MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph. D.
Director

BULLETIN 43

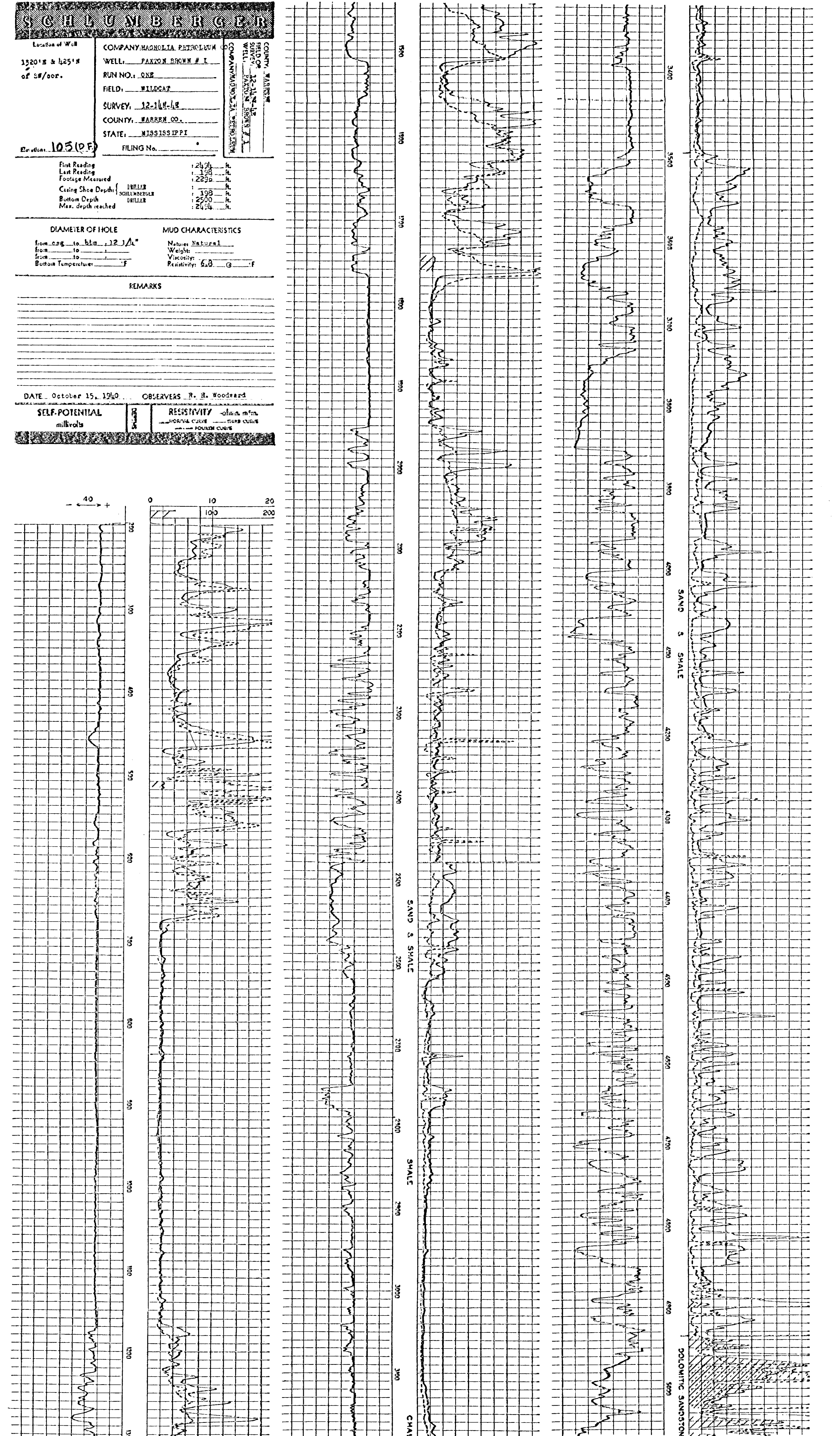
WARREN COUNTY MINERAL RESOURCES

GEOLOGY
FREDERIC FRANCIS MELLEN, M. S.

TESTS--CLAYS
THOMAS EDWIN McCUTCHEON, B. S., Cer. Engr.

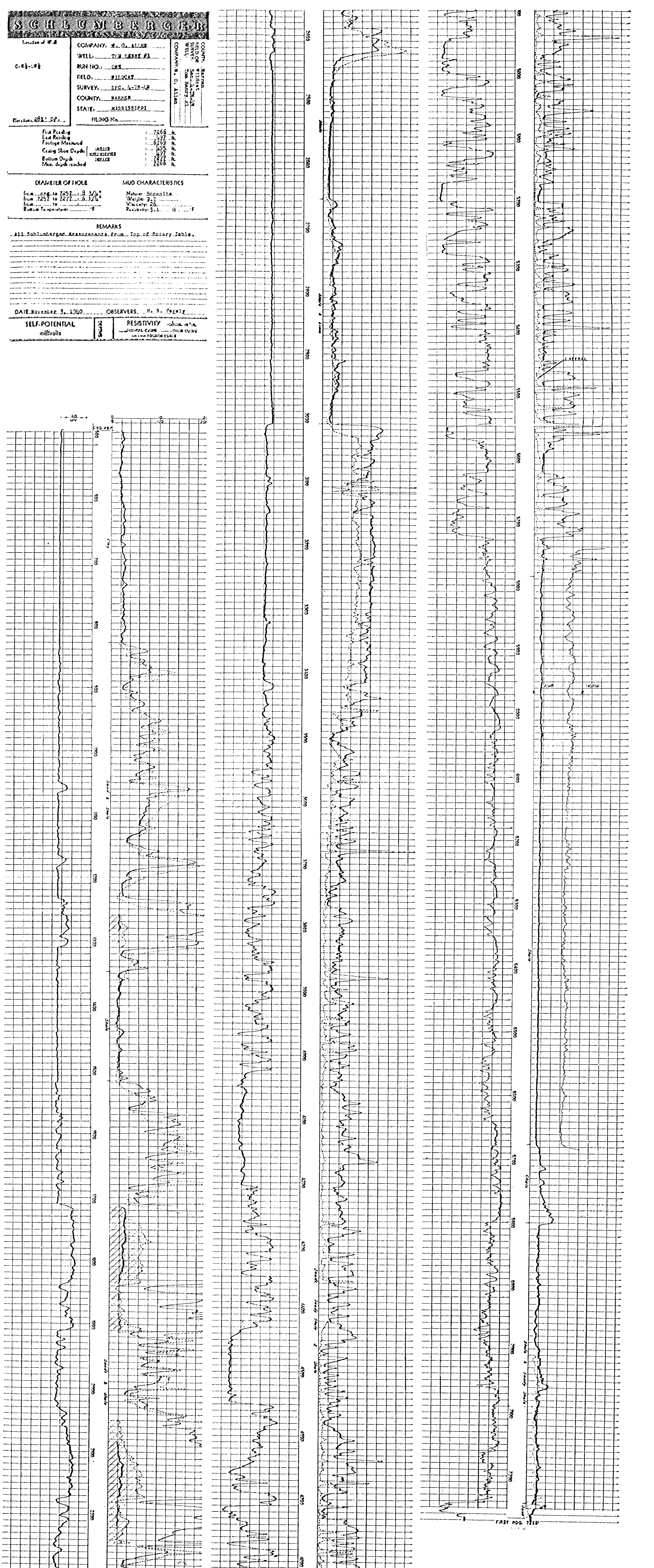
TESTS--MARLS AND LIMESTONES
MALCOLM ROGERS LIVINGSTON, M. S.

UNIVERSITY, MISSISSIPPI
1941



MAGNOLIA PETROLEUM CO. — TOTAL DEPTH
PAXTON - BROWN NO. 1 — SCHLUMBERGER 5065
WARREN CO. — DRILLER 5073

MISSISSIPPI STATE GEOLOGICAL SURVEY
BULLETIN 43 PLATE 3A



W. O. ALLEN
TOM HENRY NO. 1
WARREN CO., MISS
RUN NO. 1

SCHL. T.D. 7268
DRLR. T.D. 7277'
ELEV. D.F. 281'

MISSISSIPPI STATE GEOLOGICAL SURVEY
BULLETIN 43 PLATE 3B

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Prepared in cooperation with the Warren citizens and the WPA as a report on O.P.465-62-3-275

UNIVERSITY, MISSISSIPPI
1941

MISSISSIPPI GEOLOGICAL SURVEY

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LETTER OF TRANSMITTAL

Office of the State Geological Survey
University, Mississippi
August 4, 1941

To His Excellency,
Governor Paul Burney Johnson, Chairman, and
Members of the Geological Commission

Gentlemen:

Herewith is Bulletin 43, Warren County Mineral Resources—Geology by Frederic Francis Mellen, M.S.; Tests-Clays by Thomas Edwin McCutcheon, B.S., Cer. Engr.; Tests-Marls and Limestones by Malcolm Rogers Livingston, M.S.—the fifth in a series of mineral resources reports the publication of which "in regular bulletin form" constitutes a partial fulfillment of the Mississippi Geological Survey's pledge necessary to secure WPA funds.

The Warren County report, like each previous county report, is the fruit of the splendid cooperation of its citizens—especially Mr. W. N. Miner, Secretary-Manager of the Vicksburg Chamber of Commerce, and Hon. J. C. Hamilton, Mayor of Vicksburg—with their State Geological Survey.

In addition to the regular stratigraphic and areal geology parts, the report contains a revised structural map of importance in oil development and special parts on ceramics, light-weight aggregate, cements, mineral wool, and agricultural lime.

Very sincerely yours,

William Clifford Morse,
State Geologist and Director

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WARREN COUNTY MINERAL RESOURCES

GEOLOGY

Frederic Francis Mellen, M.S.

INTRODUCTION

Warren County lies in the west-central part of the State of Mississippi (Plate 1). It is bounded on the north by Issaquena and Yazoo, on the east by Hinds, on the south by Claiborne, and on the west by the Mississippi River and the Louisiana parishes of Carroll, Madison, and Tensas. As its boundary follows the courses of the Mississippi, Yazoo, and Big Black Rivers through most of its length, Warren is the most irregularly shaped county of Mississippi.

The total area of Warren County is 572 square miles or 366,080 acres, of which 233,224 acres (63.7 percent) are in farm lands. Of this farm acreage, 52,218 acres (22.4 percent) are in cultivation, and 106,225 acres (45.6 percent) are in pasture. The 1940 Census shows a County population of 39,421.

Vicksburg, the county seat, is an industrious city of 24,283 persons, according to the 1940 Census. It was founded in 1791 by a group of Spaniards who called it Fort Nogales. It was chartered as a city in 1825, receiving its name from Newitt Vick, a settler of 1812.

Vicksburg in 1939 had an assessed valuation of $16,891,174.00. It has two national banks, both of which offer complete banking and trust services. Its important industries include lumber mills, hardwood flooring plants, a boat oar factory, a heading mill, a box factory, cotton gins, a cotton compress, a cotton oil mill, a cotton pick sack factory, a garment factory, a mattress factory, foundry and sheet metal works, ice plants, ice cream plants, laundries, bakeries, and a petroleum oil refinery. Vicksburg also has the locomotive and car shops of the Yazoo & Mississippi Valley Railroad, and the shops of the U. S. Engineers of the Third Mississippi River District.

Vicksburg is served by two main line railroads, both parts of the Illinois Central System. The Yazoo & Mississippi Valley extends from Memphis, Tennessee, on the north to New Orleans, Louisiana, on the south. The Alabama & Vicksburg extends from Meridian, Mississippi, on the east to Vicksburg, on the west; a continuation of this line crosses the Mississippi River at the Vicksburg Bridge and extends across Louisiana to Shreveport.

The Inland Waterways Corporation-Federal Barge Line maintains a large terminal in the city. Transportation by barge is available on the Mississippi River from New Orleans to St. Louis, and on the Ohio River from Cairo to Pittsburgh. Numerous privately owned packets on the Mississippi River use the concrete municipal wharf located on the water front in the heart of the city. The Yazoo River, although officially navigable throughout its entire length to Greenwood, Mississippi, has no commerce at present to demand that the channel project depth of four feet be maintained.

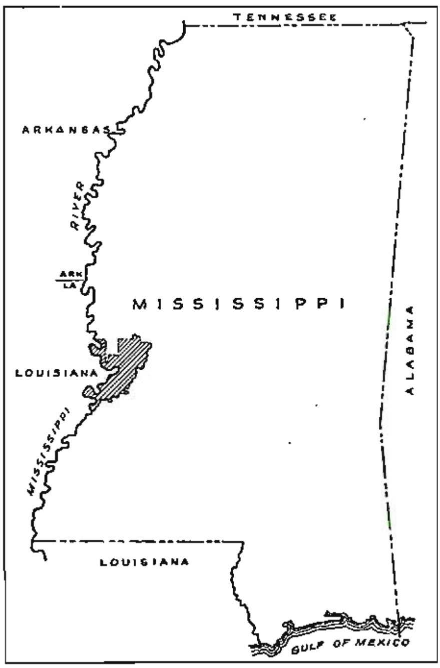


Plate 1.—Location of Warren County.

Bus lines operate north of Vicksburg on U. S. Highway 61 to Memphis, Tennessee; east on U. S. Highway 80 through Jackson to Meridian; west on U. S. Highway 80 across the Vicksburg Bridge to Shreveport, Louisiana; south on U. S. Highway 61 to Natchez and New Orleans.

The municipally owned and maintained airport is located 6 1/2 miles northeast of Vicksburg.

Water for domestic and commercial purposes is pumped from the Mississippi River and is clarified and purified in the large filtration plant owned and operated by the city.

Electricity is supplied by the Mississippi Power & Light Company from their generation plant at Sterlington, Louisiana. In addition, the Company maintains a local plant with a capacity adequate to take care of the maximum load in case of emergency.

Natural gas is distributed within the city by the Vicksburg Gas Corporation. The supply is brought to the city limits through a 6-inch pipe line of the Southern Natural Gas Company. The United Gas Pipe Line Company has an 18-inch pipe line through Warren County, eastward from its Vicksburg Bridge crossing. The gas supply comes from the Monroe and other fields in north and central Louisiana.

The climate of Vicksburg and Warren County is temperate. The records of 58 years show the mean maximum temperature to be 75 degrees, and the mean minimum temperature to be 57 degrees. The highest recorded temperature was 104 degrees, and only four times during the 58 year period have the records shown temperatures of 100 degrees or above. The mean annual temperature is 65.6 degrees; and the average annual rainfall is 53.04 inches.

STRATIGRAPHIC AND AREAL GEOLOGY

GENERAL

The range of geologic formations in Warren County is upper Eocene to Recent. The bed-rock, which underlies the hills or bluff region, consists, in ascending order, of the Jackson formation (Forest Hill member), the Vicksburg formation, and the Catahoula formation. Lying non-conformably over the bed-rock formations is a thick blanket of gravel and sand referable to the Citronelle formation of Pliocene age. This formation, in turn, is overlain dis-conformably by the loessal silt of Pleistocene age. Along Big Black River, along the Mississippi River, and in the narrow entrenched valleys of the smaller streams are deposits of Pleistocene (?) and Recent gravels, sands, silts, and clays. The geologic summary of exposed rock formations and the generalized geologic section, both of which are shown below, illustrate the stratigraphy of Warren County.

Areally, about one-third of Warren County lies within the so-called Delta, the alluvial valley of the Mississippi and Yazoo rivers, and about two-thirds of the county lies within the hills or bluff region.

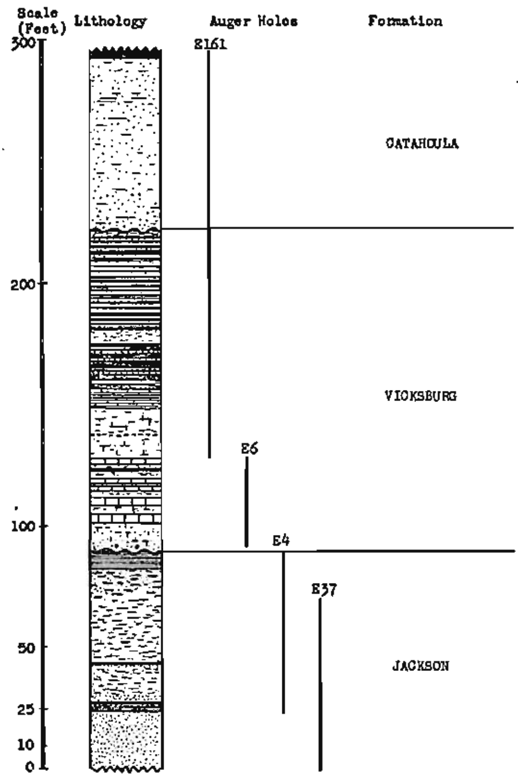


Plate 7.—Columnar section of rocks exposed in Warren County.

Warren County lies principally on the Louisiana side of the Mississippi Embayment Geosyncline, and the regional dip of formations is, consequently, to the southeast. The escarpment or Bluff at the edge of the Delta, extending southwest-northeast through the county, lies approximately in the line of regional strike. The actual center of the Mississippi Embayment Geosyncline, as determined on the surface formations, extends northward through a point near Bovina, in eastern Warren County, and through Ballground, in northern Warren County; there is a suggestion of a lateral syncline extending from the major syncline near Bovina, northeastward up the valley of Big Black. In the area of the Warren-Yazoo county line the regional dip is southwestward.

SUMMARY OF EXPOSED ROCK FORMATIONS IN WARREN COUNTY

System	Formation	Member	Character	Thickness (Feet)
Holocene			Alluvial deposits of gravel, sand, silt, clay, all more or less carbonaceous; dark brownish-gray; mostly cross-bedded and heterogeneous.	10 to 150
	Nonconformity			
Pleistocene	"Loess"		Eolian or loessal silt; bluish-gray where unoxidized, but everywhere in outcrop it is brownish-gray; abundant pulmonate gastropod shells throughout unleached portions; leached portions non-effervescent; homogeneous.	50 to 75
	Disconformity			
Pliocene	Citronelle		Diluvial terrace deposits of boulders, cobbles, gravel, sand; local deposits of silt and silty clay; cross-bedded and heterogeneous.	25 to 50
	Nonconformity			
Oligocene	Catahoula		Sands and sandstones, silts and siltstones, clays and claystones of estuarine, terrestrial, deltaic, and paludal origins, lignitic and probably tuffaceous.	over 100
	Disconformity			
	Vicksburg	Byram	Lower facies 30 to 40 feet of marine clay-and sand-marl, montmorillonitic and bentonitic, glauconitic; few thin limestone or coquina beds. Upper facies 60 to 70 feet, thin-bedded to massive silty, lignitic, montmorillonitic clay; few thin siltstone or claystone beds; some lignite.	90 to 100
		Glendon (Mint Spring at base)	Alternating strata of hard arenaceous limestone and glauconitic, argillaceous, arenaceous marl; bentonite interstratified locally; waterfalls common over basal limestones. The Mint Spring marl facies is a very fossiliferous glauconitic sand-marl, containing coarse sand grains, phosphatic and lignitic pebbles.	25 to 65 5 to 25
	Disconformity			
Eocene	Jackson	Forest Hill	Argillaceous, lignitic silt most abundant; thin argillaceous lignite; lignitic leaf-bearing silty montmorillonitic clay; fine-grained cross-bedded sand; total thickness of member about 100 feet; heterogeneous.	40

JACKSON FORMATION

GENERAL

The Jackson formation, youngest of Eocene age in Mississippi, is, in ascending order, lithologically divisible into three members; the Moodys Branch marl, the Yazoo clay, and the Forest Hill sand. The Moodys Branch is dominantly a glauconitic marly sand, encompassing the "basal conglomerate" features of the Jackson formation. It overlies the Lisbon formation disconformably, and is overlain conformably by the Yazoo member. The contact between the members, while fairly abrupt, is yet gradational, as sand and glauconite are found in graduated quantities in the lower 10 feet, more or less, of the Yazoo clay. The contact of the Yazoo member and the Forest Hill member, also, is gradational. However, this contact is somewhat variable in stratigraphical position and age, due to an inter-tonguing of the characteristic sediments. Both the Moodys Branch and the Yazoo members are entirely marine. The Forest Hill, largely continental, may be marine in part. It represents the shoaling of the Jackson sea, and the emergence of its floor, prior to the pre-Vicksburg erosion cycle.

FOREST HILL MEMBER

The stratigraphic unit, here treated as the Forest Hill member of the Jackson formation, has provoked discussions on its genetic relationship since the days of Conrad, Wailes, and Hilgard. It has been realized that a body of sand and sandy clay, containing some thin beds of lignite, lies between the marine sediments of Jackson age and the marine sediments of Vicksburg age. The differences of opinions have resulted largely because of paucity of good exposures in the region, and because most of the several investigators had undertaken extensive rather than intensive studies of the stratigraphy. As a matter of fact, many geologists are inclined to accept and to perpetuate ideas advanced by earlier geologists, and in many cases errors in figures and in interpretation have been perpetuated because of lack of investigative energy.

The lignitic beds below the marine beds at Vicksburg were known by Wailes (1854, pp. 237, 238) who reported: "The most considerable deposit of lignite, by far, which has come under my observation, is that at Vicksburg. This I had a favorable opportunity of examining on the 10th of October, 1852, owing to an unusually low stage of water in the Mississippi, it being rarely exposed to view. On that occasion I measured 500 yards on its surface, along the margin of the river, and obtained specimens of it . . . The thickness of the bed I had no means of ascertaining, no excavation having been made . . ." Harper (1857, p. 153) also knew of the lignite at Vicksburg, and was astonished "that the proprietor has not tried to quarry it here and sell it to the steamboats, for which it would prove to be a valuable fuel, as it contains very little sulfuret of iron."

From Hilgard's discussions it is doubtful whether the lignite bed referred to above was considered by him to be Jackson or to be Vicksburg. In his discussion of the Jackson group (1860, p. 136) he leaves the impression that the bed and associated strata are Jackson, but in his discussion of the Vicksburg group (1860, p. 138) he states that it (The Vicksburg) is "The highest of the marine Eocene formation and the only one which reaches the banks of the Mississippi River." His section (1860, p. 141) of the bluff shows 3 feet of white limestone, questionably referred to the Jackson, succeeded by 3 feet of solid lustrous lignite, succeeded by 25 feet of gray or black lignitic clays or sands containing pyrite and yielding sulphate efflorescence; this being succeeded by fossiliferous marls and limestones.

Crider placed the lignitic beds at Vicksburg in the Vicksburg formation (1906, p. 38), but he also wrote (1906, p. 36): "The Jackson has usually been described as being entirely made up of marls and clays, but recent investigations along the line of contact between the Jackson and Vicksburg have shown that there are from 50 to 75 feet of yellow, gray, or white siliceous unconsolidated sand at the top of the Jackson. Whether from a paleontologic standpoint this should be considered Jackson or Vicksburg is doubtful, since no fossils have been found in these sands. They are regularly stratified, showing that they were deposited very near the old shore, in more or less current . . . They outcrop in various places in southern Madison County, where the Vicksburg limestone forms outliers on the upper Jackson. The exact stratigraphic position of the sands was first discovered in this vicinity."

The strata under discussion were first placed in the stratigraphic nomenclature by Lowe (1915, p. 82), who named the unit the Madison sand, a name found to be preoccupied. He stated that the unit might belong either to the Jackson or to the Vicksburg.

Subsequently, Cooke (1923, p. 1) introduced the name Forest Hill to replace the name Madison, writing: "The name Forest Hill sand (from Forest Hill, 5 1/2 miles southwest of Jackson, Miss.) replaces the 'Madison sands' of Lowe. The Forest Hill appears to rest conformably upon the Yazoo clay member of the Jackson formation.

Although the character of the sediments indicates a change at the end of Jackson time from marine to very shallow water or palustrine conditions, it is probable that the change was gradual and that deposition was nearly continuous. The Forest Hill is overlain conformably by the Mint Spring marl member of the Marianna limestone. The relations of the Forest Hill to the Red Bluff clay are not definitely known, but it is thought that the two were formed contemporaneously, the Red Bluff in the open sea and the Forest Hill in the Mississippi embayment."

Lowe (1923, p. 31) readily adopted the name Forest Hill and Cooke's inclusion of the unit with the Vicksburg, but he considered the Vicksburg to be a formation rather than a "group."

Berry (1924, p. 98) had no doubt that the Forest Hill was of Jackson age: "These sands undoubtedly represent littoral and continental deposits that mark the oscillation of the strand in this area between Jackson and Vicksburg time, and the thin bed of lignite, which usually intervenes between them and the marine Vicksburg, confirms the floral evidence that these sands are of Jackson age."

Lowe (1925, pp. 73, 74) treated the Forest Hill as a formation of the Jackson "group" 50 to 75 feet in thickness, and gave the maximum observed thickness as 85 feet. He commented: "Seven miles southwest of Jackson the east slope of Forest Hill shows at the base typical Jackson clay soils, at the top undoubted Vicksburg limestone and marl, while between the two lie 57 1/2 feet of gray sandy clay, gray sand and yellow sand, all dipping strongly toward the west. The yellow sands at the bottom merge by gradual transition into the Jackson clays, indicating apparently a closer relationship of the sands with the Jackson formations than with the Vicksburg."

Stephenson and others (1928, p. 54) correlated the Forest Hill as basal Vicksburg and gave the thickness as 70 feet. In another part of the same report (p. 471), however, the writers say: "In the well of the Delta Ice Co. at Vicksburg (see log p. 473) 485 feet of non-water-bearing slate-colored clay, which is referred to the Yazoo clay member of the Jackson formation, was penetrated between the depths of 306.5 and 791.5 feet; the clay was followed by 67 feet of black sand with shells, which is referred to the Moodys marl member of the Jackson. Above the main body of clay lies a bed of water-bearing sand 65 feet thick whose position seems to indicate that it belongs to the Jackson formation."

Grim (1928, p. 8) correlated the Forest Hill as a formation of the Jackson "group," but in the text of his report (p. 21) treated the Jackson as a formation.

Monroe (1931, p. 9) stated that the Jackson formation is overlain by the Forest Hill sand, and that the contact may be conformable.

Grim after making detailed field and petrographic studies, reported the Forest Hill to be the uppermost member of the Jackson formation, having a maximum thickness of about 75 feet. In discussion, Grim wrote (1936, p. 217): "The Forest Hill beds were placed in the Jackson by Lowe. Later Cooke suggested that they are of Vicksburg age and the equivalent of the Red Bluff beds in eastern Mississippi. The Forest Hill beds have no marine fossils and their floral remains are too poor for identification; hence, a paleontological correlation is impossible. Because the Red Bluff beds exist only in eastern Mississippi, the Forest Hill beds only in western Mississippi, and neither in the intervening area, it is impossible to prove or disprove Cooke's suggestion. However, these beds as exposed at many places between Jackson and Vicksburg are definitely transitional, grading down into the Jackson and up into the Vicksburg. Since they grade very gradually into the Jackson and abruptly into the Vicksburg, their Jackson age is favored in this report. The material is also lithologically more like the Jackson than the Vicksburg."

A distinct unconformity separating the Forest Hill from the Mint Spring (Vicksburg) was pointed out at several localities in Warren County by Mellen (1939a, pp. 17-19). Later (1940, pp. 16, 23, 26), he reported this same condition to exist in Yazoo County, and gave the Forest Hill, 60 to 80 feet in thickness, the rank of member in the Jackson formation.

Attempts were made during the present survey to penetrate the full thickness of the Forest Hill so that a definite measure could be given. Test holes E4 and E37, records of which accompany this report, give some idea of the thickness, which is probably between 90 and 100 feet. The two holes penetrated to the important water-bearing sand in the lower part of the Forest Hill. This sand is exposed in Yazoo County in the area between Satartia and Germania where there is probably some catchment of water. Several wells in Vicksburg are reported by Stephenson and others (1928, pp. 471-474) to obtain water from this horizon. In the last few years a number of wells have been drilled in Warren County by G. T. Terry & Sons and

R. A. Young for domestic water supplies. These wells indicate persistency for this horizon. The wells at the Vicksburg Airport and of Lawrence C. Biedenharn, 5 miles northeast of Vicksburg, are finished in this sand at depths of 342 and 353 feet, respectively. Four and a half miles south of Vicksburg a well drilled for H. T. Grant was abandoned at 310 feet, failing to find an adequate supply of water. This well lacked a few feet of penetrating the water-bearing sand in the lower part of the Forest Hill. Test Hole E4, at Mint Spring water-fall, was abandoned in the top of the sand because of caving, brought on by the flow of water. Test Hole E37, near the Yazoo County line, probably almost penetrated the top of the Yazoo Clay. It was abandoned 23.5 feet in the water-bearing sand, the penetration of which was accomplished only after great and prolonged labor; it indicated a thickness of about 100 feet for the Forest Hill member. The water-bearing sand in the Forest Hill is similar to the sand throughout the member. It is a fine-grained sand, the individual grains being strikingly angular. It contains a few dark mineral grains, a small amount of glauconite, a little mica, some lignitic material, and some clay. It is persistently thicker and cleaner than sands in the upper part of the unit, and the grain size may average a little larger.

About midway of the Forest Hill there is a thin lignite bed which may be of importance only as a structural marker. What is probably the same bed is exposed in Yazoo County on Coal Creek and at Germania. In E37 it was penetrated between 26.3 and 27.4 feet, or about 56 feet below the top of the Forest Hill and 42.7 feet above the bottom of the hole. In E4 it was penetrated between 45.0 and 46.0 feet, or 45 feet below the top of the Forest Hill and 20.6 feet above the bottom of the hole. In the H. T. Grant well (East side, near center, Sec. 20, T.15, N., R.3 E.) it was penetrated between 290 and 291 feet, 48 feet below the base of the Glendon proper, and 90 feet below sea level. About 200 yards south of Glass station a test hole started at an elevation of 105 feet, encountered the lignite at 70.7, and was abandoned in it as 71.3 feet. The lignite here, at 34 feet above sea level, is 124 feet higher on the Glass Dome than in the Grant well 3 1/4 miles to the northeast in line of regional strike.

Without doubt this is the same seam of lignite reported at Vicksburg by Wailes, Harper, Hilgard, Crider, and others, a bed exposed only at extreme low water along the Mississippi River (now the Yazoo Diversion Canal). The writer is not aware of recent reports of this exposure, and it is to be expected that changes have taken place along the water-front that have permanently hidden it from view. However, the old reports of a 3-foot seam of solid lustrous lignite underlain by 3 feet of white limestone are not confirmed by the information obtained by this survey. The materials under the lignite at the two points sampled are not even effervescent, and no limestones are known elsewhere in the area in the Forest Hill. Locally the lignite may be 3 feet in thickness, although it rarely exceeds 1 1/2 feet, but even a 3-foot seam of lignite of the best quality would not be workable under such adverse sedimentary association and groundwater conditions.

The upper part of the Forest Hill is made up of interbedded fine-grained lignitic sands, lignitic silts, and silty clays, some of which may be bentonitic. At the Haynes Bluff locality biotite mica is found in the top of the Forest Hill, suggesting volcanic activity. In Yazoo County there is one locality (N. 1/2, SE. 1/4, Sec. 5, T.8 N., R.4 W.) of silty bentonitic (?) clay where fossil leaves are excellently preserved. Volcanic activity, as indicated by beds of pure bentonite, took place in upper Yegua times, at the beginning of Yazoo times, again near the close of Yazoo times, in Glendon and in Byram times. No pure bentonites have been recorded from the Forest Hill, although clays that appear to be bentonitic and the local presence of biotite mica are two points of evidence suggesting that bentonite may be found in the Forest Hill.

The areal distribution of the Forest Hill (Jackson formation) in Warren County is exceedingly small. So far as the writer is aware, exposures are present only along the Bluff bordering the Mississippi-Yazoo Alluvial Plain. It is not unlikely, however, that there are a few exposures in the extreme northeast portion of Warren County in the Big Black drainage area. Along the Bluff, exposures are to be found at intervals for the entire distance from the Yazoo County line to Centennial Cut-off at Vicksburg, except for a 4-mile or 5-mile stretch at Ballground where the formations lie in a syncline and the Forest Hill is too low for exposure. South of Vicksburg the Forest Hill is not exposed, although at Glass it is structurally high enough.

THE JACKSON-VICKSBURG CONTACT

Along the Bluff bordering the alluvial valley of the Mississippi River from southern Yazoo County to Vicksburg, a distance of about 25 miles, the lower limestone beds of the Glendon member of the Vicksburg formation produce water-falls across many of the numerous small tributary streams which flow into the Yazoo River. The limestone ledges protrude a few feet beyond the underlying Mint Spring marl facies of the Glendon and the sub-jacent Forest Hill sand. The conditions for exposures of the Jackson-Vicksburg contact are especially favorable at these places, although elsewhere slumping, which is so prevalent along the Bluff, has invariably hidden the contact.

