Madison County Geology

RICHARD RANDALL PRIDDY

BULLETIN 88

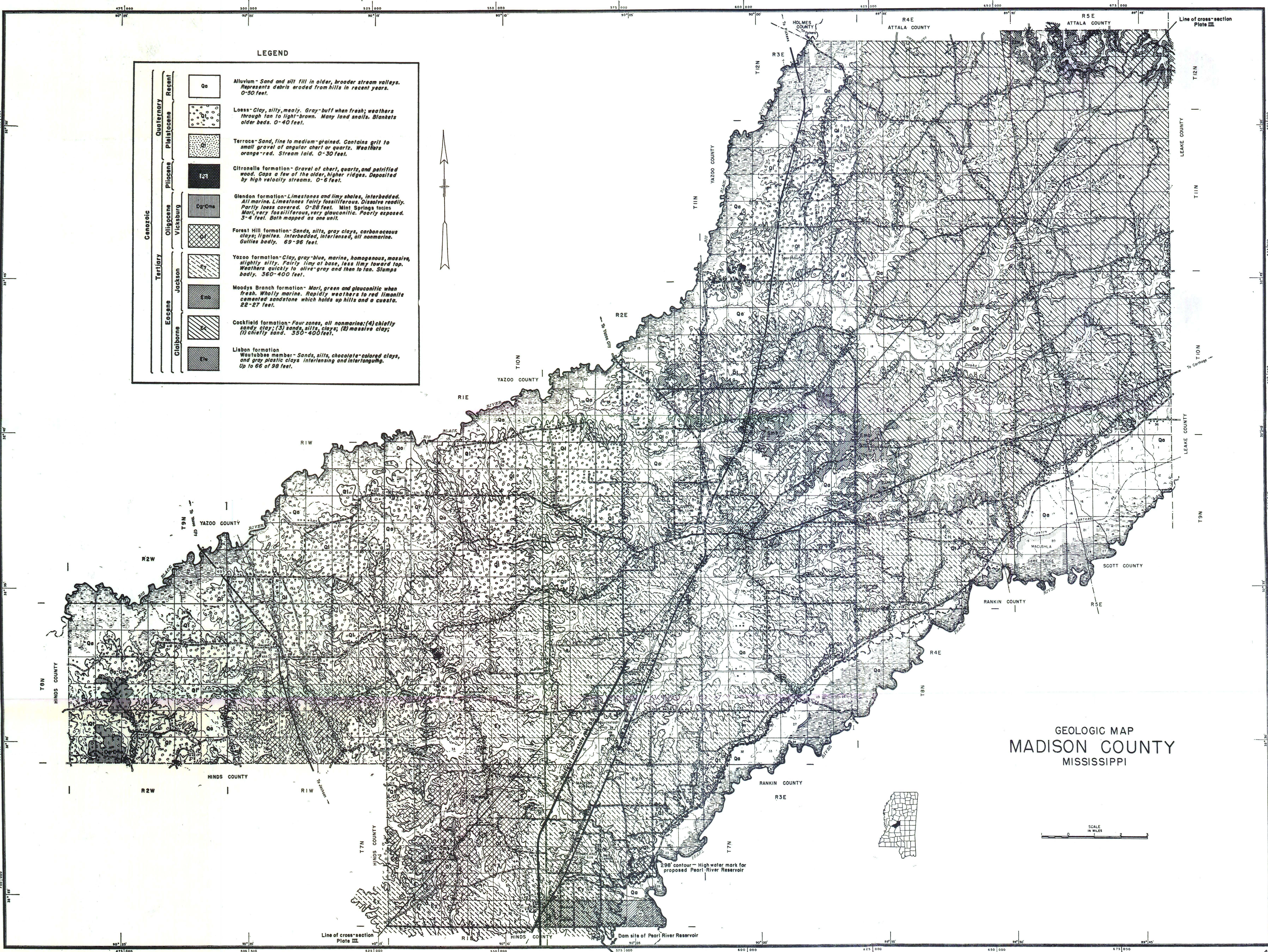
MISSISSIPPI STATE GEOLOGICAL SURVEY

TRACY WALLACE LUSK

DIRECTOR AND STATE GEOLOGIST

UNIVERSITY, MISSISSIPPI

1960


LEGEND
Cenozoic
Quaternary
Tertiary
Recent
Pleistocene
Pliocene
Oligocene
Eocene
Vicksburg
Jackson
Claiborne
Qa
Alluvium - Sand and silt fill in older, broader stream valleys. Represents debris eroded from hills in recent years. 0-50 feet.
Ql
Loess - Clay, silty, mealy. Gray-buff when fresh; weathers through tan to light-brown. Many land snails. Blankets older beds. 0-40 feet.
Qt
Terrace - Sand, fine to medium-grained. Contains grit to small gravel of angular chert or quartz. Weathers orange-red. Stream laid. 0-30 feet.
Pc
Citronelle formation - Gravel of chert, quartz, and petrified wood. Caps a few of the older, higher ridges. Deposited by high velocity streams. 0-6 feet.
Og-Oms
Glendon formation - Limestones and limy shales, interbedded. All marine. Limestones fairly fossiliferous. Dissolve readily. Partly loess covered. 0-28 feet. Mint Springs facies Marl, very fossiliferous, very glauconitic. Poorly exposed. 3-4 feet. Both mapped as one unit.
Of
Forest Hill formation - Sands, silts, gray clays, carbonaceous clays; lignites. Interbedded, interlensed, all nonmarine. Gullies badly. 69-96 feet.
Ey
Yazoo formation - Clay, gray-blue, marine, homogenous, massive, slightly silty. Fairly limy at base, less limy toward top. Weathers quickly to olive-gray and then to tan. Slumps badly. 360-400 feet.
Emb
Moodys Branch formation - Marl, green and glauconitic when fresh. Wholly marine. Rapidly weathers to red limonite cemented sandstone which holds up hills and a cuesta. 22-27 feet.
Ec
Cockfield formation - Four zones, all nonmarine: (4) chiefly sandy clay; (3) sands, silts, clays; (2) massive clay; (1) chiefly sand. 350-400 feet.
Elw
Lisbon formation
Wautubbee member - Sands, silts, chocolate-colored clays, and gray plastic clays interlensing and intertonguing. Up to 66 of 98 feet.
HOLMES COUNTY
ATTALA COUNTY
YAZOO COUNTY
LEAKE COUNTY
SCOTT COUNTY
RANKIN COUNTY
HINDS COUNTY
R4E
R5E
R3E
R2E
R1E
R1W
R2W
T12N
T11N
T10N
T9N
T8N
T7N
Line of cross-section Plate III
298' contour — High water mark for proposed Pearl River Reservoir
Dam site of Pearl River Reservoir
To Carthage
To Jackson
To Yazoo City
SCALE IN MILES
GEOLOGIC MAP
MADISON COUNTY
MISSISSIPPI

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1960

LETTER OF TRANSMITTAL

Office of the Mississippi Geological Survey
University, Mississippi
March 9, 1960

Hon. James R. Park, Chairman, and
Members of the Geological Survey Board

Gentlemen:

Herewith is Mississippi Geological Survey Bulletin 88, Madison County Geology, by Richard Randall Priddy.

The professional geologist will observe at once the unusual arrangement of the text. However, the author is of the opinion that ". . . the geologic structure is so important in Madison County that it should be explained first." He further urges ". . . those who are truly interested in Madison County's geology and mineral resources . . ." to study carefully "Structure" and "Stratigraphy" before reading "Economic Geology."

The Mississippi Geological Survey has attempted to write nearly all of its publications in a manner suitable for the layman and at the same time maintain a standard of scientific excellence. It should be explained here that a special effort on the part of the author was put forth in order that this report might be utilized on the high school level for student understanding, which is the reason for the explanatory parts of the text.

The Director wishes to take this opportunity to commend the author on the superior quality of his work. He carried the project as far as possible under the existing conditions. Unfortunately the Survey staff and research facilities were not adequate to truly complete the report according to the demands of the time. This was recognized in the report in the study of "Clays" when the statement was made that ". . . a proper evaluation must await complicated and lengthy ceramic and geochemical tests . . ." Let us hope that our next report will contain this type of information.

As usual problems arose during the preparation of the report concerning the names and ranks of geological units. It is somewhat doubtful that the conclusions reached will actually stand the test of a thorough regional study. This is particularly true of the Vicksburg Group, which is badly in need of study throughout its entire belt of outcrop across the State.

The geological study of Madison County was made possible through the cooperative spirit of the local Chamber of Commerce and the County Board of Supervisors. They are to be commended on their realistic approach to obtain factual information on the natural resources of the county which is the proper and basic method to upgrade the general prosperity. Without the financial assistance of the Board of Supervisors, the survey could not have been made.

Respectfully submitted,

Tracy W. Lusk
Director and State Geologist

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LETTER OF TRANSMITTAL

Office of the Minnesota Geological Survey
University of Minnesota
[illegible] 19[illegible]

[illegible]
[illegible] the [illegible] Survey Board

Gentlemen:

[illegible] Minnesota [illegible] Survey [illegible] Geology [illegible]

[illegible] of the [illegible] the author is of the opinion that [illegible] Minnesota [illegible] that [illegible] in Minnesota [illegible] and [illegible] [illegible]

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[illegible] the [illegible] of [illegible] [illegible] of the [illegible] of the [illegible] [illegible] of [illegible] throughout the [illegible]

[illegible] of [illegible] of the [illegible] [illegible] of [illegible] the [illegible] of the [illegible] [illegible] the [illegible] of the Board [illegible]

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[illegible]
[illegible] and State Geologist

MADISON COUNTY GEOLOGY

RICHARD RANDALL PRIDDY

ABSTRACT

Madison County is just southwest of the center of Mississippi. It is crossed from northwest to southeast by three physiographic belts: North Central Hills underlain by Cockfield sands and clays in the northeast; Jackson Prairie developed on the massive Yazoo clay in the center and in the southwest; and Vicksburg Hills carved from Oligocene limestones, marls, clays, and sands in the southwest and in the extreme south. A fourth belt, the Loess Hills, is developed in the northwest where a blanket of windblown silt is being eroded.

In the northeast part of the County, Cockfield beds have been faulted in a broad northwest-southeast belt characterized by parallel grabens and horsts. Oil and gas have been trapped against two of the faults at considerable depths, as in Pickens and Loring fields, so it is possible that other surface structures in the same belt may also provide traps that will produce. Scattered surface anomalies in other parts of the County deserve detailed investigation.

Surface strata contain beds of probable economic value: carbonaceous clays for brick; gray, silty clays for tile and brick; glauconite for soda, potash, and phosphate fertilizer; and limestone for agricultural use. Exposures of thin bentonitic clays may be indicative of thicker surface or near-surface clays which can be used for filtering. Shallow Cockfield sands and deeper Sparta sands furnish abundant water.

This report is illustrated with maps showing physiography, stratigraphy, and structure. Two cross-sections show the details of stratigraphy and structure.

INTRODUCTION

LOCATION AND HISTORY

Madison County is just southwest of the center of Mississippi (Figure 1). It is one of the larger counties despite its deceptive shape, which resembles an arrowhead pointed northeast. The County's greatest length is 51 miles but its width is only 14 to 22 miles. Canton, the county seat, is located, purposely, at the geographical center.

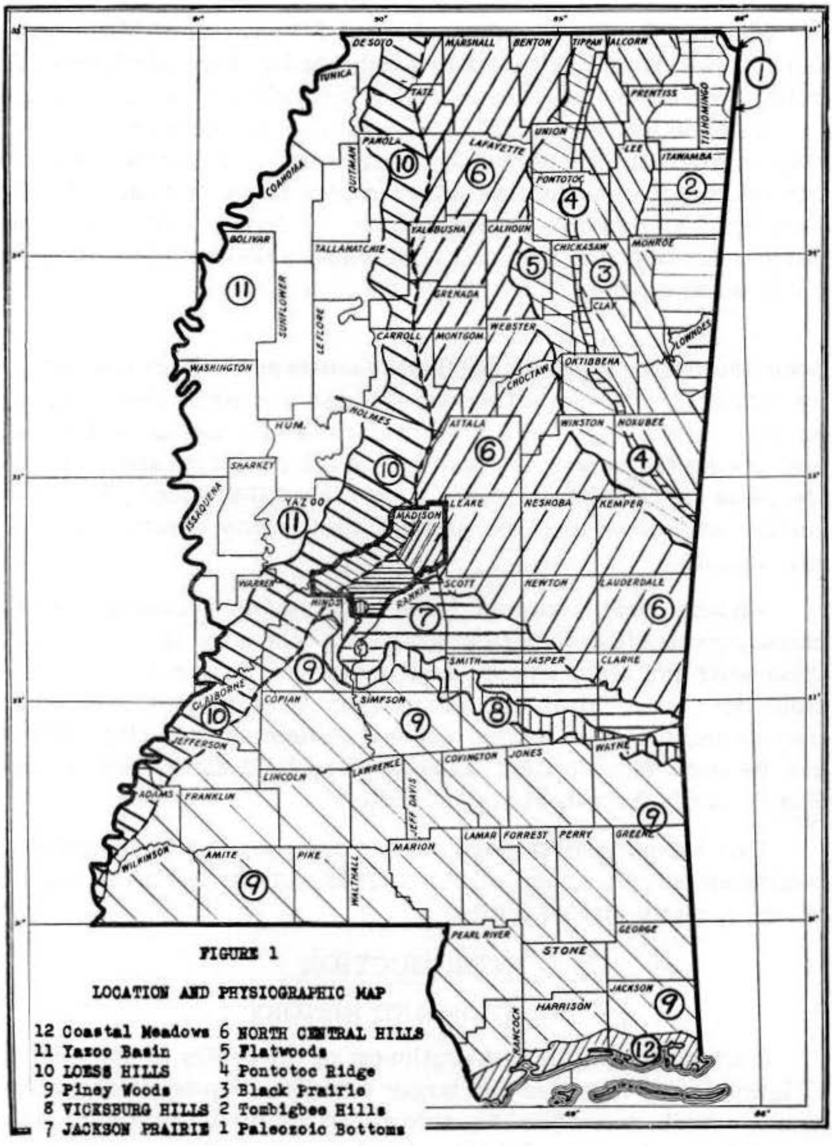


FIGURE 1

LOCATION AND PHYSIOGRAPHIC MAP

Counties having straight borders with Madison are Attala on the north, Leake on the east, and Hinds on the south and west. The Yazoo, Rankin, and Scott boundaries are irregular. The winding Big Black River makes the Yazoo County boundary on the northwest and the equally sinuous Pearl River makes the Rankin and Scott boundaries on the southeast.

Madison County, named for the fourth President of the United States, James Madison, was formed by an act of the legislature January 29, 1828, as the 23d county in Mississippi. It was carved from parts of Yazoo and Hinds Counties. A short time later a part of Leake County was added.

McCool[1] related that the County has had four seats of government, Beattie's Bluff in adjacent Yazoo County, Madisonville, Livingston, and Canton, in that order. Canton has been the county seat since 1834 when it was laid out at the geographical center of the County expressly for the purpose. The village was incorporated February 26, 1838.

CULTURE AND INDUSTRY

The County has an area of some 751 square miles and had a population in 1950 of 18,459. Canton's population was 7,048. Other incorporated towns and their 1950 populations are Flora in the southwest 655, and Madison 540 and Ridgeland 526, both in the extreme south. Crossroad settlements referred to in this discussion are indicated on the geologic map, Plate 1.

The rainfall of Madison County averages 52 inches per year. Combined with an average midday temperature of 62 degrees and a usual frost-free season from April 1 through October 20, this high rainfall accounts for far greater chemical weathering than physical weathering. Hence, as explained in the treatment of "Physiography", most of Madison County's surface consists of gently rounded, low hills blanketed with thick residual soil, and fairly broad flat bottoms of stream fill. Exceptions are the steep hills and narrow bottoms in the extreme northeast, and south of Flora where thick sands are rapidly gullied, and in the southwest where a thick mantle of easily eroded loess caps the hills.

Of the 480,640 acres in Madison County some 316,000 acres are in crop land and pasture. The balance is in woodlands, chiefly in the northeast, where steep hills, deep narrow valleys and narrow stream divides discourage extensive cultivation.

The chief crop is cotton, especially where the hills are broadest and valleys most nearly flat. However, scars left by contour plowing show that much recently cultivated land is now used for grazing. Cattle are presently ranked second as a source of agricultural income. Third in rank is probably corn which can be grown profitably even on hillside patches. A fourth source of income is the timber. The County has been repeatedly cut over to supply the planing mills at Canton which was once a busy wood-working center. Although the best hardwoods have long since been gone, some second growth is being harvested. Small growth pine is being extensively cut for pulpwood.

Canton is the center of an agricultural economy. It has a plant for making fertilizer, another for making insecticides, and an egg grading plant. A planing mill and two furniture factories use some of the County's timber.

In the southwest, just north of Flora, there is a concentration of small industries on acreage which was once a World War II arsenal. Southeast of Flora, across the line in Hinds County, a plant is now producing lightweight aggregate using upper Yazoo clays.

ACCESSIBILITY

Several highways cross Madison County. In this mineral survey, they are as important for the geology revealed in their road cuts as they are for their intended purpose, transport.

Three are U. S. Highways. Highway 51, New Orleans-Jackson-Memphis-Chicago, passes through Canton. A new north-south super-highway, Interstate 55, is being built some distance to the west of Highway 51, as indicated on the geologic map (Plate 1). U. S. Highway 49, from Jackson to Yazoo City and Memphis, passes through Flora in the most western end of the county. Natchez Trace, an historic, scenic route presently starts at Ridgeland near the south county line and follows the edge of the Pearl River floodplain to the Leake County Line. It is now open for traffic some 60 miles farther but the Trace will eventually reach Nashville, Tennessee. Plans are to extend it southwesterly from Ridgeland to Natchez on the Mississippi River.

The same map shows several Mississippi highways, Mississippi 22 connects Edwards in Hinds County with Flora and Canton. Highway 16 links Canton with Yazoo City to the northwest and Canton with Carthage in Leake County to the east. Partially improved Mississippi Highway 43 joins Canton with Kosciusko in Attala County to the northeast, and joins Canton with Pelahatchie in Rankin County to the southeast. A newly improved segment of Mississippi 17, is routed from Pickens south-southeast to Mississippi Highway 16, diagonally across the northeast part of the county. The last improvements have just been completed on Mississippi Highway 463 from Madison through Mannsdale to Livingston.

County maintained hard surfaced roads are many but most Madison County roads are gravel or clay or sand surfaced. All three types of secondary roads are well graded and passable except during prolonged wet weather. Further, most have numerous road cuts, affording exposures of 1 or 2 feet up to even 60 feet of beds on a single hill slope.

Eight railroads once served Madison County but only two are active today. The main line of the Illinois Central Railroad from New Orleans to Chicago bisects the county north-south, and connects Jackson with Ridgeland, Madison (Station), Canton, and Pickens. The other, now a branch line of Illinois Central, passes through Flora, connecting Jackson with Yazoo City. Tracks of the Canton-Carthage Railroad in the east part of the county have not been used for several years. Traces of old logging railroads can still be seen in several parts of the county, especially northeast of Canton.

MAPPING

Previous to its formation on January 29, 1828, Madison County was Choctaw Indian country when the only white settlements were on Mississippi's Gulf Coast, along the Mississippi River from Natchez to Vicksburg, and in the Aberdeen area to the northeast. The photograph (Figure 2) of a marker along Natchez Trace, shows how Indian cessions in 1811 and in 1820 released more and more land to white settlers. The significance, geologically, is that land surveys of part of Mississippi were based on these cession lines. One is preserved as "Choctaw Meridian" (Plate 1), a north-south line, where Range numbers designating Townships change from 1 West to 1 East in the Flora area, in the west of the county. The other is preserved as the "Old Choctaw Treaty Line" which passes North 7 degrees West—South 7 degrees East to make a confusing offset in the sections in the Farmhaven-Camden areas.

However, these and other lines have been used to help make the convenient survey system of Section, Town, and Range whereby lands and rock exposures can be located easily. Thus Plate 1 shows that there are all of, or parts of, 29 townships in Madison

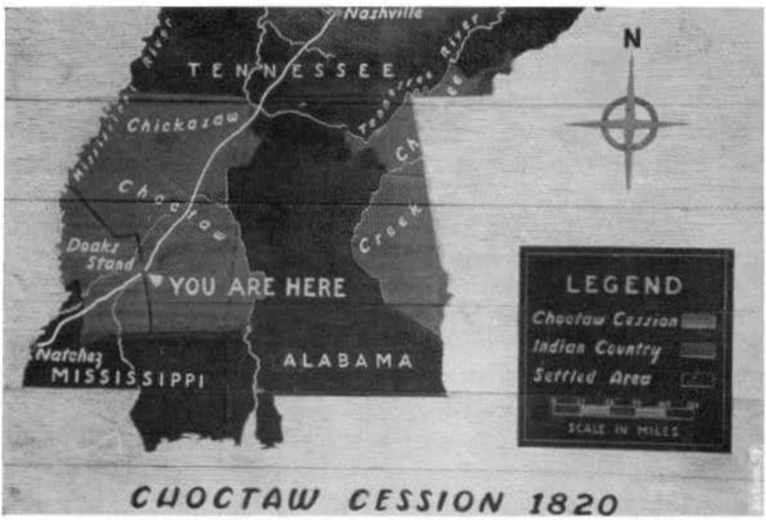


Figure 2.—Indian Cessions 1811 and 1820 indicated by a marker along Natchez Trace (SW.¼, SW.¼, NW.¼, Sec.9, T.9 N., R.5 E.). July 1, 1959.

County, from Town 7 North northward into Town 12 North and eastward through Ranges 2 West and 1 West through 5 East. Each township was intended to be 6 miles square and to be comprised of 36 sections, each one mile square and containing 640 acres. Plate 1 shows that most townships and sections meet these requirements in Madison County.

PREVIOUS INVESTIGATIONS

Previous to this mineral survey no geological investigation had been made of Madison County alone, using public funds for the free release of information. In 1854, 1857, and 1860 successive reports were made by Wailes,[4] Harper,[5] and Hilgard,[6] on the "agriculture and geology of Mississippi" in which Madison County was included. Great credit is due these men because the outcrops they visited were mostly limited to railroad exposures and cutbanks of streams. They did not have the benefit of the hundreds of road cuts made necessary by automobile travel.

A similar lack of artificial exposures hampered workers in a revived Mississippi State Geological Survey during the years 1907-1915 when sporadic work was done on a statewide basis to evaluate cement materials, clays, soils, lignites, marls, limestones, and iron ores. Madison County was visited but there was no significant contributions except by Lowe[7] who described a "Madison sand" west of Madison and also southwest of Jackson which is here recognized as part of the Forest Hill sands, silts, and silty clays. However, in this period some progress was made in establishing the sequence of beds throughout the State and in interpreting some of their lateral changes.

In 1928 a great contribution was made by Stephenson, Logan, and Waring[8] of the United States Geological Survey, who collaborated in producing Ground-Water Report 576 which for many years was the only county by county source of geological information. The work devotes only 8 pages to Madison County but contains enough regional data to aid in the recognition of the County's surface and near-surface beds.

In 1930, geological investigations were stimulated by the discovery of gas on Jackson Dome. There were two forms of activity. On the one hand, major oil companies started private programs combining surface studies with magnetometer and gravity surveys in south-central Mississippi, including Madison County. On the other hand, the United States Geological Survey started a surface and subsurface investigation of the Dome and its environs in 1930 under the directions of W. H. Monroe. Several papers were written by Monroe[9, 10, 11, 12] and one by Monroe and Toler.[13]

The greatest impetus to geological study of the area was given by the release of the description of the surface structure by Mellen[14] in April, 1939, which led to the discovery of Tinsley Field in adjacent Yazoo County. An earnest search for other fields followed, using all methods available; surface work, core drilling, and magnetometer, gravity meter, and seismic surveys. In early 1940 Pickens Field was discovered through seismic surveys which were undertaken partly on the basis of odd dips in gullies in the east of T.11 N., R.3 E. (Figure 5). In the 19 years which have elapsed, Madison County has been one of the most explored areas in the State, but the data, accumulated at great cost to the companies, were mostly reserved.

However, the Ohio Oil Company did release some valuable regional information when it permitted Thomas[15] to publish some of his 1939-1940 findings on the middle Eocene Claiborne. During this investigation the Cockfield and Wautubbee exposures in the northeast two-thirds of Madison County were visited.

Shortly thereafter the demands of World War II stimulated the search for more oil. To accelerate exploration the United States Geological Survey put a large party in the field to re-map the State on the basis of their own surface work and the contributions of several companies active in oil exploration. Most of the work in Madison County was performed by D. H. Eargle. The result was the latest geological map of Mississippi, 1945, issued by the Mississippi Geological Society, Jackson, Mississippi, at $3.25 per copy. Although the 1945 map is on a scale only one-fourth the scale of the geologic map, Plate 1 of this report, the broader details of Madison County geology as shown on the two maps are similar.

The last published geological work dealing primarily with Madison County is the recent contribution of Donald M. Keady,[16] a native of Canton. He studied the subsurface development of the Cockfield strata by correlating the drill records of water wells in Madison County with those west as far as Issaquena County, southwest as far as Claiborne County, and south as far as Smith and Simpson Counties.

Keady's investigation is much more detailed than that of the subsurface work of Priddy[17] who identified the chief fresh-water bearing sands in 7 geological units throughout Mississippi on the basis of electrical log studies. Priddy found that the surface sands of northeast Madison County fed many Cockfield aquifers downdip in the southwest of the County; that the whole County could be supplied by waters in Sparta sands, and that deeper Wilcox sands could furnish water northeast of Canton. The fourth of Priddy's 7 cross-sections, from Vicksburg through Madison County to Columbus, is reproduced here as Plate 4.

In 1958 Harvey and Lang[18] published on the ground-water of the Jackson area. Some of the data accumulated for the study was from water wells and oil tests in the south of Madison County.

A report which is eagerly awaited is that of a 3-year investigation of the geology and ground-water resources of the greater Jackson area by the Ground-Water Branch office of the United States Geological Survey at Jackson. All of Madison, Rankin, and Hinds Counties will be included.

TOPOGRAPHY

The topography, the lie of the land, is as varied in Madison County as in any other county of Mississippi. In some parts narrow ridges and deep valleys are the rule, in others broad rounded hills and broad flat plains are prevalent. In some places the surface is a monotonous plain, and near the Pearl and Big Black Rivers are broad swamps. Not all these features can be seen at a glance but their relationships are portrayed on a topographic map.

Unfortunately, less than half of Mississippi has been surveyed topographically and only the south sixth of Madison County is included in the Raymond, Jackson, and Pelahatchie quadrangles (Figure 3). These quadrangles were published in 1937, 1905, and 1924, respectively. But numerous elevations freshly painted on bridges or on posts and trees at road intersections indicate that Madison County is in the process of being surveyed. One good evidence is a number of new permanent elevation markers recently placed by the U. S. Coast and Geodetic Survey.

As shown by the index map, Madison County will have 7 additional quadrangles similar to Raymond, Jackson, and Pelahatchie quadrangles. Their names are Vaughan, Goodman, Thomastown, Bentonia, Canton, Sharon, and Lena. All quadrangle maps will have horizontal distances scaled at about 1 mile to the inch and hills and valleys portrayed by brown contour lines scaled at a contour interval of 20 feet. The maps will measure about 17 inches north-south and about 14 inches east-west. All will probably be available by 1965.

