clay. A well 127 feet deep on the upland at Burgess went through a few feet of surface loam, a few feet of red sand, 2 feet of ferruginous rock, and white sand all the rest of the depth to the bottom.

Burgess.—One of the most striking series of exposures of the Holly Springs sand is shown in a maze of great ravines washed in the sides of a high ridge on the Burgess and Batesville road, 15 miles east of Batesville, about a mile from the junction with the Water Valley road. These washes, which are on the east side of the road, form a great labyrinth of deep gullies and gorges cut in a prominent rounded hill slope. These gullies are fully 40 feet deep and form very striking features. No one could possibly descend into them except at places well down toward the base of the ridge, nor could any one on the inside readily get out. A section of the main gully at its deepest part reveals the following beds:

	Feet
4. Brown loam	10
3. Red sand, indistinctly stratified	15
2. Clay and sand, intimately mixed, pinkish-white, and showing distinct stratification	10 to 12
1. Red sand, rather coarse, stratified. Near the lower end of the gully the sand becomes white and red, interstratified; at the upper end it is distinctly purple	15

East of Sardis.—Toward the western border of the belt of outcrop of the Holly Springs sand exposures are scarce, because the surface is deeply covered with loess and Pleistocene terrace deposits. The most westerly exposure so far examined is at the cotton gin of Dan F. Smith, 6 miles east of Sardis, Panola County, as follows:

	Feet
4. Loam	4 to 5
3. Basal loam (or gumbo) with a zone of light-colored soil in the middle. This zone is seen in most of the region around Batesvlle and Sardis	8
2. "Lafayette," or terrace (?) sand and gravel; sand yellowish in the upper 2 to 3 feet, and pink and purplish-red in the lower 7 feet. Total thickness	10
1. Holly Springs sand, rusty yellow, variously cross-bedded, rather coarse-grained, micaceous; contains ferruginous sandstone plates, tubes, and corrugated masses. No gravel, except in a transition upper zone about 1 foot in thickness, where a few pieces occur	9 to 10

Here bed No. 1 is undoubtedly Wilcox, and it has all the characteristics of the middle Wilcox or Holly Springs sand. The contact lies west of this point, perhaps at no great distance.

Water Valley.—Outcrops about Water Valley, Yalobusha County, everywhere expose red and variegated sand with lenses of white clay like those seen about Oxford and Holly Springs. In the vicinity of Pine Valley, 10 miles east of Water Valley, the iron carbonate ore and clay of the Ackerman formation appear.

Calhoun County.—East of Water Valley, in the vicinity of Banner, Calhoun County, and for several miles toward the south and southwest, prominent hills show a thick capping of the Holly Springs sand. The sand is coarse-grained, yellow and red, cemented in places into thick, irregular, brown masses of sandstone with tubular flutings.

Coffeeville.—A striking and interesting section is exposed three-fourths of a mile northwest of Coffeeville, on the Water Valley road. Near the top of the first hill north of Coffeeville, on the west side of the road, a large amphitheater, 30 feet deep, which is cut out of the hill, exposes the following beds:

	Feet
5. Brown loam	4 to 5
4. Sandwiched between the loam and bed No. 3 in the western half of the exposure there is a bed of red sand, which rises noticeably toward the west	5 to 6
3. Tawny clayey sand, buttressed; beds dip slightly westward to the head of the wash, then gently rise again	5 to 6

	Feet
2. Red sand, unstratified lighter-colored below	10
1. The red sand of bed No. 2 passes downward without break in continuity of deposition into white sand on the east side of the amphitheater, and the white sand passes laterally into reddish-yellow sand on the west side	12 to 14

Other localities.—The Holly Springs formation is not prominently developed south of the latitude of Grenada, in Grenada County, perhaps because of the overlapping of the Claiborne group, and also because the threefold division so noticeable in northern Mississippi is much less marked in the southeastern part of the outcrop. The narrowing of the entire outcrop of the Wilcox to the southeast, the small development of the Holly Springs sand, and the total absence of the Hatchetigbee beds, suggest strongly that the Claiborne has overlapped and covered these formations in the territory between Grenada and Lauderdale counties.

In Webster County, 2½ miles north of Walthall, the Holly Springs sand is exposed as a small outlier in a high bluff on the right of the wagon road. The material here is stratified sand of different colors, is micaceous, and in certain zones lignitic. Everywhere in this vicinity the lignitic clay and lignite of the underlying Ackerman formation are exposed in creek beds and shallow wells.

On some of the hills in the area where the Holly Springs sand crops out there are exposures of quartzite which have been interpreted as outliers of Claiborne strata. Some of these beds, however, may be quartzitic facies of the Holly Springs sand. One of the most notable of these exposures is in Webster County, 8 or 10 miles southwest of Walthall. It is 3 miles long and half a mile wide, and occupies a ridge between two creeks. The nearest Claiborne outcrop is at least 6 miles toward the southwest.

At Mabus, on the Gulf, Mobile & Northern Railroad, about half-way between Reform and Ackerman, Choctaw County, the railroad cuts through the divide between the Pearl River and Big Black River drainage basins. A deep cut at this point exposes extensive deposits of white, yellow, and red sand, which overlie the gray clay of the Ackerman formation. Between Mabus and Reform the Ackerman clay is exposed at the surface, but yellowish sand overlaps the clay toward the south and reaches a maximum thickness of 40 to 50 feet in the great cut at Mabus. Here the sand overlies the Ackerman beds unconformably. This may be Holly Springs sand, but possibly is Naheola. At Blanton's Gap, near

Ackerman, a similar capping of coarse red, yellow, and white sand was interpreted by Crider[1] as "Lafayette" but should probably be referred to the basal part of the Holly Springs sand. Between Ackerman and Louisville, in Winston County, much of the highlands about the headwaters of Pearl River is capped by the red and yellow sand probably of this formation, in places to a thickness of 35 to 50 feet.

In all exposures the clay and lignite of the Ackerman formation constitute the base of the hills in the regions referred to above.