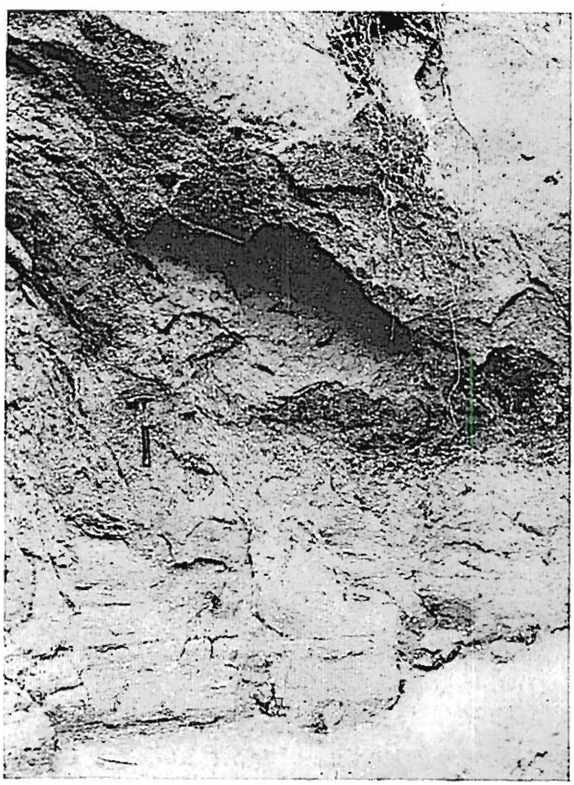


Figure 1.—Contact zone (Hammer) between the Forest Hill member of the Jackson formation below and the Mint Spring facies of the Glendon member of the Vicksburg formation above, beneath the bridge at Haynes Bluff (NE. 1/4, NW. 1/4, Sec. 26, T. 18 N., R. 4 E.) February 18, 1939.

In most places the upper part of the Forest Hill is a bluish-gray laminated fine-grained lignitic, micaceous, argillaceous, arenaceous silt.

The overlying Mint Spring marl facies of the Glendon member of the Vicksburg formation is an argillaceous, glauconitic sand-marl varying greatly in thickness from point to point. At the Thornell water-fall in Yazoo County (NW. 1/4, NE. 1/4, Sec. 4, T.8 N., R.4 W.), the Mint Spring facies has a thickness of 21.1 feet or slightly more. At Haynes Bluff, Warren County (NE. 1/4, NW. 1/4, Sec. 26, T.18 N., R.4 E.), the identifiable part of the Mint Spring facies is 13.5 feet. At another water-fall (NW. 1/4, SW. 1/4, Sec. 26, T.18 N., R.4 E.),

Figure 2.—Sample from the position of the hammer in Figure 1, showing conclusive evidence of the stratigraphic break between the Forest Hill and the Mint Spring. Lignitic roots indicate terrestrial sedimentation prevalent in Forest Hill times; the marl-filled mollusc borings indicate a subsequent transgression of the sea and the deposition of marine sediments of Mint Spring times. February 18, 1939.

about one-half mile southwest of Haynes Bluff, the full thickness of the Mint Spring facies is only 7.7 feet. At the type locality, Mint Spring Bayou (Sec. 12, T.16 N., R.3 E.), the thickness of the facies is 12.8 feet. The base of the Mint Spring is determined by the top of the bored zone of material similar lithologically to the Forest Hill, and the top is set arbitrarily at the base of the first ledge of hard limestone.

Under the bridge at Haynes Bluff is one of the most instructive sections in the area. At the base of the section typical undisturbed

Forest Hill sediments are exposed. Above this is a zone 6.0 or 8.0 feet thick of a material whose matrix is lithologically the same as the underlying Forest Hill. The material contains numerous vertical and branching mollusc borings which are filled with glauconitic sand and tiny marine shells. It also contains numerous lignitic root markings, which most commonly extend downward and which have been cut out in part by the borings. The base of the Mint Spring facies is marked by irregular lenses of fossils. The Mint Spring, approximately 13.5 feet thick, is overlain by about 20 feet of exposed alternating beds of limestone and marl. Figures 1, 2, and 3 illustrate the Jackson-Vicksburg contact at this locality.

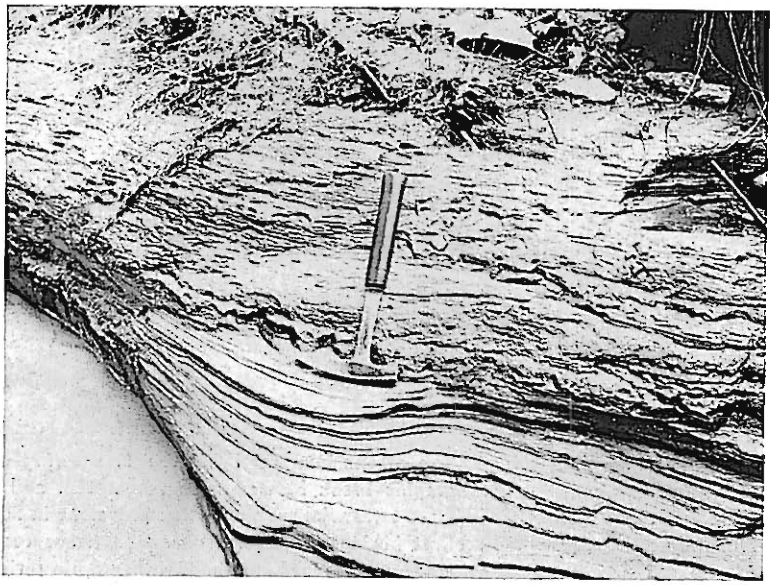


Figure 3.—Typical Forest Hill material, argillaceous, silty, lignitic laminated sand, a few feet below the Jackson-Vicksburg contact, beneath the bridge at Haynes Bluff. February 18, 1939.

At the fall one-half mile south of Haynes Bluff the exposures are similar except that there is no undisturbed Forest Hill material exposed and there are no lignitic root marks in the bored zone.

At Mint Spring water-fall the exposures are similar. No lignitic root marks have been observed. The exposures do not extend low enough to show the undisturbed Forest Hill beneath the bored zone, but trenching at the type exposure of the marl (Figures 4 and 5) has revealed the hair-line contact of the Jackson and Vicksburg formations.

On the Laura Archer property (NW. 1/4, NE. 1/4, Sec. 2, T.18 N., R.5 E.), at Blakely (NE. 1/4, NE. 1/4, Sec. 15, T.17 N., R.4 E.), and at several other points the exact contact is exposed.

From the Haynes Bluff locality, in particular, it is evident that the conditions at the close of the Jackson age were favorable for erosion and for plant growth. Evidence of erosion is to be assumed from the variations in the thickness of the overlying marine beds; it

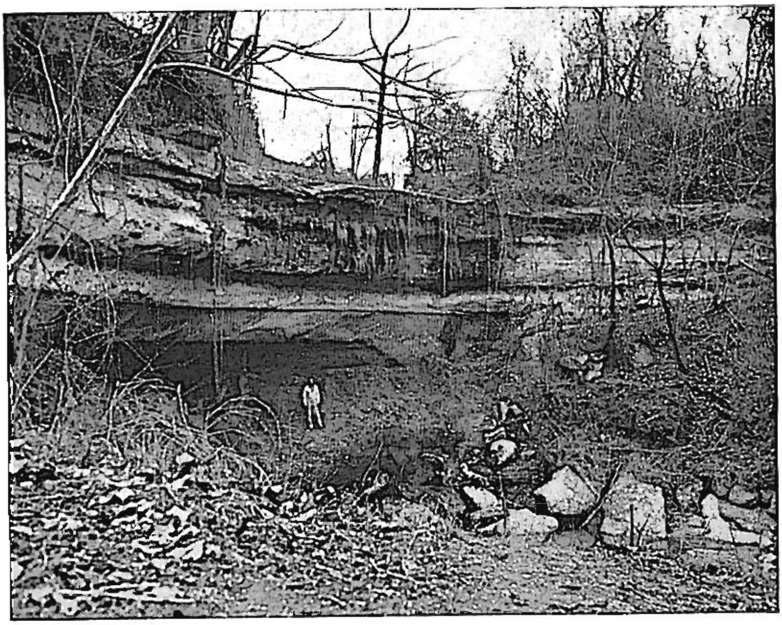


Figure 4.—Falls at Mint Spring Bayou, at National Cemetery, Vicksburg, showing small exposures of Forest Hill sand, the Mint Spring marl, and the lower half of the Glendon limestones and marls. January 23, 1939.

is also to be assumed from the presence of clay pebbles, phosphatic nodules, and lignitic fragments in the lower part of the Vicksburg formation. The Vicksburg sea, at first a relatively clear sea, resulted from a rapid submergence. The first marine animals of the Vicksburg epoch bored downward into the upper surface of the sediments of the Jackson. Into such channels were washed the shells, sand, and other sediments of early Vicksburg times. The evidences of the disconformity between the Jackson and the Vicksburg formations are:

1. Lignitic plant roots are present just below the contact.
2. Mollusc borings, penetrating Forest Hill materials, are filled with marine materials of the Mint Spring marl.
3. The base of the Mint Spring presents the features of a basal conglomerate.
4. The variation in thickness of the Mint Spring marl shows an uneven surface of deposition.
5. There is a definite lithologic change over a zone disturbed by plant and animal activity from materials showing terrestrial conditions below to materials showing marine conditions above.

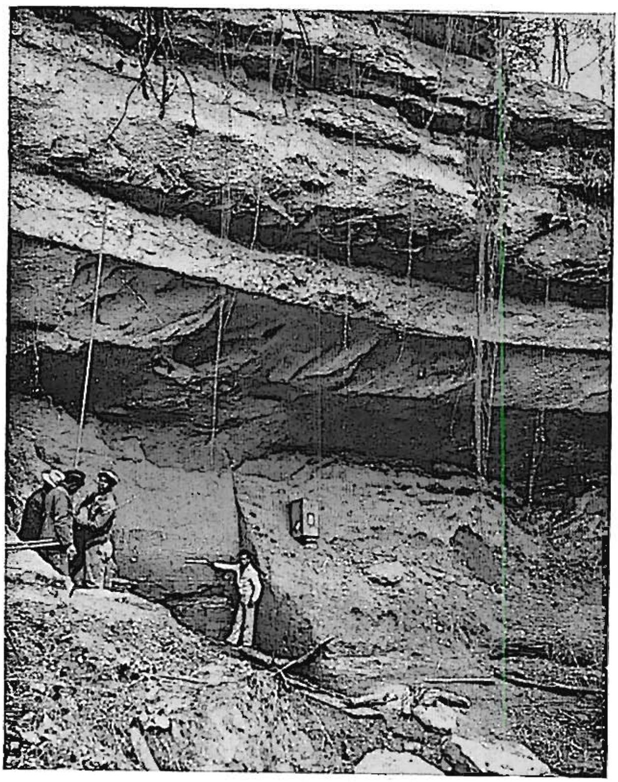


Figure 5.—Close-up view of falls at Mint Spring Bayou, showing actual contact of the Jackson and Vicksburg formations. Test Hole E 4, where men are working, was drilled to 66.6 feet in Forest Hill materials. January 23, 1939.

VICKSBURG FORMATION

GENERAL

The Vicksburg formation of the Oligocene system extends S. 70° E. across Mississippi from its type locality at Vicksburg, into Alabama at Wayne County, Mississippi. It overlies the Jackson formation of the Eocene system disconformably, and is overlain disconformably (?) by the Catahoula formation of the Oligocene system. In Warren County its thickness is 130 or 140 feet. The formation is divided into two members, the Glendon limestones and sand-marls, and the Byram marls, clays, and silts. Separated as it is from overlying and underlying formations by erosional and lithologic breaks, and being without important intra-formational breaks, the Vicksburg very properly constitutes a fundamental, genetic, geologic unit, or a formation.

It has seemed best, for reasons to be presented in another place, to alter some of the prevalent nomenclature. Because of this it appears advisable to review the literature dealing with the Vicksburg sediments.

LITERATURE

As early as 1846 Conrad (1846a, 1846b, 1848, 1856) had observed the marine marls and limestones at Vicksburg and vicinity, had collected and described the fossils, and had made comparisons with fossil collections from the Atlantic coastal states and the southeastern states. His studies, although based largely on paleontology, were very careful, and resulted in a classification which is followed in large measure to this day. From his fossil studies he recognized, in order of succession, the "Older Eocene, Claiborne," the "Older Eocene, Jackson," and the "Newer Eocene, Vicksburg."

Hilgard (1860, pp. 138-147) published a list of the Vicksburg fossils, described the lithology and distribution of the Vicksburg group across the state, and, seemingly, included the "Lignito-gypseous" strata of the underlying Jackson formation and placed the non-fossiliferous upper Byram in the Grand Gulf (Catahoula) group.

Crider (1906, pp. 37-40; 1907, pp. 60-67) appears to have been the first to assign to the Vicksburg strata the rank of formation.

During the period between Hilgard and Crider, Langdon (1886) and Casey (1901, 1903, 1905) attempted some detailed studies of the Vicksburg, the work being largely paleontological.

Detailed work by Cooke (1918, 1922, 1923) resulted in the following division of the Vicksburg "group" of the Oligocene:

Byram calcareous marl (formation)
Glendon (formation)
Marianna limestone (formation)
  Mint Spring calcareous marl (member)
Forest Hill (formation) and Red Bluff (formation) contemporaneous

The Forest Hill sand of western Mississippi and the Red Bluff clay of eastern Mississippi, the one non-marine and the other marine, are thought to be contemporaneous and are stated to be conformable with the Jackson formation below and with the Marianna limestone above. As developed in Mississippi, the Marianna limestone is divisible into the "Chimney rock" facies in the central and eastern part of the state, a very homogeneous soft white limestone, and into the Mint Spring calcareous marl member in the western part of the state. "The Glendon formation, named from a village on the Southern Railway in Clarke County, Alabama, was originally described as the Glendon limestone member of the Marianna limestone, but inasmuch as beds of Glendon age are now known to have a wider distribution than the typical Marianna, to contain a large and characteristic fauna, and to transgress older formations, it seems advisable to regard the Glendon as of formational rank. It overlies the Marianna conformably. In the type area the formation consists of a series of ledges of hard, partly crystalline yellowish or pinkish limestone interbedded with softer strata of impure limestone, aggregating 18 or 20 feet in thickness. The formation probably extends westward as far as Mississippi River, where the hard ledges in the bluffs at Vicksburg are tentatively placed in the Glendon, but the identification of the Glendon limestone in western Mississippi is somewhat questionable" (1923, p. 3). The Byram calcareous marl formation is stated to be 13 to 70 feet thick, to overly the Glendon formation conformably, and to underly the Catahoula.

Lowe (1925, pp. 33, 37) reported the Vicksburg formation to have a thickness of 200 to 250 feet by including the Forest Hill, 50 to 75 feet thick, as the basal sand member. However, in 1925 Lowe (pp. 71, 73-78) treated the Forest Hill as being a formation in the Jackson group and also treated it as a formation in the Vicksburg group "As a distinct facies of the Red Bluff formation." Aside from this inconstancy, he follows Cooke's classification of the Vicksburg.

Stephenson and others (1923, pp. 54, 470-474), following the classification of Cooke, gave the thickness of the group as 145 feet in the vicinity of Vicksburg and 185 feet in eastern Mississippi: "The Vicksburg group is believed to rest conformably on the Jackson formation. The stratigraphic relation of the group to the overlying Catahoula sandstone has not been determined. In places the Vicksburg appears to pass by gradual transition into the Catahoula, whereas elsewhere there appears to be an abrupt line of contact between the two divisions."

In June, 1935, Morse (pp. 9-13) followed the four-fold division of the Vicksburg of Cooke, but he was the first to suggest the presence of Forest Hill sediments in the section at Vicksburg (p. 12). The top of the Mint Spring was limited at the base of the lowest indurated Vicksburg limestone bed. He followed Cooke in placing the laminated nonmarine (?) sediments at the top of the Waltersville-National Cemetery section in the Catahoula formation.

In November, 1935, Mornhinveg and Garrett (pp. 1645-1667) reviewed the literature on the Vicksburg fairly completely; discussed and illustrated the stratigraphic section at Vicksburg; like Morse, followed Cooke's four-fold division; and like Morse, placed the top of the Mint Spring at the base of the lowest indurated Vicksburg limestone bed. At Mint Spring type locality, however, they did not recognize the lowermost, non-fossiliferous lignitic beds as Forest Hill (p. 1659): "The writers propose to set the upper limit of the Mint Spring at the first limestone ledge, and the lower at the last fossiliferous bed. Between these limits are included 20-25 feet of marine strata, grading from sparingly fossiliferous lignitic sands and clays in the lower portion to sandy fossiliferous marls in the upper." Following Cooke, they, like Morse, placed the laminated nonmarine (?) sediments at the top of the Waltersville-National Cemetery section in the Catahoula formation. The writers present a very thorough check list of the Vicksburg foraminifera.

MINT SPRING FACIES

The Mint Spring marl is called a facies of the Glendon because of its intimate lithologic and stratigraphic relationship to the Glendon. According to this interpretation, the Glendon is the "basal sand" of the Vicksburg formation. A study of the Mint Spring at its type locality and at other exposures (cf. Figures 4, 5, 6, 9) reveals that lithologically the Mint Spring is similar to the other beds of sand-marl which separate the limestone beds of the restricted Glendon, that the contact between the Mint Spring and the restricted Glendon at many places can only be drawn arbitrarily: at one point at the base of a hard marl or semi-indurate limestone; and at another point at the base of a hard limestone. Stratigraphically it is found that neither the top nor the base of the restricted Glendon is marked by a single constant bed of limestone. That the restricted Glendon is developed locally at the expense of the other portions of the Vicksburg is shown by its range in thickness within Warren County from

Figure 6.—Mint Spring marl and Glendon limestones and marls, Bart LaHatte property (NE. 1/4, SE. 1/4, Sec. 27, T. 18 N., R. 4 E.), showing positions of samples of Test E 11. February 18, 1939.

a minimum of about 26 feet to a maximum of about 65 feet; this is also suggested by the range in thickness of the Mint Spring from a minimum of about 5 feet to a maximum of about 25 feet, but this variation is due in part, at least, to the unconformity at the base of the Vicksburg (Mellen, 1939a, pp. 18, 19). Nevertheless, the fact remains that throughout western Mississippi, at least, there is a body of highly fossiliferous sand-marl between the lignitic Forest Hill and the lowermost indurate Vicksburg limestone bed.

The Mint Spring facies is an almost uniform massive bed of highly fossiliferous sand-marl. The sand grains average larger than the sand-grains of the Forest Hill, and, unlike the sharply angular grains of the Forest Hill, the sand of the Mint Spring is well-rounded. Many of the fossils in the lowermost Mint Spring are water-worn and the bi-valve shells are commonly found singly, indicating that deposition was in shallow water. Scattered pieces of lignitic wood and laminated clay pebbles reworked from the underlying Forest Hill show that the Mint Spring is genetically a basal conglomerate.

The abundant fossils of the Mint Spring, invariably soft, are not to be compared in perfection with the fossils from the lower part of the Byram and from the Glendon in certain localities. The Mint Spring is much more permeable than the overlying and underlying sediments, and the circulation of groundwaters within the bed probably have much to do with the friability of the fossils, a condition caused, of course, by the partial removal of lime. That the underlying Forest Hill is sulphurous probably contributes to the solution of lime from the Mint Spring and the rapid oxidation of the stratum. Almost everywhere, the outcrops are found to be fairly well oxidized. Solitary specimens of *Ostrea gigantea* (?) are found in the marl, usually in a better state of preservation than the other fossils. Locally, as at Blakely, abundant specimens of a *Natica* are found in the base of the marl and in numerous borings, probably by the species, into the upper few feet of the Forest Hill.

Some of the water wells in the county appear to derive their water from the Mint Spring, though at places the flow (permeability) appears to be negligible. The well of Mary E. Davis, 5 miles east of Vicksburg, obtained a supply of water in the bed 20 feet below the base of the Glendon, but the well of H. T. Grant, 5 miles south of Vicksburg was abandoned 77 feet below the Glendon without a satisfactory flow of water, according to the following logs:

(Miss) Mary E. Davis
Domestic Water Well
NW. 1/4, NW. 1/4, Sec. 28, T.16 N., R.4
Elevation 325 feet
North of over-pass at Mt. Albin Church

Driller: G. T. Terry & Sons
Drilled: December, 1938
Log furnished: R. A. Young
Correlation by: F. F. Mellen

0-40	Loess and gumbo
68	Yellow sand
120	Gumbo
126	Fine sand
134	Gumbo
196	Fine sand
267	Gumbo
268	Rock 0'4"
268	Gumbo
270	Rock 2'8"
272	Gumbo
277	Rock 5'2"
278	Gumbo
280	Rock 1'6"
280	Gumbo
282	Rock 2'8"
282	Gumbo
283	Rock 1'1"
286	Gumbo
289	Rock 3'0"
291	Gumbo
292	Rock 1'6"
294	Gumbo
295	Rock 0'8"
297	Gumbo
299	Rock 2'8"
300	Gumbo
301	Rock 0'6"
304	Shale
310	Gumbo
321	Sand

CORRELATION

0-40	Pleistocene
40-68	Pliocene (?) Citronelle (?)
68-268	Catahoula (?) and Byram (Vicksburg)
268-301	Glendon (Vicksburg)
301-321	Mint Spring (Vicksburg); Forest Hill (Jackson)

H. T. Grant
(Well dry)
Near center and east line of
Sec. 20, T.15 N., R.3 W.
Elevation: 200 feet

Driller: G. T. Terry & Sons
Drilled: September, 1938
Log furnished: R. A. Young.

Correlation by: F. F. Mellen

0-38	Topsoil. Loess
122	Gumbo
130	Blue sand fine
178	8" Gumbo
180	Rock 1'6"
188	Gumbo
190	Rock
197	Gumbo
201	Rock 3'9"
203	Gumbo
206	Rock 3'
209	Gumbo
210	Rock 1'1"
212	Gumbo
214	Rock 2'4"
219	Gumbo
221	Rock 1'4"
222	Gumbo
225	Rock 2'9"
226	Gumbo
229	Rock 2'6"
231	Sand
233	Rock 2'3"
239	Sand
246	Gumbo
246	Rock 0'3"
254	Sand
290	Gumbo
291	Lignite
294	Gumbo
309	Sand
310	Gumbo

CORRELATION

0-122	Pleistocene and Pliocene (?)
122-178	Catahoula (?); Byram (Vicksburg)
178-233	Glendon (Vicksburg)
233-246	Mint Spring (Vicksburg)
246-310	Forest Hill (Jackson)

GLENDON MEMBER

The Glendon member of the Vicksburg formation consists of alternating beds of semi-crystalline limestone and marl, both materials being somewhat similar in composition—arenaceous, argillaceous, glauconitic, and abundantly fossiliferous—though the limestone contains the smaller percentage of clastic sediments. Volcanic activity occurred during the deposition of the Glendon, as evidenced by the deposits of bentonite just above the middle of the unit in the region of the Warren-Yazoo county line.

The Glendon (Figures 4-10) is exposed along the Bluff from Yazoo County to Jett just south of Vicksburg, and farther south at Glass where it is arched up in the Glass Dome. Along the Big Black

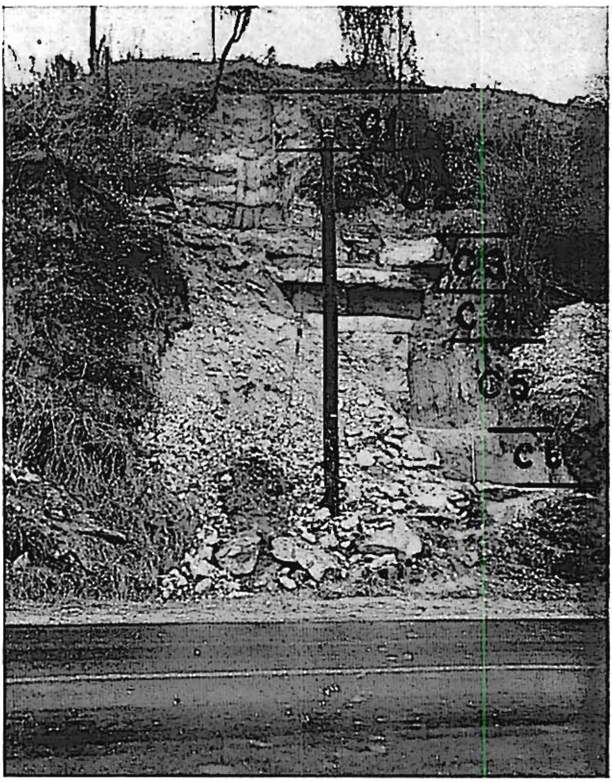


Figure 7.—Glendon limestones and marls, Mississippi-U. S. Highway 61, between Vicksburg and National Cemetery, showing trench E 10 and channels from which samples were taken. February 21, 1939.

River the Glendon is exposed from Yazoo County to the mouth of Bear Creek. Nowhere does it crop out in the hills more than about a mile from the river valleys.

The minimum recorded thickness of the Glendon is 26 feet in a test hole (E6) at Vicksburg, whereas the maximum thickness is 62 feet in the Vicksburg Airport well. The average thickness of twelve available measurements, mostly from water well logs, is 42.3 feet, four averaging 50 feet or more and six 40 feet or less. Inasmuch as the 36-foot variation, from a minimum thickness of 26 feet to a maximum thickness of 62 feet, appears to be excessive, it is to be assumed either (1) that the larger figures are the result of somewhat inaccurate logging on the part of the well drillers or (2) that

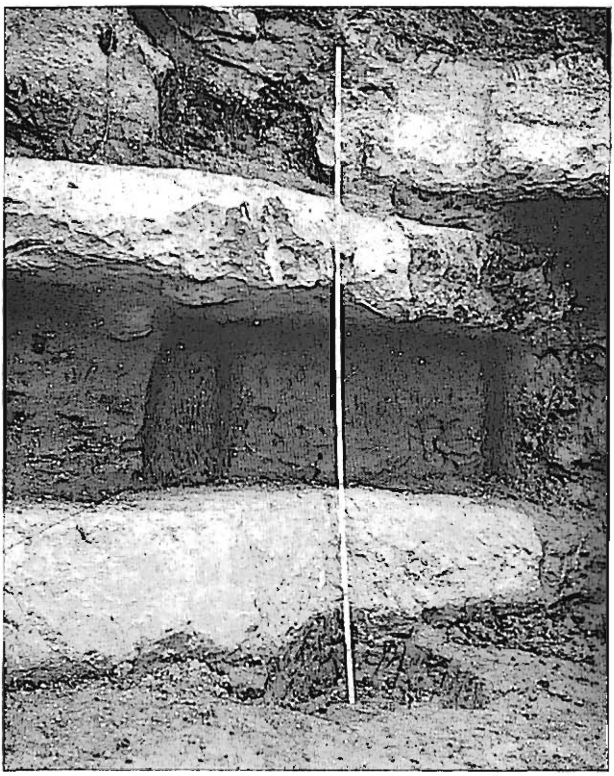


Figure 8.—Glendon limestones and marls in a close-up view of Test E 10, showing relationship of limestones and marls and method of sampling. February 21, 1939.

there is a thickening locally of the Glendon at the expense of (a) its Mint Spring facies and of (b) the overlying Byram member.

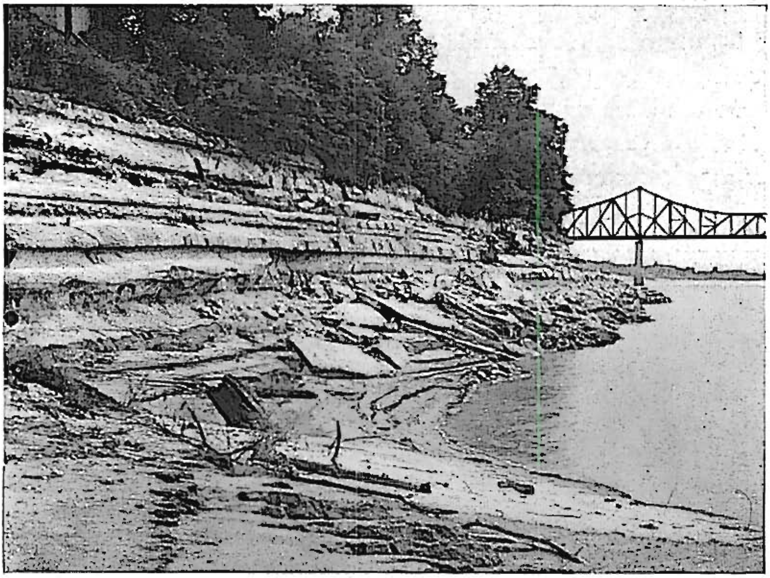


Figure 9.—Mint Spring marl and Glendon limestones and marls on the Mississippi River, just below Anderson, Clayton & Co. terminal (SW. Cor., Sec. 31, T. 16 N., R. 3 E.). July 25, 1939.

Some of the deeper test holes, drilled to establish structural control points on the Glendon, penetrated thin beds of limestone and semi-indurated marl within the Byram; and it is entirely possible that such strata are locally developed so as to be lithologically indistinguishable from the Glendon. Indeed, it is difficult at many localities around Vicksburg to point with certainty to the exact contact of the Glendon and Byram. In the north edge of Vicksburg, the marine Vicksburg is 70.5 feet thick in two test holes (E5, E6). On the outcrop interval 11 of E5 might well be taken for the top of the Glendon, but it is correlated as Byram since, unlike typical Glendon limestone strata, it was penetrated with the hand auger.

The two water well logs, which follow, were drilled slightly less than one-half mile apart, but they illustrate either (1) somewhat inaccurate logging or (2) an abrupt local thickening of the Glendon.

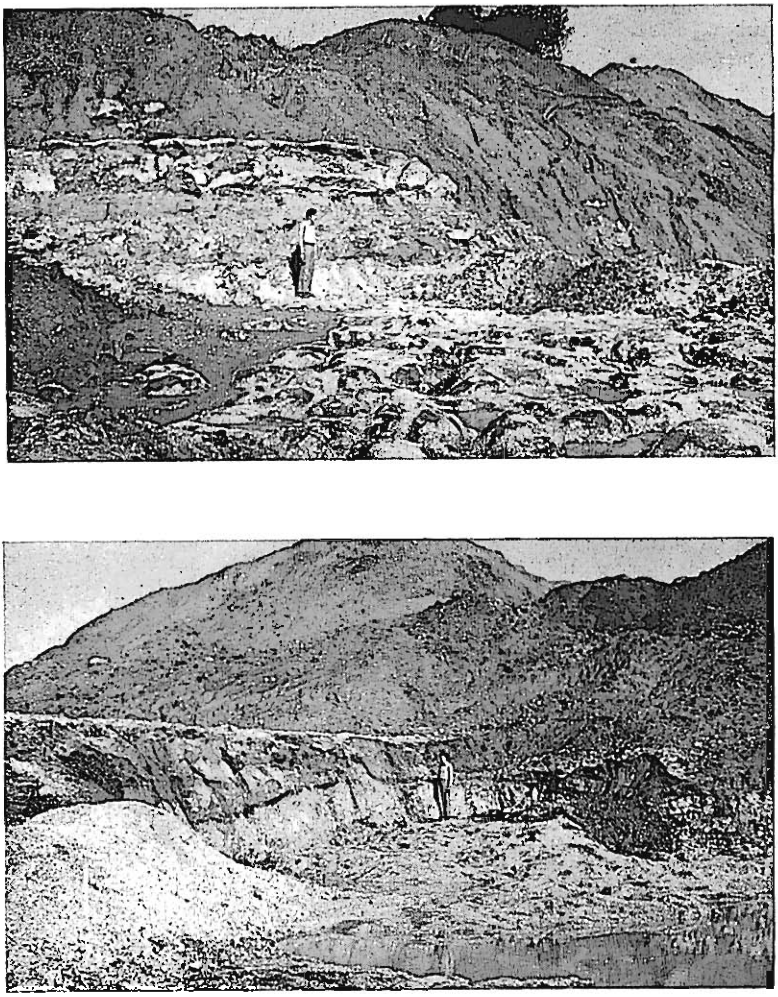


Figure 10.—Views of the Polkville, Smith County, pits of the Attapulgus Clay Company. A shows in the foreground the pinnacles of weathered limestone on which the bentonite rests, and, in the back-ground, the three beds of Glendon limestones overlying the bentonite. B shows a steep dip of the bentonite at a point where the underlying limestone was largely dissolved. Photographed by Louis C. Conant February 6, 1939.