However, in making this mineral survey two small-scale, 50-foot interval, regional topographic maps had to be used. Details of hills, valleys and hill slopes were lost but the two maps had to suffice. They are entitled

> Jackson, Miss.; La. (Bastrop, La. to Canton)
> NI 15-12
> Meridian, Miss.; Ala. (Canton to York, Ala.)
> NI 16-10

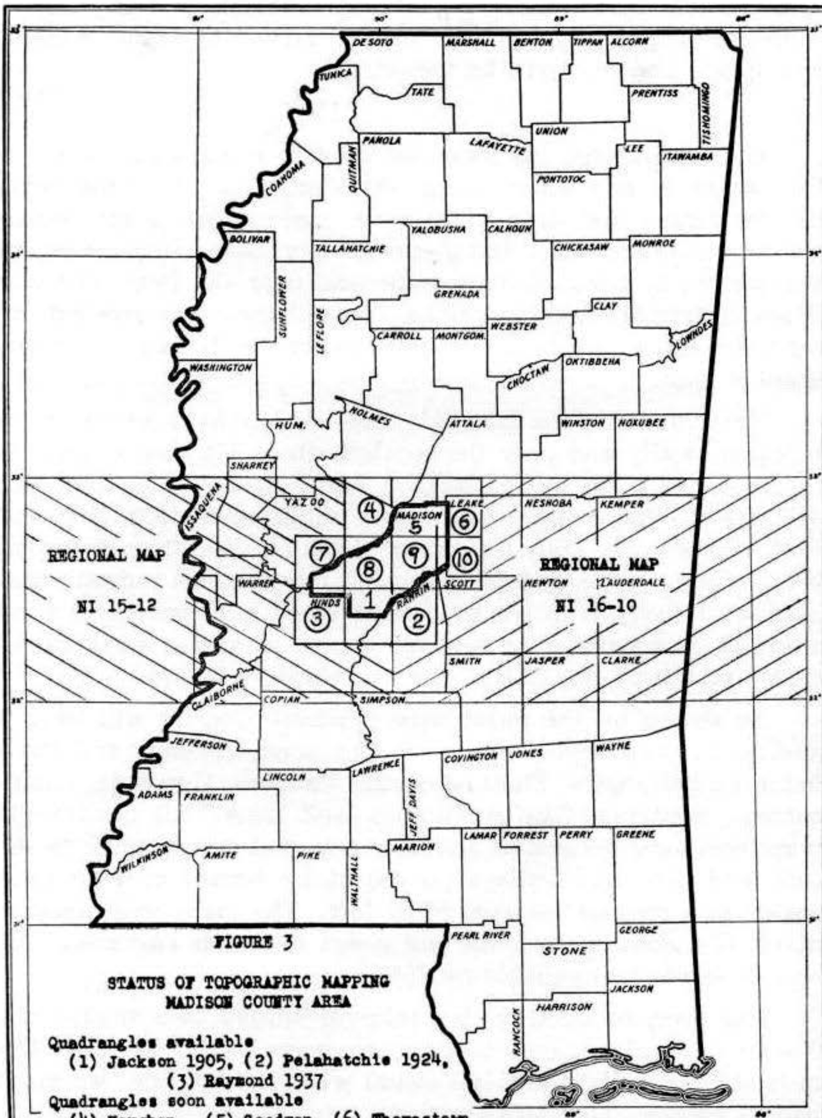
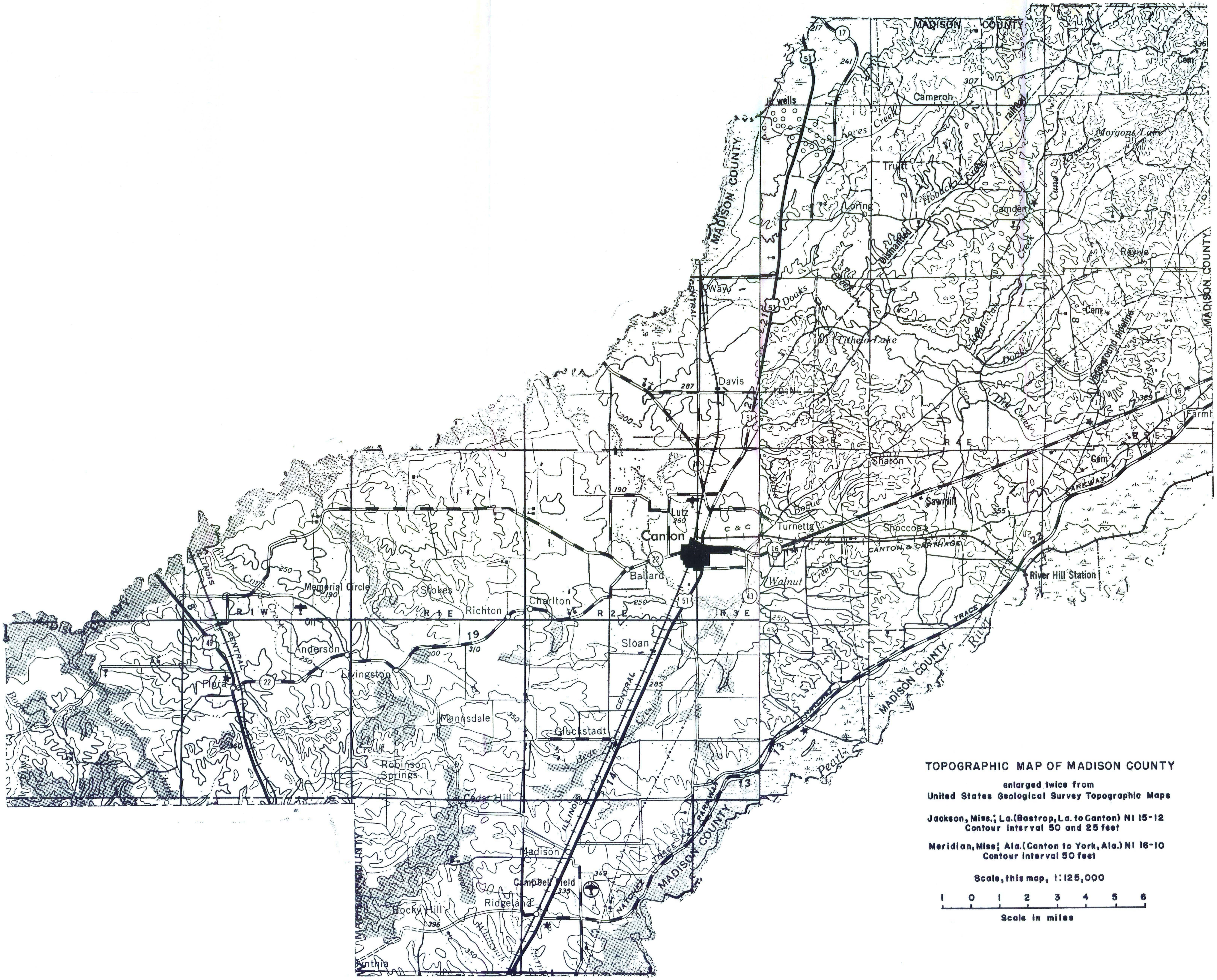


FIGURE 3

STATUS OF TOPOGRAPHIC MAPPING MADISON COUNTY AREA

Quadrangles available
(1) Jackson 1905, (2) Pelahatchie 1924, (3) Raymond 1937
Quadrangles soon available
(4) Vaughan, (5) Goodman, (6) Thomastown, (7) Bentonia, (8) Canton, (9) Sharon, (10) Lena



TOPOGRAPHIC MAP OF MADISON COUNTY

enlarged twice from
United States Geological Survey Topographic Maps

Jackson, Miss.; La. (Bastrop, La. to Canton) NI 15-12
Contour interval 50 and 25 feet

Meridian, Miss.; Ala. (Canton to York, Ala.) NI 16-10
Contour interval 50 feet

Scale, this map, 1:125,000

1 0 1 2 3 4 5 6
Scale in miles

and are available at 50 cents each, prepaid, United States Geological Survey, Washington 25, D. C. The Raymond, Jackson, and Pelahatchie Quadrangle maps can be purchased at 30 cents each from the same source.

The Madison County parts of both Jackson and Meridian maps were joined and then enlarged to make a topographic map (Plate 2) to conform to the scale of the Geologic map (Plate 1). The latter is based on a map produced from aerial photographs and may be purchased from Mississippi State Highway Laboratory, Woodrow Wilson Avenue, Jackson, Mississippi. The highway map shows railroads, streams, churches, schools, homes, stores, and most roads, but it does not show hills and valleys which can be portrayed by contour lines only. The enlarged topographic map, on the other hand, shows most roads and streams and contours at 50-foot intervals, but it does not show homes and stores.

More details of topography will be depicted on the quadrangle maps for which the surveys are now being made. These maps will show the relief on the 20-foot contour intervals, thus locating smaller hills and shallower valleys. However, for those who truly wish to study Madison County, the following plan is suggested, using Plate 2. Starting along the major streams color all the area brown which is below (down hill from) the contour labeled 250 (feet). Then color pink the belts which lie from 250 (feet) to the next contour 300 (feet). Follow by coloring the 300-350 interval light blue; the 350-400 interval orange, the 450-500 interval yellow, and the one tiny hill purple which is more than 500 (feet) in elevation.

PHYSIOGRAPHY

GENERAL STATEMENT

By coloring the topographic map the chief physiographic features of Madison County can be easily recognized. They are:

(1) a high area in northeast, elevations 300-500 feet

(2) a high area in southwest, elevations 350-500 feet

(3) low broad hills and shallow broad valleys, between (1) and (2) at 200-300 feet

(4) lowlands of Big Black River in the northwest at 200 feet

(5) lowlands of Pearl River in the southeast at 300 feet

(6) a 375-425 foot divide separating these watersheds

(7) the divide is much closer to Pearl River than to Big Black River

(8) the drainage of 95 percent of the county is northwest

This unusual variety of physiographic features is due to (1) the county's great northeast-southwest length, (2) the southwest dip of the strata, (3) the differences in resistence of the beds, (4) the geological processes at work, and (5) the stage of erosion accomplished by these processes.

A folded physiography and structure section drawing (Plate 3) has been devised to show these relationships of surface features to bedrock. The section extends North 40 degrees East-South 40 degrees West from the northeast corner of Madison County to one of the southwest corners, in the direction of dip. Unfortunately, the cross-section drawing has a great vertical exaggeration. The horizontal scale is 2 miles per inch whereas the vertical scale is only 100 feet per inch. Consequently hilltops are actually much broader than shown, hill slopes are more gentle, and valleys are much broader and more nearly flat.

The cross-section drawing should be studied in conjunction with (1) the map (Figure 1) showing the physiographic belts of Mississippi; (2) the geologic map of the whole county (Plate 1); (3) the geologic map of the Cockfield only (Plate 6); (4) the topographic map (Plate 2); and (5) the chart (Figure 4) which shows the sequence of beds from base upward, oldest to youngest. Locations of creeks, roads, settlements, and township lines are shown on the section to aid in its study.

Specifically, the cross-section shows, from northeast to southwest, three large physiographic features, (1) a hilly northeast region developed on Cockfield and Wautubbee beds, (2) a central region which is nearly flat to gently rolling developed on thick Yazoo clays, and (3) an eroded hilly southwest area underlain by Forest Hill silts and Vicksburg limestones. These areas comprise parts of 3 of the 12 major physiographic belts of Mississippi (Figure 1). They are the North Central Hills, Jackson Prairie, and Vicksburg Hills, respectively. A fourth major physiographic belt, the Loess Covered Hills, lies to the northwest off the line of cross-section and will be discussed later.

PHYSIOGRAPHY AND STRUCTURE SECTION

From a southwest corner of Madison County to northeast corner

FIGURE 4

GENERALIZED SECTION OF EXPOSED FORMATIONS IN MADISON COUNTY

Era	System	Series	Group	Formation	Lithologic character	Thickness (feet)
Cenozoic	Quaternary	Recent		Alluvium	Sand and silt fill in older, broader stream valleys. Represents debris eroded from hills in recent years. —erosional contact—	0-50
		Pleistocene		Loess	Clay; silty, mealy. Gray-buff when fresh; weathers through tan to light-brown. Many land snails. Blankets older beds. —erosional contact—	0-40
				Terrace	Sand; fine- to medium-grained. Contains grit to small gravel of angular chert or quartz. Weathers orange-red. Stream laid. —erosional contact—	0-30
	Tertiary	Pliocene		Citronelle	Gravel of chert, quartz, and petrified wood. Caps a few of the older, higher ridges. Deposited by high velocity streams. —erosional contact—	0-6
		Oligocene	Vicksburg	Glendon	Limestones and limy shales; interbedded. All marine. Limestones fairly fossiliferous. Dissolve readily. Partly loess covered. Mint Springs facies—marl; very fossiliferous, very glauconitic. Poorly exposed. 3-4 feet. —erosional contact—	0-32
				Forest Hill	Sands; silts, gray clays, carbonaceous clays, lignites; interbedded, interlensed, all non-marine. Gullies badly.	69-96
		Eocene	Jackson	Yazoo	Clay; gray-blue, marine, homogeneous, massive, slightly silty. Fairly limey at base, less limy toward top. Weathers quickly to olive-gray and then to tan. Slumps badly.	360-400
				Moodys Branch	Marl; green and glauconitic when fresh. Wholly marine. Rapidly weathers to red limonite- cemented sandstone which holds up hills and a cuesta. —erosional contact—	22-27
			Claiborne	Cockfield (Yegua)	Four zones, all non-marine: (4) chiefly sandy clay; (3) sands, silts, clays; (2) massive clay; (1) chiefly sand. —erosional contact—	350-400
				Lisbon	Wautubbee member— Sands, silts, chocolate-colored clays, and gray plastic clays interlensing and intertonguing . . . up to 66 of 98 feet for the entire unit.	66

NORTH CENTRAL HILLS

In most of Mississippi the North Central Hills have been carved from sands, silts, silty clays, claystones, and marls; but in Madison County, at the belt's southwest edge, the claystones and marls are absent. Here the beds represented are strata of the Wautubbee member of the Lisbon formation and strata of the overlying Cockfield formation, both formations being upper Claiborne in age.

The oldest beds cropping out in Madison County, the upper Wautubbee, are exposed at the Attala County line. There, hillsides show up to 66 feet of thin-bedded silts and thick sands containing lenses of chocolate-colored clay with silt partings. The clay, being more resistant to erosion, forms fairly broad flat bottoms of creeks flowing north into Attala County, Sections 19 through 30, T.12 N., R.5 E. The cross-section shows one of these floodplains.

Cockfield beds, 360 to 400 feet in thickness, form the North Central Hills from the Wautubbee bottoms southwest nearly to Canton. Their diverse lithology and some faulting are responsible for a great variation in physiographic features. Steep ridges and deep narrow valleys have been carved in massive sands; sharp but low hills have been cut in thin-bedded silts and sandy silts, and broad low hills have been formed by erosion of massive clays. The larger creeks flow on thick fill covering clays. The uppermost of the Cockfield clays is thick enough to help the overlying Moodys Branch formation, which is in most places weathered to a ferruginous sandstone, hold up a cuesta 300 to 350 feet in altitude at the juncture of the North Central Hills and the Jackson Prairie. The cuesta is shown on the cross-section drawing northeast of Canton and at the northeast edge of the Moodys Branch outcrop (Plate 1). (A cuesta is a ridge which is formed by gently dipping strata more resistant to weathering than the beds above and below. In this case the dip is southwest and the Moodys Branch is more resistant than the underlying Cockfield and the overlying Yazoo.)

JACKSON PRAIRIE

Southwest of the cuesta there may be a belt of Yazoo clay-capped Moodys Branch hills 2 to 4 miles wide, as from Sharon nearly to Canton (Plate 1). These hills are included in the Jackson Prairie as indicated on the cross-section (Plate 3).

Southwest of the Moodys Branch cuesta and Moodys Branch hills through Canton and through the settlements of Sloan and Gluckstadt the surface is gently rolling prairie. The topography is the same as surrounds Jackson and which extends southeast to the Alabama line in Clarke and Wayne Counties. The cross-section shows that the belt is a lowland at 250 feet elevation except near the sources of streams where elevations may reach 300, even 350 feet. This prairie has been established through slow stream action eroding the Yazoo clay, a massively bedded unit some 350 to 400 feet in thickness. However, the prairie encompasses one hilly area (T.7 N., R.1 E.) which is a remnant of the belt of Vicksburg Hills west of Ridgeland, and nearly surrounds another rugged region of Vicksburg strata (T.8 N., R.1 W.) southeast of Flora. A few of the higher hills in the Prairie belt are capped by loess, terrace sands, and Citronelle gravel, remnants of a cover which once mantled much of this region. The sand-capped hills are highest in the area south, southeast, and southwest of Livingston and along the Pearl River highlands in the southeast.

VICKSBURG HILLS

The three highland areas in the southwest and south of Madison County are outliers of the Vicksburg Hills, a belt of gently rolling to rugged uplands extending from Vicksburg east-southeast to the Alabama line in Wayne County. The physiographic map, Figure 1, shows how the hills detour around the uplift centered at Jackson.

The larger highland area, just west of Madison and Ridgeland, comprising most of T.7 N., R.1 E., is bisected by the cross-section (Plate 3). It is isolated from the main belt of Vicksburg hills by virtue of preservation in the Flora-Ridgeland syncline on the north flank of Jackson Dome, as explained under "Structure." It is an upland of rolling hills 350 to 425 feet in altitude, surrounded by Jackson Prairie. Some peaks, such as Rocky Hill and Richardson Hill, are broad. All hills are comprised of Forest Hill clays, silts, and silty sands, but a few are capped by remnants of Glendon limestone. Some hill slopes are clothed by loess up to 5 or 10 feet in thickness.

The second and third areas are extensions of the Vicksburg Hills belt north into Madison County. Both lie west of the line of cross-section.

The second area is south and southeast of Flora, in the south part of T.8 N., R.1 W. There, broad hills carved from Forest Hill silty clays and silts have elevations of 250 to 360 feet, 50 to 150 feet higher than the Jackson Prairie immediately west, north, and east. The crests are capped by 5 to 10 feet of loess, and 15 to 20 feet of loess is common on the gentle slopes.

The third, the most dissected area, comprises the hills in the southwest half of T.8 N., R.2 W., in the very southwest tip of Madison County. These hills are only 250 to 330 feet in elevation but they are unusually rugged due to the selective erosion of a loess mantle 20 to 40 feet in thickness. Beneath the mantle are bedrock hills of Forest Hill silty clays and silts. A few broad peaks are held up by Glendon limestone which is hidden by the loess.

LOESS COVERED HILLS

The fourth major physiographic belt, the Loess Covered Hills, crosses Madison County from southwest to northeast, off the line of cross-section to the northwest. The belt is shown on the introductory map (Figure 1) and on the geologic map (Plate 1) as bordering the Big Black River.

In Madison County the Hills represent the southeast edge of a broad loess mantle, windblown material which blankets bedrock hills east of the Mississippi Alluvial Plain. In Mississippi the belt overlooks the Mississippi River flood plain from Natchez to Vicksburg and the Yazoo Basin (the Delta) from Vicksburg through Yazoo City, Charleston, Batesville, and Memphis. On the bluffs at Yazoo City and Vicksburg, Mellen [2, 3] reports thicknesses of 50 to 75 feet, presumably on the sides of bedrock hills.

In Madison County the greatest thickness of the loess is in the very southwest corner (T.8 N., R.2 W.), where it caps a part of the Vicksburg Hills described above. The loess blanket there is so effective that only 11 tiny bedrock exposures are noted in the area comprising 17 sections (Plate 1, the geologic map). Northeastward the loess has thicknesses of 10-20 feet at Flora, 5-15 feet in the Virlilia area, 10 to 15 feet near Sharpsburg, and 10 to 20 feet in the hills southeast of Pickens. It thins noticeably eastward to 5 to 10 feet in the hills west of Madison, and to 5 feet at Madison, Gluckstadt, Canton, and Loring. On the geologic map only the larger areas of loess are shown, where thicknesses greater than 5 feet were noted.

The thought is presented that the unusual thickness of the loess blanket nearest Big Black River may be due in part to material blown out of the Big Black bottoms to augment the regional deposit blown out of the Mississippi Alluvial Plain. The same general thought is applied to the origin of isolated remnants of loess which the geologic map (Plate 1) shows on the Pearl-Big Black Divide, in the hills from Madison nearly to Farmhaven. In this area fine silts and clays may have been blown from the Pearl River bottoms. Thicknesses of 5 to 15 feet of loess were noted within sight of the Pearl River lowlands.

The lithology of the loess of Madison County will be discussed in "Stratigraphy."

SECONDARY PHYSIOGRAPHIC FEATURES

Three other important physiographic features lie to the northwest and southeast of the line of cross-section. They are the lowlands of the Big Black River at elevations of 175 to 225 feet, the lowlands of Pearl River at 275 to 325 feet, and the divide between them at 350 to 425 feet.

BIG BLACK LOWLANDS

In a belt up to 3 miles in width adjacent to Big Black River, relief is so small that in places it is impossible to distinguish between the flood plain and the bedrock hills (Plate 1). Here broad swamps border the river, making bridging so difficult that only three roads connect Yazoo and Madison Counties. They are U. S. Highway 49 (Sec.25, T.9 N., R.2 W.), Mississippi 16 (Sec.16, T.10 N., R.2 E.), and new U. S. Highway 51 (Sec.22, T.12, N., R.3 E.). A fourth, old U. S. Highway 51, crosses Big Black lowlands to enter Attala County near Pickens (Sec.23, T.12 N., R.3 E.). U. S. 49 and Mississippi 16 bridge approaches are on loess hills but the U. S. 51 approaches are across several miles of flood plain.

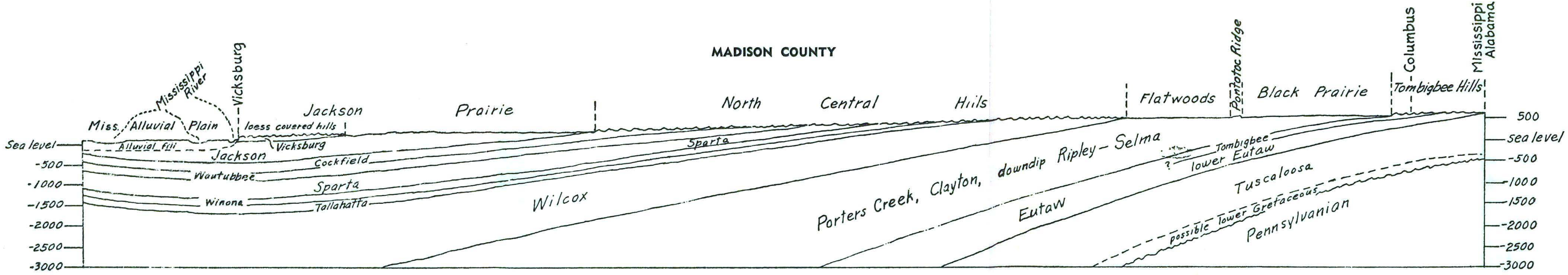
PEARL RIVER LOWLANDS

The flood plain of Pearl River at the southeast border of Madison County is equally as broad. Natchez Trace winds along the foot of the hills. Between it and the river is a belt of either cultivated or swampy bottoms up to three miles in width. Pearl River has been bridged at only one point in Madison County, by Mississippi Highway 43 in Section 25, T.8 N., R.3 E. There, two miles of swamp lie on the Madison County side but bedrock hills abut the river on the Rankin County side. At only three places in Madison County do the hills and Pearl River meet. One is a steep cutbank of alluvium at a picnic grounds along Natchez Trace in Section 23, T.7 N., R.2 E. The second is a steep cutbank of Moodys Branch marl in Section 35, T.9 N., R.4 E. The third is a cutbank of alluvium two miles upstream which had been used advantageously as a crossing for the now abondoned Canton-Carthage Railroad. All these points will be inundated when the contemplated reservoir is made by damming the Pearl at the Madison-Rankin Counties line.

BIG BLACK-PEARL DIVIDE

The Big Black-Pearl divide is one of the most unusual physiographic features of Madison County. Its position is shown on the topographic map (Plate 2) near the southeast boundary. It lies so close to Pearl River than 95 percent of the County's drainage is northwest through the large creeks, Love's, Doaks, Tilda Bogue, Bear, Panther, Persimmon, and Burnt Corn, named from northeast to southwest, respectively. Hill crests are at 350 to 425 feet but some of the valleys have been eroded to 300 to 325 feet elevation. Some 25 creeks cut across Natchez Trace as they enter Pearl River lowlands but they are so short and of such little consequence that they have never been named. Some course two miles through the hills before dropping to the bottoms but others rise less than half a mile from the Pearl River swamps.

One would surmise, then, that capture of Pearl River by Big Black River tributaries is imminent. However, the writer sees no cause for alarm despite the fact that Big Black lowlands are 75 to 100 feet lower than Pearl River bottoms. Field observations show that the differences in elevation are not the significant factors because the creeks flowing into Big Black are so long and flow on such a low gradient that they are choked with alluvium, as indicated by their broad flood plains (Plate 1). Thus, it is doubtful that they can cut much deeper. Headward erosion will probably never be effective enough to cut through the narrow divides. Proof that erosion at the divide is not very active is seen in the surprising thicknesses of weathered loess and high terrace gravels on the crest and flanks of the divide as shown in Plate 1, and the extensive cover of brown silt loam which would be the first material to be removed if erosion were very effective.



SOUTHWEST-NORTHEAST CROSS-SECTION THROUGH VICKSBURG, FLORA, AND COLUMBUS

The divide has a protective cover of woodlands which should be retained.

In the past, however, there may have been some piecemeal capture of creeks which may have originally flowed southeast into Pearl River. One example is suggested by the unusual pattern of Bear Creek and its tributaries in the Gluckstadt area (T.8 N., R.2 E.). In the southwest corner of this township the drainage is easterly as if it had once passed directly to Pearl River. But in Section 32, Bear Creek turns north-northeast toward Canton. However, this creek may be structurally controlled, as will be pointed out in "Structure," for it is unlikely that a major stream would flow 6 miles updip.

STRUCTURE

INTRODUCTION

Although in most county reports Structure is treated after Stratigraphy, the geologic structure is so important in Madison County that it should be explained first. For those who are truly interested in Madison County's geology and economic resources it is suggested that "Structure" and "Stratigraphy" be read, and "Structure" be studied before reading "Economic Geology."

Madison County surface beds are uplifted in at least two places and probably in several more. One broad belt has been extensively faulted to form a horst, a graben, and a tilted block between them (Plate 3). There are also outcrops where the dips are reversed and others where beds dipping southwesterly, in the regional direction, are tilted at angles greater than normal. To understand these anomalies it is necessary first to study the regional structure of Mississippi in the subsurface. Consult the structure map, Plate 5, which shows both subsurface and surface features. Also note the Madison County physiography and structure section (Plate 3), and the regional cross-section from Vicksburg through Madison County to Columbus (Plate 4).

It should be noted here that all structural interpretations shown by Plate 5 are derived from the records of oil tests and surface work only. No gravity, magnetometer, seismic, or core-hole data are included. Many oil company geologists and certain consulting geologists have amassed, at great expense, subsurface information which will alter the details of the structures shown.

SUBSURFACE STRUCTURES

The subsurface contours are on either the Clayton (basal Paleocene) beds or the Jackson gasrock. Most have been furnished through the courtesy of Mr. Henry N. Toler, consulting geologist of Jackson and member of the Mississippi State Geological Survey Board. Some contours, as around Pickens and Flora fields and the feature just west of Madison, are based on the writer's interpretation of electrical logs of field tests. All contours are subsea, and are on an interval of 100 feet. They show 7 major subsurface features, most of which are small numbered rectangles on the structure map (Plate 5). The features are, from northeast to southwest:

SEVEN MAJOR SUBSURFACE FEATURES

1. Regional southwest dip in the northeast half of the County. The beds are inclined westward toward the axis of the Mississippi Embayment, which roughly coincides with the course of the Mississippi River, and southward as the strata are tilted south toward the Gulf of Mexico. The southwest dip is some 70 to 80 feet per mile from the northeast corner of the County to Canton, except where interrupted by faulting.

2. An interruption of the dip caused by repeated strike faulting from northwest to southeast. This belt is part of the Pickens-Gilbertown fault zone which extends from Pickens to the Alabama line. The two major faults are designated by the small rectangles numbered 1 and 2.

3. A broad low anticline which trends northwest-southeast. Its axis passes midway between Canton and Ballard, shown by small rectangles 3.

4. A rather narrow syncline which parallels the Canton-Ballard anticline on the southwest. It, as does the anticline, trends northwest-southeast. Its axis passes through Sloan on U. S. Highway 51, as indicated by rectangles 4.

5. Dips off the huge Jackson Dome, which is centered in northeast Jackson, some 8 miles south-southwest of Ridgeland. At Ridgeland the dip is north 200 to 300 feet per mile. Five miles west of Madison the dip is 200 to 250 feet per mile northeast. Near Flora the dip is northwest at a much lower rate, only 60 to 70 feet per mile, to form a broad north nosing.

6. A flattening, rectangles 5, well down the north flank of the Jackson Dome, between Mannsdale (Sec.21, T.8 N., R.1 E.) and Madison (Sec.8, T.7 N., R.2 E.). It trends northwest-southeast. In it is situated a newly discovered structure which is making a little oil and much water at the west edge of Madison. It is provisionally called "Madison Structure." As seismic information is not available to this survey no attempt has been made to show the relationships of oil structure to the flattening except to indicate the uplift by a closed 3400-foot contour around the 3 tests in Section 7, T.7 N., R.2 E.

7. Steep northwest dip in the very west tip of the County, rectangles 6, in northwest of T.8 N., R.2 W., toward the axis of Big Black Syncline, a feature which extends northeast from Warren County. This dip also marks the east edge of the part of Mississippi Salt Dome Basin which protrudes north from Warren County and western Hinds County toward the Tinsley field in Yazoo County.

Two of the 7 features described above, Jackson Dome and Pickens-Gilbertown fault zone, merit further discussion. In addition, 5 other subsurface features, Flora nosing, Pickens faulted anticline, Loring structure, Virlilia structure, and Madison structure, deserve mention. All are labeled on the structure map, Plate 5, except Pickens-Gilbertown trend. Its northeast limit is shown by the faults (small rectangles 1) and its southwest limit is shown by the faults (small rectangles 2). The subsurface features mentioned in this paragraph will be treated in order, from northeast to southwest. Those which produce oil or gas are indicated as fields.

PICKENS-GILBERTOWN TREND

A structural belt which has attracted the attention of exploration geologists for at least 15 years is the Pickens-Gilbertown trend. As the name implies, the trend extends from Pickens field in northern Madison County southeast to Gilbertown field, just across the State line, in Choctaw County, Alabama. Along this trend is long-established production at Pickens, in Langsdale field in Clarke County, and at Gilbertown. Loring in Madison County probably belongs to this belt of fields which owe their production to faulting. A fault structure in T.8 N., R.6 E., northwest Scott County, should be included.

Many geologists reason that if oil is found at four places along this trend the intervening areas might produce if more northwest-southeast trending faults could be discovered which have trapped oil and gas migrating up the regional dip. The writer searched for such faults, especially in the Cockfield belt of outcrop in northeast Madison County. Anomalies discovered are described later in this chapter.

PICKENS FAULTED ANTICLINE

The Pickens structure is a low narrow anticline trending west-northwest—east-southeast. It has been breached longitudinally by several parallel faults, each of which is upthrown on the southwest, downdip, side. Oil was discovered in April, 1940, trapped in Eutaw sand at about 4600 to 4625 feet, subsea, against the northwest end of one of these faults. Development slowly followed the faults for some 6 miles. Several of the wells drilled in 1943 are still pumping and can be see where U. S. Highway 51 cuts Pickens field 14 miles north of Canton. In 1956 some 28 wells were producing in Madison County and 13 were pumping across Big Black River in Yazoo County to the northwest. As stated in "Previous Investigations", the field was found by seismic surveys conducted partly on the knowledge of unusual dips along old U. S. Highway 51 northeast of the field, and east of its southeast end, similar to those shown in Figures 5 and 6. Deeper drilling in the Pickens area revealed lower Cretaceous shows but no commercial oil. Because of close spacing and irregular locations to avoid some faults it is impossible to show the wells on the structure map, Plate 4. However, in Madison County 3 wells are in Section 4, 10 in Section 3, 6 in Section 10, and 9 in Section 11, all in T.11, N., R.3 E.

LORING STRUCTURE

The Loring structure is about 10 miles north-northeast of Canton. It has produced sour distillate since 1954, from two wells, one in SE.¼, NW.¼, Sec.31, T.11 N., R.4 E., and the other one mile to the southeast in NE.¼, NE.¼, Sec. 6, T.10 N., R.4 E. They produce from about 11,871 feet and 11,936 feet, subsea, respectively. Although the sour gas (hydrogen sulphide) is expensive to remove, one of the goals of Mississippi exploration, Smackover limestone production, was achieved. This writer understands that the structure was found exclusively by geophysical methods

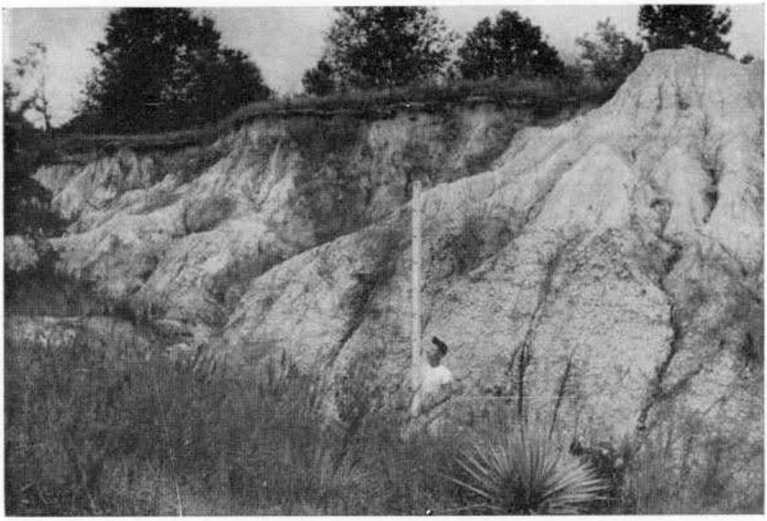


Figure 5.—East dipping basal clays of Zone 2 Cockfield, northeast roadcut (NE.¼, NE.¼, NE.¼, Sec.14, T.11 N., R.3 E.) 0.6 mile southeast of Pickens field and 1.8 miles north-northwest of Loring. July 21, 1959.