In Lauderdale County, 2 miles northeast of Marion, where the surface rises 190 feet above the bottom lands of Souwashee Creek at Marion, there is one of the most remarkable exposures of Wilcox sand in Mississippi. Here a series of great washes in the hillside, locally called "the big sand cave," has exposed 160 feet (measured by barometer) of beds interpreted as middle Wilcox or Holly Springs sand. The sand is distinctly stratified except at the top, and is beautifully cross-bedded throughout. For about 20 feet below the top it is the usual red, oxidized sand, without stratification, but it passes by easy gradations through lighter red and yellow sand into a great mass of light yellowish-brown and white sand, which shows distinct stratification and cross-bedding. These lighter sands are 140 feet in thickness. At the bottom they show intercalated thin laminae of light-gray clay, and within a few feet pass without break into rather thinly laminated pure-yellow clay. All these beds appear to be fresh-water deposits, and no evidence of marine deposits is seen around Marion, although on the old railroad line halfway between Marion and Meridian "blue dirt" containing marine shells is reported to occur. These marl beds are supposed to lie at the Bashi horizon, at a stratigraphic level above the sand exposed in the "big sand cave," mentioned above. This interpretation is based upon the following evidence: The stations at Marion and Meridian are within a few feet of the same elevation above sea level, as shown by the railroad surveys. The top of the Bashi formation is exposed at the base of the hills 1½ miles southeast of Meridian, and the beds in this vicinity have a dip of not less than 30 feet to the mile toward the south. With this dip the top of the Bashi formation in the hills 1½ miles north of Marion,

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[1]Crider, A. F., Geology and mineral resources of Mississippi: U. S. Geol. Survey Bull. No. 283, p. 26. 1906.

and 8 miles north of the exposure on the Meridian & Memphis Railroad would lie 240 feet above the station at Marion. But the hills in that vicinity reach a height of only 190 feet above the valley and 170 feet above the station. If it is assumed that the Bashi beds once capped the hills and had a thickness of 70 feet, though most of them have been removed by erosion, the underlying 160 feet of sands would seem to represent in the section the Holly Springs sand of northeastern Mississippi. Hilgard[1] states that some of the fossiliferous marine Wilcox caps the highest hills around Marion, although it was referred by him to the Claiborne.

On September 10, 1928, the writer in company with R. E. Grim carefully examined the site of old Marion for evidences of fossils. The highest point, known as Court House Hill, and slopes leading down from it, were examined without result. Old nails, brick bats, pieces of china, and other relics of human occupation, and among these scattered sparsely over the hill and slopes were a few recent oyster shells, but not a suggestion of fossils was seen. The formation of the hill is sand, resembling that in the great "Sand Cave," two or three miles to the northwest, devoid of visible fossils.

BASHI ("WOODS BLUFF") FORMATION

GENERAL FEATURES

Name.—The name Bashi was first applied to this formation in Alabama by E. A. Smith and L. C. Johnson in 1887.[2] As described by them the formation consists of fossiliferous marine marl and associated lignitic clay, lignite, and sand, which have their type exposures at Woods Bluff on the Tombigbee River, also just below Johnson's Island on the Alabama River, and on Bashi Creek and its tributaries in Clarke County, Ala. In originally describing the formation they called it the Woods Bluff or Bashi series, but in 1892 and 1894, they designated it as the Bashi or Woods Bluff group (or series). From that time until 1907 Bashi seemed to be the preferred term. In 1907,[3] Smith adopted the name Bashi formation and used Woods Bluff in parenthesis after it. The name now generally accepted for the formation is Bashi, and that name is therefore used in this report.

[1]Hilgard, E. W., Report on the geology and agriculture of the State of Mississippi, p. 118, 1860. (The old Marion of Hilgard stood in the high hills east of the present station.)

[2]Smith, E. A., and Johnson, L. C., U. S. Geol. Survey Bull. 43, 1887.

[3]Smith, E. A., "Underground Water Resources of Alabama," Ala. Geol. Survey. 1907.

These beds lie well toward the top of the Wilcox of Alabama, and at their type exposures conformably underlie the Hatchetigbee formation, which is overlain by the Tallahatta formation.

Fossils were first collected at this horizon in Mississippi in 1887, at "McKay's marl bed" on Souwashee Creek, 2 miles south of Meridian, by L. C. Johnson. In 1912, C. Wythe Cooke and E. N. Lowe searched without success for "McKay's marl bed," but they obtained a few poorly preserved fossils from a bed of yellowish-brown oxidized glauconitic sandy marl that outcrops on the roadside at the base of Seymours Hill, 1½ miles southwest of Meridian. The fossils were not identifiable, nor was their number sufficient to aid in the positive determination of the horizon. In 1915, E. N. Lowe examined a new cut on the Memphis & Meridian Railroad through a point of the sand hill about 300 yards south of the point examined in 1912 and found at the base of the cut a few feet of highly fossiliferous sand that contains great boulder-like bluish-gray limestone concretions. The fossils, according to C. Wythe Cooke, furnish definite evidence that the beds lie at the Bashi horizon.

FIG. 10. A.

A. Purdue's Cut on the Meridian and Memphis Railroad, one and one-half mile southeast of Meridian. The exposure consists of 60 feet of gray clays overlying a few feet of highly fossiliferous glauconitic sand at the bottom, with occasional large blue calcareous fossiliferous concretions. The fossiliferous sands are Bashi formation, the overlying clays are Hatchetigbee formation. Photo by L. W. Stephenson

This locality was revisited by Cooke in 1916, and a larger collection of fossils was made, including a number of fossil plants from the lignitic clays that overlie the sand containing the marine fauna. E. W. Berry[1] determined these plants to be of Grenada or Hatchetigbee age.

Most outcrops in the immediate vicinity of Meridian, especially westward, exhibit Hatchetigbee material. Northeast of Mobile & Ohio Railroad Station, opposite the freight depot, a cut exposes undoubted Hatchetigbee of stratified lignitic sandy clays to a thickness of 10 feet. About 1 mile east of the railroad crossing a road leading off to the left of the concrete road shows a good exposure on the hillside consisting at the base of 3 or 4 feet of bluish-gray calcareous concretions, large and rounded, like those above mentioned as characteristic of the Bashi formation. This locality is known as Bonita. Above the limy concretions of Bashi the cut shows horizontally bedded dark lignitic sandy clay strata of Hatchetigbee to a thickness of 15 feet. From Bonita toward Vimville the rolling topography shows on the highest ridges yellow sands of basal Claiborne, beneath which in the bases of the hills and in all the intervening lower levels the stratified lignitic sands show the presence of the Hatchetigbee.