Vicksburg Airport
Local waterwell
W. 1/2, SW. 1/4, Sec. 41,
T.17 N., R.4 E.
Elevation: 263 feet

Driller: G. T. Terry & Sons
Drilled: February, 1939
Log furnished: R. A. Young

Correlation by: F. F. Mellen

0-30	Loess	206	Rock 2'5"
74	Gumbo	207	Gumbo
80	Sand	208	Rock 0'6"
82	Gravel	209	Gumbo
86	Sand	209	Rock 0'3"
88	Gravel	210	Gumbo
92	Sand	211	Rock 1'2"
94	Gravel	212	Gumbo
123	Gumbo	214	Rock 2'2"
125	Gravel	215	Gumbo
127	Shale and sand	217	Rock 2'0"
138	Gumbo	218	Gumbo
164	Sand	218	Rock 0'4"
185	Lime rock 19'	219	Gumbo
186	Sand rock 1'8"	220	Rock 1'0"
192	Gumbo	221	Gumbo
194	Rock 1'6"	225	Rock 3'6"
197	Sand	225	Gumbo
198	Gumbo	226	Rock 1'3"
199	Rock 1'2"	276	Gumbo
200	Gumbo	338	Sand
202	Rock 1'6"	342	Shale
205	Gumbo		

CORRELATION

0-125 (?)	Pleistocene and Pliocene (?)
125(?)-164	Byram (Vicksburg)
164-226	Glendon (Vicksburg)
226-342	Mint Spring (Vicksburg); Forest Hill (Jackson)

Lawrence C. Biedenharn
Domestic waterwell
NE. 1/4, NE. 1/4, Sec. 3,
T.16 N., R.4 E.
Elevation: 306 feet

Driller: G. T. Terry & Sons
Drilled: February, 1939
Log furnished: R. A. Young
Correlation by: F. F. Mellen

0-32	Loess
112	Gumbo
116	Sand
118	Gravel
119	Sand
122	Gravel
167	Gumbo
169	Sand
232	Gumbo
234	Rock 0′3″
235	Gumbo
236	Rock 1′2″
238	Gumbo
240	Rock 2′2″
241	Gumbo
243	Rock 0′9″
245	Gumbo
245	Rock 2′6″
247	Gumbo
248	Rock 2′3″
249	Gumbo
251	Rock 0′9″
252	Gumbo
252	Rock 0′6″
253	Gumbo
254	Rock 1′2″
254	Gumbo
254	Rock 0′6″
255	Gumbo
257	Rock 0′8″
258	Gumbo
260	Rock 1′1″
263	Gumbo
265	Rock 2′9″
266	Gumbo
310	Rock 1′9″
350	Gumbo
353	Sand and shale

CORRELATION

0-122	Pleistocene and Pliocene (?)
122-235	Catahoula (?); Byram (Vicksburg)
235-265	Glendon (Vicksburg)
265-353	Mint Spring (Vicksburg); Forest Hill (Jackson)

BYRAM MEMBER

The Byram member of the Vicksburg formation is divisible into two lithologic and genetic facies: (1) a lower portion, 25 to 40 feet in thickness, of alternating fossiliferous beds of sand-marl, clay-marl, montmorillonitic clay, thin beds of limestone and coquina, and, locally, a thin bed of bentonite and one or more thin beds of water-borne lignite; (2) an upper portion, 60 to 70 feet in thickness, of non-fossiliferous beds of dark carbonaceous sulphurous clay, laminated argillaceous lignitic silts, some lignite and thin beds of siltstone or fine-grained sandstone. The contact of the Byram with the underlying Glendon is easily recognizable at some points, though at others the gradational lithology renders necessary arbitrary selection of this line of contact. Its upper contact with the basal sands and sandy clays of the Catahoula is believed to be disconformable.

Excellent exposures of the fossiliferous Byram are to be found in natural and artificial outcrops around Vicksburg, thence northeastward along the Bluff as far as Eldorado near the Yazoo County line. At the railroad bridge over Hennesseys Bayou (SW. 1/4, SE. 1/4, Sec. 8, T.15 N., R.3 E.) the top of the Glendon lies a few feet below the stream bed. Here is exposed an extremely fossiliferous portion of the lowermost Byram, the material, dominantly a massive argillaceous, highly calcareous, glauconitic, sand-marl, very similar to the Mint Spring marl. One and one-tenth miles northeast of this locality (N. part, near center, Sec. 9, T.15 N., R.3 E.), a few well-preserved fossils were found in the Byram along the road side. A test hole, begun at elevation 110 feet, penetrated Byram marls down to the top of the Glendon at a depth of 40 feet. Test holes E1 and E5, north of Vicksburg, show, respectively, 29.8 and 34.3 feet of the marine Byram, of which scattered fossiliferous exposures are found. The exposure of fossiliferous Byram *par excellence* is in Highway 61, 4.5 miles northeast of Vicksburg, where 35 feet of highly fossiliferous clay-marls and thin coquinas are exposed and where large collections for the State Geological Survey were made. At Fort St. Peter, north side of the Yazoo River bridge, a half-foot bed of lignite is between the Byram marl beds. The records of test holes E17 and E21 show the character of the Byram at Haynes Bluff. The records of test holes E160, E161, and E164, drilled to establish structural control points on the Glass Dome, show the considerable variation within the lower Byram.

The clear light-gray to light bluish-gray ashy and waxy bentonite between 158.3 and 159.3 feet in test hole E161 at Yokena, 8.2 feet above the top of the Glendon limestone, is particularly interesting. In the bentonite area of north Warren County and south Yazoo it has been demonstrated (Mellen, 1940, pp. 26-28; Fig. 7; also, cf. test hole records E40, E44) that the bentonite, ranging in thickness from 0.7 to 2.4 feet, lies 10 feet below the top of the highest limestone bed of the Glendon; also, approximately the same position has been established for it at Polkville, Smith County (Figure 10). The unoxidized Glendon bentonite is strikingly similar in appearance to this thin deposit in the Byram, as might be expected in sediments so closely related. A considerable number of auger holes have been drilled through the entire lower facies of the Byram and no other hole has shown bentonite in the Byram, although a montmorillonitic clay at this position at Haynes Bluff (E21) may be partly of volcanic origin; also, a great many exposures of the Glendon have been carefully examined throughout Yazoo and Warren counties. Thus, the Glendon bentonite, restricted to a small area in north Warren, and the Byram bentonite, restricted to a small area in south Warren, indicate either: (1) two separate and distinct ash falls; or (2) a transgression of the lithology by the time line as indicated by a single ash fall. The latter belief appears untenable in view of the fact that the Glendon at Oak Bend Landing near Yokena is 40.5 feet thick, and that the water well of Cecil Owens a mile north of Yokena cut at least a normal thickness of Glendon, whereas the Glendon bentonite is found only 20 feet above the Mint Spring marl.

Correlations and data, presented by Blanpied and others (1934 pp. 3a, 3b, 7, 8, 9, 28, etc.), purport to show that the bentonite deposits of Wayne and Smith counties lie within beds defined by them as the Bucatunna which is probably correlative in part with the upper portion or facies of the Byram as used in this report. They state that the Bucatunna is separated by an erosional unconformity from the Vicksburg "group": "On the basis of the erosional break at the base of the Bucatunna member and the Miocene character of the fauna of the overlying Chickasawhay members, the Bucatunna member is provisionally assigned to the Miocene (p. 9) . . . The evidence upon which the erosional break at the base of the Bucatunna member is dependent, is summarized as follows:

1. Overlap of the basal clays of the Bucatunna from youngest Byram across the Glendon limestone on to truncated sections of the Marianna limestone.
2. Variations in thickness of the Bucatunna member, within short distances" (p. 8).

But they also admit: "Outcrops showing the detailed character of the contact of the Bucatunna with the underlying rocks of the Vicksburg group have not been found as yet" (p. 9). Bay (1935) did not follow that correlation of the bentonite, writing: "Rather extensive deposits of bentonite are in the Vicksburg series in Smith and Wayne counties, and lesser deposits in Jasper County. Their exact stratigraphic position is uncertain, but they are thought to be younger than the Marianna limestone. In Sec. 9, T.3 N., R.7 E., Smith County, an auger hole showed the bentonite to be overlain by a fossiliferous sandy marl (Byram?). A part of the bentonite deposit on the A. P. James farm, in Sec. 32, T.4 N., R.6 E., Smith County, is overlain by 4 to 6 feet of alternating beds of soft marl and indurated blue-gray limestone, which is probably of Byram age" (p. 46).

Further, the work of P. G. Nutting of the U. S. Geological Survey on comparative qualities of bentonitic bleaching clays points to a use of the bleach ratings as an aid to stratigraphic correlation, the varying qualities of the bentonites possibly being due to differences in the original magmatic compositions. In a personal communication of April 22, 1939, Nutting wrote concerning sample E40-C1 (cf. logs of E40 and E45): "I have your . . . sample of bentonite from the Vicksburg formation in Warren County, Miss. This sample is very similar in appearance and properties to the bentonite of the discovery bed near Lemon, Miss., found by Prof. Trowbridge in 1930. I note that you have found both to belong to the Glendon member of the Vicksburg."

Still further, the fact that the materials overlying the Glendon limestones in central and eastern Mississippi are somewhat different in character, being fossiliferous at one locality and seemingly nonfossiliferous at a nearby locality, is not necessarily conclusive either of unconformity or of overlap. The variations in thickness of the Glendon in Warren County is to be explained, at least in part, by lateral gradation; and the recorded variation in thickness of megafossiliferous Byram in Warren County, from 27.5 to over 40 feet, is complimented by variations in thickness of the Glendon on the one hand and of the upper facies of the Byram on the other. Cushman and McGlamery in their study of the foraminifera of Choctaw Bluff, Alabama, observe: "In the upper marl bed above the limestone are other species which have affiliations with the Miocene rather than with the Eocene. With these, however, are species which so far as we know are confined to the Oligocene. It is probable that these soft marls represent different ecologic conditions from those of the other formations in the Vicksburg group and that the differences in the faunas may be due to this cause" (1938, p. 103).

Cushman, in studying the foraminifera of the Vicksburg, paid close attention to the ecology of the forms, and from a comparison of the environmental range and distribution of many identical and related forms now living in the Indo-Pacific ocean, he was able to conclude that the Mint Spring marl was deposited in water about 50 fathoms in depth (1922, p. 123), and that the Byram was deposited in warm shallow water about 10 to 25 fathoms in depth (1923, p. 12). The importance of paleo-ecology, the environmental factor, in the taxonomy of the Vicksburg strata is brought out by the following quotation from Cushman (1923, p. 12): "Of the 95 species and varieties of Foraminifera found in the Byram marl, 49 occur also in the Mint Spring marl, 29 persisted from the Red Bluff clay (including 2 which have not been found in the Mint Spring marl), and 34 appear to be peculiar to the Byram marl itself. Thirty species are common to the Byram marl itself. Thirty species are common to the Byram marl and the Glendon limestone and 37 to the Byram marl and the typical Marianna limestone. These figures show that the Byram calcareous marl is more closely allied to the Mint Spring marl member of the Marianna limestone than to any of the other divisions of the Vicksburg group."

Concerning the faunal relations of the Vicksburg Oligocene foraminifera, Cushman wrote (1923, p. 11): "A few species are identical with or closely similar to species now living in the Gulf of Mexico. Others are closely related to or identical with those of the Miocene of the southeastern United States. A few of them are related to the Oligocene of Panama. The most interesting relation, however, is that of this Oligocene fauna to the living fauna of the general Indo-Pacific region. Others, although described here as new, have specific relations entirely with living species from the Indo-Pacific."

The upper facies of the Byram is exposed on the Waltersville-National Cemetery road north of Vicksburg where a 25-foot or a 26-foot section of it was measured and recorded by Cooke (1922, p. 81) and by Morse (1935, pp. 11-13), both of whom referred it to the Catahoula formation; and where 33.3 feet were penetrated and sampled by test hole E1. The only full thickness measurement was in test hole E161 where approximately 67 feet of upper Byram lies beneath 73.4 feet of distinctive Catahoula sand, and above the highest, effervescent and clearly fossiliferous, marine lower Byram.

Lithologically, the upper Byram is composed of interlaminated silts, silty clays, fine-grained sands, and some local deposits of almost black massive clay, all of which are more or less lignitic or carbonaceous. Locally, there are thin beds of silty claystone or siltstone, some of which appear to have had their origin as "underclays." One such claystone crops out on the south valley wall of Glass Bayou along the road south from the Vicksburg Cemetery.

In numerous outcrops of the Byram, particularly in the vicinity of Waltersville, large gypsum crystals are found to be abundant. The origin of this gypsum is undoubtedly similar to the origin of gypsum in other Mississippi clays. Abundant gypsum in the Yazoo clay, observed by the writer in Yazoo County (1939, pp. 21, 22), was found to be developed only within the zone of oxidation, below which pyrite was found in association with lime. This relationship was observed by McCutcheon (1940, pp. 88, 89) also, in the samples. Similar conditions were noted in auger holes in Warren County, in the Byram member. The chemical reactions involved may be expressed as follows:

$$2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$$
$$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2$$
$$FeSO_4 + CaCO_3 + H_2O = Fe(OH)_2 + CaSO_4 + CO_2$$
$$4Fe(OH)_2 + 2H_2O + O_2 = 2Fe_2O_3.3H_2O$$

From solution, the calcium sulphate or gypsum is deposited along joints and bedding planes in crystal form, and the ferric hydroxide or limonite is deposited as films of iron rust or as yellow or brown stains in the clay. The above equations suggest a possibility of reaction between the ferrous sulphate and calcium carbonate (if present in excess) to form additional gypsum and limonite. It is also possible that a small amount of the gypsum is derived from connate calcium salts likely to be present in small quantity within the sediments. In any case, the gypsum, or "isinglass", as it is locally miscalled, in the Jackson and Vicksburg formations of Yazoo and Warren counties is entirely secondary in origin, and therefore, is of insufficient quantity to be of commercial interest.

The contact of the upper Byram with the overlying Catahoula is exposed at a small waterfall one mile west of Oak Ridge (SW. 1/4, NW. 1/4, Sec. 4, T.17 N., R.5 E.), and another small waterfall three-fourths mile southeast of Cedars (near NW. cor., Sec. 28, T.15 N., R.3 E.). The basal Catahoula sand and the upper Byram clay are exposed on Highway 80, 2 miles west of Clinton, Hinds County. The abrupt contact at the three localities, and the abrupt change in lithology in test hole E161, marked by a lignite bed, suggest that the Vicksburg-Catahoula contact is disconformable. At least at some localities the lowermost Catahoula sand and sandstone is kaolinitic and gibbsitic which, perhaps, is one of the best indirect evidences of an unconformity. However, the paucity of outcrops renders Warren County one of the most difficult areas in which to determine the precise relationship.

CATAHOULA FORMATION

The beds now included in the Catahoula formation are exposed, in part, at Grand Gulf, a decadent shipping point on the Mississippi River about 8 miles northwest of Port Gibson, 6 miles below the Warren County line, and 2 miles south of the confluence of Big Black and Mississippi Rivers. To them Wailes (1854, pp. 216-219) assigned the name Grand Gulf, seemingly including a variety of sandstones, clays, and siliceous limestones ranging in age from basal Eocene Clayton to upper Oligocene (?) Catahoula. Hilgard (1860, pp. 147-154), who was the first Mississippi geologist to have a modern concept of the geology, included in the "Grand Gulf complex" all the strata above the Vicksburg strata and to the south of them, excepting the "Newer Tertiary (?)" of the Gulf Coast and the "five stages of the Quarternary." Although the name Grand Gulf has priority (cf. Wilmarth, 1938, pp. 367, 368; 852, 853), the inclusion in it of a vast succession of undifferentiated strata led Veatch (1905, pp. 84, 85, 90) to propose the name Catahoula, which now has become firmly entrenched in the nomenclature.

Many investigators have written that the contact of the Vicksburg and the Catahoula is "probably" one of conformity, leaving the impression that the extent of their work was insufficient to provide the answer. Other workers, notably among whom are field geologists of some of the oil companies, report an unconformity separating the sediments of the two formations. Certainly Warren County with its thick cover of surficial sediments and absence of exposures is no place to determine the stratigraphy of the Catahoula. Nevertheless, the samples and log of E161 show an abrupt lithologic break between the lignitic, carbonaceous, silty clays of the upper Byram (Vicksburg) and the relatively coarse argillaceous basal sands of the Catahoula. The most conclusive evidence of unconformable relation observed by the writer in Warren and Hinds counties is the presence of kaolin and gibbsite filling the pore space in the basal Catahoula sands and sandstones.

In passing, it may be well to note that detailed stratigraphic studies in the last decade have shown far more unconformities in the Mississippi geologic section than had been reported in the past. In 1925 Lowe (pp. 47-54) made no mention of unconformities separating the Cretaceous formations in northeastern Mississippi; nor in 1928 did Stephenson and others (pp. 29-33; fig. 3; pl. 2) give any indication that there were hiatuses in the sedimentary column of the Gulf series. However, detailed studies of these sediments by Stephenson and Monroe (1938, pp. 1639-1657) resulted in the discovery of four wide-spread unconformities within the Gulf series. Likewise, intensive and extensive stratigraphic studies of the Eocene sediments (Mellen, 1939b; 1940; Foster, 1940) reveal wide-spread and distinct erosional unconformities cutting the sedimentary column.

The description given by Veatch (1906a, pp. 42, 43; 1906b, pp. 38-40) of the Catahoula is as follows: "Overlying the fossiliferous Vicksburg clays and limestones is a series of sandstones and greenish clays which are generally quite different, lithologically, from any of the older beds of the Tertiary series in Louisiana and Arkansas. The sandstones which are the characteristic feature of this formation range in thickness from a few inches to 50 or 60 feet, and thicknesses as much as 140 feet have been reported. These sand beds are often cemented by silica into very hard quartzites, but such occurrences are essentially local, and the quartzitic beds pass laterally in very short distances into soft sandstones or even unconsolidated sands. These sandstones and quartzitic layers have resisted erosion more than the underlying clays and unconsolidated sands of the Eocene and so have formed a line of rocky hills, the Kisatchie Wold, extending across Louisiana, into Texas on the one hand and into Mississippi on the other.

"These beds contain no indication of marine life, but land plants are abundant and fresh water shells have been found at several places. The change from the conditions existing in the Vicksburg is very marked and indicates an elevation during which the region where the oceanic conditions were favorable for the growth of marine life was considerably south of the present outcrop of the formation.

" . . . the name Catahoula formation is used in this paper as a synonym for the 'typical Grand Gulf' or the 'Grand Gulf proper.' This new name is from Catahoula Parish, La., which is directly across the Mississippi Valley from Grand Gulf and where there are many outcrops which are lithologically and stratigraphically counterparts of the beds of the old type locality."

The Catahoula formation extends as far north as Oak Ridge, west of which (SW. 1/4, NW. 1/4, Sec. 4, T.7 N., R.5 W.) ledges of the basal sandstone are exposed in the bed of a small stream. In this immediate area, which is on the axis of the Embayment Geosyncline, the Catahoula ranges from a feather edge to a few feet in thickness. Southward the Catahoula is thicker because of the dip in that direction, and in the extreme southern part of the county the thickness is probably 300 or 400 feet. The generalized stratigraphic section presented with this report shows less than 100 feet of the Catahoula section because the task of working out the Catahoula succession with a series of deep auger holes appeared too difficult to be justified economically during the survey.

Characteristically the basal member of the Catahoula formation is an argillaceous, kaolinitic sand, locally indurated to sandstone. This sandstone is exposed one mile west of Oak Ridge, (E. 1/2, Sec. 5; W. 1/2, Sec. 5; W. 1/2, Sec. 4, T.17 N., R.5 E.) west of the Grange Hall Road south of Vicksburg (SW. 1/4, Sec. 13, T.15 N., R.3 E.), southeast of Cedars (SW. Cor. Sec. 21; NW. Cor. Sec. 28, T.15 N., R.3 E.), and at several points on the east and southeast sides of the Glass Dome. Test hole E161 penetrated about 70.3 feet of this sand member, the upper 7.9 feet of which were indurated to a friable sandstone.

About 166 feet of Catahoula materials, the lower 10 feet of which are probably correlative with the indurated portion of the Catahoula sand in test hole E161, is shown in the following log:

Joe J. Ring	Driller: G. T. Terry & Sons
Domestic Waterwell	Drilled: November, 1938
SE. 1/4, Sec. 18, T.14 N., R.3 E.	Log furnished: R. A. Young
Elevation: 290 feet	Correlation by: F. F. Mellen
	Rig: Rotary

0-38	Loess	96	Rock 8'1"
64	Gravel	116	Gumbo
69	Gumbo	126	Rock 9'9"
70	Rock 0'10"	131	Gumbo
72	Gumbo	140	Rock 9'8"
77	Rock 5'1"	201	Shale
79	Gumbo	211	Rock 10'0"
84	Rock 5'3"	220	Gumbo
88	Gumbo	230	Sand

CORRELATION

0-38	Pleistocene
38-64	Pliocene (?) Citronelle (?)
64-230	Catahoula

Regarding the total thickness of the Catahoula formation, Matson (1916, p. 220) writes: "In a well at Monticello, Miss., a clay bed 300 feet in thickness overlies the Catahoula sandstone. The base of this clay lies at a depth of 380 feet, and marine shells, from their description undoubtedly Vicksburg, were encountered at about 800 feet. This gives a thickness of 420 feet. Another way of determining the thickness in this portion of Mississippi is by multiplying the rate of dip to the mile (20 feet) by the width of the outcrop in miles. This computation gives a thickness of nearly 400 feet for the formation. Farther west, near Natchez, a well penetrated 550 feet of sands, sandstones, and clays belonging to this formation."

The age of the Catahoula is now a question of considerable controversy. Many petroleum geologists and micropaleontologists are inclined to call it basal Miocene. In view of the fact that the Eocene, the Oligocene, and the Miocene are divisions of equal rank and further in view of the facts that the Eocene* of Mississippi embraces nine formations or depositional cycles, and the Oligocene (if the Catahoula is placed in the Miocene) is represented only by one, the writer is inclined to accept the Oligocene classification of the Catahoula deposits as used by Matson (1916, pp. 209 ff.) and Lowe (1925, p. 79). In support of this classification Berry (1916, p. 229) writes: "Finally the facies of the flora as a whole is that of the abundant floras found in the early Oligocene of southern Europe, notably in Provence, France, in Tyrol, and in Dalmatia and Styria. Not only does it exhibit this parallelism with these European early Oligocene floras, but when the genera are considered separately it appears that almost without exception they have not been found in what are now temperate latitudes in any beds younger than Oligocene."

CITRONELLE FORMATION

Deposits of sand and gravel which overly the Vicksburg and Catahoula formations of Warren County non-conformably and underly the Pleistocenic loess disconformably are referred to the Citronelle formation, following previous reports on the area (cf. Mellen, 1940, p. 10). As thus used, the Citronelle is possibly equivalent to the Willis formation (Doering, 1935) of Texas, Louisiana, and south Mississippi, or to the Williana formation (Fisk, 1938) of Louisiana. The equivalency of the Willis and the Williana may be open to ques-

* This includes the recently designated "Paleocene," the Midway, which is one depositional cycle. In stricter adherence to stratigraphic principles, the Midway, a "genetic unit," should be ranked as a formation.

tion, and the correlation of either with the gravels above 240 feet (elevation) in Warren and contiguous counties is merely suggested.

The thickness of the Citronelle was nowhere adequately determined, because of incomplete exposures and because of the failure of augers to penetrate the gravelly portions. It is believed to range between 25 and 50 feet in Warren County.

The gravel presents a wide assortment of materials. All common types of quartz are abundant: oolitic, fossiliferous, and non-fossiliferous chert; quartzite of several origins and various colors; agate and chalcedony; rose, milky, and black quartz; sandstone; and silicified wood. No materials other than the quartzes were found despite careful searching of gravel bars, outcrops, and road cuts for a greater variety. Inasmuch as no igneous rocks were found, and as none of the stones showed glacial striation or shape, a pre-Pleistocene age is assigned to the beds. Most of the chert and quartz sand grains are well-rounded. The largest boulders, those weighing 25 pounds and up, are only of chert, white sandstone, and silicified wood. The sandstone and silicified wood can be identified with sources less than 200 miles distant, and much of the sandstone is unquestionably derived from the Catahoula formation. Three-fourths mile east of Satartia, Yazoo County (NW. 1/4, SW. 1/4, Sec. 32, T.10 N., R.3 W.), is a sandstone boulder from the Citronelle many hundred pounds in weight, and by far the largest of the large Citronelle stones observed in the region.

LOESS

The loess of Warren County appears on the average somewhat thicker than the loess of Yazoo County. As in Yazoo County, the three zones of loess are represented, a basal unoxidized zone, a median oxidized but unleached zone, and a surficial oxidized but leached zone. The surficial zone was called non-calcareous by the surveys of both Yazoo and Warren counties, but chemical analyses show that the "non-calcareous" loess or "brown loam" contains essentially as much calcium oxide as the typical loess (McCutcheon, 1940, p. 109, cf. analyses of holes C1 and C9 with C23 and C24). Evidently the similarity in composition, which is chemical and not physical, is due to changes produced by weathering, and may in part be such changes as absorption of the calcium carbonate (lime) particles by clay particles or as a base exchange fixing the calcium ion.

Two theories of the origin of loess are to the fore. The first, and that held by the Mississippi Geological Survey and by the U. S.

Geological Survey, is that the loess is a rock flour formed by glacial action, transported and deposited by glacial waters, and reworked and redeposited by winds. The second theory, which has of late been advanced largely and supported by the Louisiana Geological Survey, maintains that loess is alluvial silt, formed through the uplift and subsequent eluviation of floodplain sediments. This process of transformation of alluvial sediments to "mature loess," dependent on relatively rapid emergence and superior drainage, has been clearly explained by Russell (1938, pp. 74-77). Russell has traveled extensively in loessal regions of continental Europe and North America and is convinced that the deposits are without exception of a similar origin. At present he is preparing an exhaustive treatise on loess.

Naturally, any scientific investigator or agency worthy of the name is receptive to arguments presented in the form of pertinent evidence, logically deduced. The writer believes the Louisiana Survey's explanation to be the simpler, and in some respects, the more reasonable theory. However, it is untenable at this time in view of its deficiency in explaining certain important facts which are clear and well-established for the loess of Yazoo and Warren counties, Mississippi. These facts, which now appear to be explained best by eolian origin, are:

1. There are randomly distributed throughout the entire thickness, 60 feet or more, of the loess myriads of shells of pulmonate (air-breathing) gastropods (snails). This has been established by numerous deep auger holes in Yazoo and Warren counties; and further, no fresh water snail or mussel shells have been found. Russell (1938, p. 77) describes a locality just north of Natchez exhibiting snail shells in floodplain materials, but he does not say whether they are land snails or fresh water snails. Some two dozen auger holes have been drilled to depths as much as 30 feet in the Mississippi-Yazoo alluvial plain in Yazoo and Warren counties, but no shells of any kind have been found.
2. There is an abrupt eastern limit to the thick gravel of the Citronelle, whereas the loess and its eastern equivalent, the "brown loam", overlap the underlying gravels and overly the bedrock formations of Eocene age.
3. The contact of the loess and the underlying Citronelle is sharp and probably unconformable; there has been observed no loess within the gravel and no gravel within the loess.

4. The loess is most remarkably uniform in texture, definitely homogeneous; but the alluvium is variable in texture within short distances and is very heterogeneous throughout the section. Auger holes, drilled 50 and 60 feet in the thickest loess, encounter no lenses of clay, sand, or gravel; but in the alluvium, beds of sand are commonly found within 25 or 30 feet of the surface, allowing such a flow of water as to force abandonment of the holes.

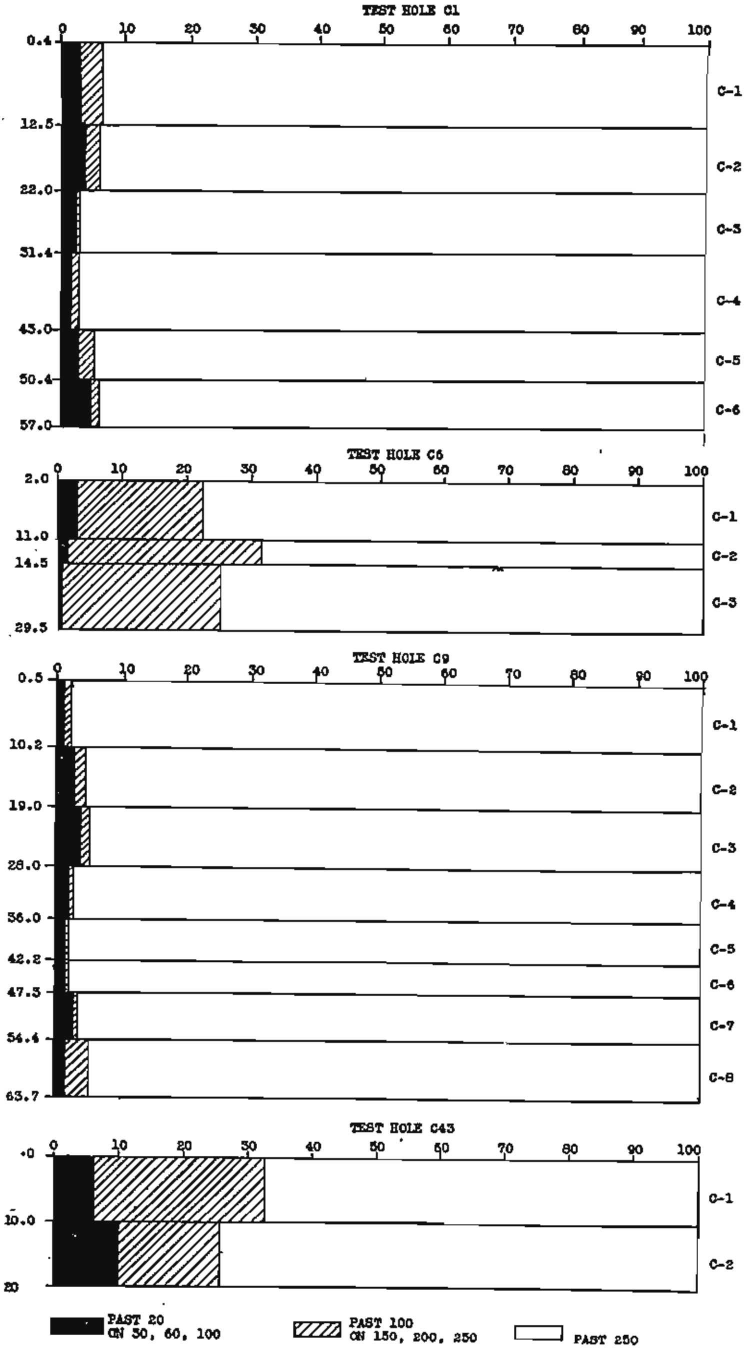
The following graphs, constructed from screen analysis data on Yazoo County samples, show the striking difference in the size and uniformity of grains of the loess and the river alluvium. It might be added that most of the larger grains in the loess samples are pieces of crushed shell and *loess kindchen* and a great number of grain aggregates, the last of which are described by the mineralogist as "calcareous arenaceous tubes and nodules." This condition renders the uniformity of grain size of the loess more striking even than presented by graph. In the preparation of the graphs, three size classes, Tyler standard screens, were applied: (1) through 20 mesh, but caught on 30, 60, and 100, (2) through 100, but caught on 150, 200, and 250, and (3) through 250 and caught in pan. The percentages are shown by symbols, respectively from left to right on the graphs, and the sample numbers and thicknesses are represented vertically (cf. McCutcheon, 1940, pp. 103, 104, 118, 119; and Mellen, 1940, pp. 48, 53, 55, 65).

HOLOCENE OR RECENT DEPOSITS

The recent deposits of Warren County lie in the Mississippi-Yazoo alluvial plain, along the Big Black river, and along the smaller streams in the county. In the "Delta" the deposits of gravel, sand, silt, and clay are reportedly as much as 150 to 200 feet in thickness.

The sands and silts in the upper part of the alluvial profile, interbedded with clays, afford water for driven wells, and the sands and gravels in the lower part of the profile afford larger and more dependable supplies of water. These alluvial sediments lie across the bevelled Oligocene and Eocene formations in Warren County, and it is conceivable that important catchment of water from the base of the profile by the Forest Hill sands is effected in the region north, west, and immediately south of Vicksburg.

The deposits, as might be expected, are heterogeneous in character. Locally, however, there are deposits of "blue mud" of exceptional freedom from silt and sand, reported by the U. S. Engineer



Histograms 1-4—Histograms representing screen analyses of loess and alluvium—Yazoo County.

Histogram 1 is of loess from Test hole C1, Jim Gibbs property, T. 12 N., R. 2 W., Sec. 33, E. 1/2, SW. 1/4, NE. 1/4

Histogram 2 is of alluvium from Test hole C6, Mrs. Ida Thomas Page property, T. 11 N., R. 2 W., Sec. 6, S. 1/2, SW. 1/4

Histogram 3 is of loess from Test hole C9, J. A. Bunner property, T. 13 N., R. 1 W., Sec. 19, NE. 1/4, SW. 1/4

Histogram 4 is of alluvium from Test hole C43, F. W. Sharbrough, Jr. property, T. 11 N., R. 5 W., Sec. 9, NE. 1/4

office, Vicksburg, to attain thicknesses as much as 90 feet. The "blue mud" has been deposited in still waters in many of the old ox-bow lakes, subsequently filled to various degrees with the "blue mud," silts, and silty clays. The "blue mud" has a rubbery plasticity and a higher content of absorbed water than any other known Mississippi clay. When dry, it is very tough. Under pressure it flows plastically, and will not satisfactorily bear pressures exerted by levees or other super-elevated structures, and it is, consequently, much feared by the U. S. Engineers.

Alluvial deposits of the Big Black River and of the smaller streams are composed in large part of reworked materials from the loess and Citronelle, and in lesser part of reworked bedrock sediments.