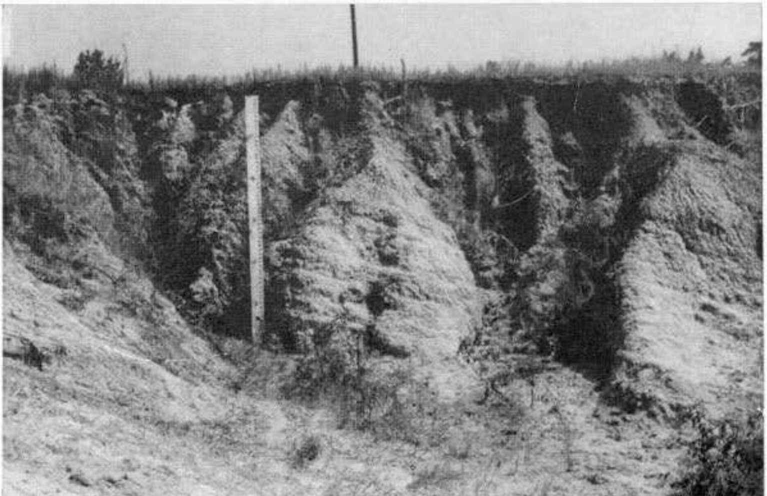


Figure 6.—Northeast dipping silty clays near base of Zone 2 Cockfield in gully just west of old U. S. Highway 51 (SW.¼, SE.¼, NE.¼, Sec.35, T.12 N,. R.3 E.) 2.2 miles northeast of Pickens field. July 17, 1959.

but he believes that the anomaly is reflected on the surface by Zone 1 Cockfield sands which are uplifted in a region of hills two miles southwest of their normal outcrops (Plate 4). According to altimeter readings the field has a surface uplift of some 50 feet centered in the northeast of Section 6. The closure on top of the Smackover limestone is in the center of Section 31. The closure appears to be against the southwest of the two faults which characterize the Pickens-Gilbertown fault zone in Madison County.

VIRLILIA STRUCTURE

The Virlilia structure, some 7 miles west-northwest of Canton, has been tested by three wells in the southwest of Section 36, T.10 N., R.1 E. They produced briefly from lower Cretaceous Glen Rose sands at about 11,000 feet on yet another structure

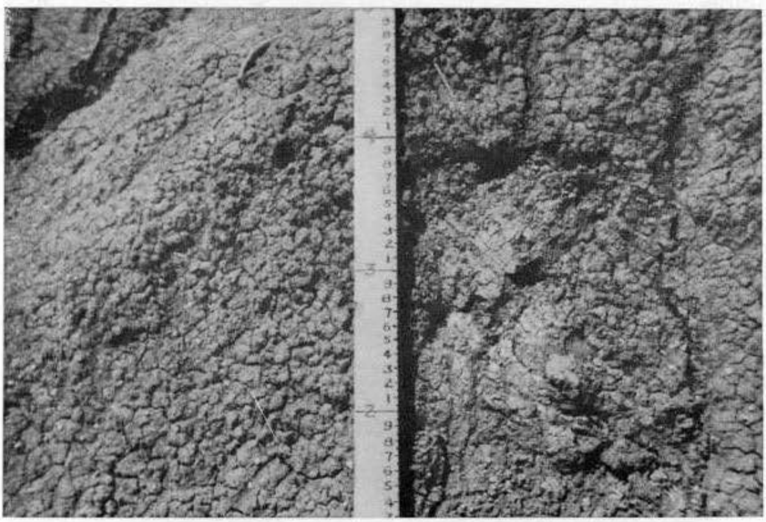


Figure 7.—Slickensided lower Yazoo clays in fault zone, one mile west of abandoned Virlilia field, north cut of road under construction (SW.¼, SE.¼, SW.¼, Sec.35, T.10 N., R.1 E.) 8 miles west-northwest of Canton. The slickensides are the lighter areas to the right of the rod. The large oyster *Ostrea trigonalis* is abundant. July 28, 1959.

found by geophysical means. The loess blanket adjacent to Big Black River in this area is so thick as to mask most outcrops. However, the writer did note two suggestions of surface structure in north cuts of a road now under construction one mile west of the abandoned wells. Here, in SW.¼, SE.¼, SW.¼, Sec.35, T.10 N., R.1 E., are numerous slickensided fault planes cutting nearly fresh Yazoo clay (Figure 7). Here, also, is an abundance of the large oyster *Ostrea trigonalis* which is common in the lower 50-foot interval of the Yazoo clay in the Jackson Dome area. If one assumes that the oyster is confined to the lower Yazoo, calculations of dip indicate that the surface beds on the Virlilia structure have been uplifted 25 to 75 feet.

MADISON STRUCTURE

The Madison anomaly is centered in Sections 7 and 18, T.7 N., R.2 E. on the west outskirts of Madison. Drilling in late 1953 and recently in 1958 and 1959 showed small quantities of oil and much

Figure 8.—Tilted and faulted upper Yazoo clays overlain by Forest Hill sands and silts, and loess in southwest cut of Mississippi Highway 463 (NE.¼, SE.¼, SE.¼, Sec.1, T.7 N., R.1 E.) 1.8 miles northwest of Madison. Leaning 12 foot rod marks a hillside slump fault. To left are east-tilted fresh Yazoo clays showing several thin bentonites. At bushes are Forest Hill sands and silts capped by loess. August 14, 1959.

salt water in three tests, but to date none of these holes has been declared a producer. The oil is from the Jackson gasrock, the same unit which produced so much gas in the Jackson Field prior to 1940. It is also the same gasrock which produces at Flora. Inasmuch as the oil shows are reported in one well at 3701 to 3712 feet the area may become one of the shallowest producers in Mississippi.

The Madison Structure is indicated in the subsurface by the dashed 3400-foot contour in the belt (rectangle 5) described earlier in this chapter as the Mannsdale-Madison flattening where north dips off Jackson Dome intersect regional southwest dip. The feature is also just northeast of the axis of the Flora-Ridgeland syncline. At the surface are some dips and minor faulting attributed to hillside slumping (Figure 8) in upper Yazoo clays and lower Forest Hill beds in southeast of Section 1, T.7 N., R.1 E., but no true faults. However, a related feature may be indicated by the peculiar behavior of Bear Creek to the northeast. As mentioned in "Physiography," the Creek flows southeast toward Pearl River in Section 31, T.8 N., R.2 E., but turns abruptly northeast through Sections 32, 28, 22, 14, and 12, as if it were structurally controlled. Accordingly, a northeast-southwest dashed fault is drawn in Section 32, 33, and 28. Upthrown side is southeast. If projected southwest the tentative fault would just miss the Madison Structure.

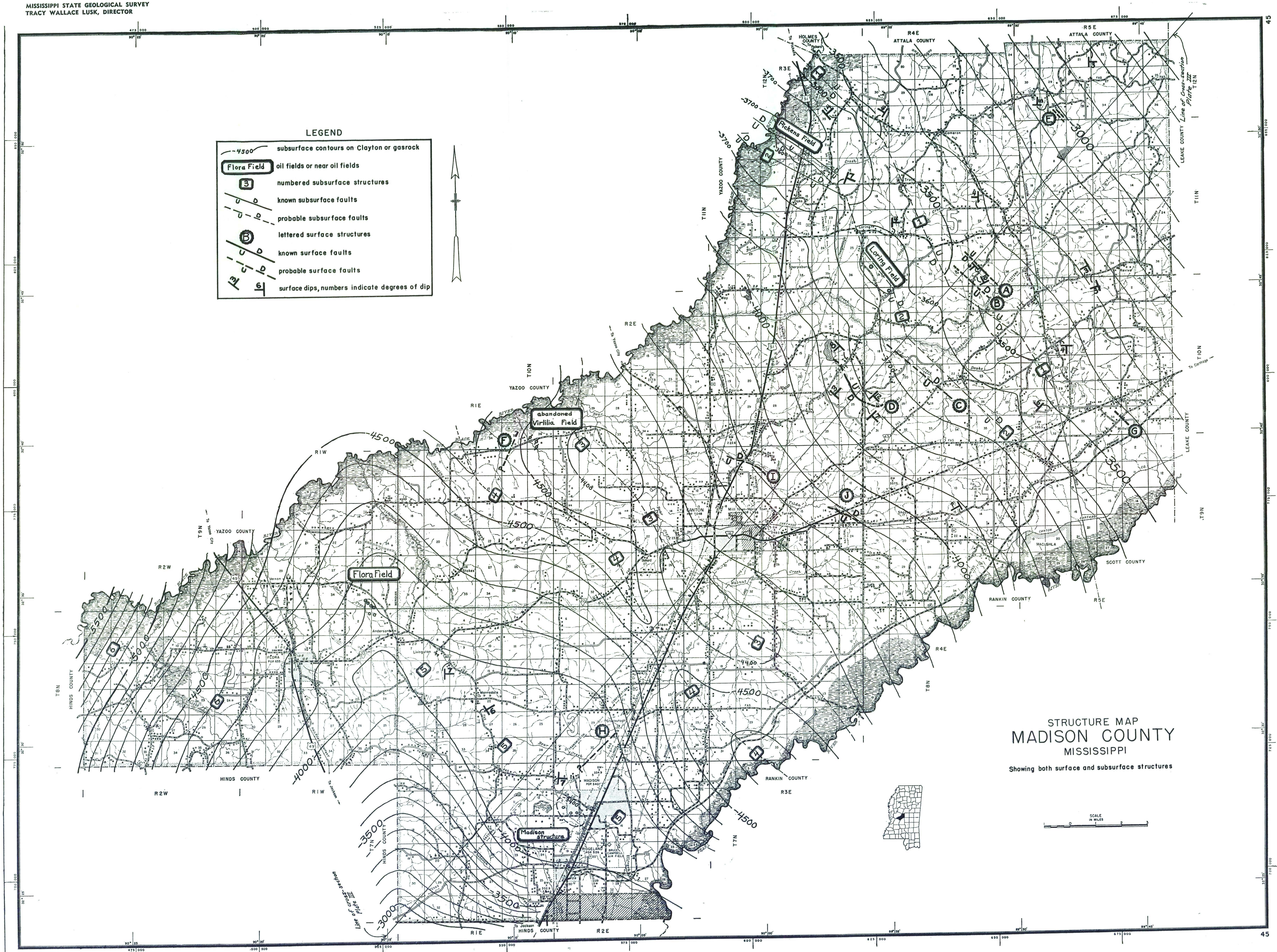
JACKSON DOME

Jackson Dome, which centers in northeast Jackson, and Kilmichael Dome in eastern Montgomery County, are two large subsurface features which are also the two most prominent surface structural features in Mississippi. As noted in "Previous Investigations," Jackson Dome has been investigated several times.

Drilling has shown that the Dome has been repeatedly uplifted, eroded, and then covered with sediments. Dike intrusions and volcanic extrusions accompanied more than one of the uplifts. During one submergence an extensive coral reef capped the dome. A late uplift trapped oil in the reef limestone at its crest but the latent heat of a later intrusion volatized much of the oil. Today only a little gas is produced but much thick gummy asphalt remains. The Dome's peak production was in 1934, when 148 wells were producing. Part of the Dome is now being used as a gas storage reservoir.

FLORA NOSING

Oil in western Madison County was discovered 3 miles northeast of Flora in 1943. Six wells have produced fairly heavy oil and some salt water at various times. They are situated where Section 35, T.9 N., R.1 W. joins Sections 1 and 2, T.8 N., R.1 W.


LEGEND
subsurface contours on Clayton or gasrock
Flora Field
oil fields or near oil fields
numbered subsurface structures
known subsurface faults
probable subsurface faults
lettered surface structures
known surface faults
probable surface faults
surface dips, numbers indicate degrees of dip
STRUCTURE MAP
MADISON COUNTY
MISSISSIPPI
Showing both surface and subsurface structures
SCALE IN MILES
Pickens Field
Loring Field
abandoned Virlilia Field
Flora Field
Madison structure
YAZOO COUNTY
HOLMES COUNTY
ATTALA COUNTY
LEAKE COUNTY
SCOTT COUNTY
RANKIN COUNTY
HINDS COUNTY
Line of Cross-section Plate III

Production is from limy sands near the top of the gasrock, the same unit which once produced so much gas at Jackson.

Oil is obtained from a combined structural and stratigraphic trap where the dip is sharpened on a long nosing which projects north-northwest from Jackson Dome. However, because of a thick loess blanket in the area, no surface structure was seen during this survey.

RELATIONS OF SUBSURFACE AND SURFACE STRUCTURES

Unfortunately surface work provides so little regional structural information that contours can not be drawn on exposed beds. Difficulties encountered are (1) a mantle of thick residual soil, (2) a partial blanket of loess, (3) a thick Cockfield unit which is difficult to zone, (4) a thick, homogeneous Yazoo clay which defies zoning, and (5) Forest Hill sands, silts, and clays which, like the Cockfield, are too intertongued and interlensed to zone. Ironically, the thin Moodys Branch marl, a good key bed, shows no structural anomalies except for two probably fault scarps which are described at the end of this chapter.

But wherever dips can be compared the surface dips are much more gentle. Thus the contours on Plate 5 show southwest regional dips of 70 to 80 feet per mile in the northeast of the County, whereas surface dips are South 15 to 20 degrees West at a rate of only 15 to 25 feet per mile. These divergences in direction and magnitude indicate extensive downwarping of the Mississippi Embayment during Cenozoic time, and a consequent thickening of Tertiary beds basinward.

The regional thickening down dip is evident on Plate 4, a cross-section after Priddy[19] from Vicksburg North 35 degrees East through Madison County to Columbus in Lowndes County.

Similarly, the surface dips northward off Jackson Dome are more gentle than shown by the contours because post-Clayton units are thinner on the crest but thicker down the flanks. For example, the contoured north dips of 200 to 300 feet per mile west of Ridgeland are but 25 to 30 feet per mile on the base of the Forest Hill silts and sands.

The best evidence for thickening of post-Clayton beds is the shallow Flora-Ridgeland surface syncline at the left of the cross-section, Plate 3. Here the southwest regional surface dip and the northeast surface dip off Jackson Dome meet. The axis of this syncline coincides with the Mannsdale-Madison flattening (6) of subsurface structure, not with the Sloan syncline (4) some 5 to 6 miles to the northeast, where the corresponding Clayton dips meet. This Flora-Ridgeland syncline is referred to repeatedly in "Physiography," "Stratigraphy," and "Economic Geology" because Forest Hill strata and some Glendon limestones lying in it have been protected from extensive erosion (Plate 1).

SURFACE STRUCTURES

It is gratifying to associate surface anomalies with producing fields but one of the purposes of this survey is to report other surface anomalies; beds out of place, consistent dips, and faults. Conceivably they may help in finding other oil and gas fields. Yet the writer believes that these surface features are already known because Madison County has been the site of 20 years of repeated surface and geophysical exploration by major oil companies and by consulting geologists. In fact, in June, 1959 two seismograph crews and one gravity crew were active in Madison County. However, it must be remembered that the data obtained were accumulated at tremendous expense, and as such, they are not for public use.

Consequently it is the duty of the writer to publish the surface anomalies he has seen. They may help smaller operators and late arrivals in Mississippi petroleum exploration. They may even help in interpreting subsurface data as more refined geophysical techniques are developed.

Surface structures in Madison County were first noted in the stratigraphic studies which resulted in the geologic map, Plate 1. Except for probable faulting and some uplift near the abandoned Virlilia field and abnormal dips near Livingston and Mannsdale, all structures were found in the northeast, northeast of the Moodys Branch outcrop belt. To help in detailing them the Cockfield was zoned (Plate 4) and altimeter elevations contoured on the Wautubbee-Cockfield and Cockfield-Moodys Branch contacts. The contact studies showed regional dip, only, but the Cockfield zoning showed three types of structural anomalies (1) uplifted strata, (2) faulting, (3) abnormal dips.

These surface anomalies are indicated on the structure map (Plate 5) by heavier lining than the Clayton subsurface contours.

Two uplifted areas are associated with oil fields. A probable third in the far northeast is described. Faults are designated in the conventional manner by heavy, long dashed lines labeled U for the upthrown side and D for downthrown side. They are designated as lettered circles for easy reference. All dips which are consistent for 100 or more feet are indicated by an enlarged letter T whose stem points in the direction of dip and whose magnitude of dip is shown by figures parallel to the stem of the T. An arrow from the dip symbol points to the exact location of each dipping bed.

UPLIFTED STRATA

Uplifted strata were noted in two areas of Madison County, associated with the Loring field and the recently abandoned Virlilia field. At Loring field, Zone 1 Cockfield sands are some 50 feet higher than they should be in and around the northeast of Section 8, T.10 N., R.4 E., as will be described in "Stratigraphy." As mentioned in "Subsurface Structure," basal Yazoo fossils in a new road cut (SW.¼, SE.¼, SW.¼, Sec.35, T.10 N., R.1 E.) one mile west of the Virlilia field are also believed to be higher than they should be.

There is a third area which appears to be uplifted but the time necessary for proving the existence of the uplift by core drilling was not available to this survey. The area referred to is the valley in the east of Section 31 and northwest of Section 32, T.12 N., R.5 E., where the lower part of the basal Cockfield (Zone 1) sand is exposed in valleys much farther south, downdip, than it should be. Valley walls were inspected but no Wautubbee chocolate-colored clays were discovered despite valley bottoms so broad that they must be floored in Wautubbee clays. A few oddly slanted gullies in the southeast of Section 32 may have been eroded from fault planes associated with the supposed uplift. The faulting is described later.

FAULTING

Faulting is difficult to detect in unconsolidated non-marine sediments such as the Cockfield beds of northeast Madison County or the Forest Hill beds in the south and southwest where interlensing, intertonguing, and channel filling are common. It is impossible to recognize faults in the homogeneous Yazoo marine

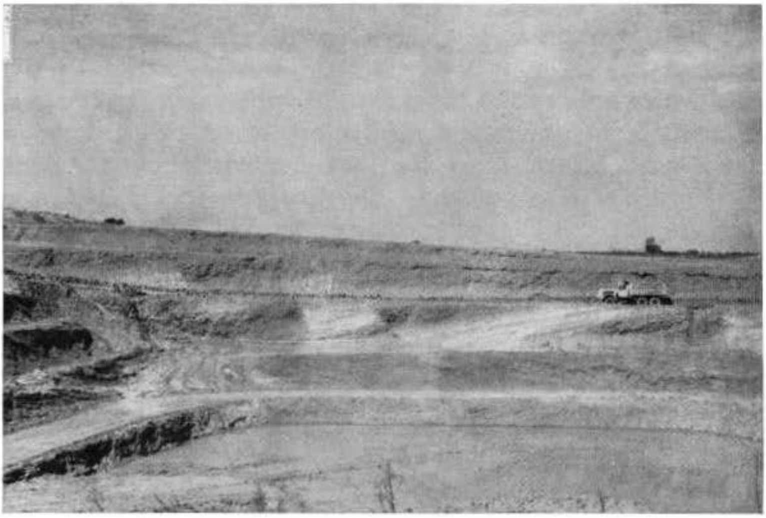


Figure 9.—South tilted block faults involving thin limestones in fresh upper Yazoo clays, west wall of Jackson Ready-Mix Concrete — Light Aggregate quarry (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W., Hinds County) 7 miles west-southwest of Madison. September 4, 1959.

Figure 10.—Fault A in northwest roadcut showing weathered fault plane between two 6 foot level rods. Basal Zone 3 Cockfield red sands downthrown at least 110 feet on the left. Colluvium from upper Zone 1 Cockfield clays on right. (Center E. line, SE.¼, NW.¼, Sec.35, T.11 N., R.4 E., about 1.9 miles southwest of Camden.) July 18, 1959.

plastic clays except at the very top of the unit where thin bentonites and limestones provide stratigraphic markers. In not a single instance of certain faulting does the stratigraphic throw involve more than one unit. Fortunately two faults can be recognized by zoning of the Cockfield, as shown in Plate 6. In the Yazoo clays and in the clays of the Cockfield formation numerous small and repeated displacements are common in road side exposures (Figure 8) or on the walls of steep excavations (Figure 9). As these features are believed to have been caused by slumping during wet weather they are not considered faults in this discussion.

True surface faults in the County are designated by the circled letters A through D (Plate 5). Possible faulting is shown as E and F. Faults A, B, C, and D are drawn on the cross-section (Plate 3), which shows stratigraphic throws of 110, 50, 45, and 35 feet respectively. Fault A (Figure 10), B, and D involve zones of the Cockfield (Plate 6). Faults A and B are probably the surface expression of the Subsurface Fault 1. Fault C is masked by alluvium in the valley of Dry Creek. It may be the surface expression of Subsurface Fault 2. Fault D has been known for some years, as suggested by the number of dry oil tests on its southwest, downdip side. The inclination of none of the fault planes is known.

Areas of supposed faulting E, F, and G are shown on Plate 5, only. The faults at E are probably related to the third of the uplifted areas as already described, in Sections 31 and 32, T.12 N., R.5 E. They are recognized by erratic dips and by gullies which are slanted as if they had been eroded from dipping fault planes, all in the southeast of Section 32. Abundant slickensiding (Figure 7) at F strongly suggests repeated faulting of lower Yazoo strata in northwest of Section 2, T.10 N., R.1 E. on the west flank of now abandoned Virlilia field, as previously described in uplifted areas. Recognition of faulting at G is less certain in Sections 34 and 35, T.10 N., R.5 E. because of slumped road cuts and an overlay of terrace sands. Beds are tilted as much as 10 degrees in all directions at and near the road fork (SE.¼, SE.¼, NE.¼, Sec.34). The faulting at G may bear the same relationship to the Pickens-Gilbertown fault trend as do the surface faults A and B to the Subsurface Fault 1.

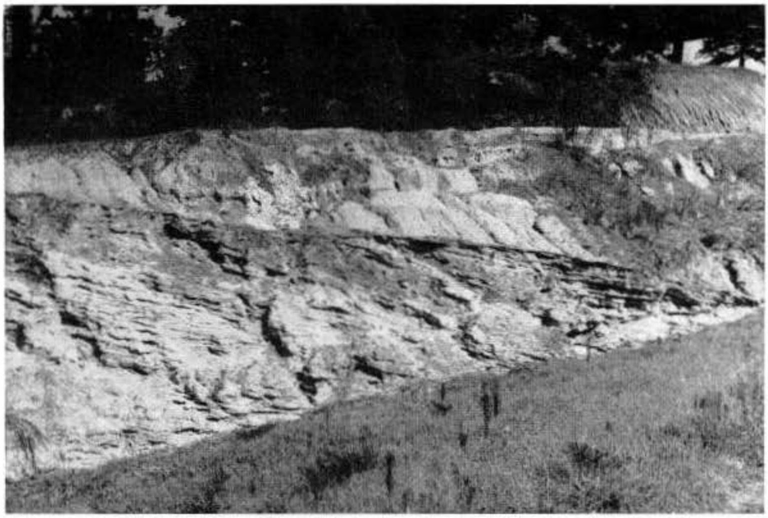


Figure 11.—Cross-bedding in silts near middle of Zone 3 Cockfield, east cut of Mississippi Highway 17 (NW.¼, NW.¼, SW.¼, Sec.28, T.10 N., R.5 E.). July 3, 1959.

Figure 12.—Southeast dipping silty clays and limonite parting in Zone 4 Cockfield, east roadcut (NE.¼, NE.¼, SE.¼, Sec.25, T.10 N., R.3 E.) 1.8 miles north of Sharon. July 27, 1959.

ABNORMAL DIPS

Beds showing dips up to 14 degrees are common in the Wautubbee, Cockfield, and Forest Hill strata but most are probably cross-bedding much as in the photograph, Figure 11. Viewed in a short road cut such anomalies are deceptive because they suggest structure.

Thus, in this study only those beds which slope consistently for more than 100 feet are considered to have abnormal dips. All were measured with Brunton Compass or by hand level and level rod, and by pacing. One of the best is pictured in Figure 12.

Figure 13.—Two limestones near top Yazoo clay dipping east (NW.¼, NW.¼, NW.¼, Sec.16, T.8 N., R.1 E.) in fresh northwest cut of Mississippi Highway 463 about 0.8 mile southeast of Livingston. Limestones are fossiliferous. August 26, 1959.

Plate 5, the structure map, shows 20 dip-strike symbols to indicate the most reliable abnormal dips.

Most of the dips are in the Cockfield belt of outcrop and seem to be related to the Pickens-Gilbertown Fault Zone. In the north, in T.11 N., R.3 E. and T.12 N., R.3 E. the dips probably reflect Pickens field (Figures 5 and 6). The one in Section 20, T.11 N., R.4 E. may indicate reversal off the Loring Structure. Those dips, such as Figure 12, between Canton and Camden are drag or other adjustments near the faults A, B, and D. To the southeast an apparent dip is southwest in road cuts of Section 15, T.9 N., R.4 E. Here, on the northeast valley wall of a tributary to Dry Creek the ferruginous sandstone of the Moodys Branch is thicker than it should be, due to tilting or to faulting. In either case the anomaly might represent a southeast extension of surface fault D.

Dips are numerous in the Yazoo belt of outcrop but most are probably slump. Unfortunately the clay weathers so rapidly that bedding planes are quickly obliterated. Exceptions are where limestones (Figures 9 and 13) or bentonite (Figure 8) in the upper Yazoo weather more slowly than the clay. The two dips involving limestones in the upper Yazoo near Mannsdale (Plate 5) are eastward at angles too steep to reflect the normal dip as contoured on the northeast flank of the subsurface feature which projects from Jackson toward Flora. Consequently they may indicate northwest-southeast faulting.

PHYSIOGRAPHIC EVIDENCES FOR STRUCTURE

In Madison County there are three physiographic evidences of structure. One is the peculiar course of Bear Creek. The other two are low, straight cliffs which probably are fault scarps, one 3 miles north-northeast of Canton, the other, 5 miles east of Canton.

The unusual course of Bear Creek has been cited in "Physiography" as suggesting that the creek may be structurally controlled. In Sections 31 and 32, T.8 N., R.2 E., near Madison, the creek flows southeasterly as if it once entered Pearl River; but in Section 32 the course turns sharply northeast past Gluckstadt nearly to Canton, as if it follows a fault plane which is shown as short heavy dashed lines, circle H on Plate 5. If a fault does exist it is probably related to Madison structure previously described. Unfortunately, thick residual soil and thick alluvium mask bedrock so there is no other evidence of faulting.

Three miles north-northeast of Canton a scarp faces north in Section 5 and 6, T.9 N., R.3 E. It makes the south valley wall of Tilda Bogue Creek. This low cliff can be easily recognized where U. S. Highway 51 cuts it in the southwest of Section 5. If there is faulting the plane is hidden in the creek valley as indicated by the short heavy dashed lines circled I on Plate 5. The writer judges from the elevations of Zone 4 Cockfield clays and projected dips on the Moodys Branch marl that the tentative fault has a vertical displacement of some 25 feet. Upthrow is on the south-southwest.

Five miles east of Canton, in Section 13, T.9 N., R.3 E., another fault scarp appears to form the southwest valley wall of Tilda Bogue Creek. The cliff is comprised of the full thickness of the Moodys Branch marl and overlooks the creek's channel which is cut in Zone 4 Cockfield silts and clays. The scarp has been cut by Mississippi Highway 16 at the west section line. The heavy dashed line circled J on Plate 5 is the presumed trace of the fault in the valley. Projected dips on the Moodys Branch-Yazoo contact suggest a vertical displacement of about 30 feet. Upthrow is on the southwest.

STRATIGRAPHY

GENERAL STATEMENT

To "Physiography" and "Structure" should be added "Stratigraphy" in order to evaluate the rocks whose probable economic value is one of the subjects of this report. In a region of sedimentary rocks such as Madison County, a stratigraphy involves establishing the order of deposition of the beds, describing them, and determining their geographic extent. Structure of sedimentary beds, on the other hand, deals with abnormally dipping strata, uplifted beds, depressed beds, or interruptions in their sequence produced by faulting.

The stratigraphic studies in Madison County revealed 10 units (Plate 1). They are shown on the stratigraphic column, Figure 4, oldest to youngest, from the base upward. The physiographic map, Figure 1, has already indicated how the Wautubbee and the Cockfield help make the North Central Hills, how the Yazoo clay makes Jackson Prairie, how Forest Hill and Glendon beds make the Vicksburg Hills, and how Pleistocene windblown materials blanket these 3 belts to make the Loess Hills bordering Big Black River.

Details of the lithology, thickness, and development of the first nine of the ten mapped units are recorded on the following pages. On Plates 1 and 6 the certain contacts between units are shown as solid lines and uncertain contacts are shown by dashed lines.

LISBON FORMATION

WAUTUBBEE MEMBER

Upper strata of the Wautubbee constitute the oldest surface beds of Madison County. In this report the Wautubbee is considered a member of the Lisbon formation although some geologists have given it formational rank. These strata crop out in the extreme north, along the valley walls of creeks flowing north into Attala County (Plates 1 and 3). Wautubbee strata help make the belt of North Central Hills (Figure 1). They are exposed from the Alabama line in Wayne County west-northwest to the edge of the Mississippi Alluvial Plain in Holmes County.

The lithology of the Wautubbee is highly variable in the North Central Hills. Three facies are recognized: (1) chiefly marls from southeast Leake County east-southeast to Alabama; (2) sands, silts, chocolate-colored clays, and gray plastic clays in an area comprising western Leake, Madison, Attala, and southeastern Holmes counties; and (3) a chocolate-colored clay facies, the Shipps Creek, in the Lexington region of Holmes County. Thomas[20] very ably shows these relationships in a composite diagram portraying the changes in lithology and thicknesses of the several Claiborne units.

In northern Madison County are 5 to 66 feet of upper Wautubbee strata. But across the line in Attala County the full thickness, 80 feet, of the Wautubbee can be measured by fitting together scattered outcrops. The most accessible good section of similar strata is along U. S. Highway 51 in Holmes County some 11 to 12 miles north of the Madison County line. A fairly continuous series of road cuts shows 83 feet of Wautubbee in 1.9 miles, which represents 63 feet of Wautubbee beds, when the regional west-southwest dip is considered. The staggered section comprised of 5 weathered road cuts is recorded below, north to south, from base upward:

Composite Section of Wautubbee Beds
Along U. S. Highway 51, Holmes County
Sec.33, T.14 N., R.4 E., and Secs.4 and 5, T.13 N., R.3 E.