Towards Russell, one mile east of Russell station a deep cut on the wagon road exposes 12 feet of gray Hatchetigbee (?) sandy clay overlying a foot or two of dark glauconitic sand, probably Bashi. It will be seen that the Bashi has in Mississippi a very small outcrop immediately around Meridian. The Hatchetigbee extends considerably farther east and west, but is apparently limited to Lauderdale County.

Lithology and stratigraphy.—In the outcrops in the high hills southwest of Meridian, 110 feet of fossiliferous glauconitic sandy marl, lignitic clay, lignite, and light-colored cross-bedded sand—all referred to upper Wilcox—underlie the beds of the Claiborne group, which cap the hills. Only the basal 10 to 15 feet consists of fossiliferous sand and marl of recognizable Bashi age. The overlying dark clay, sand, and lignite represent the Hatchetigbee formation of Smith. In Alabama the fossiliferous marl forms the topmost beds of the Bashi formation, and is underlain by lignitic clay, lignite, and sand to the thickness of about 60 feet. The cuts south

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[1]Berry, E. W., U. S. Geol. Survey Prof. Paper 108-E, pp. 61-72. 1917.

of Meridian fail to expose these underlying beds of the formation, but wells pass through lignitic beds and strike water-bearing sands of the Bashi at 62 feet.

FIG. 10. B.

B. Large rounded fossiliferous blue lime concretions exposed in the marl bed of the Bashi formation, at the base of Purdue's Cut on the Meridian and Memphis railroad. Same locality as A. Photo by E. N. Lowe.

Paleontology.—No extensive collections have been made from these beds in Mississippi; the largest is that of L. C. Johnson from "McKay's marl bed" in 1887:

Station 2105.—"McKay's marl bed," Souwashee Creek, 2 miles south of Meridian.

(L. C. Johnson, collector; identified by C. Wythe Cooke)

Tornatellaea bella Conrad.
Cyclichna aldrichi Langdon?
Philine alabamensis Aldrich.
Cyclichna sylvaerupis Harris.
Pleurotoma cainei Harris.
Pleurotoma terebralis Lamarck var.
Pleurotoma 3 species.
Cancellaria tortiplica Conrad?
Plejona petrosa var. tuomeyi Conrad.
Pseudoliva vetusta (Conrad).
Cornulina armigera (Conrad).
Calyptraphorus trinodiferus (Conrad)?
Siphonalia subscalarina (Heilprin).
Turritella clevelandia Harris var.
Lunatia newtonensis (Meyer and Aldrich).
Solariella louisiana Dall.
Dentalium microstria Heilprin.
Dentalium sp.
Cadulus abruptus (Meyer and Aldrich).
Nucula sp.
Leda robusta Aldrich.
Leda pharcida Dall.
Ostrea trigonalis var. sylvaerupis Harris.
Ostrea sellaeformis Conrad.
Corbula aldrichi Meyer.
Corbula alabamiensis Lea.
Corbula cf. C. engonata Conrad.
Spisula sp.
Tellina trumani Harris.
Tellina virginiana Clark.
Meretrix nutaleiopsis Heilprin.
Meretrix subimpressa (Conrad) var.
Lucina subvexa Conrad.
Phacoides (Miltha) pandatus (Conrad).
Phacoides (Parvilucina) smithi Meyer.
Venericardia planicosta (Lamarch).
Venericardia cf. V. rotunda Lea.
Diplodonta hopkinsensis Clark?

Johnson also collected a few fossils[1] in 1888 from McLemore's Hill, near Meridian (Station 2134):

Pseudoliva vetusta var. Tuomeyi (Conrad).
Cornulina armigera (Conrad).
Ostrea sp. (fragment).
Venericardia planicosta Lamarck.

In 1915, E. N. Lowe collected at Purdue's cut on the Memphis & Meridian Railroad, 1½ miles southwest of Meridian, the following fossils[2] (Station 7267a):

Plejona petrosa var. tuomeyi (Conrad).
Plilene alabamensis Aldrich.
Pseudoliva vetusta (Conrad) var.
Buccinanops sp.
Cornulina armigera (Conrad).
Cyllene bellana Harris.
Tuba antiquata Conrad.
Solariella louisiana Dall.
Turritella sp.
Natica sp.
Cadulus abruptus Meyer and Aldrich.
Ostrea thirsae Gabb? (Woods Bluff var).
Corbula alabamiensis Lea.
Phacoides (Miltha) pandata (Conrad)?
Cytherea subimpressa Conrad.
Venericardia planicosta (Lamarck).

LOCAL DETAILS

All the outcrops of this formation which have been critically studied are within a few miles of Meridian.

"**McKay's marl bed.**"—The "McKay's marl bed" of Johnson has only lately been rediscovered. Unsuccessful attempts were made by Cooke and Lowe in 1912 and by Lowe in 1915 to locate this bed. It was thought that the stage of water in Souwashee Creek, or the alluvium that had been deposited by the creek since Johnson's visit, had concealed the outcrops of marl, for nowhere were any of them seen along the creek beds south of Meridian. The nearest approach to marl beds noted by the writer in 1915 was on the west side of Souwashee Creek at the water tanks of the Mobile & Ohio Railroad, which were on a low bluff 15 feet above the creek. The upper half of this bluff reveals indistinctly stratified, tawny, or yellowish sandy clay, nonfossiliferous, that lies unconformably upon a bluish-gray sand, which weathers yellowish and is somewhat glauconitic. On close examination this sand was found to be slightly fossiliferous, a fairly well preserved *Leda* proving the deposit to be marine. It was supposed that this fossiliferous sand underlay the whole creek valley and that its exposure at some point in the valley on the McKay property furnished Johnson his fossils.

[1]Identified by C. Wythe Cooke.
[2]Identified by C. Wythe Cooke.

Early in 1920 W. E. Crane,[1] of Washington, D. C., while visiting eastern Mississippi on a collecting trip, located the original excavations of McKay in the face of the bluffs on the east side of Souwashee Creek, 3 miles southwest of Meridian.

Purdue's cut.—On the south side of the creek valley directly across from the Mobile & Ohio water tanks, the new Memphis & Meridian Railroad has cut off the point of a ridge 300 yards south of the wagon road that ascends Seymour's Hill. This cut which is known as Purdue's cut, exposes 45 feet of fresh surface. The base of the cut at track level is 15 feet above the creek flat. Slump material has covered the outcrop of the beds below track level, but above that level to the top of the cut a most interesting section is exposed as follows:

Section at Purdue's Cut, on the Memphis & Meridian Railroad, 1½ miles south of Meridian.

