Mississippi Geologic Research Papers-1962

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MISSISSIPPI GEOLOGICAL ECONOMIC AND TOPOGRAPHICAL SURVEY

FREDERIC FRANCIS MELLEN

DIRECTOR AND STATE GEOLOGIST

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ACKNOWLEDGMENT

The sponsorships of the 1962 Geological Research Paper Contest by the following companies and agency have made possible this volume:

Bass Pecan Company
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Mississippi Industrial & Technological Research Commission

For their extra effort in providing financial support and for their encouragement of our investigation of Mississippi's valuable mineral resources we are deeply grateful.

Mississippi Geological Economic and Topographical Survey

LETTER OF TRANSMITTAL

Office of the Mississippi Geological Economic and
Topographical Survey
Jackson, Mississippi
April 2, 1963

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

Gentlemen:

Pursuant to the authority granted by the Board, the Mississippi Geological Survey conducted a Geologic Research Paper Contest for the purpose of stimulating among geologists the development of ideas pertaining to economic geology of Mississippi. As a result of this contest, Mr. Marshall Keith Kern, a staff geologist, was the winner of the $500.00 first prize for his paper, "Economic potential of alumina-rich clay and bauxite in Mississippi."

The other papers were not entered in the contest and although some of them are not economic in nature, all of them are geologic research papers and will be of great use to the Geology Departments of our Universities and to other students of geologic science in Mississippi.

Mr. Moore, another staff geologist, prepared his paper on studies that he had made for the Survey and which was earlier presented before the Gulf Coast Association of Geologic Societies with the approval of the Board and the Survey Director. This paper, as well as the paper by Mr. E. H. Rainwater, should be thought-provoking to those exploration geologists, geophysicists and others interested in finding oil and natural gas in Mississippi.

The two papers by Leslie Hubricht give lists of the species of snails from the loess of the Bluff Hills in western Mississippi extending from the Louisiana line to the Tennessee line at Memphis. These lists are the first that have been published by the Survey.

In Mississippi one of the great problems that has serious economic import is that of obtaining firm foundations for highways and buildings. Serious damage has resulted at Clarksdale, Mississippi, and in other places, because of sinking of alluvial soils. This paper was the result of a study made some years ago by Tracy W. Lusk. The paper should point out some of the hazards of construction in the Delta area of Mississippi where there has been excessive drying or desiccation of the alluvial clays, in part caused by heavy pumpage from shallow alluvial water sands.

The Director feels that Bulletin 97 is a very creditable contribution, made possible directly by interest developed through the contest. It is the Director's sincere desire to see the Survey continue this type of contest each year. Without contributions from outside sources this bulletin would not have been possible. We recommend that this group of papers be published as Bulletin 97 of the Survey.

Respectfully submitted,
Frederic F. Mellen
Director and State Geologist

FFM:js

CONTENTS

ILLUSTRATIONS

FIGURES

Economic Potential of Alumina-rich Clays and Bauxite in Mississippi (M. K. Kern)

ECONOMIC POTENTIAL OF ALUMINA-RICH CLAYS AND BAUXITE IN MISSISSIPPI

MARSHALL K. KERN

ABSTRACT

Large deposits of high-alumina clay and lesser concentrations of bauxite are present in Mississippi. These materials are of quality suitable for the manufacture of refractories, white ware, china, electrical and chemical porcelains and abrasives.

The kaolin may be used as a filler and pigment for paint and in the manufacture of ultramarine blue. It may also be digested in sulfuric acid to produce "alum cake," and it may be processed to extract alumina (Al_2O_3) for utilization in various chemical compounds.

Processes which are now in developmental stages make these alumina-rich materials potentially suitable for the extraction of metallic aluminum.

Most raw materials and other resources necessary in the utilization of kaolin and bauxite are readily accessible.

Utilization and development of these materials offer a vast industrial and economic potential to the State of Mississippi.

INTRODUCTION

Aluminum, the most abundant metal on earth, is surpassed only by oxygen and silicon as the most common element. It has, in the span of a life-time, risen from a rare and expensive curiosity to a rank that is exceeded only by iron production on a volume basis. Being easily oxidized, it is never found in a native metallic state. It is found most commonly in silicates, such as feldspars, micas, clays; less commonly as the oxide, corundum, as the hydroxide, bauxite, as a flouride in cryolite, and as various sulphates and phosphates. Qualitatively, its natural compounds range from the common alum to the beautifully colored rubies and sapphires.

Additions to more than 4,000 known end products of aluminum are being made continuously. Primary production of aluminum was more than doubled in 1941 to 309,067 short tons, with the entry of the United States into World War II. The larger portion of this increased production went into aircraft construction. Many uses today were stimulated by war use. Production steadily increased to 1960 when the 2 million short ton mark was passed with a value of more than 1 billion dollars. With development of improved metallurgical techniques in alloys and the need for strong light-weight materials in transportation and space facilities, aluminum is destined for still greater demands.

Its qualities of fast heat dissipation, resistance to weathering, ease of forming and eye appeal, make aluminum highly suitable for home and commercial construction.

Many uses of alumina and high-alumina clays in the chemical and ceramics industries greatly enhance the potential of alumina-rich materials found in Mississippi.

The principal ore of aluminum, today, is the hydroxide of alumina, bauxite ($Al_2O_3.2H_2O$). Bauxite is found in many parts of the world, but the only large deposits in the United States are located in Arkansas. Consequently, this Country must obtain a large part of its bauxite supply from foreign sources. Four-fifths of the ore used in the United States is supplied by Dutch Guiana, British Guiana, Jamaica and Haiti.

Other alumina-bearing materials, such as kaolin, alunite, anorthosite and other aluminum silicates are present in virtually unlimited supply.

Although the cost of extracting alumina from high-silica materials is not presently competitive, further experimentation should find ways to improve this situation.

Mississippi has an abundance of alumina-rich clays and a considerable quantity of bauxite. With improved methods of processing these materials, the economic potential to the State of Mississippi is of considerable importance.

Because of the dangers in shipping during World War II, bauxite imports were sharply curtailed. Consequently, the domestic deposits were heavily drawn upon to supply a very much increased demand for aluminum in the war effort. In the realization that our high-grade ore was being rapidly depleted, the Federal Government initiated a more concerted research program in the processing of high-alumina clays and the lower grade bauxites.

The Mississippi Geological Survey staff played a significant part in this research effort carried on within the bounds of the State. Chemical analyses, sample descriptions and locations of known deposits were made available to Federal agencies concerned.

PROCESSES FOR EXTRACTION OF ALUMINA AND ALUMINUM

Two separate and distinct operations are necessary in the production of aluminum from ore. It is in this respect that reduction of aluminum differs from most other metals which are directly reduced from their ores. Each operation requires a complete plant facility for the production of its end product.

The first operation is the production of alumina (Al_2O_3), a white gritty powder, from bauxite. Karl Joseph Bayer developed the process for the extraction of alumina in the latter part of the 19th century. Modifications have been made in this process, but the basic principles remain.

Basically the operation is to digest finely ground bauxite in a concentration of hot caustic soda, lime and sodium carbonate. This produces a liquor of sodium aluminate which is introduced into precipitating tanks. The liquor is seeded with aluminum hydroxide which causes the sodium aluminate to hydrolize and form aluminum hydroxide crystals that settle in the bottom of the tanks. The crystals are classified, washed and filtered and calcined to drive off water of hydration, leaving pure anhydrous aluminum oxide or alumina (Al_2O_3). This product is now ready for the process of reduction to metallic aluminum (Al). It is a continuous electrolytic process in which alumina is dissolved in molten cryolite and then electrolized into its components, oxygen and aluminum. The oxygen ion is attracted by the carbon anode to form carbon monoxide or carbon dioxide, liberating the aluminum at the cathode in a pure molten metal state. The molten metal settles to the bottom of the pot and is periodically siphoned into a ladle. It is poured from the ladle into pigs weighing up to 50 pounds or billets of 1,000 pounds.

Prior to the end of World War II, research in the utilization of bauxite and alumina-rich clays for the extraction of alumina was stepped up. The United States was, and still is, dependent upon imports for large amounts of bauxite.

The U. S. Bureau of Mines and several state geological surveys made considerable progress toward utilization of certain aluminous clays. The processes worked out were basically the same with slightly different techniques and are referred to as the "lime-sinter" and "lime-soda-sinter" processes.

Aluminous clays, such as kaolin, with a high silica content, are mixed in a slurry with lime or lime and caustic soda and sintered to a clinker and reground and dissolved, forming a solution of sodium aluminate as in the Bayer process. Development of the process has not yet reached the stage to be competitive with the process of production from bauxite.

About the same time that the United States was experimenting with the clays, a process was developed in Norway known as the Pedersen process. It was used primarily for the production of high-grade pig iron. Bauxite with a low-silica and high-iron content was imported from France and smelted with limestone and coke in electric furnaces. The iron was drawn off and poured as pig iron and the slag comprised of calcium aluminate was pulverized and treated with a soda solution as in the Bayer process. The Pedersen process is in use on a commercial scale in Norway, Sweden and Russia. Bauxite ores of these countries have a high iron content. Again, this process cannot compete with production from high-grade bauxite available to the United States.

Announcements have been made more recently of processes whereby aluminum could be extracted directly from bauxite, bypassing the Bayer process.

Aluminium Ltd. has been issued patents which relate to the recovery of aluminum from aluminum chloride (AlCl). In 1960 they planned an experimental plant in Arvida, Quebec with a capacity of 6,000 to 8,000 tons per year.

In France, Pechiney was granted patents relating to the decomposition of aluminous nitride (AlN) to metallic aluminum. Plans were underway in collaboration with Ugine of France to erect a plant with a capacity of 5,000 tons per year at Norgueres.

In the United States, Anaconda Aluminum Company was assigned patents on processes to produce silica- and iron-free alumina from iron-containing clays of Idaho.

One patent involved calcining the clay and dissolving aluminum and iron with hydrochloric acid, leaving silica as an insoluble residue. The resulting mixture of iron and aluminum chlorides is evaporated and heat-treated at 1,000° to 1,300°F to produce iron and aluminum oxides. The alumina and residual chlorides are dissolved in caustic soda, and aluminum hydroxide is precipitated from the solution and calcined to drive off the water of hydration.

Another patent espoused that calcining the mixture of chlorides at 1500° to 1900°F produced an iron-containing crude alumina, free from silica and chlorides. Sintering the calcined material with sodium carbonate at 1500°F converted the alumina to sodium aluminate that could be extracted with an aqueous medium.

The third patent involved the sintering above 1700°F of an aluminiferous raw material containing a very small amount of silica, with sodium carbonate and calcium oxide to form insoluble calcium aluminum silicate and soluble sodium aluminate. The mixture is then leached with an alkaline aqueous solution and the alumina is precipitated and calcined.

GEOLOGY OF HIGH-ALUMINA CLAY AND BAUXITE

Although the entire geologic column which is represented on or near the surface in Mississippi contains clays composed of alumina (Al_2O_3) in varying percentages, the deposits considered in this writing are restricted to the residual material found in a position between the Midway and Wilcox groups.

This material is described by Mellen (MGS Bull. 38): "The Betheden residuum or formation includes all residual material at the top of the Midway and below the Midway-Wilcox unconformity. It includes the deposits of bauxite, kaolin, bauxitic and kaolinitic clays and the overlying lignite." Mellen (MGS Bull. 34) also describes bauxitic and kaolinitic materials in the Little Bear residuum in Tishomingo County, at the Cretaceous-Paleozoic contact.

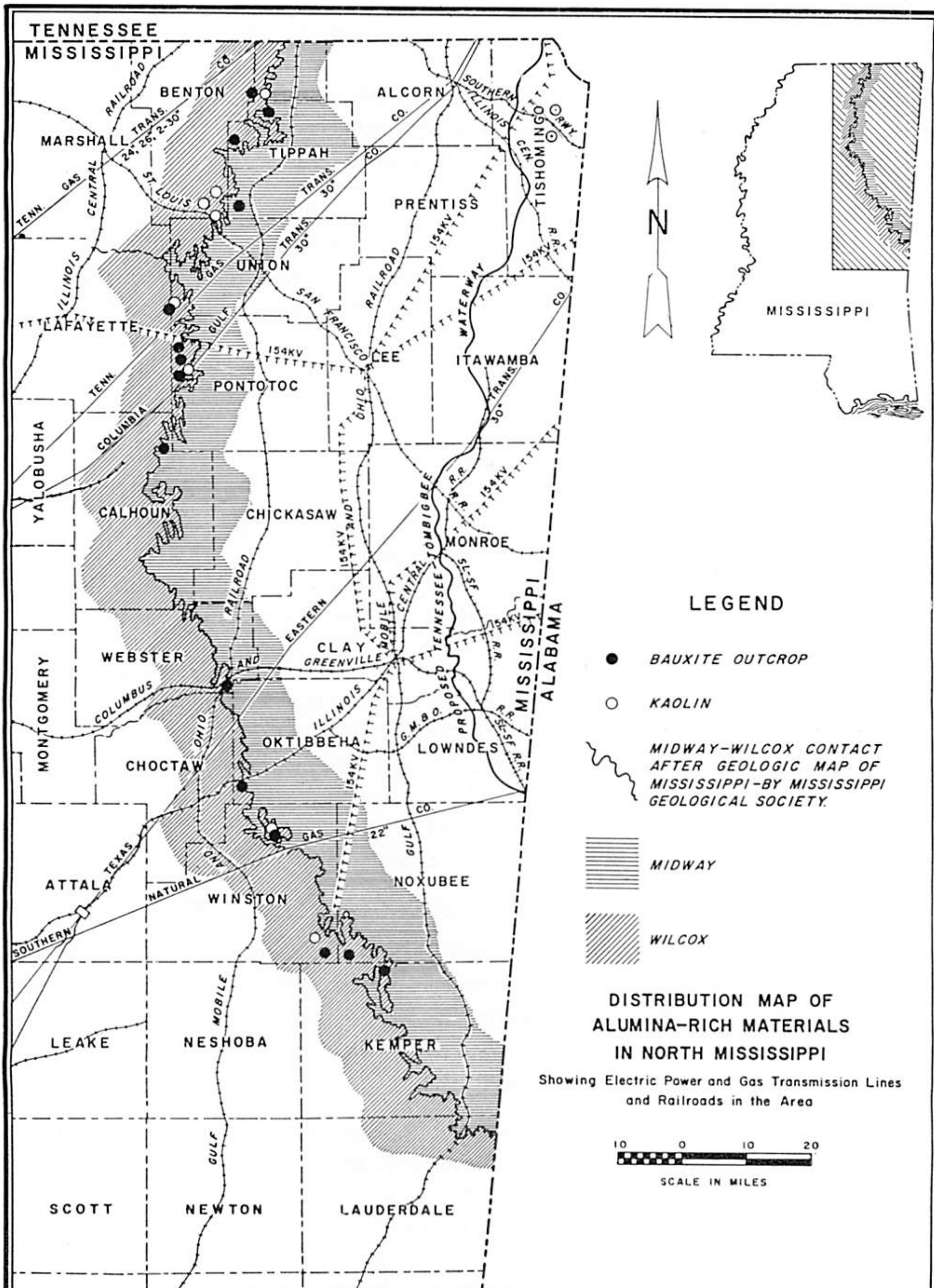

Figure 1.—Map showing distribution of kaolin and bauxite in northeastern Mississippi and other information.

Figure 1 shows the outcrop belt and some of the known exposures of this material, along with areas where some exploratory drillings and diggings have been made.

Hundreds of samples have been collected and chemical analyses made and published in numerous reports which are included in the list of references of this paper.

These materials are the product of lixiviation and lateritization which took place in the process of weathering under peculiar sub-aerial conditions.

The contact of the Midway (Paleocene) and the Wilcox (Eocene) extends from Tennessee into Tippah County, south to Winston County, then southeast to Lauderdale County and into Alabama. The overall length is approximately 200 miles in Mississippi.

Erosion subsequent to the lateritization process has left some areas void of the kaolinitic-bauxitic material. In these areas the Wilcox is deposited in direct contact with the underlying Midway. Consequently, thicknesses of the alumina-rich material varies considerably from place to place. The range of this variation is from a feather edge to as much as 30 feet, but is more commonly 5 to 10 feet thick.

The width of the belt is difficult to estimate due to topographic irregularities. Kaolinitic material at this stratigraphic level has been noted in drill holes down the dip at depths of several hundreds of feet. The regional rate of dip in most areas is approximately 30 feet per mile. A reasonable estimate of the outcrop width is one mile, with mineable depths to 40 or 50 feet.

In 1922, Paul F. Morse, carried out the first exploratory program for the Mississippi Bauxite Company. Properties were examined in ten counties and over 100 samples from numerous test pits were analyzed. Although little attention was given the high-alumina clays at that time, several analyses of such material are contained in the report which was published by the Mississippi Geological Survey as Bulletin 19.

Under the direction of the late W. C. Morse, then State Geologist, a series of surveys of the mineral resources on a county-by-county basis was undertaken in the late 1930's. The reports were published as bulletins on the counties of Winston, Tippah, Union and Pontotoc and contain many analyses on bauxitic and kaolinitic material. More recent publications, by the Mississippi Geological Survey, containing information on bauxite and high-alumina clays include Benton, Webster, Calhoun and Kemper Counties.

In 1952 the Bureau of Mines published a Report of Investigations covering field investigations on nine areas in Benton, Union, Pontotoc, Kemper, Noxubee and Winston Counties. The field work was done in 1941, 1942 and 1943.

Table I shows the chemical analyses of samples from areas along the Betheden formation outcrop (and one from the Little Bear residuum). The analyses indicate a gradation from a silty, sandy, kaolinitic clay to kaolin and then to bauxite.

Morse (MGS Bull. 19) estimated 1,548,000 tons of bauxitic and kaolinitic material in the deposits which he prospected. Additional deposits of several millions of tons have been examined by later workers. However, no actual estimates have been made.

USES OF KAOLINITIC AND BAUXITIC MATERIAL

Processes for the extraction of metallic aluminum from this material have not been fully developed. However, many other uses can be made which are considered of more immediate importance.

McCutcheon (MGS Bull. 38, p. 97) states: ". . . . all factors indicate that the materials available could be made into refractory shapes equal to, and in some instances exceeding, the standard specifications for No. 1 first quality clay refractory. . . . . products such as glass pots, saggers, special shapes, kiln furniture, furnace and retort linings, metallurgy crucibles and refractory patching material, are possibilities within its limits of use."

In testing the kaolin it was found that by calcining the clay as much as 97.7 per cent of the total alumina present is soluble in sulfuric acid (MGS Bull. 45). This simple process renders the high-alumina, low-iron clays suitable for the production of aluminum sulphate, aluminum chloride and alum for commercial uses.

Chemical and physical properties of much of this material make it suitable for the production of artificial mullite or sillimanite which can be used in refractories, spark plugs and chemical porcelain.

The soft-grained kaolins would be equal to the best grades of domestic and foreign kaolins when washed. This clay is especially suitable for compounding into various white ware including electrical, chemical and dinner ware, table porcelain, hotel china, pottery and art shapes. They are also adaptable for non-ceramic use as a filler in paper, rubber, oil cloth and linoleum, and as an extender and pigment in paint. Utilization may also be made as a decolorizer in the refining of edible oils.

The manufacture of white finishing cement and cement with a quick-setting quality are possible with the utilization of these materials.

Logan describes a rather simple process for the manufacture of ultramarine blue pigment. The pigment is made from a mixture of kaolin, silica, soda, charcoal and sulphur. After the mixture has been fused and roasted it is ground to a powder and used in paints and dyes.

The bauxite, with minor beneficiation, may be suitable for fusing with carbon in an electric furnace for the manufacture of abrasives.

ACCESSIBILITY OF RAW MATERIALS AND NECESSARY RESOURCES

The area (Figure 1) in which the alumina-rich materials are located is one of gentle to moderately rough topography. County, State and Federal roads are adequate for the transportation of raw materials from mines to plants.

Several railroads traverse the area providing immediate transportation to market centers. The future completion of the proposed Tombigbee Waterway will enhance the transportation facilities by providing low cost shipping to distant ports.

Numerous gas transmission lines make available abundant supplies of natural gas for consumption as fuel for calcining and sintering processes.

Tennessee Valley Authority serves the area with a network of 154 KV lines offering a source of low-cost electrical power for the processing of the ores.

The area affords supplies of plastic clays for bonding material used in ceramic production.

Beneficiation and processing of these materials require large supplies of water. Mississippi Geological Survey Bulletin 90 reports an abundance of surface and ground-water in the area. The supply is of such quality as to require little or no treatment for industrial and commercial purposes.

OTHER RAW MATERIALS UTILIZED IN THE PRODUCTION OF ALUMINUM AND ALUMINUM CHEMICALS

The development of the "Lime-Sinter" and "Lime-Soda-Sinter" processes for extraction of alumina (Al_2O_3) from clays and low-grade bauxite require a source of lime (CaO) and soda ($NaOH$).

Limestones from northeastern Mississippi and northwestern Alabama are a source of calcium oxide.

The salt domes of South Mississippi contain abundant supplies of sodium chloride ($NaCl$). A chlorine-caustic plant can produce sodium hydroxide ($NaOH$) from the materials contained therein. Hydrochloric and sulphuric acids produced can be mixed with aluminiferous material to make commercial grade aluminum chloride ($AlCl$) and alum. ($Al_2S_3O_{12}$).

A market for aluminum sulfate or "papermakers alum" is the expanding pulp and paper industry of Mississippi and the Southeast.

Carbon, used in the electrolytic process of the reduction of aluminum, is made of petroleum coke and coal tar. The petroleum coke is a by-product of crude oil refining, which is done in the State. Lignite is found in numerous areas in Mississippi. With proper processing it may be a source of coal tar.

It is conceivable that a very broad and integrated industrial program can be developed around alumina-rich materials of Mississippi.

TABLE I

CHEMICAL ANALYSES* OF KAOLINITIC AND BAUXITIC MATERIAL FROM NORTHEASTERN MISSISSIPPI

	1	2	3	4	5	6	7	8	9	10	11
Aluminum oxide (Al_2O_3)	52.10	34.5	39.5	35.6	26.0	54.95	39.00	39.70	36.84	47.57	38.82
Silicon dioxide (Si02)	19.51	47.1	46.6	52.0	59.0	16.94	45.07	45.31	42.52	28.54	44.23
Ferric oxide (Fe_2O_3)	3.42	1.8	0.5	2.0	2.0	0.15	1.17	0.70	1.85	1.97	.81
Titanium oxide (TiO_2)	1.68	2.0	2.2	—	—	1.60	2.01	—	1.63	1.47	—
Loss on ignition	22.05	13.9	13.6	—	—	23.45	13.54	13.32	15.88	18.62	15.49

1. Sample No. S-96: Pontotoc County, Morse, P. F., Miss. Geol. Survey Bull. No. 19, 1923, p. 93.
2. Sample No. Mis-113: Benton County, Reed, D. F., Bureau of Mines Rept. of Inv. 4827, 1952.
3. Sample No. Mis-68: Union County, Reed, D. F., Bureau of Mines Rept. of Inv. 4827, 1952.
4. Sample No. Mis-32: Pontotoc County, Reed, D. F., Bureau of Mines Rept. of Inv. 4827, 1952.
5. Sample No. Mis-21, Pontotoc County, Reed, D. F., Bureau of Mines Rept. of Inv. 4827, 1952.
6. Surface sample from Kemper County, Morse, P. F., Miss. Geol. Survey Bull. 19, p. 174. Location of only commercial mining of bauxite in state. About 400 tons was shipped to Monsanto Chemical Co. in 1942.
7. Test Hole 88: Winston County, Mellen, F. F., Miss. Geol. Survey Bull. 38, 1939, p. 63.
8. Kaolin outcrop: Benton County, Lusk, T. W., Miss. Geol. Survey Bull. 80, 1956, p. 130.
9. Test Hole A 200: Tippah County, Conant, L. C., Miss. Geol. Survey Bull. 42, 1941, p. 130.
10. Test Hole D 187: Union County, Conant, L. C., Miss. Geol. Survey Bull. 45, 1942, p. 126.
11. Sample No. 5: Tishomingo County, after Logan in Mellen, F. F., Miss. Geol. Survey Bull. 34, 1937, p. 25.

*Expressed in percent by weight.

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STRATIGRAPHIC IMPLICATIONS FROM STUDIES OF THE MESOZOIC OF CENTRAL AND SOUTHERN MISSISSIPPI

WILLIAM H. MOORE

ABSTRACT

Beds of Mesozoic age hold much promise of further oil and gas production in Central and Southern Mississippi without "getting farther downdip and drilling deeper." Examination of cuttings and cores from many wells, and correlation with electrical logs of these wells, point out some areas which may contain facies favorable for oil and gas accumulation.

In Southwestern Mississippi, sediments from the Upper Tuscaloosa suggest a return to depositional environments prevalent in Lower Tuscaloosa time. The Lower Tuscaloosa is productive in this area from deltaic and stream channel deposits. Some production is already established from the Upper Tuscaloosa.

Recent deep tests have added to knowledge of the Lower Cretaceous carbonate section in Southern Mississippi and this information can be used in interpreting the environment of deposition of the section. No porosity trends have been established but a few zones with some porosity are present.

In Central Mississippi, beds of Jurassic age can be reached at depths which are economically feasible to drill. The Cotton Valley is for the most part continental, but a few wells pierce beds which may be rich enough in organic material to be source beds. The Smackover Formation has possible objective zones in this area, but the belt of possible porosity is very narrow.

Stratigraphic cross sections in these favorable areas show the possible extent of favorable zones and help to explain the depositional history of these areas. Lack of identifiable fossils makes paleontological determinations very difficult. Lithologic studies with consideration of the environment and paleogeography are the most useful tools of study in this area.