	Feet
Clay, chocolate-colored, numerous partings of gray silty sand	8
Clay, chocolate-colored, numerous partings of gray silt	7
Sand, fine-grained, buff, micaceous	12
Clay, chocolate-colored, numerous partings of gray silty sand	8

Sand, silty, red-buff, micaceous	13
Clay, chocolate-colored, numerous gray silty partings	5
Clay, mottled yellow and brown, silty but plastic	2
Sand, fine-grained, red, pebbles of white flaky clay	3
Clay, chocolate-colored, buff, silty partings	2
Clay, chocolate-colored, a few gray silty partings	3

In Madison County are 22 scattered exposures (Sections 19 through 29, T.12 N., R.5 E.), which show thicknesses of 5 to 36 feet of Wautubbee beds. They are comprised of massive sand, thin-bedded silts, chocolate-colored clays, and gray plastic clays, in that order of abundance. However, it is the several bodies of chocolate-colored clay which identify the Wautubbee.

There are at least three such bodies, each 5 to 15 feet in thickness, interbedded with, and lensing into the other strata which, unfortunately, for study, resemble the overlying Cockfield sands, silts, and plastic clays. The records of Drill Tests 1, 2, and 3 best illustrate the complexity of the Wautubbee lithology. Test Hole 2 shows a thickness of 98 feet for the Wautubbee unit. The interlensing sands, silts, and clays are also demonstrated by the self potential (SP) and resistance (R) Widco logger curves of Holes 2 and 3 traced on the cross-section (Plate 3).

Test Hole 1

Location: Hilltop 15 feet above Wautubbee-Cockfield contact, southwest side of road (NE. Corner SW.¼, Sec.24, T.12 N., R.5 E.) 0.6 mile southwest of northeast tip of County

Elevation: 361 feet, altimeter

No.	Thickness	Depth	Description
1	5.0	5.0	Fragments red sandstone and red sandy soil
			Cockfield formation (Zone 1)
2	5.0	10.0	Clay, deep-yellow with red mottling, very silty
3	5.0	15.0	Clay, bright red, fairly silty
			Lisbon formation (Wautubbee member)
4	9.0	24.0	Sand, yellow-orange, silty
5	4.0	28.0	Sand, yellow, fine-grained, partings of yellow clay
6	12.0	40.0	Clay, brownish-black, carbonaceous; probable silt partings
7	8.0	48.0	Clay, chocolate-brown, waxy, partings of yellow silty clay

8	9.0	57.0	Silt, yellow-cream, clayey
9	9.0	66.0	Clay, brownish-black, fairly silty
10	4.0	70.0	Clay, nearly black, slightly silty
		70.0	TD, lost hole.
			Drilled August 6, 1959

Test Hole 2

Location: On north side of road, southeast corner of church yard (SW.¼, SW.¼, SW.¼, Sec.24, T.11 N., R.4 E.).

Elevation: 293 feet, altimeter

No.	Thickness	Depth	Description
1	6.0	6.0	Soil and rocks
			Cockfield formation, Zone 1
2	3.0	9.0	Clay, silty, yellow-buff, red mottled
3	6.0	15.0	Clay, slightly silty, buff, yellow mottled; streaks sand
4	16.0	31.0	Sand, silty, buff, micaceous; streaks cream-colored silty clay
5	25.0	56.0	Sand, very fine-grained, buff
			Lisbon formation (Wautubbee member)
6	4.0	60.0	Clay, slightly silty, tan; laminae very silty yellow clay
7	8.0	68.0	Clay, brown, laminae yellow silty clay
8	20.0	88.0	Clay, brownish-black, plastic
9	14.0	102.0	Sand, gray-white, fine-grained
10	14.0	116.0	Clay, very dark brown, very plastic
11	12.0	128.0	Sand, gray-white, fine-grained
12	26.0	154.0	Alternate beds dark silty shale and gray-tan siderite, a few grains fine glauconite; a 7 inch bed of siderite at 153.0
			Kosciusko (Sparta) sand
13	16.0	170.0	Sand, fine- to medium-grained, light-gray; numerous grains fine glauconite
		170.0	TD
		170.0	TD by electric log
			Drilled August 17, 1959

Test Hole 3

Location: South corner of road fork (NE.¼, NE.¼, NE.¼, Sec. 25, T.10 N., R.3 E.) 8 miles northeast of Canton and 2.4 miles north of Sharon

Elevation: 312 feet, altimeter

No.	Thickness	Depth	Description
1	7.0	7.0	Soil and subsoil, buff silt loam

			Cockfield formation (Zone 3)
2	7.0	14.0	Clay, yellow with red mottling, silty
3	11.0	25.0	Clay, yellow-buff, slightly silty
4	16.0	41.0	Clay, light-gray, slightly silty; thin limonitic partings
			Cockfield formation (Zone 2)
5	22.0	63.0	Clay, gray, slightly silty; partings yellow-buff sand
6	8.0	71.0	Clay, gray-tan, slightly silty, partings buff sand
7	4.0	75.0	Sand, buff, fine- to medium-grained
8	6.0	81.0	Clay, light-gray, fairly silty; partings of yellow limonite
9	4.0	85.0	Clay, gray-tan, slightly silty
10	4.0	89.0	Clay, gray-brown, fairly silty, lignitic
			Cockfield formation (Zone 1)
11	14.0	103.0	Sand, gray, fine- to medium-grained; fine dark mineral grains
12	9.0	112.0	Clay, dark-gray, slightly silty
13	10.0	122.0	Sand, gray, fine-grained, micaceous; thin interbeds dark gray clay
14	16.0	138.0	Sand, gray, fine-grained, micaceous
15	5.0	143.0	Clay, yellow-buff, slightly silty, very plastic
16	15.0	158.0	Sand, light-gray, fine-grained, micaceous; fine dark mineral grains; interbeds of yellow silty clay
17	4.0	162.0	Silt, yellow-buff, clayey; interbedded with light-gray sand
18	28.0	190.0	Sand, light-gray, fine-grained, slightly micaceous
19	6.0	196.0	Sand, yellow-buff, fine-grained; streaks yellow micaceous silt
20	25.0	221.0	Sand, cream-colored, fine-grained, slightly micaceous
21	3.0	224.0	Sand, yellow, fine-grained to medium grained
22	6.0	230.0	Sand, cream-colored, silty to fine-grained
23	15.0	245.0	Sand, light-yellow, fine-grained; thin partings of limonite
			Lisbon formation (Wautubbee member)
24	2.0	247.0	Clay, tan, slightly silty; streaks yellow clay
25	3.0	250.0	Sand, light-gray, fine-grained, micaceous
26	2.0	252.0	Clay, light-brown, slightly silty
27	11.0	263.0	Sand, yellow-buff, fine-grained, fairly micaceous
28	23.0	286.0	Sand, cream-colored, fine-grained to medium-grained
29	4.0	290.0	Clay, dark-brown, lignitic
		29.0	TD
		289.0	TD by electric log
			Drilled August 18, 1959

In new road cuts the chocolate-colored clays resemble freshly cut baking chocolate. They contain no grit, but they have, unfortunately, for their economic value, 5 to 25 laminae per foot of gray silty sand. Most partings contain leaf fragments. As they weather, the chocolate-colored clays bleach tan and then cream, and split along the partings to make a talus of shingle.

The massive Wautubbee sands are fine- to medium-grained, fairly micaceous, and somewhat cross-bedded. When fresh, they are yellow, but they rapidly alter to orange-red and eventually to a red colluvium. In most places they contain stringers of small pebbles of white flaky clay. On weathering these clays expand and pop out, leaving pits.

The silts are thin-bedded, very micaceous, and fantastically cross-bedded. When fresh they are white, but they rapidly change to yellow or buff.

The bodies of plastic clay are surprisingly silty. When fresh, beds of 1, 2, and 3 feet in thickness are common, but on wetting, the clays swell, and on drying they crack, to obliterate all bedding. In new road cuts the plastic clays are gray but they soon mottle yellow, tan, brown, and red.

Several easily accessible exposures which show the 4 Wautubbee lithologies, all along roads in T.12 N., R.5 E., are:

1. NE.¼, SW.¼, SW.¼, Sec.21, where there are interbedded silts and sands 20 feet in thickness.

2. SE.¼, NW.¼, SW.¼, Sec.21, where there are chocolate-colored clays 8 feet in thickness.

3. NE.¼, NE.¼, NE.¼, Sec.22, where there are sands 21 feet in thickness.

4. W.½, NW.¼, NW.¼, Sec.24, where 10 feet of sands overlie 3 feet of chocolate-colored clays.

5. NW.¼, NE.¼, SW.¼, Sec.25, where there are 4 feet of silts overlying 3 feet of white plastic clays.

The best section is available at the road fork in nearby Attala County (Center SW.¼, SE.¼, Sec.17, T.12 N., R.5 E.) where 36.6 feet of Wautubbee beds are exposed (Figure 14).

Figure 14.—Wautubbee-Cockfield contact in north roadcut at roadfork (Center, SW.¼, SE.¼, Sec.17, T.12 N., R.5 E., Attala County). Massive Zone 1 Cockfield sands overlie chocolate-colored Wautubbee clays. July 27, 1959.

SECTION OF WEST VALLEY WALL OF SENEATCHA CREEK FROM FLOOD PLAIN WEST TO ROAD FORK (CENTER, SW.¼, SE.¼, SEC.17, T.12 N., R.5 E., ATTALA COUNTY) IN BADLY GULLIED ABANDONED ROAD (FIGURE 14).

	Feet	Feet
Recent		
Soil, brown silty loam at hill crest (0.12 mile west of road fork)	8.0	8.0
Rubble layer, ferruginous sandstone cobbles	0.7	0.7
Claiborne group		
Cockfield formation (Zone 1)		9.9
Sand, orange-red, fine-grained, massive, badly weathered	9.1	
Sandstone, red, very ferruginous; discontinuous	0.8	
Lisbon formation (Wautubbee member)		36.6
Clay, gray-white, slightly silty, plastic	0.3	
Clay, chocolate-colored; weathers tan; thin-bedded; interbeds of orange-red silts	4.2	
Clay, chocolate-colored; weathers tan; 15-20 lamine per foot of silty sand with fragments macerated vegetation	9.4	
Sand, yellow-orange, fine-grained; badly weathered (base at road intersection)	3.6	
Clay, chocolate-colored; 5-8 laminae per foot	2.4	

Sand, yellow-buff, silty; laminae of brown limonitic siltstone; lensing eastward (downhill) into red sand with yellow clay partings	2.6
Clay, chocolate-colored; 4-7 laminae per foot; lenses eastward (downhill) into yellow massive sand	1.9
Sand, red, massive; colluvial (downhill to flood plain 0.08 mile east of road fork)	12.2

LISBON-COCKFIELD CONTACT

In Madison County unusual care was taken to study the Wautubbee-Cockfield contact as a possible aid in working out structure by the use of altimeter elevations.

In all the 18 certain or presumed contacts, 11 in Madison County, 5 in adjacent Attala County, and 2 in nearby Leake County, the relationship is one of small erosional unconformity. The uppermost Wautubbee beds, whether sand, silt, or chocolate-colored clay, are capped by thin limonitic claystones or ferruginous sandstones cemented by circulating ground waters. Nowhere is the overlying basal Cockfield sand conglomeratic.

The Wautubbee-Cockfield contact is identified with certainty in only two places in Madison County, along valley walls where the massive Cockfield sand directly overlies chocolate-colored clays. The two places are:

(1) Along the north-south road in NE.¼, NW.¼, SE.¼, Sec. 20, T.12 N., R.5 E.

(2) Along the northwest-southeast road, SW.¼, SE.¼, NW. ¼, Sec. 24, T.12 N., R.5 E., in the northeast corner of the County.

At each place the clay-sand juncture is marked by a limonitic siltstone 2 to 6 inches in thickness. A third certain contact is just over the line in Attala County near the top of a deeply gullied abandoned road (Center, SW.¼, SE.¼, Sec.17, T.12 N., R.5 E.) as shown in the preceding section.

Determination of the position of the contact is fairly certain where the basal Cockfield sand overlies Wautubbee thin-bedded silts. The contact is placed at the top of a zone of ferruginous sandstones or limonitic siltstones interbedded with silts or silty sands. In places the interval is but 2 feet in thickness but at others it is 20 feet and may contain 5 to 10 rock ledges from a few inches to one foot in thickness. The rocks are used locally for flagging, for chimneys, and for foundations.

The silt-sand Wautubbee-Cockfield contact is shown in a gullied farm road in exact center, Section 21, T.12 N., R.5 E. It can also be seen at other road cut exposures in the same township:

1. SE.¼, NE.¼, SW.¼, Sec.19, where basal Cockfield sands overlie 9 feet of Wautubbee silts.

2. At road fork (NE.¼, SE.¼, SE.¼, Sec.20) where Cockfield sands overlie 10 feet of silts which, in turn, overlie 3 feet of chocolate-colored clay.

3. South (uphill) from road fork (NE.¼, NW.¼, SE.¼, Sec.25) where the section below was measured.

Section along North-South Road (NE.¼, NW.¼, SE.¼, Sec.25, T.12 N., R.5 E.). Uphill from Road Intersection South 0.15 Mile, 8.5 Miles Northeast of Camden.

	Feet	Feet
Cockfield formation (Zone 1)		16.6
Sand, orange-buff, fine- to medium-grained, massive	14.2	
Sandstone, red, medium-grained; highly cross-bedded, contorted; laminae of yellow silt	2.4	
Lisbon formation (Wautubbee member)		25.7
Silt, cream-colored, clayey; thin beds of fine red sand up to 2 inches in thickness	5.4	
Sand, orange-buff, fine-grained, badly weathered	8.1	
Sand, orange-buff, fine-grained; very thin beds of white clay pebbles	7.4	
Silt, light tan, clayey, very micaceous; partings of yellow silty sand	4.8	
Covered interval to road intersection	1.8	1.8

The decision as to the position of the contact is least reliable where Cockfield sands overlie Wautubbee sands. In four outcrops the contact was placed at whatever siltstone or sandstone separates a massive sand containing pebbles of flaky clay from the overlying featureless massive sand of the basal Cockfield. Three of the sand-sand contacts can be seen in road cuts, in T.12 N., R.5 E., as follows:

1. NW.¼, NW.¼, NE.¼, Sec.22, at the Attala County line where 14 feet of Cockfield sands overlie 12 feet of Wautubbee sands.

2. W.½, NW.¼, NW.¼, Sec.24, where 25 feet of Cockfield sand overlies 10 feet of Wautubbee sand which, in turn, overlies 3 feet of chocolate-colored clay.

3. NE.¼, NE.¼, SE.¼, Sec.25, at the Leake County line, where 7 feet of massive basal Cockfield sand overlies 6 feet of Wautubbee sand.

COCKFIELD FORMATION

The Cockfield formation has the second greatest breadth of outcrop of any unit in Madison County (Plate 1). The belt extends from the Wautubbee bottoms in the extreme northeast to the Farmhaven-Sharon-Davis areas in the southwest. The Cockfield constitutes the uppermost unit making the North Central Hills belt (Figure 1) and, as such, extends from the edge of the Yazoo Basin in Yazoo, Holmes, and Carroll Counties east-southeast to the Alabama line in Clarke County. A very small circular area of Cockfield beds is exposed at the crest of the Jackson Dome (Figure 1).

The naming, age, relationships, and general lithology of the Cockfield in Mississippi were discussed by Thomas.[21] Later Keady[22] reviewed these data in the light of the downdip development of the Cockfield in southwest Madison County and in nearby counties.

Four zones of the Cockfield are readily noted (Plates 3 and 6). Their lithology, ranges in thicknesses in feet, and certain physiographic data are stated below, from base upward, oldest to youngest:

Zone		Feet
4	Clay; gray, sandy, plastic, massive. Tongues into silty sand northwestward. Forms hills, steep hill slopes	20-80
3	Silty clays, silts, silty sands, sands, chocolate-colored clay, and lignite; in that order of abundance. Confusingly interbedded, intertongued, and interlensed. Forms broad shallow valleys and low broad hills. Thins northwestward	80-115
2	Clay; silty, plastic, massive. Mottles on exposure	40-70
1	Sand; massive, buff, medium-grained, fairly micaceous, cross-bedded. Contains lenses of thin-bedded silts, silty clays, and lignitic clays at any interval. Sands make steep hill slopes. Clays make benches, morvans, flat valley bottoms. Thickens northwestward	160-180

All Cockfield beds, both on the surface and down the dip, are non-marine. They are also non-fossiliferous except for plant fragments in the lignites and in a few clays.

The above zones should not be projected far beyond the bounds of Madison County. Massive sands of Zone 1 are water-bearing down dip in Hinds and Rankin Counties and can be identified on the surface along Mississippi Highway 16 in western Leake County. However, Zones 3 and 4 become very sandy down the dip in Hinds and Rankin Counties and beneath the loess mantle in Yazoo County.

Thomas [23] in 1942 showed massive sands comprising most of the Cockfield in Madison County, and lenses of shales, clayey silts, and clays in the upper part, becoming more numerous northwestward. However, Keady[24] recognized Zones 4 and 3 in the subsurface of northern Rankin County.

ZONE 1, COCKFIELD FORMATION

Of the four Cockfield zones in Madison County, Zone 1 has the greatest thickness and the broadest belt of outcrop. Its thickness varies from 156 to 180 feet as measured on the outcrop and in Test Hole 3. The northeast limit is the Wautubbee bottoms. Its southwest limit is irregular due to several structures and to stream dissection (Plate 6).

Zone 1 consists chiefly of massive sands but contains also thin-bedded silts, lenses of gray plastic clay, lenses of brown carbonaceous clay, and thin lignites, in that order of abundance. The records of Test Holes 2 and 3 best show this lithology. The sands and silts erode easily to make narrow A-shaped ridges and narrow V-shaped valleys in most of the outcrop belt. In contrast, the lenses of plastic clay cap many of the narrow ridges, form the broader valley floors, and make broad benches, at any elevation, wherever the lenses are thickest.

The sands are mostly massive, medium-grained, micaceous, and fairly well cross-bedded. In fresh outcrops they are buff but they soon weather yellow-orange, then orange-red. The next product of weathering is red sandy colluvium. Eventually the sands produce red-brown sandy loam. In contrast, the silts are thin-bedded. They are also micaceous and cross-bedded. When fresh the silts are cream-colored but they soon weather buff and eventually produce brown silty loam.

Good exposures of Zone 1 massive sands are shown by 2 photos, Figures 14 and 15. Exposures where the massive sands can be visited easily are described in the next 4 sections.

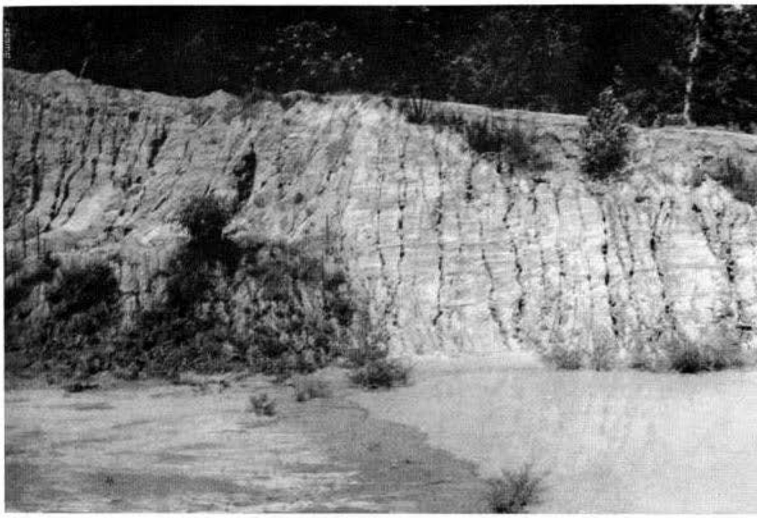


Figure 15.—Massive sand near top Zone 1 Cockfield, 28 feet in thickness, northwest wall of recent borrow pit (NE. 1/4, NE. 1/4, SE. 1/4, Sec. 25, T.12 N., R.3 E.) about 3 miles southeast of Pickens. July 17, 1959.

SECTION OF NORTHEAST WALL OF BORROW PIT (SE. 1/4, SW. 1/4, SW. 1/4, SEC. 24, T.11 N., R.4 E.) ADJACENT TO LORING-CAMDEN ROAD 0.35 MILE SOUTHWEST OF CAMDEN.

	Feet	Feet
Soil, yellow sandy loam	1.4	1.4
Cockfield formation (Zone 1)		18.9
Sand, orange-buff, fine- to medium-grained, massive	5.8	
Sand, orange-buff, fine-grained, very micaceous, well cross-bedded; partings of white clay	3.9	
Sand, yellow-buff, fine-grained, massive	9.2	

SECTION OF ROAD CUT WEST VALLEY WALL OF UNNAMED CREEK (SE. 1/4, NW. 1/4, NE. 1/4, SEC.28, T.11 N., R.5 E.) 3.1 MILES EAST OF CAMDEN. SECTION IS 0.1 MILE LONG.

	Feet	Feet
Sand, yellow-buff, fine-grained, colluvial	5.6	5.6
Cockfield formation (Zone 1)		35.8
Sand, yellow-buff, fine-grained, massive, slightly micaceous	8.3	
Sand, yellow-buff, fine-grained; lenses and stringers of white clayey silt 1 to 18 inches in thickness at any horizon	13.4	
Sand, yellow-buff, silty to fine-grained, cross-bedded	2.8	
Sand, buff, fine-grained; massive but contains lenses of very silty white clay 3 to 4 feet in thickness at any horizon	7.9	
Sand, orange-red, fine-grained to silty; to flood-plain	3.4	

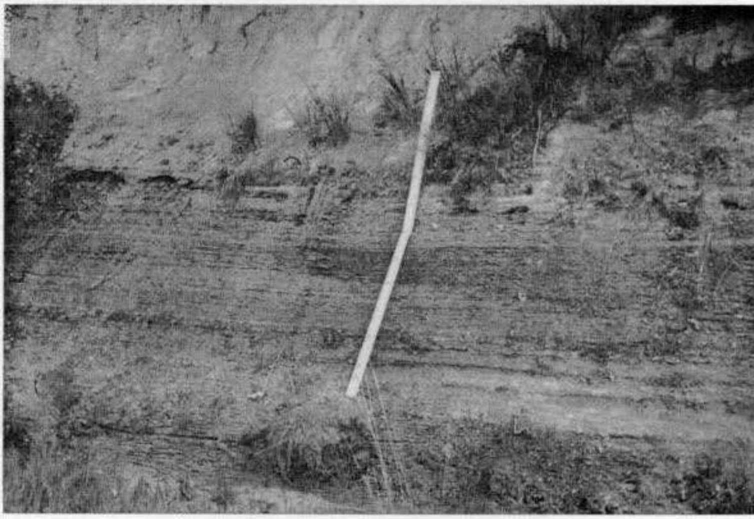


Figure 16.—Carbonaceous clay near top of Zone 1 Cockfield. Lens is 8.2 feet in thickness in south roadcut (NE.¼, NW.¼, NW.¼, Sec.4, T.11 N., R.4 E.) at west base of long hill 0.7 mile west of Cameron. July 18, 1959.

SECTION OF EAST VALLEY WALL OF LOVE'S CREEK, SOUTH ROAD CUTS OF MISSISSIPPI HIGHWAY 17, 0.7-0.4 MILE WEST OF CAMERON (NE.¼, NW.¼, SEC.4, T.11 N., R.4 E.) (FIGURE 16).

	Feet	Feet
Colluvium, orange-buff silty loam	3.2	
Cockfield formation (Zone 1)		51.2
Sand, yellow-orange, silty, slightly micaceous, massive; a few thin partings buff sandy silt	14.6	
Sand, yellow-buff, silty, micaceous, cross-bedded; contains lenses of silty mottled clay near top	6.7	
Sand, orange-red, fine-grained, slightly micaceous, massive, slightly cross-bedded	9.2	
Covered interval—0.1 mile long	3.8	
Sand, orange-yellow, silty, micaceous, cross-bedded; weathers to red sandy loam at top	6.4	
Sand, yellow-orange, silty, micaceous; 4 to 5 thin laminae of buff silty clay per foot	2.3	
Clay, chocolate-brown, 8 to 10 thin laminae buff silty sand per foot; beds dipping slightly west with highway	8.2	

Section began at flood plain of Love's Creek uphill to E. A. Simpson Grocery.

SECTION OF GULLIED ABANDONED ROAD AND PRESENT ROAD UPHILL (NORTH) FROM HOUSE NEAR FLOOD PLAIN OF HOBUCK CREEK (SW.¼, NE.¼, NW.¼, SEC.32, T.12 N., R.5 E.) TO ROAD INTERSECTION (SW.¼, SE.¼, SW.¼, SEC. 29, T.12 N., R.5 E.) A DISTANCE OF 0.25 MILE, 5 MILES NORTH-NORTHWEST OF CAMDEN.

	Feet	Feet
Soil, brown clay loam (at road intersection)	1.7	1.7
Cockfield formation (Zone 1)		69.9
Clay, buff-brown, slightly silty; weathered	3.0	
Sand, orange-red, fine-grained, massive (to head of gullied road)	6.9	
Clay, purplish-red, silty; laminae of yellow silts; beds dip 4 degrees southeast (in gullied road)	7.6	
Sand, orange-red; fine- to medium-grained, massive, slightly micaceous (in gullied road)	18.1	
Sand, red, fine- to medium-grained, fairly cross-bedded	8.6	
Silt, yellow-buff; interbeds cream-colored clay	7.4	
Sand, red, fine-grained (in gullied road)	4.1	
Silt, orange-red, ferruginous; laminae of gray clay pellets; beds dip 4 degrees south in gully	3.2	
Sand, yellow-buff, fine-grained to silty; badly weathered; thin lenses gray silty clay (road cut)	11.0	

When fresh Zone 1 plastic clays are gray, slightly silty, and massively bedded. Shortly after exposure they weather lilac. Later they turn buff, yellow, red, or purple. Finally they produce brown clay loam. Test Holes 2 and 3 show that plastic clays 6 to 9 feet in thickness are present at several intervals. However, at the surface thin beds and lenses of plastic clay may have thicknesses of 10 to 20 feet in a few places. Some of the beds are continuous for several miles in which cases they floor narrow flood plains such as are shown in Plate 6 or they cap sand ridges to make morvans where the clays dip southwestward at the same rate the ridge crests slope. Excellent morvans are to be seen along ridge roads at the localities specified below:

1. Sections 34 and 35, T.12 N., R.5 E.
2. Sections 16, 17, 20, 29 and 30, T.11 N., R.5 E.
3. Sections 6 and 7, T.11 N., R.5 E.
4. Sections 2 and 11, T.11 N., R.5 E.
5. Southwest of Section 34, T.12 N., R.4 E.

In places the clays are lenses 15 to 20 feet in thickness and one to two miles across. There, the clays hold up broad level benches (Plate 3). Several high-level benches are recognized in the following areas:

1. Sections 1, 2, and 11, T.11 N., R.5 E.
2. At the juncture of Sections 23 and 26, T.11 N., R.5 E.
3. Along Mississippi Highway 17 in Section 16, T.11 N., R.4 E.
4. Section 25, T.11 N., R.5 E.
5. Sections 35 and 36, T.12 N., R.4 E.

In the early stages of field study of the Cockfield the morvan and bench-forming clays were thought to represent continuous beds within the massive lower sand. However, the records of Test Holes 2 and 3 proved that they were merely locally developed thick clays in Zone 1 Cockfield.

Zone 1 carbonaceous clays, lignitic clays, and lignites are recorded in Test Holes 2 and 3 but only one outcrop of each was noted.

The carbonaceous clay is exposed near the base of Zone 1 as a lens in massive sand 0.7 mile west of Cameron in a south cut of Mississippi Highway 17 (NE. Corner, NW.¼, NW.¼, Sec.4, T.11 N., R.4 E.) (Figure 16). The clay looks very much like a Wautubbee clay. It is chocolate-colored and has numerous partings of silty sand, as shown in the hillside section last described.

One of the two lignites cropping out in the whole of the Cockfield belt is in the mid-portion of Zone 1 about 15 miles southwest of Camden. This lignite has a thickness of but 8 inches, is clayey, and badly weathered. It lies at the base of a north slope, near creek level, west road cut, Center NW.¼, NE.¼, Sec. 35, T.11 N., R.4 E. (The other Cockfield lignite exposed in Madison County is at the base of Zone 3 along Mississippi Highway 16.)

ZONE 2, COCKFIELD FORMATION

At the surface Zone 2 of the Cockfield formation consists of massively bedded gray, silty, plastic clay 40 to 70 feet in thickness. It is thickest along Mississippi Highway 16 at the Leake County line and in the northwest near Loring. Between these areas it thins to 40 to 50 feet.

On exposure the clays rapidly mottle yellow, buff, orange, and purple and eventually form tan colluvium and brown clay loam. However, alternate tan, brown, red, and gray clays probably make up the near surface beds, as indicated by a 40-foot auger test drilled by Dr. B. W. Brown[25] along Highway 16 at the Madison-Leake line.

AUGER TEST 2. B. W. BROWN, JUNE, 1959

Location: Crossroads (NW.¼, SW.¼, SW.¼, Sec.19, T.10 N., R.6 E., Leake County).

Elevation: 370 feet, some 215 feet below base of Moodys Branch marl.

No.	Thickness	Depth	Description
1	5.0	5.0	Clayey, silty loam
			Cockfield formation (Zone 2)
2	4.0	9.0	Clay, dark tan to brown, plastic
3	1.0	10.0	Clay, gray and red mottled, plastic
4	7.0	17.0	Clay, red, sandy
5	9.0	26.0	Clay, tan to light brown, sandy
			Cockfield formation (Zone 1)
6	14.0	40.0	Sand, olive-gray, medium-grained; water-saturated

It is this dominantly clay lithology of the outcrop and in Brown's shallow test which has been mapped as Zone 2 on the Cockfield map, Plate 6.

In contrast, clays are less evident down dip. In Test Hole 3 near Sharon and Test Hole 5 near Canton cuttings show that Zone 2 is comprised of alternating thin carbonaceous clays, thin gray silty clays, and thin sands. The tracings of the electric logs of these tests in the cross-section (Plate 3) confirm this alternation.

TEST HOLE 5

Location: On north side of road at curve, 2 miles northeast of Canton (SW. Corner Sec.9, T.9 N., R.3 E.). Drilled August 4-5, 1959.