ECONOMIC GEOLOGY

GENERAL

Mississippi has no known metallic mineral resources other than ores of iron and aluminum; and the principal development in the past has been of such non-metallic resources, as sand, gravel, clays, natural gas, and oil. The ores of iron and aluminum are principally deposited in the northeastern quarter of the state. The sand and gravel deposits have been developed extensively over the state for a number of years and used for road metal and concrete aggregate. The surface clays have been used extensively in the manufacture of red brick. Since the World War days there has been increasing attention paid to the high-grade clays, and at the present time several important types of clays are either being produced or investigated for production. Deposits of high-grade kaolin (china clay) are known only in a few counties in northeastern Mississippi. High-grade anauxitic clays, suitable for pottery, light-colored brick and tile, and other similar products, are found in a number of counties in the central and northern part of the state. Bentonite and other montmorillonitic clays are fairly well distributed in marine formations over the state. In south Mississippi the clays appear to be largely montmorillonitic.

The statistical summary, below, is a recapitulation of the prospecting work in Warren County. Inasmuch as detailed descriptions of the materials are given in the test hole records and in the section on Stratigraphic geology, it is thought unnecessary to attempt fuller descriptions here under the several headings of Economic geology.

STATISTICAL SUMMARY OF PROSPECTING IN WARREN COUNTY

Test hole No.	Total depth	Number of samples	Thickness of materials	Character of materials	Position
E1	66.3	4	33.3	Silt, argillaceous	Byram (Up.)
		4	28.9	Clay-marl and sand-marl	Byram (L.)
E5	34.3	6	33.9	Clay-marl and sand-marl	Byram (L.)
E6	36.2	7	26.2	Limestone and marl	Glendon
		1	10.0	Sand-marl	Mint Spring
E7	39.3	4	37.5	Clay-marl and sand-marl	Byram (L.)
E9	28.1	5	18.1	Limestone and marl	Glendon
E10	27.7	6	21.7	Limestone and marl	Glendon
E11	24.8	4	19.1	Limestone and marl	Glendon
		1	5.7	Sand-marl	Mint Spring
E17	50.5	4	28.4	Clay-marl and sand-marl	Byram (L.)
E21	28.6	1	8.6	Clay, montmorillonitic	Byram (L.)
E40	20.6	1	2.4	Bentonite, oxidized	Glendon
E44	21.0	1	2.1	Bentonite, unoxidized	Glendon
E52	28.6	1	15.4	"Blue swamp mud"	Alluvium
E144	28.6	3	14.9	Loess, non-calcareous	Loess
E155	10.6	1	7.9	Loess, non-calcareous	Loess
14	445.2	54	314.1	Totals	

Note: This table is made from logs of test holes from which samples were taken for testing; it does not include logs of holes drilled for stratigraphic or structural geologic information.

CLAYS AND SILTS

Bentonite beds are found at two horizons in the Vicksburg formation of Warren County. The position of these beds is discussed in the paragraphs on Vicksburg stratigraphy; and the position, description, and thicknesses are given in test hole records E40, E44, and E161. The only bed of possible economic importance is that lying within the Glendon member in a small area at the Yazoo-Warren county line (Pl. 2).

The Glendon bentonite, sampled in the incipiently oxidized condition (E40) and in the unoxidized condition (E44), possibly does not exceed 2.5 feet in thickness. In the Yazoo part of the area the maximum thickness recorded (Mellen, 1940, pp. 27, 67) is 1.8 feet; and in Warren County thicknesses of 2.1 and 2.4 feet are recorded on the Laura Archer property.

As long as the high-grade bentonites as much as 8 to 10 feet in thickness are available in the Cretaceous belt of northeastern Mississippi, and as long as the extensive weathered deposits of the Glendon in the Smith County region are recoverable by surface methods of mining, the Glendon bentonite of Warren County will probably remain undeveloped. Mining would, of necessity, be by underground methods similar to those employed in coal mines, and further prospecting of the deposits would have to be done by core-drilling. The log of E44 shows a working interval of only 3.3 feet between floor and roof; and this could be increased only by blasting to remove either the limestone below or that above. Exposures of unoxidized bentonite are exceedingly rare in Mississippi; and very few samples have been taken. Nearly all tests that have been made by the State, by the Federal Government, and by commercial interests have been of samples ranging from incipient oxidation to complete oxidation; and, as yet, little is known of the properties of the unoxidized bentonites of Mississippi, which, in total quantity, greatly exceed the weathered facies which have been, and are being, mined in large tonnage. The writer believes that ultimate exhaustion of the surface deposits of bentonite will lead to underground mining; and the varied effects of oxidation and weathering on bentonites suggest that the unoxidized facies, recoverable almost only by underground mining, will yield far more uniform materials than are now obtained.

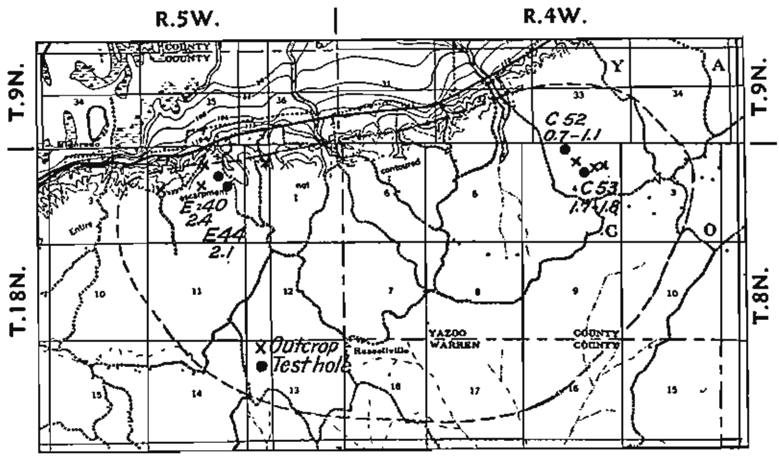


Plate 2.—Probable bentonite area in Warren County and adjoining Yazoo County

Beds of tough semiplastic dark-colored montmorillonitic clay, more or less marly, lie above the Glendon, interbedded with the marl and coquina beds of the Byram. It is these beds of clay which cause the numerous and frequent land slips along Highway 61 northeast of Vicksburg and Waltersville. The beds vary in thickness from 1 foot to 9 feet. Test hole E21 penetrated 8.6 feet of the clay, a clay more or less typical of the clays of the lower Byram. If this type of clay can be used commercially, the Bluff from Waltersville to Eldorado offers the greatest promise for prospecting. Even there, the steep hill slopes would limit the amounts of clay recoverable from any single pit, and underground mining is out of the question.

Argillaceous silt or silty clay, present in the upper Byram, is found under workable conditions at intervals from Hennesseys Bayou to Eldorado. The material is thick, relatively uniform, but its commercial possibilities are obviously limited. It is somewhat similar in composition to the Yegua silts and silty clays sampled in Yazoo County, test holes C35 and C55. Four samples, representing 33.3 feet of the material, were taken in test hole E1.

Loessal silts overlie a large part of Warren County, as of Yazoo County. Inasmuch as detailed sampling and testing of typical loess was carried out in Yazoo County, samples were not collected in Warren County.

However, the weathered or "brown loam" phase of the loess, more plastic and seemingly less calcareous than the typical loess, and non-fossiliferous, was sampled in test holes E144 and E155. This phase of the loess was formerly used throughout the region in the manufacture of soft mud brick. At Yazoo City the material has been used in the manufacture of brick by soft mud, stiff mud, and dry press processes; and it might also be used in the manufacture of common red flower pots. The chief advantage of loessal materials for commercial ceramic usage appears to be the remarkable uniformity of color and texture obtained in finished products. The chief disadvantage of the material appears to be its lack of plastic properties. Test hole E144 sampled the weathered phase of the loess on a flat terrace where conditions for mining are favorable, and where both highway and railway transportation are available. Numerous terraces of this sort along Big Black River and its tributaries afford great tonnages and excellent working sites. A relatively thin blanket of weathered non-fossiliferous loess covers the typical loess on the hills around Vicksburg. In such locations, the thickness is variable from about 3 to about 10 feet. Test hole E155, 2 miles southeast of Vicksburg, sampled the weathered loess, 7.9 feet thick, that overlies approximately 52 feet of typical shell-bearing loess.

An unusual type of clay is found in the alluvium of the "Delta" region. The "blue mud" which has been deposited through the centuries in the ox-bow lakes of that region is reported to have a natural water content as high as 60 per cent in some samples. Because of this unusually high water content, and because of the great plasticity and fineness of grain of the "blue mud," it is entirely possible that commercial applications may be discovered for the clays. Because of this possibility, a number of holes were drilled in the Alluvial Plain Region of Warren County, all in the crescent-shaped depressions and marshy areas which indicate the former locations of ox-bow lakes. Although the U. S. Engineers Office reports a maximum thickness of 90 feet of uniformly textured blue mud in the Mississippi River Valley, only one locality was found during this survey where a sample of typical "blue mud" could be secured. In test hole E52 a sample representing 15.4 feet of somewhat silty clay was taken. Due to the geographic position of the "blue mud" deposits, and the high water-table associated therewith, special mining equipment would be needed for the winning of these clays.

The more typical materials of the "Delta" region, the silty clays and argillaceous silts, were not sampled in Warren County because they are similar to the alluvium in Yazoo County where samples were taken in test holes C6, C7, C40, and C43. Concerning the Yazoo County samples McCutcheon (1940, p. 124) writes: "Due to the lack of natural plasticity the alluvium is limited in its uses. It is suited for the production of an excellent quality red face brick when using the semi-drypress process and for the production of machine-made flower pots. It would be difficult to find a better material for flower pot manufacture."

The thin silty underclays of the upper parts of the Jackson, Vicksburg, and Catahoula formations are all so thin and so poorly leached, and are so generally inaccessible, that they are worthless to the clay industries.

BAUXITIC SAND

No true bauxite is present in Warren County or in the immediate region; nor is any known in the Gulf Coastal Province younger than that of the Betheden formation at the top of the Midway (Eocene) series. However, the basal Catahoula sand and sandstone presents, in weathered phase, a very distinctly white kaolinitic appearance; and, from dehydration data on a sample from Highway 80 two miles west of Clinton, Hinds County, McCutcheon (personal communication, 1941) reports that the clay-like substance is a mixture of kaolinite ($Al_2O_3.2SiO_2.2H_2O$) and gibbsite ($Al_2O_3.3H_2O$).

Screen analysis of bauxitic Catahoula sand, Hinds County

Through screen	Caught on screen	Percent
20	30	0.07
30	60	36.48
60	100	34.65
100	150	9.55
150	200	2.26
200	250	0.14
250	cloth	16.85

The material passing 250-mesh screen is about 50 percent kaolinite-gibbsite and about 50 percent non-hydrous mineral matter. A considerable percentage of the total kaolinite-gibbsite content of the sample remained on the coarser screens with the sand, partly as closely adhering coatings to the sand grains, and partly as hard white free grains. McCutcheon estimates not over 15 percent kaolinite-gibbsite in the sample.

The bauxitic sand does not appear to have economic value, but suggests the advisability of a limited field survey in collaboration with laboratory investigations on the extent of the Catahoula basal sand and its kaolinite-gibbsite content; this in view of the highly refractory nature of both kaolinite and gibbsite, but particularly in view of present National Defense efforts to obtain a vital supply of commercial grade aluminum ore. If the writer's information is correct, commercial kaolin is separated from sedimentary kaolinitic sand of an Oligocene formation in Florida, but only a comprehensive survey of the Catahoula kaolinite-gibbsite horizon is necessary to determine whether the production of kaolin or of bauxite is similarly possible in Mississippi.

A few outcrop localities of this sedimentary bauxitic sand in Warren County are given in the stratigraphic part of this report. Although at these localities the composition is similar to the Hinds County sample, the material is far less accessible, and the overburden is prohibitive.

LIMESTONES AND MARLS

The most valuable mineral resources of Warren County (other than possible oil and gas deposits) are the marls and impure limestones. The stratigraphic part of this report and several test hole records describe these deposits of the Vicksburg formation.

According to the 1940 Minerals Yearbook, the manufacture of cement in 1939 ranked 7th in importance among the domestic mineral industries, the manufacture of lime ranked 21st, the production of greensand marl 73rd, and the production of calcareous marl 82nd. Data on the mineral wool industry was not given.

An investigation of the Glendon member of the Vicksburg formation for the manufacture of cement was conducted in Warren County by the Marquette Cement Company. In a letter of December 16, 1938 W. A. Wecker, President, wrote: "Accordingly, we secured options on large tracts of what appeared to be rock deposits immediately north of Vicksburg in Warren County. Subsequently we drilled these rock deposits and discovered a peculiar formation in the form of alternating thin layers of rock and soft clay. The average of the whole on analysis indicated the presence of too much argillaceous material and it became apparent, therefore, that part of this material would have to be removed or separated from the whole in order to produce a satisfactory raw mixture for making portland cement. We then opened a small face of the entire deposit [Bart LaHatte property; cf. Fig. 6 and test hole record E11] and removed several hundred tons of material which we shipped to our plant at Cape Girardeau, Missouri. There we put the entire material through an existing washing mill in order to separate a portion of the clay from the limestone. After this test was conducted and our calculations were made, we discovered that we would have to quarry at least three tons of stone for every ton of usable raw material with the further complication that very elaborate and expensive equipment would be required. In addition the problem of disposing of the waste material appeared insurmountable."

As a further barrier to the manufacture of cement in Warren County, the steep hills which rise above the outcrops of limestone prevent the removal of any great quantity of cement rock without the removal of excessive overburden. The relatively thin Glendon limestone member, and the large percentage of clastic impurities (waste) contained in the member render underground mining infeasible.

In 1939 there were produced 4,254,348 short tons of manufactured quicklime and hydrated lime. Of this amount, only 362,335 short tons (about 11.7 percent) were used for the liming of agricultural lands. However, there has been a steady increase in the use of crushed limestone, chalk, marl, and shell for the liming of soils; and lime in the natural state (calcium carbonate), though not as effective as manufactured lime (calcium oxide or hydroxide), is more easily obtainable and is generally much cheaper. The tonnage of lime carbonate used for fertilizer is not given in the Minerals Yearbook, but it probably greatly exceeds the amount of agricultural lime of all other forms.

The Glendon limestone of Warren County is not pure enough for the manufacture of quicklime or of hydrated lime, but it can be blasted, crushed, and distributed, along with the interstratified high-calcium clay-marls and sand-marls, on agricultural lands deficient in lime content. Thus, the use of the Glendon beds for agricultural lime, may prove one of the most valuable surface mineral products of Warren County.

In explaining the general usage of agricultural lime, Schreiner and others (1938, p. 517) write: "Lime is not, strictly speaking, a fertilizer material but a soil amendment applied to correct soil acidity, improve the physical condition of the soil, and promote bacterial activity. However, one of its functions is to supply calcium if this is deficient in the soil. The chief sources are: (1) Burnt lime (CaO), known as caustic lime, stone lime, etc.—the product resulting from the burning of limestone; (2) hydrated lime or slaked lime, produced by adding the proper amount of water to burnt lime; (3) ground limestone, the most common form of lime used in farming practice, its agronomic value depending on the content of carbonate of lime and how finely it has been ground; and (4) marl, a natural deposit consisting chiefly of calcium carbonate mixed with clay, sand, or organic material."

The production of ground limestone and marl is, and will continue to be, a decentralized industry. This is because of the relatively low cost of quarrying and grinding, the wide distribution of suitable deposits over the nation, and the low price that can be afforded for these commodities. Since these conditions exist, portable crushing units which can be moved easily from quarry to quarry will permit the working of the more favorable outcrops of the Glendon, and abandonment of those outcrops whenever excessive overburdens or other unfavorable quarry factors are reached.

The distribution of the Glendon is described in the stratigraphic part of this report. In brief review, favorable localities for working agricultural limestone and marl are: at Glass, J. W. Culley property; at Vicksburg, along the waterfront northward from the River Bridge and in Glass and Mint Spring bayous; on the Bluff, extending from Waltersville to Redwood to Haynes Bluff and to the Yazoo County line; and in the vicinity of Youngton (Sec. 16, T.7 N., R.4 W.) in northeastern Warren County.

There are no concentrations of glauconite in the Mint Spring or in the Byram that suggest a possibility of the mining of greensand marl. Glauconite is present in relatively small percentages throughout the marine facies of the Vicksburg formation.

Rock wool is a mineral insulation product made by melting and blowing siliceous limestones of certain rather wide ranges of composition. The rock wool industry is a decentralized one, because (1) the light weight of the substance makes for high transportation costs, (2) relatively little capital is required for the establishment of a plant and its production and sales organization, and (3) the raw materials for rock wool manufacture are universally distributed, and in limitless quantity. The industry has shown a phenomenal growth in the last few years, the concentration of plants and production being in the north-central states. In 1937 the total value of rock wool (including slag wool) produced for building insulation was $8,279,374. At present there are no rock wool plants in the southeastern states, although Tennessee and Alabama each have a plant producing slag wool.

The technologic aspects of the usefulness of Glendon limestones and marls for the manufacture of rock wool are discussed in the second part of this report. Figures 4, 5, 6, 7, 8, and 9 show how the marls and limestone are interstratified. The limestones are probably all too high in calcium carbonate for use alone as woolrock; at least some of the marl is too deficient in calcium carbonate; however, mixtures of limestone and marl for suitable compositions can be determined by studying the chemical analyses. In this connection, it is well to remember that immediately overlying the Glendon at almost every outcrop are considerable thicknesses of loess, the composition of which appears suitable for mixing, in predetermined quantities, with the Glendon for an artificial mixture. The physical form of the woolrock which can be supplied to the furnace is a technologic consideration which will determine the type of furnace to be used. The second part of this report will present the necessary data to show whether the woolrock charge can be supplied in lump, pulverized, or in briquetted form.

COPPERAS

Copperas, green vitriol, or ferrous sulphate ($FeSO_4.7H_2O$), is found commonly in Mississippi clays, particularly those of the montmorillonite or beidellite type. In some communities of south Mississippi this substance is produced commercially for medicinal purposes by leaching the mineral salts from clay, which has been dried and placed in a hopper and then sprinkled with water. The brownish mineral concentrate is placed in barrels or bottles and marketed as "acidine," "nature's aid," or under some other name. There are local claims of curative effects in ailments ranging from rheumatism to consumption, but its medical efficacy is due to: (1) its strong astringent and coagulent actions, (2) its disinfectant properties, and (3) its effect as an inhibitor of, or as a corrective agent in, cases of anemia. Copperas is a relatively unstable compound, and, as extracted by the process in use in Mississippi today, is undoubtedly considerably oxidized.

The upper facies of the Yazoo clay—Red Bluff clay equivalent?—in the hills south of Satartia, Yazoo County, carries, in some exposures, a high content of copperas, as can be told by the strongly astringent and acid taste.

Likewise, the upper facies of the Byram, under local conditions, is highly impregnated with copperas. Notably, is the exposure just west of the Vicksburg Cemetery (NE. cor., Sec. 13, T.16 N., R.3 E.) of black carbonaceous slightly silty clay. After drying, the clay can be crushed, steeped for a short time in water, and then the copperas-bearing water can be separated by filtering or siphoning.

The extent of the copperas-rich clay deposits has not been determined, but it is thought that the heavy overburden, and the probable limit of the concentration to a zone near the surface of the ground, will discourage consideration of any large-scale production of copperas. The writer has no information as to the quantity of copperas and copperas waters consumed by the market.

STRUCTURAL AND PETROLEUM GEOLOGY

GENERAL

In Mississippi structural geology is important principally because of its use in helping to locate oil or gas. The structure of the earth's crust can be determined only after a working knowledge of the succession of formations (stratigraphic geology) has been developed.

The methods of structural mapping now commonly employed in Mississippi are:

A. Direct-Geological
   1. Surface geology
   2. Core-drilling

B. Indirect-Geophysical
   1. Seismograph
   2. Gravity meter
   3. Magnetometer

None of these methods are without limitations; some are better in one area, and others are better in other areas; and under many local conditions a combination of methods is required to determine best the geologic structure.

The structure of a region is shown by contour lines, lines connecting points of equal elevations on a key horizon. The structure of a large part of Warren County is indicated on the map at the end of this report. The key horizon is the top of the Glendon limestone member of the Vicksburg formation; and the contour interval is 20 feet. Surface outcrops, auger test holes, oil test well logs, and water well logs were used in obtaining the structural data; and the resulting contour map is believed to be somewhat more accurate than the reconnaissance structural map of O. B. Hopkins in 1916.

In general, the structure of Warren County is geosynclinal, the axis passing north-south about the longitude of Bovina, eastern Warren. From this axis the beds are higher in normal homoclinal attitude toward the northeast in Mississippi, and to the northwest in Louisiana. The homoclinal flanks of the geosyncline, and even its axis, are geologically disturbed in local areas by salt dome structures, by igneous structures, and by numerous obscure faults, which are, in some places, due to the salt and volcanic intrusions.

THE GLASS DOME AND THE BLAKELY STRUCTURE

Preliminary press memoranda were released on July 31, 1939, and August 12, 1939, on structures in Warren County favorable for oil and gas accummulation. Both structures were first discovered by Toler, but data supplementing Toler's original information were secured by the present minerals survey of Warren County.

MISSISSIPPI STATE GEOLOGICAL SURVEY

University, Mississippi

IMMEDIATE RELEASE

MEMORANDUM FOR THE PRESS

JULY 31, 1939

The Glass Dome

The discovery at Glass, seven and a half miles southwest of Vicksburg, of the Glendon limestone at an elevation of 160 feet above sea level, or 250 feet above its normal position, revealed the presence of a structural high of the type favorable to oil and gas accumulation. Although this discovery in 1930 by Henry Toler led to the drilling by the United Gas Public Service Co. of the Tchula Store No. 1 well a mile northwest (Sec. 33, T.15 N., R.3 E.), the well was not an adequate test, for it was stopped at 4007 feet in the mid-Wilcox or above both the Midway formation and the Selma chalk.

More recent diversion work by the Mississippi River Commission and tests now being made by the WPA-Mississippi State Geological Survey minerals survey of Warren County, cosponsored by the Vicksburg Chamber of Commerce, confirm Toler's work, outline this structure more in detail, and reveal a dome of such magnitude as to warrant thorough sub-surface seismographic survey, and possibly to warrant the drilling of a well to much greater depths in order to make a test of lower beds productive elsewhere.

The top of the Glendon limestone at the Y. & M. V.-Hennesseys Bayou bridge lies at 80 feet above sea level; in the Kimberly-Wing water well at Cedars, at 36 feet above. The test holes of the present survey show the limestone a mile and a half south of Warrenton to lie at 48 feet above sea level; a half mile east of Glass, at 100 feet above; and at Yokena at an undetermined depth below sea level. (See Test Hole Record E161).

Mississippi River Commission test holes for the Diamond Point Cut-off 1933 show the limestone a half mile above Oak Bend Landing to be 5 feet above sea level; at the middle of the cut-off to lie 2 feet above; and at the lower end, 23 feet below sea level.

Accordingly, the Glass structure, through an arc of 226°, has a known northward closure of 124 feet, an eastward (down-dip) closure of at least 60 feet; a southward closure of more than 200 feet; and a southwest closure of 183 feet. The alluvium of the Mississippi River through the remaining 134°-arc prevents the determination of the elevation of the beds toward the northwest.

Because of the great expense involved in oil and gas exploration and especially in deep drilling tests, this press notice is being released by William C. Morse, State Geologist, who spent a few days in the field, and by Frederic F. Mellen, Field Geologist, only on the condition that this article be accepted in its entirety.

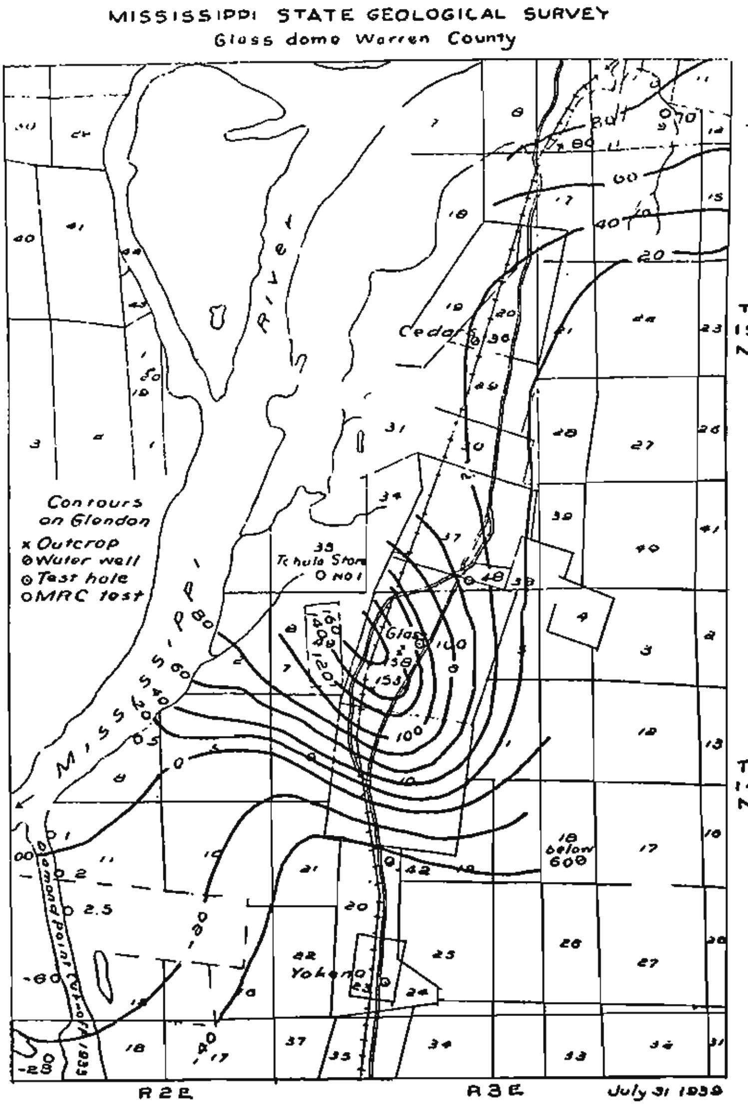


Plate 4.—Glass dome

MISSISSIPPI STATE GEOLOGICAL SURVEY

University, Mississippi

IMMEDIATE RELEASE

MEMORANDUM FOR THE PRESS

AUGUST 12, 1939

Structures in Warren County north of Vicksburg

At Blakely, 7 miles northeast of Vicksburg, the Forest Hill member of the Jackson formation is exposed (NE. part, Sec. 15, T.17 N., R.4 E.) higher than at any other place on the escarpment south of Eldorado. The top of the Glendon member of the Vicksburg formation is correspondingly high, and the contours of the Vicksburg Quadrangle show a topographic recession in the escarpment occasioned by under-cutting of the Glendon beds during formation of the alluvial valley. At Redwood two miles north-northeast of Blakely and at Ft. St. Peter 1.5 miles still farther northeast, the beds are 25 feet and 45 feet, respectively, lower than at Blakely. At C. M. Gooch's mill, 3 miles southwest of Blakely, the beds are 30 feet lower than at Blakely. The dip of the beds in the area is southeast; and the closure in that direction is confirmed by the low position of the Glendon in numerous wells drilled in central Warren County. However, surface geology cannot reveal the structure of the beds underlying the alluvial deposits north and west of Blakely; accordingly, seismographic prospecting methods will have to be used.

In addition to the Blakely structure, there are several noticeable undulations of the strata between Vicksburg and the Warren-Yazoo County line. One of these flexures is revealed by the Forest Hill-Mint Spring contact beneath the waterfalls both at the Bart LaHatte and at the L. C. Biedenharn (Haynes Bluff, 5 miles northeast of Blakely) properties. The contact at Ft. St. Peter to the southwest and Ball Ground to the northeast is calculated to be 35 feet and 45 feet lower, respectively, than at the LaHatte and Biedenharn places. A part of this flexure is, no doubt, due to a northward-trending fault above the waterfall on the Bart LaHatte property (NW. 1/4, SW. 1/4, Sec. 26, T.18 N., R.4 E.), having a displacement of 40 to 50 feet. The fault plane is obscured, but from an exposure of the Glendon limestone one walks eastward to an exposure of the downthrown upper Byram at practically the same level. Another small flexure is at Kings Crossing, 4.5 miles southwest of Blakely.

The significance of this series of three or more flexures is unknown. They probably represent the eastward Bluff extension of a series of structural highs favorable to oil and gas accumulation beneath the thick alluvium of the Mississippi Valley or they may represent noses of a major structural high beneath the alluvium. In any event, despite the negative results of the drilling of Kistler and Stivers' Blake No. 1 well at Blakely on Henry N. Toler's recommendation, this series of structures should be thoroughly tested by seismographic surveys in the adjacent alluvial plain; and perhaps test wells should be drilled to a greater depth than 5114 feet, or through the Wilcox, Midway, and Selma chalk.

Because of the great expense involved in oil and gas exploration and especially in deep drilling tests, this press notice is being released by William C. Morse, State Geologist, who spent a few days in the field, and by Frederic F. Mellen, Field Geologist, only on the condition that this article be accepted in its entirety.

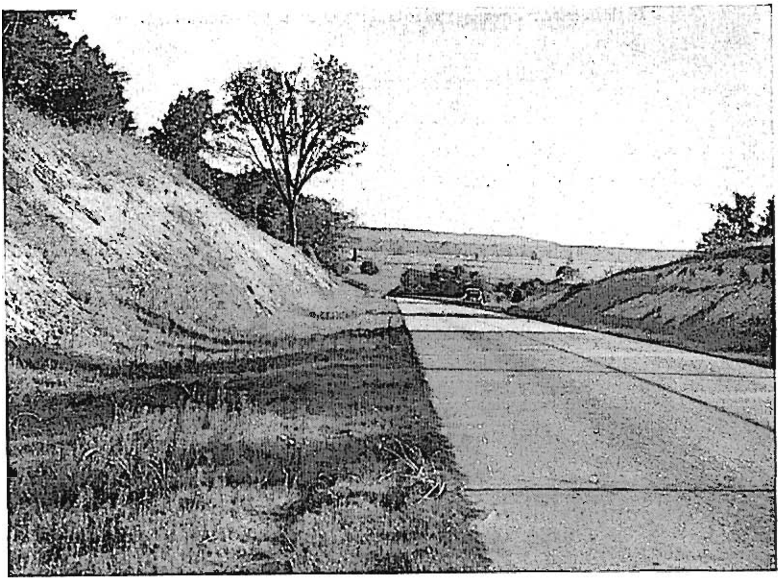


Figure 11.—The Blakely structure, looking southwest from Blakely. The recession in the bluff line is developed on a structural high. The National Cemetery is on the ridge in the right distance, beyond which is Vicksburg. The lowland is at the southern tip of the "Mississippi Delta." August 7, 1939.

Figure 12.—"Coming out" of test hole E 161, one fourth mile south of Yokena; elevation 108 feet; drilled to top of Glendon limestone at 168 feet. July 28, 1939.

THE NEWMAN SALT DOME

The fifth salt dome discovery for Mississippi, the second for Warren County, is the Newman Dome in southeastern Warren County, 10 miles east of the Glass Dome in that county and 12 miles southwest of the Edwards Dome in Hinds County. The Newman Dome was discovered and detailed by the use of the reflection and refraction seismographs, and seemingly is a structure with no surface geologic expression. Indeed, the surface bedrock formations appear to lie abnormally low: the eastward dip on the Glendon limestone from the top of the Glass Dome to the top of the Newman Dome averages 50 feet per mile; and the southward dip on the Glendon limestone from a point just northeast of Bovina to the top of the Newman Dome is 35 feet per mile. This dome represents a type which, because of solution or other phenomenon, can only be detected by deep drilling or by geophysical work, and its discovery is one of the remarkable successes of geophysical exploration. Neely (1941) has described the discovery of this dome as follows:

"Mississippi's fifth shallow salt dome was discovered by the drilling of the Magnolia Petroleum Company's Brown-Paxton No. 1, in Sec. 12, T.14 N., R.4 E., Warren County, Mississippi. This test, located as the result of geophysical work, was abandoned as a dry hole on November 23, 1940, after penetrating 293 feet into salt. After drilling 1,620 feet into the Wilcox section, dolomitic sand was encountered at a depth of 4,935 feet, followed by porous broken dolomitic limestone at 5,055 feet, anhydrite cap rock at 5,086, and finally salt at 5,108 feet. The name which is used to designate this salt dome was taken from the town of Newman, located in the vicinity of the test."

OTHER AREAS

The present minerals survey of Warren County has determined data which suggest structural conditions in several areas where the absence of outcrops renders detailed surface work impracticable. In these areas core-drilling or geophysical work is recommended.

On Highway 80, 4 miles east of Vicksburg (NW. 1/4, SE. 1/4, Sec. 24, T.16 N., R.4 E.), the Citronelle-Loess contact is at 323 feet above sea level. Two miles southwest of the above-named point (NW. 1/4, Sec. 31, T.16 N., R.4 E.), the Citronelle-Loess contact was found in an auger hole 60.0 feet below the surface, lying at elevation 210 feet. The difference, 113 feet, may be due: (1) to structural uplift in the vicinity of the first-mentioned locality, or (2) to separate gravel terrace levels being present in this area. Indeed, the relatively high topographic elevations just east and northeast of Vicksburg, and the correspondingly high elevations on the gravel-loess contact, are suggestive of deep-seated structural up-warp of the area, yet it is also possible that there is a remnant of a high-level gravel terrace in this immediate area. In any event, it will be necessary to have more data before the exact reason for the difference in elevation can be determined, and this area (Vicksburg Monocline of Hopkins) is certainly one meriting careful surveys.