INTRODUCTION

Beds of Mesozoic age hold much promise of further oil and gas production in Central and Southern Mississippi. The establishment of this production faces the usual problems of high drilling costs and limited objectives. Two paths can be followed in seeking production from sections which are not now producing or have produced only small amounts of oil and gas. The first is the traditional one of moving farther downdip and drilling deeper. This type of exploration can become very costly when one is attempting to reach some of the older horizons in Central

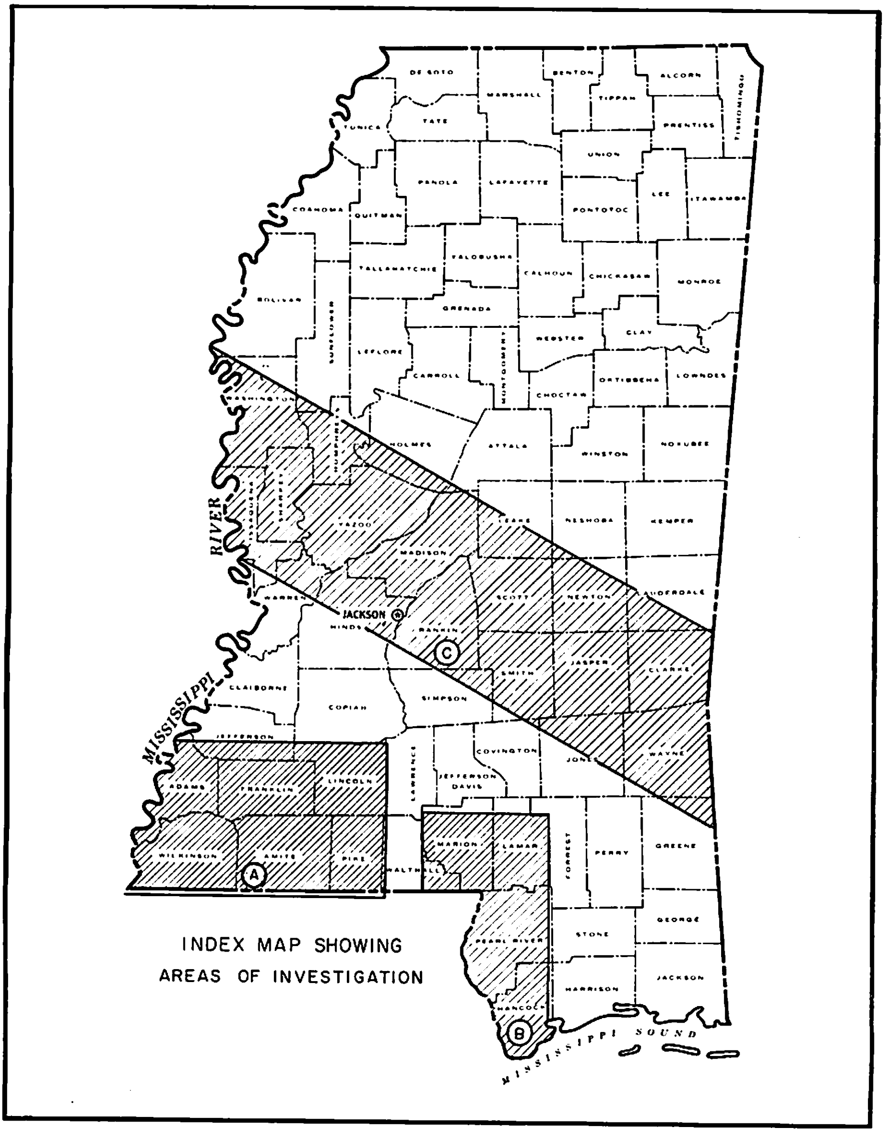

Figure 1. Index map showing areas of investigation: (A) Lower Tuscaloosa, (B) Lower Cretaceous, and (C) Jurassic.

and Southern Mississippi. The other path is that of making a closer study of the depositional environment and lithologic character of possible objective intervals. This would aid in the location of favorable areas that can be explored economically.

The examination of cuttings and cores from many wells in Central and Southern Mississippi points out three areas of interest (Figure 1). The first area (A) is in the southwestern corner of Mississippi, where recent discoveries have directed attention to the upper part of the Tuscaloosa group (Upper Cretaceous). The second area (B) is the extreme southern portion of the state. Several deep tests in this area have added to our knowledge of the Lower Cretaceous carbonate section. This additional information gives a better picture of the depositional environment of the section and will aid in predicting possible porosity trends. The third area (C) is a southeast trending belt across Central Mississippi. In this belt, beds of Jurassic age have been penetrated in enough wells to give a good idea of the variations in Jurassic strata. This information can be used to outline favorable areas.

UPPER TUSCALOOSA OBJECTIVE AREA IN SOUTHWESTERN MISSISSIPPI

In 1960, two Upper Tuscaloosa oil discoveries in Amite County awakened some interest in this formation. These discoveries were made at East Fork Field and O'Neil Field (Figure 2). They have not proved to be too important and have produced only minor amounts of oil. They are significant because they are in an area in which most wells have been drilled with a "one shot" objective in the Lower Tuscaloosa; another possible producing horizon makes prospecting there more attractive.

The geological conditions under which the sediments in which the new discoveries were made were deposited are worthy of closer consideration in an attempt to determine why they are productive. The structural features of the Central Gulf Coastal Plain are shown by Figure 3. Some of these features were active during Tuscaloosa time, but Watkins (1962) points out that they did not affect deposition in this area to any great degree. The controlling factors in the accumulation of oil in the area are mainly stratigraphic.

A review of the stratigraphic nomenclature of the Tuscaloosa group is shown in Figure 4. The subsurface nomenclature of the Mississippi Geological Society is applicable to most areas in the Mississippi subsurface, but in this particular area some revisions seem appropriate. On the surface, and in most of the Mississippi subsurface, the Upper Tuscaloosa is separated from the underlying strata by a pronounced unconformity. This unconformity is not recognizable in extreme southwestern Mississippi. The term "Marine Tuscaloosa" is not used because most of the Tuscaloosa in the area is of marine origin, and the "Massive Sand" member is not applicable because it was not deposited in this area. The area under investigation is small and for that reason no formal changes in nomenclature are proposed. A simple, lithologically-based breakdown is used in this paper (Figure 5). The electrical log of the Pan-Am, Moore No. 1, drilled in Section 15-T 3 N-R 5 E Amite County, Mississippi is used as the type log for this division of the Tuscaloosa. The name Upper Tuscaloosa is used for the sandstone, shale and mudstone sequence at the top of the group. Middle Tuscaloosa is used for the distinctive shale sequence below the Upper Tuscaloosa, and the name Lower Tuscaloosa is applied to the

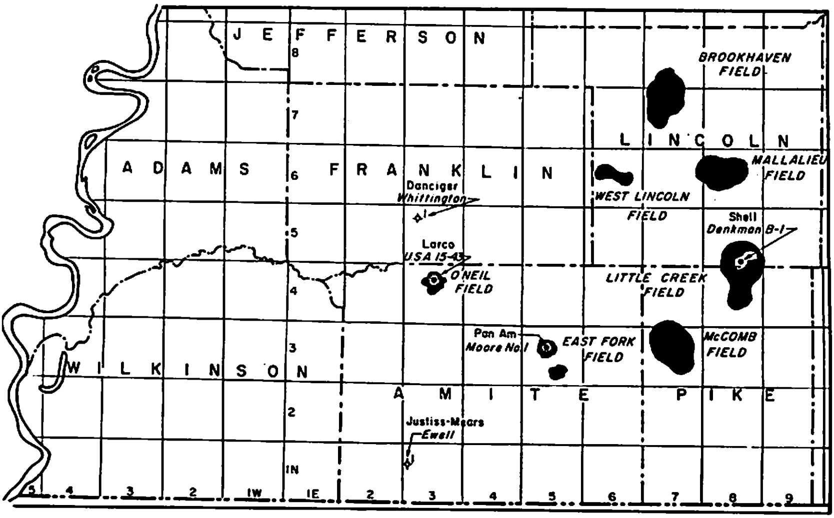

Figure 2.—Map showing area of Lower Tuscaloosa studies in southwestern Mississippi.

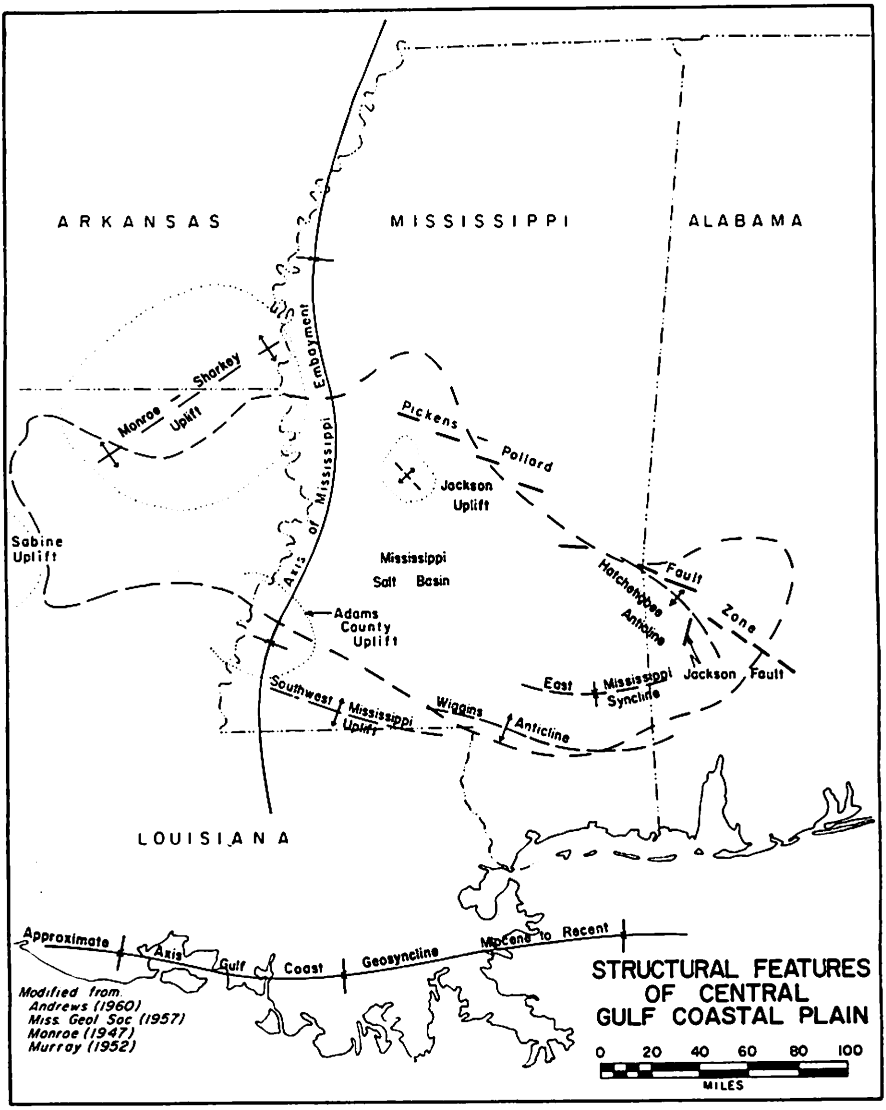

Figure 3.—Major structural features of central Gulf Coastal Plain.

sandstone, shale, and mudstone sequence between the Middle Tuscaloosa and the top of the Lower Cretaceous.

The depositional environments of the Tuscaloosa have been discussed in detail by Braunstein (1950) and, to a lesser degree, by others. In most of the up-dip and mid-dip areas, the Upper Tuscaloosa is considered to be of shallow marine origin, with a few fluvial beds. The sediments become more marine basinward until they are nearly all of deep marine origin in the extreme

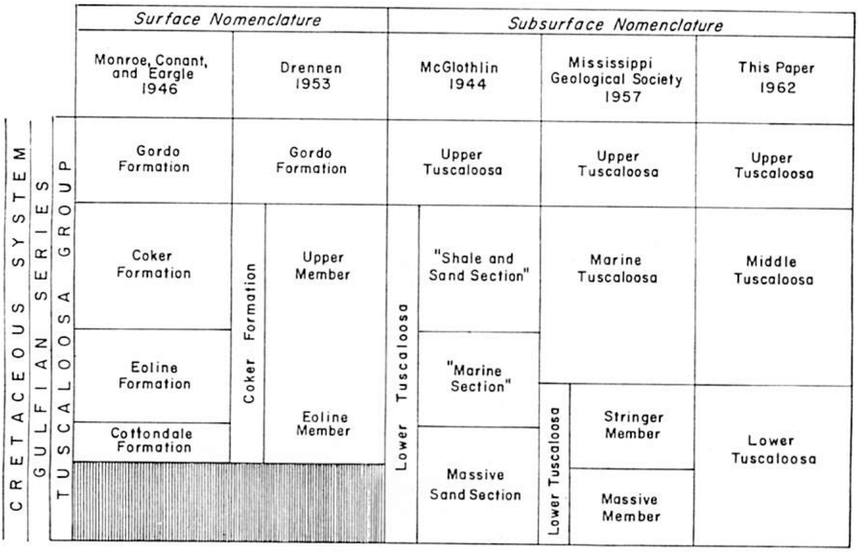

Figure 4.—Chart showing Tuscaloosa nomenclature.

southwestern corner of the state. The writer concurs with this interpretation of the depositional environment and would consider it to be a basis for explaining the Upper Tuscaloosa production in Amite County.

In wells at Little Creek Field in Lincoln County, such as the Shell Oil Company, Denkman No. B-1, in Section 35-T 5 N-R 8 E, the Upper Tuscaloosa has many sandstones, some with good porosity (Figure 6). The sandstones are white to light gray, slightly porous to porous, fine-to medium-grained. They are micaceous in part, and contain some chert in the upper part of the formation as well as some clayey intersitial material. The associated beds are gray, green, red, and purple

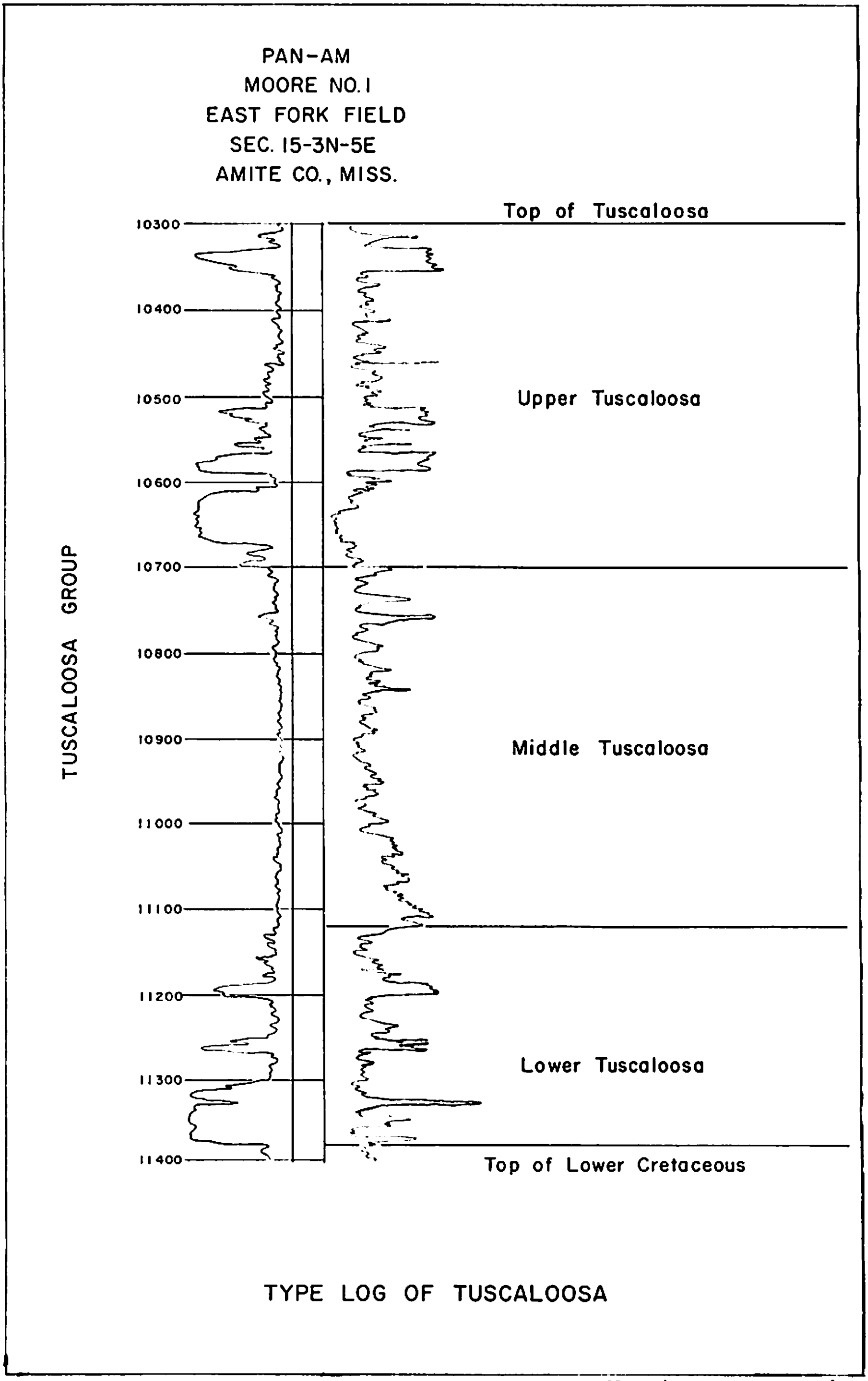

Figure 5.—Correlated electrical log illustrating typical Tuscaloosa sequence in area studied.

mudstones. The gray and green mudstones contain siderite nodules. Some gray shales are present in the lower part of the formation along with more gray and green mudstones. In the Danciger, Whittington No. 1, in Section 12-T 5 N-R 3 E, Franklin County, the section is practically the same, with slightly less sandstone. These wells show lithology typical of the area north and east of the producing area. This type of lithology suggests shallow marine, lagoonal and possibly interdeltaic deposition. A few wells have certain intervals with lithology which could be interpreted as being of fluvial origin. Sediments formed in such environments could contain enough organic matter for the

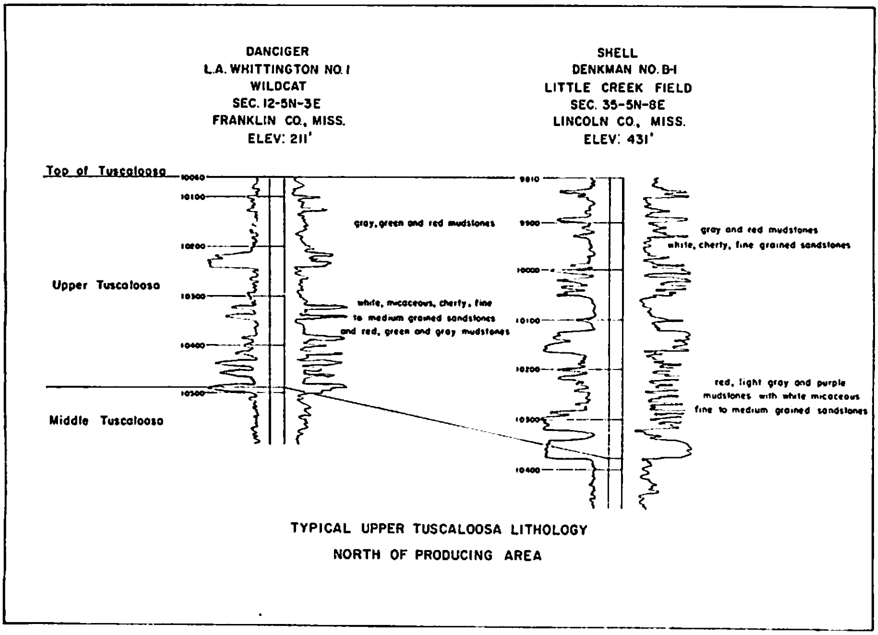

Figure 6.—Lithologic annotations on electrical logs of typical Upper Tuscaloosa north of producing area.

generation of hydrocarbons, but the presence of red and purple mudstones shows that conditions which favored oxidation existed during and after deposition. This oxidation would have tended to prevent formation of hydrocarbons.

The lithology of the Upper Tuscaloosa in Amite County is demonstrated by two producing wells. They are the Larco, U.S.A. (15-43) No. 1, in Section 15-T 4 N-R 3 E, the discovery well of O'Neil Field; and the Pan-Am, Moore No. 1, in Section 15-T 3 N-R 5 E, in East Fork Field (Figure 7). In the upper Tuscaloosa in these wells, the sandstones are predominantly white, slightly porous, micaceous, glauconitic and fine-grained. There are a few fossiliferous zones and some cherty zones. The associated beds are gray and green mudstones, carbonaceous mudstone and gray shale. The depositional environment in this

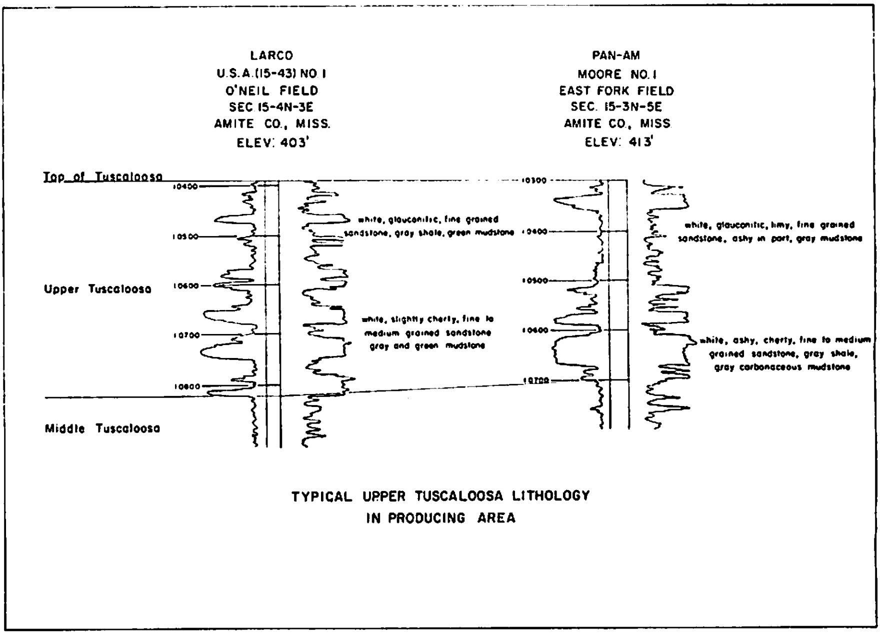

Figure 7.—Lithologic annotations on electrical logs of typical Upper Tuscaloosa in producing area.

area is interpreted as having been delta and delta fringe. Present also are deposits from some distributary streams, and rare deep marine beds. These sediments were not subjected to oxidation as were the ones to the north and east. This appears to be the more favorable area for generation of hydrocarbons. Farther south and west the Upper Tuscaloosa becomes a deeper marine deposit and contains mainly dark gray shales with a few thin beds of white, glauconitic, fine-grained sandstone.

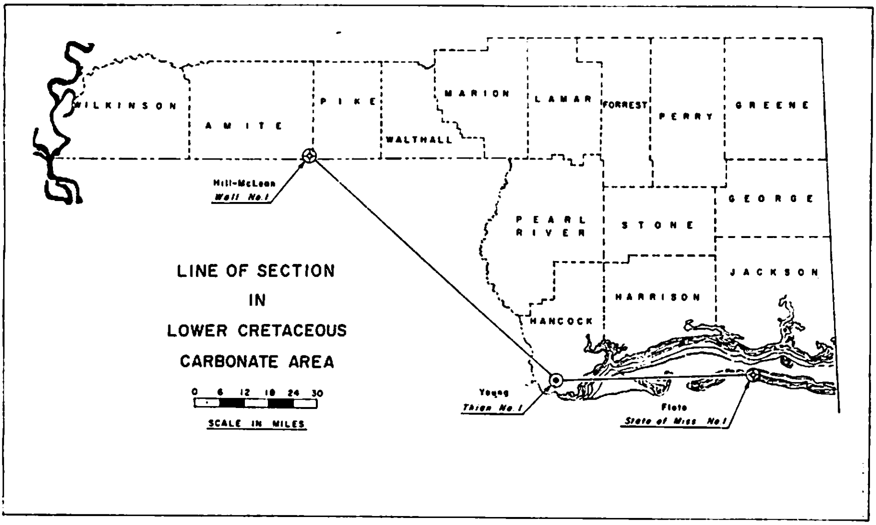

Figure 8.—Index map to line of section in Lower Cretaceous carbonate area, (Figure 9).

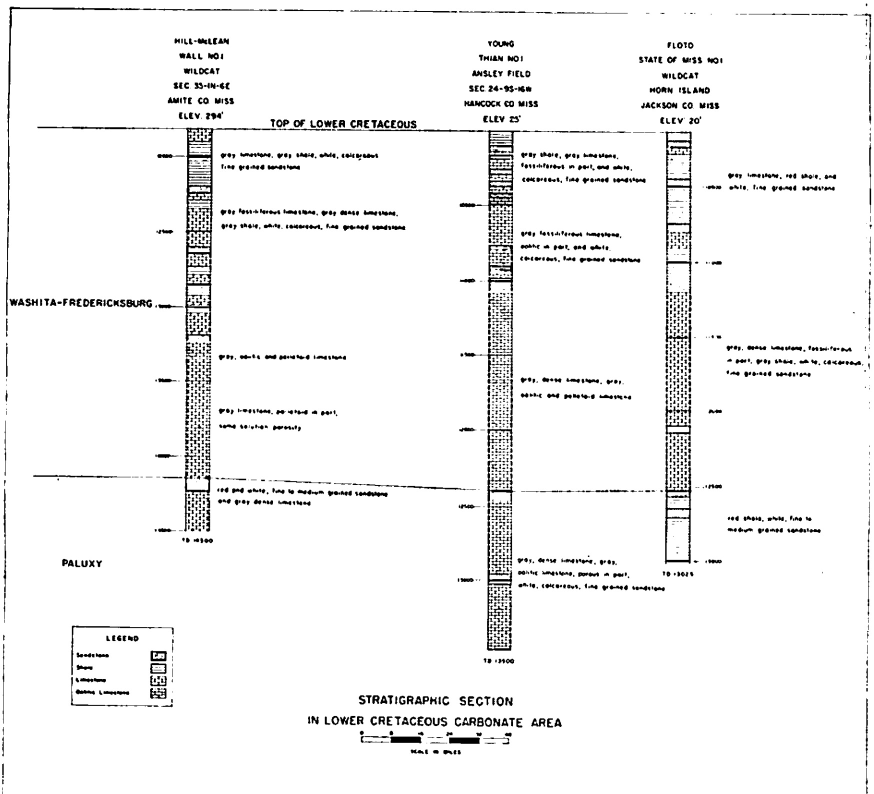

Figure 9.—Stratigraphic and lithologic section in Lower Cretaceous carbonate area.

Production at O'Neil Field comes from a sand at 10,478 feet while at East Fork the production is from a lower sand at 10,614 feet. The lower sand seems to be present over a larger area and can be considered to be one of the better objectives; other sands, particularly in the lower part of the formation, could be productive if encountered in a favorable structural position.

LOWER CRETACEOUS CARBONATE AREA IN SOUTHERN MISSISSIPPI

The Lower Cretaceous formations have become important as producers of oil and gas in Mississippi since production was established from these beds in 1951. All the production from the Lower Cretaceous has come from sandstone reservoirs, although the Lower Cretaceous contains many feet of carbonate rocks in the southern part of the state. In the extreme southern portion of the state (Figure 8), most of the Lower Cretaceous section that has been penetrated is of marine origin, comprising a sequence of limestone, gray shale and a few sandstones. The sandstones of Washita-Fredericksburg age produce oil and gas at Ansley and Kiln Fields in Hancock County. The great thicknesses of limestone in the wells of this area are potential reservoir rocks if zones of porosity are present.