	Feet
Hatchetigbee formation:	
9. Thinly laminated light-gray clay and sand alternating, becoming yellowish above and passing upward into yellowish-red soil	12
8. Light-gray sandy clay	1¼
7. Dark lignitic clay, jointed and massive below, becoming lighter-colored and more thinly laminated above; weathers into thin, shaly flakes; nonfossiliferous	18
6. Grayish-brown sand; nonfossiliferous	½
5. Dark-gray thinly laminated clay	1
Bashi formation:	
4. A thin zone of reddish glauconitic sand, with blue clay mottlings; nonfossiliferous	1
3. Yellowish-gray nonfossiliferous glauconitic sand	4½
2. Yellowish-gray, highly fossiliferous calcareous sand or sandy marl; fossils mostly rather large, some quite perfect. Species not numerous, but individuals, especially of certain univalves, very abundant, particularly so in the basal 12 inches. In places highly indurated calcareous bluish-gray nodular masses of marl occur. On the west side of the track these nodular masses are immense, some of them several tons in weight; they are partly embedded but project above the surface like great toadstools. They are very dense, highly fossiliferous, and decidedly bluish in the interior	6
1. Thin beds of alternating dark-gray clay and gray sand, thickest at the north end of cut, dip south and disappear at track level	2 to thin edge

The fossils from bed No. 2 of this section (Station 7267a) are listed on page 104. Cooke[2] noted a probable unconformity between the beds referred to the Bashi and those referred to the Hatchetigbee.

[1]Oral communication.

[2]U. S. Geol. Survey Prof. Paper 108-E, p. 61. 1917.

The beds of this section dip perceptibly toward the south. In Alabama Smith places the fossiliferous marl bed at the top of the Bashi formation, so that all the overlying materials exposed in this cut are probably to be referred to his Hatchetigbee formation. A few rods north of this cut wells sunk to a depth of 62 feet strike water in the sands of the Bashi. The water stands within 3 feet of the surface.

Seymour's Hill.—The section exposed along the wagon road that passes over the point of Seymour's Hill reveals the relation of these beds and of still higher beds, of probable Wilcox age, to the Claiborne, which caps the hill.

Section exposed in road at Seymour's Hill, 1½ miles south of Meridian.

	Feet
Tallahatta formation:	
17. Light-gray thinly bedded siliceous claystone of Tallahatta (Claiborne) age. This rock is very light and brittle, finely jointed, joints and lamination planes iron-stained. Iron stains commonly occur in thin concentric or wavy lines independent of lamination. Sparingly fossiliferous. Characteristic Claiborne material caps the hill	40
16. Greenish-gray rock, streaked and stained with iron, very hard and tough, almost quartzitic, coarse-grained	3
15. Gray, much-jointed clay	3.5
14. Greenish-gray glauconitic sand, coarse rounded grains	10
13. White and yellowish sand, showing cross-bedding; upper 4 feet mottled with leopard-like spots	25
12. Red and yellow sand containing sandstone boulders at the base and a dark-gray clay parting several feet thick near the middle (exact thickness unknown because largely covered with slump)	75
Hatchetigbee formation:	
(Unconformity)	
11. Dun-colored clays, passing up into light-gray clay, more or less weathered red along the lamination planes	25
10. Iron-stained sandy parting, somewhat indurated	1
9. Lignitic dark-gray clay, showing darker thin lignitic bands	7
8. Light-brown lignitic clay, becoming almost black toward top	4
7. Ferruginous parting (1 inch thick) at base of brown clay.	
6. Fine white sand, laminated and clayey in the uppermost 4 feet	15
5. Yellowish sand with here and there thin gray clay partings which show pink impressions of plants	10
4. Gray clay, lighter-colored than No. 3 and with less sand, no glauconite, no observed fossils; red iron-stained joint planes, distinctly laminated; here and there thin bands of lignite toward the top; general color becomes darker for 3 or 4 feet to the top	15
Bashi formation:	
3. Very dark greenish-gray sandy clay, slightly glauconitic, having a few small marine fossils	1
2. Highly ferruginous parting ¼ to ½ inch in thickness.	
1. Yellowish-brown oxidized glauconitic sandy marl containing a few poorly preserved marine fossils, bivalve shells being apparently the most abundant	4

In this section the uppermost two or three members are undoubtedly Claiborne, and the basal beds are undoubtedly Wilcox, but the age of 110 feet of the nonfossiliferous sand is still in doubt. According to Dr. E. A. Smith's interpretation of the sections in Alabama along the Tombigbee probably all the beds in this section below No. 15 should be regarded as Wilcox. However, in this section and in all the adjoining regions there is included in the base of the Claiborne the whole thickness of underlying sand, which in this section includes at least Nos. 15, 14, 13, and 12—that is, the thickness of 110 feet of sands which lie between the Tallahatta rock and Wilcox clay. This interpretation has been followed because here and at Lost Gap, 6 miles west of Meridian, the Tallahatta rock and underlying sand lie unconformably upon the lignitic beds of the Wilcox.

Subway in Meridian.—In the excavation made for the subway in Meridian beds of yellow sand like those exposed at Purdue's cut were penetrated at a depth of 16 feet and also beds of gray clay. These beds are probably the same as those at Purdue's cut, but they appear not to be fossiliferous. The total thickness of these beds of sand including the thickness at Purdue's cut, must be at least 40 feet.

Marion.—In cuts on the old roadbed of the Mobile & Ohio Railroad west of the present road, between Meridian and Marion, beds of bluish sandy marl, or so-called "blue dirt," which are exposed, contain marine fossils. At Marion on the slopes east of Souwashee Creek the following exposure occurs in the public road:

	Feet
2. This bed passes without break into greenish-gray to yellowish sand, distinctly stratified, which passes up into red sand faintly stratified at bottom, but stratification lost in a short distance; upper sand presents the red, massive characteristics of the so-called "Lafayette" but is distinctly a weathered product of the gray sand. Neither this nor the underlying gray sand is fossiliferous	45
1. Lignitic clay, at bottom, a few feet above level of the creek flat; becomes lighter and somewhat sandy above, rather heavily bedded below; joints large and wide apart, showing yellow flaky and shaly iron partings which project out like small dikes; nonfossiliferous	20

The lignitic clays of bed No. 1 are exposed at Kinard's water mill (the old Meadow mill) a few hundred yards north of the section, on a spring branch that flows into Souwashee Creek. An excavation in the hillside for the overshot wheel exposes 10 to 12 feet of very dark lignitic clay. From the known dip of the Bashi beds east and southeast of Meridian, it would seem that unless the Bashi is much thicker here than in Alabama the section given above must represent the top of the middle or Holly Springs division of the Wilcox. Northeast of Kinard's water mill the surface of the country rises into high sand hills and ridges. A mile northeast of the water mill the tops of the uplands rise 190 feet higher than the bridge over Souwashee Creek at Marion (barometric measurement).