The wide space between the 80-foot and 60-foot contours (see contour map) in the area north of Bovina (N. 1/2, T.6 N., R.5 E.) is suggestive of structural disturbance, and an excessive dip on the Glendon limestone between the center of Sec. 16 and the SE. 1/4, Sec. 20 has been recorded.

Another divergence of the contour lines in the northeastern part of Warren County north of Youngton suggests another area in which careful surveying is recommended.

Structural data from the Mississippi Flood-plain can be determined only by the more expensive prospecting methods, core-drilling and geophysical work. Yet from the various data obtained from surface outcrops and well logs, it is very evident that neither the "Delta" nor any large area in the Hill Region has been condemned for possible oil or gas production.

WILDCAT PROSPECTING

More unsuccessful test wells (18 to April, 1941) have been drilled in Warren County than in any other non-productive county of Mississippi, but despite this, Warren County must be, and is, considered one of the most favorable areas for great production of oil and gas in the state. The first test well drilled was the Mississippi Oil, Gas, & Investment Co.'s Mildred No. 1, in 1916. In 1931 five tests were abandoned; in 1940 four. These two periods of maximum wildcat activity coincide with the plays following the Jackson Gas Field discovery and the Tinsley Oil Field discovery. A list of the test wells in Warren County, arranged in chronological order, follows:

LIST OF TEST WELLS IN WARREN COUNTY

1. Mississippi Oil, Gas & Investment Co., Mildred No. 1, Sec. 32, T.16 N., R.4 E.; spudded August, 1916; abandoned November, 1916; T. D. 3462.
2. Mississippi Oil, Gas & Investment Co., Mildred No. 2, Sec. 21, T.16 N., R.4 E.; spudded January, 1917; abandoned March, 1917; T. D. 2630.

3. Edmonds Oil & Refining Corp., Archer No. 1, NE. 1/4, NW. 1/4, SE. 1/4, Sec. 35, T.9 N., R.5 W.; spudded March 17, 1921; abandoned September 13, 1921; T. D. 3684.
4. Mississippi Oil Co., Henry No. 1, NW. cor., SE. 1/4, NW. 1/4, Sec. 20, T.7 N., R.4 W.; spudded September 17, 1927; abandoned December, 1927; T. D. 2816.
5. Frank N. Henderson, et al., Dornbusch No. 1, Center of E. line, SW. 1/4, NW. 1/4, Sec. 8, T.18 N., R.5 E.; spudded June 11, 1929; abandoned January 13, 1930; T. D. 2473.
6. Vicksburg Oil & Gas Co., Dornbusch No. 1, 2080 ft. S. and 1520 ft. W., NE. cor., Sec. 8, T.18 N., R.5 E.; spudded September 25, 1930; abandoned April 28, 1931; T. D. 1425.
7. Dixie Petroleum Co., Clark No. 1, 300 ft. E., 660 ft. S., NW. cor., Sec. 6, T.16 N., R.5 E.; spudded January 8, 1931; abandoned March 31, 1931; T. D. 3092.
8. Dixie Petroleum Co., Pat Henry No. 1, 1375 ft. W., 380 ft. N., SE. cor., NE. 1/4, Sec. 36, T.17 N., R.4 E.; spudded April 15, 1931; abandoned May 15, 1931; T. D. 2271.
9. Eagle Lake Oil & Gas Co., Kiger No. 1, SW. cor., SE. 1/4, SW. 1/4, Sec. 9, T.18 N., R.2 E.; spudded May 15, 1931; abandoned July 12, 1931; T. D. 2607.
10. United Gas Public Service Co., Tchula Store No. 1, 1980 ft. W., 660 ft. N., SE. cor, Sec. 33, T.15 N., R.3 E.; spudded September 10, 1931; abandoned December 1, 1931; T. D. 4008.
11. Harry W. Elliott, R. L. Parker No. 1, 780 ft. E., 1270 ft. S., NW. cor., Sec. 14, T.14 N., R.1 E.; spudded September 25, 1933; abandoned October 1, 1934; T. D. 3252.
12. Kistler & Stivers, Blake No. 1, 1215 ft. N. 65 degrees W. of Blakely Station, Sec. 15, T.17 N., R.4 E.; spudded June 17, 1933; abandoned July 23, 1933; T. D. 5114.
13. Harry W. Elliott, Parker No. 2, 780 ft. E., 1570 ft. S., NW. cor., Sec. 14, T.14 N., R.1 E.; spudded 1935; abandoned 1935; T. D. 1673.
14. Burden & Cummings, T. M. Morrissey No. 1, NE. 1/4, Sec. 8, T.17 N., R.2 E.; spudded December 20, 1939; abandoned June 2, 1940; T. D. 6001.
15. W. O. Allen, Culley No. 1, Sec. 6, T.14 N., R.3 E.; spudded March 3, 1940; abandoned April 1, 1940; T. D. 4490.
16. W. O. Allen, Tom Henry No. 1, Center, W. 1/2, SW. 1/4, Sec. 4, T.7 N., R.4 W.; spudded October 5, 1940; abandoned November 3, 1940; T. D. 7277.
17. Magnolia Petroleum Co., Paxton Brown No. 1, 1320 ft. E., 425 ft. N., SW. cor., Sec. 12, T.14 N., R.4 E.; spudded October 3, 1940; abandoned November 23, 1940; T. D. 5401.
18. Waggoner Brothers Oil Co., Inc., R. Lee Parker, Jr. No. 1, 1560 ft. S., 690 ft. E., NW. cor., Sec. 17, T.14 N., R.1 E.; spudded March 1, 1941; abandoned May 14, 1941; T. D. 7013.

Electric logs (Plate 3) of two recently drilled test wells are included with this report to illustrate something of the subsurface geology of Warren County.

Most of the wells drilled prior to 1940 were relatively shallow, and possibly not one of them was drilled to a conclusive depth. With two of Mississippi's five proven salt domes having been found by drilling in 1940, and with subsurface stratigraphic data being determined weekly by deep wells in Warren and contiguous counties, information is being developed continuously which will undoubtedly lead to the discovery of Warren County's first oil or gas pool.

TEST HOLE RECORDS

NATIONAL CEMETERY PROPERTY

TEST HOLE E1

Location: T.16 N., R.3 E., Sec. 1; 60 yards N. 60° E. from north corner National Cemetery wall
Drilled: Feb. 7, 1939
Elevation: 188.0 ft.
Water level: dry

No.	Depth	Thick.	Description of strata and designations of samples
1	3.0	3.0	Loess; sand and gravel; lime concretions and shells of pulmonate gastropods in loess
2	3.2	0.2	Sand and gravel, brownish yellow
3	5.8	2.6	Clay, yellowish to brownish very silty laminated incipiently oxidized non-calcareous plastic; C1
4	8.8	3.0	Clay, gray very silty laminated unoxidized non-calcareous plastic; C2
5	16.2	7.4	Silt, gray argillaceous laminated unoxidized non-calcareous semi-plastic; fine-grained sand along bedding planes; C2
6	26.6	10.4	Silt, gray argillaceous laminated unoxidized non-calcareous semi-plastic; fine-grained sand along bedding planes; a little finely comminuted lignitic matter throughout; C3
7	36.5	9.9	Silt, gray argillaceous laminated unoxidized non-calcareous semi-plastic; fine-grained sand abundant in lower 5.0 feet; C4
8	42.1	5.6	Marl, sand-clay-, greenish-gray glauconitic hard; marine fossils very abundant; C5
9	52.1	10.0	Marl, shell-, greenish-gray abundantly fossiliferous; clay-marl, dark-gray montmorillonitic tough sparingly fossiliferous; C6
10	55.2	3.1	Marl, sand-clay-, greenish-gray glauconitic abundantly fossiliferous; C7
11	60.4	5.2	Marl, sand-, argillaceous greenish-gray glauconitic abundantly fossiliferous; C7
12	65.4	5.0	Marl, clay-, silty dark-gray montmorillonitic abundantly fossiliferous; C8
13	66.3	0.9	Marl, sand-clay-, greenish-gray glauconitic abundantly fossiliferous; S1

Remarks: Abandoned because of limestone.

NATIONAL CEMETERY PROPERTY

TEST HOLE E4

Location: T.16 N., R.3 E., Sec. 12, near center; north side Mint Spring waterfall
Drilled: December, 1938

Elevation: 88 feet
Water level: 6.9 feet

No.	Depth	Thick.	Description of strata and designations of samples
1	0.2	0.2	Marl, sand-, light-gray glauconitic, calcareous
2	2.9	2.7	Clay, dark-gray tough, plastic laminated silty; contains some glauconite, shell fragments, and coarse sand grains; materials probably from overlying Mint Spring marl; mostly non-effervescent; S1
3	3.2	0.3	Sand, medium-gray fine-grained glauconitic, micaceous non-effervescent; S2
4	7.8	4.6	Silt and silty clay, medium- to dark-gray lignitic, micaceous slightly glauconitic non-effervescent; S3
5	15.2	7.4	Sand, medium- to dark-gray fine-grained argillaceous, lignitic, micaceous, slightly glauconitic non-effervescent; S4
6	21.7	6.5	Sand, dark-gray fine-grained argillaceous, lignitic, micaceous, slightly glauconitic non-effervescent; S5
7	45.0	23.3	Silt and silty clay, medium- to dark-gray laminated lignitic, micaceous, slightly glauconitic non-effervescent; S6
8	46.0	1.0	Lignite, dark-brown to black soft argillaceous non-effervescent; S7
9	51.4	5.4	Sand, brownish- and greenish-gray micaceous, argillaceous, lignitic, slightly glauconitic non-effervescent; S8
10	63.4	12.0	Sand, medium- to dark brownish-gray fine-grained lignitic, micaceous, slightly glauconitic non-effervescent; S9
11	65.6	2.2	Clay, dark brownish-gray lignitic, micaceous, arenaceous; S10
12	66.6	1.0	Sand, greenish-gray argillaceous, micaceous, lignitic, slightly glauconitic, water-bearing; S11

Remarks: Abandoned at 66.6 because of caving. Hole was started at Mint-Spring-Forest Hill contact. The few grains of glauconite and a few grains of coarse rounded quartz sand found in the samples below S2 are thought to be contamination, in part, from the Mint Spring marl or from the first 3 or 4 feet of the hole. The mica is all or largely muscovite.

W. H. McGEE PROPERTY

TEST HOLE E5

Location: T.16 N., R.3 E., Sec. 13, W. 1/2, NW. 1/4; 80 yards S. of Yazoo & Mississippi Valley bench mark and mile post 236 Drilled: Jan. 20, 1939

Elevation: 167 feet Water level: dry

No.	Depth	Thick.	Description of strata and designations of samples
1	0.4	0.4	Marl, yellowish-brown argillaceous; numerous shells and grass roots
2	2.0	1.6	Marl, brownish argillaceous, arenaceous; shells abundant; C1
3	9.3	7.3	Marl, clay-, greenish-gray montmorillonitic, glauconitic, silty slightly plastic; shells numerous; sample unoxidized; C1
4	10.9	1.6	Marl, greenish-gray argillaceous, arenaceous, glauconitic semi-plastic; shell common; C2
5	14.5	3.6	Marl, clay-, dark greenish-gray montmorillonitic, glauconitic, arenaceous; shells common; C2
6	16.0	1.5	Marl, very hard greenish-gray glauconitic, argillaceous, arenaceous; shells abundant; C3
7	16.2	0.2	Marl, clay-, dark brownish-gray montmorillonitic, glauconitic silty; shells rare; C3
8	19.0	2.8	Marl, greenish-gray glauconitic; shells abundant; C3
9	23.1	4.1	Marl, very hard greenish-gray glauconitic, argillaceous, arenaceous; shells abundant; C4
10	26.6	3.5	Marl, clay-, dark-gray montmorillonitic, glauconitic, silty, arenaceous plastic; shells common; C4
11	29.9	3.3	Marl, very hard greenish-gray glauconitic, argillaceous, silty, arenaceous; thin seams of plastic montmorillonitic clay; shells abundant; C5
12	33.0	3.1	Marl, clay-, dark-gray montmorillonitic, glauconitic, silty, arenaceous, plastic; shells common; C5
13	34.3	1.3	Marl, very hard light greenish-gray glauconitic, argillaceous, silty, arenaceous; shells abundant; C6

Remarks: All of section is Byram marl member, Vicksburg formation; hole abandoned at top of Glendon limestone (interval No. 1 of test holes E6; intervals No. 2 of test hole E9, E10).

S. E. MACKEY PROPERTY

TEST HOLE E6

Location: T. 16 N., R.3 E., Sec 13, W. 1/2, NW. 1/4; 32 yds. N. of Yazoo & Mississippi Valley bench mark and milepost 236 and 31 yards E. of railroad track
Drilled: Jan. 17, 1939

Elevation: 133 feet
Water level: dry

No.	Depth	Thick.	Description of strata and designations of samples
1	3.4	3.4	Limestone, light-gray hard massive glauconitic; calcareous fossils common; C1
2	5.6	2.2	Marl, light brownish-gray to greenish-gray hard glauconitic, very calcareous; calcareous fossils abundant; C2
3	8.1	2.5	Marl, grayish-brown soft glauconitic argillaceous, silty; interlaminated with dark bluish-gray montmorillonitic clay; C3
4	11.9	3.8	Limestone; 1.6 feet light-gray hard massive glauconitic; 0.8 foot marl, light grayish-brown hard argillaceous, arenaceous lenticular in shape; 1.4 feet limestone, light bluish-gray glauconitic; calcareous fossils common; C4
5	15.6	3.7	Marl and limestone: 0.4 foot clay, montmorillonitic, glauconitic, calcareous; 0.2 foot marl, incipiently oxidized; 1.3 feet clay-marl, montmorillonitic semi-plastic fossiliferous glauconitic; 1.3 feet limestone, light bluish-gray glauconitic; 0.5 foot marl, grayish-green glauconitic fossiliferous; C5
6	19.7	4.1	Limestone, light-gray to light greenish-gray massive glauconitic; calcareous fossils common; lower 0.9 feet softer; C6
7	26.2	6.5	Limestone: 2.9 feet light-gray hard massive glauconitic; 0.8 foot marl, light brownish-gray arenaceous; 2.8 feet limestone, light-gray hard massive glauconitic; calcareous fossils common; C7
8	36.2	10.0	Marl, yellowish-brown to greenish-gray fossiliferous glauconitic, argillaceous, arenaceous; upper 2.7 feet most argillaceous; upper 5.2 feet incipiently oxidized; lower 4.8 feet unoxidized; C8

Remarks: Samples from trenches and from a pit (now filled) below road level. See analysis of composite sample C1-C7 by Johns-Manville. 0-26.2 Glendon (Vicksburg); 26.2-36.2 Glendon, Mint Spring facies (Vicksburg).

ELIZA MCGRAW PROPERTY

TEST HOLE E7

Location: T.17 S., R.4 E., Sec. 33; part of Lot 6, South Barefield Subdivision; 180 yds. S. along Highway from culvert at Kings School

Drilled: Dec. 4, 1938

Elevation: 167 ft. Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	1.6	1.6	Gravel and sand
2	1.8	0.2	Clay, dark bluish-brown; appears to be bentonitic
3	2.4	0.6	Marl, incipiently weathered argillaceous, glauconitic; C1
4	2.6	0.2	Marl, almost unweathered argillaceous, glauconitic; C1
5	2.7	0.1	Clay, dark brownish-gray silty bentonitic (?); C1
6	3.8	1.1	Marl, argillaceous, glauconitic; lumps of clay at 3.2; C1
7	11.6	7.8	Marl, dark greenish-gray argillaceous, silty, glauconitic; micro-fossils particularly abundant; C1
8	21.9	10.3	Marl, dark greenish-gray argillaceous, silty, glauconitic; micro-fossils particularly abundant; C2
9	25.8	3.9	Marl, dark greenish-gray argillaceous, silty, glauconitic; micro-fossils particularly abundant; dark-bluish-gray plastic clay from 22.4 to 22.7; C3
10	28.0	2.2	Marl, light brownish-gray argillaceous, silty, glauconitic; micro-fossils and mega-fossils very abundant; C3
11	34.6	6.6	Marl, light-gray to light-blue argillaceous, silty, glauconitic, highly calcareous; micro-fossils and mega-fossils very abundant; C3
12	39.3	4.7	Marl, bluish-brown to grayish-brown argillaceous, silty, glauconitic highly calcareous; micro-fossils very abundant; mega-fossils not abundant; C4

Remarks: Material below interval 1 is Byram marl. Pebbles in samples are foreign material from interval 1. Hole abandoned on top of Glendon limestone, which could be mined here for blending if necessary.

MISSISSIPPI-U. S. HIGHWAY 61

TEST HOLE E9

Location: T.16 N., R.3 E., Sec. 13, W. 1/2, NW. 1/4; 144 yds. N. along highway from E6 Drilled: Jan. 20, 1939

Elevation: 133 feet Water level: dry

No.	Depth	Thick.	Description of strata and designations of samples
1	10.0	10.0	Overburden, badly slumped mass of calcareous loess and dark clay-marl
2	12.8	2.8	Limestone, light brownish-gray hard; calcareous fossils common; C1
3	17.9	5.1	Marl and limestone: upper 1.9 feet light brownish-gray fossiliferous argillaceous, arenaceous; lower 3.2 feet very light-brown slightly argillaceous and arenaceous fossiliferous; C2
4	22.1	4.2	Marl and limestone: upper 1.9 feet very hard dark-gray fossiliferous limestone; 1.0 foot grayish-brown argillaceous, glauconitic fossiliferous marl; 1.3 feet very hard dark-gray fossiliferous limestone; C3
5	25.9	3.8	Marl and limestone: upper 1.8 feet glauconitic fossiliferous incipiently weathered limestone; 0.9 foot soft glauconitic fossiliferous incipiently weathered limestone; 1.1 feet argillaceous, arenaceous fossiliferous marl; C4
6	28.1	2.2	Limestone, hard fossiliferous almost unoxidized; C5

Remarks: Lower 18.1 feet of this section equivalent to same thickness of material in upper part of E6.

MISSISSIPPI-U. S. HIGHWAY 61

TEST HOLE E10

Location: T.16 N., R.3 E., Sec. 13, SW. 1/4, NW. 1/4; 164 yds. S. along Highway 61 from hole E6 Drilled: Jan. 20, 1939

Elevation: 133 ft. (top of limestone) Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	6.0	6.0	Overburden, badly slumped mass of loess, clay-marl, and very soft incipiently weathered limestone
2	9.2	3.2	Limestone, very hard unoxidized fossiliferous; C1
3	14.0	4.8	Marl and limestone: upper 1.6 feet very soft incipiently weathered fossiliferous limestone; 0.4 foot dark bluish-brown montmorillonitic clay; 1.0 foot very soft incipiently weathered fossiliferous limestone; 1.8 feet dark bluish-brown very arenaceous montmorillonitic clay; C2
4	16.8	2.8	Marl and limestone; upper 1.4 feet very hard bluish-gray fossiliferous limestone; 0.6 foot soft argillaceous, arenaceous, highly calcareous marl; 0.8 foot very hard bluish-gray fossiliferous limestone; C3
5	20.1	3.3	Marl and limestone: 1.0 foot highly oxidized fossiliferous marl; 0.6 foot blue plastic fossiliferous montmorillonitic clay-marl; 1.3 feet very hard fossiliferous limestone; 0.4 foot bluish-gray fossiliferous montmorillonitic clay-marl; C4
6	24.8	4.7	Marl and limestone: 1.5 feet completely oxidized light-gray firm limestone; 2.6 feet hard unoxidized fossiliferous glauconitic limestone; O.6 foot blue plastic fossiliferous arenaceous, montmorillonitic clay-marl; C5
7	27.7	2.9	Limestone: upper 1.1 feet hard incipiently oxidized fossiliferous glauconitic; lower 1.8 feet completely oxidized soft fossiliferous limestone; C6

Remarks: Lower 21.7 feet of this section equivalent to same thickness of material in upper part of E6. Samples from trench.

B. E. LAHATTE PROPERTY

TEST HOLE E11

Location: T.18 N., R.5 E., Sec. 27, NE. 1/4, SE. 1/4; face of water-fall

Drilled: Feb. 11, 1939

Elevation: 130 ft. Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	2.1	2.1	Limestone, light-gray hard glauconitic; calcareous fossils common; C1
2	3.6	1.5	Marl, light-gray compact laminated glauconitic, very calcareous; calcareous fossils abundant; C1
3	4.7	1.1	Limestone, light-gray hard glauconitic; calcareous fossils abundant; C1
4	8.6	3.9	Marl, dark bluish-gray (upper 0.6 ft. grayish-brown) argillaceous, glauconitic, very calcareous; calcareous fossils common; C2
5	13.2	4.6	Limestone: 3.1 feet greenish-gray soft glauconitic, larger calcareous fossils common; 0.2 feet argillaceous fossiliferous glauconitic marl; 1.3 feet greenish-gray hard glauconitic limestone, large calcareous fossils abundant; C3
6	19.1	5.9	Limestone: 1.9 feet greenish-gray soft glauconitic; 0.5 foot greenish-gray very glauconitic soft limestone; 0.5 foot sandy, glauconitic shell marl; 1.1 feet hard glauconitic limestone; 1.9 feet sandy, glauconitic shell marl; C4
7	24.8	5.7	Marl, light- to dark-gray sandy, slightly argillaceous, glauconitic; calcareous fossils abundant; C5

Remarks: Samples represent lowermost Glendon, including 7.6 feet of Mint Spring marl at base. From the face of this fall the Marquette Cement Company sampled for testing for cement.

W. G. BIEDENHARN PROPERTY

TEST HOLE E17

Location: T.18 N., R.5 E., Sec. 26, NW. 1/4, NE. 1/4; 516 yds. S. 64° E. of BM-K56 Drilled: Feb. 14, 1939

Elevation: 196 feet Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	4.2	4.2	Loess, yellowish-brown noncalcareous
2	21.3	17.1	Loess, yellowish-brown calcareous (lime nodules)
3	21.8	0.5	Clay, grayish arenaceous plastic tough; yellow stains
4	22.1	0.3	Gravel and sand, reddish argillaceous
5	28.6	6.5	Marl, dark greenish-gray argillaceous, arenaceous, glauconitic; some dark-gray montmorillonitic clay; shells very abundant; C1
6	32.3	3.7	Marl, clay-, dark brownish- gray tough plastic silty, montmorillonitic; small calcareous foraminifera appear to be abundant; C2
7	38.7	6.4	Marl, brownish- and greenish-gray argillaceous, arenaceous, glauconitic; calcareous fossils, especially foraminifera, are abundant; C3
8	40.6	1.9	Marl, clay-, dark brownish-gray tough plastic slightly silty montmorillonitic; C3
9	40.8	0.2	Marl, glauconitic; C3
10	46.5	5.7	Marl, clay-, dark brownish-gray silty montmorillonitic, calcareous; fossils, especially foraminifera, are common; C4
11	51.5	5.0	Marl, light greenish-gray argillaceous, arenaceous, very glauconitic; calcareous fossils abundant; C4

Remarks: Hole abandoned on top of Glendon limestone. All material below interval 4, 28.4 feet, is lower Byram. The Glendon limestone could be mined nearby for blending, if necessary.

W. G. BIEDENHARN PROPERTY

TEST HOLE E21

Location: T.18 N. R.5 E., Sec. 26, NE. 1/4, NW. 1/4; 268 yds. S. 57° E. of B M. K 56

Drilled: Feb. 20, 1939

Elevation: 177 feet

Water level: 28.0 ft.

No.	Depth	Thick.	Description of strata and designations of samples
1	1.0	1.0	Loess, dark brownish-gray
2	2.5	1.5	Loess, yellowish-brown; shells of pulmonate gastropods
3	3.0	0.5	Sand and gravel, argillaceous; lime nodules
4	3.5	0.5	Clay, yellow arenaceous, gravelly plastic; lime nodules
5	6.2	2.7	Marl, yellow; lime nodules
6	9.2	3.0	Clay, yellow tough plastic; lime nodules
7	14.7	5.5	Marl, yellowish; lime nodules and marine fossils
8	23.3	8.6	Clay, dark brownish-gray plastic tough montmorillonitic; patches of marl and marine fossils throughout; P1
9	28.6	5.3	Marl, sand-, glauconitic greenish-gray; lumps of brownish plastic clay and marine fossils
10	28.6		Limestone

Remarks: Interval 9 rests on top of Glendon limestone.

LAURA ARCHER PROPERTY

TEST HOLE E37

Location: T.18 N., R.5 E., Sec. 2, NW. 1/4, of NE. 1/4; by a walnut tree at SE. corner of yard, Laura Archer homestead Drilled: March, 1939

Elevation: 134 feet Water level: 24 feet

No.	Depth	Thick.	Description of strata and designations of samples
1	3.3	3.3	Soil, black sandy, argillaceous
2	4.4	1.1	Silt, reddish-brown argillaceous
3	10.4	6.0	Clay, dark-red tough sandy; grading to sand downward
4	10.7	0.3	Sand, reddish-brown argillaceous
5	11.5	0.8	Rock, soft ferruginous sandstone
6	13.8	2.3	Sand, yellowish and grayish argillaceous, micaceous
7	24.6	10.8	Silt, yellowish and grayish argillaceous
8	26.3	1.7	Silt, brownish-gray lignitic, slightly glauconitic, non-calcareous; fine-grained sand; S1
9	27.4	1.1	Lignite, dark-brown to black; S2
10	28.3	0.9	Sand, fine-grained brownish-gray lignitic, argillaceous, non-glauconitic, non-calcareous; S3
11	39.6	11.3	Silt, medium-gray argillaceous, glauconitic (?), non-calcareous; fine-grained sand; S4
12	42.6	3.0	Sand, medium-gray very silty fine-grained angular slightly glauconitic, non-calcareous; S5
13	46.6	4.0	Clay, bluish-gray very silty, micaceous, lignitic, non-calcareous; S6
14	49.8	3.2	Sand, medium-gray silty fine- to medium-grained angular slightly glauconitic, non-calcareous; S7
15	70.1	20.3	Sand, as above; water-bearing

Remarks: Abandoned at 70.1 because of caving. Hole was started about 30 feet below the Mint Spring marl and was abandoned probably within a few feet of the top of the Yazoo clay; entire section is Forest Hill.

LAURA ARCHER PROPERTY

TEST HOLE E40

Location: T.18 N., R.5 E., Sec. 2, SW. 1/4, NE. 1/4; 150 yds. due N. of E44 (trench)
Drilled: April 10, 1939

Elevation: 190 ft.
Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	2.2	2.2	Topsoil
2	4.0	1.8	Loess, oxidized
3	5.9	1.9	Sand and gravel
4	7.6	1.7	Clay, grayish-yellow tough plastic; lime nodules
5	18.0	10.4	Marl, grayish-yellow semi-plastic; lime nodules; very hard near bottom
6	20.4	2.4	Bentonite, clay, very light-yellow to light yellowish-gray semi-plastic; C1
7	20.6	0.2	Marl, greenish-gray glauconitic very fossiliferous
8	20.6	N.D.	Limestone

Remarks: Thickest measurement of bentonite in area. Sample of clay nearly all oxidized; some incipiently oxidized.

LAURA ARCHER PROPERTY

TEST HOLE E44

Location: T.18 N., R.5 E., Sec. 2, SW. 1/4, NE. 1/4; 150 yds. due S. of E40
Drilled: July 14, 1939

Elevation: 172 ft.
Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	3.1	3.1	Topsoil and loess, yellowish-brown oxidized
2	4.8	1.7	Gravel and sand, yellowish-red
3	9.4	4.6	Clay, yellowish-brown plastic tough; lime nodules abundant
4	10.4	1.0	Limestone, oxidized and badly dissolved
5	16.2	5.8	Marl, clay-, yellowish-brown; few fossil shells; numerous lime nodules
6	17.7	1.5	Limestone, yellowish to bluish-gray hard oxidized to unoxidized
7	18.6	0.9	Marl, yellowish to bluish-gray oxidized to unoxidized; glauconitic shells abundant
8	20.7	2.1	Bentonite, clay, dark-gray unoxidized; scattered shells and glauconitic grains; P1
9	21.0	0.3	Marl, dark greenish-gray glauconitic; shells abundant
10	21.0	N.D.	Limestone

Remarks: Trench 95.5 ft. in length. Bentonite is oxidized to head of trench. Unoxidized clay increased in thickness toward the rear of drift from bottom of bed. No iron stains or oxidation at head of drift.

B. N. SIMRALL PROPERTY
TEST HOLE E46

Location: T.18 N., R.5 E., Sec. 18, NW. 1/4 SE. 1/4 — Drilled: July 19, 1939
Elevation: 130 ft. — Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	2.7	2.7	Soil, light-brown silty
2	18.0	15.3	Silt, loessal grayish-brown; lime nodules; shells of pulmonate gastropods
3	24.7	6.7	Silt, loessal bluish-gray; shells of pulmonate gastropods
4	27.2	2.5	Marl, clay-, bluish-gray plastic; marine shells
5	27.2	0.0	Limestone

Remarks: This hole drilled to determine elevation of Glendon limestone. 0-24.7 Pleistocene; 24.7-27.2 Byram (Vicksburg); 27.2 Glendon (Vicksburg).

DR. H. H. JOHNSON PROPERTY
TEST HOLE E52

Location: T.17 N., R.3 E., Sec. 5, SW. 1/4, NW. 1/4; in old filled channel of Yazoo River — Drilled: July 20, 1939
Elevation: 75 ft. — Water level: 1.7 ft.

No.	Depth	Thick.	Description of strata and designations of samples
1	0.9	0.9	Sand, fine-grained light-brown argillaceous
2	7.8	6.9	Clay, very silty plastic brownish-gray incipiently oxidized
3	23.2	15.4	Clay, slightly silty very plastic bluish-gray unoxidized; P1
4	28.6	5.4	Clay, very silty plastic bluish-gray unoxidized

Remarks: This sample was taken for testing as a type of the "blue mud" of the alluvial plain region. Near this point is considerable lateral gradation into siltier phases of the clay.

O. L. ELDER PROPERTY
TEST HOLE E144

Location: T.16 N., R.5 E., Sec. 22, SW. 1/4, NW. 1/4; N side U. S. Highway 80, 1/4 mi. W. of Clear Creek Bridge — Drilled: March 20, 1939
Elevation: 159 ft. — Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	5.0	5.0	Loess, brown oxidized non-calcareous; C1
2	10.0	5.0	Loess, brown oxidized non-calcareous; C2
3	14.9	4.9	Loess, light-brown oxidized non-calcareous; C3
4	28.6	13.7	Loess, brown oxidized non-calcareous; ferruginous mottling
5	28.6		Loess, light brownish-gray oxidized calcareous; shells of pulmonate gastropods

Remarks: Samples from broad flat terrace (?) near highway and railroad.

R. F. FERGUSON PROPERTY

TEST HOLE E155

Location: T.16 N., R.4 E., Sec. 31; Lot 7; 285 yds. N. 47° E. of Ferguson's house

Drilled: May 10, 1939

Elevation: 270 ft. Water level: Dry

No.	Depth	Thick.	Description of strata and designations of samples
1	7.9	7.9	Clay, loessal, brown non-calcareous semiplastic; P1
2	10.6	2.7	Loess, brown non-calcareous oxidized
3	10.6	0.0	Loess, brown calcareous oxidized

J. W. CULLEY PROPERTY

TEST HOLE E160

Location: T.14 N., R.3 E., Sec. 6, near center; Highway 61

Drilled: June 12, 1939

Elevation: 134.5 ft. Water level: 17.9 ft.

No.	Depth	Thick.	Description of strata and designations of samples
1	0.4	0.4	Soil, loessal dark-brown silty
2	3.3	2.9	Silt, loessal reddish-brown; lime nodules
3	16.0	12.7	Silt, loessal light reddish-gray; large lime nodules
4	18.4	2.4	Silt, loessal light brownish-gray; shells of pulmonate gastropods
5	21.2	2.8	Silt, loessal reddish-brown
6	23.0	1.8	Silt, loessal bluish-gray to light yellowish-gray
7	29.4	6.4	Clay, grayish-brown to very dark bluish-brown slightly silty, arenaceous plastic
8	33.9	4.5	Marl, greenish-gray glauconitic arenaceous, argillaceous semi-plastic; marine fossils abundant
9	33.9	0.0	Limestone

Remarks: Location: 38 feet west of pavement, Highway 61; 6 feet east of R. O. W. fence; 13 feet west of 3-branched red gum tree; 122 feet north of west guard rail. Intervals 1 - 6 Pleistocene; Intervals 6 - 8 Oligocene (Vicksburg: Byram); Interval 9 Oligocene (Vicksburg: Glendon).