The three wells in the section shown in Figure 9 are separated by many miles, but are almost on depositional strike. The Floto, State of Miss. No. 1, on the tip of Horn Island in Mississippi Sound, is slightly up-dip from the other two; the Young, Thian No. 1, in Section 24-T 9 S-R 16 W, Hancock County and the Hill-McLean, No. 1 Wall, in Section 35-T 1 N-R 6 E, Amite County. The Floto well contains more clastic sediments in the Washita-Fredericksburg and Paluxy sections than the others do. The carbonate platform on which the wells are located must have reached its greatest extent in early Washita-Fredericksburg time. Later structural movements in the area of the Hill-McLean well caused the top of Lower Cretaceous to be some 1500 feet lower structurally there than in the other two wells.

Zones of porosity are present in two of the wells. In the Hill-McLean well, what appears to be solution porosity occurs at 13,400 feet. This is in the Washita-Fredericksburg. In the

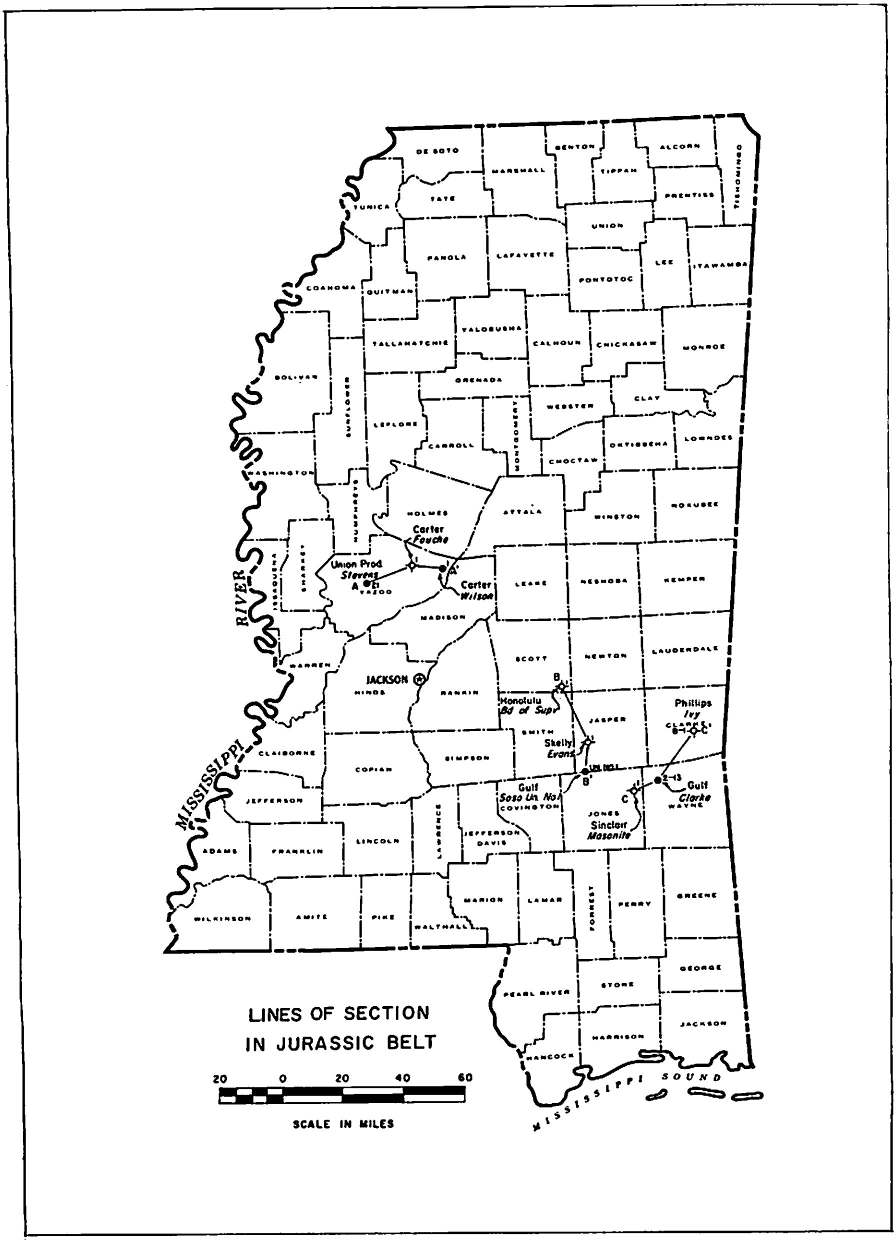

Figure 10.—Index map showing lines of section in Jurassic belt.

Young well, porosity is developed in the oölitic limestones near the bottom of the well. The presence of these zones of porosity and considerable thicknesses of oölitic and pelletoid limestone, make this area attractive for prospecting. There are some favorable conditions present, but no definite porous trends have been established and no reef type deposits have been found. Lack of deep well control makes predicting these trends extremely speculative, and it is possible that they do not exist. Rainwater (1960) points out that some carbonate shelves subside very slowly and offer little protection to the organic matter necessary for generation of hydrocarbons. These factors must be weighed against the fact that structural dip flattens in the Mississippi coastal counties. This means that the Lower Cretaceous carbonates can be reached at feasible depths far out into Mississippi Sound. If geophysical surveys point out structural anomalies to enhance the stratigraphic possibilities, more exploration will be undertaken.

JURASSIC BELT IN CENTRAL MISSISSIPPI

As the search for oil in Mississippi becomes more difficult, geologists must take a closer look at the older formations. Beds of Jurassic age are prolific producers in states adjoining Mississippi on the west, and there is no reason to believe that more production will not be obtained from them in Mississippi. The Smackover has long been a magic name in the oil business, and minor Smackover production, along with numerous shows, has kept alive the hope for Smackover oil in Mississippi. Recent discoveries of Cotton Valley oil, in fields where production has already been established from younger beds, have drawn attention to this formation, too.

SMACKOVER FORMATION

The only Smackover production in Mississippi is at Loring Field in Madison County. This production is obtained from dolomitic sandstones and dolomitic limestones in the Upper Smackover. The Smackover lithology is variable along the subcrop belt and shows have been found in almost all of the lithologic types. Stratigraphic sections in several areas give a good idea of the changes in lithology (Figure 10).

The Smackover lithology in eastern Madison and Yazoo Counties is demonstrated by Section A-A′ (Figure 11). The

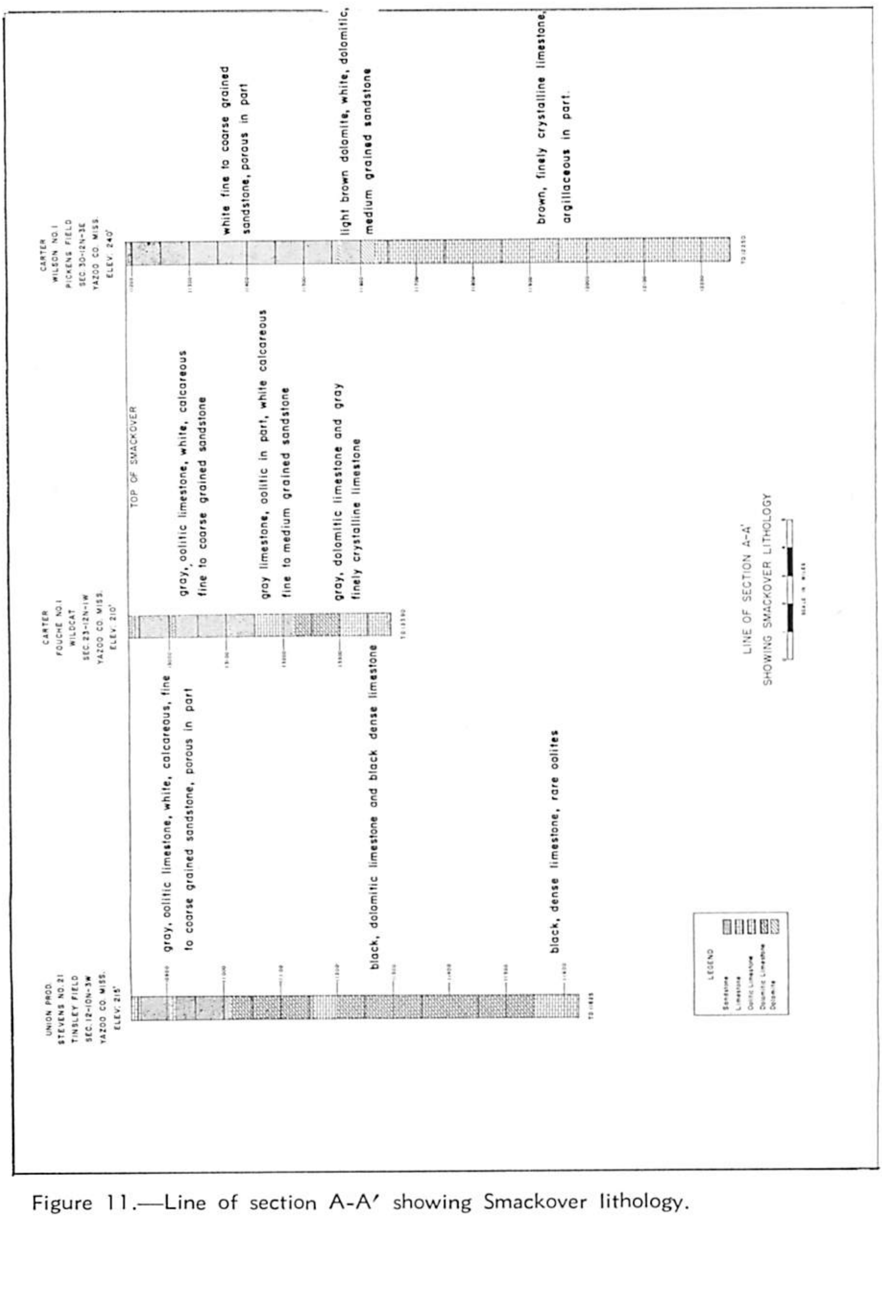

Figure 11.—Line of section A-A′ showing Smackover lithology.

lower part of the Smackover is fairly consistent in all the wells and is made up of dark gray to black, dense limestone, dolomitic limestone and rare oölitic limestone. Some wells here have limestones that are finely crystalline and slightly porous. In this area the upper part of the Smackover is very sandy. In Yazoo County and parts of Madison County sandstone, dolomite and some oölitic limestone are present in this section. Around the Carter, Wilson No. 1, in Section 20-T 12 N-R 3 E, Yazoo County, the upper four hundred feet of the Smackover is made up of limy, fine- to coarse-grained sandstone with zones of porosity. In addition to oil production at Loring Field, non-inflammable gases are present in the Upper Smackover in this field and in wells in Tinsley and Virlillia Fields. These gases are high in hydrogen sulfide and carbon dioxide and are not being put to any commercial use.

The Smackover lithology undergoes gradual change to the southeast, so that in Rankin and Scott Counties the sandy, dolomitic, Upper Smackover is very thin. The lower part of the formation is made up of dark gray and brown, finely crystalline limestone and dolomitic limestone, with some light gray dolomite. Minor amounts of oil and non-inflammable gas have been tested from the lower Smackover in this area. This gas was almost pure carbon dioxide.

In southeastern Jasper County, central and southwestern Clarke County, northeastern Jones County and northwestern Wayne County, the Upper Smackover includes the familiar oölitic limestone that characterizes the formation in other states. This lithology is shown by Section C-C′ (Figure 12). The oölitic zone contains small and large oölites, some of them loosely cemented, and gray crystalline limestone. There are many zones of porosity, and there have been shows of oil in several wells. Gray to brown, finely crystalline limestones make up the lower part of the Smackover in this area.

COTTON VALLEY FORMATION

The Cotton Valley formation is a very thick and extensive formation. It contains many feet of porous and permeable sandstone with discrete shale bodies, yet it is not productive in most areas. The reasons for this lack of production are evident after a study of the lithologic character of the formation. The

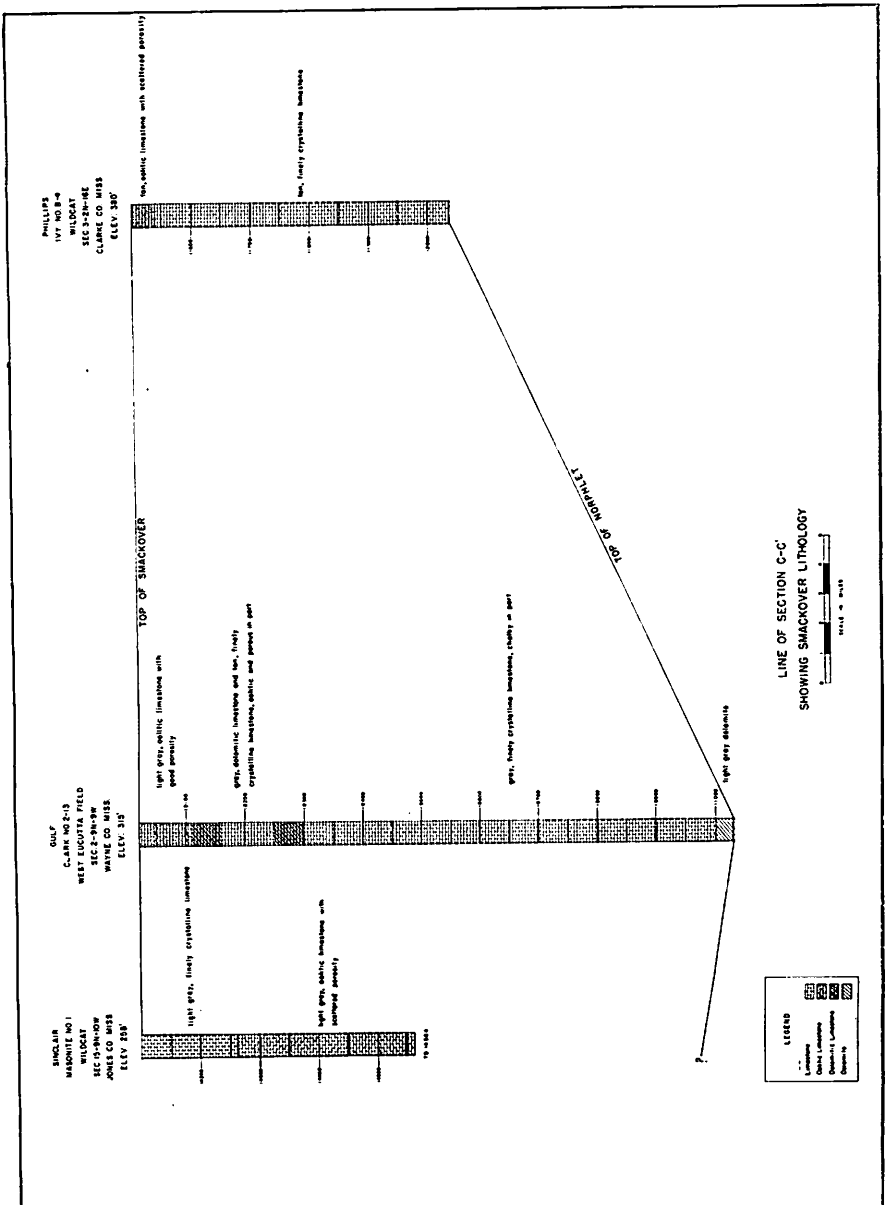

Figure 12.—Line of section C-C′ showing Smackover lithology.

Cotton Valley has been penetrated in a band trending southeast across the central portion of the state. At the northwestern end of the band, the Cotton Valley is entirely a continental deposit made up of fine- to coarse-grained sandstones with quartz pebbles and chert fragments, along with red shale and pastel mudstone. The amount of sand in the section, and its grain size, decreases to the southeast, but the greater portion of the formation is still of continental origin. In the southeastern portion of the belt, the Cotton Valley contains some beds of marine and brackish origin. This is the area of Cotton Valley production.

The change from totally continental beds to continental, brackish and marine beds is shown by Section B-B′ (Figure 13). The Honolulu, Board of Supervisor No. 1, in Section 16-T 5 N-R 9 E, Scott County, penetrated 2300 feet of Cotton Valley sediments, consisting of white and red, fine-to medium-grained sandstones with some quartz pebbles and rare chert fragments, and associated beds of red shale, and purple, green and ochre mudstone. In the southernmost well in the section, the Gulf, No. 1 Soso Unit, Tract 28-7, in Soso Field, the Cotton Valley section contains some gray limestone, limy fossiliferous siltstone, gray shale and gray mudstone as well as some carbonaceous and lignitic sandstone. The Cotton Valley is productive from this type of lithology at Soso and Heidelberg Fields.

South of this area, several wells have penetrated Cotton Valley sections which contain many feet of marine beds. There are probably productive zones in this marine section, but the depths at which they could be expected to be reached make them unattractive as drilling prospects.

FAVORABLE AREAS FOR SMACKOVER AND COTTON VALLEY PRODUCTION

Figure 14 shows the more favorable areas for potential Smackover and Cotton Valley production in Mississippi. The favorable Smackover area is controlled on the north by probable subcrop limits, and on the south by depth. Drilling for objectives below 16,000 feet is not considered to be economical at this time. The most favorable Smackover area is in the oölitic trend at the southeastern end of the belt. While the areas in Scott, Rankin, Madison and Yazoo Counties are not

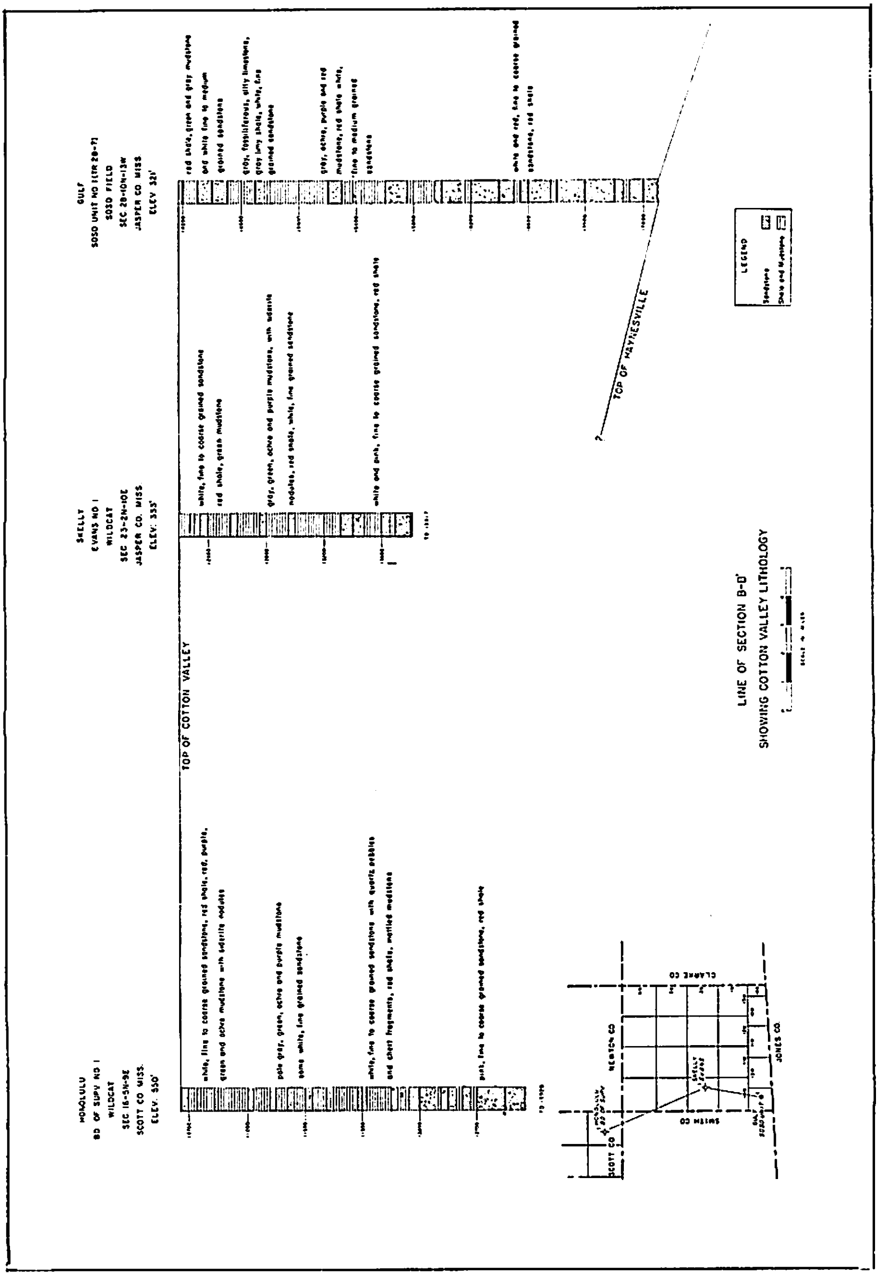

Figure 13.—Line of section B-B′ showing Cotton Valley lithology.

as favorable lithologically, they cannot be completely discounted since there have been many shows and some production in this area. The Sharkey and Issaquena County area is included in the favorable belt for structural reasons. The area is on the Sharkey platform and this uplift makes it possible to reach the Smackover at shallower depths.

The favorable Cotton Valley trend is controlled to the south by depth and in other directions by change in lithology. This confines the favorable area to the southern part of Smith, Jasper and Clarke Counties and the northern part of Covington, Jones and Wayne Counties. The Smackover and Cotton Valley favorable areas overlap in portions of Jasper, Jones, Clarke and Wayne Counties, and all wildcats there should test both formations before the acreage on which they are drilled is condemned.

CONCLUSION

In addition to the three areas discussed in this paper, there are other areas in Mississippi that need to be more adequately tested before resorting to the costly process of drilling wells in the deepest portions of the sedimentary basin. Mellen (1958) described the production possibilities of the Cretaceous Shelf Sediments. The Paluxy and Hosston formations of the Lower Cretaceous are just beginning to be developed by exploratory drilling.

ACKNOWLEDGMENTS

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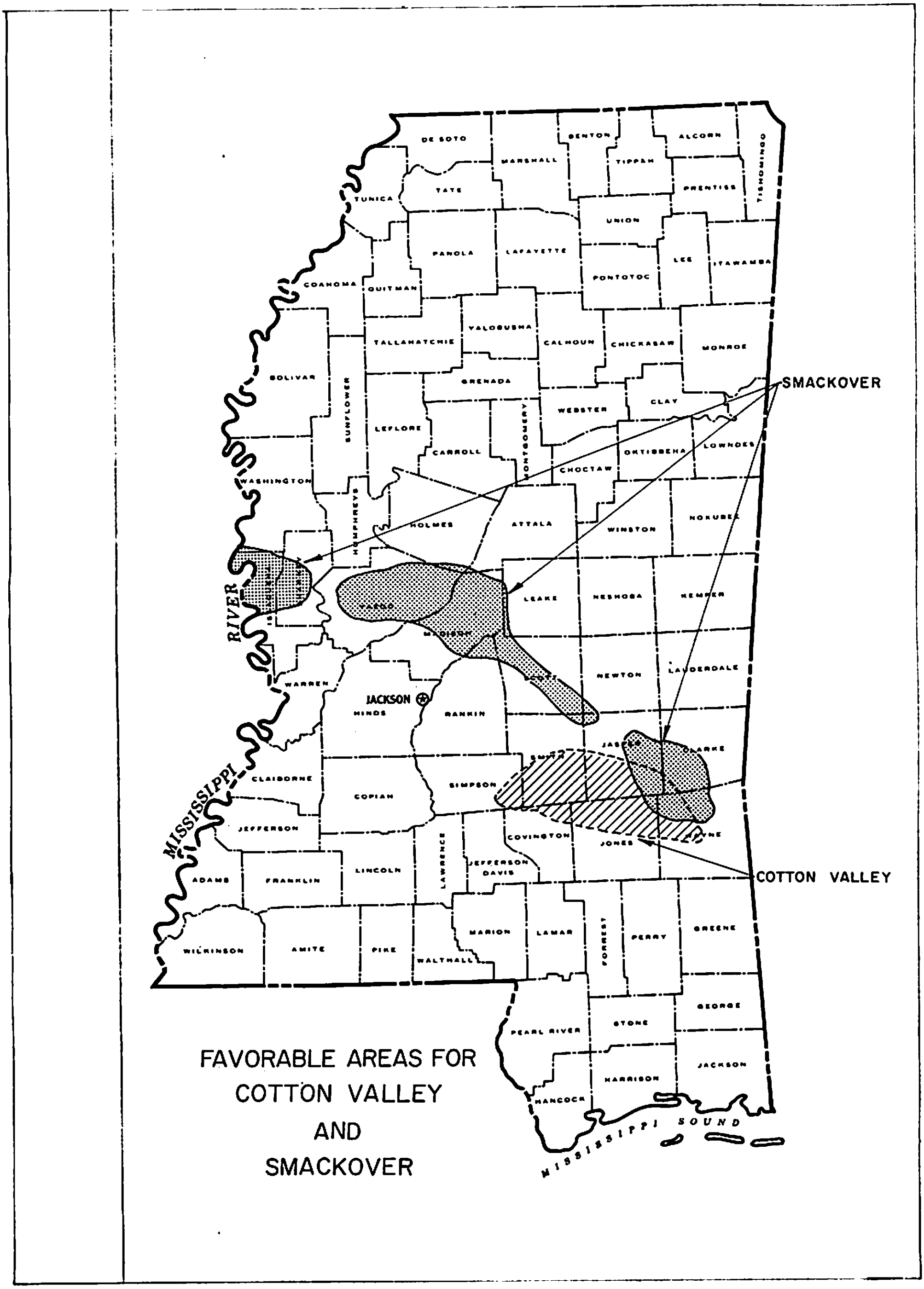

Figure 14.—Index map showing areas considered favorable for Jurassic (Smackover and Cotton Valley) production.

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LAND SNAILS FROM THE LOESS OF MISSISSIPPI*

LESLIE HUBRICHT

ABSTRACT

On the river bluffs in western Mississippi thick deposits of loess are frequently found. This loess in many places is highly fossiliferous. Although there are some records of loess fossils from the vicinity of Vicksburg and Natchez, the loess fauna of the State has been largely neglected. Recently the author had the opportunity to collect in the loess of Mississippi at a number of localities extending from near the northern border to near Port Gibson in the southern part of the State. Because of available time it was not possible to make the kind of search necessary to find the minute species. For this reason the following lists should be considered as only a preliminary report. The author hopes to be able to make more thorough collections at some future date.