HATCHETIGBEE FORMATION

GENERAL FEATURES

Name and correlation.—The name Hatchetigbee[1] was first given to the uppermost beds of the "Lignitic" (Wilcox) of Alabama, which overlie the Bashi ("Woods Bluff") formation, and only recently has the formation been identified by Berry[2] in Mississippi. Berry has also shown that the Hatchetigbee formation is approximately the equivalent of the Grenada formation, which it resembles in some respects.

Stratigraphic relations.—In the vicinity of Meridian the Hatchetigbee formation appears to rest conformably upon the Bashi formation. At Seymour's Hill and at Lost Gap (see pp. 106, 107), the formation is overlain unconformably by the basal sand of the Claiborne group.

Lithology.—The formation is composed chiefly of more or less laminated and lignitic brown, yellow, and gray clay, interbedded with thin and thick beds of white, gray, yellow, and brown sand. In places the clay becomes very dark brown to almost black. The formation was evidently laid down in very shallow waters and in part in swamps.

Structure.—In Lauderdale County the dip, where it has been observed along the bases of the hills east of Meridian, is at least 25 feet to the mile toward the south, although a reverse dip has been observed east of Meridian. In the section at Seymour's Hill, where the entire thickness is exposed, the formation is 77 feet thick.

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[1]Smith, E. A., and Aldrich, T. H., Ala. Geol. Survey, Bull. 1, pp. 7-14, 44-60. 1886.

[2]Berry, E. W., U. S. Geol. Survey Prof. Paper 108-E, pp. 61-72, Pls. XXIV-XXVI. 1917; Lowe, E. N., Miss. Geol. Survey Bull. 14, pp. 70-72. 1919.

Distribution and physiographic expression.—The formation outcrops in a narrow belt, probably nowhere more than a few miles wide, which trends east and west across the central part of Lauderdale County. The outcrop appears to be terminated near the western boundary of the county by the overlapping strata of the Claiborne sand.

To the east and southeast of Meridian the beds of the Hatchetigbee are exposed on the steep slopes of the hills capped by the Tallahatta formation. At a point 1½ miles southeast of the railroad station at Meridian the wagon road crosses Souwashee Creek and passes up Seymour's Hill. This hillslope presents an interesting section, which is given on p. 106 under the discussion of the Bashi formation.

In the more subdued hills and rolling lands to the west and northwest of Meridian, where for 8 or 9 miles the Hatchetigbee beds come to the surface, the outcropping clays produce a less rugged topography than that produced by the Claiborne beds to the south.

Paleontology.—In the spring of 1916 Dr. C. Wythe Cooke, of the United States Geological Survey, visited this section and in making a collection of marine fossils from the Bashi formation on the Meridian & Memphis Railroad at Purdue's cut, near Meridian, discovered abundant impressions of leaves in the overlying lignitic clay. A collection of the leaves was submitted to E. W. Berry for identification, and he reported the following:[1]

Species of fossil plants found at Meridian, Miss.

	Previously known range.		
	Lower Wilcox	Middle Wilcox	Upper Wilcox
Lygodium binervatum (Lesquereux) Berry	x	....	(?)
Zamia mississippiensis Berry, n. sp.	....	....	....
Sabalites grayanus Lesquereux	....	x	x
Ficus puryearensis Berry	x	x	x
Nelumbo protolutea Berry	....	....	....
Gleditsiophyllum eocenicum Berry	....	x	x
Dalbergites ellipticifolius Berry	....	....	x
Sapindus mississippiensis Berry	....	x	x
Sapindus formosus Berry	....	x	x
Mespilodaphne pseudoglauca Berry	....	x	x
Mespilodaphne eolignitica Berry	x	x	x
Nectandra lowii Berry	....	x	x
Combretum obovalis Berry	....	....	x
Aralia acerifolia Lesquereux	....	....	x

[1]U. S. Geol. Survey Prof. Paper 108-E, p. 62. 1917.

"It will be seen that of the fourteen species identified from Meridian, three occur in the lower Wilcox or Ackerman formation, eight in the middle Wilcox or Holly Springs sand, and twelve, or all but the two new species, in the upper Wilcox or Grenada formation. In addition it should be noted that several recorded from the middle Wilcox are found only near the top of that division, so that the present assemblage would be referred unhesitatingly to the upper Wilcox or Grenada formation, even were its stratigraphic position unknown. * * * * It would seem indisputable that the lignitic sands overlying the glauconitic marl at Meridian correspond to the Hatchetigbee formation as it occurs to the southeast in Alabama and also to the Grenada formation as it occurs to the northwest.

"The presence of land plants and scattered lignitic material (allocthonous) in the sediments argues for the nearness of a vegetation-covered shore. The legitimate evidence in the Meridian locality, however, justifies more than this inference, for the upper layers of the middle member are not only filled with the remains of land plants, but contain in addition the rootstocks and abundant leaves of what appears to be the Eocene ancestor of the American Lotus. This species (*Nelumbo protolutea*) belongs to a genus whose known living representatives are large perennial herbs growing exclusively in shallow and still fresh water, or occasionally in water that is only very slightly brackish. Were the leaves the only traces of this plant present in the deposits they might be interpreted as having been drifted into an estuary, although their great abundance in all sizes and the fact that the leaves are not deciduous but would have to be torn away from their stout petioles are opposed to such an interpretation. But inasmuch as the clays contain rootstocks which during life creep in the mud at the bottoms of ponds, and as a great abundance of rootlets permeate the clays in every direction, many of them with the root hairs preserved, it is obvious that these remains were not transported but grew on the spot where they are now found.