MISSISSIPPI-U. S. HIGHWAY 61 PROPERTY

TEST HOLE E161

Location: T.14 N., R.3 E., Sec. 23, SE. 1/4, SE. 1/4; Yokena, about 400 yards S. of T. J. Kinzer's store; E. side of Highway. Drilled: September, 1939

Elevation: 108 feet Water level: 14.0 feet

No.	Depth	Thick.	Description of strata and designations of samples
1	11.0	11.0	Sand, medium-grained rounded light-gray argillaceous; clay, medium-gray very sandy; sample non-calcareous, slightly micaceous; soft sandstone 3.1 to 11.0; S1
2	20.0	9.0	Sand, fine-grained silty light-gray argillaceous, non-calcareous; S2
3	30.0	10.0	Sand, fine-grained silty, argillaceous light-gray; clay dark-gray slightly lignitic, containing large rounded quartz grains; sample non-calcareous; S3
4	40.0	10.0	Sand, fine- to medium-grained light- to medium-gray argillaceous, silty, slightly micaceous, slightly lignitic, non-calcareous; S4
5	50.0	10.0	Sand, fine- to medium-grained light- to medium-gray argillaceous, silty, non-calcareous; S5
6	60.0	10.0	Sand, fine- to medium-grained light- to medium-gray argillaceous, silty, slightly lignitic, pyritiferous, non-calcareous; S6
7	70.0	10.0	Sand, fine- to coarse-grained light- to dark-gray argillaceous, silty, lignitic, pyritiferous, non-calcareous; S7
8	80.0	10.0	Lignite, 73.4 to 73.7; clay, dark-gray and greenish-gray silty; contains some fine-grained quartz sand, pyritiferous, lignitic, slightly micaceous, non-calcareous; S8
9	85.0	5.0	Silt, and silty clay, medium- to dark-gray sandy, pyritiferous, lignitic, non-calcareous; S9
10	86.0	1.0	Silt, medium- to dark-gray argillaceous, sandy, slightly lignitic, non-calcareous; S10
11	88.0	2.0	Silt, medium- to dark-gray argillaceous, sandy, slightly lignitic, non-calcareous; S11
12	95.0	7.0	Silt, medium- to dark-gray argillaceous, sandy, slightly lignitic, non-calcareous; S12
13	100.0	5.0	Silt and silty clay, medium- to dark-gray, sandy, slightly lignitic, non-calcareous; S13
14	105.0	5.0	Clay and silt, dark-gray slightly lignitic, sandy, montmorillonitic, non-calcareous; S14
15	115.0	10.0	Clay and silt, dark-gray slightly lignitic, sandy, montmorillonitic, non-calcareous; S15

(Continued on next page)

Test Hole E161—(Continued)

No.	Depth	Thick.	Description of strata and designations of samples
16	120.3	5.3	Sand, brownish-gray fine-grained silty, non-calcareous; S16
17	132.3	12.0	Clay and silt, dark-gray slightly lignitic, sandy, montmorillonitic, non-calcareous; thin gray siltstone 123.4 to 124.0
18	142.0	9.7	Clay and silt, dark-gray slightly lignitic, sandy, montmorillonitic, non-calcareous; clay-marl, fossiliferous, calcareous, 140.0 to 142.0; S17
19	148.5	6.5	Clay-marl, dark-gray slightly lignitic, silty, sandy, montmorillonitic, calcareous, fossiliferous; S18
20	158.3	9.8	Sand-marl, greenish-gray argillaceous, silty, glauconitic very fossiliferous very calcareous; S19
21	159.3	1.0	Bentonite, light-gray to bluish-gray; the light-gray clay has an ashy appearance; the bluish-gray is hard, waxy, having the appearance and fracture of chalcedony; neither type is calcareous; S20
22	165.0	5.7	Sand-marl, light- to dark-gray argillaceous, silty, glauconitic, micaceous, montmorillonitic, very fossiliferous, very calcareous; S21
23	167.5	2.5	Sand-marl, light- to medium-gray argillaceous, silty, glauconitic, micaceous, very fossiliferous, very calcareous; S22
24			Limestone

Remarks: Correlation: Surface to 73.4′—Catahoula

73.4′ to 140.0′—Byram (Upper)

140.0′ to 167.5′—Byram (Lower)

167.5′ not drilled—Top of Glendon

J. V. MASSEY PROPERTY

TEST HOLE E164

Location: T.15 S., R. 3 E., Sec. 35; S. 4° E. approximately 50 yds. from SE. corner Highway 61 bridge
Drilled: June 6, 1939

Elevation: 104.5 ft.
Water level:

No.	Depth	Thick.	Description of strata and designations of samples
1	0.5	0.5	Topsoil, brownish-gray loessal
2	8.2	7.7	Loess, reddish-brown*
3	22.0	13.8	Loess, light brownish-gray
4	24.1	2.1	Loess, light-gray; a few shells
5	24.5	0.4	Clay, light-gray silty
6	25.5	1.0	Sand, light-gray fine-grained; shells (?)
7	26.2	0.7	Silt, greenish-gray argillaceous, arenaceous
8	35.4	9.2	Clay, very dark grayish-brown silty, arenaceous; no shells
9	37.7	2.3	Marl, clay-, laminated glauconitic, argillaceous, arenaceous, dark grayish-brown to greenish-gray semi-plastic; marine fossils
10	37.9	0.2	Limestone
11	40.9	3.0	Marl, greenish-gray glauconitic, argillaceous, arenaceous semi-plastic; marine fossils
12	41.0	0.1	Limestone
13	53.3	12.3	Marl, clay-, laminated glauconitic, argillaceous, arenaceous dark grayish-brown to greenish-gray semi-plastic; marine fossils abundant
14	56.1	2.8	Marl, glauconitic, arenaceous greenish-gray; marine fossils abundant
15	56.1		Limestone, hard

Remarks: 0-24.1 Pleistocene or recent; 24.1 - 56.1 Byram (Vicksburg); 56.1 top of Glendon (Vicksburg); could not be broken.

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WARREN COUNTY MINERAL RESOURCES

TESTS — CLAYS

THOMAS EDWIN McCUTCHEON, B.S., CER. ENGR.

INTRODUCTION

The five samples of clay and clay-like materials that were tested represent inexhaustable deposits of distinctly different materials. It is to be expected that the properties of the several materials will vary from place to place; consequently the results given here should be considered as being specifically characteristic of the particular samples under consideration and generally characteristic of the large deposits that they represent, as discussed in the geologic part of this report.

The "blue swamp mud" (E52, 7.8-23.2 ft.) and the clay of the lower Byram (E21P1, 14.7-23.3 ft.) are extremely plastic and burn to a dense but vesicular body at low temperatures. The clays are not suited as the sole ingredient for ceramic products.

The "brown loam" (E144C1-2-3) and the silt of the upper Byram (E1, 3.2-36.5 ft.) are deficient in plastic properties. The silt burns to a weak, porous body over a considerable range of temperature. These materials are limited in their use as the sole ingredient of ceramic products.

The above observations during the routine tests led to the blending of the plastic materials with the non-plastic for a better balanced body in the raw and fired states. The result of such blending of materials is the production of ceramic bodies that are suitable for a wide variety of heavy clay products which is not possible from clays and clay-like materials from the different deposits when used alone.

It is believed that a better understanding of the typical characteristics of the clays of Warren County, and the suggestion of blending these materials, will result in a more successful production of heavy clay products from the materials at hand, than has heretofore been experienced.

The weathered loess or brown loam (E155P1, 0.-7.9 ft.) is exceptional inasmuch as it does have sufficient plastic properties to be formed into brick by the stiff-mud process and burns to a good red body over a wide range of temperature. An improvement of plastic properties could be effected by blending with the "blue swamp mud" (E52) for the purpose of producing thin walled hollow tile and roofing tile.

On the following pages the results of testing the several materials and the blends are given in tabular form and under the heading, Summary and Conclusions, a detailed discussion of the results is given.

PHYSICAL PROPERITIES IN THE UNBURNED STATE

Sample No.	Water of plasticity in percent	Drying shrinkage		Modulus of rupture in lbs./sq. in.	Texture	Color
		Volume in percent	Linear in percent			
E1-3.2-36.5 ft.	25.09	20.87	7.52	216	Silty	Gray
E21P1-14.7-23.3 ft.	44.33	13.23	4.65	686	Fine	Gray
E52P1-7.8-23.2 ft.	39.56	52.87	22.20	719	Fine	Gray
E144C1-2-3	24.64	11.78	4.10	211	Fine	Brown
E155P1-.0-7.9 ft.	23.85	14.52	5.12	308	Fine	Brown

SCREEN ANALYSES

SAMPLE E1, 3.2-36.5 FT.

Retained on screen	Percent	Character of residue
30	.07	Abundance of gray micaceous, argillaceous, arenaceous nodules; small amount of limonite; trace of pyrite
60	3.04	Abundance of gray micaceous, argillaceous, arenaceous nodules; small amount of limonite; traces of lignite, glauconite, and pyrite
100	10.77	Abundance of gray clay nodules; considerable quantity of quartz; small amounts of pyrite and glauconite; trace of shells
150	19.02	Abundance of quartz; considerable quantity of clay nodules; small amounts of pyrite and glauconite
200	25.49	Abundance of quartz; small amount of clay nodules; trace of rutile
250	3.68	Abundance of quartz; small amount of clay nodules; trace of rutile
Cloth	37.93	Silt including residue from above

SAMPLE E21P1, 14.7-23.3 FT.

Retained on screen	Percent	Character of residue
30	.52	Abundance of gypsum; considerable quantity of shell fragments; small amounts of clay and pyrite
60	6.73	Abundance of clay nodules; small amounts of gypsum and shell fragments
100	8.43	Abundance of clay nodules; small amount of shell fragments; trace of glauconite and gypsum
150	5.64	Abundance of clay nodules; considerable quantity of shell fragments; traces of pyrite, quartz, and glauconite
200	10.79	Abundance of clay nodules; small amount of shell fragments
250	2.62	Abundance of clay nodules; traces of shell fragments and pyrite
Cloth	65.27	Clay substance including residue from above

SAMPLE E52P1, 7.8-23.2 FT.

Retained on screen	Percent	Character of residue
30	4.29	Abundance of gray arenaceous clay nodules
60	14.75	Abundance of gray and limonitic, arenaceous clay nodules
100	13.22	Abundance of gray and limonitic, arenaceous clay nodules
150	4.28	Abundance of limonitic, arenaceous clay nodules and gray clay nodules
200	6.65	Abundance of gray and limonitic clay nodules
250	1.34	Abundance of clay nodules; trace of quartz
Cloth	55.47	Silt including residue from above

SAMPLE E144C1-2-3

Retained on screen	Percent	Character of residue
30	.17	Abundance of limonitic, arenaceous nodules; traces of lignite and calcareous material
60	1.29	Abundance of limonitic, arenaceous nodules; traces of lignite and calcareous material
100	1.36	Abundance of limonitic, arenaceous nodules; trace of calcareous material
150	.17	Abundance of limonitic, arenaceous nodules; small amounts of calcareous material and muscovite
200	1.07	Abundance of limonitic, arenaceous nodules; small amounts of calcareous material and muscovite
250	.46	Abundance of limonitic, arenaceous material; small amounts of quartz and muscovite
Cloth	95.48	Clay substance including residue from above

Alta Ray Gault, Technician

CHEMICAL ANALYSES*

SAMPLE E1, 3.2-36.5 FT.

Moisture, air dried 0.80 Sulphur, SO_3 1.36

Ignition loss	3.86	Iron oxide, Fe_2O_3	1.98	Magnesia, MgO	0.46
Silica, SiO_2	78.23	Titania, TiO_2	0.94	Potash, K_2O	0.90
Alumina, Al_2O_3	11.22	Lime CaO	1.39	Soda, Na_2O	0.90

SAMPLE E21P1, 14.7-23.3 FT.

Moisture, air dried 2.20 Sulphur, SO_3 1.30

Ignition loss	9.61	Iron oxide, Fe_2O_3	4.44	Magnesia, MgO	1.77
Silica, SiO_2	51.00	Titania, TiO_2	1.27	Potash, K_2O	0.87
Alumina, Al_2O_3	23.13	Lime, CaO	5.65	Soda, Na_2O	1.32

SAMPLE E52P1, 7.8-23.2 FT.

Moisture, air dried 1.10 Sulphur, SO_3 0.01

Ignition loss	7.66	Iron oxide, Fe_2O_3	1.85	Magnesia, MgO	1.04
Silica, SiO_2	60.30	Titania, TiO_2	0.88	Potash, K_2O	0.99
Alumina, Al_2O_3	24.74	Lime, CaO	0.78	Soda, Na_2O	1.57

SAMPLE E144C1-2-3

Moisture, air dried 1.20 Sulphur, SO_3 1.47

Ignition loss	2.84	Iron oxide, Fe_2O_3	2.31	Magnesia, MgO	0.31
Silica, SiO_2	74.67	Titania, TiO_2	0.89	Potash, K_2O	1.09
Alumina, Al_2O_3	15.02	Lime, CaO	0.47	Soda, Na_2O	1.55

* All samples ground to pass 100-mesh screen.

M. R. Livingston, analyst.

PYRO-PHYSICAL PROPERTIES

ORIGINAL SAMPLES

Sample No.	At cone	Porosity in percent	Absorption in percent	Bulk specific gravity	Apparent specific gravity	Volume shrinkage in percent	Linear shrinkage in percent	Modulus of rupture in lbs./sq. in.	Color and remarks
E1-3.2-36.5 ft.	02	26.89	15.17	1.76	2.40	—1.43	—.50	335	Salmon
	1	24.36	13.88	1.76	2.32	—1.80	—.60	463	Salmon
	3	26.44	15.37	1.72	2.34	—4.50	—1.52	545	Buff Bl.
	5	28.68	17.81	1.61	2.26	-10.47	—3.63	571	Dk. buff Bl., Not St. H.
E144 C1-2-3	02	21.62	11.53	1.87	2.39	9.07	3.13	1059	Red
	1	18.55	9.88	1.94	2.33	10.65	3.70	1470	Red
	3	15.70	8.42	1.98	2.40	12.98	4.55	1534	Red
	5	12.53	5.80	2.16	2.40	21.38	7.71	1666	Dk. red St. H.
	7	10.21	4.72	2.16	2.47	20.96	7.56	2217	Dk. red
	9	1.60	.77	2.08	2.11	20.32	7.32	2108	Reddish brown
E155P1-.0-7.9 ft.	01	25.75	13.58	1.87	2.49	6.11	2.11	801	Red
	2	20.70	10.62	1.95	2.46	11.19	3.88	1367	Red
	4	17.54	8.79	2.00	2.43	12.97	4.54	1435	Red St. H.
	6	9.54	4.49	2.15	2.37	18.95	6.78	1772	Dk. red
	8	8.64	3.98	2.18	2.39	20.33	7.32	N.D.	Dk. red
	10	4.93	2.67	1.85	1.95	6.66	2.29	N.D.	Reddish brown

Note: Samples E21P1, 14.7-23.0 ft. and E52P1, 7.8-23.2 ft. were burned to cone 02 and bloated to such extent that the data on their fired properties are unreliable; however, the measured results are as follows:

Sample E21P1, 14.7-23.0 ft.

Porosity, 16.15 percent; absorption, 11.19 percent; bulk specific gravity, 1.44; apparent specific gravity, 1.72; volume shrinkage, —17.60 percent; linear shrinkage, —6.85 percent.

Sample E52P1, 7.8-23.2 ft.

Porosity, 7.60 percent; absorption, 12.23 percent; bulk specific gravity, .66; apparent specific gravity, .71; volume shrinkage, —168.8 percent; linear shrinkage, —59.8 percent.

BLENDS

At cone	Porosity in percent	Absorption in percent	Bulk specific gravity	Apparent specific gravity	Total linear shringage in percent	Modulus of rupture in pounds per square inch	Color and remarks
Mixture of 50 percent E21P1 and 50 percent flint							
02	28.21	15.40	1.84	2.56	10.40	2038	Salmon
1	24.78	13.51	1.89	2.47	10.40	2252	Salmon
3	23.63	12.56	1.83	2.43	10.40	3299	Salmon
5	22.20	12.02	1.85	2.37	10.30	3452	Salmon
7	22.83	12.38	1.85	2.39	10.50	3668	Salmon
Mixture of 50 percent E52P1 and 50 percent flint							
02	29.56	16.62	1.78	2.53	7.30	1515	Salmon
1	29.22	15.90	1.86	2.53	9.00	2107	Salmon
3	26.18	14.03	1.86	2.60	10.00	2244	Salmon
5	24.07	12.56	1.96	2.51	10.10	2499	Salmon
7	22.08	11.31	1.92	2.53	9.50	3205	Salmon
Mixture of 90 percent E144C1-2-3 and 10 percent E52P1							
02	27.17	14.87	1.84	2.54	7.80	1584	Red
1	27.40	14.84	1.85	2.55	10.60	2176	Red
3	22.34	11.42	1.96	2.53	10.60	2737	Dk. red
Mixture of 80 percent E144C1-2-3 and 20 percent E52P1							
02	24.85	13.10	1.90	2.53	9.00	1894	Red
1	24.50	12.98	1.90	2.52	11.00	2387	Red
3	19.12	9.53	2.01	2.49	12.10	2985	Red
Mixture of 70 percent E144C1-2-3 and 30 percent E52P1							
02	26.10	13.89	1.88	2.55	12.10	2612	Red
1	22.00	11.26	1.96	2.52	12.90	2956	Red
3	19.14	9.49	2.03	2.51	11.00	2790	Red Bl.

SUMMARY AND CONCLUSIONS

SAMPLE E1, 3.2-36.5 FT.

The Byram silt possesses some plastic properties but is too short for successful processing. It would be improved by blending with a substantial quantity of the "blue swamp mud." On burning to cones 02 and 1, there is no shrinkage but a slight expansion. At cones 3 and 5 there is a tendency toward bloating. At all temperatures the body is very porous and too weak for structural purposes. A blend of the silt and "blue swamp mud" would likely produce a strong and dense body suitable for common brick and drain tile when burned at low temperatures. The silt is less desirable than the loess or the loam for blending with plastic clays.

SAMPLE E21P1, 14.7-23.0 FT.

The Byram clay is very plastic but has a low drying shrinkage. It contains a considerable quantity of silt and an appreciable amount of lime in the form of gypsum. The dry strength is unusually high and indicates good bonding properties. On burning, the clay cracks and bloats and the body is brittle. Lime specks are obvious.

The clay blended with fifty per cent non-plastic material (flint) produces a body having uniform burning characteristics over a firing range of seven cones. The clay could be blended with the loess (not sampled) for use in the production of common brick, face brick, hollow tile, and drain tile. The clay should be finely ground to reduce the particle size of the gypsum to prevent popping. This clay is not as desirable for a plastic bonding material as the "blue swamp mud."

SAMPLE E52P1, 7.8-23.2 FT.

The "blue swamp mud" is extremely plastic and shrinks to about half its volume on drying. The dry clay is tough and dense and has a cross breaking strength of 719 pounds per square inch. On burning to cone 02 the clay expands or bloats to approximately three times its dry volume. The resulting vesicular mass is somewhat impervious and floats in water even after being boiled in it for four hours. The bulk specific gravity of the clay after burning is 0.66.

The clay alone is not suitable for the usual ceramic products but is particularly suited for the production of a light weight aggregate for concrete that would reduce the dead weight of the concrete by approximately one-third without sacrificing strength over sand and gravel concretes. Such a material is produced commercially under the trade name of "Haydite."

Although the clay alone has undesirable ceramic properties in the raw and fired states, when blended with non-plastic materials these properties become useful. A blend containing fifty per cent flint possesses good plastic and drying characteristics and burns rather uniformly over a firing range of seven cones. The ceramic possibilities of the "blue swamp mud" are discussed further in relation to the brown loam.

SAMPLE E144C1-2-3

This sample of the brown loam is less plastic than a similar material obtained from test hole E155. The variation in plasticity of the brown loam from place to place is characteristic of this material. The loam is probably the most accessible of all ceramic materials in Warren County by being at the surface of the ground and blanketing a large area. For this reason its economic importance is worthy of considerable attention even though it does not possess all of the desirable properties of a material suitable for heavy clay products. Very beautiful, red colored and uniformly textured face brick have been produced from the loam but not economically so. Past production has been necessarily confined to the dry-press or semi-dry-press process; however, brick made by this method cannot be produced as cheaply as by the stiff-mud process, which is not adaptable to the relatively non-plastic loess or brown loam.

It was observed during the testing of the loam that a blend of this material with various amounts of the "blue swamp mud" produced a ceramic body that would lend itself to the stiff-mud process of production without sacrificing the desirable evenly colored and textured quality of the loess brick. Results of the blending of the brown loam with 10, 20, and 30 per cent "blue swamp mud" are shown on a preceeding page. The part that is not shown is the improvement in working properties which it to such an extent that the mixtures are suitable for the manufacture of common brick, face brick, hollow tile, structural tile, drain tile, facing tile, and roofing tile. Flower pots, art pottery and decorative faience are possibilities worthy of investigation.

SAMPLE E155P1, 0-7.9 FT.

This sample of brown loam is more plastic than that from test hole E144. It has fair working properties, a normal drying shrinkage, and good strength. On burning, the loam responds normally to increased heat treatment, becoming steel hard at cone 4 and not overburning before cone 10. The color is a rich dark red and the texture is smooth and uniform throughout the firing range of seven cones.

The material is especially suitable for the production of red face brick and flower pots. With the addition of a small amount of plastic clay of the type from test hole E52, the loam is suitable for the manufacture of roofing tile, facing tile, hollow tile, structural tile, and possibly quarry tile. This sample of brown loam offers the best possibilities for development.

LABORATORY PROCEDURE

Due to the limited number of clays tested, the detailed procedure will not be given in this report. However, it may be stated that all testing was done in strict accordance with procedures outlined by the American Ceramic Society and the American Society for Testing Materials.

WARREN COUNTY MINERAL RESOURCES

TESTS — MARLS AND LIMESTONES

MALCOLM ROGERS LIVINGSTON, B.S.E., M.S.

INTRODUCTION

One of the chief topographic features of Warren County is the long high bluff extending north and south through the City of Vicksburg. For several miles, this bluff consists mainly of outcrops of the Glendon limestone, Mint Springs marl, and Byram marl, all members of the Vicksburg series.

The purpose of this investigation has been to find uses for these materials. The results will be discussed under four heads: (1) Cement, (2) Mineral wool, (3) Sand-lime brick, and (4) Agricultural lime.

Vicksburg is ideally located as a site for a manufacturing plant producing any of these materials. It has two railroads and the Mississippi River for transportation routes; it has access to the Louisiana gas and oil fields for fuel; it has the entire lower Mississippi Valley as a practically non-competitive market area; it has the raw materials; it has, in addition, river-marine transportation to Gulf and South American ports.

The determination of the value of a deposit of raw material is dependent on a number of factors beside the law of supply and demand. The more important of these are: chemical composition, physical character, amount of workable material available, location with respect to fuel supplies, location with respect to transportation facilities, and location with respect to markets. A lack of knowledge about one of these factors frequently leads to overestimates of the value of deposits of raw material.

This section of the report deals only with the study of the potentialities of the Warren County materials, based on the chemical composition and physical character of these materials.

The raw material must have the correct chemical composition required by any particular process in which it is to be used. In some processes, the chemical composition of a material may be altered by the addition of other materials having a high percentage of the deficient constituent or constitutents. For instance, if a clayey limestone contains less than 75 percent of lime carbonate, the addition of pure limestone, to give the optimum mixture for cement production, is a process that may be, and often is, applied. Of course, if material in sufficient quantities and correct composition is available, the process is greatly simplified.

The value of a raw material depends to a large extent, too, on the amount of treatment necessary before being used in the manufacturing process. If the material is used as a dry powder, economy demands that it should be as soft and dry as possible. In some processes, the raw materials are introduced as small lumps. In these cases, the material is more valuable when found in a relatively hard state, because in such a condition it can be crushed to the correct size.

LABORATORY DATA

The ignition loss and carbon dioxide content of all samples were determined. From preliminary tests it was known that these materials contain very little magnesia, so the approximate percentage of calcium carbonate in each sample was calculated. From this approximation, the lime content was calculated on a calcined basis (Table 1).

After a study of these results, it was decided to attempt to concentrate the lime by washing out the clay. Then, too, since few beds alone are thick enough to be workable, composite samples of all the beds of the section were made. After being washed on a 250-mesh screen, the retained residue was ground to pass a 100-mesh screen and completely analysed (Table 2). The same data was reduced to a calcined basis (Table 3). The percentage of each composite sample retained on the 250-mesh screen was determined as well as that passed through the screen (Table 4).

After further study, it was found necessary to have analyses of the whole composite samples. Accordingly, determinations were made of silica and then of alumina, iron oxide, and titania combined. The weighted averages of ignition losses and CaO contents were calculated from the data (Table 1). Results were reduced to a calcined basis (Table 5).

TABLE 1. IGNITION LOSS AND CARBON DIOXIDE CONTENT OF MARLS (M) AND LIMESTONES (L) (PERCENT)

Hole	Sample	Feet	Ignition	CO2	CaCO3	CaO
E1	C5-M	5.6	23.24	22.10	50.2	36.8
E1	C6-M	10.0	23.70	18.52	42.1	31.0
E1	C7-M	8.3	24.04	21.96	49.9	36.7
E1	C8-M	5.0	24.54	19.51	44.4	32.9
E5	C1-M	8.9	25.88	20.55	46.6	35.3
E5	C2-M	5.2	18.27	13.68	31.1	20.8
E5	C3-M	4.5	24.32	23.91	54.2	40.2
E5	C4-M	7.6	24.52	18.09	41.1	30.5
E5	C5-M	6.4	22.76	18.08	41.1	29.8
E5	C6-M	1.3	29.13	27.47	62.5	49.5
E6	C1-L	3.4	34.58	34.99	79.5	68.0
E6	C2-M	2.2	29.61	27.45	62.5	49.7
E6	C3-M	2.5	28.26	27.68	63.0	49.3
E6	C4-L	3.8	38.53	31.70	72.0	65.7
E6	C5-ML	3.7	29.22	26.71	60.6	48.0
E6	C6-L	4.1	36.91	36.37	82.5	73.3
E6	C7-L	6.5	35.88	34.36	78.0	68.0
E6	C8-M	10.0	10.82	8.93	20.3	12.8
E7	C1-M	9.8	15.98	12.09	27.4	18.3
E7	C2-M	10.3	20.65	18.46	41.9	29.6
E7	C3-M	12.7	21.82	18.69	42.4	30.3
E7	C4-M	4.7	27.03	24.30	55.2	42.4
E9	C1-L	2.8	36.57	37.23	84.8	75.0
E9	C2-ML	5.1	28.64	26.01	59.2	46.6
E9	C3-ML	4.2	38.32	38.15	68.8	79.0
E9	C4-ML	3.8	32.12	32.04	84.1	69.8
E9	C5-L	2.2	37.32	37.01	72.9	65.0
E10	C1-L	3.2	34.86	34.07	77.5	68.7
E10	C2-ML	4.8	29.02	20.92	47.5	37.5
E10	C3-ML	2.8	37.47	37.94	86.1	77.5
E10	C4-ML	3.3	29.67	27.41	62.4	49.8
E10	C5-ML	4.7	35.93	34.86	79.4	69.3
E10	C6-L	2.9	34.92	34.26	77.9	67.1
E11	C1-ML	4.7	34.20	32.59	74.0	63.2
E11	C2-M	3.9	21.19	17.13	39.0	27.7
E11	C3-L	4.6	35.41	34.00	77.2	66.9
E11	C4-L	5.9	29.35	26.46	60.2	47.7
E11	C5-M	5.7	11.67	10.79	24.5	15.5
E17	C1-M	6.5	15.08	13.40	30.4	20.0
E17	C2-M	3.7	12.15	5.66	12.8	8.2
E17	C3-M	8.5	16.93	11.75	26.7	17.9
E17	C4-M	10.7	14.00	8.16	18.6	12.1

TABLE 2. AVERAGE ANALYSES OF WASHED COMPOSITE SAMPLES OF MARLS AND LIMESTONES (PERCENT)

Hole	E1	E5	E6	E7	E9	E10	E11	E17
Ignition	25.27	26.90	26.71	22.13	36.41	36.58	25.81	17.20
SiO_2	28.10	25.02	30.58	41.07	10.01	9.37	32.16	46.93
Al_2O_3	5.43	5.25	3.50	3.39	3.21	3.14	4.09	9.35
Fe_2O_3	4.49	3.37	1.96	2.42	2.12	2.45	2.35	3.04
TiO_2	0.19	0.19	0.31	0.11	0.17	0.09	0.20	0.36
CaO	31.05	34.85	34.93	27.99	45.87	46.77	33.04	21.33
MgO	0.86	1.32	0.31	0.25	0.06	0.16	0.46	0.28
MnO_2	1.93	0.63	0.33	1.34	0.55	0.60	0.65	0.53
K_2O	0.88	0.90	0.21	0.52	0.20	0.36	0.04	0.01
Na_2O	1.38	1.73	0.24	1.07	1.22	0.89	1.02	0.83
SO_3	1.80	0.99	1.17	1.47	0.97	1.53	0.84	2.72
P_2O_5	0.10	0.09	0.67	0.11	0.11	0.09	0.10	0.11

TABLE 3. ANALYSES OF WASHED COMPOSITE SAMPLES, CALCINED BASIS (PERCENT)

Hole	SiO_2	R_2O_3	CaO	Others
E 1	37.55	13.22	41.50	6.99
E 5	34.20	11.78	47.60	6.51
E 6	40.70	7.46	47.60	1.91
E 7	52.80	7.46	35.99	4.23
E 9	15.70	8.38	72.00	3.44
E 10	14.80	8.81	73.39	3.31
E 11	43.40	8.68	44.63	3.20
E 17	56.55	14.95	25.72	3.42

TABLE 4. PERCENT OF COMPOSITE SAMPLES RETAINED AND PASSED, 250-MESH SCREEN

Hole	Retained, 250	Passed, 250
E 1	51.5	48.0
E 5	44.0	55.5
E 6	66.0	33.0
E 7	53.0	46.0
E 9	62.0	37.0
E 10	58.5	38.0
E 11	68.0	31.0
E 17	40.0	60.0

TABLE 5. ANALYSES COMPLETE COMPOSITE SAMPLES, CALCINED BASIS

Hole	SiO_2	R_2O_3	CaO	Others
E 1	42.5	16.5	34.0	7.0
E 5	44.0	18.0	31.3	7.0
E 6	40.0	8.0	48.7	3.0
E 7	55.8	10.5	28.5	5.0
E 9	18.5	11.4	65.7	4.0
E 10	21.8	14.8	60.0	3.5
E 11	44.0	9.0	43.6	3.5
E 17	62.0	20.0	15.0	3.0

Two different types of material are represented: those containing about 70 percent lime and those containing less than 50 percent. The only possible exception to this classification is the material from hole E11. This hole is in the Glendon limestone but in this area the limestone is less pure. Hence, it is grouped with the low lime series of E1, E5, E7, and E17.

All samples were subjected to screen analysis and microscopic examination (Tables 6 and 7) by Alta Ray Gault and arranged in the following tables by the writer.