DISCUSSION

On the river bluffs in western Mississippi thick deposits of loess are frequently found. This loess in many places is highly fossiliferous. Although there are some records of loess fossils from the vicinity of Vicksburg and Natchez, the loess fauna of the State has been largely neglected. Recently the author had the opportunity to collect in the loess of Mississippi at a number of localities extending from near the northern border to near Port Gibson in the southern part of the State. Because of available time it was not possible to make the kind of search necessary to find the minute species. For this reason the following lists should be considered as only a preliminary report. The author hopes to be able to make more thorough collections at some future date.

DE SOTO County: 3 miles east of Lake Cormorant.

Stenotrema barbatum (Clapp)
Helicodiscus jacksoni Hubricht
Zonitoides arboreus (Say)
Helicodiscus parallelus (Say)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Cionella morseana Doherty

DE SOTO County: 4.5 miles northeast of Banks.

Haplotrema concavum (Say)
Retinella electrina (Gould)
Helicodiscus jacksoni Hubricht
Zonitoides arboreus (Say)
Discus catskillensis (Pilsbry)
Punctum minutissimum (Lea)
Helicodiscus parallelus (Say)
Strobilops labyrinthica (Say)
Gastrocopta pentodon (Say)
Hendersonia occulta (Say)

*Reprinted from *Sterkiana* 3-11-14, 1961.

DE SOTO County: 3 miles west of Eudora.

Stenotrema barbatum (Clapp)
Stenotrema fraternum (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Ventridens ligerus (Say)
Anguispira alternata (Say)
Helicodiscus parallelus (Say)
Hendersonia occulta (Say)

TATE County: 4 miles south of Savage.

Stenotrema barbatum (Clapp)
Stenotrema fraternum (Say)
Mesodon clausus (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Retinella electrina (Gould)
Retinella indentata (Say)
Mesomphix friabilis (W. G. Binney)
Helicodiscus jacksoni Hubricht
Ventridens ligerus (Say)
Anguispira alternata (Say)
Helicodiscus parallelus (Say)
Succinea gelida F. C. Baker
Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
Gastrocopta pentodon (Say)
Vertigo elatior Sterki
Cionella morseana Doherty
Hendersonia occulta (Say)

TATE County: 5.5 miles south of Savage.

Stenotrema barbatum (Clapp)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Retinella electrina (Gould)
Retinella indentata (Say)
Ventridens demissus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Helicodiscus parallelus (Say)
Strobilops labyrinthica (Say)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Cionella morseana Doherty
Hendersonia occulta (Say)

PANOLA County: 2.8 miles west of Pleasant Grove.

Allogona profunda (Say)
Anguispira alternata (Say)
Helicodiscus parallelus (Say)
Hendersonia occulta (Say)
Pomatiopsis lapidaria (Say)

TALLAHATCHIE County: 4 miles north of Paynes.

Stenotrema barbatum (Clapp)
Allogona profunda (Say)
Retinella indentata (Say)
Helicodiscus jacksoni Hubricht
Helicodiscus, sp. This is a new species which will be described in another paper. (*H. notius* Hubricht)
Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Vertigo milium (Gould)
Hendersonia occulta (Say)
Pomatiopsis lapidaria (Say)

GRENADA County: 5.5 miles southwest of Holcomb.

Stenotrema barbatum (Clapp)
Stenotrema leai aliciae (Pilsbry)
Mesodon inflectus (Say)
Anguispira alternata (Say)
Helicodiscus notius Hubricht
Helicodiscus intermedius (Morrison)
Strobilops labyrinthica (Say)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Hendersonia occulta (Say)
Helicina orbiculata (Say)

CARROLL County: 3.5 miles southeast of Avalon.

Stenotrema barbatum (Clapp)
Allogona profunda (Say)
Helicodiscus notius Hubricht
Hendersonia occulta (Say)

CARROLL County: 1 mile west of Valley Hill.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Stenotrema leai aliciae (Pilsbry)
Mesodon clausus (Say)
Mesodon inflectus (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Retinella indentata (Say)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Discus catskillensis (Pilsbry)
Helicodiscus notius Hubricht
Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
Gastrocopta pentodon (Say)
Gastrocopta contracta (Say)
Cionella morseana Doherty
Hendersonia occulta (Say)
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

YAZOO County: near Junction of U. S. 49 and U. S. 49E, 1 mile east of Yazoo City.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon zaletus (Binney)
Triodopsis vulgatus (Pilsbry)
Triodopsis denotata (Férussac)
Triodopsis fosteri (F. C. Baker)
Ventridens ligerus (Say)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Discus patulus (Deshayes)
Helicodiscus sp.
Succinea ovalis Say
Strobilops labyrinthica (Say)
Gastrocopta armifera (Say)
Hendersonia occulta (Say)
Pomatiopsis lapidaria (Say)

HINDS County: 3 miles northwest of Edwards.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Stenotrema fraternum (Say)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Euconulus chersinus (Say)
Retinella indentata (Say)
Mesomphix capnodes (W. G. Binney)
Helicodiscus jacksoni Hubricht
Ventridens ligerus (Say)
Anguispira alternata (Say)
Helicodiscus sp.
Gastrocopta contracta (Say)
Gastrocopta corticaria (Say)
Vallonia perspectiva Sterki
Cionella morseana Doherty
Helicina orbiculata (Say)

WARREN COUNTY: near Clear Creek, 0.6 mile northeast of Bovina.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Mesodon inflectus (Say)
Retinella indentata (Say)
Zonitoides lateumbilicatus (Pilsbry)
Succinea ovalis Say
Succinea gelida F. C. Baker
Cionella morseana Doherty
Helicina orbiculata (Say)

WARREN County: 3.5 miles east of Vicksburg.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon inflectus (Say)
Triodopsis vulgatus (Pilsbry)
Triodopsis obstricta (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Euconulus fulvus (Müller)
Guppya sterkii (Dall)
Retinella indentata (Say)
Paravitrea multidentata (Binney)
Helicodiscus jacksoni Hubricht
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Zonitoides lateumbilicatus (Pilsbry)
Anguispira alternata (Say)
Discus patulus (Deshayes)
Helicodiscus parallelus (Say)
Helicodiscus sp.
Punctum minutissimum (Lea)
Succinea ovalis Say
Strobilops aenea Pilsbry
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Gastrocopta corticaria (Say)
Vertigo gouldi (Binney)
Columella edentula (Draparnaud)
Cionella morseana Doherty
Helicina orbiculata (Say)
Carychium exile H. C. Lea
Snail eggs. These are quite small. They are probably those of *Discus patulus.*

CLAIBORNE County: 4 miles east of Port Gibson.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Mesomphix capnodes (W. G. Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Helicina orbiculata (Say)

PLEISTOCENE LAND SNAILS OF SOUTHERN MISSISSIPPI AND ADJACENT LOUISIANA*

LESLIE HUBRICHT**

ABSTRACT

In a previous paper (Sterkiana 3: 11-14, 1961) the author reported on the land snails of the loess of Mississippi from the northern border south to near Port Gibson, Claiborne County. In the present paper the species found from the vicinity of Vicksburg, Warren County south into West Feliciana Parish, Louisiana are listed. More time was available for collecting at the localities reported in the present paper and the lists are more complete.

DISCUSSION

There are some pitfalls in attempting to determine climatic and ecological conditions from snail faunas. Snails may live in different habitats in different parts of their ranges. Thus *Hendersonia occulta* (Say) and *Pomatiopsis lapidaria* (Say) are found on floodplains in the North, but in the southern Appalachians they are usually found on talus slopes or on the slopes of ravines, and sometimes are found high up on mountain sides well away from any water. *Stenotrema barbatum* (Clapp) is found on floodplains over most of its range, but is an upland snail in parts of West Virginia. Near St. Louis, Missouri, *Stenotrema leai aliciae* (Pilsbry) is found only in wet meadows in the vicinity of springs, but in Mississippi it is common on dry roadsides. Snails are adaptable. In a somewhat overgrazed mountainside pasture in West Virginia I once found ten species of typically woodland snails in abundance crawling about after a rain. Although the trees had been removed many years ago the snails had adapted themselves to the new environment and had survived there with only short grass for cover.

Stenotrema barbatum (Clapp) is the species usually called *Stenotrema hirsutum* (Say) in loess faunal lists. It is doubtful if *S. hirsutum* occurs anywhere as a loess fossil as its range is south and east of the main loess areas. It ranges from Connecticut west to southern Indiana, south of the southern limit of Pleistocene glaciation, southward to western North Carolina and northeastern Mississippi. *Stenotrema barbatum* ranges from

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Massachusetts west to southern Minnesota and eastern Kansas, south to South Carolina, southern Alabama, and Missouri.

Since the loess hills of Mississippi are forested at the present time, in the absence of any factor that would prevent the growth of trees, they probably were covered with a forest at the time the loess was formed, except where it was destroyed by fire or storm. The snails found in the loess are such a mixture of northern and southern species that it is difficult to determine the climate during the time it was deposited. It was probably moderate with cool summers which would prevent the dying off of the northern species, yet the winters were not severe enough to kill the southern species. It was probably wetter than at present — at least there were no prolonged dry spells in the summer.

A number of species found in the loess of southern Mississippi were not found in northern Mississippi, notably *Mesodon zaletus* (Binney), *Mesodon elevatus* (Say), *Triodopsis vulgatus* Pilsbry, and *Mesomphix capnodes* (W. G. Binney). Although some of these species are found living today in the upper Mississippi Valley, it does not seem possible that they could have reached southern Mississippi by moving down along the Mississippi River without leaving some evidence of their passing. All of these species are native of northern Alabama. During the Pleistocene many species of land snails of the southern Appalachians moved southward onto the Coastal Plain and then spread westward at least as far as the Mississippi River. The presence of *Paravitrea significans* (Bland) in the loess of southern Mississippi would indicate that a similar migration of the Ozarkian fauna occurred at the same time. Apparently there was some exchange of faunas between the Appalachians and Ozarks at this time. *Triodopsis obstricta* (Say), *Glyphyalina solida* (H. B. Baker), *Mesomphix capnodes* (W. G. Binney) [=*Mesomphix cupreus ozarkensis* (Pilsbry & Ferris)], and *Paravitrea multidentata* (Binney) reaching the Ozarks, and *Triodopsis alleni* (Wetherby) migrated into the southern Appalachians. *Mesodon zaletus* (Binney), *Triodopsis obstricta* (Say), *Glyphyalina praecox* (H. B. Baker), *Mesomphix capnodes* (W. G. Binney), and *Paravitrea significans* (Bland) have survived in the Tunica Hills of southwestern Mississippi, and Louisiana as relicts of this migration, although they have not been found anywhere else in Mississippi.

Some of the species reported in the previous paper were known only from immature or fragmentary material. The finding of good series of mature specimens together with a better understanding of the origin of the fauna has made it necessary to revise some of the names used in the previous paper.* *Mesomphix friabilis* (W. G. Binney) is *Mesomphix capnodes* (W. G. Binney) except in Tate Co. *Zonitoides limatulus* (Binney) is *Zonitoides lateumbilicatus* (Pilsbry). *Hawaiia minuscula* (Binney) is *Helicodiscus jacksoni* Hubricht. And *Helicodiscus singleyanus inermis* H. B. Baker is *Helicodiscus intermedius* Morrison. The undescribed species of *Helicodiscus* is *Helicodiscus notius* Hubricht.

MISSISSIPPI

1. HINDS County, loess, 1 mile northeast of Edwards.
   - *Stenotrema barbatum* (Clapp)
   - *Stenotrema stenotrema* (Pfeiffer)
   - *Stenotrema leai aliciae* (Pilsbry)
   - *Stenotrema fraternum* (Say)
   - *Mesodon thyroidus* (Say)
   - *Mesodon zaletus* (Binney)
   - *Mesodon elevatus* (Say)
   - *Mesodon inflectus* (Say)
   - *Triodopsis vulgatus* Pilsbry
   - *Triodopsis fosteri* (F. C. Baker)
   - *Allogona profunda* (Say)
   - *Haplotrema concavum* (Say)
   - *Mesomphix friabilis* (W. G. Binney)
   - *Anguispira alternata* (Say)
   - *Helicodiscus notius* Hubricht
   - *Helicina orbiculata* (Say)

2. HINDS County: loess, 1.7 miles northwest Edwards.
   - *Stenotrema barbatum* (Clapp)
   - *Stenotrema stenotrema* (Pfeiffer)
   - *Stenotrema leai aliciae* (Pilsbry)
   - *Stenotrema fraternum* (Say)
   - *Mesodon thyroidus* (Say)
   - *Mesodon clausus* (Say)
   - *Mesodon zaletus* (Binney)
   - *Mesodon inflectus* (Say)
   - *Triodopsis vulgatus* Pilsbry
   - *Triodopsis fosteri* (F. C. Baker)
   - *Allogona profunda* (Say)
   - *Haplotrema concavum* (Say)
   - *Glyphyalinia lewisiana* (Clapp)
   - *Glyphyalinia indentata* (Say)
   - *Glyphyalinia solida* (H. B. Baker)
   - *Paravitrea significans* (Bland)
   - *Ventridens demissus* (Binney)
   - *Zonitoides arboreus* (Say)
   - *Zonitoides lateumbilicatus* (Pilsbry)
   - *Anguispira alternata* (Say)
   - *Discus patulus* (Deshayes)
   - *Helicodiscus parallelus* (Say)
   - *Helicodiscus notius* Hubricht
   - *Succinea ovalis* Say
   - *Catinella gelida* (F. C. Baker)
   - *Strobilops labyrinthica* (Say)
   - *Gastrocopta armifera* (Say)
   - *Gastrocopta corticaria* (Say)
   - *Vallonia perspectiva* Sterki
   - *Cionella morseana* Doherty
   - *Helicina orbiculata* (Say)

*These revisions have been made, at the writer's request, in the present reprinting of the preceding (1961) paper. Ed.

3. HINDS County: loess, 2 miles northwest of Edwards. (Due to a typographical error this locality was given as 3 miles northwest of Edwards in the previous paper. The species listed below are in addition to those listed previously).

Mesodon zaletus (Binney)
Paravitrea significans (Bland)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Succinea ovalis Say
Strobilops aenea Pilsbry
Strobilops texasiana Pilsbry & Ferriss
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Vertigo gouldi (Binney)

4. WARREN County: loess, 1.2 miles south of Blakely.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon inflectus (Say)
Triodopsis vulgatus Pilsbry
Triodopsis obstricta (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Guppya sterkii (Dall)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia indentata (Say)
Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Anguispira alternata (Say)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Gastrocopta armifera (Say)
Gastrocopta pentodon (Say)
Gastrocopta corticaria (Say)
Vertigo gouldi (Binney)
Columella edentula (Draparnaud)
Vallonia perspectiva Sterki
Cionella morseana Doherty
Carychium exile H. C. Lea
Hendersonia occulta (Say)
Helicina orbiculata (Say)
Snail eggs (*Anguispira*)

5. WARREN County: loess, 0.5 mile northeast Bovina.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Stenotrema leai aliciae (Pilsbry)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon inflectus (Say)
Triodopsis vulgatus Pilsbry
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia indentata (Say)
Glyphyalinia solida (H. B. Baker)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Anguispira alternata (Say)
Helicodiscus notius Hubricht
Succinea ovalis Say
Cionella morseana Doherty
Hendersonia occulta (Say)

6. WARREN County: loess, 2 miles east of Vicksburg. As the result of using an inaccurate map this locality was listed as 3.5 miles east of Vicksburg in the previous paper. An interchange is being constructed at this locality and there are a good many cuts in the loess here. All of the shells were collected at the southernmost cut, on the south side of U. S. 61 bypass just west of the junction of U. S. 80. This locality was more thoroughly collected than any other and I believe that the entire fauna was collected as the latest collections resulted in no additional species. Additional species are listed below.

Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Triodopsis denotata (Férussac)
Glyphyalinia lewisiana (Clapp)
Paravitrea significans (Bland)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Philsbry)
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Vertigo oscariana Sterki
Vertigo tridentata Wolf
Columella alticola (Ingersoll)
Vallonia perspectiva Sterki
Snail eggs (*Anguispira*)
Snail eggs (*Zonitoides*?)

7. WARREN County: loess, 2 miles northeast of LaTourneau.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Mesodon zaletus (Binney)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Euconulus fulvus (Müller)
Guppya sterkii (Dall)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia circumstriata (Taylor)?
Glyphyalinia indentata (Say)
Paravitrea multidentata (Binney)
Ventridens ligerus (Say)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Anguispira alternata (Say)
Helicodiscus notius Hubricht
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Gastrocopta corticaria (Say)
Vertigo milium (Gould)
Vertigo gouldi (Binney)
Columella edentula (Draparnaud)
Columella alticola (Ingersoll)
Cionella morseana Doherty
Helicina orbiculata (Say)
Snail eggs (*Anguispira*)

8. CLAIBORNE County: loess, 7.5 miles north of Port Gibson.

Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon elevatus (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Ventridens demissus (Binney)
Ventridens intertextus (Binney)
Anguispira alternata (Say)
Discus patulus (Deshayes)
Helicina orbiculata (Say)

9. CLAIBORNE County: loess, 7.6 miles east of Port Gibson.

Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Haplotrema concavum (Say)
Mesomphix globosus (MacMillan)

Mesodon clausus (Say)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Ventridens intertextus (Binney)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Helicina orbiculata (Say)

10. CLAIBORNE County: loess, 4 miles east of Port Gibson. Additional species.

Mesodon clausus (Say)
Triodopsis vulgatus Pilsbry
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia circumstriata (Taylor)?
Ventridens intertextus (Binney)
Discus patulus (Deshayes)
Gastrocopta armifera (Say)

11. CLAIBORNE County: loess, 2 miles south of Port Gibson.

Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Stenotrema fraternum (Say)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Ventridens intertextus (Binney)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Succinea ovalis Say
Cionella morseana Doherty
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

12. JEFFERSON County: loess, 5 miles northwest of Lorman.

Stenotrema stenotrema (Pfeiffer)
Stenotrema fraternum (Say)
Mesodon elevatus (Say)
Mesodon zaletus (Binney)
Triodopsis vulgatus Pilsbry
Triodopsis albolabris (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Anguispira alternata (Say)

13. JEFFERSON County: loess, 2 miles northwest of Lorman.

Stenotrema fraternum (Say)
Mesodon elevatus (Say)
Triodopsis vulgatus Pilsbry
Anguispira alternata (Say)
Hendersonia occulta (Say)
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

14. JEFFERSON County: loess, 7.3 miles northwest of Fayette.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus jacksoni Hubricht
Succinea ovalis Say
Cionella morseana Doherty

Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Ventridens demissus (Binney)
Hendersonia occulta (Say)
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

15. JEFFERSON County: loess, 3.2 miles southwest of Fayette.

Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon elevatus (Say)
Mesodon clausus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Ventridens intertextus (Binney)
Anguispira strongylodes (Pfeiffer)
Cionella morseana Doherty
Helicina orbiculata (Say)

16. ADAMS County: loess, Selma.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsby)
Mesodon elevatus (Say)
Haplotrema concavum (Say)
Anguispira alternata (Say)
Helicina orbiculata (Say)

17. ADAMS County: loess, 1 mile northeast of Washington.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Ventridens demissus (Binney)
Discus patulus (Deshayes)
Helicodiscus parallelus (Say)
Succinea ovalis Say
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

18. ADAMS County: loess, 2 miles west of Fenwick.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia indentata (Say)
Mesomphix capnodes (W. G. Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Succinea ovalis Say
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

19. ADAMS County: silt along small creek, 1.6 miles west of Fenwick. In addition to the land snails this deposit contained several species of aquatic mollusks, fossil wood and other plant remains, and large numbers of spruce needles.

Stenotrema barbatum (Clapp)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Haplotrema concavum (Say)
Euconulus fulvus (Müller)
Guppya sterkii (Dall)
Glyphyalinia sp. (related to *G. circumstriata* (Taylor) but more depressed and with smaller umbilicus. Probably an undescribed species).
Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Hawaiia minuscula (Binney)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Striatura exigua (Stimpson)
Deroceras laeve (Müller)
Helicodiscus parallelus (Say)
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Catinella gelida (F. C. Baker)
Gastrocopta armifera (Say)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Gastrocopta tappaniana (C. B. Adams)
Vertigo milium (Gould)
Vertigo, n. sp. (same as at locality 20)
Vertigo ovata Say
Carychium exiguum (Say)
Carychium exile H. C. Lea
Hendersonia occulta (Say)
Pomatiopsis lapidaria (Say)

20. ADAMS County: loess, south side of road, 1.7 miles west of the junction of U. S. 61 and U. S. 84, Washington.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Euconulus fulvus (Müller)
Guppya sterkii (Dall)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia indentata (Say)
Glyphyalinia indentata paucilirata (Morelet)
Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Zonitoides lateumbilicatus (Pilsbry)
Anguispira alternata (Say)
Helicodiscus parallelus (Say)
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Succinea ovalis Say
Succinea, n. sp.
Catinella gelida (F. C. Baker)
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Gastrocopta corticaria (Say)
Vertigo, n. sp. (With teeth similar to *V. alabamensis conecuhensis* Clapp, but smaller and more slender than *V. milium* (Gould).
Vertigo tridentata Wolf
Vertigo gouldi (Binney)
Columella edentula (Draparnaud)
Columella alticola (Ingersoll)
Vallonia perspectiva Sterki
Cionella morseana Doherty
Carychium exile H. C. Lea
Hendersonia occulta (Say)
Helicina orbiculata (Say)
Pomatiopsis lapidaria (Say)

Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Snail eggs (*Anguispira*)
Snail eggs (*Discus*)
Snail eggs (*Zonitoides?*)

21. ADAMS County: loess, 1 mile southeast of Anna.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Euconulus fulvus (Müller)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia indentata (Say)
Glyphyalinia solida (H. B. Baker)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Helicodiscus jacksoni Hubricht
Succinea ovalis Say
Cionella morseana Doherty
Hendersonia occulta (Say)

22. ADAMS County: silt, ditch, 2.5 miles northeast of Anna. This deposit is on the Mississippi River floodplain, and is from 8 to 10 feet below the surface. It is probably the youngest deposit reported in this paper. Many of the shells appear to have been washed out of loess deposits on the nearby hills and were redeposited.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Euglandina rosea (Férussac)
Haplotrema concavum (Say)
Glyphyalinia indentata (Say)
Mesomphix globosus (MacMillan)
Ventridens demissus (Binney)
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Succinea ovalis Say
Hendersonia occulta (Say)
Helicina orbiculata (Say)

23. ADAMS County: loess, first cut east of the Mississippi River bridge, on the south side of U. S. 84, Natchez.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
ney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)

Haplotrema concavum (Say)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia indentata (Say)
Glyphyalinia solida (H. B. Baker)
Mesomphix capnodes (W. G. Bin-
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Succinea ovalis Say
Cionella morseana Doherty
Helicina orbiculata (Say)

24. ADAMS County: loess, 3 miles southwest of Natchez.
Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis denotata (Férussac)
Triodopsis obstricta X denotata
Triodopsis albolabris (Say)
Triodopsis alleni (Wetherby)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia lewisiana (Clapp)
Glyphyalinia indentata (Say)
Mesomphix capnodes (W. G. Binney)
Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Succinea ovalis Say
Cionella morseana Doherty
Helicina orbiculata (Say)

25. ADAMS County: loess, Cloverdale.
Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis fosteri (F. C. Baker)
Allogona profunda (Say)
Haplotrema concavum (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)

26. WILKINSON County: loess, 5.7 miles west of Lessley.
Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis denotata (Férussac)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia indentata (Say)
Mesomphix capnodes (W. G. Binney)
Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Anguispira alternata (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus notius Hubricht
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Succinea ovalis Say
Gastrocopta corticaria (Say)
Vertigo gouldi (Binney)
Helicina orbiculata (Say)
Snail eggs (*Anguispira*)

27. WILKINSON County: loess, 2.3 miles southeast of Lessley.

Stenotrema stenotrema (Pfeiffer)
Mesodon thyroidus (Say)
Mesodon elevatus (Say)
Allogona profunda (Say)
Mesomphix globosus (MacMillan)
Mesomphix capnodes (W. G. Binney)
Anguispira strongylodes (Pfeiffer)

28. WILKINSON County: loess, 1.5 miles east of Fort Adams.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon clausus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Paravitrea significans (Bland)
Ventridens demissus (Binney)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Succinea ovalis Say
Helicina orbiculata (Say)

29. WILKINSON County: loess, 0.5 mile northwest of Pond.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon zaletus (Binney)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Mesomphix capnodes (W. G. Binney)
Ventridens demissus (Binney)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicina orbiculata (Say)

LOUISIANA

WEST FELICIANA Parish: silt, Little Bayou Sara, Retreat. In addition to the land snails this deposit contained several species of aquatic mollusks, fossil wood and other plant remains. The spruce needles found at locality 19 were not found at this locality. The readily identifiable tree remains were of deciduous species: black walnut, beech, hickory, oak, sycamore, and maple.

Stenotrema barbatum (Clapp)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis albolabris (Say)
Haplotrema concavum (Say)
Guppya sterkii (Dall)
Glyphyalinia, sp. (same as at locality 19)
Glyphyalinia indentata (Say)
Helicodiscus parallelus (Say)
Helicodiscus intermedius Morrison
Helicodiscus jacksoni Hubricht
Punctum minutissimum (Lea)
Succinea, sp. (immature)
Strobilops aenea Pilsbry
Gastrocopta contracta (Say)
Gastrocopta pentodon (Say)
Gastrocopta tappaniana (C. B. Adams)

Paravitrea multidentata (Binney)
Paravitrea significans (Bland)
Hawaiia minuscula (Binney)
Ventridens intertextus (Binney)
Zonitoides arboreus (Say)
Striatura exigua (Stimpson)
Striatura milium (Morse)
Deroceras laeve (Müller)
Anguispira strongylodes (Pfeiffer)
Vertigo milium (Gould)
Vertigo, n. sp. (same as at locality 20)
Vertigo ovata Say
Vertigo tridentata Wolf
Vertigo gouldi (Binney)
Carychium exiguum (Say)
Carychium exile H. C. Lea
Pomatiopsis lapidaria (Say)

31. WEST FELICIANA Parish: loess, Tunica.

Stenotrema barbatum (Clapp)
Stenotrema stenotrema (Pfeiffer)
Stenotrema leai aliciae (Pilsbry)
Mesodon thyroidus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia indentata (Say)
Paravitrea significans (Bland)
Mesomphix capnodes (W. G. Binney)
Ventridens demissus (Binney)
Ventridens intertextus (Binney)
Anguispira strongylodes (Pfeiffer)
Discus patules (Deshayes)
Helicina orbiculata (Say)

32. WEST FELICIANA Parish: loess, Brandon.

Stenotrema stenotrema (Pfeiffer)
Mesodon thyroidus (Say)
Mesodon zaletus (Binney)
Mesodon elevatus (Say)
Mesodon inflectus (Say)
Triodopsis obstricta (Say)
Triodopsis albolabris (Say)
Allogona profunda (Say)
Haplotrema concavum (Say)
Glyphyalinia lewisiana (Clapp)
Mesomphix globosus (MacMillan)
Mesomphix capnodes (W. G. Binney)
Ventridens ligerus (Say)
Ventridens intertextus (Binney)
Anguispira strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Helicodiscus parallelus (Say)
Helicina orbiculata (Say)

PROBLEM OF DESICCATION SINKING AT CLARKSDALE

TRACY W. LUSK

ABSTRACT

Clarksdale, in the north-central part of the Mississippi Alluvial Plain of Mississippi, became concerned with foundation problems, which were not particularly new to its citizens, when sinking caused damage to the relatively new (at the time of this study, 1957) Eliza Clark Elementary School Building.