"They thus afford a record for this locality of a period of changing conditions during which green sands carrying a marine fauna became replaced by littoral sands and muds and these in turn were overlain by the sandy muds of what was probably a shallow pond containing a vigorous growth of innumerable nelumbos or lotuses and receiving the leaves that fell from the trees along its shores."

LOCAL DETAILS

All the striking exposures of the Hatchetigbee formation that have been studied in Mississippi are in Lauderdale County in the vicinity of Meridian. Detailed descriptions of outcrops at Purdue's cut and at Seymour's Hill are given on pages 105, 106, in connection with the description of the local details of the Bashi formation.

GRENADA FORMATION

GENERAL FEATURES

Name.—A series of beds of lignite and lignitic clay, with intercalated beds of gray clay and sand, crops out along the face of the bluffs that border the Mississippi Delta lowlands. Harper[1] briefly mentions a number of outcrops and refers the beds to the Miocene. Hilgard[2] maps these beds with his "Northern Lignitic." Safford[3] calls them the "Bluff Lignite Group," without definitely placing them. Crider[4] noted the occurrence of beds of chocolate-colored clay, 200 to 250 feet in thickness at the top of the Wilcox from Grenada to Memphis.

This division of the Wilcox has been well established as a recognizable unit for many years. Until 1913 the only name given to these beds in western Mississippi was that used by Safford, "Bluff Lignite," which under present-day usage is not permissible. In 1913 they were called the Grenada beds,[5] because of their notable exposures near the town of Grenada, in Grenada County, along the Yalobusha River and its tributary, the Bogue. As is shown elsewhere the Grenada formation is of about the same age as the Hatchetigbee formation.

Stratigraphic relations.—As the beds of this formation are deeply buried under later formations throughout most of their extent, their relations to the underlying formations are revealed at very few places, practically only in well records.

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[1]Harper, Lewis, Preliminary report on the geology and agriculture of the State of Mississippi, pp. 182-222. 1857.

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

[3]Safford, J. M., Geology of Tennessee, pp. 428-431. 1860.

[4]Crider, A. F., Geology and mineral resources of Mississippi, p. 28. 1906.

[5]Lowe, E. N., Mississippi Geol. Survey Bull. No. 10, Iron Ores of Mississippi, p. 24. 1913.

Throughout the greater part of the outcrop of these beds they apparently overlie conformably the sandy Holly Springs, though the absence of the Bashi formation between the two formations probably indicates unconformable relations. The writer has referred to the Grenada certain brown and gray stratified clays exposed in a vertical face 60 feet high at Duck Hill, Montgomery County. These beds pass down without any evidence of break in continuity of deposition into yellow sands, probably of the Holly Springs formation.

The relation of the Grenada beds to overlying terranes may be observed at many places. From Grenada northward along the bluff front the clays and lignites of this group outcrop beneath terrace deposits of sand and gravel, probably of Pliocene and Pleistocene age, which in turn are overlain unconformably by the loess or bluff silt, of later Pleistocene age. As a long time elapsed between the deposition of the Grenada beds and that of these overlying deposits, their contact is marked by a distinct erosional unconformity.

On the hills west of Grenada the Grenada beds are overlain unconformably by materials of lowermost Claiborne age. On the high hills 2 miles east of Grenada a thin veneering of weathered and more or less concretionary glauconitic sand caps the uppermost Wilcox. On the hills west of Duck Hill, Montgomery County, certain concretionary masses, apparently glauconitic, strongly suggest the Claiborne, but there are no continuous deposits. The high hills several miles farther west, are capped by undoubted Claiborne, very much like that which occurs west of Grenada. In all the territory south of Duck Hill the Claiborne overlaps and conceals the Grenada beds.

Lithology.—The Grenada formation at Grenada is composed mostly of lignitic clay and lignite. The clay has been called "brown," "chocolate-colored," and "pink." It is prevailingly dark, its color ranging from chocolate-brown to black, being due to lignitic matter. The chocolate-brown clay becomes much lighter or pinkish on drying. The very dark clay that contains little iron burns white. The clay is nearly everywhere distinctly micaceous, and the beds at some places include considerable fine sand. It occurs generally in thin beds, in which the lamination is very fine and regular, and at many places it shows silvery-white thread-like edges of sandy partings.

Though generally dark, some of the clay of this formation is light gray or, where it is exposed to the action of the weather, even white, for weathering produces a whitish flaky surface which toward the bottom of the exposure is covered with loose slump material.

As already stated, the clay at some places is very sandy, and at others the sand becomes predominant. It may be intimately mixed with the clay in the beds or it may form distinct sand partings, which locally become decidedly sandy beds. On the whole, however, the formation consists mainly of clay, as the Holly Springs beds consist mainly of sand, so that as the two formations dip beneath the lowlands of the Mississippi flood plain the lower beds form an important aquifer and the overlying clays form effective confining beds, producing ideal conditions favorable to artesian flows.

The lignite of this formation, so far as observed, is not so firm as the older lignite of the Ackerman formation but is quite as pure. The color is rich brown, of lighter tint than the earlier lignites, and the specific gravity is lower. The deposits of lignite are perhaps as extensive but of less average thickness.

Distribution and physiographic expression.—In western Mississippi this formation crops out in a narrow, broken band that skirts the Mississippi flood plain. In fact, this part of the formation can hardly be said to have any actual outcrop except in the face of the bluffs that border the Delta and in the banks of streams that have cut through overlying younger deposits as they pass out of the uplands and debouch upon the Mississippi flood plain. These younger deposits, consisting of basal sands and gravels with an overburden of loess and brown loam, are thickest near the bluffs and thin out eastward, so that the Grenada beds are buried beneath them to a depth of 25 feet toward their eastern limit and 75 or 100 feet in the edge of the bluffs.

The formation outcrops in the bluffs of the Yalobusha River and its tributary, the Bogue, in the vicinity of Grenada, where it was first named as a distinct formation. A continuation of this outcrop is exposed on the Bogue a mile north of Duck Hill and on the hillslopes on the southwestern edge of the town. These exposures are confined to the river bluffs and to small areas sloping up to the hills west of Duck Hill, where the beds pass under what seems to be the base of the Tallahatta formation.

Wells at Oakland, Yalobusha County, pass through the younger surficial deposits and the Grenada beds and strike water in the Holly Springs sand at a depth of 450 feet. Small exposures of the Grenada beds occur in the base of the bluffs near Charleston and are generally capped with small outlying masses of Tallahatta quartzite. Wells at Charleston pass through the Grenada formation.