Elevation: 275 feet, altimeter

No.	Thickness	Depth	Description
			Yazoo formation
1	5.0	5.0	Soil and subsoil, brown, clayey
2	6.0	11.0	Clay, weathered, tan, slightly silty; small limonitic nodules
3	6.0	17.0	Clay, slightly weathered, brown; streaks dark limonite
4	6.0	23.0	Clay, yellow-brown; yellow stains
5	3.0	26.0	Clay, light-tan; yellow stains
			Moodys Branch formation
6	2.0	28.0	Marl, very clayey, blue-gray, slightly limy; very small brown limonitic pellets at top; 2 percent glauconite

7	2.0	30.0	Marl, clayey, blue-gray, fairly limy, slightly glauconitic; fragments of marine shells (*Pecten*); 5 percent glauconite
8	2.0	32.0	Marl, sandy, greenish-blue, fairly glauconitic, fairly limy; pellets of limonitic claystone; 15 percent glauconite
9	2.0	34.0	Sand, very marly, greenish-black, very glauconitic; fairly limy; fragments of marine fossils (sand dollars, *Pelecypods*); 20 percent glauconite
10	2.0	36.0	Sand, very marly, nearly black, very glauconitic; fairly limy; abundant fragments marine fossils (sand dollars, razor back clams); 30 percent glauconite
11	2.0	38.0	Sand, fairly marly, greenish-black, very, very glauconitic; abundant fragments marine shells; 35 percent glauconite
12	2.0	40.0	Marl, both sandy and clayey, greenish-gray; fairly glauconitic, slightly limy; 10 percent glauconite
13	2.0	42.0	Marl, both sandy and clayey, greenish-gray; slightly glauconitic, slightly limy; 5 percent glauconite
14	2.0	44.0	Marl, sandy, greenish-gray, fairly glauconitic, fairly limy, fragments marine shells (*Pelecypods*); 15 percent glauconite
15	2.0	46.0	Clay, marly, gray-tan, slightly glauconitic, slightly limy; streaks yellow-tan clay; 5 percent glauconite
16	2.0	48.0	Marl, silty; greenish-gray, fairly glauconitic, fairly limy; 15 percent glauconite
17	2.0	50.0	Clay, marly, yellow-tan, slightly glauconitic, slightly limy; 2 percent glauconite
18	2.0	52.0	Marl, sandy, greenish-gray, fairly glauconitic, fairly limy; abundant fragments marine shells (*Pelecypods*); 15 percent glauconite
19	2.0	54.0	Marl, sandy, greenish-gray; fairly glauconitic, slightly limy; 15 percent glauconite
			Cockfield formation (Zone 4)
20	11.0	65.0	Clay, yellow-gray, fairly plastic; streaks yellow clay
21	14.0	79.0	Clay, yellow-gray, fairly plastic; streaks lignitic dark-brown clay; fragments nearly black lignite
22	23.0	102.0	Clay, dark-gray, slightly silty, fairly plastic
23	22.0	124.0	Clay, yellow, fairly silty; streaks gray plastic clay

			Cockfield formation (Zone 3)
24	57.0	181.0	Clay, dark-gray, slightly silty; fairly plastic
25	22.0	203.0	Clay, yellow-buff and gray, slightly silty, fairly plastic; a few streaks dark carbonaceous clay
26	4.0	207.0	Sand, light-gray, fine-grained; slightly micaceous
27	4.0	211.0	Silt, sandy, light-gray, slightly micaceous
28	2.0	213.0	Clay, yellow and light-gray, very slightly silty
			Cockfield formation (Zone 2)
29	48.0	261.0	Clay, light-gray, slightly silty; a few partings of light-gray sand; other partings of yellow limonitic clay and brown clay
30	3.0	264.0	Clay, dark-gray, carbonaceous, slightly silty
			Cockfield formation (Zone 1)
31	16.0	280.0	Sand, gray, fine-grained, fairly micaceous; a few scattered grains of very fine heavy minerals
32	3.0	283.0	Clay, dark-gray, carbonaceous; streaks yellow-buff silty clay; abundant brownish-black limonitic pellets
33	7.0	290.0	Sand, gray, fine-grained, slightly micaceous
		290.0	TD 12 noon August 5, 1959
		288.0	TD by electric log

Zone 2 silty clays have a very irregular belt of outcrop due to stream dissection and to structure. At the Leake County line the clays form low hills in a belt 2 to 4 miles in width. To the northwest between Camden and Sharon the belt widens to 7 miles where the valley of Doaks Creek seems to occupy to broad graben (Plate 3). However, the belt is constricted to less than one mile in Section 12, T.10 N., R.3 E., where a probable fault in Doaks Creek Valley has cut out most of Zone 2 clays. Northward the belt of outcrop broadens to 4 to 5 miles where the loess mantle has protected the clays between Loring and Pickens.

Brown's section as recorded above shows lower Zone 2 clays of probable economic value at the Leake County line. Other Zone 2 clays are well exposed in fairly recent road cuts, at places listed below:

1. Section 25 and 26, T.10 N., R.5 E. (Highway 16).

2. Northeast Section 14, T.10 N., R.5 E. (newly made road).

3. Section 3, T.10 N., R.5 E. south of Revive, where 20.1 feet of good clay is recorded in the succeeding section (Figure 17).

4. Section 31, T.10 N., R.5 E. where Mississippi Highways 17 and 43 intersect.

5. Section 2, T.10 N., R.4 E. where there are both gray silty clays and some carbonaceous clay.

6. Section 8 and 9, T.10 N., R.4 E., along a ridge.

7. West of Loring in Sections 23 and 24, T.11 N., R.3 E., and east of Loring in Sections 19 and 20, T.11 N., R.4 E., where an 18-foot section of east-dipping Zone 2 clays was observed.

8. Sections 13 and 14, T.11 N., R.3 E. near Pickens Field where Zone 2 clays show dip (Figure 5).

Figure 17.—Yellow and purple clays near base of Zone 2 Cockfield in deep gullies east of road, NW.¼, NE.¼, SE.¼, Sec.3, T.10 N., R.5 E.) 0.8 mile south of Revive.

SECTION ALONG ABANDONED ROAD EAST OF PRESENT ROAD (SW.¼, SE.¼, NE.¼, SEC.3, T.10 N., R.5 E.) FROM NARROW FLOOD PLAIN (UPHILL) SOUTH, 0.56 TO 0.71 MILE SOUTH OF MISSISSIPPI HIGHWAY 43, 0.8 MILE SOUTHWEST OF REVIVE (FIGURE 17).

	Feet	Feet
Soil, buff clay loam (overgrown with kudzu vines)	3.3	3.3
Cockfield (Zone 2)		20.1
Clay, light-gray, slightly silty to silty; mottles yellow; plastic when wet (overgrown with kudzu vines)	2.1	
Clay, light-gray, slightly sandy; mottled purple and yellow, very plastic when wet	18.0	

SECTION OF NORTH ROAD CUT, CAMDEN-LORING ROAD, WEST VALLEY WALL OF HOBUCK CREEK (SW.¼, SW.¼, SW.¼, SEC.20, T.11 N., R.4 E.) 1.3 MILES EAST OF LORING.

	Feet	Feet
Colluvium, buff clayey loam	3.7	3.7
Cockfield formation (Zone 2)		18.0
Clay, slightly silty, mottled gray, red and purple, fairly plastic; swells when wet, cracks when dry	2.8	
Clay, very slightly silty, light-gray, weathers red an purple	0.9	
Clay, slightly silty, mottled gray, red and purple, very plastic	1.6	
Clay, very slightly silty, light-gray, partings of silt	2.2	
Clay, slightly silty, mottled gray and yellow, massive, very plastic; swells when wet, cracks when dry	6.1	
Clay, slightly silty, light-gray, discontinuous thin partings of limonitic shale	4.4	

ZONE 3, COCKFIELD FORMATION

Zone 3 of the Cockfield has a thickness of about 115 feet in the eastern part of Madison County along Mississippi Highway 16 (Plate 6), but it thins northwestward. Down dip in Test Hole 5 just northeast of Canton its thickness is only 89 feet and at the surface along U. S. Highway 51 some 9 to 11 miles north of Canton its thickness is only 80 feet. However, sub-surface data in Yazoo County indicate that Zone 3 beds thicken again to the northwest.

The width of outcrop partly reflects these variations (Plate 6). In the southeast, in T.9 N., R.5 E. and T.10 N., R.5 E., the outcrop belt is 6 to 10 miles in width where the Zone is thickest, where sands and silts prevail, and where there may be some doming. It is much narrower, 2 to 4 miles in width, east of Sharon where the zone is thinner, and where clays predominate. North and northeast of Sharon faulting has eliminated most Zone 3 beds. However the belt of outcrop broadens west of U. S. Highway 51 where Zone 3 starts to thicken in a facies of sands and silts.

Zone 3 consists chiefly of silty clays, silts, silty sands, and sands, in that order of abundance. Near the base a sand-silty clay sequence contains lenses of clayey lignite 8 to 12 inches in thickness. Except for the lignite these several lithologies are treated in this report without regard to stratigraphic position because they interfinger and interlens at any interval. Depending on the disposition of the lenses some areas are chiefly sand, some are mostly clay, a few are exclusively silt, and others are comprised of clays, silts and sands which intertongue deceptively.

The silty clays of Zone 3 are thin-bedded to massive. Where interbedded with silts or silty sands they are thin, only 2 to 3 feet in thickness, and are highly cross-bedded (Figure 11). But the silty clays are massive, 10 to 30 feet in thickness, where they are interlensed with sand or where they constitute the whole of Zone 3 as in Tests 3 and 5. On fresh exposure they are gray-tan but when subjected to alternate wetting and drying the clays

Figure 18.—Clays and limonite in Zone 3 Cockfield dipping east, north roadcut (Center, SW.¼, SW.¼, Sec.19, T.10 N., R.4 E.) 2.2 miles north of Sharon. July 27, 1959.

swell and crack and oxidize to buff or yellow. Finally, the silty clays produce a brown, very silty, loam which mantles fairly broad hills northeast of Sharon on the south sides of Dry Creek and Doaks Creek.

Fresh road cuts showing good Zone 3 silty clays are easily recognized in places specified below:

1. Hilltop where Sections 24 and 25, T.10 N., R.3 E. join Section 19, T.10 N., R.4 E. (Figure 18).

2. Sections 19 and 20, T.10 N., R.4 E.

3. Section 22, T.10 N., R.4 E.

The silts and silty sands of Zone 3 are thin-bedded and interbedded. At most places they are well cross-bedded and highly micaceous. Rarely are beds more than 12 inches in thickness although some sections measure at least 25 feet. Both silts and silty sands are yellow or cream-colored where fresh but where they have weathered they are buff or tan. On the steepest slopes rainwash has removed the oxide stain leaving an apron of snow-white silt and sand glistening with mica. Figure 11 shows cross-bedding typical of the zone in the eastern part of the County along Mississippi Highway 17. Where either the silts or silty sands overlie clays or silty clays, perched water-tables are formed. Thus hillside seeps are abundant. When cut as in road building, these aquifers soon become sealed, the soluble iron they carry being concentrated at the outcrop by evaporation. In consequence, limonitic siltstones and claystones are common in many cuts of the older roads, as along Mississippi Highway 16. Cuts showing the silt and silty sand facies are numerous in the following areas:

1. Sections 5 and 6, T.9 N., R.5 E. northeast and northwest of Farmhaven school.

2. West-east road in Sections 28, 29, and 30, T.10 N., R.5 E.

3. Mississippi Highway 17 in Sections 28, 29, 32, and 33, T. 10 N., R.5 E.

4. West-east road; Sections 10 and 11, T.10 N., R.3 E.

5. U. S. Highway 51, Section 9, T.10 N., R.3 E.

Zone 3 silts and sandy silts are deeply gullied in the northwest:

1. Along the north valley wall of Doaks Creek in Sections 34 and 35, T.11 N., R.3 E., where farm lands and even homes have been destroyed.

2. In the hills east and west of U. S. Highway 51, Section 9, T.10 N., R.3 E.

3. In Sections 31 and 32, T.11 N., R.3 E., north and northwest of Allison's Wells, where deep gullies are an added attraction.

Because they make conspicuous road cuts the sands appear to be more plentiful in Zone 3 than all the other rocks. Beds vary in thickness from 2 to 3 feet where associated with silts or silty clays to huge lenses 15 to 30 feet in thickness and up to one mile in width. Either thin-bedded or massive, the sands are fine- to medium-grained and fairly micaceous. When fresh they are white but they quickly weather buff and orange. Eventually they produce red colluvium and red-brown sandy loam. Some roads 20 years old expose 10 to 15 feet of vertical cuts of firm deep-red colluvial sand criss-crossed by deeply incised joints and weathered planes of cross-bedding. Standing in relief are irregular laminae of white flaky clay. On gentler slopes or in recent

Figure 19.—Massive basal sands of Zone 3 Cockfield in double cut (NE.¼, SE.¼, NE.¼, Sec.15. T.10 N., R.5 E.) about 2.7 miles south of Revive. July 1, 1959.

borrow pits rainwash removes the iron stain as far as formed, producing broad aprons of snow-white micaceous sand. The sands can be visited readily at the following localities, chiefly in the southeast part of Zone 3 outcrop belt:

1. Massive sands in the mid-portion of the zone, borrow pit, north side of Mississippi Highway 16 (Southeast Corner Sec.36, T.10 N., R.4 E.) where some 19 feet are exposed. In the south road cut 9 more feet higher sands are exposed beneath 12 feet of terrace sand.

2. Massive sands in lower part of Zone 3 dipping southeast in northeast cut of Mississippi Highway 17 (NE.¼, NW.¼, SW.¼,

Sec.7, T.10 N., R.5 E.). Similar sands capped by terrace sands form both valley walls of Doaks Creek to the south (Secs.20, 21, 28, and 29, T.10 N., R.5 E.).

3. West-east road in Sections 14 and 15, T.10 N., R.5 E. (Figure 19).

4. Hilly area in Sections 14, 15, 16, 21, 22, and 23, T.10 N., R.5 E., where surprisingly steep slopes are efficiently cultivated.

5. North valley wall of Dry Creek (Center, SE.¼, NW.¼, Sec.7, T.10 N., R.4 E.) 10 miles northeast of Canton, where the following section shows 17.2 feet of the uppermost Zone 3 sands.

SECTION ALONG ROAD (CENTER, SE.¼, NW.¼, SEC.7, T.10 N., R.4 E.) NORTH VALLEY WALL OF DRY CREEK FROM FLOOD PLAIN NORTH TO ROAD FORK, A DISTANCE OF 0.1 MILE, 10 MILES NORTHEAST OF CANTON.

	Feet	Feet
Soil, yellow-buff silty clay loam	3.9	3.9
Cockfield formation (Zone 4)		4.1
Clay, red-buff, silty; weathered	4.1	
Cockfield formation (Zone 3)		17.2
Sand, yellow-buff, fine-grained; interbeds of purple silty clays 2 to 3 inches in thickness	4.5	
Sand, yellow-buff, fine-grained, slightly cross-bedded, micaceous	3.9	
Sand, orange-buff, fine-grained to silty, very micaceous, massive	4.2	
Clay, purple, slightly silty	0.3	
Sand, white, fine-grained to silty	1.2	
Sand, yellow-orange, fine-grained, weathered	3.1	

The minor constituents of Zone 3 are carbonaceous clays and lignites. They are rare at the surface but test holes show that they may be common in the subsurface. They may be at any horizon. Carbonaceous clays were noted as follows:

(1) Along the north-south road where a lens of carbonaceous clay some 8 feet in thickness is at the very base of the unit in the west cut (N. line, NW.¼, SW.¼, Sec.2, T.10 N., R.4 E.) about 2.9 miles southwest of Camden.

(2) Other carbonaceous clays, aggregating some 28 feet in thickness, are interbedded with plastic gray silty clays in the upper part of the unit along an abandoned farm road just south of Mississippi Highway 16 (NE.¼, NE.¼, SW.¼, Sec.2, T.9 N., R.4 E.).

(3) Older carbonaceous clays extend nearly to the base of Zone 3 as shown by Dr. Brown[26] in another auger hole along the Highway 0.8 mile east of (2) (NW.¼, SW.¼, NW.¼, Sec.1, T.9 N., R.4 E.).

AUGER TEST 1, B. W. BROWN, JUNE, 1959

Location: Crossroads (NW.¼, SW.¼, NW.¼, Sec.1, T.9 N., R.4 E.)

Elevation: 305 feet, some 105 stratigraphic feet below base of Moodys Branch marl.

No.	Thickness	Depth	Description
1	5.0	5.0	Loam
			Cockfield formation (Zone 3)
2	3.0	8.0	Clay, brown, silty
3	5.0	13.0	Clay, red, plastic
4	3.0	16.0	Clay, red
5	9.0	25.0	Clay, olive-brown to gray
6	3.0	28.0	Clay, chocolate-gray
7	10.0	38.0	Clay, brown
8	6.0	44.0	Sand, gray, medium-grained, clayey, micaceous
9	1.0	45.0	Clay, brown, limonitic; small granules of friable limonite
10	10.0	55.0	Sand, olive-gray to charcoal-gray, fine- to medium-grained, silty, clayey; water-saturated

The second of the two Cockfield lignites observed at the surface of Madison County is near the base of Zone 3. The other lignite has been cited in the mid-portion of Zone 1 (Center NW.¼, NE.¼, Sec.35, T.11 N., R.4 E.). The Zone 3 lignite has a thickness of only 12 inches. It is exposed as a badly weathered sooty clay in a north roadside ditch of Mississippi Highway 16 (NW.¼, NE.¼, SW.¼, Sec.26, T.10 N., R.5 E.), exactly 2 miles west of the Leake County line.

ZONE 4, COCKFIELD FORMATION

Beds of Zone 4, the uppermost Zone of the Cockfield, are exposed in a belt (Plate 6) of varied lithology northwest across Madison County from the divide overlooking Pearl River to the low hills near Big Black River.

A sandy clay about 50 feet in thickness comprises the zone from Natchez Trace to near Sharon, making a belt of steep hillsides which in a few places is one mile in width. But from near Sharon to U. S. Highway 51 north of Canton the belt broadens to 3 to 5 miles as the sandy clays are interbedded with silts and silty sands which increase in thickness westward to 80 feet at the Highway. West of Highway 51 Zone 4 beds are mostly hidden by a thick mantle of loess; however, available exposures suggest that the belt has narrowed to 2 to 3 miles where silts, silty sands, and thick lenses of sandy clay aggregate 60 feet in thickness.

The clay is sandy, not silty. Yet it is quite plastic and should make an excellent brick and tile material. It is gray when fresh

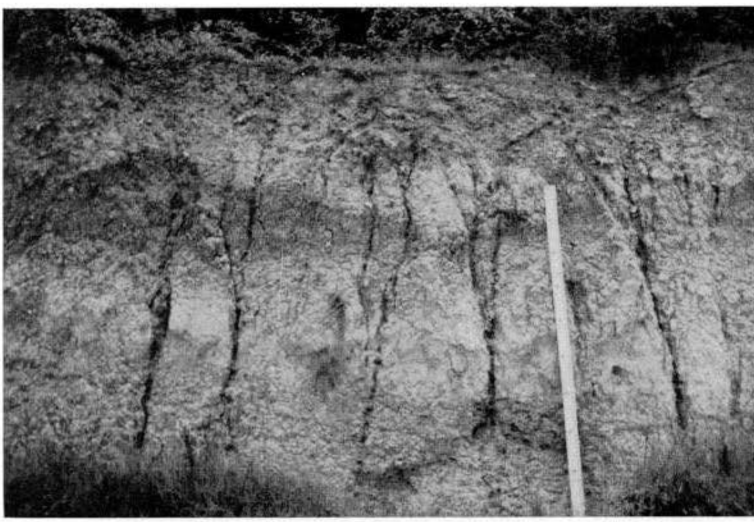


Figure 20.—Massive silty clays near top Zone 4 Cockfield, southeast roadcut (Center, SW. ¼, SE. ¼, Sec.23, T.10 N., R.3 E.) about 3 miles north-northwest of Sharon and 7 miles northeast of Canton. Section shows that Zone 4 sandy clays are 30.1 feet in thickness. July 27, 1959.

but it slowly changes color through yellow and buff to tan as it alternately swells when wetted and cracks when dried. Both the silts and silty sands are buff when fresh but they rapidly oxidize to orange-red, especially where waters from the overlying ferruginous Moodys Branch sandstone have stained them.

The sandy clay helps form the winding Moodys Branch cuesta from the Natchez Trace to Sharon as described in "Physiography" and as portrayed in the cross-section, Plate 3. From Sharon northwest to U. S. Highway 51 it makes the steeper hillsides, whereas the silts and silty sands make the gentler hill slopes. West-northwest of Sharon and due south of Sharon the silts and silty sands form narrow Cockfield inliers (Plate 6) along streams between Moodys Branch and Yazoo capped hills (Plate 1).

Zone 4 sandy clays are studied best along fresh road cuts, as follows:

1. Sections 12 and 13, T.9 N., R.5 E., near the Natchez Trace.

2. Along Mississippi Highway 43, Sections 29, 31, and 32, T.10 N., R.4 E., 1 to 3 miles northeast of Sharon.

3. Sections 25 and 36, T.10 N., R.3 E., 1.2 to 1.7 miles north of Sharon.

4. Section 23, T.10 N., R.3 E. (Figure 20) about 3 miles north-northwest of Sharon and 7 miles northeast of Canton where the following hillside section shows 30.1 feet of sandy clay just beneath the Moodys Branch marl.

5. Along the road which curves through Sections 15 and 21, T.10 N., R.3 E. some 7 to 8 miles north-northeast of Canton.

6. In the west cut of U. S. Highway 51 beneath Moodys Branch marl (SW.¼, NE.¼, SW.¼, Sec.5, T.9 N., R.3 E.) on the south valley wall of Tilda Bogue Creek, 3 miles north of Canton.

The record of Drill Test 5 just northeast of Canton shows 70 feet of plastic sandy clays containing some thin beds of lignite and silty clays which are identified as Zone 4, Cockfield. This zone is also shown on the electric log (Plate 3).

SECTION OF SOUTH VALLEY WALL OF SOUTH FORK OF DOAKS CREEK, SOUTHEAST ROAD CUT 0.4-0.3 MILE NORTHWEST OF ROAD FORK. NW.¼, SW.¼, SE.¼, SEC.23, T.10 N., R.3 E., 7 MILES NORTHEAST OF CANTON.

	Feet	Feet
Moodys Branch formation		3.7
Gravel, dark-red, small to coarse; ferruginous sandstone; a residuum of Moodys Branch marl	3.7	
Cockfield formation (Zone 4)		30.1
Clay, buff with yellow and red mottling, slightly sandy, massive, very plastic when wet; shrinks on drying	7.1	
Clay, light-gray, slightly sandy; a few thin limonitic partings	2.7	
Clay, yellow-buff with red mottling, slightly sandy, massive, very plastic	6.2	
Clay, gray-white, slightly sandy, very plastic	3.4	
Clay, light-gray-tan, slightly sandy, massive, very plastic	6.2	
Silt, yellow-buff, clayey; thin limonitic partings overlying thin beds of clay	1.8	
Clay, light-gray, slightly sandy, massive	2.7	
Section began at flood plain		

COCKFIELD-MOODYS BRANCH CONTACT

Although contacts of non-marine Cockfield beds with the overlying marine Moodys Branch marl in Madison County are numerous, few details of the relationship are known because a talus of red ferruginous sandstone prevents extensive study.

However, four kinds of contacts are recognized: (1) Moodys Branch sandstone overlying Cockfield Zone 4 sandy clays; (2) Moodys Branch sandstone overlying Cockfield Zone 4 sands and silts; (3) Moodys Branch marl overlying Cockfield Zone 4

Figure 21.—Contact of Cockfield Zone 4 silts and Moodys Branch in northwest roadcut of Mississippi Highway 43 (SE.¼, NW.¼, SW.¼, Sec.1, T.9 N., R.3 E.) 0.9 mile southwest of Sharon. Thin ledge marks contact of Zone 4 Cockfield silts and basal Moodys Branch ferruginous sand. July 27, 1959.

sandy clays; and (4) Moodys Branch marl overlying Cockfield Zone 4 silts or sands. Because the Moodys Branch is exposed across the County chiefly as a red ferruginous sandstone, types 1 and 2 prevail.

In Type (1) the contact of sandstone with clay is sharp. Erosion of some of the clay had taken place before the Moodys Branch seas transgressed, but there is no sign of angular relationship. Sandy tubes, presumed to have been worm borings, leave the sandstone and enter several inches of the clay, as seen along the east-west road (Secs.5 and 6, T.9 N., R.4 E.) east of

Sharon. There, also, a few small pebbles of Zone 4 Cockfield clays are incorporated in the basal few inches of the sandstone.

In Type (2), sandstone over sands or silts, the contact is conformable (Figure 21), as along Mississippi Highway 43 (SE.¼, NW.¼, SW.¼, Sec.1, T.9 N., R.3 E.) about 0.9 mile southwest of Sharon, where the following road cut section was measured. The Cockfield sands and silts are cemented to ferruginous sandstones or siltstones or they are so iron-stained that the only feature of the contact is the parallelism of Cockfield and Moodys Branch strata.

In Type (3), the marl over sandy clay, the contact is sharp. Here also worm tubes and clay pebbles are common, as along U. S. Highway 51, west cut, (SW.¼, NE.¼, SW.¼, Sec.5, T.9 N., R.3 E.) about 3 miles north of Canton on the south valley wall of Tilda Bogue Creek. In Test Hole 5 (SW. Corner Sec.9, T.9 N., R.3 E.) about 2 miles northeast of Canton, drilling by 2-foot intervals and electric logging showed green glauconitic Moodys Branch marl overlying yellow-gray fairly plastic clay which had probably been weathered before Moodys Branch seas transgressed Madison County.

SECTION ALONG MISSISSIPPI HIGHWAY 43 (SW.¼, SEC.1, T.9 N., R.3 E.) CONTINUOUS FROM 0.9 TO 0.5 MILE SOUTHWEST OF SHARON (FIGURE 21).

	Feet	Feet
Soil, buff clay loam	4.3	4.3
Yazoo formation		13.9
Clay, buff with yellow and red mottling, slightly silty, massive; fairly plastic; weathered	7.1	
Clay, red-buff, slightly silty, massive, plastic	6.8	
Moodys Branch formation		25.7
Sandstone, dark-red, fine- to medium-grained, poorly cemented, very ferruginous, massive; concretionary; lower 3.0 feet partly hidden by buff sandy loam	4.4	
Sandstone, bright-red, fine-to coarse-grained, poorly cemented, massive; marks of grader blades; lower 9.1 feet partly hidden by ferruginous sandy clay	20.5	
Sand, dark-red, fine- to medium-grained, ferruginous; interbedded with yellow-orange silts	0.8	
Cockfield formation (Zone 4) (Figure 21)		4.1
Silts, orange-red, clayey; thin-bedded; iron-stained.		
Section began at flood plain		

In Type (4), marl over silt or sand, the contact is disconformable. In the area northwest of Canton the Cockfield strata are riddled by mollusc borings filled with glauconitic sand to a depth of 6 to 8 inches, as in the borrow pit section described by Mellen[27] in 1939 along Mississippi Highway 16 (NE.¼, NW.¼, Sec.9, T.10 N., R.2 E.), on the Yazoo County side of Big Black River. Mellen's section follows. His Yegua silt (Lisbon) is Cockfield Zone 4.

SECTION BY MELLEN

(Mississippi State Geological Survey Bulletin 39, page 17, 1940.)

"Section beginning about flood-plain level of Big Black River on the north side of the Canton-Yazoo City Highway on the W. H. Brister property (NE.¼, NW.¼, Sec.9, T.10 N., R.2 E.) (Figure 23)

	Feet
Brown loam, variable	16.5
Brown loam and transitional material to the weathered Yazoo clay below; scattered chert and quartz pebbles near base of interval; black manganiferous "buck shot" near middle	
Yazoo Clay (Jackson), variable	5.5
Clay, calcareous, silty, fossiliferous, glauconitic; lime nodules; thin stringers of bentonite; joints stained with iron and manganese precipitates	
Moodys Branch marl (Jackson)	31.0
Sand, yellowish-brown argillaceous, glauconitic; glauconite mostly changed to limonite; fossiliferous	
Disconformity, marked by an irregular band of thin hollow limonite concretions; elevation about 203 feet	
Yegua silt (Lisbon)	1.6
Silt, riddled by mollusc borings which are filled with sand from above; top part reddish to yellowish-brown; bottom part mottled gray and yellowish-brown"	

MOODYS BRANCH FORMATION

The Moodys Branch formation is the basal unit of the Jackson group (Figure 4). Because of its famous fossil collecting places the marl is one of the best known units in Mississippi. Its fossils were first described by Wailes[28] in 1854 along Moodys Branch Creek in northeast Jackson, where the marl and the upper Cockfield beds have been exposed by an uplift of some 250 feet at the crest of the Jackson Dome. This Moodys Branch inlier is shown on the physiographic map (Figure 1).

However, the normal outcrop belt of the marl crosses Madison County in its narrow mid-section at the juncture of the North Central Hills and the Jackson Prairie (Figure 1). The belt of outcrop trends west-northwest—east-southeast in keeping with its exposure across Mississippi from northern Yazoo County to Clarke County at the Alabama line (Plate 1).

In the hills overlooking Pearl River and in the hills adjacent to Big Black River the outcrop is narrow as would naturally be true of a unit having a thickness of but 22 to 27 feet. In these areas weathering of the glauconite in the marl has produced enough limonite to form a cemented sandstone which holds up a low cuesta up to several hundred feet in breadth. However, in the intervening area, from Shocco through Sharon to U. S. Highway 51 north of Canton the outcrop belt widens to 2, 3, and even 4 miles where a higher glauconite content has weathered to produce a well-cemented ferruginous sandstone holding up broad hills.

Some 95 exposures of Moodys Branch marl were noted during this Madison County survey. All but four were recognized on the basis of the red ferruginous sandstone. Weathering is so advanced that only two can be identified by fossil content, in contrast to the easy identification by fossils throughout the rest of the Mississippi outcrop. Typical examples of road cut exposures are shown in Figures 21, 22, and 23. The preceding section of continuous cut along Mississippi Highway 43 (SW.¼, Sec.1, T.9 N., R.3 E.) is also typical of most exposures. In contrast, the green marl of the fresh Moodys Branch, by 2-foot intervals, is shown in the record of Drill Hole 5 (SW.¼, SW.¼, SW.¼, Sec.9, T.9 N., R.3 E.) two miles northeast of Canton. Such beds are to be sought for their high glauconite content.

In the larger exposures the ferruginous sandstone is yellow, yellow-brown, brown, or red-brown, firm, and so concretionary as to make warty, contorted surfaces. Despite the firmness of the steeper cuts they show the marks of road graders, so it is evident that circulating waters have concentrated the limonitic cement since the cuts were made, in most cases, during the road building program of the Works Progress Administration, 1934-1940. On digging, limonitic casts of fossils and fairly fresh glauconite are encountered inches from the surface. However, only a large fragment of a single sand dollar was found to represent the unaltered state in the whole of the County, at the long hillside cut along Mississippi Highway 16 four miles east of Canton (NW.¼, NW.¼, SW.¼, Sec.13, T.9 N., R.3 E.).