The Mississippi Geological Survey approached the problem by power drilling six test holes. However, it was discovered that hand auger drilling from the surface to the water level provided much more information than drilling with water. In the first test hole the cause of the sinking was indicated by the loss of circulation in a clay zone. The reason for this condition was revealed in the dry samples of the auger holes by slickensides and by deposits of illuviated silt and very fine sand along cracks in the clay. Conclusive evidence was provided by the digging of a 19-foot pit at the Eliza Clark School. The walls of the pit 15 to 18 feet below the surface were characterized by cracks in the clay filled with silt and very fine sand that obviously had washed from above, thereby, eluviating some of the overlying material. This results in sinking (recompaction) in the stratum so eluviated.

Shrinkage due to drying (desiccation) is the apparent reason for the cracks. This probably has been accelerated by the cone-of-depression on the water table because of pumpage and because of prolonged periods of drought.

The filled cracks would not be expected to cause further trouble, but the more recent cracks might open larger with further drying and allow more silt and fine sand to be eluviated from above. Areas to be watched are the ones with sandy soil underlain by more sand and silt all being above a clay zone—a condition that allows free movement of percolating water when the process of desiccation begins.

Future construction in this or any similar area should be designed to withstand surface sinking.

DESICCATION SINKING AT CLARKSDALE

The problem of sinking was called to the attention of the Mississippi Geological Survey after damaging settling had developed in the Eliza Clark Elementary School building. This damage was caused apparently by a rather large depression developing under the east end of the building. The City Engineer, Mr. R. A. Miller, was able to locate numerous other depressions in the city, many of which are in the vicinity of the Eliza Clark School, but most of Clarksdale has experienced this problem to some extent.

Inasmuch as the terms sinks and sink holes are usually and properly associated with limestone areas, a brief explanation and description of these sinks or depressions are in order. Clarksdale is located in the north-central part of the Mississippi

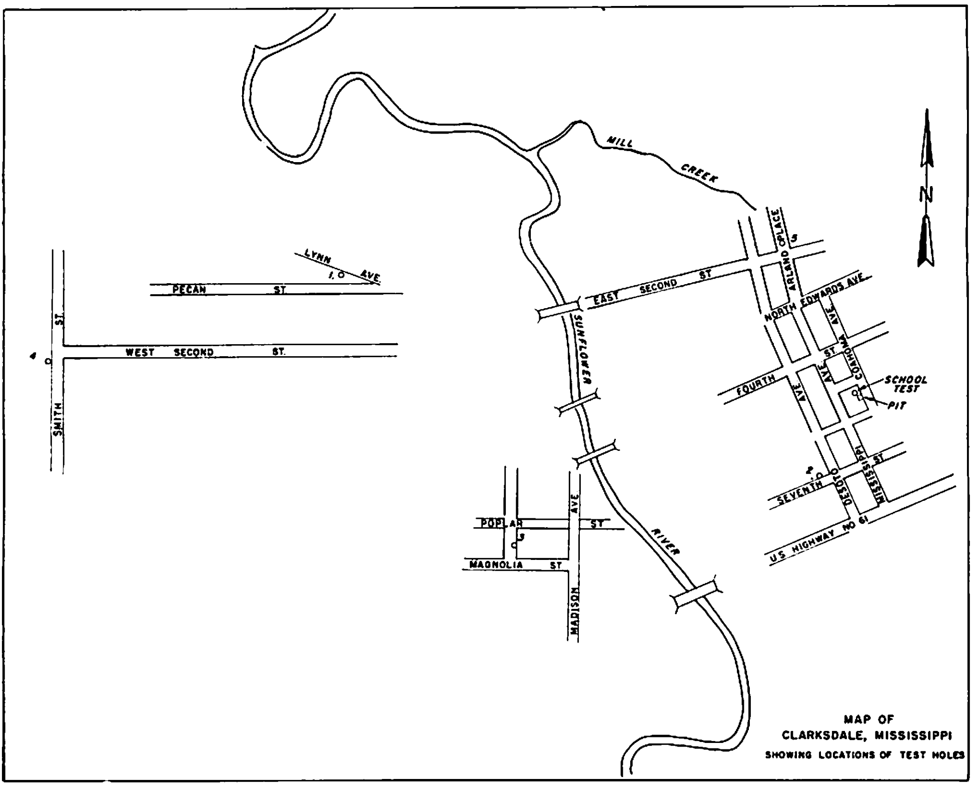


Figure 1.—Locations of test holes drilled in Clarksdale, Mississippi during study of dessication sinking problem.

Alluvial Plain of Mississippi. This area is underlain by approximately 160 feet of alluvial deposits of clay, silt, sand and gravel. The term "sink hole" may be considered by some to be misused; however, the observed holes have the same appearance as actual sink holes. The holes are virtually circular and vary from two feet in diameter to as much as 15 to 20 feet. The depths of the holes vary from about one foot to about three feet.

The investigation began with a study of the geologic conditions at the Eliza Clark School. A drill hole was put down to a total depth of 110 feet. Three feet from the drilled hole, a hole was augered down to the water level. This dry hole was made in an effort to determine why circulation was lost in the drill hole at 15 to 19 feet from the surface, inasmuch as the electrical log indicated this zone to be clay. The samples taken from the auger hole proved the zone to be clay but presented evidence of cracks in the clay, some of which evidently were filled with silt and very fine sand, a condition which, if proven, would explain the depressions.

Figure 1 shows the location of test holes drilled in Clarksdale. All the holes except No. 4 were drilled very near depressions. The holes were drilled dry (with an Iwan-type auger on the drill rods), to as great depths as possible. At most locations these were to or just above the water table. Drilling was finished by standard rotary procedures.

Each hole showed evidence of cracking in the clay zone that was found at depths between 10 and 22 feet. The evidence usually was in the form of slickensides, highly polished surfaces in the clay caused by a very slow movement of clay on clay. This condition here probably is caused from shrinkage due to drying.

Normally a clay bed with 10 or more feet of overburden would have a rather stable moisture content. Probably the greatest aggravation has come about by the cone-of-depression on the water table due to pumpage. This statement does not mean that the water supply is being exhausted. A cone-of-depression is a normal lowering of the water level in the vicinity of a pumping well or wells. The top 10 to 12 feet of sand beneath the clay zone in holes 2, 5, and Eliza Clark School test were dry. This condition would not only aid in drying the clay, but would stop capillary water from passing into the clay from the sand. Long periods of drought would also be a major factor in drying the clay.

In addition to shrinkage cracks, rotted vegetation, roots, and trees have probably furnished other openings.

The test pit dug at the Eliza Clark School provided the necessary proof to explain the sinking. As the cracks open, water percolating downward carries the silt and very fine sand that lie above the clay into the cracks, thereby removing some

Figure 2.—Wall of Eliza Clark School test pit 15-16 feet below surface showing vertical silt-filled crack in the clay.

of the overlying material. In due course of time a void develops, and when the void becomes so large that the soil crust above it cannot support its own weight or perhaps additional load, as the situation might be, then the soil caves. The cracks that are already filled would not be expected to give any further trouble, but the recent unfilled cracks are subject to opening larger and allowing more fine sand and silt to wash down.

Unless the moisture content of the clay is stabilized, the shrinkage will continue until such time as the maximum is reached. At the time of this study (1957), during a prolonged interval of rainfall, the moisture content is no doubt higher than it is at other times of the year. During wet seasons the shrinkage will not only cease but swelling will begin; however, laboratory tests indicate that the clay will never return completely to its original state.

Figure 3.—Slickensided surfaces and open cracks, wall of test pit at Eliza Clark School.

Areas that are particularly susceptible to desiccation sinking are where the soil is very sandy and in turn is underlain by more sand and silt all being above a clay zone. The reason is that this type soil and subsoil will allow the downward percolation of water much more freely than would a clay soil. The logs of Holes Nos. 2, 3, 4, 5, and Eliza Clark School illustrate this situation.

The photographs taken in the test pit show clearly the conditions explained above. The largest cracks were 15 to 16 feet from the surface (Figure 2). This coincides with the loss of circulation in the test hole located about 50 feet from the pit. A network of recent cracks not yet filled could be seen

Figure 4.—Diagonally-filled crack in the wall of the pit at Eliza Clark School.

all around the walls of the pit. An excellent illustration of a recent crack showing the slickensided surface is Figure 3. Other veins of silt are illustrated by Figures 4 through 6. All the photographs were taken from depths of 14 to 18 feet from the surface.

At the beginning of this investigation, the best that was hoped to be gained was a recommended procedure to follow in order to answer the question why. However, the investigation did provide the answer as to the cause of the sink holes. On the basis of information obtained from the study, the following recommendations seem in order:

1. Redrill the test holes at the same locations near the end of the summer (dry season), probably in August, for a comparison.

Figure 5.—Irregularly silt-filled cracks and probable iron precipitate, pit at Eliza Clark School.

2. For the city of Clarksdale to require that all future wells drilled for air-conditioning inside the city and completed in the alluvial sand and gravel (down to depths of 160 to 170 feet) to have a second well drilled for the return of the water to the formation. This can be done satisfactorily by the installation of a closed system.

Figure 6.—Closeup of portion of Figure 5.

It is very doubtful if a normal foundation study would have revealed the true conditions, or enabled the designer to predict future sink holes. Even now such predictions cannot be made, but if feasible, the possibility of desiccation sinking should always be taken into account in the future. At least one manner in which this type of foundation failure can be

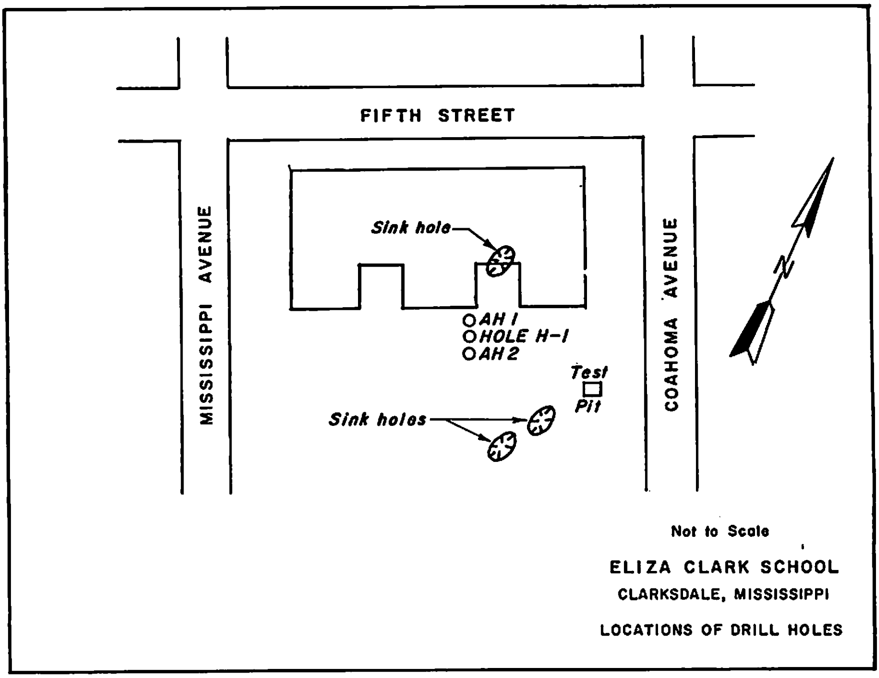


Figure 7.—Location of sink holes, test holes and pit at Eliza Clark School.

avoided is by placing piles deep enough to be in the sand below the clay zone.

Foundation failures in alluvial deposits are common and in areas where the problem is known, steps can be taken to prevent them or to reduce their intensity. A very costly case was reported recently in alluvial foundation in South Louisiana. The January 18, 1963, edition of the *Times-Picayune* reported that the new $900,000 incinerator in New Orleans has been rejected by the City Council because of sinking of a

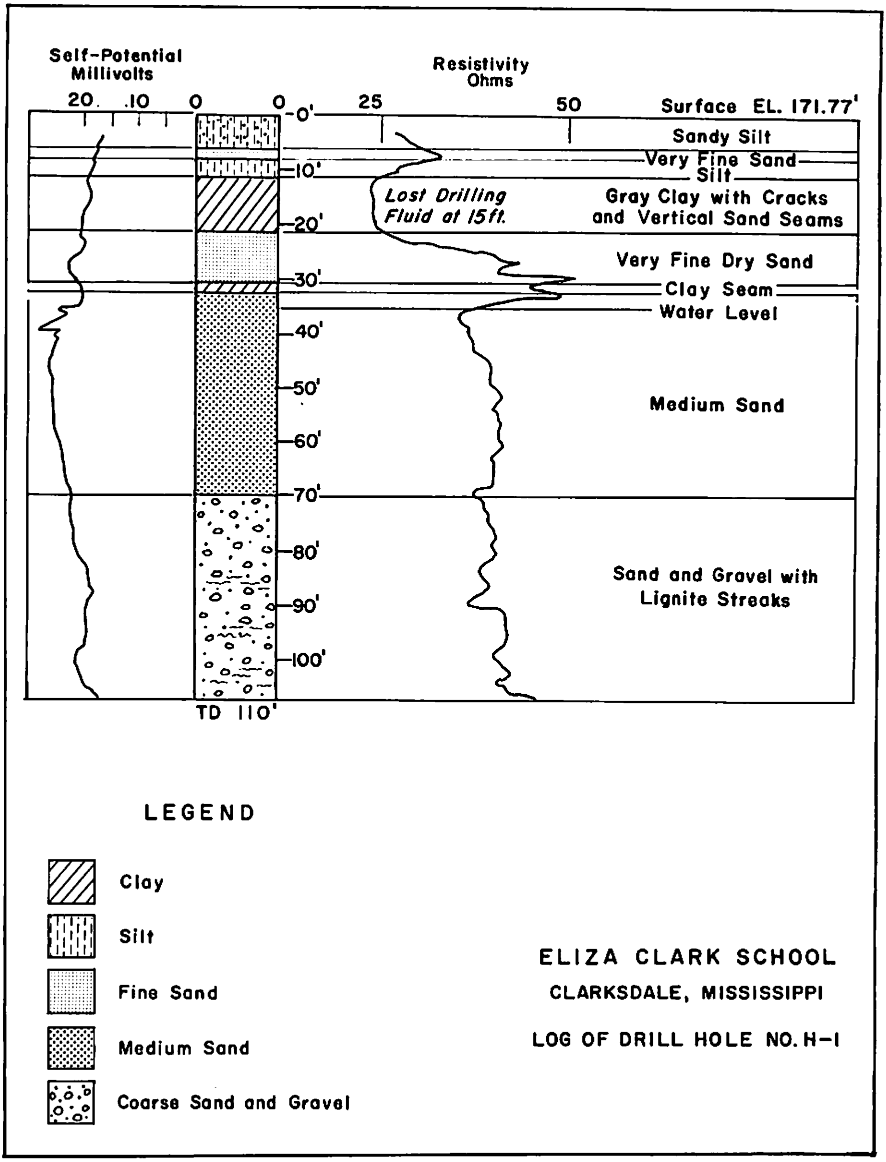


Figure 8.—Electrical log, lithology and other data, test hole H-1 at Eliza Clark School.

portion of the building. This portion has a floating slab construction. Another portion of the building is built on piles and has not been affected by sinking. The problem at New Orleans may not be identical to that at Clarksdale, but both point up the need for adequate foundation design in alluvial sediments.

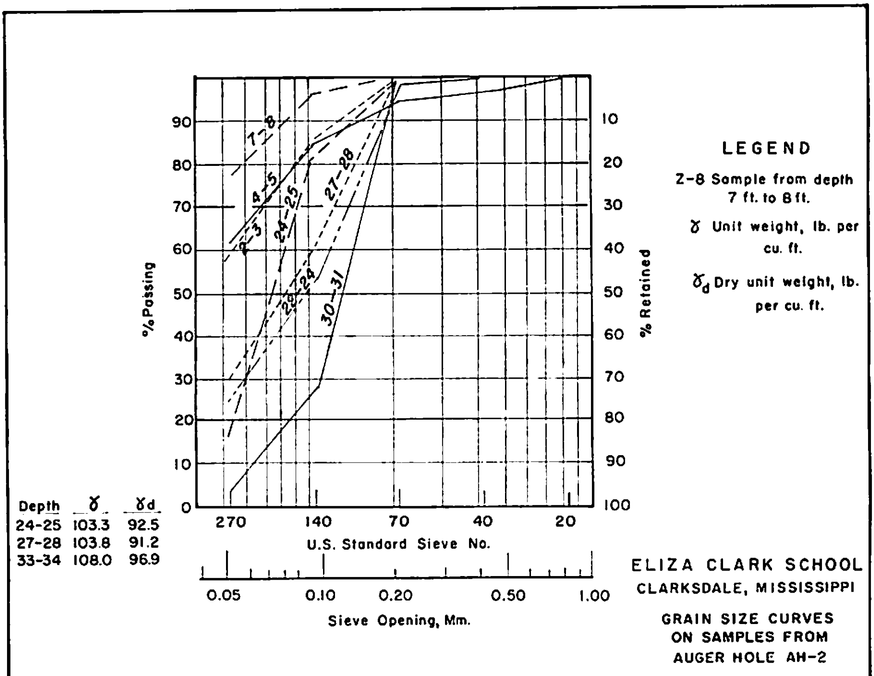


Figure 9.—Grain size curves on samples from auger hole AH-2, Eliza Clark School.

SUMMARY

The study of desiccation sinking at Clarksdale consisted of drilling six test holes and one pit. The first hole was drilled at the Eliza Clark School, also the location of the pit. The other holes were located near trouble spots and spaced over the city in order to get a complete coverage.

Every hole showed evidence of cracking in the clay zone underlying the soil and subsoil. Some of the cracks were filled with silt and very fine sand, material that was foreign to the

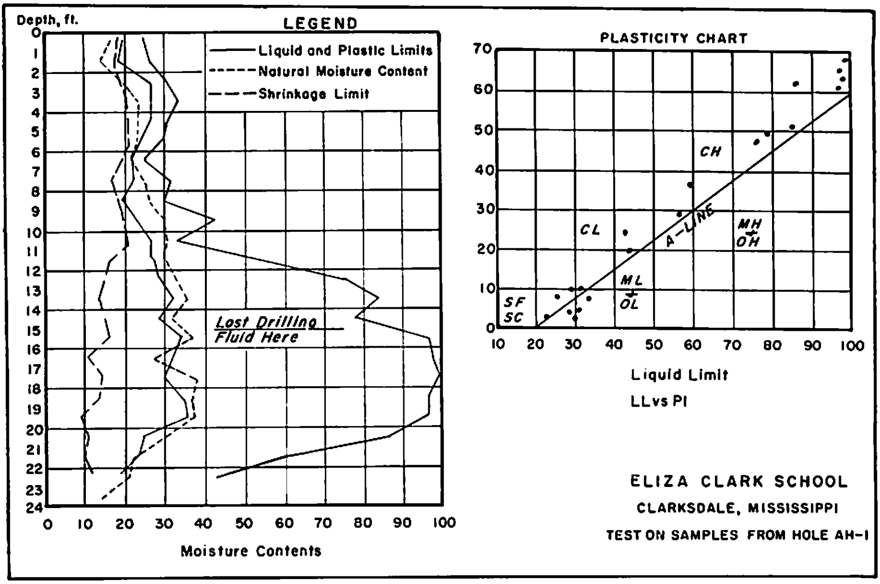


Figure 10.—Tests on samples from Hole AH-1, Eliza Clark School.

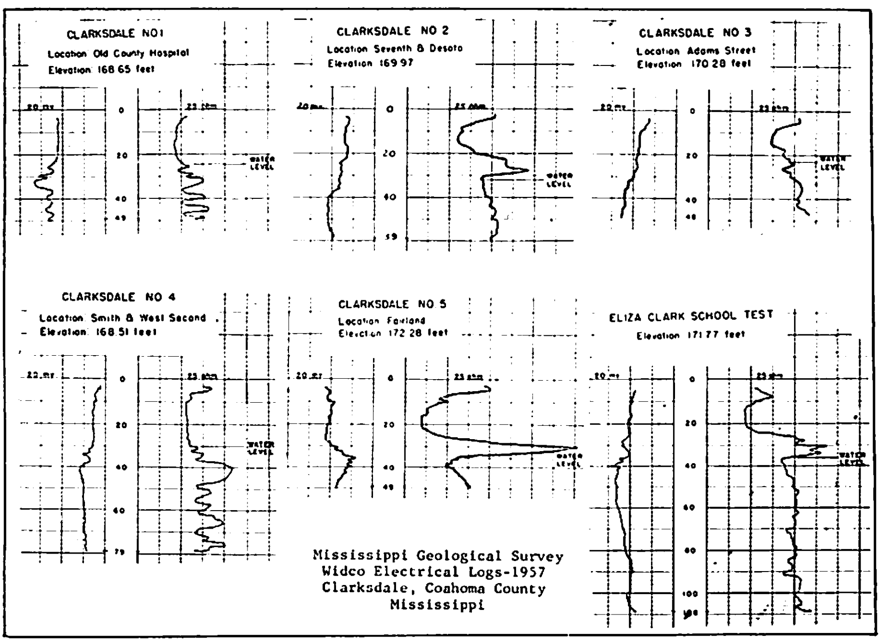


Figure 11.—Widco electrical logs of test holes drilled in Clarksdale, Mississippi.

clay and suggestive of being illuviated from above. Such evidence led to digging the pit at the Eliza Clark School. The walls of the pit, which was 19 feet deep, showed veins of silt and very fine sand in the clay zone 14 to 19 feet below the surface. The walls, as well as the lumps of clay dug from the pit, showed many recent unfilled cracks, evidenced by slickensided surfaces.

As a result of this cracking, the silt and fine sand are washed down leaving a void above, allowing the soil crust to sink.

No doubt the cracks are caused by shrinkage due to drying (desiccation). The two main factors that promote this drying are the low water table and extended periods of drought. Future construction should, if possible, be designed to allow for surface sinking. Probably, the best way to do this is to begin the foundation below the clay in the underlying sand. At the present time no one can locate or predict future sinking of this type.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. F. H. Kellogg, Dean of Engineering at the University of Mississippi, for his valuable advice on this project and for the many laboratory tests he provided.

To the officials and citizens of Clarksdale thanks are due for their wholehearted cooperation. Especial acknowledgment is due to Mr. R. A. Miller, City Engineer, for his expert advice and complete cooperation.

LOGS OF TEST HOLES

Eliza Clark School Test

Location: At the Eliza Clark Elementary School

Elevation: 171:77 feet

Date Completed: 2/12/57

Thickness	Depth	Description
		Alluvium
4.0	4.0	Soil and subsoil, sandy, brown, roots.
4.5	8.5	Sand, very fine, silty, brown.
3.5	12.0	Silt and clay, brown and gray.
10.0	22.0	Clay, gray, plastic, slickensides and cracks with sand and silt in cracks, lost circulation between 15 and 19 feet.
1.0	23.0	Silt, clayey, brown and gray, some very fine sand.
10.0	33.0	Sand, very fine, silty, brown, only slightly moist.
2.0	35.0	Sand, fine to medium grading down into coarse sand.
34.0	69.0	Sand, coarse, water bearing at 36.0 feet.
41.0	110.0	Gravel, light to heavy near bottom, few streaks of blue clay and lignite.

Clarksdale No. 1

Location: Old County Hospital

Elevation: 168.65 feet

Date Completed: 2/14/57

Thickness	Depth	Description
		Alluvium
2.0	2.0	Soil, dark, clayey.
3.0	5.0	Clay, slightly silty, brown, very moist.
2.0	7.0	Clay, same as above except much less moist.
2.0	9.0	Clay, brown, plastic.
3.0	12.0	Clay, brown and blue-gray, plastic, tougher than above.
3.0	15.0	Clay, slightly silty, brown.
3.0	18.0	Clay, blue, tough, plastic, calcareous shell fragments, slickensides (cracks), some brownish clay at top (probably iron stained.)
4.5	22.5	Clay, brown, silty, fine sand and silt in cracks.
1.0	23.5	Clay, brown, very silty, some fine sand.
1.0	24.5	Silt, clayey, brown.
25.5	50.0	Sand, very fine, brown, water bearing, streaks of blue clay and lignite.

Clarksdale No. 2

Location: Vacant lot at corner of Seventh and Desoto
Elevation: 169.97
Date Completed: 2/18/57

Thickness	Depth	Description
		Alluvium
2.0	2.0	Soil, black to brown clay, slightly sandy.
4.5	6.5	Sand, brown, silty, very fine, wet.
0.5	7.0	Silt, light gray, clayey, only slightly moist.
11.0	18.0	Clay, brown, very tough, slightly moist, some gray at 14 feet, cracks.
3.0	21.0	Silt, brown, some very fine sand.
8.5	29.5	Sand, brown, very fine, nearly dry, increasing moisture at 23 feet.
15.5	45.0	Sand, gray, fine, increasing moisture to water level at 32 feet.
14.0	59.0	Sand, gray, medium to very coarse, carbonaceous.
1.0	60.0	Gravel.

Clarksdale No. 3

Location: About the center of the 200 block of Adams Street
Elevation: 170.28 feet
Date Completed: 2/18/57

Thickness	Depth	Description
		Alluvium
1.0	1.0	Soil, black.
3.0	4.0	Sand, brown, very fine, silty, some clay, grading into silt.
5.0	9.0	Silt, brown, some clay, slightly sandy, wet.
7.0	16.0	Clay, brown, mottled with red and gray, silty, wet.
5.0	21.0	Silt, brown, clayey, grading into sand.
14.0	35.0	Sand, brown, very fine, very moist at top with water level at 23 feet.
15.0	50.0	Sand, medium to coarse.

Clarksdale No. 4

Location: Corner of Smith and West Second Streets at the site of future Methodist Church
Elevation: 168.51 feet
Date Completed: 2/19/57

Thickness	Depth	Description
		Alluvium
4.0	4.0	Soil zone, brown, very sandy, fine, silty.
2.0	6.0	Silt, brown, some clay and sand, water (perched water table.)
2.0	8.0	Clay, brown, silty, wet.