In Panola County, west of Batesville, around Tocowa and Nirvana, lignite and gray clays of this formation occur at or near the surface over considerable areas. The lignitic clays are exposed on Coldwater River, in Tate County, and a similar small exposure of brown lignite and gray clay occurs in a bluff on a small stream near Pleasant Hill, 10 miles northeast of Hernando, DeSoto County.

The localities enumerated show that the actual areal outcrop of the Grenada formation in western Mississippi is limited to bluffs and hillslopes, and the areal extent of the deposits is determined largely by well records.

As already seen, the Grenada beds of western Mississippi disappear beneath the Claiborne south of Duck Hill, in Montgomery County.

Structure.—Aside from the evidence obtained from well records, the ascertained dip of the water beds of the underlying Holly Springs sand gives fairly reliable data on the dip of these beds. The dip of the water-bearing beds of the Holly Springs sand from Oxford to Clarksdale, Coahoma County, is estimated from well borings to be 24 feet to the mile. The dip from Oxford to Clayton, Tunica County, as similarly estimated, is 24 1/3 feet to the mile, and that from Holly Springs to Lake Cormorant, DeSoto County, is 30 feet to the mile. If the formation has a dip of 25 feet and an average width of outcrop of 10 miles, its thickness would be 250 feet, but its maximum thickness may in fact be considerably greater than this.

The dip of these beds is toward the west and southwest, and, so far as the available evidence shows, varies but slightly. The strata apparently have undergone no disturbance or deformation.

Paleontology.—No fossils have been discovered in the Grenada beds except impressions of vegetable remains, which have been found in the lignitic clays at a few places. The outcrop on the Bogue near Grenada furnished an interesting collection of fossil leaves, a list of which is given below:[1]

Fossil leaves from the Grenada formation near Grenada.

Anacardites grevilleafolia.
Apocynophyllum mississippiensis.
Apocynophyllum sapindifolium.
Aralia acerifolia.
Aralia jorgenseni.
Artocarpus pungens (?)
Banksia saffordi.
Bumelia grenadensis.
Caenomyces pestalozzites.
Canavalia eocenica.
Canna eocenica.
Carpolithus grenadensis.
Carpolithus pilocarpoides.
Carpolithus sophorites.
Capparis eocenica.
Cassia glenni.
Cassia lowii.
Cassia mississippiensis.
Chrysobalanus eocenica.
Chrysobalanus inaequalis.
Crhysophyllum ficifolia.
Dalbergites ellipticifolius.
Dalbergites ovatus.
Dillenites tetracerafolia.
Dillenites texensis.
Dryophyllum puryearensis.
Dryophyllum tennesseensis.
Englehardtia ettingshauseni.
Eugenia grenadensis.
Ficus monodon.
Ficus puryearensis.
Fraxinus johnstrupi.
Gleditsiophyllum eocenicum.
Juglans schimperi.
Melastomites americanus.
Meniphylloides ettingshauseni.
Mespilodaphne eolignitica.
Metopium wilcoxianum.
Mimosites variabilis.
Mimusops mississippiensis.
Myrcia bentonensis.
Myrcia grenadensis.
Myrcia wilcoxensis.
Nectandra lancifolia.
Nectandra pseudocoriacea.
Nipadites burtini umbonatus.
Oreodaphne obtusifolia.
Phyllites wilcoxensis.
Planera crenata (?)
Proteoides wilcoxensis.
Pteris pseudopennae formis.
Rhamnus coushatta.
Rhamnus cleburni.
Sabalites grayanus.
Sapindus formosus.
Sapindus mississippiensis.
Sapindus oxfordensis.
Sophora wilcoxiana.
Sterculia puryearensis.
Terminalia wilcoxiana.
Ternstroemites lanceolatus.
Ternstroemites ovatus.

Economic products.—This formation contains an abundance of gray clay suitable for making stoneware and pottery, and also an abundance of clay suitable for making common brick. Some of the sandy clay may make excellent fire brick.

In Tallahatchie and adjoining counties the white refractory clay of this formation, which occurs in large deposits, has been worked to some extent, and the clay has been marketed profitably. The deposits are worthy of further development and will eventually prove a valuable resource.

Lignite of good quality outcrops at a number of places in the bluffs but has not yet been developed.

[1]Berry, E. W., Lower Eocene floras of southeastern America: U. S. Geol. Survey Prof. Paper No. 91. p. 38. 1916.

LOCAL DETAILS

Grenada and vicinity.—At the type exposures near Grenada Crider[1] gives the following section of uppermost Wilcox in the hill just west of Grenada:

	Feet
4. Yellow loam and Lafayette capping top of hill.	
3. Impure laminated gray clay	50
2. Greensands interbedded with thin layers of clay	50
1. Darker colered laminated clay, the lower 15 feet being the dark-blue, highly cross-bedded, shaly clay seen in the bank of the river. It is almost entirely free from sand	50

The glauconitic bed, No. 2, is nonfossiliferous, so that it is impossible to be sure whether all of this section is upper Wilcox, or in part lowermost Claiborne. There seems to be no stratigraphic break in the section, yet the sands and clays underlie highly oxidized glauconitic sandy marl that seems identical with similar material of Claiborne age in the sections both east and west of Winona and at Vaiden. This Claiborne material forms a continuous outcrop in the cuts and washes along the Greenwood road from the top of the hill west of Grenada to the poor farm, 4½ miles to the west. At this point Claiborne quartzite appears on the hillsides. East of Vaiden the glauconitic marls both underlie and overlie the quartzitic bed, so that these ferruginous glauconitic beds west of Grenada would seem to be basal Tallahatta, and the underlying beds uppermost Wilcox.

A mile east of Grenada and half a mile up the Bogue from the wagon bridge, on the east side of the river, the bluff shows the following section:

	Feet
5. Yellowish-gray, siliceous sand, passing upward into yellow and then reddish-yellow sand (all partly concealed by slump and vegetation)	52
4. Gray sandy clay, containing here and there beds of pure clay	40
3. Laminated gray clay, micaceous, passing into the underlying bed	4-10
2. Gray lignitic clay, fossiliferous, with good black impressions of leaves, thicker bedded than bed No. 3 or No. 1	1
1. Chocolate-colored clay (pinkish on drying), thin-bedded, micaceous and somewhat finely sandy along lamination planes, fossiliferous	12

This deposit yielded the collection of fossil plants reported above.