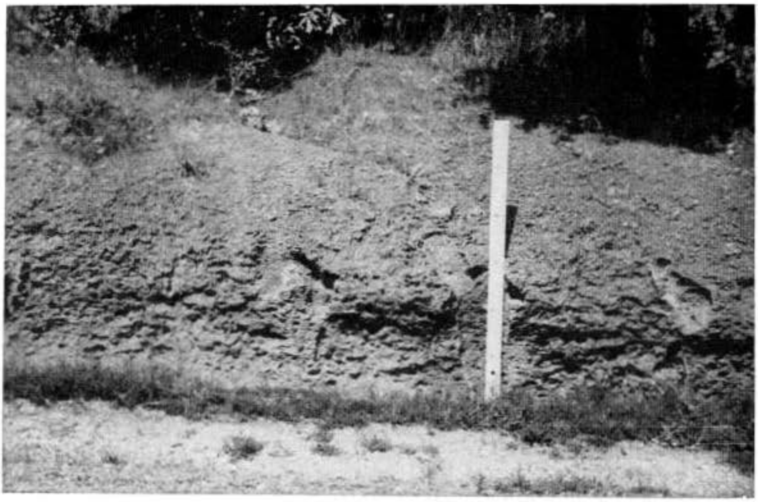


Figure 22.—Warty, ferruginous sandstone typical of most Madison County Moodys Branch exposures, west roadcut (Center, SE.¼, SE.¼, SE.¼, Sec. 36, T.9 N., R.6 E.) 0.35 mile north of Sharon. July 27, 1959.

Figure 23.—Moodys Branch strata, Yazoo clay, and loess at top of borrow pit on southwest side of Mississippi Highway 16 (NE.¼, NW.¼, Sec.9, T.10 N., R.2 E., Yazoo County) 1.7 miles northwest of Big Black River, the Madison County line. Figure stands on dark Moodys Branch marly sand. Behind figure is white Moodys Branch marl with abundant caliche. The thin dark zone at the figure's arms is basal Yazoo clay. In the background is weathered loess. August 14, 1959.

An exposure of Moodys Branch marl showing surprisingly little alteration is a west road cut of U. S. Highway 51 (SW.¼, NE.¼, SW.¼, Sec.5, T.9 N., R.3 E.) about 3 miles north of Canton on the south valley wall of Tilda Bogue Creek. Here, in 1947, glauconitic marl was collected from hand auger holes as part of a state-wide study of glauconite. Analyses showed 32.8 percent glauconite, an amount similar to that from several 2-foot intervals in Test Hole 5 two miles to the southeast.

Another little altered exposure is a borrow pit along Mississippi Highway 16 on the Yazoo County side of Big Black River (Figure 23) which was sectioned by Mellen[29] in 1939 or 1940, as previously mentioned. Here the marl contains a fair number of marine shells (*Pelecypods*) although many have been dissolved by capillary waters, as indicated by large and small nodules of white caliche.

Until 1958 the full thickness of Moodys Branch marl was exposed at low water in the bank of Pearl River at a picnic ground along the Natchez Trace (NE.¼, NE.¼, NW.¼, Sec.35, T.8 N., R.4 E.). Now the bank has been largely covered as part of a parking area. Samples collected in 1948 and now in the Department of Geology, Millsaps College, show that the marl of the river bank was greenish-gray, quite sandy, rather clayey, slightly glauconitic, poorly consolidated, and sparingly fossiliferous. A short distance downstream the Moodys Branch is crossed by Pearl River. There rounded residual masses of ferruginous sandstone up to 6 feet in diameter mark the shoals known as "the rocks." The glauconite, in all stages of alteration from bright green grains through olive and brown grains, reveals the source of the limonite which circulating ground-waters concentrate at the outcrop to produce the ferruginous sandstone characterizing most of today's Moodys Branch outcrop. Both the picnic ground exposure and "the rocks" will be inundated by waters of the projected Pearl River Reservoir.

MOODYS BRANCH — YAZOO CONTACT

Some 60 contacts of the Moodys Branch formation with the overlying Yazoo formation are to be seen in Madison County. They are along roads or in gullies at the crest of, or behind, southwest of, the Moodys Branch cuesta. Six are shown in the cross-section, Plate 3.

The contact is readily recognized where gently sloping clays overlie benches held up by the ferruginous Moodys Branch sandstone (Figure 24). It is more difficult to determine the position of the contact where the marl has not produced a sandstone, as at some places west of U. S. Highway 51 and to the southeast between Mississippi Highway 16 and the Natchez Trace. In these areas buff-tan clays overlie red-brown clayey sands or sandy loam. This color contrast facilitated tracing the contact on aerial maps.

Figure 24.—Deeply weathered contact of Moodys Branch marl and Yazoo clay in east roadcut (SW.¼, SW.¼, NW.¼, Sec.30, T.10 N., R.3 E.) 5.0 miles north of Canton. The upper Moodys Branch is a deep red ferruginous sandstone. The clay is buff and featureless. August 14, 1959.

All fresh exposures in Madison County showed that the contact is conformable but that it is gradational through a one-foot interval. Glauconitic sands in the uppermost bed of the Moodys Branch diminish in amount upward and the clay content of the Yazoo diminishes downward. As on the crest of the Jackson Dome, the beds are parallel, but the 3- to 7-foot gradational interval noted there is less evident in Madison County. Fossils are of no aid because virtually all have been dissolved by the deep weathering of both units. A fresh exposure of the contact would probably look like Mellen's borrow pit section (Figure 23) in adjacent Yazoo County, just across Big Black River on Mississippi Highway 16.

To see the Moodys Branch-Yazoo contact to best advantage one should travel the roads described as follows:

1. North-south road between Sections 1, 12, and 13, T.9 N., R.3 E. and Sections 6 and 7, T.9 N., R.4 E., south of Sharon.

2. West-east road in Sections 5 and 6, T.9 N., R.4 E., east of Sharon.

3. Mississippi Highway 43 southwest of Sharon in Sections 1, 2, 9, and 8, T.9 N., R.3 E.

4. The curving road through Sections 32, 33, and 34, T.10 N., R.3 E.

5. West-east road at the south line of Sections 23 and 24, T.10 N., R.2 E.

6. North-south road between Sections 19, 30, and 31, T.10 N., R.3 E. and Sections 24, 25, and 36, T.10 N., R.2 E.

On some hillsides the Moodys Branch-Yazoo contact can be detected by an accumulation of brown to black nearly spherical limonitic pellets, know locally as "buckshot." They vary in size from that of a pinhead to one inch. At first they collect in the transitional zone, where ascending iron-rich waters from weathering Moodys Branch marl meet the impervious Yazoo clay. Later, as the contact is weathered further, the pellets roll to the base of the exposure and form a poorly cemented conglomerate.

Large quantities of "buckshot" can be collected along the roads mentioned below:

1. North cut of Mississippi Highway 16 (NW.¼, NW.¼, SW.¼, Sec.13, T.9 N., R.3 E.) 4.2 miles east of Canton, just east of "Club 16."

2. Northeast cut of Mississippi Highway 16 (SE.¼, NE.¼, NW.¼, Sec.26, T.9 N., R.2 E.) 5 miles north-northwest of Canton.

3. As conglomeratic "buckshot" let down from the contact at crossroads (SW.¼, NE.¼, NE.¼, Sec.32, T.10 N., R.3 E.) 4.7 miles north-northeast of Canton.

YAZOO FORMATION

The Yazoo formation is the chief surface unit in Madison County. It is exposed in the south and southwest three-fifths of the mapped area (Plate 1). Its outcrop is widest despite a thickness of 360 to 400 feet, the same thickness as that of the Cockfield formation in the northeast. The greater width of outcrop is attributed to its position astride the Flora-Madison syncline north of Jackson Dome, as explained in "Structure."

The Yazoo belt of outcrop, which forms the Jackson Prairie (Figure 1), extends from the Alabama line in Clarke and Wayne Counties west-northwest through Rankin and Madison Counties to the edge of the Yazoo basin in Yazoo County. The Yazoo outcrop bulges southward where the formation surrounds the crest

Figure 25.—Thin bentonite near top of Yazoo clay, northwest end of southwest roadcut at curve of Mississippi Highway 463 (NE.¼, SE¼, SE.¼, Sec. 1, T.7 N., R.1 E.) 2.0 miles northwest of Madison. Bentonite dips southeast. July 2, 1959.

of Jackson Dome and where Forest Hill strata capped by some Glendon limestones are preserved in the Flora-Madison syncline. Thus, the southwest edge of the Yazoo belt of outcrop is its juncture with the Vicksburg cuesta (Figure 1). Its northeast limit is the Yazoo outliers comprising part of the Moodys Branch cuesta.

Except for several thin limestones (Figures 9 and 13) and thin bentonitic clays (Figure 25) in the upper 50-foot interval, the Yazoo is an homogeneous clay. This lithology is best illustrated in the record and electric log of Test Hole 6 drilled at the west edge of Gluckstadt (SW.¼, SW.¼, SW.¼, Sec.20, T.8 N., R.2 E.). Contrast this record and this log with the records and logs of Test Holes 3 and 5 where heterogeneous Cockfield beds prevail.

When fresh the Yazoo is blue-gray, slightly silty, fairly calcareous, massively bedded clay. A drop of hydrochloric acid on the clay produces active effervescence by the release of carbon dioxide gas, hence the newer exposures are recognized by their $CaCo_3$ (calcium carbonate) content, determined by this test. The source of much of the lime is Foraminifera tests, minute shells of Protozoa, one-celled animals. The larger of these fossils can be seen by the naked eye as white objects much smaller than a pin head. However a hand lens or an ordinary reading glass will reveal amazing differences in these often beautiful forms as portrayed by Bergquist[30] in the back of Mississippi State Geological Survey Bulletin 49, Scott County, 1942.

TEST HOLE 6

Location: North side of Gluckstadt-Mannsdale road at entrance to farm lane (SW.¼, SW.¼, SW.¼, Sec.20, T.8 N., R.2 E.) exactly 1.0 miles west of Gluckstadt.

Elevation: 298 feet, altimeter

No.	Thickness	Depth	Description
1	18.0	18.0	Soil and subsoil; orange-buff, fairly silty
			Yazoo formation
2	6.0	24.0	Clay, yellow-buff, slightly silty, slightly limy, very plastic
3	13.0	37.0	Clay, yellow-cream, slightly silty, slightly limy, fairly plastic
4	41.0	78.0	Clay, blue-gray, slightly silty, fairly limy; thin beds of yellow-buff clay, slightly plastic
5	87.0	165.0	Clay, yellow-buff, very slightly silty, slightly limy, non-plastic; interbeds of blue-gray, slightly silty, slightly limy clay
		170.0	TD
		164.0	TD by electric log
			Drilled August 18 and 19, 1959

Fresh Yazoo clay weathers quickly. Its blue-gray color alters to dark olive-gray and then to buff and tan. Color changes are irrespective of bedding, as shown in Figure 26, a photograph of an 18-month old cut of Mississippi Highway 463 (NE.¼, NW.¼, SE.¼, Sec.1, T.7 N., R.1 E.) 2.5 miles northwest of Madison. The alteration is accompanied by alternate swelling when wet and shrinking when dry so that bedding is soon obliterated. These changes in volume cause hillsides to slump and fresh road cuts to develop small block faults as described in "Structure." Solution is also active so that in a short time the calcareous tests of the Foraminifera are removed with a consequent diminishing of lime content.

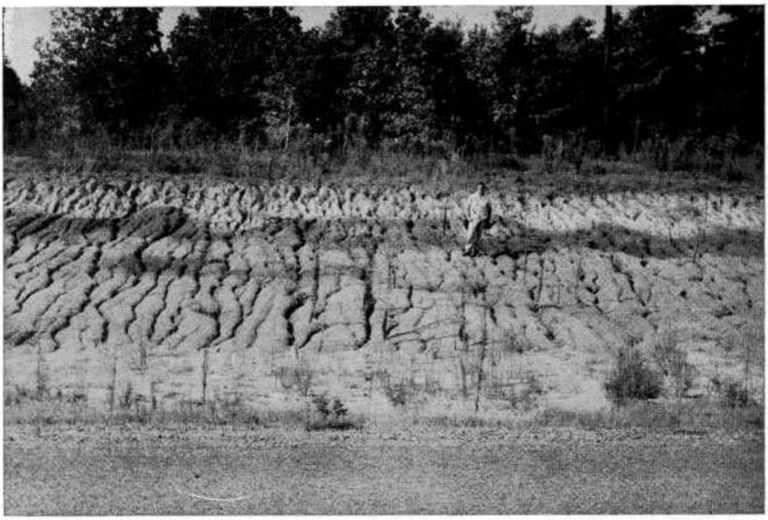


Figure 26.—Upper Yazoo clay overlain by loess in south roadcut Mississippi Highway 463 (NE.¼, NW.¼, SE.¼, Sec.1, T.7 N., R.1 E.) 2.5 miles northwest of Madison. Figure is standing on gray fresh clay. The darker beds are weathering Yazoo. Light-colored upper strata are loess. August 14, 1959.

Solution also removes all but the larger fossils which are surprisingly abundant locally but are not so well distributed as in Hinds and Yazoo Counties. Two fossil collecting areas are worthy of visits:

1. North cuts of the road being reconstructed in Section 35, T.10 N., R.1 E. Here are huge oysters (*Ostrea trigonalis*), many species of *Pecten*, and numerous *Yoldia* (Figure 7).

2. Just over the line in Hinds County, in the Jackson Ready-Mix Concrete-Light Aggregate quarry (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W.) 7 miles west-southwest of Madison. Here are to be found vertebrae and ribs of the small whale (*Basilosaurus cetoides*) (Figure 27), many small *Gastropods*, and a profusion of *Pelecypods* such as are described by Harris and Palmer[31] in their work on the Mollusca of the Jackson Eocene.

Figure 27.—Two vertebrae of extinct whale-like mammal *Basilosaurus cetoides* some 10 inches across in upper Yazoo clay, southwest wall of Jackson Ready-Mix - Light Aggregate quarry (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W, Hinds County) 7 miles west-southwest of Madison. September 4, 1959.

Figure 28.—White caliche in upper Yazoo clay in excavation for U. S. Interstate 55 bridge overpassing Mississippi Highway 463 (SW.¼, NE.¼, NW.¼, Sec. 7, T.7 N., R.2 E.) 1.4 miles northwest of Madison. August 14, 1959.

As part of the weathering process mentioned above much of the calcium carbonate is leached. In some places all the lime is removed from older road cuts. In Test Hole 6 near Gluckstadt leaching extends to 18 feet. However, capillary waters have returned some of this dissolved material to the surface as white nodules of "lime caliche" or have deposited it as caliche along bedding planes and in joints similar to those in Figure 28, a photo of a day-old excavation northwest of Madison. In other places circulating waters brought about a reaction of calcium carbonate with the oxidation products of pyrite and marcasite concretions in the Yazoo clay. In dry weather capillary waters then deposited calcium sulphate as selenite, a variety of gypsum, crystals on the surface and in joints near the surface.

Despite the broad belt of outcrop of the Yazoo formation, good exposures of Yazoo clay are rare. Broad nearly flat uplands near the sources of streams are undissected, so one must visit the valley walls of the major streams to find slopes steep enough to provide natural exposures. Road cuts on the lower valley walls and at the crests of narrow divides are the best places to study the lower half of the Yazoo clay and collect samples for ceramic testing:

1. South of Section 35, T.10 N., R.1 E., about 3 miles northwest of Virlilia (Figure 7).

2. West of Sections 6 and 7, T.8 N., R.2 E., some 6 to 7 miles southwest of Canton.

3. Newly improved north-south road between Sections 3 and 4, T.9 N., R.2 E., about 4.5 miles northwest of Canton (Figure 30).

4. Along Mississippi Highway 43 in Sections 9, 16, 15, and 22, T.8 N., R.3 E., from 4 to 8 miles southwest of Canton.

Good road cut exposures of probable ceramic clays in the upper half of the Yazoo are located as follows:

1. Along newly re-routed Mississippi Highway 463 from Madison to Livingston:

A. Cuts for overpass bridge for Interstate Highway 55, SW. ¼, NE.¼, NW.¼, Sec.7, T.7 N., R.2 E. (Figure 28).

B. Southwest cut NE.¼, SW.¼, SE.¼, Sec.1, T.7 N., R.1 E. (Figure 25).

C. South cut NE.¼, NW.¼, SE.¼, Sec.1, T.7 N., R.1 E. (Figure 26).

D. Double cuts in Sections 27 and 34, T.8 N., R.1 E., just south of Mannsdale.

E. Many cuts in Sections 8, 9, 16, and 17, T.8 N., R.1 E., just southwest of Livingston.

2. In cuts now being made along Interstate Highway 55 from Mississippi Highway 463 north toward Gluckstadt, Sections 6 and 7, T.7 N., R.1 E.

3. In older cuts in north of Section 32, T.8 N., R.1 E.

4. In the Jackson Ready-Mix Concrete-Light Aggregate quarry (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W.) in Hinds County to west of the Madison County line (Figures 9, 27, and 29).

5. In both cuts of the Anderson-Stokes road in Sections 28, 29, 31, and 32, T.9 N., R.1 E.

YAZOO-FOREST HILL CONTACT

As indicated by the solid or dashed lines on Plate 1 the Yazoo-Forest Hill contact is definitely recognizable in a few places but indefinite in most. There can be no doubt as to the disconformable relation in Test Holes 7 and 8 where non-marine strata overlie calcareous marine clays. However, on the surface the contact is difficult to find where (1) non-marine Forest Hill clays lie on Yazoo clays which had been leached before Forest Hill deposition, and (2) where aprons of rain-washed Forest Hill sands or silts hide the contact in gullied areas.

In Case (1) the contact is transitional along most of the edges of the large Forest Hill outlier in T.7 N., R.1 E. For example, in the south of Section 28 it is impossible to differentiate the units in an exposure of 32 feet of clays. Similar deeply weathered Yazoo clays and Forest Hill clays are in 15- to 40-foot outcrops in Sections 32 and 35, T.8 N., R.1 W. south of Flora. In Case (1) cross-bedded silty clays were mapped as Forest Hill, but lower, featureless strata were designated weathered Yazoo.

Figure 29.—Selenite crystals in joints of upper Yazoo clays, west wall of Jackson Ready-Mix Concrete - Light Aggregate quarry (SW. ¼, NE. ¼, NW. ¼, Sec. 36, T.7 N., R.1 W., Hinds County) 7 miles west-southwest of Madison. September 4, 1959.

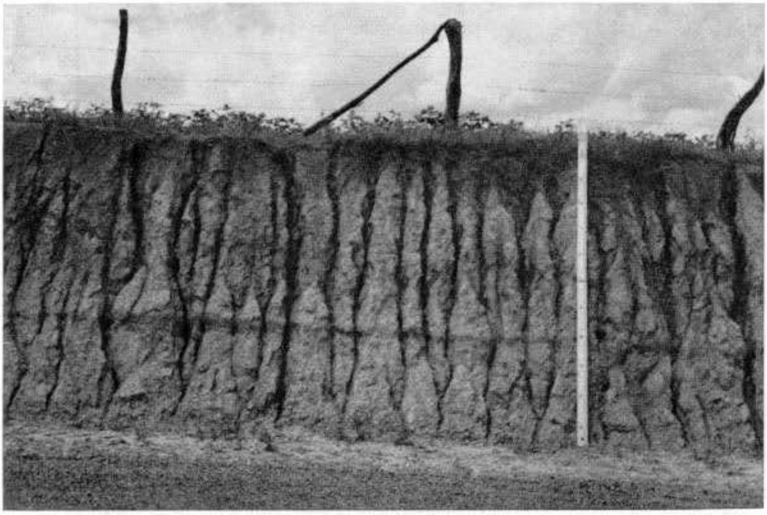


Figure 30.—Deeply weathered Yazoo clay and loess, west cut of road under construction (NE. ¼, NE. ¼, NE. ¼, Sec.4, T.9 N., R.2 E.) 4.5 miles northwest of Canton. Dark line represents an old soil horizon. Yazoo clay is below, loess is above. July 28, 1959.

TEST HOLE 7

Location: In pasture 0.2 mile north of road, 0.7 mile northwest of road fork in south of Section 16. Test location is NE.¼, SW.¼, NW.¼, Sec.16, T.7 N., R.1 E., about 5 miles west-northwest of Ridgeland.

Elevation: 432 feet, altimeter

No.	Thickness	Depth	Description
1	18.0	18.0	Soil and subsoil, red-brown, clayey; fragments limestone 11.0-18.0 (basal Glendon limestone)
			Forest Hill formation
2	29.0	47.0	Clay, dark-gray, fairly silty
3	1.0	48.0	Sand, light-gray, silty
4	9.0	57.0	Clay, dark-gray, slightly silty
5	7.0	64.0	Clay, nearly black, very lignitic
6	2.0	66.0	Sand, light-gray, very silty
7	3.0	69.0	Clay, dark-gray, slightly silty
8	6.0	75.0	Lignite, nearly black; streaks of carbonaceous clay
9	1.0	76.0	Sand, light-gray, very fine-grained
10	9.0	85.0	Clay, dark blue-gray, slightly silty
11	2.0	87.0	Sand, light-gray, very fine-grained
12	18.0	105.0	Clay, medium-gray, slightly silty
13	11.0	116.0	Sand, light-gray, fine-grained; thin beds of dark clay
			Yazoo formation
14	14.0	130.0	Clay, blue-gray, slightly silty, fairly plastic
		130.0	TD
		129.0	TD by electric log
			Drilled August 20 and 21, 1959

TEST HOLE 8

Location: Southwest corner of road fork at hill crest (SE.¼, SW.¼, NE.¼, Sec.20, T.8 N., R.2 W.) about 7 miles west-southwest of Flora.

Elevation: 321 feet, altimeter

No.	Thickness	Depth	Description
1	8.0	8.0	Soil and subsoil, yellow-brown; weathered loess
			Glendon formation
2	5.0	13.0	Clay, red-brown, silty; residue from limestone
3	2.0	15.0	Limestone, yellow-buff, red mottled, fragments marine shells
4	6.0	21.0	Shale, cream-colored, very limy; interbeds cream-colored limestone, weathered; fragments marine shells

5	3.0	24.0	Limestone, yellow, fairly fresh; fragments marine shells
6	13.0	37.0	Shale, yellow-cream, very limy; fragments marine shells
			Forest Hill formation
7	11.0	48.0	Clay, dark-gray, very silty
8	2.0	50.0	Clay, nearly black, slightly silty; interbeds of cream-colored clay
9	2.0	52.0	Clay, cream-colored, slightly silty
10	8.0	60.0	Sand, light-gray, fine-grained
11	9.0	69.0	Clay, yellow-buff, slightly silty
12	13.0	82.0	Sand, light-gray, fine-grained to silty
13	17.0	99.0	Sand, light-gray, silty; interbedded with yellow silty clay
14	4.0	103.0	Clay, dark-gray, slightly lignitic, fairly silty
15	5.0	108.0	Clay, medium-gray, very silty
16	36.0	144.0	Clay, dark-gray, slightly silty
			Yazoo formation
17	6.0	150.0	Clay, blue-gray, slightly silty, slightly limy
		150.0	TD
		149.0	TD, electric log
			Drilled August 21, 1959

In Case 2, in a rugged highland southeast of Flora in Sections 13, 14, and 22 gullies have disgorged so much sand and silt that the contact is hidden by thick alluvium. Similar aprons conceal the contact east of Ridgeland in Sections 22 and 27, T.7 N., R.2 E.

But, fortunately, road cuts in less rugged terrain and along narrow ridge crests permit observation of the contact where sands or silts overlie freshly exposed calcareous Yazoo clay. Visits should be made to:

1. Southwest cut of Mississippi Highway 463 (NE.¼, SE.¼, SE.¼, Sec.1, T.7 N., R.1 E.) 2.0 miles northwest of Madison (Figure 31), where upper Yazoo clays have been removed by stream erosion and the cavity filled with Forest Hill sands and silts.

2. In gullies west and north of the crossroad (NE.¼, Sec.3, T.7 N., R.1 E.).

3. In northeast cuts of newly constructed Mississippi Highway 463 in southeast of Section 8 and northwest of Section 16, T.8 N., R.1 E., along the high ridge just southeast of Livingston. Here Forest Hill sands, clays, and silts aggregating 10 to 15 feet in thickness overlie eroded Yazoo calcareous clays.

Figure 31.—Erosional contact of Yazoo clay and Forest Hill sands, southeast end of southwest roadcut at curve of Mississippi Highway 463 (NE.¼, SE.¼, SE.¼, Sec.1, T.7 N., R.1 E.) 2.0 miles northwest of Madison. Figure stands on top of Yazoo clay. Forest Hill silts to his right, Forest Hill massive sands to his left. July 2, 1959.

FOREST HILL FORMATION

In Madison County the beds normally overlying the Yazoo clay are Forest Hill non-marine silts, sands, lignitic clays, plastic clays, and lignites, in that order of abundance. Their thicknesses vary from 69 to 96 feet.

Some geologists consider the Forest Hill formation to be the uppermost unit of the Jackson group because in some areas of west Mississippi the contact is gradational from the Yazoo formation. Other geologists designate the Forest Hill as the basal unit of the Vicksburg group, reasoning that the preponderance of sands and silts in some places makes the unit the basal deposit of the Oligocene. In this report the Forest Hill is considered Vicksburg in age (Figure 4) because it helps make the Vicksburg Hills, as explained in "Physiography."

Forest Hill beds are extensive in three areas and are represented by a few thin outliers on hilltops up the dip (Plate 1).

The larger areas are (1) southwest of Flora, in the southwest of T.8 N., R.2 W., (2) south and southeast of Flora, in T.8 N., R.1 W.; and (3) west of Madison and Ridgeland, in T.7 N., R.1 E.

Only 12 small exposures of Forest Hill strata were noted beneath the thick loess cover in the Loess Hills, Area (1), southwest of Flora. However, Test Hole 8, at the road fork on the highest hill (SE.¼, SW.¼, NE.¼, Sec.26, T.8 N., R.2 W.) about 7 miles west-southwest of Flora, showed that the unit is fully developed beneath the loess and Glendon limestone cover. There 96 feet of clays and sands were drilled.

In Area (2), southeast of Flora, where the loess cover is thinner, Forest Hill sands and silts are deeply eroded and make the worst badlands of the County. Nearly 50 gullies head into the east-west ridge road which crosses Sections 22, 23, and 24, T.8 N., R.1 W. At least 70 feet of Forest Hill beds are exposed.

Shallower gullies in lower Forest Hill sands and silts about 2 miles south-southwest of Flora have exposed huge petrified logs, especially on lands of the J. S. Black estate. There an effort has been made to develop a "petrified forest" which is so designated on some highway maps.

The "forest" is just west of the north-south road, in NW.¼, NE.¼, NW.¼, Section 29 and in adjacent parts of Section 22, T.8 N., R.1 W. Figure 32 shows one of the larger logs which has been dropped to the floor of a gully as the enclosing silts and sands were eroded. Figure 33 is a photograph of two much smaller logs embedded near the base of the gully.

It is assumed that the logs were stranded by floods during deposition of the silts and sands because no stumps were observed, and no logs have smaller limbs, and the enclosing Forest Hill sands and silts were well cross-bedded. However, a thorough study of the "forest" should be undertaken from 3 standpoints: (1) How the logs accumulated; (2) how they were petrified; and (3) what kind of wood is represented. In the writer's opinion the study is worthy of a joint thesis, by a geologist and a botanist.

Some progress was made in studying the flora by Dukes[32] in 1958 and 1959. He thin-sectioned and identified petrified wood from Madison, Hinds, Yazoo, Smith, and Rankin Counties as a thesis problem in botany at Mississippi College. Two specimens he chose were from Flora Petrified Forest. They are shown in Figure 34 as one microphotograph each of the wood of a fir tree and of the wood of a maple tree cut by a diamond power saw to show the cross section. That maple and fir, trees of a more

Figure 32.—Large petrified log exposed by erosion of basal Forest Hill sands and silts, "Petrified Forest" (SW.¼, SE.¼, SW.¼, Sec.20, T.8 N., R.1 W.) about 2 miles south-southwest of Flora. August 27, 1959.

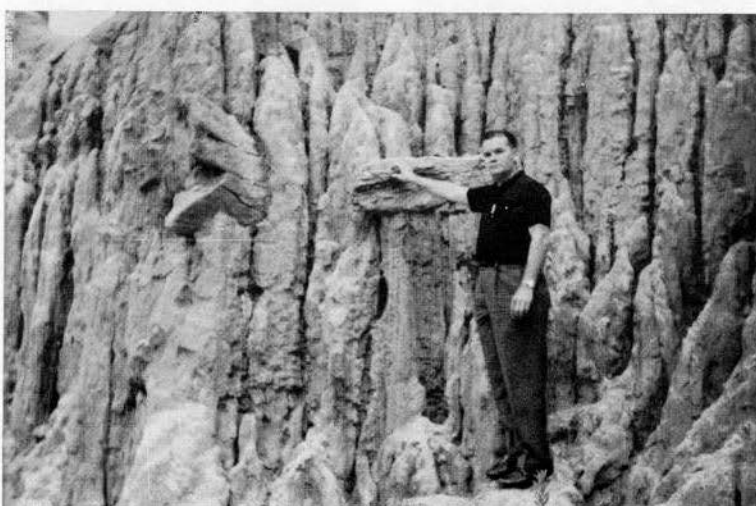


Figure 33.—Small petrified logs embedded in basal Forest Hill sands and silts, "Petrified Forest" (SW.¼, SE.¼, SW.¼, Sec.20, T.8 N., R.1 W.) about 2 miles south-southwest of Flora. August 27, 1959.

northern clime, were incorporated in Forest Hill sands and silts suggests that the climate during Forest Hill deposition was cooler than the climate of today.

Forest Hill strata are most accessible in the north of Area (3) west of Madison and Ridgeland where the topography is gently rolling, where recent road cuts are numerous, and where the

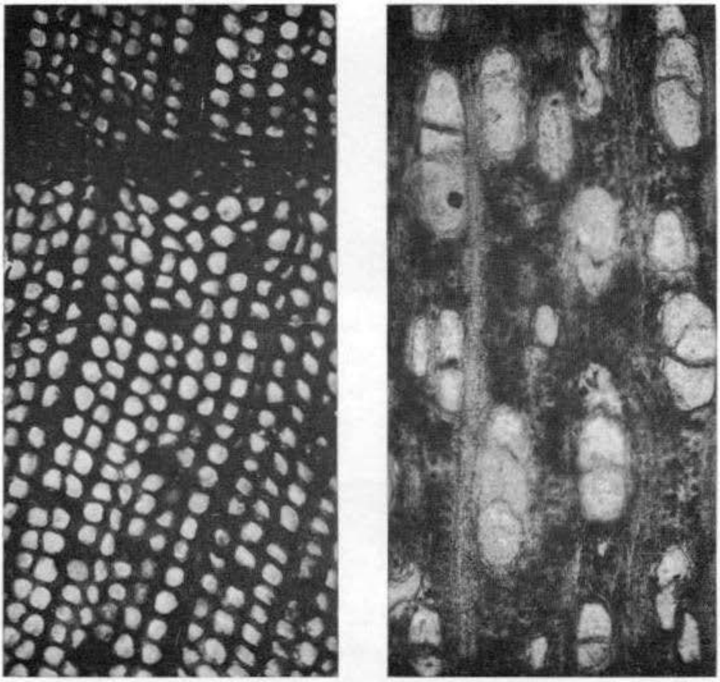


Figure 34.—Thin sections of petrified woods from Flora Petrified Forest (SW.¼, SE.¼, SW.¼, Sec.20, T.8 N., R.1 W.). Cross-sections of Abies (fir) on left and Acer (maple) on right, magnification X 78.75, by George H. Dukes, Jr. April, 1959.

loess mantle is negligible. Outcrops easy to visit are in road cuts as follows:

1. On the secondary road west of Rocky Hill Church (NE.¼, NW.¼, SW.¼, Sec.20, T.7 N., R.1 E.) as measured in the next section where 15.6 feet of upper Forest Hill clays, sands, and silts are exposed on the hillside.