4.0	12.0	Clay, gray, plastic, grading into a tough blue clay.
18.0	30.0	Clay, blue, plastic, tough, slickensides (cracks), some calcareous fragments.
7.0	37.0	Silt and very fine sand.
43.0	80.0	Sand, fine, streaks of blue clay.

Clarksdale No. 5

Location: On Fairland in grassy plot in center of street.

Elevation: 172.28 feet

Date Completed: 2/19/57

Thickness	Depth	Description
		Alluvium
1.0	1.0	Soil, black, slightly sandy.
8.5	9.5	Sand, brown, very fine, silty, much moisture.
2.5	12.0	Silt, brown, slightly moist.
4.0	16.0	Clay, light gray and brown, silty, slightly moist.
6.0	22.0	Clay, blue, plastic, tough, calcareous, pieces of dark gravel, slickensides (cracks), silt deposits in cracks.
1.0	23.0	Clay, gray, mottled with iron stain.
4.0	27.0	Silt, brown, sandy, very moist.
13.0	40.0	Sand, brown, silty, water level at 35 feet.
10.0	50.0	Sand, coarse to very coarse.

GEOLOGICAL HISTORY AND OIL AND GAS POSSIBILITIES OF MISSISSIPPI[1]

E. H. RAINWATER[2]

ABSTRACT

The occurrence of oil and gas is closely related to depositional environment of the sediments in which the hydrocarbons occur. Recognition of this relationship and its application in the search for petroleum should lead to important discoveries in all parts of Mississippi.

Thick sections of very old to very young clastic and carbonate rocks which were deposited in many environments underlie the state. The general sedimentation history of the rocks is described, and the areas most favorable for the generation and preservation of oil and gas are pointed out.

INTRODUCTION

The saying "Oil is where you find it" implies that it may occur anywhere and under any conditions. But geologists long ago recognized that there are "oil provinces" and also areas where petroleum is not expected. Some generally accepted requirements for an oil or gas producing area are: a thick section of sedimentary rocks, usually including some marine beds; the presence of some dark shales or limestone which are generally considered possible source rock; porous beds in which the hydrocarbons may accumulate; and a trap (anticline, fault, or wedge-out of the porous beds) to hold the oil or gas. All parts of Mississippi have these requirements.

Once an area or a formation is known to contain hydrocarbons, the geologists concentrate on finding the traps and, since structural uplifts (anticlines, domes, faults) are the easiest to find, most of the exploration effort and money is spent searching for such structures.

It is true that much of the oil and gas does occur in structurally uplifted areas within sedimentary basins. It is also true, but not generally recognized, that the productive formations were deposited in specific environments, and that there

[1]This report is based on numerous publications by many geologists as well as an original work by the writer who is responsible for the interpretations presented. A list of references is omitted for the sake of brevity.

[2]Shell Development Company, Houston, Texas.

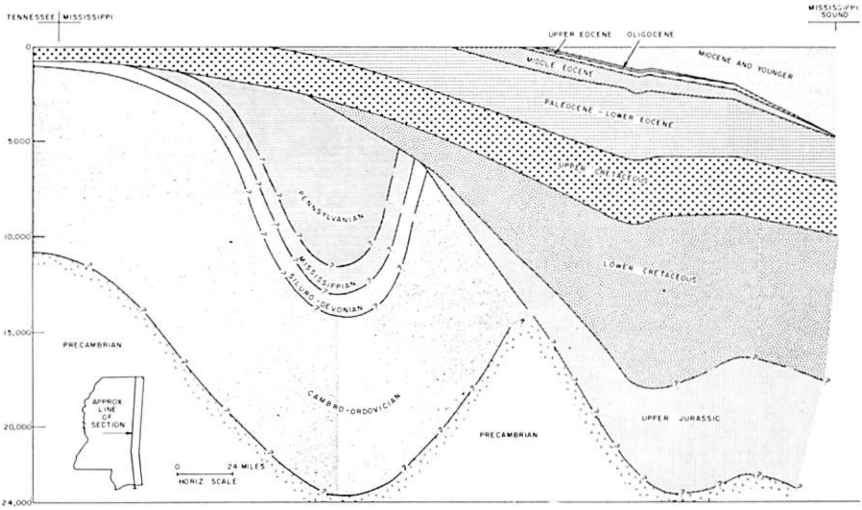
is a close relationship between depositional history and hydrocarbon occurrences. One of the most favored habitats is at the fringes of large deltas where organic productivity is great, sedimentation is rapid to preserve this source material, porous beds are available to collect the hydrocarbons, local structures form contemporaneously as a result of loading by the newly deposited sediments, and stratigraphic traps are numerous. Many of the fields in Mississippi are productive from formations deposited in this environment.

Carbonate shelf areas with rapid deposition of stagnant lime mud in bays and tidal flats behind a barrier such as a coral reef are also favorable for the accumulation of hydrocarbons. Organic productivity is great both in the reef and in the restricted bodies of water behind the reefs. However, the organic material is not preserved in active reefs, but these porous rocks make good reservoirs, after burial, for the hydrocarbons formed in the richly organic lime muds behind the reef. The porous dolomites which form in the back-reef environments and the shell mounds and oolite beds which form on the carbonate shelves are also good reservoirs. There is production in Mississippi from formations which were deposited under these conditions, and there are, doubtless, many such occurrences yet to be discovered.

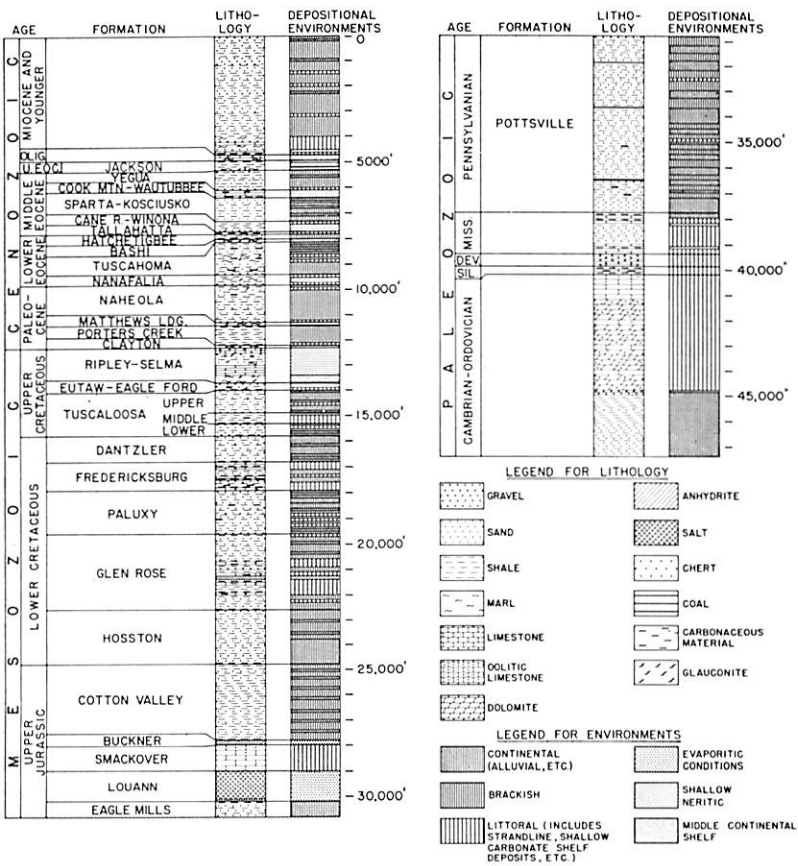
There are oil and gas possibilities in all parts of Mississippi and in many formations of widely different geological ages. The main objective of this paper is to outline the geological history of Mississippi and to point out the areas and formations which are most likely to have commercial accumulations of hydrocarbons.

REGIONAL SETTING

Mississippi has had a complex and interesting geological history. Some of the main events are indicated on the cross section, Figure 1, which shows two deep basins, of very different geological ages, within the state. Thick sections of sedimentary rocks, ranging in age from Cambro-Ordovician to Recent, underlie Mississippi. The entire section known from outcrops and wells is shown in Figure 2, but at no one locality are all of the rocks present, as can be seen by examining Figure 1.



SCHEMATIC NORTH-SOUTH CROSS SECTION THROUGH MISSISSIPPI
FIGURE I



GENERALIZED SECTION OF THE FORMATIONS IN MISSISSIPPI
FIGURE 2

THE PALEOZOIC IN NORTHERN MISSISSIPPI

The thick section of Paleozoic sediments under northern Mississippi has long been considered by petroleum geologists to have oil and gas possibilities. Gas was discovered in the upper part of this section at Amory in 1927, and other discoveries have been made since 1950.

CAMBRO-ORDOVICIAN

Shallow seas covered much of the interior United States, including northern Mississippi, during Upper Cambrian and Ordovician time, and great thicknesses of carbonate rock accumulated as the region subsided. Oil and gas occur in rocks of this age in many parts of the United States and it can be expected that parts of the section will prove to be favorable in northern Mississippi. Exploration thus far has been directed toward finding porous beds structurally uplifted. The real key is original depositional environment. During the long period represented, the sedimentation conditions did not remain uniform: doubtless, there were times when sedimentation was rapid, organic productivity was great, and conditions were favorable for the preservation and accumulation of petroleum in certain areas. It is almost certain that the Cambro-Ordovician rocks of northern Mississippi contain source beds, as the Athens shale, and also porous reservoir rocks. It is also probable that parts of the Cambrian, as the Conasauga shale and limestone, are source beds for petroleum, and that other parts of the section will contain reservoir rocks.

SILURIAN

The few wells which have penetrated the Silurian, on the north edge of the Black Warrior Basin, show the section to be thin and composed mainly of shallow marine shale and argillaceous limestone, with some marginal marine shale and fine-grained sandstone in the upper part. It appears that the area where Silurian rocks have been penetrated subsided very slowly and that sedimentation was also slow. Such conditions were not favorable for the generation of oil and gas.

DEVONIAN

Devonian rocks are the oldest which appear at the surface in Mississippi. Quite a few wells in the northern part of the state have penetrated the Devonian section which is composed mainly of limestone and chert which were deposited in a shallow warm sea. Sedimentation was slow so that, in general, this section is not favorable for the occurrence of hydrocarbons even though the chert is very porous in some places. It is possible that subsidence and sedimentation were more rapid just northeast of the "Central Mississippi Ridge", that the Devonian is thicker and that parts of the Devonian in that area were deposited under favorable conditions.

MISSISSIPPIAN

Limestone, shale, sandstone and chert of Mississippian age crop out in the northeastern corner of the state, and equivalent strata have been penetrated by wells in northern Mississippi. This period began with deposition of black muds (Chattanooga) in restricted arms of a sea that extended into Mississippi from the north. The sea then deepened somewhat and gained normal oceanic circulation, and shallow marine limestone formed in the area. In the middle part of the period large amounts of sand and mud were brought to northern Mississippi by streams which drained the land areas to the south. The rapid influx of these sediments quickly filled the shallow sea and deltaic and lagoonal sediments were deposited rapidly over northeastern Mississippi and northwestern Alabama. Large amounts of organic material in the delta fringe deposits were preserved by quick burial, and this material was later converted into hydrocarbons. Gas and distillate have been discovered in these deltaic sands in Monroe, Clay, and Chickasaw Counties. Asphalt occurs in the outcropping sands (Hartselle) in northwestern Alabama.

The sea transgressed southward over the deltaic deposits in late Mississippian time and limestone and shale were deposited in the shallow, open sea which had abundant organisms.

The middle, deltaic part of the Mississippian section is known to be favorable for hydrocarbons. Depositional conditions were optimum for the generation and preservation of organic material, and many discoveries should be made in this facies in the Warrior Basin. The carbonates in the upper and lower parts of the Mississippian section should also be considered objectives in the deeper parts of the basin and on the northeast flank of the "Central Mississippi Ridge" where limestone and dolomite may have formed rapidly in favorable habitats.

PENNSYLVANIAN

The lower Pennsylvanian (Pottsville), with a maximum known thickness of about 9,000 feet, underlies much of northern Mississippi. Younger Pennsylvanian, if present in the deep part of the Warrior Basin, has not been penetrated by wells.

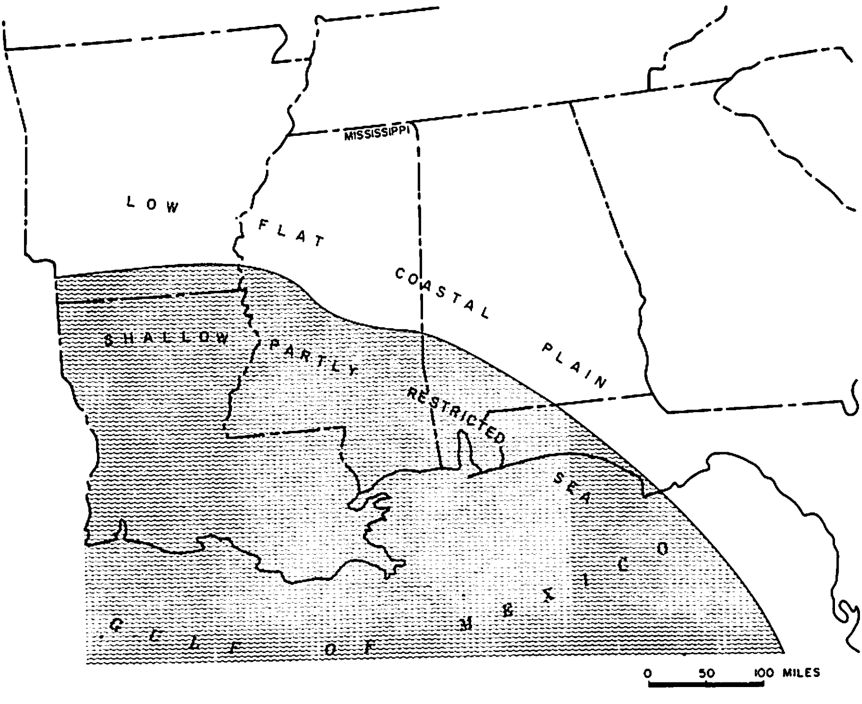
The Pottsville is composed mainly of sand and shale. Fine gravel is common in the lower part of the formation; thin coal beds occur throughout; and a few very thin, shallow marine shales are present in the upper part of the section. Except for the marine shale the sediments were deposited in continental (coastal plain) environments, in meander belts, backswamps, and upper deltaic plains of many streams which drained the land areas to the south (Llanoria) and east (Appalachia). Early Pennsylvanian was a tectonically active period when some areas were greatly uplifted and others, as the Appalachian Basin (including the Warrior Basin), were downwarped. Sedimentation in the Warrior Basin was rapid but the continental environment did not favor preservation of most of the organic material. Some coal was formed and abundant carbonized plant remains were preserved in the shales and sandstones. However, most of the organic material was destroyed by subaerial oxidation. The optimum deltaic environments were west of central Mississippi, even though shallow restricted seas did extend briefly as far eastward as northwestern Alabama during late Pottsville time.

THE MESOZOIC IN MISSISSIPPI

Thick sections of Upper Jurassic, Lower Cretaceous and Upper Cretaceous underlie southern Mississippi. Oil and Gas are known to occur in various parts of this upper Mesozoic section, and the potential for future discoveries in these rocks is enormous. Successful exploration, however, must be based on a knowledge of the depositional history of each stratigraphic unit within this very thick and generally favorable section of rocks.

UPPER JURASSIC

Rocks of the late Jurassic age have been penetrated by wells in central and southern Mississippi. Some of the rocks are marine and, as marine formations of this age are known to occur on all sides of the Gulf of Mexico, this great mediterrannean sea must have been in existence in late Jurassic time. From then until now a sea in the general area of the Gulf has been present and there is almost a continuous record of these later geologic periods in the sediments of Mississippi. However, the Gulf as we know it today is probably a very young feature, possibly originating during the Pleistocene.



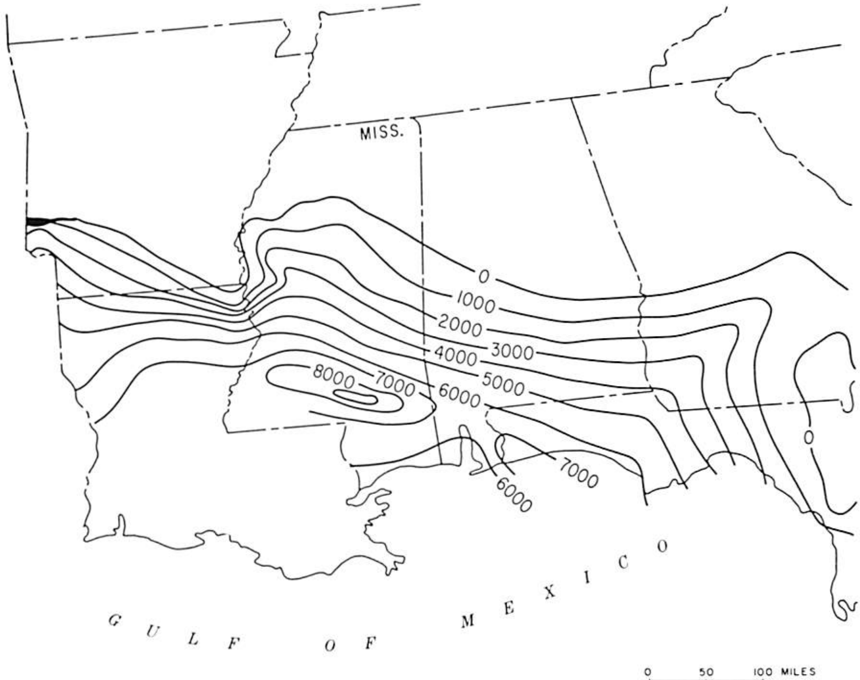
PALEOGEOGRAPHY OF UPPER JURASSIC (SMACKOVER) TIME, ABOUT 115 MILLION YEARS AGO
FIGURE 3

Early in upper Jurassic time an arm of the newly formed Gulf of Mexico covered southern Mississippi, but it was restricted from the open sea, and great quantities of salt and anhydrite were precipitated. Less restricted marine conditions followed and the Smackover limestone was deposited. Parts of this formation accumulated in open marine, shallow shelf areas; some of it, however, was deposited as organic-rich lime muds in subsiding stagnant bays behind barriers. Porous beds adjacent to such rapidly deposited muds should have hydrocarbon accumulations in Mississippi as they do in northern Louisiana, southern Arkansas, and eastern Texas. Such reservoirs may or may not coincide with present structure. The Smackover is a prime objective for petroleum exploration in Mississippi, especially around salt domes which probably started their growth during deposition of this formation. Porous limestone, possibly reefs, may have developed around the domes, and source beds likely accumulated in the interdomal areas. The northern limit of the sea during this period is shown in Figure 3.

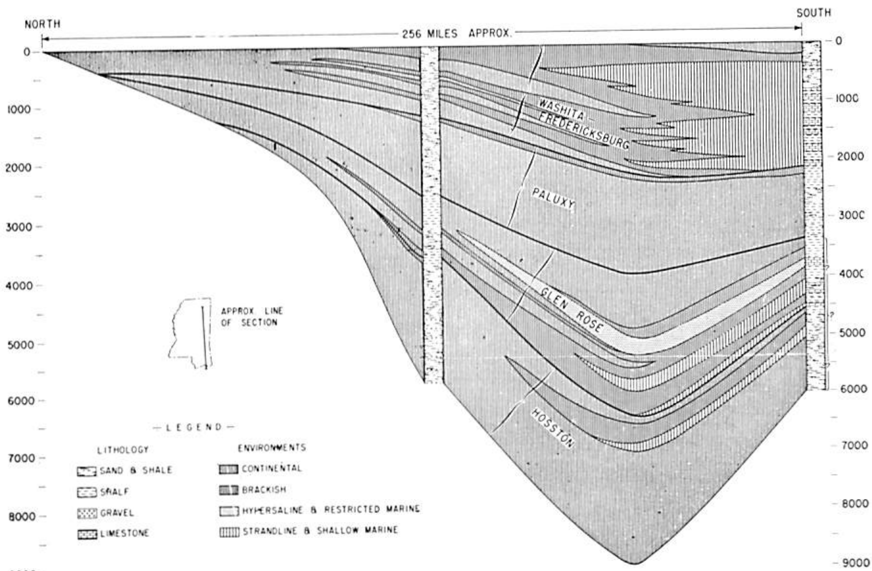
The shoreline retreated southward at the end of Smackover deposition, and the sea which covered coastal Mississippi became restricted and salt (Buckner) was again precipitated. A thick section of argillaceous and anhydritic limestone and dolomite (Haynesville) was deposited in somewhat less restricted seas, above the salt. Farther north shales and sands were deposited at the same time in coastal plain environments which permitted oxidation of the sediments making them "red beds".

The Cotton Valley formation is at least 2,000 feet thick in parts of southern Mississippi, and it is composed mostly of nonmarine shale and sandstone as far down dip as wells have penetrated the formation. This thick section of terrigenous clastic rocks reflects a major uplift of the sediment source areas. The sediments were deposited in broad alluvial valleys, upper deltaic plains and in fresh water lakes. Most of the sediments were subjected to subaerial weathering which turned them to "red beds".

Some very shallow nearshore marine beds occur in the upper part of the Cotton Valley in southeastern Mississippi, and sands and shales which were deposited in upper deltaic plain environments occur throughout the formation. Farther seaward than any wells which have penetrated Cotton Valley there should be deltaic deposits throughout most of the formation and this facies should have both porous sands and organic rich shales and silts. Even in the dominantly continental facies there were, doubtless, depocenters where petroleum was generated and preserved.



OUTCROP AND THICKNESS OF
LOWER CRETACEOUS SEDIMENTS
FIGURE 4



SECTION OF LOWER CRETACEOUS SEDIMENTS IN EASTERN MISSISSIPPI
FIGURE 5

LOWER CRETACEOUS

The Lower Cretaceous formations, with a maximum thickness of about 9,000 feet (Figure 4), probably have the greatest potential for petroleum production of any group of rocks in Mississippi. Already several fields in the state produce from various zones in the Lower Cretaceous and many more important accumulations will be discovered. All of the facies which are richly productive in Texas and Louisiana are present in southern Mississippi, but the formations are buried deeper in the latter area. The most favorable belts for each part of the section can be roughly delineated from knowledge of the sedimentation history (relative rate of sedimentation, position of shorelines and depocenters, etc). It is apparent from study of Figure 5 that the favorable habitat for much of the Lower Cretaceous is within the Mississippi Salt Basin where the formations are thickest. However, the environments constantly shifted during this long period, as shown by Figures 6 and 7, so that the favorable area for one part of the section may not correspond to the favorable areas for other parts of the section.

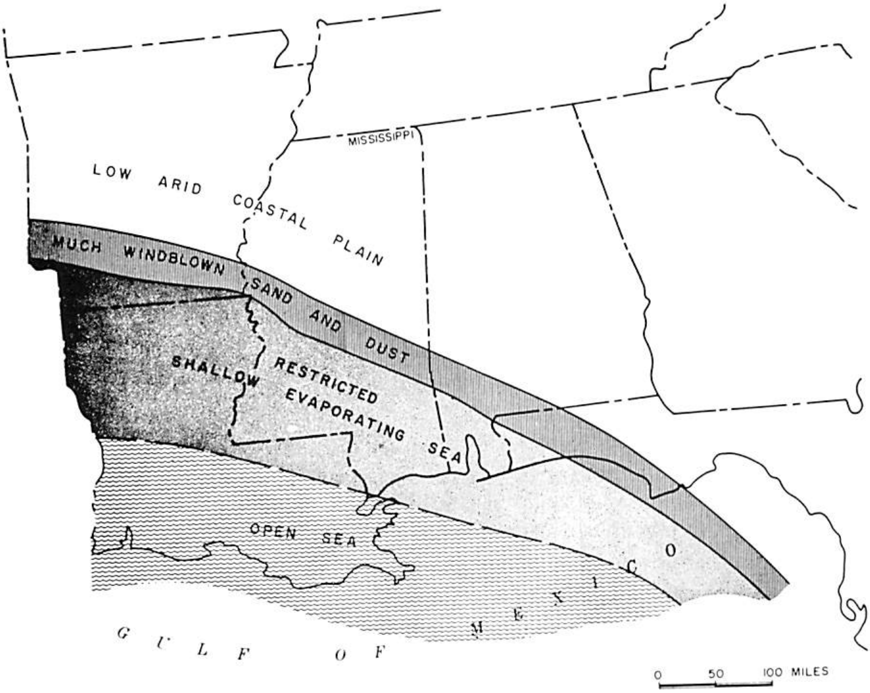
HOSSTON FORMATION

The lower Hosston in central Mississippi is composed of about 1,000 feet of gravel, sand, and varicolored shales which were deposited in continental (alluvial) environments.

The upper Hosston in central and southeastern Mississippi, about 1,000 feet thick, is composed of varicolored shale, silt, and fine sand which were also deposited in continental environments. The main deltaic centers of deposition most favorable for the occurrence of petroleum must have been south of the latitude of Jackson during most of upper Hosston time. However, some of the upper Hosston in Bolton, Soso, Eucutta and other fields along this "trend" was deposited rapidly in deltas.

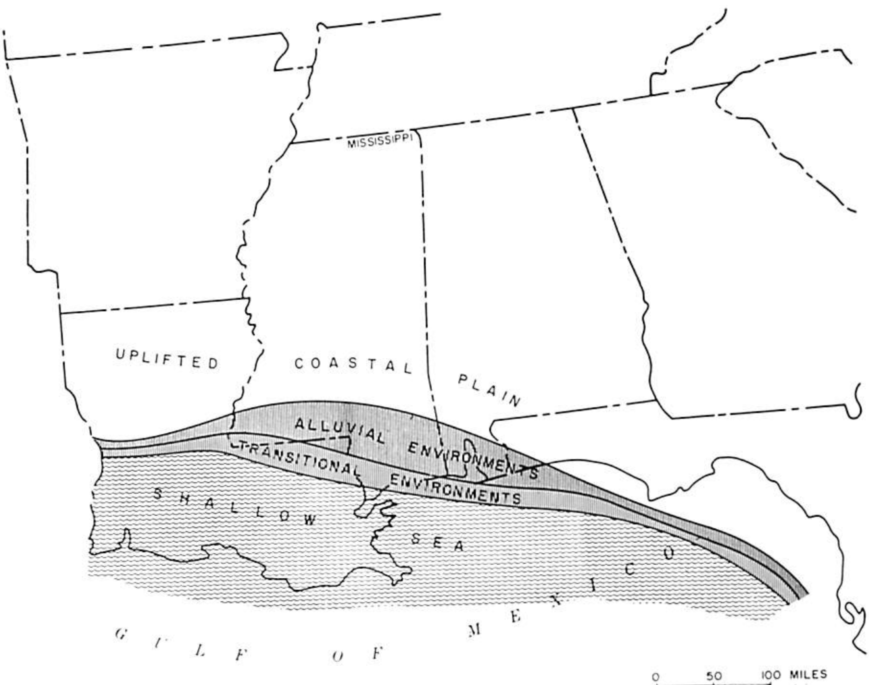
GLEN ROSE DEPOSITS

More than 2,000 feet of Glen Rose shale, limestone, and some sand and anhydrite were deposited in the rapidly subsiding Mississippi Salt Basin in environments which varied from shallow marine to continental. Farther north a thinner section of sand and shale was deposited in continental environments (Figure 5). Thus, there are great lateral and vertical variations in the



PALEOGEOGRAPHY OF MIDDLE LOWER CRETACEOUS (MIDDLE GLEN ROSE) TIME, ABOUT 90 MILLION YEARS AGO

FIGURE 6



PALEOGEOGRAPHY OF LATE LOWER CRETACEOUS TIME, ABOUT 85 MILLION YEARS AGO

FIGURE 7

lithology and environments of deposition within this thick section of sediments, and the habitat was favorable for the formation and preservation of petroleum many times and in many areas. In general, this period was one of transgression. The Glen Rose shoreline deposits, and thus the favorable belts for hydrocarbons, are generally farther north than those of the Hosston. Oil has been discovered in the deltaic facies of various parts of the Glen Rose, and the numerous depocenters which must have existed during deposition of this thick section offer opportunities for many important future discoveries.