TABLE 6: SCREEN ANALYSES OF HIGH-LIME SERIES

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other Materials (a: considerable amount; b: small amount; c: trace)
E6	C1	30	24.12	Calcareous, argillaceous nodules	
		60	16.60	Calcareous, argillaceous nodules	b: glauconite
		100	10.81	Calcareous, argillaceous nodules	b: glauconite
		150	4.23	Calcareous nodules	b: glauconite
		200	6.06	Calcareous nodules	b: glauconite b: quartz
		250	1.50	Calcareous material	b: glauconite b: quartz
		cloth	36.68	Clay substance including residue from above	
E6	C2	30	0.56	Shell fragments	a: gypsum c: glauconite
		60	2.04	Shell fragments	a: gypsum c: glauconite
		100	11.78	Shell fragments	b: glauconite b: quartz
		150	16.78	Shells and shell fragments	b: glauconite
		200	18.34	Calcareous material	b: glauconite
		250	3.07	Calcareous material	c: glauconite c: gypsum
		cloth	47.43	Clay substance including residue from above	
E6	C3	30	2.29	Shell conglomerate	a: gypsum
		60	8.34	Gray clay nodules	a: shell conglomerate b: gypsum
		100	11.39	Gray clay	a: shell fragments b: quartz
		150	11.45	Fossil and fossil fragments	a: clay nodules
		200	17.28	Fossil fragments	a: clay nodules
		250	2.05	Fossil fragments	a: clay c: quartz
		cloth	47.20	Clay substance including residue from above	

TABLE 6. SCREEN ANALYSES OF HIGH-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E6	C4	30	57.67	Limestone fragments	
		60	8.28	Limestone fragments	
		100	7.06	Limestone fragments	a: foraminifera
		150	3.30	Calcareous material	
		200	5.27	Calcareous material	c: quartz
		250	1.12	Calcareous material	c: quartz
		cloth	13.30	Clay substance including residue from above	
E6	C5	30	25.51	Limestone fragments, with glauconite embedded	
		60	10.62	Limestone fragments, with glauconite embedded	c: quartz c: glauconite
		100	14.93	Calcareous material	a: quartz a: glauconite
		150	6.43	Calcareous material	b: glauconite
		200	8.22	Calcareous material	b: glauconite b: quartz
		250	1.90	Calcareous material	b: glauconite
		cloth	32.39	Clay substance including residue from above	
E6	C6	30	46.10	Limestone fragments, with glauconite embedded	
		60	12.94	Limestone fragments, with glauconite embedded	
		100	9.21	Limestone fragments	b: quartz b: glauconite
		150	4.79	Limestone material	b: glauconite b: quartz
		200	4.65	Limestone material	c: quartz c: glauconite
		250	.99	Limestone material	c: quartz c: glauconite
		cloth	21.32	Clay substance including residue from above	

TABLE 6. SCREEN ANALYSES OF HIGH-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E6	C7	30	43.17	Limestone fragments, with glauconite embedded	
		60	7.01	Limestone fragments with glauconite	
		100	9.98	Calcareous material with fossils	c: quartz
		150	4.70	Calcareous material	b: quartz
		200	7.67	Calcareous material	b: quartz
		250	1.50	Calcareous material	c: quartz
		cloth	25.97	Clay substance including residue from above	
E9	C1	30	46.51	Calcareous glauconitic nodules	
		60	11.86	Calcareous glauconitic, quartzitic nodules	
		100	9.59	Calcareous nodules	b: quartz b: glauconite
		150	4.44	Calcareous nodules	b: quartz b: glauconite
		200	4.26	Calcareous nodules	b: quartz b: glauconite
		250	.98	Calcareous nodules	c: quartz c: glauconite
		cloth	22.36	Clay substance including residue from above	
E9	C2	30	14.18	Calcareous glauconitic quartzitic nodules	
		60	8.52	Calcareous nodules	a: gypsum b: quartz b: glauconite
		100	15.73	Calcareous material	a: glauconite b: quartz
		150	7.26	Calcareous material	b: glauconite
		200	9.06	Calcareous material	c: glauconite c: quartz
		250	1.99	Calcareous material	
		cloth	43.27	Clay substance including residue from above	

TABLE 6. SCREEN ANALYSES OF HIGH-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E9	C3	30	46.11	Limestone fragments	
		60	7.38	Limestone fragments	
		100	5.83	Calcareous nodules	b: glauconite
		150	2.97	Calcareous nodules	b: glauconite c: quartz
		200	4.02	Calcareous nodules	c: quartz c: biotite c: glauconite
		250	1.01	Calcareous nodules	b: quartz
		cloth	32.68	Clay substance including residue from above	
E9	C4	30	1.10	Calcareous nodules	b: gypsum
		60	5.22	Calcareous nodules	a: gypsum c: glauconite
		100	7.42	Fossils and calcareous nodules	b: quartz b: glauconite
		150	18.12	Calcareous nodules	c: quartz c: glauconite
		200	19.23	Calcareous nodules	c: quartz c: glauconite
		250	2.32	Calcareous material	
		cloth	46.59	Clay substance including residue from above	
E9	C5	30	9.99	Calcareous nodules	
		60	23.39	Calcareous nodules	c: glauconite
		100	12.90	Calcareous nodules	b: glauconite b: quartz
		150	5.63	Calcareous material	b: glauconite b: quartz
		200	7.72	Calcareous material	b: glauconite b: quartz
		250	1.77	Arenaceous calcareous material	
		cloth	38.79	Clay substance including residue from above	

TABLE 6. SCREEN ANALYSES OF HIGH-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount, b: small amount, c: trace)
E10	C1	30	6.92	Calcareous nodules	b: shell fragments
		60	13.91	Calcareous nodules	b: shell fragments
		100	9.97	Calcareous nodules	b: fossils b: glauconite b: quartz
		150	5.01	Calcareous nodules	b: glauconite
		200	7.09	Calcareous material	b: quartz c: glauconite
		250	1.70	Calcareous material	a: quartz b: glauconite
		cloth	55.40	Clay substance including residue from above	
E10	C2	30	.94	Shell fragments	b: pyrite b: glauconite
		60	4.42	Shell fragments	a: quartz a: glauconite
		100	11.73	Shell fragments	a: quartz a: glauconite
		150	12.63	Shell fragments	a: glauconite b: quartz
		200	19.16	Shell fragments	a: glauconite b: quartz
		250	3.63	Shell fragments	a: glauconite b: quartz
		cloth	47.49	Clay substance including residue from above	
E10	C3	30	63.45	Limestone fragments	
		60	8.29	Limestone fragments	c: limonite
		100	7.24	Calcareous material	b: quartz c: limonite
		150	2.89	Calcareous material	b: limonite b: glauconite
		200	3.78	Calcareous material	c: quartz c: glauconite c: limonite
		250	0.96	Calcareous material	c: quartz c: glauconite c: limonite
		cloth	13.39	Clay substance including residue from above	

TABLE 6. SCREEN ANALYSES OF HIGH-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E10	C4	30	19.66	Limestone fragments	
		60	8.22	Calcareous material	b: gypsum c: glauconite c: aragonite
		100	12.97	Calcareous material	b: glauconite b: quartz
		150	7.98	Calcareous material	b: glauconite b: quartz
		200	10.16	Calcareous material	b: glauconite
		250	1.67	Calcareous material	b: glauconite
		cloth	59.34	Clay substance including residue from above	
E10	C5	30	55.63	Calcareous nodules, with glauconite embedded	
		60	10.75	Calcareous material, with glauconite embedded	
		100	7.92	Calcareous material	b: glauconite c: quartz
		150	3.90	Calcareous material	b: glauconite b: quartz
		200	5.03	Calcareous material	c: glauconite c: quartz
		250	1.35	Calcareous material	c: glauconite c: quartz
		cloth	15.42	Clay substance including residue from above	
E10	C6	30	32.99	Calcareous nodules, with glauconite embedded	
		60	5.53	Calcareous nodules	c: gypsum
		100	8.65	Calcareous nodules	b: quartz b: glauconite c: gypsum
		150	7.26	Calcareous nodules	b: fossils
		200	13.03	Calcareous nodules	c: quartz c: pyrite
		250	2.29	Calcareous material	c: quartz
		cloth	31.25	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E1	C5	30	0.89	Shell conglomerate	c: quartz c: limonite
		60	6.86	Shell conglomerate	c: quartz
		100	18.80	Shell fragments	a: glauconite
		150	19.94	Shell fragments	a: quartz b: glauconite
		200	20.52	Shell fragments	a: quartz b: glauconite
		250	2.87	Shell fragments	a: quartz
		cloth	30.12	Clay substance including residue from above	
E1	C6	30	1.66	Shell fragments	b: pyrite c: glauconite
		60	7.79	Gray clay	a: shells b: glauconite b: quartz
		100	17.74	Shell fragments	a: clay nodules b: glauconite
		150	12.40	Shell fragments	a: clay b: glauconite b: quartz
		200	15.01	Gray clay nodules	a: quartz a: shells b: glauconite
		250	2.27	Clay nodules	a: shells b: glauconite
		cloth	43.13	Clay substance including residue from above	
E1	C7	30	2.45	Shell fragments	c: limonite c: glauconite
		60	11.40	Shell fragments	a: quartz b: glauconite
		100	23.44	Quartz	a: glauconite a: shell fragments
		150	9.24	Shell fragments	a: glauconite b: quartz
		200	11.77	Clay nodules	a: shells a: glauconite b: quartz
		250	1.75	Clay nodules, glauconite	a: shell fragments
		cloth	40.65	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E1	C8	30	5.72	Shell fragments	
		60	7.33	Gray clay nodules	a: shells b: glauconite b: quartz
		100	17.60	Gray clay nodules	a: shells b: glauconite b: quartz
		150	10.01	Gray clay nodules	a: shells b: glauconite b: quartz
		200	12.75	Gray clay nodules	a: shells b: glauconite b: quartz
		250	1.72	Gray clay nodules	a: glauconite
		cloth	44.87	Clay substance including residue from above	
E5	C1	30	1.15	Shell fragments	c: quartz c: limonite
		60	4.66	Shell fragments	a: clay c: limonite b: quartz b: glauconite
		100	23.67	Shell fragments	a: clay b: glauconite
		150	13.42	Shell fragments	a: clay b: glauconite c: quartz
		200	16.04	Clay nodules	a: shells b: glauconite
		250	1.89	Clay nodules	a: shells b: glauconite
		cloth	39.17	Clay substance including residue from above	
E5	C2	30	1.42	Shell fragments	b: calcite
		60	1.39	Shell fragments	b: clay b: quartz
		100	11.22	Clay nodules	b: shells c: glauconite c: quartz
		150	8.94	Clay nodules	b: shells c: quartz c: glauconite
		200	12.07	Clay nodules	a: shells b: glauconite b: quartz
		250	2.37	Clay nodules	b: shells c: quartz c: glauconite
		cloth	62.59	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials	
				Abundance of material	Other materials a: considerable amount b: small amount c: trace
E5	C3	30	2.01	Shell fragments	
		60	13.13	Shell fragments	a: glauconite b: quartz
		100	25.21	Quartz	a: glauconite a: shells
		150	10.58	Shell fragments	b: glauconite c: quartz
		200	12.30	Shell fragments	b: glauconite
		250	2.21	Shell fragments	c: glauconite
		cloth	34.56	Clay substance including residue from above	
E5	C4	30	0.34	Shell fragments	c: pyrite
		60	3.39	Shell fragments	a: clay c: glauconite c: quartz c: lignite
		100	17.63	Gray clay nodules	b: shells b: quartz b: glauconite
		150	11.49	Gray clay nodules	a: shells b: quartz b: glauconite
		200	15.14	Gray clay nodules and shell fragments	b: glauconite
		250	1.97	Gray clay nodules and shell fragments	b: glauconite
		cloth	50.04	Clay substance including residue from above	
E5	C5	30	.54	Shell fragments	c: calcite
		60	3.09	Shell fragments	b: clay c: calcite
		100	8.10	Shell fragments	a: clay c: quartz b: glauconite c: pyrite
		150	7.70	Shell fragments	b: clay c: quartz c: glauconite
		200	14.31	Shell fragments	b: clay
		250	2.40	Shell fragments	a: clay
		cloth	63.86	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E5	C6	30	0.50	Nodules of shells	
		60	7.37	Nodules of heterogeneous material	
		100	12.83	Shells	b: glauconite b: pyrite
		150	12.58	Shell fragments	c: glauconite c: quartz c: pyrite
		200	20.99	Shell fragments	b: quartz c: glauconite
		250	2.62	Shell fragments	c: quartz c: glauconite
		cloth	43.11	Clay substance including residue from above	
E7	C1	30	1.80	Shell fragments	b: calcareous, argillaceous glauconite
		60	3.32	Shell fragments	b: pyrite b: clay b: quartz b: lignite
		100	31.07	Shell fragments	a: calcareous b: g. clay b: glauconite b: pyrite
		150	18.58	Quartz	a: calcareous b:glauconite b:limonite
		200	11.73	Calcareous argillaceous material	c: muscovite c: quartz c: glauconite
		250	1.25	Calcareous argillaceous material	
		cloth	32.25	Clay substance including residue from above	
E7	C2	30	3.62	Shell fragments	
		60	5.55	Shell fragments	b: clay b: quartz
		100	15.18	Shell fragments	a: clay c: muscovite b: glauconite b: quartz
		150	14.87	Calcareous material	a: clayey material b: glauconite
		200	16.80	Calcareous material	a: clay nodules b: quartz
		250	2.33	Calcareous argillaceous material	c: quartz
		cloth	41.65	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E7	C3	30	1.35	Shell fragments	c: clay
		60	8.09	Calcareous clay nodules	a: shells
		100	18.33	Calcareous clay nodules	b: shells b: glauconite
		150	8.02	Calcareous clay nodules	a: shells b: glauconite
		200	14.09	Calcareous material	b: clay b: glauconite c: quartz
		250	1.99	Calcareous clay nodules	c: quartz
		cloth	48.13	Clay substance including residue from above	
E7	C4	30	3.68	Shell fragments	b: limestone
		60	5.35	Shell fragments	a: limey clay b: quartz
		100	13.04	Clay nodules	a: shells b: quartz b: glauconite
		150	11.67	Shell fragments	b: clay b: quartz c: glauconite
		200	16.22	Shell fragments	b: clay b: quartz b: glauconite
		250	3.00	Clay nodules	a: calcareous material c: glauconite
		cloth	46.84	Clay substance including residue from above	
E11	C1	30	55.99	Limestone fragments, with glauconite embedded	
		60	5.94	Limestone fragments, with glauconite embedded	
		100	9.99	Calcareous material and fossils	b: glauconite b: quartz
		150	5.79	Calcareous material	b: quartz c: biotite
		200	5.68	Calcareous material	b: quartz b: glauconite
		250	1.26	Calcareous material	c: quartz c: glauconite
		cloth	15.35	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Other materials (a: considerable amount; b: small amount; c: trace)
E11	C2	30	0.52	Calcareous nodules	b: shells
		60	7.00	Calcareous argillaceous nodules	b: quartz b: shells c: pyrites
		100	24.59	Calcareous material	a: quartz a: glauconite
		150	11.68	Calcareous material	b: quartz b: glauconite
		200	13.94	Calcareous material	b: quartz
		250	2.37	Calcareous material	b: quartz c: glauconite
		cloth	39.90	Clay substance including residue from above	
E11	C3	30	74.22	Limestone fragments	
		60	4.68	Limestone fragments, glauconitic	c: pyrite
		100	4.30	Limestone fragments	b: glauconite b: quartz
		150	1.87	Calcareous material	b: glauconite b: quartz
		200	2.01	Calcareous material	c: glauconite c: quartz
		250	0.50	Calcareous material	c: glauconite c: quartz
		cloth	12.42	Clay substance including residue from above	
E11	C4	30	23.21	Limestone fragments	
		60	10.64	Calcareous material	b: glauconite b: quartz
		100	16.32	Calcareous material	a: quartz b: glauconite
		150	10.96	Quartz	a: calcareous material b: glauconite
		200	11.34	Calcareous material	c: glauconite c: quartz
		250	1.97	Calcareous material	c: glauconite c: quartz
		cloth	45.16	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Other materials (a: considerable amount; b: small amount; c: trace)
E11	C5	30	10.25	Shell fragments	
		60	7.47	Shell fragments	b: quartz b: glauconite
		100	45.39	Quartz	b: calcareous material
		150	14.03	Quartz	a: calcareous material b: glauconite
		200	8.63	Calcareous material	a: quartz b: glauconite
		250	1.56	Calcareous material	c: quartz c: glauconite
		cloth	22.57	Clay substance including residue from above	
E17	C1	30	1.43	Shell fragments	b: calcareous clay c: lignite
		60	3.96	Shell fragments	a: limey clay b: lignite c: pyrite
		100	14.03	Calcareous argillaceous nodules	a: quartz c: glauconite b: shells c: pyrite
		150	27.76	Quartz	b: calcareous material c: glauconite
		200	17.43	Calcareous material	a: quartz
		250	2.76	Calcareous material	b: quartz c: glauconite
		cloth	32.63	Clay substance including residue from above	
E17	C2	30	0.18	Shell fragments	b: pyrite c: limonite
		60	2.73	Gray clay nodules	b: shells c: pyrite
		100	9.48	Gray clay nodules	b: calcareous material c: glauconite
		150	7.58	Clay nodules	a: calcareous material b: glauconite b: quartz
		200	9.75	Clay material	a: calcareous material
		250	2.32	Clay material	a: calcareous material
		cloth	67.96	Clay substance including residue from above	

TABLE 7. SCREEN ANALYSES OF LOW-LIME SERIES (CONTINUED)

Hole No.	Sample No.	Screen No.	Percent Retained	Description of materials: Abundance of material	Description of materials: Other materials (a: considerable amount; b: small amount; c: trace)
E17	C3	30	0.83	Shell fragments	b: pyrite
		60	1.76	Shell fragments	b: pyrite
		100	6.68	Shell fragments	a: clay b: quartz b: glauconite
		150	11.89	Clay nodules	a: calcareous material b: quartz
		200	16.74	Clay nodules	a: calcareous material b: quartz
		250	1.48	Clay nodules	a: calcareous material c: quartz
		cloth	60.62	Clay substance including residue from above	
E17	C4	30	1.52	Shell fragments	a: lignite b: pyrite c: limonite
		60	4.52	Shell fragments	a: clay b: quartz b: pyrite
		100	12.68	Clay nodules	a: calcareous a: quartz b: glauconite
		150	6.29	Clay nodules	b: calcareous material c: glauconite
		200	8.98	Calcareous material	a: clay c: pyrite c: glauconite
		250	2.09	Calcareous material	a: clay
		cloth	63.92	Clay substance including residue from above	

CEMENTS

GENERAL

Cements consist of certain anhydrous double silicates of calcium and aluminum and small amounts of calcium aluminates, several of which are capable of combining chemically with water to form a hard mass. Limestone free from clayey impurities, or containing only small amounts of them, is changed to quick-lime by decarbonation. This substance has a high affinity for water and, when mixed with water, "slakes," forming a hydrate of lime. With an increase in clayey and siliceous impurities, the burned material shows a marked decrease in slaking qualities, and develops hydraulic properties, or "sets," when mixed with water, or even under water. Products of this type are called cements, and their hydraulic properties are due to the formation of certain hydrated double and triple silicates and aluminates of lime. On mixing the ground burned-rock with water, the anhydrous compounds take up the water and crystallize, thereby producing the set of the cement.

There are three general classes of cements. (1) Those formed from volcanic tufas, or artificial mixtures resembling these. These usually need the addition of lime before they have hydraulic properties. In this group are natural volcanic tufas, Pozzuolan, trass, and Santorin earth, blast furnace slags, and certain coal ashes. (2) Those which contain a large proportion of free lime, having been made by burning impure argillaceous limestone at a temperature just high enough to drive off the carbon dioxide but not to fuse the product. These include so-called "hydraulic limes" and natural or "Roman" cements. (3) Those prepared by burning to incipient fusion an intimate artificial mixture of alumino-siliceous material and powdered calcium carbonate and grinding the resulting clinker to a fine powder.[1]

No volcanic ash for use in Pozzuolan cement is worked in the United States, and only a small amount of slag cement is now made in this country. Since there are no materials for the production of this type of cement in Warren County, no further discussion will be given to the first type.

Natural cements, known also as Roman cements, quick-setting cements, and Rosendale cements, are made by burning a limestone containing from 15 to 40 percent of clayey impurities at a temperature between decarbonation and clinkering. Warren County contains large amounts of limestones from which natural cements could be made.

Most of these materials are ideal for the production of natural cements.

Portland cement is entirely an artificial product. It represents by far the most important branch of the cement industry. The materials used are limestone or marl and clay or shale rich in silica. The proportion of lime to clayey materials must be controlled within tolerably narrow limits. There are large deposits of material in Warren County that could be used in the production of Portland cement. Some of the materials need treatment to remove part of the clayey impurities. With the large amounts of water near at hand, this removal would be comparatively simple. The new flotation process so effectively employed in a plant at Valley Forge, Penna., and in a new 7,000-barrel plant at Los Altos, Calif., could be easily applied in a plant located in this area.

A comparatively new method for concentrating cement raw materials developed by Universal Atlas Cement Co., Missouri School of Mines and Metallurgy, and U. S. Bureau of Mines, in conjunction, consists of agglomeration and tabling[2]. In application, the process consists of making a wet slurry and then adding a solution of a soluble soap. The limestone particles become coated with an insoluble film of the calcium salt of the fatty acid of the soap. At the same time, the rock is treated with an oil, whereby the coated particles acquire a second film of oil. Clayey or siliceous particles acquire neither. The first step, referred to as agglomeration, is followed by tabling. Contrary to the action in ordinary tabling, in which there is simply a stratification of heavy and light particles, the oiled particles of limestone actually float and pass over the side of the table. The unoiled particles follow the riffles and come off the end of the tables. This is exactly the reverse of ordinary gravity separation.

When an excess of clay is present in a cement mix, a device used by the Southwestern Portland Cement Company at Victorville, Calif., may be successfully employed. Clay, shale, silica rock, and limestone are all dumped together into the initial crusher. The product falls below through a special feeder to a screw conveyor supplying the elevator to the hammer mills. When more clay than is necessary is found, a stream of water is turned on the material discharged by the feeder, thereby allowing the clay silt to be carried down a trough against the tendency of the screw conveyor to carry it in the opposite direction. By means of a conical screen at the end of the screw, the fine clay silt is permitted to be wasted, while any limestone or shale carried down by the water is brought back by the screw conveyor[3].

One of these processes could probably be used advantageously in the production of cement in Warren County, where at least two materials offer excellent possibilities. There are several others from which Portland cement probably could be produced with some treatment.

NATURAL CEMENTS

Natural cement is made from limestones which contain from 15 to 40 percent of clayey material, which are burned at a temperature slightly higher than that required to burn lime. The raw materials used in the manufacture of natural cements in the United States have a very wide variation in composition (Table 8).

TABLE 8. NATURAL CEMENT ROCKS OF THE UNITED STATES (PERCENT)[4]

Source	SiO_2	R_2O_3	CaO	MgO	CO_2
Georgia	22.10	7.25	24.40	12.48	32.72
Indiana	9.69	4.72	29.09	15.69	40.14
Illinois	17.01	5.74	32.85	8.45	34.12
New York	10.90	5.68	29.57	14.04	37.90
New York	23.80	8.88	22.27	12.09	31.00
Wisconsin	17.56	3.64	27.14	13.89	36.45
Virginia	17.38	7.80	34.23	9.51	30.40
Ohio	42.00	14.10	9.91	5.81	14.18
Ohio	16.41	8.82	26.05	12.55	34.32
N. Dakota	16.60	7.10	35.50	Not Given	Not Given

These cements are excellent for certain types of construction and are much cheaper than Portland cement.

Natural cements are closely allied to hydraulic lime, but differ in their refusal to slake unless ground very fine. Natural cement differs from Portland cement not only in chemical composition, but also in physical properties. The natural cements are lighter in weight, set quicker, have a lower ultimate strength, a lower specific gravity, a yellowish brown color, and greater latitude of composition.

The composition of the natural cements from different materials varies with the locality and limestone purity (Table 9).

TABLE 9. CHEMICAL ANALYSES OF NATURAL CEMENTS (PERCENT)[4]

Source	SiO_2	R_2O_3	CaO	MgO
Georgia	22.58	10.58	48.18	15.00
New York	17.17	10.80	48.28	19.13
New York	29.00	10.40	32.35	19.62
Indiana	18.92	12.96	46.90	0.97
Illinois	19.89	12.93	29.51	20.38
North Dakota	23.60	16.50	52.30	Not Given

There are three quite distinct steps in the manufacture of natural cements: namely, quarrying, burning, and grinding. In quarrying, the problem is to produce a maximum quantity of stone in pieces from 5 to 8 inches in diameter, and a minimum of smaller pieces. Pieces larger than 8 inches are liable to have unburned cores, whereas fine pieces may choke the draft of the ordinary kiln, which, except for its larger size, is similar in structures to the common lime kiln. The daily output is between 80 and 400 barrels a kiln. The temperature is very little above that required to cause decarbonization, being between 1800° and 2000° F. When it is cool, the material is ground to the fineness required, mixed with a retarder, barreled, and marketed.

Warren County contains many materials which may be used for the production of natural cement (Table 10).

TABLE 10. CHEMICAL ANALYSES OF COMPOSITE SAMPLES OF NATURAL CEMENT MATERIALS IN WARREN COUNTY (PERCENT)

Hole No.	SiO_2	R_2O_3	CaO	Ignition	Others
E 1*	28.1	9.9	31.0	25.3	6.1
E 5	25.0	8.6	34.8	26.9	5.6
E 6	39.6	5.5	34.9	26.7	3.1
E 9	10.0	5.3	45.9	36.4	3.3
E 10	9.4	5.6	46.8	36.6	3.7
E 11	32.1	6.4	33.0	25.8	3.3
E 9 (A)	13.0	8.3	42.7	33.7	3.0
E 10 (A)	17.0	6.0	39.2	33.3	3.0

*E 1 Samples used in composite: C 5, C 6, C 7, C 8. With the exception of those marked (A), all materials retained on a 250-mesh screen were ground and analyzed.

PORTLAND CEMENTS

MANUFACTURE

The definition of Portland cement, as given in the American Society of Testing Materials Specifications for Cements which became effective September 2, 1940, is as follows: "Portland cement is the product obtained by pulverizing clinker consisting essentially of hydraulic calcium silicates, to which no additions have been made subsequent to calcination other than water and/or untreated calcium sulfate, except that not to exceed 1 percent of other materials may be added, provided such materials have been shown not to be harmful by tests acceptable to Committee C-1 on Cement."[6]

The definition given by the Missouri Bureau of Geology and Mines probably comes nearer to giving the true definition of Portland cement, since it contains every detail which should be included in a strict definition: "By Portland cement is meant the finely ground product obtained by reducing the clinker produced in burning to incipient fusion intimate mixtures of finely pulverized argillaceous and calcareous materials which shall consist approximately of three parts of carbonate of lime to one part of silica, alumina and iron oxide and to which there has been made no addition greater than 3 percent subsequent to calcination."[6]

The following materials are being used at present in the production of Portland cement in the United States: marl and clay, limestone and clay, limestone and shale, chalk and clay, pure limestone and argillaceous limestone, limestone and granite, and various other mixtures of two, three, or, in a very few cases, four of these materials. The chief requirement is that the final mixture shall contain about 75 to 77 percent of calcium carbonate and about 20 percent of alumino-siliceous materials. Over 3 percent of magnesia is considered harmful, so dolomitic limestones cannot be used. Alkalies and sulfates should not exceed 3 percent.

"The raw materials must not only have the proper composition, but they also must show proper physical character, extent, and location, with respect to market and fuel supplies."[7]

The manufacture of Portland cement, depending upon several factors, necessarily varies, but twelve fundamental operations are necessary anywhere.[8]

1. Excavation of raw materials
2. Transportation of raw materials to the plant
3. Handling and storage of raw materials
4. Pulverization of raw materials
5. Accurate and thorough mixing of raw materials
6. Burning to incipient fusion
7. Cooling the clinker
8. Handling and storage of clinkers
9. Pulverization of clinker
10. Handling and storage of cement
11. Packaging and shipping of cement
12. Analysis and testing of all materials, raw and finished

If these processes are to be carried out in a profitable way, they must be done on a rather large scale, involving and requiring considerable outlay of capital for suitable deposits of raw materials, plant equipment, and a skilled operating crew.

As defined, Portland cement contains about three parts of lime carbonate to one part of silica, alumina, and iron oxide. Obviously, if a large quantity of rock having this composition could be found, the process of manufacture would be simplified and much more economical. Unfortunately, no such material in workable quantities has ever been found. It is always necessary to add one or the other constituent in a practically pure state, and more often than not, both constituents are obtained in the practically pure state and mixed in the proper proportions.

Economically, the ideal condition is one in which the removal of one raw material uncovers a sufficient amount of the other, thus avoiding additional stripping. Only once in a great while do such conditions exist. Usually the argillaceous material must be hauled to the site of the calcareous, since three-fourths of the cement is derived from the latter.

In this country, cement is usually burned in rotary kilns, 6 to 12 feet in diameter and 60 to 450 feet in length. The kiln is lined with firebrick of the most resistant type, and the speed is usually one revolution a minute. The materials are gradually brought by gravity from the upper cool end to the lower hot end, where the heat fuses them into clinker. The clinker passes from the kiln into some type of cooler. After cooling, it is carried through several grinding operations and reduced to a fine powder. The fuel is powdered coal, oil, or gas, blown into the lower end of the kiln by an air blast. The temperature varies somewhat with the materials but usually is around 2800° to 3000° F. If the temperature is too high or too low, or the material remains in the hot part of the kiln too long, the cement will be of inferior quality.

RANGE OF COMPOSITION

Certain definite proportions of lime, silica, and alumina are required to produce the best possible Portland cement. Consequently, all Portland cements have approximately the same composition, regardless of the fact that different raw materials are used.

Minimum and maximum amounts of each constituent of good Portland cement have been determined by LeChatelier and Bleininger (Table 11).

TABLE 11. LIMITS OF COMPOSITION OF PORTLAND CEMENT (PERCENT)

Constituent	LeChatelier		Beininger	
	Minimum	Maximum	Minimum	Maximum
Silica, SiO_2	21	24	19	26
Alumina, Al_2O_3	6	8	4	11
Iron oxide, Fe_2O_3	2	4	2	5
Lime, CaO	60	65	58	67
Magnesia, MgO			0	5
Sulfur trioxide, SO_3			0	2.5
Alkalies			0	3

The chemical analyses of so-called cement rocks, limestones, marls, and clays and shales, used in the manufacture of Portland cement, varies from one plant to another (Table 12).

TABLE 12. CHEMICAL ANALYSES OF PORTLAND CEMENT RAW MATERIALS[0]

Source of Material	Type of Material	Chemical composition—percent					Material Added
		SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	
Lehigh, Pa.	Cement rock	10.0	6.26		78.65	4.71	Limestone
Lehigh, Pa.	Cement rock	16.1	2.20		76.23	3.54	Limestone
Lehigh, Pa.	Limestone	3.0	0.70		92.05	2.03	Cement rock
Utah	Cement rock	21.2	8.00		62.08	3.8	Limestone
California	Cement rock	20.1	10.07	3.39	63.40	1.54	Limestone
Mid-West	Limestone	1.7	1.63	6.59	90.58		Clay
Mid-West	Clay	63.6	27.32		3.60	2.60	Limestone
Alabama	Chalk	12.1	4.17	3.28	75.07	0.92	Clay
Texas	Chalk	23.5	1.50		70.21	0.58	Limestone
Ohio	Marl	1.9	0.97		90.98	0.55	Clay
Ohio	Clay	59.1	24.01		2.2	2.00	Marl
Missouri	Limestone	0.4	0.44		96.21	0.22	Shale
Missouri	Shale	56.8	24.48	3.82	2.54	2.11	Limestone

WARREN COUNTY CEMENT MATERIALS

The materials that might be used in the production of cement in Warren County are found along the bluffs near the U. S. Engineers shops, north of Vicksburg (test holes E6, E9, and E10). Although the material tested covers a distance of over 300 yards and extends to a depth of some 20 feet, unfortunately the area is in a partly developed suburb of the city.

From each of the holes, a composite sample of the material was made and analyzed. In Hole E6, the bottom ten feet of material, which is a calcareous clay, was omitted. The composite samples from E9 and E10 were washed on a 250-mesh screen which seemed to concentrate the limey materials. However, the opposite effect was noted in E6, so the sample was analyzed as a whole. The screen residue from E9 and E10 was ground and analyzed as was the whole sample from E6 (Table 13).

TABLE 13. RATIONAL ANALYSES OF COMPOSITE SAMPLES OF LIMESTONES FROM WARREN COUNTY (PERCENT)

Hole No.	E 6	E 9	E 10
Silica, SiO_2	18.0	10.0	9.4
Alumina and Iron, R_2O_3	5.0	5.3	5.7
Calcium carbonate, $CaCO_3$	72.5	82.0	83.5
Others	4.5	2.6	1.4

There are large deposits of loess in the immediate vicinity that offer possibilities in case an argillaceous material is required. At least one ledge of almost pure limestone is found in each test hole, in case a pure calcareous material is required.

The only difficulty that might become a problem is the non-uniformity of the deposits. The beds, according to the test holes, consist of alternate ledges of limestone and clayey marl. Some method of balancing the amounts of limestone and marl would have to be worked out in order to produce Portland cement from these deposits.

A study of the screen analyses and microscopic examinations of these materials (Tables 6 and 7) reveal that about two-thirds of the total, that is, that part retained above 250-mesh, is composed of limestone and shell fragments and calcareous nodules, containing small amounts of glauconite and quartz and traces of limonite, gypsum, pyrite, and biotite. The remainder is a clay substance including the residue from the materials listed above. None of these minerals in the amounts found would be harmful in the manufacture of Portland cement.

The material is not extremely hard, so it may be easily crushed for use in either the wet or dry process.

The Louisiana gas and oil fields are nearby, as is the new Mississippi oil field, assuring a constant source of cheap fuel.

Undoubtedly, a cement plant in Vicksburg would be a very profitable enterprise, if the raw materials described could be secured for a reasonable cost. Their location makes this cost the main factor to be determined before any promotion work can be started.

MINERAL WOOL

GENERAL

Mineral wool is the mining industry's fastest growing product. The insulation industry has only recently come to the forefront along with air-conditioning. The present building activity has brought the problem of insulation directly before the construction world, and mineral wool is the perfect solution to the problem. This industry is just beginning to have a present; the future is most certainly important.

In 1788, the United States Government sent out a group of scientists who happened to visit the crater of Kilauea in Hawaii. As they climbed the volcano, they noticed a soft, wooly material that floated in the air and caught on foliage or rocks. According to the Hawaiian folklore, when the goddess of the volcano, Pele, became angry, she plucked out her hair by the handful and threw it out of the cråter. Hence, the material was known as Pele's hair. The scientists found that Pele's hair was formed by jets of steam blowing through the molten lava. Samples were brought back and a process devised for making the material, but no plants were set up. Not until 1897 did C. C. Hall of Alexandria, Indiana, set up the first successful and continuous manufacturing plant for rock wool.

Mineral wool is a fibrous material having the appearance of loose wool or cotton. It is chiefly glassy material consisting of calcium and aluminum silicates. The term, mineral wool, covers the entire field of the insulation wools, including rock wools, slag wools, and glass wools or glass silk. The name of each of these implies the raw material used in its production; that is, rock wool is made from limestone, dolomite, shale, clay, and sandstone or quartz; slag wool is produced from furnace slags; and glass wools are manufactured from the same raw materials as that required for making glass.