2. On the west slope of Richardson Hill (SW.¼, SW.¼, NW. ¼, Sec.16, T.7 N., R.1 E.) where the second section, measured

when the road was newly cut in 1949, revealed 60.8 feet of middle and upper Forest Hill clays, lignites, silts and sands. These beds intertongue and interlens in a complicated manner.

3. At the road forks in northeast of Section 3, T.7 N., R.1 E., where lower Forest Hill sands and silty clays intertongue and interlens much as do Zone 3 Cockfield beds.

SECTION ALONG PRESENT ROAD AND ABANDONED ROAD (NE.¼, NW.¼, SW.¼, SEC.20, T.7 N., R.1 E.) DOWN THE SLOPE (WEST) OF ROCKY HILL CHURCH, 5 MILES WEST OF RIDGELAND (FIGURE 37).

	Feet	Feet
Glendon formation		13.5
Limestones, cream-colored, dense, thin-bedded; interbedded with limy shales, to church	5.3	
Limestones, cream-colored, finely crystalline, massive; contain casts of large *Unio*	1.9	
Shale, yellow-buff, very limy	0.6	
Limestone, cream-colored, finely crystalline; *Pelecypod* casts	0.4	
Shale, buff, fairly limy; *Gastropod* casts	0.2	
Limestone, cream-colored, dense, massive; a few *Hemiasters*	1.1	
Shale, yellow-buff, fairly limy; *Pelecypod* casts	0.6	
Limestone, cream-colored, dense, massive, *Pelecypod* casts	1.7	
Shale, yellow-cream colored, very limy; fossil prints	0.9	
Limestone, cream-colored, dense, massive; *Echinoderm* spines	0.8	
Covered interval of red colluvial sand probably representing Mint Springs marl	3.7	3.7
Forest Hill formation		15.6
Clay, cream-colored, slightly silty, very plastic	1.9	
Clay, gray-tan, slightly lignitic	0.7	
Sand, gray-buff, fairly micaceous, cross-bedded	2.6	
Sand, yellow-buff, silty, fairly micaceous, cross-bedded; thin beds of very silty yellow clay	6.1	
Silt, buff, clayey; partings of yellow very silty sand; starting uphill at very small cabin on north side of road; beds dip west at 8 to 10 degrees	4.3	

SECTION ALONG ROAD (SW.¼, SW.¼, NW.¼, SEC.16, T.7 N., R.1 E.) CONTINUOUS UPHILL FROM NEAR FLOOD PLAIN TO NEAR TOP RICHARDSON HILL, ABOUT 6 MILES WEST OF MADISON. SECTION MADE IN OCTOBER, 1949, WHEN ROAD CUTS WERE FRESH, 95 VERTICAL FEET BUT ONLY 85.7 FEET OF SECTION DUE TO SOME WEST DIP (FIGURE 36).

	Feet	Feet
Soil, light-brown clay loam; weathered loess	3.8	3.8
Glendon formation		15.9

Limestone and shale to near crest of hill (SE.¼, SW.¼, SW.¼) in roadbed; alternate layers; weathered	8.1	
Shale, fairly limy; in roadbed	0.9	
Limestone, cream-colored, fairly crystalline, massive; a few large *Unios* and *Hemiasters;* in roadbed	1.3	
Shale, buff, fairly limy, a few small *Gastropods*	0.7	
Limestone, light-buff, fairly crystalline, massive, small *Pelecypods*	1.6	
Shale, buff, very limy; in roadbed and cuts	2.0	
Limestone, cream-colored, dense, massive, few fossils; in roadbed	1.3	
Covered interval on bench 100 feet wide, probably developed on Mint Springs marl	2.9	2.9
Mint Springs facies		
Marl, cream-colored, very limy, slightly glauconitic; badly weathered. Contact with Forest Hill indistinct (Figure 36)	2.3	2.3
Forest Hill formation		60.6
Clay, light blue-gray, very slightly silty; partings of yellow limonitic silt	9.9	
Lignite, dark-brown, silty, blocky	1.4	
Clay, chocolate-brown, slightly silty, lignitic; partings of yellow clay	7.5	
Silt, yellow-buff, fairly clayey; partings of limonitic clay	6.2	
Clay, red-buff, slightly silty, fairly plastic	3.4	
Clay, tan, silty; interlensed with thinly laminated gray clay	4.9	
Clay, tan, very silty, lignitic; thinly laminated	2.1	
Sand, buff, silty, very micaceous	1.2	
Silt, buff, clayey; thin partings of yellow clay; beds dipping northwest a distance of 72 feet	1.7	
Clay, light-gray, slightly silty; beds dipping northwest to make bench 100 feet in breadth	0.9	
Covered interval on bench 220 feet in breadth probably on clay (lake to southwest)	9.1	
Silt, light-gray, slightly clayey, unusually massive; thin partings of gray clay; starting near flood plain at intersection of field road to west	12.3	

The smaller outliers (Plate 1) up dip are remnants of a more extensive Forest Hill belt of outcrop. They are best seen as intervals 5 to 15 feet in thickness of sands, clays, lignitic clays, and silts overlying the Yazoo clays in fresh cuts of Mississippi 463 now being constructed on the high ridge just southeast of

Livingston southeast at the common corners of Sections 8, 9, 16, and 17, T.8 N., R.1 E. One of four small exposures is shown in Figure 35. On this ridge the Forest Hill may be capped by loess or by terrace sands. Where the terrace sands overlie Forest Hill sands it is difficult to differentiate them.

Figure 35.—Forest Hill, terrace sand, and Citronelle gravels (SE.¼, SE.¼, SE.¼, Sec. 8, T.8 N., R.1 E.) in fresh northeast cut Mississippi Highway 463, 0.42 mile southeast of Livingston. Cut shows 2.2 feet white Forest Hill silts, 2.7 feet red terrace sand, and 0.9 feet Citronelle gravels. August 26, 1959.

GLENDON FORMATION

The uppermost of the Oligocene units in Madison County is the Glendon formation of the Vicksburg group. The Glendon contains all the interbedded limestones and limy shales above the Forest Hill, including the Mint Springs marl of Monroe (Plate 1). All Glendon exposures are preserved in the Flora-Madison syncline. At most of them the rock is so badly weathered that only a few ledges of limestone are exposed on the steepest hillsides. In one area small box canyons alone suggest limy beds beneath loess mantle.

Above Forest Hill strata in Rankin, Hinds, Yazoo, and Warren Counties is the very fossiliferous, glauconitic Mint Springs marl some 10 to 15 feet in thickness. Geologists agree that it should be included in the Vicksburg Oligocene, but some question its further classification. In this report the Mint Springs unit is considered a facies of the Glendon formation of the Vicksburg group. It is hoped that in the near future the Mississippi Geological Survey can make a study of the Vicksburg belt in Mississippi in order to establish the classification of the units.

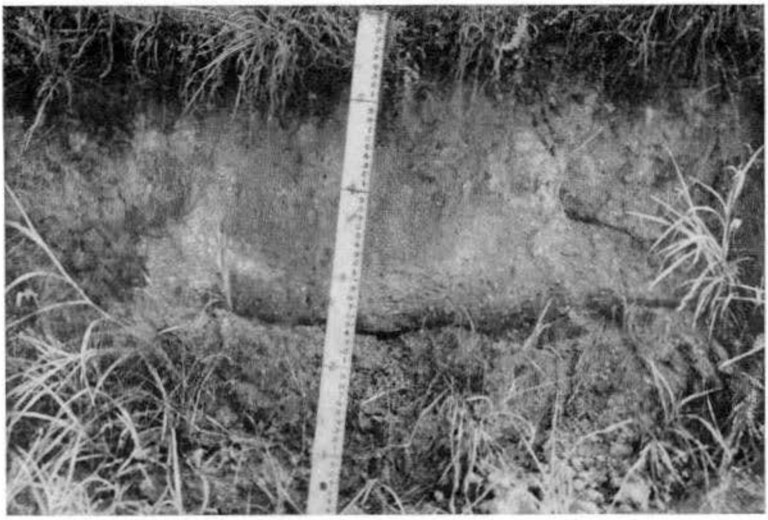


Figure 36.—Badly weathered Mint Springs marl in northeast roadcut (SW.¼, SW. ¼, NW.¼, Sec.16, T.7 N., R.1 E.) on west flank of Richardson Hill, about 6 miles west of Madison. August 27, 1959.

Fresh outcrops of the Mint Springs marl are not visible in Madison County today. However, one very badly weathered exposure (Figure 36) can still be seen in the 1947 Richardson Hill section described above. Benches high on the shoulders of hills capped by Glendon limestone in T.7 N., R.1 E. apparently coincide with the marl where it was uncovered below the limestone. A section described by Millsaps students in 1947 when the limestone beds in Richardson quarry (NW.¼, SE.¼, NW.¼, Sec. 16, T.7 N., R.1 E.) could still be traced, showed 3.2 feet of Mint Springs marl. However, no Mint Springs marl was drilled in Test Hole 8 (Sec.20, T.8 N., R.2 W.) about 7 miles west-southwest of Flora, despite the unit's development some 45 miles to the west in the Vicksburg area and 12 to 15 miles to the southeast in the Brandon area. It is well to remember that if agricultural limestone should ever be quarried from the hills in T.7 N., R.1 E., and T.8 N., R.2 W., the Mint Springs marl could also be used.

Observations in this Madison County survey indicate that Monroe[33] in his 1930-1937 work must have included in the Mint Springs marl several of the limestones which Priddy includes in the overlying Glendon limestones. In Madison County Monroe seems to have differentiated Mint Springs and Glendon on the basis of fossils which were available when exposures of the marl were fresh. Consequently Monroe's 1947 map shows more Mint Springs marl than Glendon. In Plate 1 Priddy shows only Glendon limestone as the youngest bed preserved in the Flora-Madison syncline.

Figure 37.—Three thin beds of Glendon limestone looking east, uphill, (NE.¼, NW.¼, SW.¼, Sec.20, T.7 N., R.1 E.) just west of Rocky Hill Church, 5 miles west of Ridgeland. Notebook marks the lower limestone, another is in the middle distance, the third is at the top of the ridge. August 27, 1959.

The limestones are best developed in 4 areas which appear small on the map but which could furnish great quantities of agricultural lime.

1. On Rocky Hill in the west part of Section 20, T.7 N., R.1 E., some 5 miles west of Ridgeland. The topography indicated that alternate limestone (Figure 37) and limy shales total 22 feet in thickness, the lower 13.5 feet of which are recorded in the description of a preceding road cut section on the slope west of Rocky Hill Church. The area underlain by Glendon beds at least 15 feet in thickness is about 12 acres in extent. Three acres might provide 20 feet of limestone.

2. On Richardson Hill in northwest part of Section 16, T.7 N., R.1 E., 6 miles west of Madison. On its west slope cuts showed 15.9 feet of Glendon limestones and shales when the road was rebuilt in 1947. This section is included in the treatment of the Forest Hill. Ridge crests trending northwest-southeast expose ledges of Glendon limestone on their flanks, suggesting that an area of some 30 acres could furnish a section 15 feet in thickness. Several of the higher ridges might provide 25 feet of limestones and shales as indicated by a dim 1947 photograph of an old quarry face which is believed to have been the "Madison County Quarry" from which road metal was removed from 1934 to 1938 to surface roads built under the Works Progress Administration.

3. Beneath a loess mantle which caps the broad ridge in Sections 16, 17, 20, 21, and 28, T.8 N., R.2 W., about 7 miles west-southwest of Flora. The area is shown on Plate 1 rimmed by the symbol for Glendon beneath the loess symbol to indicate no limestone exposures. Depressions in the loess suggested buried sinkholes where limy beds might have been dissolved. Accordingly Test Hole 8 was drilled at the hill crest at the road fork (SE.¼, SW.¼, NE.¼, Sec.20). Drilling showed 24 feet of limestones and limy shales beneath 5 feet of residual limestone, almost the full thickness of the Glendon, which is about 32 feet near Vicksburg 40 miles west and about 32 feet near Brandon 30 miles southeast. In the test hole the loess mantle measured 8 feet, an overburden which could be easily moved to reach the calcareous beds below. Topography indicates that 300 to 400 acres may furnish 10 to 15 feet of materials.

4. Beneath a loess mantle which caps the ridges farther south where depression topography again suggests buried limestones in Sections 29, 31 and 32, T.8 N., R.2 W. Time did not permit drilling of a test here, but the ridges are high enough to provide as much material beneath a thin loess overburden as in Area 3.

CITRONELLE FORMATION

In Madison County small patches of thin Citronelle gravels cap a few hills in the north, west, and south (Plate 1). The gravel beds are inches to six feet in thickness. These beds are remnants of a once thick blanket of gravels, coarse sands, and sandy clays which covered the hilly section of south and southwest Mississippi. The Madison County deposits are now at the east and north limits of the belt, as indicated by thicknesses of 20 to 70 feet beneath loess southeast of Yazoo City and thicknesses of 30 to 40 feet in the hills along U. S. Highway 51 south of Jackson. Obviously, the Citronelle of Madison County is too thin to exploit.

The age of the Citronelle is shown in Figure 4 as Pliocene although some geologists call it Pleistocene. Whatever its age, the formation has been deposited on eroded Cockfield, Yazoo, Forest Hill, and Glendon strata, therefore it must be younger

Figure 38.—Citronelle gravel, Yazoo clay, and loess in fresh east cut of U. S. Highway 51 (SE.¼, NE.¼, NW.¼, Sec.1, T.6 N., R.1 E., Hinds County) 0.2 mile south of Madison County line. Figure stands on 12 feet of slightly weathered Yazoo clay. Behind him is 2.3 feet weathered Yazoo clay, 1.6 feet Citronelle gravel, 2.0 feet of loess, and 2.6 feet of dark soil. August 14, 1959.

than those units. However, it is obviously older than the loess which overlies it.

In Madison County the Citronelle is small chert and quartz gravel, and subrounded fragments of petrified wood up to several inches across. Because the chert contains Paleozoic fossils similar to those in cherty limestone of the Nashville-Chattanooga region it is believed to have been eroded by streams which had been rejuvenated by uplift. The source of the quartz is probably the Appalachian highland farther east. The petrified wood is doubtless locally derived.

Typical Citronelle gravels are found in the following hill crest road cuts:

1. On the Allison's Wells-Way road (NE.¼, NE.¼, NW.¼, Sec.6, T.10 N., R.3 E.) about 10 miles due north of Canton. Here eroding loess mantle reveals 2 to 6 feet of gravel lying on Zone 3 Cockfield silts and clays. The same relationship is seen at the heads of gullies to the northeast in Section 32, T.11 N., R.3 E.

2. Along newly re-routed Mississippi 463 (NW.¼, SE.¼, SE. ¼, Sec.8, T.8 N., R.1 E.) just southeast of Livingston (Figure 35) where up to 2 feet of gravels overlie Yazoo clays in some cuts and Forest Hill sands in others.

3. Along U. S. Highway 51 in Hinds County, 0.2 mile south of the Madison County line. Here (SE.¼, NE.¼, NW.¼, Sec.1, T.6 N., R.1 E.) 1.6 feet of Citronelle gravel overlie Yazoo clay and underlie loess (Figure 38).

TERRACE SANDS

In several areas of Madison County massive sands containing small pebbles of quartz or chert (1) cap the sharper divides or (2) border fairly large stream valleys (Plate 1). They are termed terrace sands. As they overlie Cockfield, Yazoo, Forest Hill, Glendon, and Citronelle beds they are younger. As loess may overlie the sands, they are older than the loess. Except for the small pebbles, some of the terrace sands can not be distinguished from Forest Hill or Cockfield sands. Terrace sands (1) and (2) are both of value as topping material in road construction.

The terrace sands on the (1) divides are presumed to have been deposited by the major streams in late Pliocene or early Pleistocene time when the surface stood higher. Subsequently stream erosion lowered the surface so that today the higher terrace sands (1) are chiefly confined to four areas:

1. On the crest and upper shoulders of Pearl River-Big Black divide in the southeast. Here dark-red sands up to 30 feet in thickness overlie Cockfield and Yazoo strata. Plate 1 shows some 40 hilltops where thicknesses of at least 10 feet can be seen in road cuts at the ridge crests. Borrow pits have been opened for road materials in many of the larger areas.

2. On sharp ridge crests along the north-south road south of Truitt (Secs.17 and 20 in T.11 N., R.4 E.) some 13 miles north-

northeast of Canton. Here gullies show 10 to 30 feet of red, massive, coarse-grained sands overlying a basal few feet of reworked Citronelle gravel containing large fragments of petrified wood.

3. On ridge crests and upper slopes of hills (Secs.8, 16, 17, 18, 19, 20, and 21, T.8 N., R.1 E.) south and southwest of Livingston. Some road cuts show 20 to 30 feet of red massive sand at the approaches to Lake Cavalier. Borrow pits on the ridges have furnished topping for parts of Mississippi Highways 22 and 463.

4. Along the knife edge ridge southeast of Livingston where Mississippi Highway 463 is being re-routed. Fresh cuts (Secs.8 and 9, T.8 N., R.1 E.) show 6 to 12 feet of red terrace sands indistinguishable from underlying Forest Hill sands except for the small pebbles in the terrace (Figure 35).

As the terrace sands (1) on the divides were eroded they were subsequently redeposited at lower elevations along (2) the borders of fairly large streams, some of which are as follows:

1. Both valley walls of Doaks Creek in Sections 20, 21, 28, and 29, T. 10 N., R.5 E. Cuts along Mississippi Highway 17 show massive red terrace sands up to 30 feet in thickness, where they overlie, and are easily confused with, Zone 3 Cockfield sands.

2. Along Mississippi Highway 16 (Secs.1 and 2, T.9 N., R.4 E.) where they overlie Zone 3 and Zone 4 Cockfield beds. About 14 feet of red terrace sands overlie Zone 3 Cockfield sands at the road intersection (NE. Corner Sec.1) just south of a large borrow pit in Zone 3 massive sands.

3. At the foot of Pearl River-Big Black River divide just northwest of Natchez Trace. A good example of this lower level terrace is afforded by the extensive borrow pit (NW.¼, NW.¼, NE.¼, Sec.26, T.9 N., R.4 E.).

4. Draped over low divides in Section 13, T.10 N., R.3 E., where massive red terrace sands are 15 to 25 feet in thickness.

It is believed that the lower valley walls of many major streams in Madison County are similarly draped with terrace sands but they can only be distinguished by trenching and hand auger drilling.

LOESS

As explained in "Physiography," much of the northwest one-fourth of Madison County is mantled by loess, the youngest unit to be laid down in the County (Figure 4). In Plate 1 are mapped those areas having thicknesses of more than 10 feet. Thicknesses in excess of 40 feet are on the Loess Covered Hills overlooking Big Black River bottoms but the material thins progressively southeastward away from the river. Figures 30 and 38 show some of the thinner exposures in fresh road cuts. Thin deposits also cap some hills comprising the Pearl-Big Black divide in the southeast.

The loess overlies all strata in Madison County from Zone 1 Cockfield through terrace sands. Its age is Pleistocene. It was laid down at several intervals in the last million years when winds picked up dried clays and fine silts from the Mississippi Alluvial Plain, carried them eastward, and dropped them as the hills slowed down the winds. Consequently the material thins eastward. In the Plain the clays and silts had been deposited by vast floods fed by melting continental glaciers far to the north. As there were known to have been 4 or 5 glacial invasions, some thicker loess exposures should show interruptions in their deposition caused by soil production during periods of non-deposition. In Madison County weathering has eradicated evidence of interrupted bedding, but old soil profiles break the loess continuity on the hills near Charleston and Yazoo City, and at Vicksburg.

The loess is a peculiar deposit. When fresh it is gray-buff, mealy to the touch, and so soft that initials are frequently carved on road cut faces. Yet it is so resistant to weathering that vertical cuts stand for years. On weathering its color changes through tan to light-brown. Eventually the loess produces a brown silt loam. In one of the first stages of alteration small white masses of lime caliche appear as some of the limy silt or clay fragments are dissolved and reconstituted. In very new exposures shells of garden-variety snails can be seen at various horizons; on solution, these shells contribute to the lime caliche. Unfortunately, rainwash starts gullying in the loess mantle so that the areas of thicker loess are badly dissected, as in the region southwest and west of Flora.

STRATIGRAPHIC METHODS

In order to determine the stratigraphy of Madison County, as discussed above, a variety of methods was employed. Most of the various methods were used in the field, a few in the office or laboratory.

In the field some 3000 miles of roads were traveled to record and describe the rock exposures and soils, map the outcrops, establish the sequence of beds, and draw in the drainage, all on a map of the County scaled at one inch to one mile. On these journeys 92 photographs were taken of typical exposures and 29 were taken of those outcrops showing faulting or other unusual features. Side trips afoot were made where stream valleys were narrowest, where hillsides were gullied, or where summer foliage concealed the view. Several hand auger holes were drilled through weathered exposures to determine the nature of the bedrock. In a few places trenches were dug to sample promising clays. Later, an altimeter, a barometer for recording minute changes in air pressure proportionate to changes in elevation, was used for topographic control. Near the end of the field work 8 holes were drilled with the Geological Survey's Failing drill rig to verify the sequence of beds seen at the surface and to obtain some of the glauconitic marls for laboratory study. Depths of the tests varied from 25 to 290 feet. Cuttings were saved from appropriate intervals. Electrical potential and resistivity of the beds were measured by a Widco electric logger, as shown by the tracings on Plate 3 of 5 of the 8 Drill Holes, SP (self potential) on the left and R (resistance) on the right of each test.

In the office the field maps (Plates 1 and 6) were redrawn and the cross-section (Plate 3) was made on the bases of both the surface and the drilling information. Belts of outcrop were checked against topographic maps and aerial photographs, especially for areas of rugged topography and poor coverage by roads. Another map, Plate 5, was drawn to show structural data. Samples taken by hand augering, trenching, and drilling were examined. Finally, this report was written.

ECONOMIC GEOLOGY

GENERAL STATEMENT

One of the chief purposes of this investigation is to report rocks which are of probable economic value. To locate and describe them hundreds of road cuts, gullies, and valley walls were studied. The chapters on "Physiography," "Structure," and "Stratigraphy" were directed toward this goal—finding and measuring.

The investigations discovered many types of clays which may be used for several purposes; limestones and marls for agricultural lime; bentonite for a variety of uses; and glauconite for mineral sources of soda, potash, lime, and phosphate. If this survey had been made as early as 1940 it might have helped in oil-gas exploration, and if it had been made as recently as 1955 it would have helped materially in ground-water studies. Oil-gas possibilities will be considered first, ground-water second, but the greater part of this discussion will be directed to the clays, the limestones and marls, the bentonite, and the glauconite.

OIL AND GAS

The possibilities of discovering oil and gas would ordinarily be ranked first in some county reports, but, as pointed out in "Previous Investigations," and again in "Structure," it is very unlikely that this survey will materially help in finding either one, because since 1939 the Madison County surface has been tramped by many geologists and the subsurface has been explored by hundreds of geophysical crews. For example, in June, 1959, two seismograph parties and one gravity meter party were at work in the County, years after the peak of exploration following the Pickens discovery.

Nevertheless, the surface anomalies discovered in this survey were carefully recorded, mapped if they were large enough to disrupt the normal sequence of beds, and photographed wherever practical. These anomalies were treated in "Structure" and need not be repeated here.

GROUND-WATER

As mentioned in "Previous Investigations," much of the recently published reports which include Madison County geology have dealt with ground-water resources.

A report is eagerly awaited on a 3-year study of ground-water resources of the greater Jackson area by the Ground-Water Branch office of the United States Geological Survey at Jackson. The investigation embraces Madison, Hinds, and Rankin Counties. It will show, far better than this report can, the stratigraphic and geographic positions of the several aquifers, their thickness, and their potential output. Included will be some discussion of the surface geology in the areas of intake.

As far as this survey is concerned, the ground-water supply of Madison County is derived from sands of two geologic units, the Sparta and the Cockfield. Upper Wilcox sands might produce in the northeast part at considerable depths.

The Sparta provides water for the entire County, from northeast to southwest, from depths of 100 to 800 feet. The basal Cockfield contains several good water-bearing sands, as shown by the stratigraphic chart (Figure 4). Cockfield aquifers produce in the southwest three-fourths of the County, from northeast to southwest, from depths of 50 to 500 feet. These sands crop out in the northeast one-fifth of the County (Plate 6). Their stratigraphic and structural relationships are also indicated on the County physiographic cross-section (Plate 3). The regional cross-section (Plate 4) shows Cockfield, Sparta, and Wilcox strata from Vicksburg, Mississippi North 28 degrees East to Columbus, Mississippi. The line of section passes through T.8 N., R.2 W., in the southwest of Madison County through the County's northeast corner. This section (Plate 4) is the fourth of 7 cross-sections by Priddy[34] in Mississippi State Geological Survey Bulletin 83, 1955.

CLAYS

Clays in Madison County have a wide variation in color, composition, texture, geologic range, and geographic distribution. In the field those which appeared to have economic value were sampled, but a proper evaluation must await complicated and lengthy ceramic and geochemical tests such as were reported in the bulletins of county surveys published during the years 1939-1943. Then, there was an efficient Works Progress Administration ceramics testing program attached to the Mississippi State Geological Survey. It is hoped that the Survey can resume ceramic and geochemical testing soon.

Before the kinds of clays are discussed it should be pointed out that only three clays in the whole County fit the field requirement of a true clay—no grit on biting. These will be described as clays. The others will be referred to as silty or sandy clays. Both are unusually plastic and hence can be easily molded for firing.

It should also be stated here that the three months allotted this survey were insufficient time for detailed sampling of clays, marls, limestones, and glauconites. Consequently the text which follows is designed to inform as to where likely materials are to be found, not how much of each is available. To properly evaluate these deposits many months of careful work will be required to hand auger, core drill, and trench the areas cited. However, it is hoped that suggestions in this report may lead to extensive private exploration and eventual utilization of the materials described. Field work should be started in late Autumn and continued through the winter when foliage interferes least and when rains bring out color contrasts. More intensive exploration, by drilling, should await drier weather in summer months and early autumn.

Although Madison County clays were sampled on the bases of lithology and texture they are classified on the bases of (1) geologic range, (2) color, (3) lithology, and (4) texture. Nine clays are of probable economic value. They are listed below in order of their geologic age, oldest to youngest, in the same sequence as the formation names on the stratigraphic chart (Figure 4). The more massive clays are actually parallel belts of outcrop successively from northeast to southwest (Plates 1 and 6). Occurrences of isolated clays, or those clays which interlens with silts or sands, are carefully noted. The three true clays are identified thus*. Several of the clays and silty clays are near gas transmission lines which could be tapped for fuel (Plate 1).

*9—upper Yazoo slightly silty clay; blue-gray, slightly limy, massive, fairly plastic, comprising the south half of the Yazoo outcrop (Plate 1).

8—lower Yazoo slightly silty clay; blue-gray, fairly limy, massive, fairly plastic, comprising the north half of the Yazoo outcrop (Plate 1).

7—Cockfield Zone 4 sandy clay; light-gray, massive, very plastic, fairly continuous in outcrop (Plate 6, Figure 20).

6—Cockfield Zone 3 slightly silty clays; light-gray, massive, slightly plastic, discontinuous because of interlensing and interfingering with silts and sands, at any place in Zone 3 outcrop (Plate 6, Figure 18).

*5—Cockfield Zone 3 clay; dark-brown, carbonaceous, massive, very plastic, only one isolated lens 2.7 miles south-southwest of Camden (Plate 6).

4—Cockfield Zone 2 slightly silty clay; mottled gray, yellow, red, purple; massive, fairly plastic, continuous in outcrop (Plate 6, Figures 5 and 17).

*3—Cockfield Zone 1 clay; chocolate-brown, many silty sand partings, a single lens near base of zone, 0.7 mile west of Cameron (Plate 6 and Figure 16).

2—Cockfield Zone 1 silty clays; light-gray, slightly plastic, discontinuous because of interlensing and interfingering with very silty clays, at any horizon in the zone (Plate 6).

*1—Wautubbee clay; chocolate-brown, many silt partings, 2 or 3 lenses among silts and sands (Plate 1 and Figure 14).
The above clays are fully described in "Stratigraphy."

*True clays

WAUTUBBEE CLAY

The chocolate-colored Wautubbee clays are true clays, despite numerous partings of silty sand. Careful hand-auger drilling or power coring should reveal lenses containing fewer partings—lenses similar to those found in Drill Tests 1, 2, and 3. However, some sand may be advantageous in making brick or tile. In Tallahatchie County similar highly carbonaceous brown clays in the Zilpha unit yielded burned test pieces of a pleasing salmon-pink color.

Lenses of chocolate-colored clay containing a minimum of silt partings are present in road cuts in the extreme northeast of Madison County, all in T.12 N., R.5 E., near the Attala County line. Locations and thicknesses follow:

1. Road fork, NE.¼, SE.¼, SE.¼, Sec.20—3 feet.
2. Northwest road cut, SE.¼, NW.¼, SW.¼, Sec.21—8 feet.
3. Northwest road cut, NW.¼, SE.¼, NE.¼, Sec.21—8 feet.
4. Northeast road cut, SW.¼, SE.¼, NW.¼, Sec.24—4 feet.
5. South road cut, NW.¼, NE.¼, SE.¼, Sec.25—8 feet.
6. Gullied abandoned road at intersection, NE.¼, SW.¼, SE.¼, Sec.17 (just north of line in Attala County)—14 feet.

COCKFIELD ZONE 1 SILTY CLAYS

As described in "Stratigraphy," clays of Zone 1 Cockfield are slightly silty and slightly plastic. Although they are massive they are discontinuous because of interlensing and interfingering. In fresh outcrops they are light-gray but they soon weather lilac. Later they turn buff, yellow, red, or purple. Lenses of plastic clay may attain thicknesses of 10 to 20 feet, as indicated by ridgetop exposures noted along roads in the places named below, all in the northeastern part of the County:

1. Sections 2 and 11, T.11 N., R.5 E.
2. Sections 6 and 7, T.11 N., R.5 E.
3. Sections 34 and 35, T.12 N., R.5 E.
4. Sections 16, 17, 20, 29, and 30, T.11 N., R.5 E.