Argillaceous limestones above and below the Ferry Lake anhydrite were deposited as organic-rich lime muds in stagnant, partly restricted seas which covered part of the Salt Basin, and porous beds may have developed in the high energy zones at the seaward margin of these bodies of water.

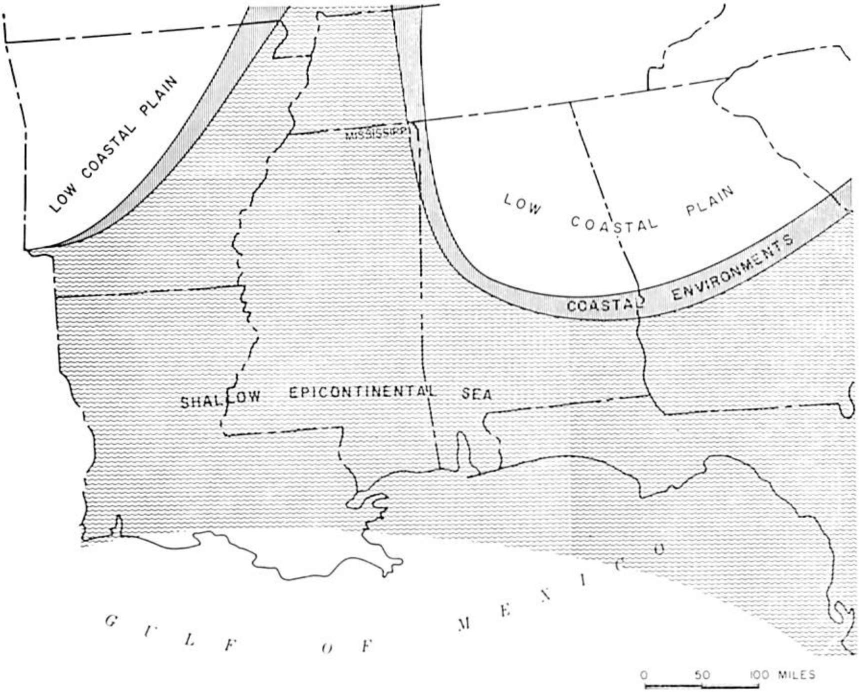
PALUXY FORMATION

During Paluxy time there was rapid subsidence and sedimentation in southern Mississippi. The formation, with a maximum thickness of about 2,000 feet, consists of sand and shale which were deposited mainly in oxidizing, coastal plain environments. But there were also deltas which built into subsiding coastal bays and lakes, and thus the habitat was locally favorable for the preservation of organic material to form petroleum. Porous sand bodies were also deposited in that environment, and structures associated with salt movement or "growth faults" formed contemporaneously. Therefore, much of the Paluxy regressive section which was deposited in coastal and marginal marine environments can be expected to have petroleum accumulations. The truly continental sections developed no source beds and thus they should not be considered objectives.

The Paluxy is more regressive than the underlying Glen Rose or the overlying Washita-Fredericksburg; therefore, its favorable belts are, in general, farther seaward.

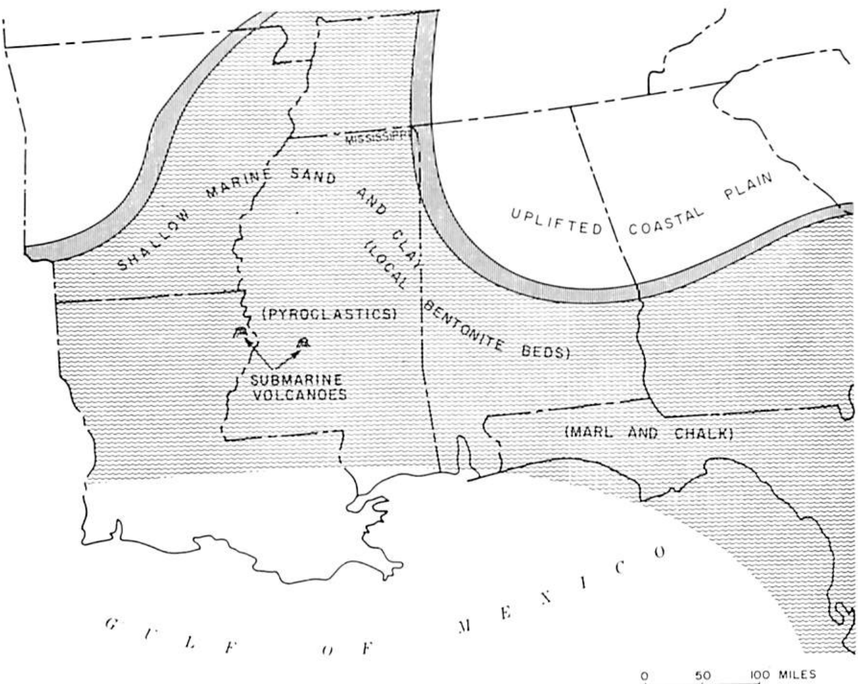
FREDERICKSBURG-WASHITA DEPOSITS

The youngest Lower Cretaceous, with a maximum thickness in southern Mississippi of more than 2,000 feet, is composed of a lower section of gray shale, sand, and argillaceous lime-



PALEOGEOGRAPHY OF MIDDLE UPPER CRETACEOUS (LOWER SELMA) TIME, ABOUT 75 MILLION YEARS AGO

FIGURE 8



PALEOGEOGRAPHY OF LATE UPPER CRETACEOUS (RIPLEY) TIME, ABOUT 70 MILLION YEARS AGO

FIGURE 9

stone and an upper section of sand and varicolored shale. The upper, dominantly continental section has been named the Dantzler formation. This facies changes southward and southwestward into shallow, restricted marine sediments which are not differentiated from the underlying unnamed formation.

The Fredericksburg-Washita is more transgressive than the Paluxy, and it is probable that the Lower Cretaceous sediments which extend farthest north in Mississippi are late Lower Cretaceous in age, as indicated on Figure 5. North of a line between Vicksburg and Mobile the section is composed mainly of nonmarine sands and shales which are mostly "red beds", indicating deposition in continental, oxidizing environments. South of this line the shoreline fluctuated greatly, due to deltaic shifts and unequal rates of subsidence and sedimentation. In the deltaic deposits conditions were optimum for the generation and preservation of petroleum. Also the carbonate shelf deposits farther southwest can be expected to have source beds and reservoir beds.

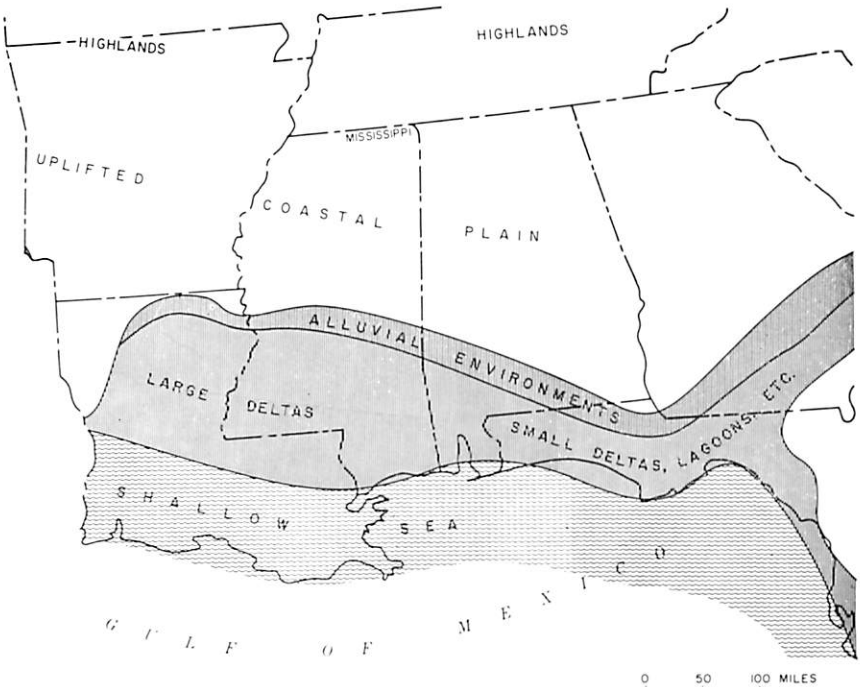
UPPER CRETACEOUS

This was a transgressive period in Mississippi, as it was in many parts of the world. The Gulf of Mexico reached farthest inland in the central Gulf Coast during this period than it did before or since, and most of the state was covered by the sea during the latter two-thirds of the Upper Cretaceous (Figures 8 and 9).

TUSCALOOSA FORMATION

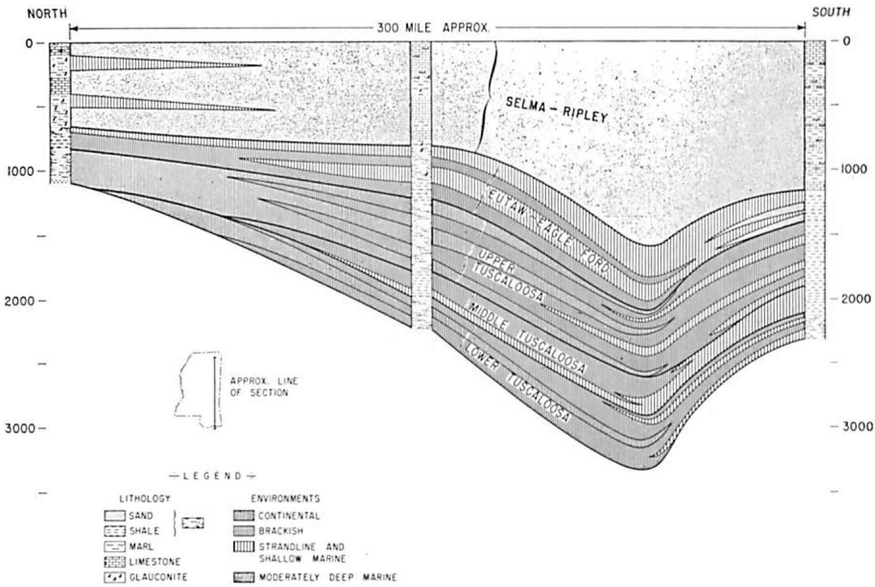
During early Tuscaloosa time sand and shale were deposited rapidly in deltaic environments in the southern part of the state (Figure 10). Then followed a period when sedimentation slowed, and mainly clay (Middle Tuscaloosa) accumulated in a stagnant restricted sea and in adjacent coastal bays and marshlands. The Upper Tuscaloosa was a regressive period, due to uplift of the Appalachian region, and coarse chert gravels were transported early in the period by high gradient streams and deposited in alluvial fans and braided channels in northern Mississippi. Coarse sand and fine gravel were deposited farther seaward, in the lower alluvial valleys, and fine sand and shale accumulated in deltas and other coastal environments in southern Mississippi.

Even though there was rapid sedimentation and delta building during the early part of Upper Cretaceous, this was a time of onlap (Figure 11) which marked the beginning of the widespread invasion of the continents by seas later in this period. The truly continental Tuscaloosa sediments, some of which was deposited directly on Paleozoic rocks in northern Mississippi have been preserved, proving that even the coastal plain area was sinking during and immediately after Tuscaloosa time. The deltas which were built into the encroaching sea in southern

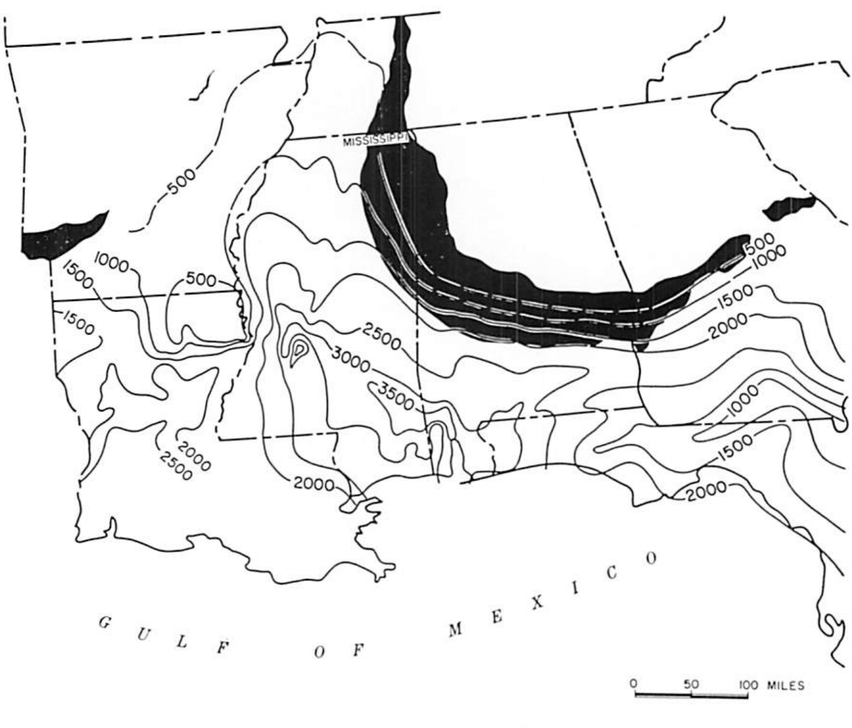


PALEOGEOGRAPHY OF EARLY UPPER CRETACEOUS (LOWER TUSCALOOSA) TIME, ABOUT 80 MILLION YEARS AGO
FIGURE 10

Mississippi during Lower and Upper Tuscaloosa times had optimum conditions for the generation and preservation of petroleum. There is production of oil and gas from these beds in several fields, and as the favorable habitats are better outlined, many more discoveries can be expected. The most rapid deposition, mainly in coastal (deltaic) environments, was in the Mississippi Salt Basin (Figures 11 and 12) and the Tuscaloosa is an important objective in that area.



SECTION OF UPPER CRETACEOUS SEDIMENTS IN EASTERN MISSISSIPPI
FIGURE 11



OUTCROP AND THICKNESS OF UPPER CRETACEOUS SEDIMENTS
FIGURE 12

EUTAW FORMATION

The marine shoreline which was in southern Mississippi at the end of Tuscaloosa deposition moved inland at the beginning of Eutaw time (Figure 11). Large amounts of sediments continued to be supplied to the encroaching sea and the coastal areas, and deltas were built even during this transgression. However, much of the sediment was reworked by waves soon after its deposition, and some widespread sands with very shallow marine fossils resulted. There were depocenters where richly organic delta fringe clay and silt were preserved and are interbedded with the clean, porous sands. It is in these deltaic deposits that Eutaw oil and gas have been found.

Near the end of this period the sea moved rapidly inland due to faster relative sea level rise and decrease in supply of sediments, and waves winnowed the marginal marine and coastal plain sediments to produce a "blanket" shallow marine transgressive sand (Tombigbee).

SELMA-RIPLEY

The Upper Cretaceous sea reached farthest inland soon after the end of Eutaw deposition, and much of the Gulf Coast, including nearly all of Mississippi (Figures 8 and 9), was inundated and remained under the sea until the end of Cretaceous time. Several hundred feet of chalk, marl, clay, and some sand were deposited in this epicontinental sea. The water remained relatively shallow throughout this period, and sedimentation more or less kept pace with subsidence. There was shallowing and actual retreat of the sea when the strandline and shallow marine Ripley sands were deposited in northern Mississippi. At the same time submarine volcanoes were active in west-central Mississippi and some of the widespread fine volcanic material was later changed to bentonite. Some of the igneous bodies intruded upward but did not reach the surface. On the uplifted shallow platforms (Jackson and Sharkey) a reefy porous limestone was formed, and gas from adjacent organic-rich muds moved into the porous rock of the Jackson area in early Tertiary time.

The Selma-Ripley section is not, in general, favorable for the occurrence of petroleum. Most of the sediments were deposited slowly in an open-sea, oxidizing environment; therefore, little organic material was preserved. In the area of igneous activity there were restricted marine environments of rapid sedimentation to produce source beds, and reservoir rocks are also present. But for most of the area, even where porous Ripley Sand or Selma Chalk are present, the habitat was not favorable for production of large amounts of petroleum.

TERTIARY

Most of Tertiary time is represented by sediments in Mississippi, as shown by Figures 1 and 2. In general this was a period of regression, or offlap, when the land areas north of the Gulf of Mexico were rising and supplying large quantities of sediments to the subsiding coastal plain. Even though the northern Gulf of Mexico shoreline was shifting southward most of the time, there were brief periods when the sea made important advances.

Land-derived sediment (sand, silt, and clay) makes up most of the Tertiary section. However, carbonate deposition dominated in coastal Mississippi during the Middle and Upper Eocene periods and in most of southern Mississippi during early Oligocene.

The areas with thickest sections of Tertiary sediments, deposited very rapidly in coastal (mainly deltaic) environments during the regressive stages, are west of Mississippi, in coastal Texas and Louisiana. Many large accumulations of oil and gas have been discovered in those favorable facies. In southwestern Mississippi somewhat similar conditions obtained during the Upper Paleocene and Lower Eocene, and many fields (mostly small) produce from porous deltaic sands of this age. The other Tertiary sediments in Mississippi were deposited slowly in environments generally unfavorable for the preservation of organic material to form hydrocarbons.

PALEOCENE (MIDWAY)

The late Cretaceous sea remained over most of Mississippi during the earliest part of the Paleocene, though locally the sea became very shallow at the end of Cretaceous time and submarine erosion took place (Figure 13). After deposition of the thin Clayton marl the sea was restricted by a barrier (possibly a chain of islands) in coastal Mississippi. Porters Creek clay was deposited in this stagnant body of water which reached far up the Mississippi embayment.

Following deposition of the restricted marine Porters Creek clay, open sea conditions existed briefly throughout most of the southern coastal plain, and the shallow marine Matthews Landing marl (Figures 14 and 15) was deposited.

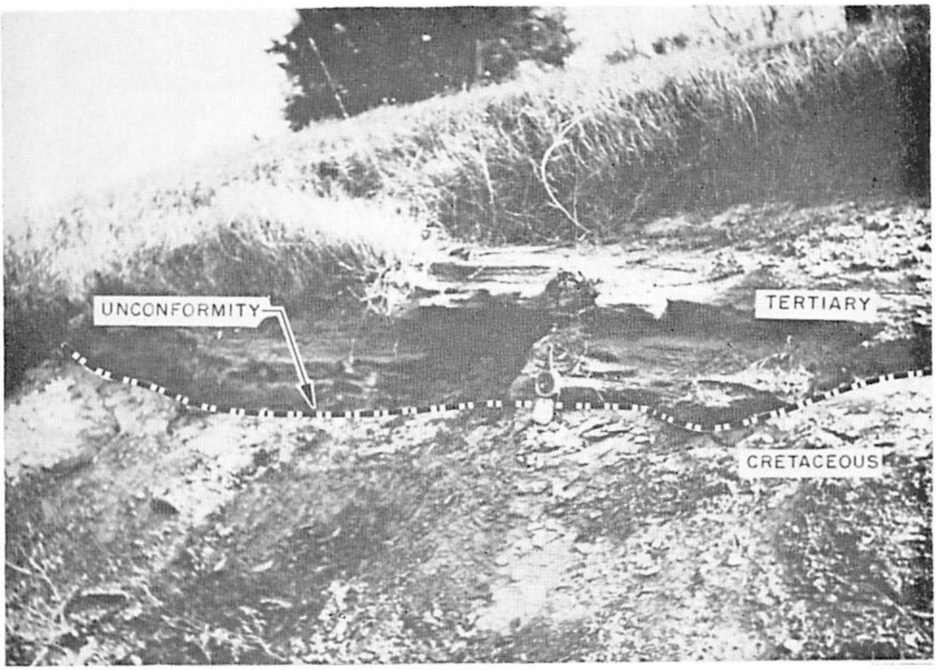
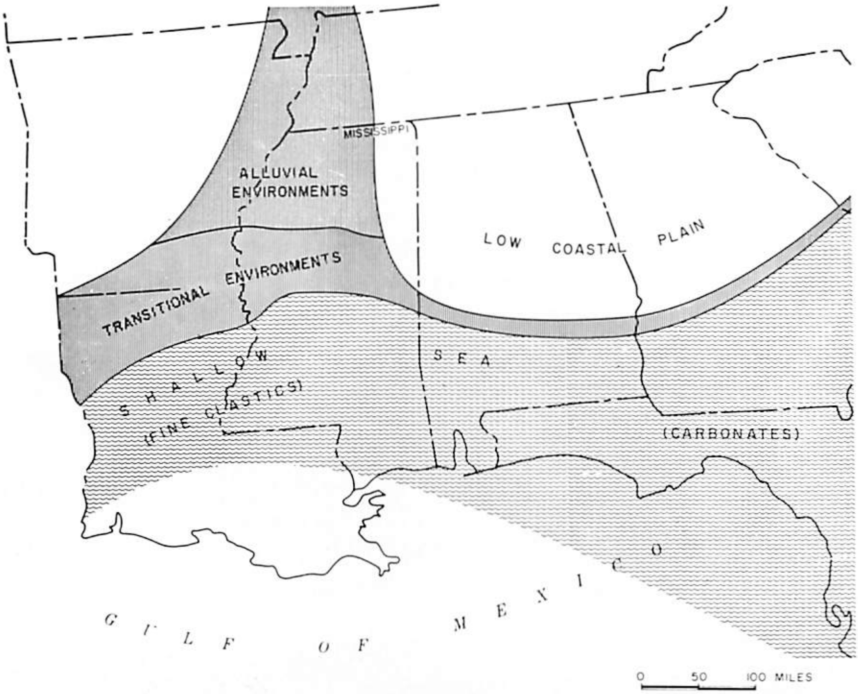


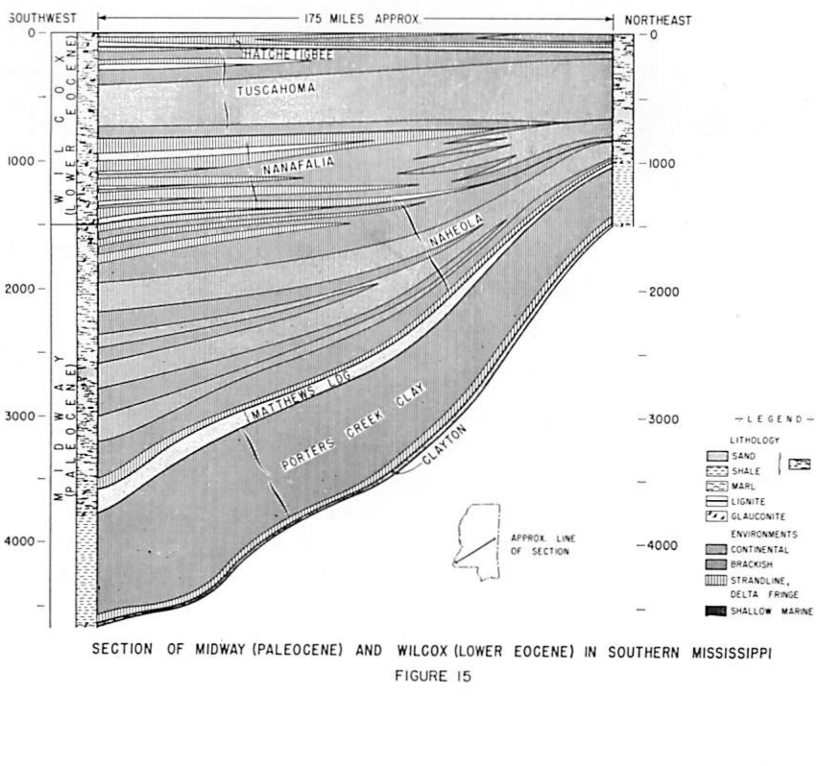
Figure 13. Cretaceous-Tertiary contact. Cut of U. S. Highway 45, 4.3 miles south of Noxubee-Kemper County line, 1.6 miles south of Wahalak Creek bridge, Kemper County, Mississippi. Photographed by E. H. Rainwater, March 11, 1961.

It was in late Paleocene (Naheola) time that the most important Tertiary regression of the Gulf Coast began, caused by a tremendous influx of sediment from the recently uplifted Rocky Mountains and other interior regions. The sand and shale which were deposited mainly in alluvial environments during Upper Paleocene are about 2,000 feet thick in southwestern Mississippi (Figures 15 and 16).