[1]Crider, A. F., Geology and mineral resources of Mississippi, U. S. Geol. Survey Bull. 283, p. 28, 1906.

On the Providence road, 3 or 4 miles east of Grenada, the high broken hills are capped with masses of ferruginous concretionary sandstone which, as the lens shows, is glauconitic. The rock is not fossiliferous but appears to be identical with the Claiborne material noted west of Grenada and at Winona and Vaiden. The discovery in it of scattered angular blocks of quartzite increases the probability that it is of Claiborne age and suggests that the edge of the Claiborne once extended over the range of high hills between the Bogue and the Yalobusha several miles east of Grenada, but has been for the most part stripped away by erosion, leaving only scattered outliers.

Duck Hill.—In the suburbs of Duck Hill the beds of the Grenada formation are exposed at the bases of surrunding slopes and on the east bank of the Bogue 1 mile northeast. On the north slope of a little eminence upon which stands a negro church, in the southwest part of Duck Hill, an old excavation has exposed the following section, all of which belongs to this formation:

	Feet
3. Red clayey sand, unstratified, except toward the base, where it passes into the underlying clay	10
2. Clay, dark gray when wet, light gray on drying; thin bedded; on weathering the material separates into very thin laminae; somewhat finely sandy, the sand being unevenly disseminated through the clay or interstratified with it in thin laminae; rather coarse, micaceous, commonly cross-bedded, gray to yellow and red	10
1. Continuous with bed No. 2, but clay freer of sand and the gray clay at the base almost pure. Nonfossiliferous	5

The base of this exposure is at the elevation of the main part of the town. Wells in the town strike water-bearing sands at a depth of 40 feet, which are probably beds intercalated between the clay beds of the Grenada formation. The ridges just west of Duck Hill are capped with glauconitic sand, which is probably Claiborne.

About a mile northeast of Duck Hill the Bogue has undercut the point of a ridge 60 feet high. The strata exposed make the finest section of the Grenada formation that has yet been seen in one vertical face. The section, which is 60 feet high and 200 feet long, shows the following beds:

	Feet
11. Coarse red sand	5 or 6
10. Thinly laminated light-gray clay with sandy partings	4
9. Mottled gray and rusty red indurated sand, in places hardened into rock and forming slight projections that are noticeable in outcrops around the hill	1 to 1 1/6
8. Thinly laminated clay like bed No. 10	4½

7. Brown snuff-colored sand and light-gray clay intermixed in horizontal thin strata, the clay in laminae one-half to 1 inch thick, rarely more, the sand in broader bands and predominating, becoming more abundant toward the top	12
6. Stratified and cross-bedded sand, variegated in color but yellow below, pinkish-red above, and shading to white in the middle; forms a steep slope above the clay bed, which stands in a vertical face	5-6
5. Rather heavily bedded pink and gray clay (chocolate colored when wet), with very thin sandy partings, generally silvery white. The beds show heavy joint blocks, so that the face of the wall contains numerous projecting points and re-entrant angles alternating with smooth surfaces. This clay seems to be identical with that 1 mile east of Grenada, on the Bogue, and here as there it is highly fossiliferous but the leaves are more fragmentary	5½
4. Yellowish-gray sand parting and a few streaks of light-gray clay	1 to 1 1/6
3. Thinly laminated gray clay, somewhat micaceous and finely sandy, locally with thin lenses of sand. Darker material at base	4
2. Reddish-yellow, thinly laminated sand, indurated more or less into ferruginous brown horizontal plates	2
1. Yellow, medium fine micaceous sand, loose, stratified; shows some cross-bedding toward the top and contains a few streaks of white and gray sand	20

The basal sand furnishes water to the shallow wells in Duck Hill.

The southernmost outcrops of the Grenada beds, now known, are those around Duck Hill. From that point southward the Tallahatta beds seem to have transgressed the Wilcox, and outliers of Claiborne quartzite surrounded by Wilcox beds are found on the high ridges at a number of points several miles east of the main outcrop. Some of these apparent outliers may, however, prove to be quartzitic facies of the Wilcox strata.

Occurrences north of Grenada.—North of Grenada the outcrops of this formation occur in a series of small areas along the bluffs. Lignite and lignitic clay of this group are exposed at several points from 3 to 5 miles north of Charleston, Tallahatchie County. Along the face of the bluffs between the Tallahatchie and the Yocona, in Secs. 8, 9, and 10, T. 10S., R. 8W., there are outcrops of beds of lignite and leaf-bearing clay of the Grenada formation. These outcrops are in the vicinity of Tocowa,—one in a ravine a short distance behind the hotel and another about a mile farther down the valley. Similar outcrops have been noted at Nirvana, 2 miles east of Tocowa, in a deep wash. A bed of lignite 16 feet thick was reported from this vicinity by Harper,[1] but later investigations have

[1]Harper, Lewis, Preliminary report on the geology and agriculture of the State of Mississippi, p. 196. 1857.

failed to discover beds of more than 2 or 3 feet in thickness. In Sec. 25, T. 7S., R. 6W., in Panola County, on the south side of a small creek, Harper notes a bluff 30 feet high, the whole thickness of which, except a few feet of soil, exposes beds of the Grenada formation. These beds consist of white, red, and black clay, the last micaceous, finely laminated, and interbedded with gray sand. Lignite was not seen in this exposure, though the basal clay is highly lignitic and probably overlies beds of lignite.

At Sarah, on the Coldwater River, in Tate County, the lignite and clay of this formation outcrop in a railroad cut. In a ravine east of the railroad, a hundred yards or more from the station, a bed of lignite is reported to have been once exposed to a thickness of 12 feet, though the base of the bed was not revealed. Other beds have been reported on the hills at higher levels.

In DeSoto County, 8 miles northeast of Hernando, and 2 miles from Pleasant Hill, in a ravine 40 feet deep, the following beds of the Grenada formation are exposed beneath 30 feet of loess loam and terrace sand and gravel.

	Feet
5. Stratified yellowish sand	4
4. Gray joint clay, quite pure and plastic	4
3. Rich brown lignite, not so firm as that of No. 1	2
2. Gray clay	0.25
1. Brown lignite, rather firm	1.5

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