Other areas where there are thicknesses of 15 to 20 feet in desirable clays are broad level benches at the locations listed below:

1. At the juncture of Sections 23 and 26, T.11 N., R.5 E.
2. Along Mississippi Highway 17 in Section 16, T.11 N., R.5 E.
3. In Sections 1, 2, and 11, T.11 N., R.5 E.
4. In Section 25, T.11 N., R.5 E.
5. In Sections 35 and 36, T.12 N., R.4 E.

COCKFIELD ZONE 1 CHOCOLATE-COLORED CLAY

A single lens of chocolate-colored clay containing numerous silty sand partings (Figure 16) is exposed near the base of Zone 1 clays, 0.7 mile west of Cameron on the south side of Mississippi

Highway 17 (NE. Corner NW.¼, NE.¼, Sec.4, T.11 N., R.4 E.). The outcrop is near flood plain level. The lens has a thickness of 8.2 feet and a length of 80 feet. The clay appears very much like the chocolate-colored clay lenses of the Wautubbee. Probably it will also burn salmon-pink. Topography indicates that the lens forms the east valley wall of Love's Creek northeast and southwest of Mississippi Highway 17 for at least half a mile.

COCKFIELD ZONE 2 SILTY CLAY

The massive silty mottled clay which constitutes Zone 2 of the Cockfield is one of the more promising of Madison County materials. It is easily recognized in the field by its gray, yellow, and red mottling and by its plasticity when wet. The outcrop extends from the Millville area in the east to the Loring area in the northwest (Plate 6). It is thickest, 40 to 50 feet, and best exposed near Loring in the northwest and along Mississippi Highway 16 near the Leake County line in the southeast. Zone 2 silty clays can be prospected in road cuts at the places specified below:

1. Sections 25 and 26, T.10 N., R.5 E. (Highway 16).

2. Northeast Section 14, T.10 N., R.5 E. (newly made road).

3. Section 3, T.10 N., R.5 E., south of Revive, where 20.1 feet of good clay is recorded (Figure 17).

4. Section 2, T.10 N., R.4 E., where there are both gray silty clays and some carbonaceous clay.

5. Section 8 and 9, T.10 N., R.4 E. along a ridge.

6. West of Loring in Sections 23 and 24, T.11 N., R.3 E., and east of Loring in Sections 19 and 20, T.11 N., R.4 E. where there is an 18-foot section of east dipping Zone 2 clays.

7. Sections 13 and 14, T.11 N., R.3 E. near Pickens Field, where Zone 2 clays show dip (Figure 5).

COCKFIELD ZONE 3 CARBONACEOUS CLAYS

Unfortunately, only a few carbonaceous, massive clays free from silt partings crop out on the surface of the whole County. These desirable materials interlens and interfinger with Zone 3 gray silty clays in a confusing manner, as explained in "Stratigraphy." They may occupy any interval within the zone. The three exposures worth prospecting are:

1. Along the north-south road where a lens of carbonaceous clay some 8 feet in thickness is near the base of Zone 3 in a west cut (N. line, NW.¼, SW.¼, Sec.2, T.10 N., R.4 E.) about 2.9 miles southwest of Camden.

2. Other carbonaceous clays, aggregating some 28 feet in thickness, are interbedded with plastic, gray, silty clays in the upper part of Zone 3 along an abandoned farm road (NE.¼, NE. ¼, SW.¼, Sec.2, T.9 N., R.4 E.) just south of Mississippi Highway 16.

3. Older carbonaceous clays extend nearly to the base of Zone 3, as discovered by Dr. B. W. Brown in an auger hole along the Highway 16 0.8 mile to east of the abandoned road mentioned above. Brown's drill test showed 13 feet of desirable brown clays alternating with gray silty clays.

COCKFIELD ZONE 3 SLIGHTLY SILTY CLAY

Lenses or tongues of slightly silty gray clays can be found at any interval in Zone 3 of the Cockfield formation and at any place in the outcrop (Plate 6). In hand auger holes the silty clays are gray-tan but they rapidly bleach gray in the freshest exposures. On alternate wetting and drying the clays swell and crack and oxidize buff or yellow.

The slightly silty Zone 3 clays merit examination in two areas: north of Sharon and along Mississippi Highway 16. In the Sharon area road cuts show thicknesses of 10 to 30 feet, as follows:

1. Hill top at juncture of Sections 24 and 25, T.10 N., R.3 E., and Sections 19 and 30, T.10 N., R.4 E. (Figure 18).

2. Hill slopes in Sections 19 and 20, T.10 N., R.4 E.

3. Hill slopes in Section 22, T.10 N., R.4 E.

In the Highway 16 area are some weathered road cuts which should be cheked by hand augering. They are:

1. Along Mississippi Highway 16 in Section 2, T.9 N., R.4 E., and in Sections 31, 33, and 27, T.10 N., R.5 E.

2. Along the west-east road at the south line of Sections 34 and 35, T.10 N., R.4 E.

3. Along the road in southwest of Section 29, T.10 N., R.5 E.

COCKFIELD ZONE 4 SANDY CLAY

The most promising material for brick and tile appears to be the sandy clay which constitutes most of Zone 4 Cockfield formation (Plate 6). The clay is easy to find. It is 50 feet in thickness in a hilly belt in few places more than a mile in width below (northeast of) the Moodys Branch cuesta from Natchez Trace to near Sharon. From Sharon northwest to U. S. Highway 51 the clays are present as lenses 25 to 40 feet in thickness among silts and silty sands in a belt which widens to 3 to 5 miles.

Despite its sand content the clay is very plastic. It swells when wet and cracks as it dries. In fresh exposures it is light-gray, but on weathering it mottles yellow, buff, and orange-red. Good sections of Zone 4 clays are found in the Sharon-Highway area as follows:

1. In southeast road cut (Center, SW.¼, SE.¼, Sec.23, T.10 N., R.3 E.) at the top of the Cockfield 7 miles northeast of Canton and about 3 miles north-northwest of Sharon (Figure 20). Here is a thickness of 30.1 feet of massive clays.

2. In road cuts along Mississippi Highway 43 from 1 to 3 miles northeast of Sharon, in Sections 29, 31, 32, T.10 N., R.4 E. where thicknesses of 10 to 15 feet are common.

3. In cuts of a north-south road in Sections 25 and 36, T.10 N., R.3 E., from 1.2 to 1.7 miles north of Sharon where several sections indicate 25 to 40 feet of upper Zone 4 sandy clays.

4. In cuts beneath loess along the curving ridge road through Sections 15 and 21, T.10 N., R.3 E., some 7 to 8 miles north-northeast of Canton.

5. In west cut of U. S. Highway 51 beneath Moodys Branch marl (SW.¼, NE.¼, SW.¼, Sec.5, T.9 N., R.3 E.) on the south valley wall of Tilda Bogue Creek, 3 miles north of Canton.

LOWER, SILTY, FAIRLY LIMY YAZOO CLAY

Although exposures of the lower Yazoo clay are fairly numerous, it is doubtful if the clay at these places will be of economic value except where weathering has removed most of its fairly high calcareous content.

As here defined, the lower, silty, fairly limy division comprises the approximate lower half of the Yazoo clay which has a total thickness of 360 to 400 feet in Madison County. The outcrop belt of this division consequently trends west-northwest—east-southeast across the central part of the County. Its northeast limit is, of course, the Moodys Branch outcrop (Plate 1). Its southwest limit is arbitrarily drawn from the Loess Hills near Stokes southeastward through Gluckstadt to near Pearl River in Section 32, T.8 N., R.3 E.

Between these limits the lower, more calcareous, facies of the Yazoo clay is exposed in the fresher road cuts. The material is blue-gray, slightly silty, massive, and fairly calcareous as shown by its rapid effervescence with hydrochloric acid. In contrast, beds of the upper Yazoo clay effervesce but little, although they are identical with the lower clay in other ways. Rapid volumetric analyses show lime (CaO) percentages of 5 to 8 in the cuttings from Drill Tests 5 and 6, the calcareous content having increased with depth.

A lime content of 3 to 5 percent is found in the fresher road cuts:

1. Northwest Section 2, T.9 N., R.1 E. (Figure 7), about 3 miles north-northwest of Virlilia. Here cuts of 20 to 30 feet are exposed by recent construction.

2. In the west of Sections 6 and 7, T.8 N., R.2 E. some 6 to 7 miles southwest of Canton. At this locality thicknesses up to 20 feet are exposed in recent hill slope cuts.

3. Along Mississippi Highway 43 in Sections 9, 15, 16, and 22, T.8 N., R.3 E., from 4 to 8 miles southwest of Canton. At these places single cuts of 15 to 25 feet are common.

Weathered cuts from which most of the lime has been removed abound across the County in a belt 2 to 3 miles in width just southwest of the Moodys Branch outcrop (Plate 1). They are worthy of detailed study inasmuch as their burned products should not blister as much as high-lime clays. Some exposures of leached lower Yazoo clay are as follows:

1. In a series of hill slope cuts capped by loess (Figure 24) along the new road between Sections 3 and 4, T.9 N., R.2 E., about 5 miles northwest of Canton. In these cuts sections of 5 to 25 feet are common.

2. In shallow road cuts in the Shocco area, in Sections 16, 17, 20, and 21, T.9 N., R.4 E.

3. In shallow cuts of Mississippi Highway 16, Sections 14, 21, and 22, T.9 N., R.3 E., from 2 to 4 miles east of Canton.

UPPER, SILTY, SLIGHTLY LIMY YAZOO CLAY

Because of its proximity to a potential market in Jackson the upper Yazoo clay may be of considerable economic value. Except for less calcareous content this division is identical with the lower half of the Yazoo clay.

The updip limit of the upper Yazoo clay is arbitrarily drawn from Stokes southeasterly through Gluckstadt to near Pearl River in Section 32, T.8 N., R.3 E. The belt of outcrop trends east-southeast—west-northwest across southwest Madison County except for two areas where the younger Forest Hill and Glendon beds are preserved in the Flora-Ridgeland syncline (T.8 N., R.2 W., and T.7 N., R.1 E.), and in the one area just south of Flora (T.8 N., R.1 W.) where Forest Hill strata are preserved. The upper Yazoo clay projects south of Ridgeland into Hinds County where it forms the outer rim of the Jackson Dome, enclosing lower Yazoo silty clays, Moodys Branch marl, and upper Cockfield lignites, silts, and sands at the Dome's crest.

Upper Yazoo clay cuttings from Drill Tests 6, 7, and 8 showed a calcareous content of only 2 to 3 percent, but this may be enough lime to prevent the use of fresh material for ceramic purposes. On the other hand, near-surface beds are much less calcareous because the lime content has largely been leached. Such is the case of the upper material removed from the shallow pits of Jackson Ready-Mix Concrete-Light Aggregate plant which makes artificial rock (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W.), near one of the southwest corners of Madison County some 7 miles west-southwest of Ridgeland. There, because of weathering, a new problem is introduced by masses of the selenite variety of gypsum filling joints and some bedding planes (Figure 29). This hydrated calcium sulphate, $CaSO_4 \cdot 2H_2O$, is deposited by capillary waters in the drier months. Although the crystals slowly dissolve in wet weather the calcium content remains in the clay long enough to produce some swelling and weakening during the firing of the product.

Another difficulty which may be encountered is the concentration of caliche at the surface of Yazoo clay outcrops or, like the selenite, in joints and along bedding planes near the surface. Figure 29, is a photograph of a fresh footing excavation for the Mississippi Highway 463 overpass of new Interstate Federal Highway 55 about 1.4 miles west-northwest of Madison in northwest part of Section 7, T.7 N., R.2 E. The white material, caliche, is a form of calcium carbonate, $CaCO_3$, and was concentrated by the upward moving waters, just as the selenite was formed. Dumping of whole truckloads of caliche-or selenite-contaminated clays may be required to eliminate the danger of lime blistering of the fired product. Selective digging may be necessary to avoid both the caliche and the selenite.

County exposures of upper silty, slightly limy Yazoo clay are fairly numerous. Some of the freshest are:

1. Cuts along Mississippi Highway 463 in Sections 6 and 7, T.7 N., R.2 E. and Section 1, T.7 N., R.1 E. from 1 to 3 miles northwest of Madison (Figures 8 and 26).

2. Cuts presently being made along new Interstate Highway 10 from Mississippi Highway 463 in Section 7, T.7 N., R.2 E. north-northeast to the northwest of Section 28, T.8 N., R.2 E. near Gluckstadt.

3. In many hill slope road cuts in Section 32, T.8 N., R.1 E.

4. In fairly recent cuts of Mississippi Highway 463 in Sections 34, 27, and 22, T.8 N., R.1 E. south of Mannsdale.

LIMESTONES AND MARLS

Limestones and marls for the liming of fields could be a valuable agricultural asset to Madison County. Mellen[35] has shown that most Mississippi soils are 85 percent deficient in lime, a figure which could very well apply to the northeast two-fifths of Madison County, where there are no calcareous beds on the outcrop. The loess mantle provides some lime in the Loess Hills but the Yazoo clay of the Jackson Prairie has been weathered so deeply, 18 feet in Drill Test 6, that the extensively cultivated

Yazoo outcrop belt should be limed too. Certainly the sandy and clayey soils of the Cockfield outcrop should be treated.

Glendon limestones on some of the hilltops in T.7 N., R.1 E., have been quarried at intervals for about 100 years, for burning lime (nearby is Limekiln Creek), for foundation blocks and chimney stones. Some road metal was removed from one ridge in Section 16 during the Works Progress Administration road building program about 1937.

On only a few of the broader and higher hilltops is it certain that the limestone is bedded. On other hilltops rounded boulders are probably float, blocks which have been lowered from their original position as the underlying unconsolidated beds have eroded. Areas of limestone known to be bedded are shown on Plate 1. The total area so underlain is small but observation has shown that a small quarrying operation can furnish enough agricultural lime to supply the yearly requirements for many thousands of acres.

The only source of agricultural limestone is the Glendon, in 4 areas: (1) on Rocky Hill in west of Section 20, T.7 N., R.1 E., some 5 miles west of Ridgeland; (2) on Richardson Hill in northwest of Section 16, T.7 N., R.1 E., six miles west of Madison; (3) beneath a loess mantle capping the broad ridge of Sections 16, 17, 20, 21, and 28, T.8 N., R.2 W., about 7 miles west-southwest of Flora; and (4) beneath loess capping other ridges in Sections 29, 31, and 32, T.8 N., R.2 W., on the Hinds County line 9 to 10 miles west-southwest of Flora. Test Hole 8 was drilled at a hillcrest road fork (SE.¼, SW.¼, NE.¼, Section 20) to confirm the presence of limestone in area (3). Time did not permit drilling in area (4) but the topography of the area and outcrops in gullies just across the Hinds County line indicate that the limestone must underlie the loess.

The writer judges from analyses of the Glendon in the Vicksburg and Brandon areas that some beds of limestone may contain 30 to 35 percent lime (CaO) but that the interbedded limy shales may have a lime content of only 10 to 15 percent. If, as suspected, the shales make up two-thirds of the Glendon section and the limestones only one-third, the content of limy beds will be but 20 to 25 percent, scarcely adequate for making great quantities of agricultural lime. However, if only the limestones were crushed (the leaner shales could be bull-dozed down hill) the product would be very satisfactory. In areas (1) and (2) an overburden of but 2 to 5 feet of soil and weathered limestone need be removed, but in areas (3) and (4) an overburden of 5 to 15 feet of loess will be encountered, a thickness which is not prohibitive. Details of thicknesses of limestones, limy shales, and overburden must be ascertained by drilling some 15 to 30 test holes in areas (3) and (4).

The following chart indicates the probable thicknesses of the Glendon section in the four areas, in feet and by acres.

	(1)	(2)	(3)	(4)
Greatest thickness of Glendon in feet	22	27	29	25
Hilltops having 25 feet of Glendon in acres	0	2	10	20
Hilltops having 20 feet of Glendon in acres	3	4	35	60
Hill slopes having 15 feet of Glendon in acres	12	30	180	60
Hill slopes having 10 feet of Glendon in acres	6	20	120	50

BENTONITE

Bentonite is classed by some as clay, but in this report, because of its distinctive texture, it is considered an economic prospect along with clays, limestones, and glauconites.

Bentonite is believed to have been volcanic ash which, in the territory that is now Madison County, was deposited in very late Yazoo seas. It is present as thin beds among the youngest (higher) Yazoo beds in the region west of Madison as a cream-colored to yellow mealy material which does not absorb water. It has a soapy feel but lacks the plasticity of most clays.

On the outcrop it is readily distinguished (Figure 8) by its contrast in color and texture with the blue-gray gritty Yazoo clays above and below. However, experience has shown that the Yazoo clays swell when wetted, whereas the bentonite does not; consequently, in road cuts the bentonite is usually thicker some distance back from the outcrop than it is at the surface. This same property of being wetted without becoming plastic is used as a suspensory in drilling mud. Some other uses of bentonite are as a filtering agent by which color and taste are removed. Bentonites from Smith County have been processed at the Filtrol Corporation plant in south Jackson for many years.

Upper Yazoo clays containing thin bentonites have been noted in two localities:

1. A single bed 8 inches in thickness is exposed in an east road cut in the very center of Section 32, T.8 N., R.1 E., about 8 miles west-northwest of Madison.

2. Two bentonites, each 6 inches in thickness, are in the southwest cut of a road curve (SW. Corner, Sec.6, T.7 N., R.2 E.) 1.7 miles west-northwest of Madison (Figure 8).

3. In the west walls of Jackson Ready-Mix Concrete-Light Aggregate quarry (SW.¼, NE.¼, NW.¼, Sec.36, T.7 N., R.1 W.) just over the line in Hinds County some 7 miles west-southwest of Madison. Here beds of bentonite 2 to 4 inches in thickness help thin limestones define faulting (Figure 8).

There are probably other thin bentonites in the region as near the top of the Yazoo clay in Yazoo County to the west. However, deposition of volcanic dust must have been erratic, for beds of bentonite in one hillside road cut are not present in strata at the same elevation in cuts on the other side of the hill. No bentonitic clays were found in Test Holes 7 and 8, which penetrated uppermost Yazoo clays. But careful inspection of water-well logs may show other beds. A systematic surface study in the winter months, when the color contrast of yellow bentonite and gray-blue Yazoo clay is most vivid in gully and road cut exposures is suggested.

GLAUCONITE

The Moodys Branch marl may contain enough glauconite to use directly on pastures and on cultivated soils as a source of soda, potash, lime, and phosphate. Glauconite is a green sand, a complex aluminum silicate found in some marls which were once shallow sea bottoms. One variety is believed to be the fossil excrement of worms and small shrimp-like creatures which continuously reworked the bottoms of the Moodys Branch seas.

Mississippi greensands were studied by Price, Galloway, and Priddy[36] in 1946 and 1947. They collected and processed some 72 samples from 13 different glauconite beds throughout the State and then determined the greensand's physical and chemical characteristics, as part of a joint Millsaps College-Carnegie Foundation research program.

In the course of that investigation one Moodys Branch sample was obtained from a then-fresh west cut (SW.¼, NE.¼, SW.¼, Sec.5, T.9 N., R.3 E.) of U. S. Highway 51 about 3 miles north of Canton on the south valley wall of Tilda Bogue Creek. A second was collected just over the line in Yazoo County, from a borrow pit on the west side of Mississippi Highway 16 (NE.¼, NW.¼, Sec.9, T.10 N., R.2 E.), from the same beds as are now so badly weathered (Figure 23). Analyses of these greensands are shown as columns (1) and (2) in the following tabulation. Column (3) represents an approximate analysis of the more vital compounds in greensand separated from the glauconite-rich cuttings 36 to 38 feet in Test Hole 5 (SW. Corner Sec.9, T.9 N., R.3 E.) about 2 miles northeast of Canton. The log of this test hole is shown in "Stratigraphy." Column (4) is the record of an analysis furnished by Clarke[37] of glauconite from greensand marl, Hanover County, Virginia, where it has been mined for years for use as fertilizer and water softener. Flame photometry (indicated *) was used to determine potash and soda content. The percentages of the other constituents were ascertained by laborious gravimetric methods.

CONSTITUENTS IN PERCENT	SAMPLES			
	(1)	(2)	(3)	(4)
Water (-H_2O) by loss on ignition	9.31	16.40		10.32
SiO_2 (silica)	33.41	38.16		51.56
CaO (lime)	3.28	2.33	3.90	0.62
MgO (magnesia)	2.25	2.39	2.95	0.95
FeO (ferrous oxide) and Fe_2O_3 (ferric oxide)	17.87	13.33		23.49
Al_2O_3 (alumina)	29.04	23.82		6.62
TiO_2 (titania)	0.25	0.22		
MnO (manganous oxide)	0.002	0.002		
P_2O_5 (phosphorous content)	0.32	0.18	0.18	
*K_2O (potash)	*3.45	*2.62	*3.01	4.15
*Na_2O (soda)	*0.92	*0.56	*0.78	1.84
Total	100.10	100.01		99.55

These glauconite analyses show that the potash, soda, lime, magnesia, and phosphate, although small in quantity, should contribute to the fertility of the soil through slow decomposition of the glauconite. The writer judges from the rate of weathering of road cut exposures, such a fertilizer should contribute plant foods over a period of several years. Further, the quartz sand content of the Moodys Branch marl should improve the texture of waxy clay soils derived from the Yazoo clay. Both increased fertility and better texture have been observed in similar soils in Jackson where glauconitic sand and quartz sand washings have been dumped.

Exposures of Moodys Branch glauconitic marl are many in a belt across northeast central Madison County (Plate 1). The central part of the belt is broadest due to extensive weathering of the greensand which has furnished iron oxide (limonite) to cement the grains of quartz and thus produce a ferruginous sandstone. Here, shallow hand auger holes starting at least 50 feet from the sandstone outcrops should reveals green marl as glauconitic as that described in the record of Test Hole 5, in which are noted, percentages of 5 to 35 glauconite from depths of 30 to 54 feet. Care should be taken to start the holes in the clay at least 15 feet above the Moodys Branch-Yazoo contact, on steep slopes. Otherwise the glauconite found will be badly weathered, as in the drilling of Test Hole 4 on a low hillcrest, on the north side of the road (SE.¼, SE.¼, NE.¼, Sec.16, T.9 N., R.4 E.) about 9 miles east of Canton.

Test Hole 4

Location: North side of road intersection with wide farm lane (SE.¼, SE.¼, NE.¼, Sec.16, T.9 N., R.4 E.) 1.0 mile east of Shocco and about 9 miles east of Canton.

Elevation: 316 feet, altimeter

No.	Thickness	Depth	Description
1	3.0	3.0	Soil and subsoil, yellow-buff, clayey
			Yazoo formation
2	7.0	10.0	Clay, yellow-buff, slightly silty
			Moodys Branch formation (cored)
3	5.0	15.0	Marl, red-brown; alternate beds of sandy marl and clayey marl; 10 percent weathered glauconite in cuttings. Only 5 percent recovery of core

4	5.0	20.0	Marl, yellow-brown, sandy; 10 percent weathered glauconite in cuttings. Only 2 percent recovery of core
5	5.0	25.0	Marl, greenish-gray, sandy; many partings of yellow limonite clay; 25 percent glauconite in cuttings. Only 2 percent recovery of core
		25.0	TD, lost core catcher, abandoned hole Drilled August 18, 1959

Locations of Yazoo-capped exposures where hand auger holes can test the glauconite marl are:

(1) Along the north-south road between Sections 25 and 26, T.10 N., R.2 E. and Sections 30 and 31, T.10 N., R.3 E., 5 to 7 miles north of Canton.

(2) Along the winding road in Sections 32, 33, and 34, T.10 N., R.3 E., some 5 to 7 miles north-northeast of Canton.

(3) Along Mississippi Highway 43 in Sections 1, 2, 10, and 11, T.10 N., R.3 E., southwest of Sharon, and in the hills immediately northwest of the Highway.

(4) Along the west-east road in Sections 5 and 6, T.10 N., R.4 E. just east of Sharon.

(5) Along the north-south road between Sections 12 and 13, T.10 N., R.3 E. and Section 7, T.10 N., R.4 E. south to its intersection with Mississippi Highway 16, about 5 miles east of Canton.

(6) Along the curving roads through Section 5, 8, and 9, T.10 N., R.4 E., about 8 miles east of Canton.

PROPOSED PEARL RIVER RESERVOIR

At this writing so much progress has been made in planning for a Pearl River Reservoir that its creation seems assured. It is expected to be finished by January, 1962. Engineers' drawings call for an earthen dam to span the Pearl River lowlands just south of the Madison-Hinds County line, as shown on Plate 1. Also shown is a heavy dashed 298-foot contour line. This recently surveyed line, furnished through the courtesy of Lester Engineering Company[38] of Jackson, Mississippi, will mark high water when the reservoir is filled. Then river waters will be backed up some 20 miles, as far as Section 30, T.9 N., R.5 E., to about the crossing of the now unused Canton-Carthage railroad. The lake's width will be from 2 to 4 miles in places. A few minor elevations in the flood plain will become low islands. Obviously portions of the Natchez Trace will be flooded. Also inundated will be the only outcrops on the river as cited in the part of the text which relates to the Moodys Branch formation.

In addition to the expected drainage control and recreation which the Reservoir will afford, an industrial area is planned in and around Section 23, T.9 N., R.4 E. If used, this center should revive the Canton-Carthage Railroad. It is proposed that industries which use large quantities of water should build there.

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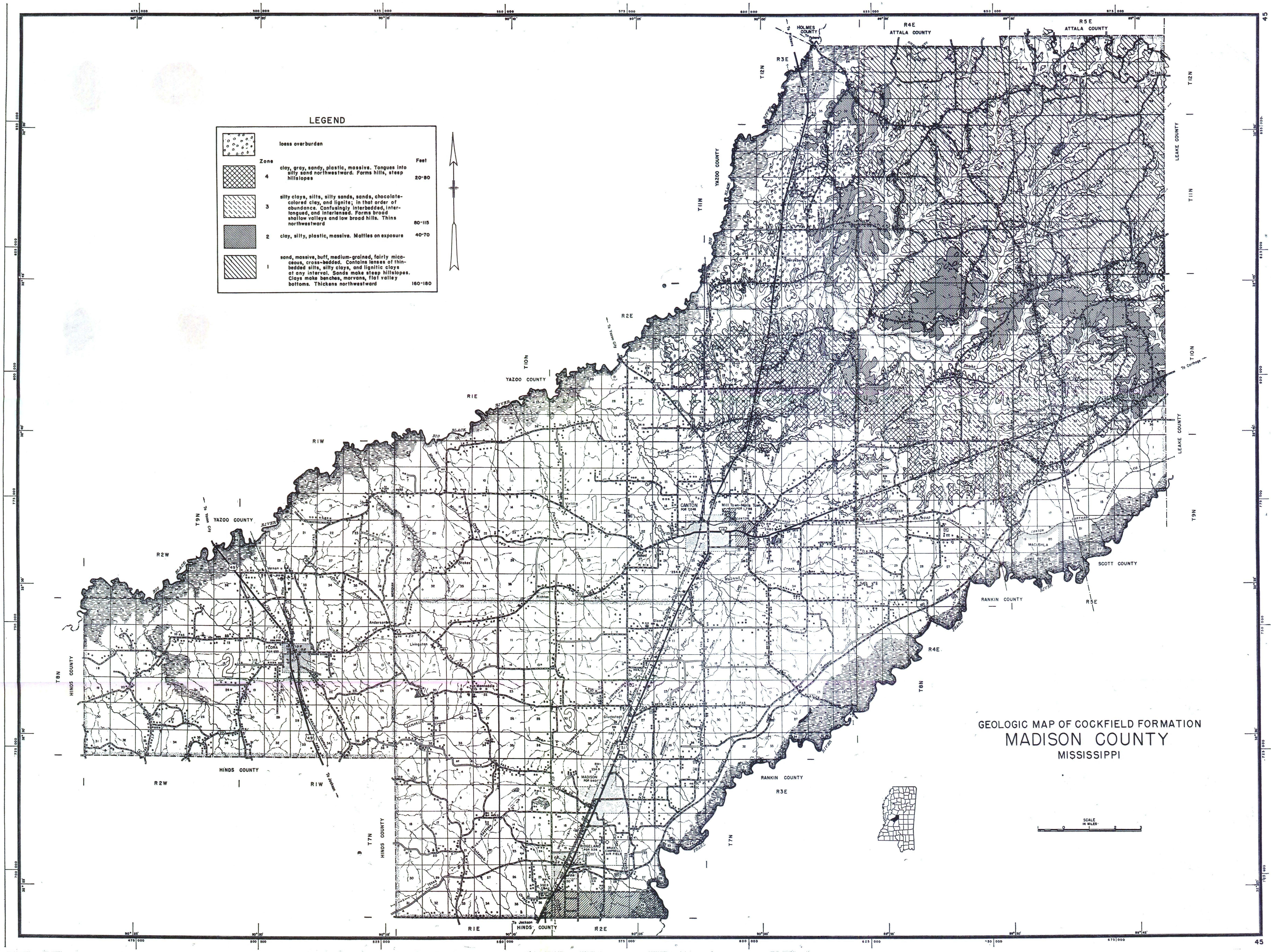
LEGEND
loess overburden
Zone
Feet
4
clay, gray, sandy, plastic, massive. Tongues into silty sand northwestward. Forms hills, steep hillslopes
20-80
3
silty clays, silts, silty sands, sands, chocolate-colored clay, and lignite; in that order of abundance. Confusingly interbedded, intertongued, and interlensed. Forms broad shallow valleys and low broad hills. Thins northwestward
80-115
2
clay, silty, plastic, massive. Mottles on exposure
40-70
1
sand, massive, buff, medium-grained, fairly micaceous, cross-bedded. Contains lenses of thin-bedded silts, silty clays, and lignitic clays at any interval. Sands make steep hillslopes. Clays make benches, morvans, flat valley bottoms. Thickens northwestward
160-180
GEOLOGIC MAP OF COCKFIELD FORMATION
MADISON COUNTY
MISSISSIPPI
SCALE
IN MILES
HOLMES COUNTY
ATTALA COUNTY
LEAKE COUNTY
SCOTT COUNTY
RANKIN COUNTY
HINDS COUNTY
YAZOO COUNTY
CANTON
FLORA
MADISON
RIDGELAND
Livingston
Gluckstadt
Richton
Sharon
Camden
Flora
T12N
T11N
T10N
T9N
T8N
T7N
R2W
R1W
R1E
R2E
R3E
R4E
R5E
BIG BLACK RIVER
PEARL RIVER
To Carthage
To Jackson