PALEOGEOGRAPHY OF LATE MIDDLE PALEOCENE (MATTHEWS LANDING) TIME, ABOUT 65 MILLION YEARS AGO

FIGURE 14

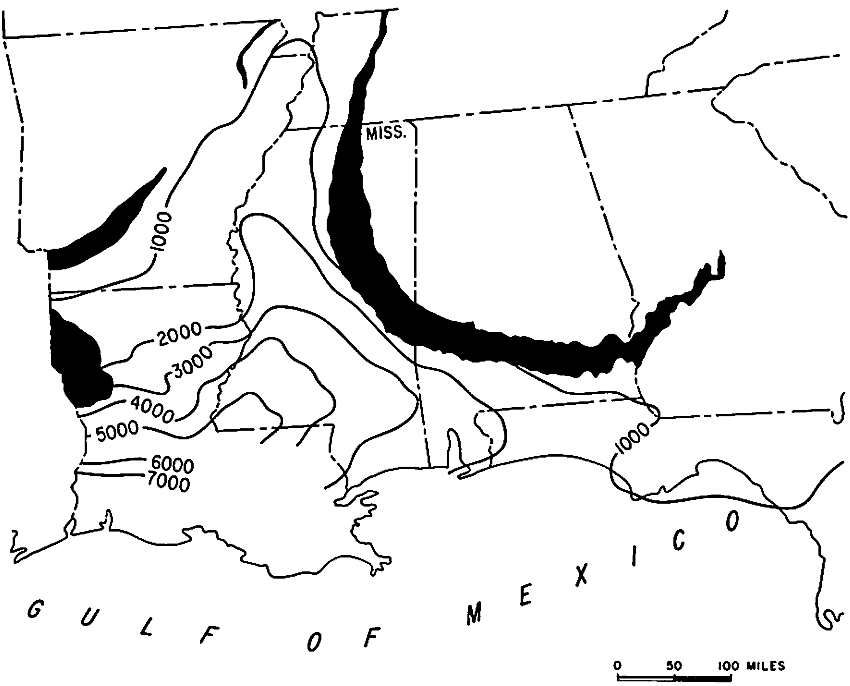


SECTION OF MIDWAY (PALEOCENE) AND WILCOX (LOWER EOCENE) IN SOUTHERN MISSISSIPPI

FIGURE 15

LOWER EOCENE (WILCOX)

The Paleocene-Lower Eocene boundary is not firmly established anywhere in Mississippi; therefore, the sediments of these ages are mapped as a unit (Figure 16). Petroleum geologists commonly include all of the lower Tertiary sands down to top of Porters Creek clay, in the Wilcox. The lower one-half, or more, of their "Wilcox" is probably of Midway (Paleocene)



OUTCROP AND THICKNESS OF WILCOX (LOWER EOCENE) AND MIDWAY (PALEOCENE) SEDIMENTS

FIGURE 16

age. The shallow marine "Baker shale" in southwestern Mississippi may be near the base of Lower Eocene. However, in the area of slower deposition, farther east, the Nanafalia ("Big shale") transgressive marine beds, including the basal Gravel Creek sand member, are considered earliest Lower Eocene.

The outcrop section of Wilcox in Mississippi is entirely nonmarine except for the thin Bashi "marl" in Lauderdale County. The much thicker subsurface Wilcox in southwestern Mississippi (Figure 15) consists of interbedded shallow marine, brackish, and alluvial sand and shale. Oil and gas are produced from the deltaic sands in that region, and large accumulations have been discovered in the same facies in Louisiana and Texas. The nonproductive, continental sections of "Wilcox" of southwestern Mississippi grade seaward into marginal marine sediments which should be favorable for petroleum. Coastal plains during the regressive stages of Wilcox time were very wide, and strandline (including delta fringe) deposits can be expected far seaward of any wells which have thus far penetrated the "Wilcox".

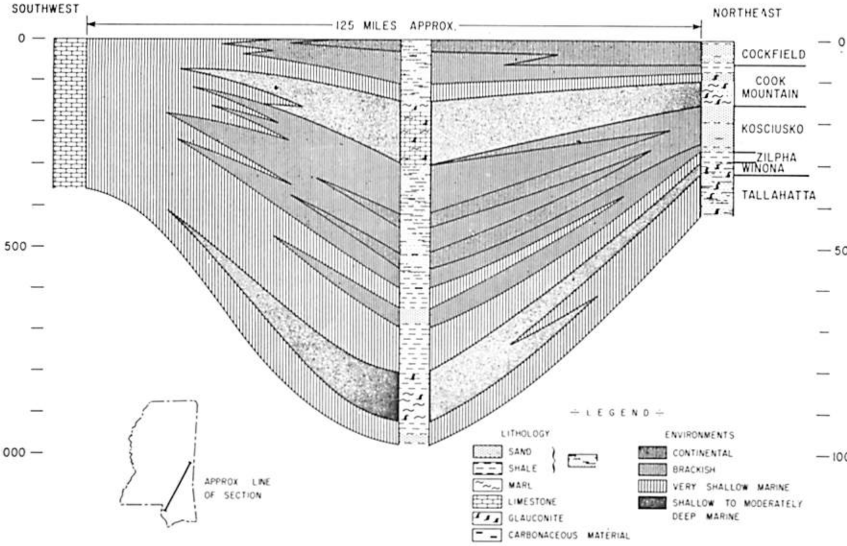
"Wilcox" oil and gas production in Mississippi is mainly confined to the southwestern part of the state where the formation is thickest, sedimentation was fastest, and deltaic environments were prominent. However, there were probably small depocenters throughout coastal Mississippi at different times during "Wilcox" deposition, and thus hydrocarbon accumulations should be present in the section outside of the presently productive area.

MIDDLE EOCENE (CLAIBORNE)

The Claiborne in Mississippi consists of two transgressive marine sequences (Tallahatta-Winona and Cook Mountain) and two regressive sequences (Zilpha-Kosciusko and Cockfield), except in the coastal area where a thin section of limestone was deposited on a shallow open-sea shelf (Figure 17). During the early part of this period there were restricted arms of the sea and barred basins when the siliceous ("opaline") Tallahatta claystone was deposited (Figure 18). The Winona and Cook Mountain marine strata, which crop out in central Mississippi, were deposited mainly in shallow neritic environments.

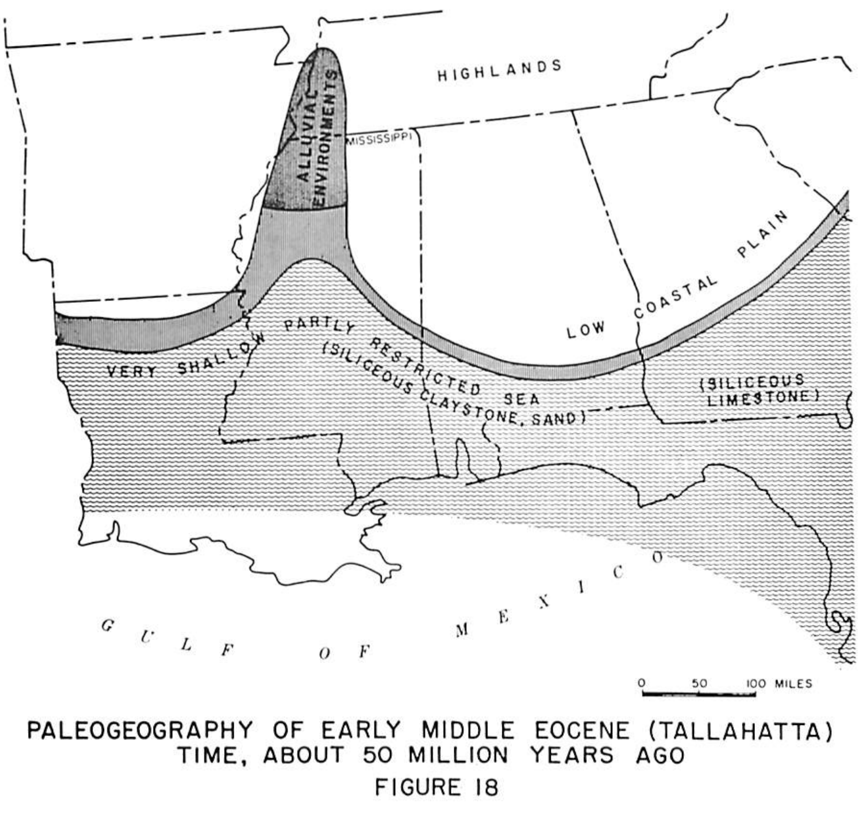
The regressive Kosciusko (Sparta) and Cockfield sand and shale were deposited in alluvial and marginal marine environments. The streams which transported the sediment were mostly small, the depositional area in most of southern Mississippi subsided rather slowly, and the deltas which built into the sea over the Salt Basin were small.

Thickness of the Claiborne is shown in Figure 19. The depocenter in southwestern Mississippi had faster sedimentation



SECTION OF MIDDLE EOCENE (CLAIBORNE) SEDIMENTS IN SOUTHERN MISSISSIPPI

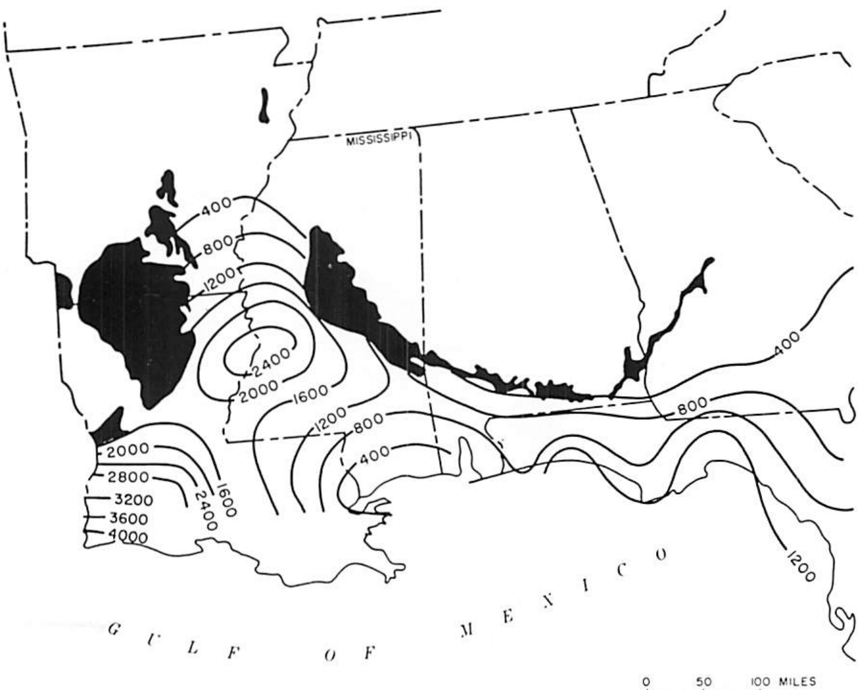
FIGURE 17



PALEOGEOGRAPHY OF EARLY MIDDLE EOCENE (TALLAHATTA) TIME, ABOUT 50 MILLION YEARS AGO

FIGURE 18

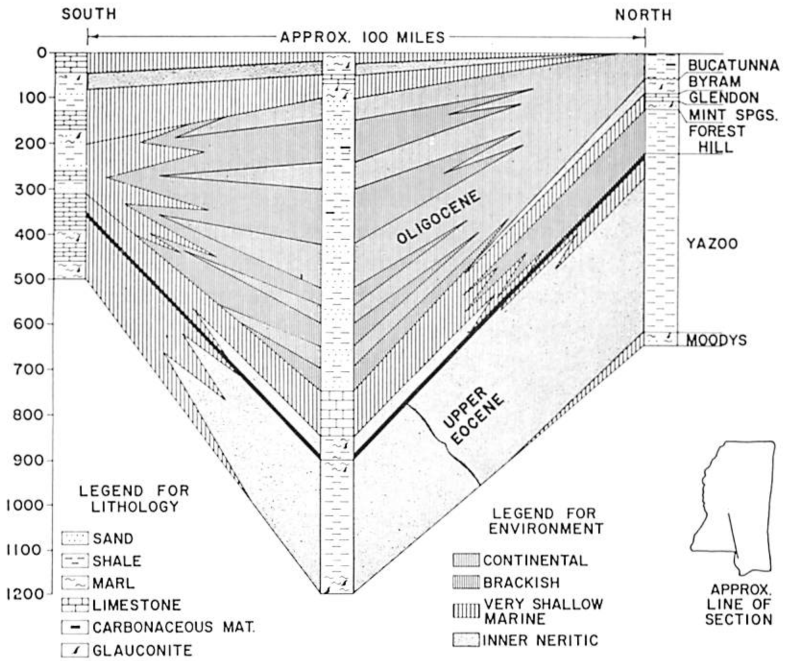
than the areas farther east, and the deltaic deposits of the former area should have possibilities for hydrocarbon production. However, the large depocenters were in coastal Louisiana and Texas where there are numerous large fields producing from Cockfield and Sparta (Kosciusko) sands which were deposited in and around large deltas.



OUTCROP AND THICKNESS OF MIDDLE EOCENE SEDIMENTS
FIGURE 19

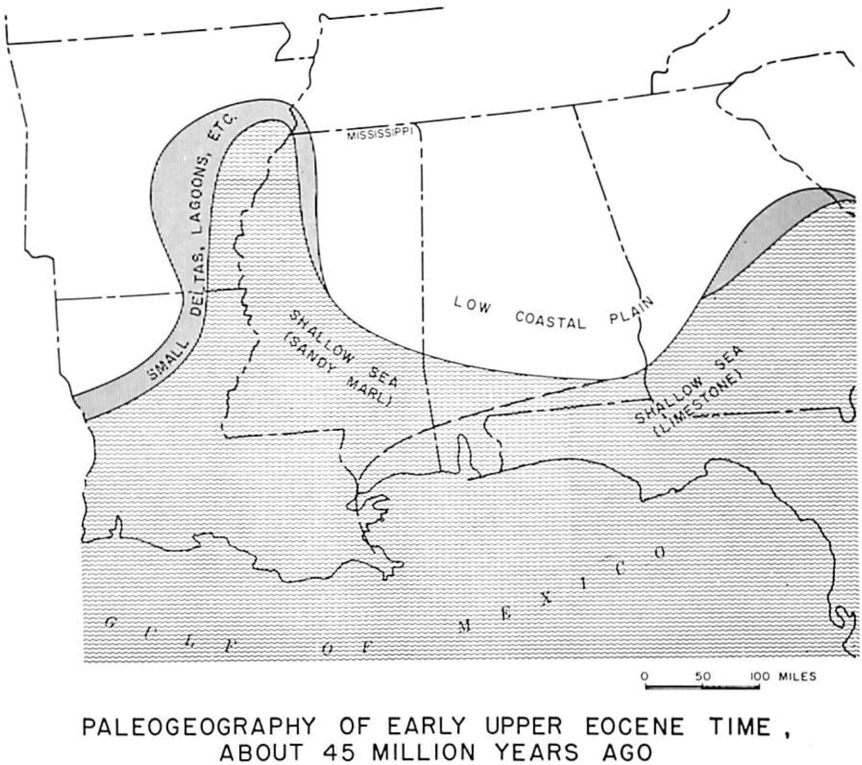
UPPER EOCENE (JACKSON)

This was a transgressive and inundative period in Mississippi (Figure 20), when mainly marine clay was deposited in the Salt Basin area and limestone accumulated on the carbonate shelf area to the south and southeast. At the beginning of Upper Eocene deposition, the marine shoreline which was near the present coast at the end of Middle Eocene time, transgressed rapidly over the low-lying coastal plain and covered southern and western Mississippi (Figure 21). This important transgres-



SECTION OF UPPER EOCENE AND OLIGOCENE SEDIMENTS IN SOUTHERN MISSISSIPPI

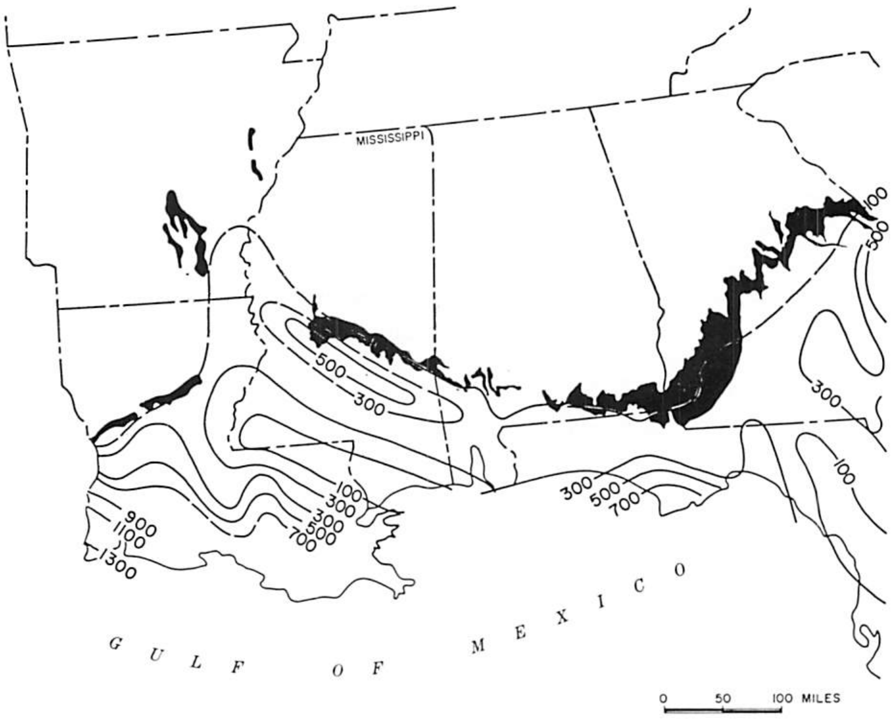
FIGURE 20



PALEOGEOGRAPHY OF EARLY UPPER EOCENE TIME, ABOUT 45 MILLION YEARS AGO

FIGURE 21

sion was possible because the supply of sediments was greatly reduced while the coastal plain and Gulf Basin continued to subside. The Salt Dome Basin subsided more rapidly than did the carbonate shelf area to the south, and more than 500 feet of clay were deposited in the moderately deep sea over part of southern Mississippi while less than 100 feet of limestone accumulated on the shallow carbonate shelf (Figure 22). The Upper

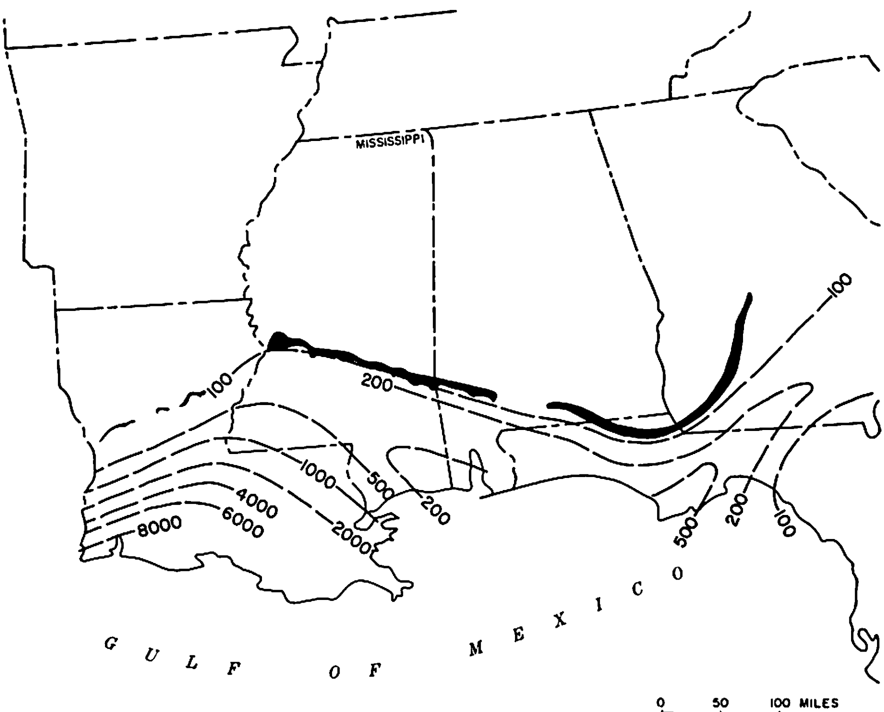


OUTCROP AND THICKNESS OF UPPER EOCENE SEDIMENTS
FIGURE 22

Eocene deltas, whose sands do produce oil and gas, were built far to the west, in coastal Texas.

THE OLIGOCENE SEDIMENTS IN MISSISSIPPI

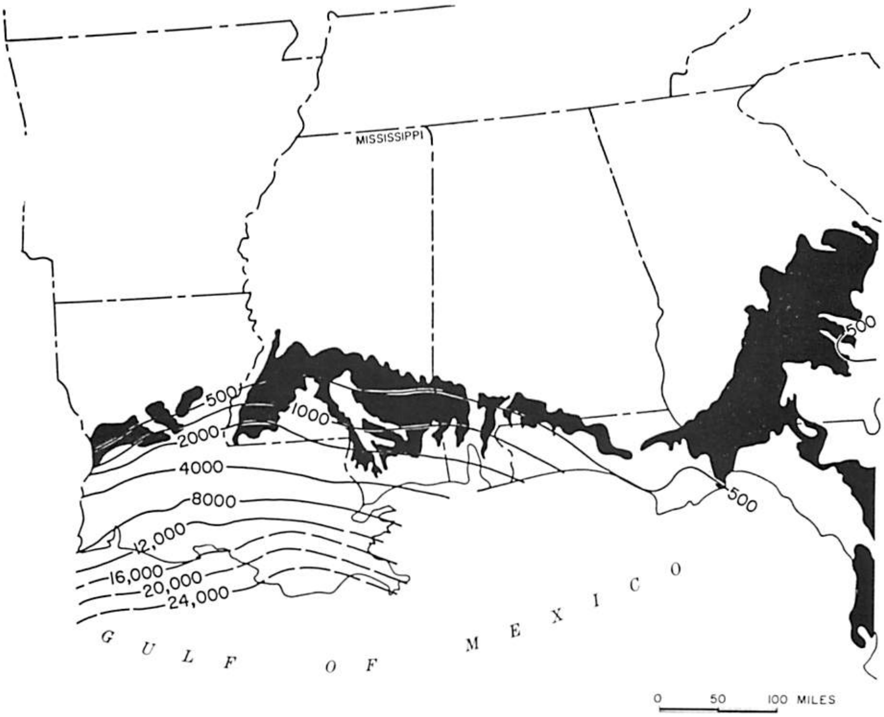
Sediments deposited in Mississippi during the Oligocene period are thin, whereas equivalent strata in coastal Louisiana and Texas, which are prolifically productive of oil and gas, are thick (Figure 23). The sea remained over southern Mississippi during early Oligocene time and shallow marine shelf limestone (Vicksburg) was deposited during this period farther north and west than any time since the Upper Cretaceous (Figure 20). Then followed deposition, in southern Mississippi, of a relatively thin section of sand and shale in coastal environments while more than 5,000 feet of clastics (Frio formation) accumulated in southern Louisiana. The Oligocene period ended with a widespread transgression of a shallow sea in which the Chickasawhay-*Heterostegina* limestone was deposited.



OUTCROP AND THICKNESS OF OLIGOCENE SEDIMENTS
FIGURE 23

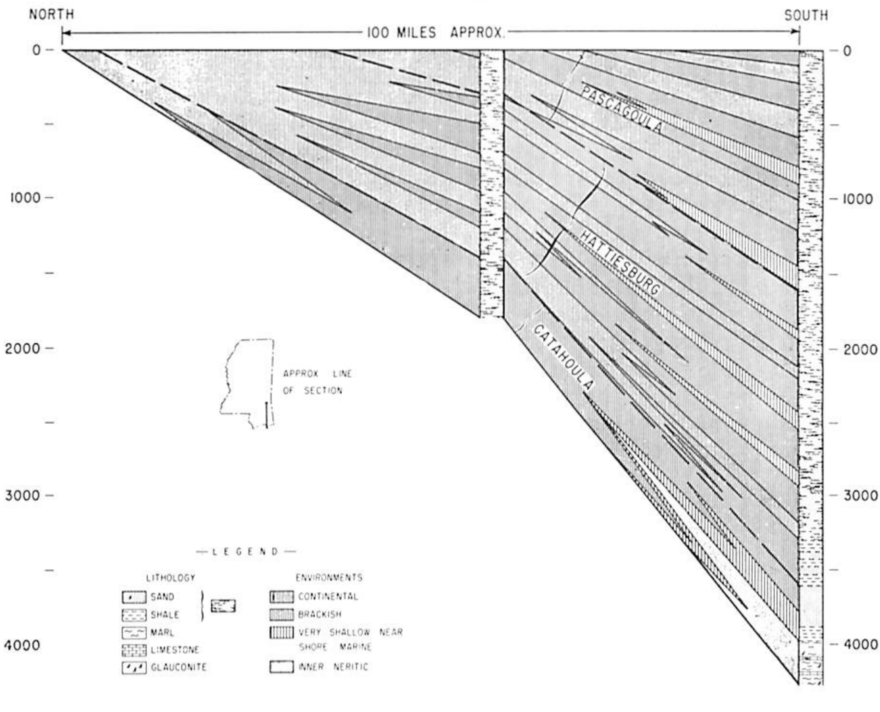
THE MIOCENE SEDIMENTS IN MISSISSIPPI

The outcrop and thickness of Miocene and younger sediments in Mississippi and adajacent areas are shown in Figure 24. It is at once apparent that the area of fast subsidence and sedimentation was in southern Louisiana and the adjacent offshore region, where large deltas were built and where there is prolific production of oil and gas. There were numerous transgressions and regressions of the sea in coastal and offshore Louisiana, mainly due to shift in deltas of the large, ancestral Mississippi River, with continued subsidence. In coastal Mississippi the streams were small, comparable to the present ones; subsidence and sedimentation were relatively slow so that at no time were there large, projecting deltas; and the sea transgressed the area but few times (Figure 25). The Miocene of southern Mississippi does not have a depositional history favorable for the formation of large quantities of hydrocarbons.



OUTCROP OF MIOCENE AND THICKNESS OF MIOCENE AND YOUNGER SEDIMENTS

FIGURE 24



SECTION OF MIOCENE SEDIMENTS IN SOUTHEASTERN MISSISSIPPI

FIGURE 25

STATEMENT OF POLICY IN STRATIGRAPHIC NOMENCLATURE

The Mississippi Geological Survey has many requests for "official statements" on geologic nomenclature. At the present time we do not recognize that we have any "official nomenclature." Geologic knowledge is accrual: therefore, geologic conclusions and the nomenclature of geology are subject to review and to revision.

The rules of stratigraphic nomenclature are understood by us, by the geologists of the Surveys of our sister States, by those of the U. S. Geological Survey and by most other geologists. They are most recently expressed by American Commission on Stratigraphic Nomenclature in its "Code of Stratigraphic Nomenclature," A. A. P. G. Bull. Vol. 45, *No.* 5, *pp.* 645-665, *May,* 1961.

The problems being studied continually by us are those of stratigraphic nomenclature and taxonomy as they affect our economic investigations. Ranking of stratigraphic units appears to change as the detail of geologic knowledge unfolds. Is this advisable, desirable, or necessary? At what degree should "usage" take precedence over "priority?" These are some of the questions that concern us.

We are definitely working in the direction of standardization of nomenclatural usages. We are anxious to cooperate with other departments, geologists and organizations in the simplification and better definition of our nomenclature. We feel that it is a bit too early to announce "official nomenclature," for we, too, are trying to work out of a maze of duplication, poor descriptions and misunderstandings. The geologists writing our reports consult constantly with us and with others in their selection of names, and those names used in these reports are deemed most appropriate and valid by the individual on the basis of his consultations and information available to him at the time. It has been our policy to consult with and to inform the Geologic Names Committee, U. S. Geological Survey, of which George V. Cohee is Chairman. Such matters deal with opinions on stratigraphy, clearing and reservations of new names, and advice on revisions in nomenclature or rank.

The Staff

Mississippi Geological Survey

March 1, 1963