The same principle of blowing the molten material with steam jets as used by nature at Kilauea has been applied in the production of the artificial wools. A stream of molten rock, slag, or glass is directed to a jet of either steam or air, where it is blown into a mass of fine globules that are propelled through the air at high speed. Air friction causes the globules to be drawn out into fine threads which cool and solidify into wool fibers.

If the conditions are not right, part of the globule will not be stretched into a thread and will harden into "shot." Examination of most wools will show small particles of shot throughout the mass.

Commonly, the raw materials are melted in water-jacketed steel cupolas by placing alternate layers of crushed rock and coke in the cupola. Other types of furnaces used are: reverberatory, oil fired; reverberatory, gas fired; and electric, having electrodes immersed in the molten mass.

"Many factors must be more or less rigidly controlled to assure a finished product that will meet the rapidly narrowing limits of consumer requirements. The first of these is the chemical composition of the raw materials, which exhibits a wide range. It has been proved experimentally that a combination of pure calcium carbonate and silica without other ingredients can be blown into wool. However, all manufacturing plants use alumina in some form, and in most mixtures some magnesia is present. Some operators attempt to achieve and maintain a chemical balance between acids and bases. Others contend that this is not necessary and that better wool results when there are more acids than bases, or vice versa. It is sufficient here to point out that similar chemical compositions in the furnace charge may be obtained by combining two, three, four, or more of a large number of natural or waste materials and that the chemical composition of the charge is reflected in the chemical composition of the wool."[10]

The insulating properties of any material depend upon low heat conductivity and low bulk density. Therefore, it seems that the necessary approach in the study of rock wool would consist of producing samples of wool under various known conditions and measuring the heat conductivity and density. However, the two properties are very dependent on each other and are extremely susceptible to variations in preparation of the wool for use.

The properties which must be taken into account when evaluating the quality of rock wool are of two types: namely, fiber characteristics and chemical considerations. The constancy of the average diameter of the fibers is a convenient index of the characteristics of rock wool. Chemical considerations, usually taken into account, affect the stability and color. Rock wool shows two types of stability: namely, resistance to devitrification when subjected to high temperature, and resistance to hydrolysis which yields corrosive or obnoxious substances. As for color, the four major components regardless of proportions produce a pure white rock wool; but small amounts of certain impurities seriously affect the color. Iron oxide in fairly large quantities has but little effect on the color. Small amounts of manganese produce little color. Sulphur alone, or with small amounts of manganese, produces no color, but in the presence of iron oxide, it produces a deep brown. Small amounts of pyrites and gypsum have marked effects on the color. However, if the materials containing these impurities in small amounts are subjected to strong, prolonged heating, white wools may be produced.

Other variables which have an effect on rock wool are: pouring temperature, length of fall of the molten stream, pressure across the steam nozzle, design of the nozzle, pouring rate, and the medium, compressed air or steam, used for blowing.

RANGE OF COMPOSITION

The most necessary information in the evaluation of a raw material deposit in any area is an accurate knowledge of the composition limits of both finished product and raw materials. A study of this type was undertaken by the Illinois Geological Survey in 1934, and the results were incorporated in Bulletin No. 61 of that Survey.

In this study, it was found advantageous to consider rock wool composition in terms of a four-component system consisting of silica, alumina, lime, and magnesia. All other substances were considered impurities.

Previous to this study, very little information on the limits of composition of raw materials for rock wool production was available. Herbert Lang[11] made some study of the problem in 1923. The first attempt to set definite limits on the main constituents was made by Thoenen[12] in 1929. In the same year a German, Guttmann, published limits of composition of slag wools. Goudge[13] in 1931, and Logan[14] in 1932, published limits of the main components as found from investigations carried on by the Canadian and Indiana Geological Surveys, respectively. The limits were closely determined by experimental work of the Illinois Geological Survey, using prepared synthetic mixtures of amorphous silica, aluminum hydroxide, pulverized limestone, and hydrated magnesium carbonate (Table 14).

TABLE 14. CALCULATED LIMITS OF ROCK WOOL COMPOSITION (PERCENT)

	Thoenen	Goudge	Logan	Ill. Geol. Survey
SiO_2	39-47	33-45	22-50	35-65
R_2O_3	13-16	13-21	5-16	0-33
CaO	21-33	21-31	21-68	5-50
MgO	11-17	13-19	4-19	0-32

Of course, the table contains compositions from which satisfactory rock wools cannot be produced. As a rule, however, any material having a composition within the limits given by the Illinois Geological Survey offers distinct possibilities as a raw material for the production of rock wool.

In prospecting, a quick test is necessary to eliminate unlikely raw materials for rock wool. A valuable index is the carbon dioxide content of the sample. If this be found to be between 20 and 30 percent, the material is a potential wool rock. The validity of this test may be established by comparison with experimentally determined limits of composition.

The analyses of the raw materials of several wools were compiled for study and comparison with materials from Warren County. Included in this study of materials are typical analyses of finished commercial rock wools (Table 15).

TABLE 15. CHEMICAL ANALYSES OF RAW MATERIALS OF ROCK WOOL AND OF FINISHED WOOLS

Source	Type of Material	Chemical Analyses (percent)				
		SiO_2	R_2O_3	CaO	MgO	Others
Thoenen	Slag	38.0	12.0	28.0	19.0	3.0
Thoenen	Rock	36.0	24.0	37.0	2.0	1.0
Thoenen	Rock	21.0	10.0	59.0	8.0	2.0
Thoenen	Rock	40.0	18.0	22.5	16.0	3.5
Thoenen	Rock	50.0	13.0	17.0	12.0	8.0
Thoenen	Shale	33.0	29.0	30.0	6.0	2.0
Goudge	Rock	32.8	13.7	30.2	18.1	5.2
Goudge	Rock	28.0	16.0	42.0	10.0	4.0
Goudge	Rock	38.0	18.0	30.0	13.0	1.0
Ill. Geo. Surv.	Dolomite	40.4	13.2	24.0	19.0	3.5
Ill. Geo. Surv.	Rock (1)	40.1	13.4	41.7	3.7	1.1
Ill. Geo. Surv.	Rock	48.9	4.8	42.4	3.9	0
Ill. Geo. Surv.	Rock	54.1	6.6	35.1	3.7	0.5
Goudge	Wool	38.1	14.5	28.2	16.3	3.2
Ill. Geo. Surv.	Wool	44.0	12.2	41.8	0.6	1.4
Ill. Geo. Surv.	Wool	36.9	20.9	33.8	7.8	0.6
Thorndyke	Wollastonite	47.12	1.6	41.7	2.7	Not Given
Nordberg	Rock	38.4	19.3	28.0	12.7	1.1

WARREN COUNTY ROCK WOOL MATERIALS

Many materials found in Warren County are ideal for the manufacture of rock wool (Table 16).

TABLE 16. ANALYSES OF WARREN COUNTY WOOL ROCKS, CALCINED BASIS (PERCENT)

Composite Sample From Hole No.	SiO_2	R_2O_3	CaO	Others
(A) E 1*	37.55	13.22	41.50	6.99
(B) E 1*	42.5	16.5	34.0	7.0
(A) E 5	34.20	11.78	47.60	6.51
(B) E 5	44.0	18.0	31.3	7.0
(A) E 6	40.70	7.46	47.60	1.91
(B) E 6	40.0	8.0	48.7	3.0
(A) E 7	52.80	7.46	35.99	4.23
(B) E 7	55.8	10.5	28.5	5.0
(A) E 9	15.70	8.38	72.00	3.44
(B) E 9	18.5	11.4	65.7	4.0
(A) E 10	14.80	8.81	73.39	3.31
(B) E 10	21.8	14.8	60.0	3.5
(A) E 11	43.40	8.68	44.63	3.20
(B) E 11	44.0	9.0	43.6	3.5
(A) E 17	56.55	14.95	25.72	3.42
(B) E 17	62.0	20.0	15.0	3.0

*E 1 Samples used in composite: C 5, C 6, C 7, C 8
(A) Washed through 250-screen, residue ground and analyzed.
(B) Whole sample ground and analyzed.

A comparison of the analyses and the limits of composition (Table 16) shows that all these materials offer excellent possibilities for use in the manufacture of rock wool. The possible exceptions are materials from holes E 9, E 10, and E 17. By addition of small amounts of loess to E 9, and E 10, the silica content may be raised slightly and lime somewhat lowered. If a small proportion of lime is added to E 17, this rock will produce a good wool.

All of these materials contain small amounts of sulfur, usually in the form of pyrite. However, this need not be detrimental, as shown by Fryling in his experiments on color in the Illinois Geological Survey laboratories[15]. This sulfur may be burned out by slightly longer or stronger heating of the molten rock, and a good white wool can be produced. The iron and manganese do not affect the color when sulfur is not present.

A study of the physical characteristics of these materials (Tables 6 and 7) shows that they contain no harmful materials other than the pyrite already mentioned. The softness of the materials makes the problem of crushing very simple.

With the exception of test holes E 6, E 9, and E 10, all materials described are located so that the cost is a minor factor. These three holes are on properties in a rapidly growing suburb of the city of Vicksburg, whereas all others are on properties far enough from the city to be reasonably obtained but not so far that transportation would be a problem.

The reverberatory type of furnace would probably be required to produce rock wool from the Warren County materials. Since large amounts of the material are in a finely divided condition, the cupola type furnace would quickly become clogged and would, therefore, be useless. If the cupola is to be used, the raw materials must be either in small lumps or must be briquetted. With the Louisiana oil and gas fields and the Mississippi oil field so close to this section, a cheap source of fuel is assured. The best way to use these types of fuel in the production of rock wool is in the reverberatory type furnace. The proper control of such a furnace using Warren County materials would produce excellent quality white wools.

SAND-LIME BRICK

Although sand-lime brick are a comparatively new building material in America, they are not a new product. It is known that they were used in the buildings of Solomon's time, some of these same brick being still preserved in the British Museum in London. For centuries, the industry was small, and it did not grow until late in the 19th century. The first patent on the process was taken out by a German, Dr. Michaelis, in 1880. After his patent expired, there was a rush to get into the "new" industry.

The first sand-lime brick plant in this country was founded at Michigan City, Ind., in 1901. However, because of poor equipment, the plant did not flourish. Later the same year a plant with proper equipment and management was opened at Saginaw, Mich. This plant is still in operation.

In many regions, clay of the type required to make good brick is very scarce or cannot be found at all. In a country where there is little clay, there are usually large amounts of sand, some of which is of good quality. The ability to make brick from sand has been a decided advantage to the people in these areas. Because of the durability, strength and beauty of these bricks, they are rapidly cutting into the market of the clay brick industry.

Sand-lime brick are made by mixing clean, ground sand with 5 to 20 percent of slaked lime, molding the mixture in a pressure brick mill, and placing the molded brick under a steam pressure of 125 to 150 pounds to the square inch from four to six hours. These brick are strong, durable, and almost waterproof (Table 17).

TABLE 17. COMPARISON OF PROPERTIES OF BRICK[19]

Type of brick	Clay		Sand-lime
	Soft-burned	Hard-burned	
Absorption, percent, 48 hrs.	14.75	11.76	10.75
Crushing test lbs./sq. in.	1750	2090	2330
Transverse test lbs./sq. in.	29	73	78
Freezing test: Elastic limit			
frozen and dried out			3430
not frozen			2490

Sand-lime brick manufactured at Savannah, Ga. are reported to have a dry compression strength of over 5000 pounds to the square inch.[20]

Under the action of the high pressure steam, the lime combines with some of the silica of the sand to form calcium silicates which are excellent bonding materials. The remainder of the sand acts as a filler. There are few voids in this material, the brick being a solid, impervious block of tiny sand grains cemented together.

There are plenty of materials in Warren County for the production of these bricks. The almost pure limestone ledges could be profitably used in this process as a source of lime (Table 18). There are hundreds of sand bars in and around the Yazoo and Mississippi Rivers that the flood control engineers would be glad to have removed. These clean, washed sands would be ideal for this process because they would give a very white brick.

TABLE 18. LIMESTONES OF WARREN COUNTY
(THICKNESS IN FEET; $CaCO_3$ IN PERCENT)

Sample No.	Thickness	$CaCO_3$
E6, C1	3.4	79.5
E6, C6	4.1	82.5
E9, C1	2.8	84.8
E9, C3, C4	8.0	85.6
E10, C3	2.8	86.1
E11, C1	4.7	74.0
E11, C3	4.6	77.2

AGRICULTURAL LIME

The benefits of lime to soils and crops are well known to most farmers, but the return of lime to the land in humid regions of the United States nowhere approaches the loss of lime from leaching and cropping. In most regions, abundant deposits of limestone, chalk, oyster or clam shells, marl, or marble are near at hand. Also, facilities for testing soils for acidity and lime content are furnished at numerous experiment stations as is information on methods of preparing and applying the lime to the soil. In spite of all this, the loss continues on most farms.

To maintain the proper amount of lime in American soils would require about 33 million tons annually, or about 10 times the total amount of lime sold in the entire country in 1938.[21] In that year, only 2 million tons of lime were applied to soils. Comparatively little liming is done in the South, although the loss each year is great on account of the heavy rainfall.

The farmer can often increase his crop yields by liming alone; and by liming along with cultivation of legumes, the fertility of the soil can be increased for future crops. Lime is one of the big three—"lime, legumes, and livestock"—so effectively used in improving and conserving soil fertility.[22]

All soils do not need lime for the same reason. Some soils are benefited through neutralization of free acid, some by remedying a deficiency of plant-food calcium, and some by improvement of physical condition. A few cases have been found where soils apparently have enough calcium to do all three, and yet the soil is acid in character. In these cases, the lime has been found to be present as the sulfate rather than the carbonate. In this form, of course, the acidity is not neutralized so the indicated procedure is the addition of more lime in the form of carbonate, hydroxide, or oxide.

Lime may be applied as quicklime (CaO), as hydrated lime ($Ca(OH)_2$), as lime carbonate ($CaCO_3$), or as dolomitic limestone ($CaCO_3.MgCO_3$). The first two forms, quicklime and hydrated lime, are not as beneficial as the last two, since they cause humus or vegetable matter to be rapidly converted into soluble salts, which are carried away by percolating water. The element, nitrogen, so vital to plant growth, becomes quickly depleted. Various experiment stations have found that lime carbonate gives decidedly better results than any other material used as a source of lime for agricultural purposes. It has been conclusively demonstrated in Maryland, Pennsylvania, New York, Ohio, Tennessee, Illinois, and New Jersey that ground limestone is an efficient and economical aid to crop production.

There are five general types of soil cultivated in Mississippi—each requiring a definite amount of lime for optimum fertility (Table 19).

TABLE 19. SOIL TYPES AND LIME REQUIREMENTS

Type of Soil	Lime required[1]	
	Per cent	Lbs. per acre
Clay	1.0	20,000
Silty clay	0.5	10,000
Sandy clay	0.4	8,000
Silty loam	0.3	6,000
Sandy loam	0.3	6,000

[1]Basis: 7 in. soil or 2,000,000 lbs. per acre.

The soils of Mississippi were tested and classified by W. N. Logan—Agricultural Experiment Station Technical Bulletin No. 7—who divided the state into ten regions, each representing a definite type. A study of the condition of the soils of the state with respect to their lime content has been compiled from this bulletin (Table 20). Sub-soils were included in order to determine whether lime is available underneath the usually cultivated portion of the soil.

From Logan's map, it is readily seen that part of the Shortleaf Pine region and all of the Longleaf Pine and Brown Loam and Loess regions are within practical hauling distance of the Warren County limestones. All of these areas need lime in some form. Also, the

Yazoo basin is within easy reach, and any alfalfa grown in that region requires considerably more lime than the soil contains. For that matter, the only soils in Mississippi that require no lime additions for alfalfa are in the Northeast Prairie and in the Central Prairie.

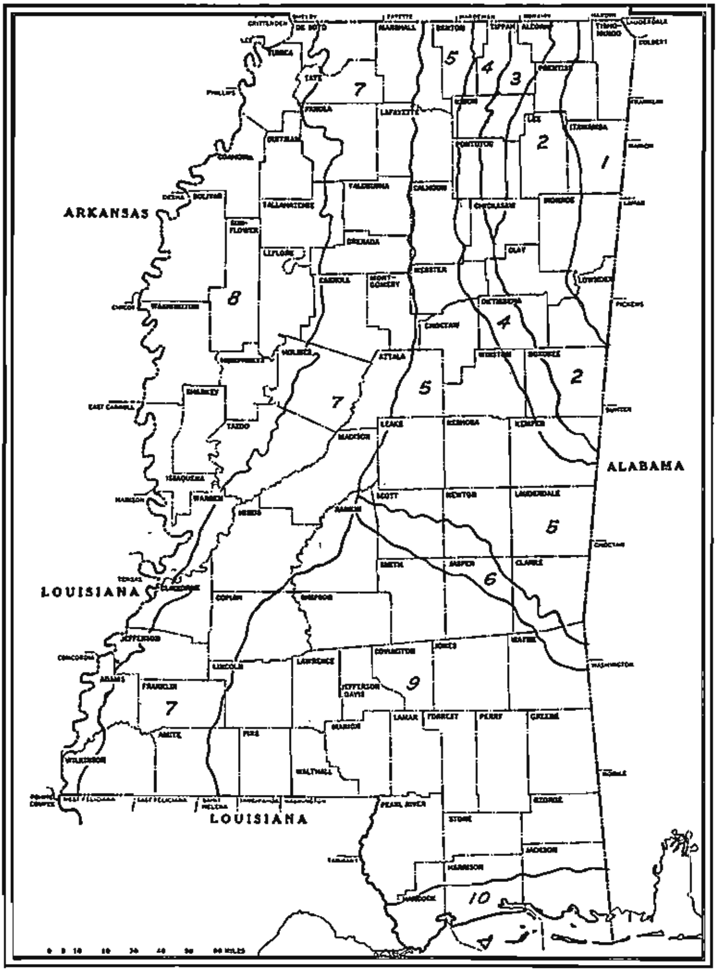

Plate 5.—Soil areas of Mississippi

1. Northeast Highland
2. Northeast Prairie
3. Pontotoc Ridge
4. Flatwoods
5. Shortleaf Pine
6. Central Prairie
7. Brown Loam-Loess
8. Yazoo Basin
9. Longleaf Pine
10. Coastal Region

(Mississippi Agricultural Experiment Station Tech. Bull. 7)

TABLE 20. SOIL TYPES AND LIME CONDITIONS OF MISSISSIPPI

Region	Soil	Type	Lime percent		Treatment needed
			Average	Optimum	
Northeast Highland	Upland residual	Gray sandy loam	0.15	0.3	Two to three tons ground limestone per acre, followed by legume crop
Northeast Highland	Upland subsoils	Red sandy clay	0.12		
Northeast Highland	Lowland alluvial	Gray sandy loam	0.385	0.3	One ton ground limestone with same amount rock phosphate per acre
Northeast Highland	Lowland subsoils	Gray silty loam	0.17		
Northeast Prairie	Upland residual	Clay	2.60	1.0	No lime needed
Northeast Prairie	Upland subsoils	Silty clay	7.19		
Northeast Prairie	Lowland alluvial	Clays and sandy loam	2.32	0.5-1.0	No lime needed
Northeast Prairie	Lowland subsoils	Black clay	0.57		
Pontotoc Ridge	Residual	Red clay Sandy loam	0.165	1.0 0.3	Two to four tons limestone per acre to improve fertility and physical condition
Pontotoc Ridge	Subsoils	Red clay	0.181		
Flatwoods	Upland residual	Clays and silty clay	0.28	0.5-1.0	Soil has about one-fourth enough lime. Fertility and condition could be improved
Flatwoods	Upland subsoils	Clay	0.55		
Flatwoods	Lowland alluvial	Clays and silty loam	0.17	0.5-1.0	Two to four tons limestone and a legume crop would produce an excellent soil
Flatwoods	Lowland subsoils	Gray clay	0.6		
Shortleaf Pine Area	Upland residual	Sandy loam	0.203	0.3	Contains considerable sulfate; is probably acid; two or three tons limestone needed
Shortleaf Pine Area	Upland subsoils	Sandy clay	0.15		

TABLE 20. SOIL TYPES AND LIME CONDITIONS OF MISSISSIPPI (CONTINUED)

Region	Soil	Type	Lime percent		Treatment needed
			Average	Optimum	
Shortleaf Pine Area	Lowland alluvial	Silty loam	0.162	0.3	Liming is a necessity to these soils; some are strongly acidic
Shortleaf Pine Area	Lowland subsoils	Silty clay	0.113	0.5	
Central Prairie	Residual	Black clay	2.71	1.0	No lime needed
Central Prairie	Residual subsoils	Yellow clay	0.304		
Central Prairie	Post-oak soils	Clay	0.312	1.0	Lime is present as sulfate; soil is acidic; considerable lime needed
Central Prairie	Post-oak subsoils	Clay	0.497		
Brown Loam and Loess	Loess	Silty loam	0.264	0.3	Lime is generally low; one to three tons per acre should be added
Brown Loam and Loess	Subsoils	Clay loam	0.138		
Yazoo Basin	Loams	Sandy and silty loam	0.434	0.3	Lime is adequate except for alfalfa
Yazoo Basin	Clays	Buckshot—black clay	1.205	1.0	Lime is adequate except for alfalfa
Longleaf Pine Area	Upland residual	Sandy loam	0.209	0.3	Soil is acidic; needs lime to neutralize acidity
Longleaf Pine Area	Upland subsoils	Sandy clay	0.226		
Longleaf Pine Area	Lowland alluvial	Sandy loam	0.270	0.3	Soil is slightly acid; needs lime to neutralize and improve physical condition
Longleaf Pine Area	Lowland subsoils	Clay loam	0.225		
Gulf Coast Area	Alluvial	Sandy loam	0.193	0.3	Only lime here is derived from shells; more lime needed
Gulf Coast Area	Subsoils	Sandy loam	0.360		

In addition to lime, several Warren County limestones contain small amounts of phosphorus, manganese, potash, and magnesia, all of which are necessary to plant growth. Therefore, by using these limestones as a source of lime, the soils would also be enriched in other vital plant foods.

"Where cotton is grown and non-acid forming fertilizers are used, lime probably isn't needed on most soils in Mississippi. However, the use of superphosphate might be reduced if the soils were limed.

"The black prairie soils in the Northeast and Central Prairie belts do not need lime. Many of the Delta soils do not need lime. Probably 67 to 70 percent of the other soils need lime for legumes, for hay, and for pasture.

"As a rule, better results are being obtained with 500 to 750 pounds of lime per acre than with larger amounts. On certain soils as high as 4 tons per acre may be used safely. However, 2000 pounds per acre on light soils may be harmful."[23]

" . . . a deposit of limestone in Warren County should certainly be of interest to people along the east side of the Delta. The west side of the Delta, . . . is already sufficiently well stocked with lime that alfalfa and such crops can be grown without further treatment. Limestone and slag are both used to a limited extent along the east side of the Delta in the growing of both summer and winter legumes."[24]

The Warren County limestones and marls are especially adaptable for use as agricultural lime, because they can be easily crushed to the necessary fineness.

ANALYTICAL PROCEDURE

As an index, it was necessary to run preliminary tests on all samples. Representative samples of each were taken, ground to pass a 100-mesh screen, and tested for ignition loss and carbon dioxide content. Preliminary tests showed that the samples contained little magnesia, so an approximation of the calcium carbonate content and subsequently, the calcium oxide content, was possible (Table 1). The ignition loss determinations were made on one gram samples, heated for one hour in a platinum crucible over a blast lamp. The carbon dioxide determinations were made with a Bunsen alkalimeter. As a check against this method, several determinations were made by absorption of the CO_2 in an ascarite tube. Results were found to agree extremely well.

After studying this data, it was thought best to try to remove some of the argillaceous materials from the samples by washing. Then, too, since few sections were thick enough to be of value alone, composites, representing the entire thickness of the beds of each test hole, were made. These composite samples were washed through a 250-mesh screen. The amount of each retained and passed was determined (Table 4). The material retained was ground to pass a 100-mesh screen and a complete chemical analysis was made.

The procedure followed in the chemical analysis was as follows:

Ignition loss: One gram of each sample was heated in a platinum crucible at full heat of a blast lamp for one hour.

Silica: The ignited samples were fused with about 8 grams of anhydrous sodium carbonate, and the fusion dissolved in dilute hydrochloric acid. Double dehydrations of the silica with hydrochloric acid were carried out in all cases. The silica was filtered out, ignited, weighed, volatilized by hydrofluoric acid, and the crucible reweighed. SiO_2 was found by difference.

Alumina: Alumina, iron, and titania were precipitated together as hydroxides by ammonium hydroxide in the presence of ammonium chloride. Double precipitations were found necessary to remove manganese, lime, and magnesia. The mixed hydroxides were filtered out, washed free from impurities, ignited, and weighed. This weight is the total of alumina, iron oxide, and titania. The mixed oxides were fused with sodium pyrosulfate and dissolved in water. In a few cases, small amounts of silica were recovered here by filtration, ignition, and volatilization with hydrofluoric acid. Accordingly, this was added to silica and subtracted from alumina.

Iron oxide: An aliquot of the solution of the bisulfate fusion was reduced with 20-mesh special zinc and sulfuric acid, and titrated with standard potassium permanganate solution standardized so that percent of Fe_2O_3 equals cubic centimeters of solution used.

Titania: Another aliquot of the solution of the bisulfate fusion was placed in a tube of a colorimeter of the Schreiner type. The standard was made up so that the length of the standard column divided by the length of the unknown column gave percent of titania.

The total of iron and titania was subtracted from the total of alumina, iron, and titania to leave the alumina.

Manganese: The first filtrate in the alumina determination was buffered by acetic acid and sodium acetate and a small amount of bromine added. MnO_2 was precipitated, filtered out, ignited, and weighed.

Lime: The filtrate from manganese determination was treated with oxalate in the presence of ammonium acetate in alkaline solution. Lime was precipitated as the oxalate, filtered out, ignited, and weighed.

Magnesia: Magnesia was determined in the lime filtrate by precipitation as the mixed ammonium phosphate. It was ignited and weighed as $Mg_2P_2O_7$.

Alkalies: Alkalies were determined by the J. Lawrence Smith method as outlined in Scott "Standard Methods of Chemical Analysis."

Sulfur: Sulfur was determined in a separate sample by carbonate-nitrate fusion, solution in water, oxidation to SO_4 with bromine, and precipitation with 10 percent barium chloride solution. The precipitate was weighed as $BaSO_4$. The percentages of sulfate were not included in totals of analyses, because they were also included in ignition loss.

Phosphorus: A separate 10-gram sample was treated with hot hydrochloric acid, filtered, neutralized with ammonium hydroxide, acidified with nitric acid, and precipitated as ammonium phosphomolybdate. This was filtered into a Gooch crucible, dried, and weighed.

Duplicate analyses were made of each material and the average was reported (Table 2).

For convenience, these data were reduced to a calcined basis (Table 3).

After further study, it was found necessary to have analyses of the whole composite samples. Accordingly, determinations were made of silica and of alumina, iron oxide, and titania, all together. The weighed average of ignition loss, and calcium oxide content were used from Table 1. The results were calculated to a calcined basis (Table 5).

The procedure for the screen analysis was as follows:

A quantity of material from each quartered sample was dried at 110° C. to constant weight, after which exactly 100 grams were blunged in approximately two liters of water by pouring the slip back and forth until all the substance had apparently disintegrated.

The disintegrated sample in slip form was poured through a nest of Tyler standard screens, the sizes being 30, 60, 100, 150, 200, and 250 mesh. The material passing through the 250-mesh screen was caught on a cloth in a plaster vat. After a fair sample was caught on the cloth, the screens, still in nest, were washed with a stream of water until no further material passed through the screens.

The screens were dried at 110° C., after which the residue from each screen was weighed and collected in glass vials for further study.

It is evident that the above treatment would not completely disintegrate all clay nodules, and though this could have been accomplished by blunging with rubber balls, it was not the purpose of this screen analysis to break the clay down to a finer state of division than would ordinarily occur in the usual commercial blunging procedure, which indicates that a very thorough blunging will be necessary to completely disintegrate the clay.

The residue from each screen was examined carefully under a binocular microscope. The finer material was examined under a petrographic microscope. Determinations were made from the physical appearances of mineral grain and crystal form, corroborated by use of physical properties tests, magnetized needle, reactions to wet reagents, and, where grain size permitted, blow pipe analysis (Table 6 and 7).

Undoubtedly, there were minerals present in the materials that could not be distinguished under the microscope, because of their fine state of division. However, those that have been recorded were definitely identified.

Terms used in the tables of screen analyses for describing quantity of residue are: "abundance," meaning one-half or more of residue on screen; "considerable quantity," between one-fourth and one-half; "small amount," less than one-fourth; "trace," few grains scattered throughout residue.

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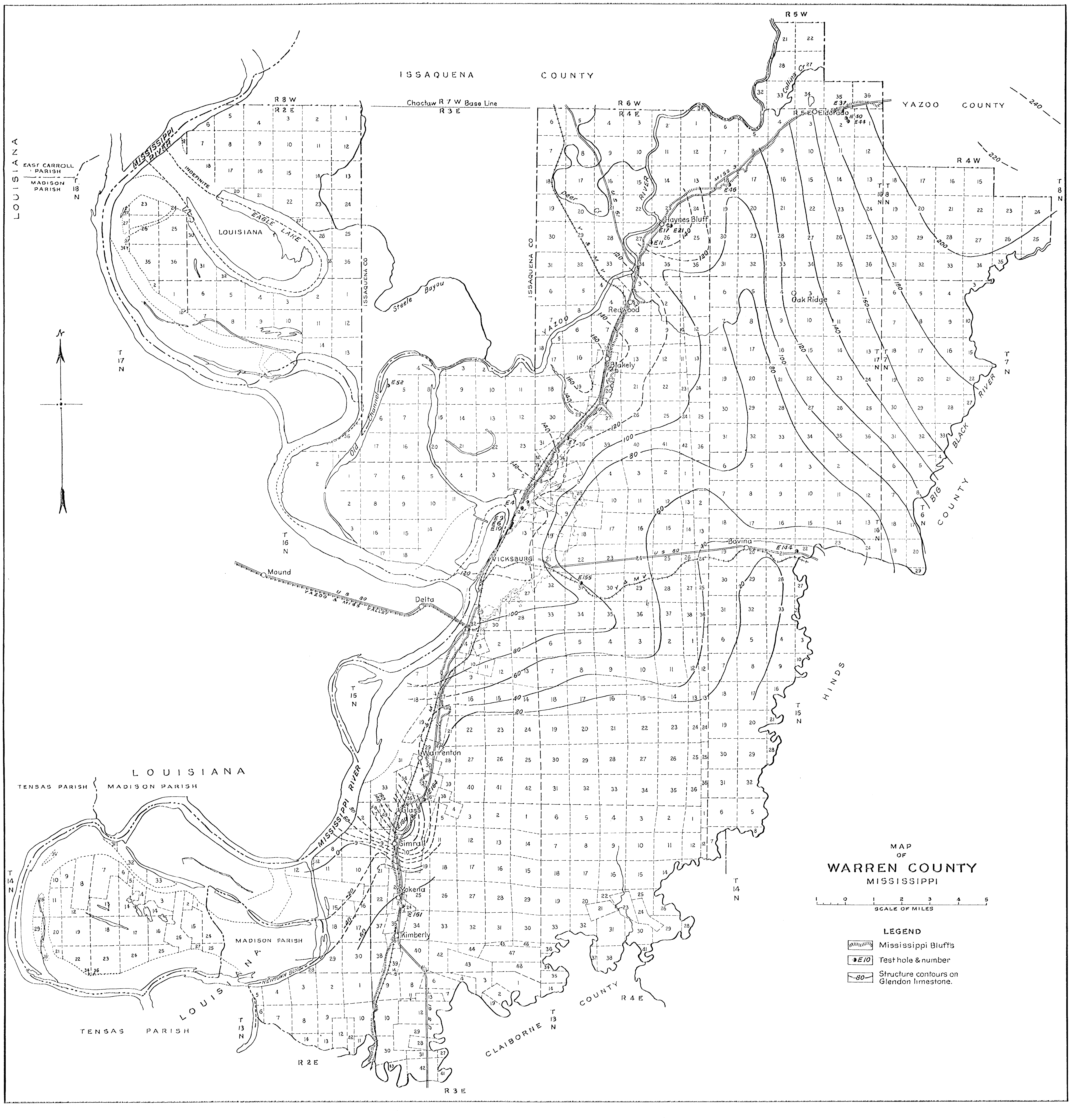
MAP
OF
WARREN COUNTY
MISSISSIPPI
SCALE OF MILES
LEGEND
Mississippi Bluffs
Test hole & number
Structure contours on Glendon limestone.
ISSAQUENA COUNTY
YAZOO COUNTY
HINDS
CLAIBORNE COUNTY
LOUISIANA
EAST CARROLL PARISH
MADISON PARISH
TENSAS PARISH
Choctaw R 7 W Base Line
MISSISSIPPI RIVER
YAZOO RIVER
BIG BLACK RIVER
EAGLE LAKE
Steele Bayou
Old Channel
Haynes Bluff
Eldorado
Redwood
Oak Ridge
Blakely
Vicksburg
Bovina
Mound
Delta
Warrenton
Glass
Simrall
Yokena
Kimberly
R 5 W
R 8 W
R 2 E
R 3 E
R 6 W
R 4 E
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