Mississippi Geologic Research Papers - 1964

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BULLETIN 104

MISSISSIPPI GEOLOGICAL, ECONOMIC AND TOPOGRAPHICAL SURVEY

FREDERIC FRANCIS MELLEN
DIRECTOR AND STATE GEOLOGIST

JACKSON, MISSISSIPPI
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LETTER OF TRANSMITTAL

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

November 17, 1964

Mr. Henry N. Toler, Chairman, and

Members of the Board

Mississippi Geological Survey

Gentlemen:

Pursuant to the authority granted by the Board, the Mississippi Geological Survey has prepared for publication a series of papers dealing with current geological work in the State. We recommend that these papers be published collectively as Bulletin 104 entitled, "Mississippi Geologic Research Papers-1964."

This bulletin is the third of the series bearing similar titles, but, unlike the 1962 and 1963 bulletins, there was no contest involved in preparation of these latest research studies.

The Survey is pleased that interest is mounting in the geology of the State. We find that a great number of researchers in Mississippi geological science are anxious to take advantage of the Survey's desire to cooperate with them through the publication of their work. This represents major economic contributions to the State at practically no cost.

The papers herein outline studies that are in progress by the Survey staff and by advanced students in a number of colleges and universities. This bulletin will give the reader an idea of the duties, responsibilities and accomplishments of the Mississippi Geological Survey in its primary role of investigating and publishing on the mineral natural resources of the State and in its secondary role of cooperating with the schools of our State and with research workers engaged in the development of geological knowledge of Mississippi.

The reader will also be able to see the marked increase in research investigations which has developed in the past few months. This promises that an increasing number of worthwhile research papers will be submitted to the Survey for publication in the years ahead. The Survey is proud of the success that this series of bulletins has attained and of the fine reception that has been accorded these bulletins throughout the Nation.

Respectfully submitted

Frederic F. Mellen

Director and State Geologist

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(Moore, Parks and Kern)

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TYPE LOCALITIES SAMPLING PROGRAM

W. H. MOORE, W. S. PARKS and M. K. KERN

ABSTRACT

As a part of the regular field work conducted in conjunction with the Mississippi Geological Survey's various projects, the Survey is undertaking a program of sampling the type localities of the geologic units that have been named for exposures in the State. Thus far seven Jackson (Eocene) and Vicksburg (Oligocene) localities have been sampled. These are, in the order that they were sampled, (1) the Yazoo clay at Yazoo City, Yazoo County; (2) the Byram marl at Byram, Hinds County; (3) the Forest Hill sand at Forest Hill, Hinds County; (4) the lower Jackson Yazoo clay and Moodys Branch marl at Jackson, Hinds County; (5) the Vicksburg "group" at Vicksburg, Warren County; (6) the Pachuta marl at Barnett, Clarke County; and (7) the North Twistwood Creek clay near Rose Hill, Jasper County.

The samples taken under this program are excellent working materials for academic research, for mineral resources investigations, and for geological engineering studies. The Survey encourages the use of these materials by competent research personnel on a cooperative basis. The cuttings and cores and electrical logs are on file at the Mississippi Geological Survey Sample Library, 2525 North West Street, Jackson, Mississippi.

INTRODUCTION

The type localities sampling program was initiated September 27, 1963, with the sampling of the Yazoo clay at its type locality at Yazoo City. To date a total of seven Jackson and Vicksburg type localities or alternate localities have been sampled. As yet this work has been conducted as a part of the regular field work in conjunction with projects in progress. No special effort has been made to make this program a separate project but rather the work has been done piecemeal with the approval of the Survey Board as time and funds have permitted.

If continued, it is hoped that it will be possible eventually to sample all of the rock units that have been named for exposures in the State and also those other units and unit boundaries that present stratigraphic problems which hinder a more complete understanding of the geology of the State.

It is intended to show herein some of the economic aspects of the type localities sampling program in order to give the layman an insight as to the importance of this project, as well as of similar projects, and to give the professional geologist some idea as to what materials the Survey has available for study. The cuttings and cores and electrical logs obtained during this sampling program provide excellent materials for study in at least three fields of endeavor: academic research, mineral resources investigations, and geological engineering studies. The problems to be pursued in any one of these fields are many.

METHOD OF SAMPLING

In order to obtain fresh, unweathered materials, samples are taken either by drilling or by coring, or by a combination of both methods, depending on the nature of the information desired. The Survey's Failing 750 truck-mounted rig is used in the drilling operation (Figure 1). Electrical logs are made

Figure 1.—Survey's Failing 750 rotary drilling rig being used in coring the type locality of the Yazoo clay (M.G.S. Bull. 100, Fig. 31). Norman A. Mott photo. September 27, 1963.

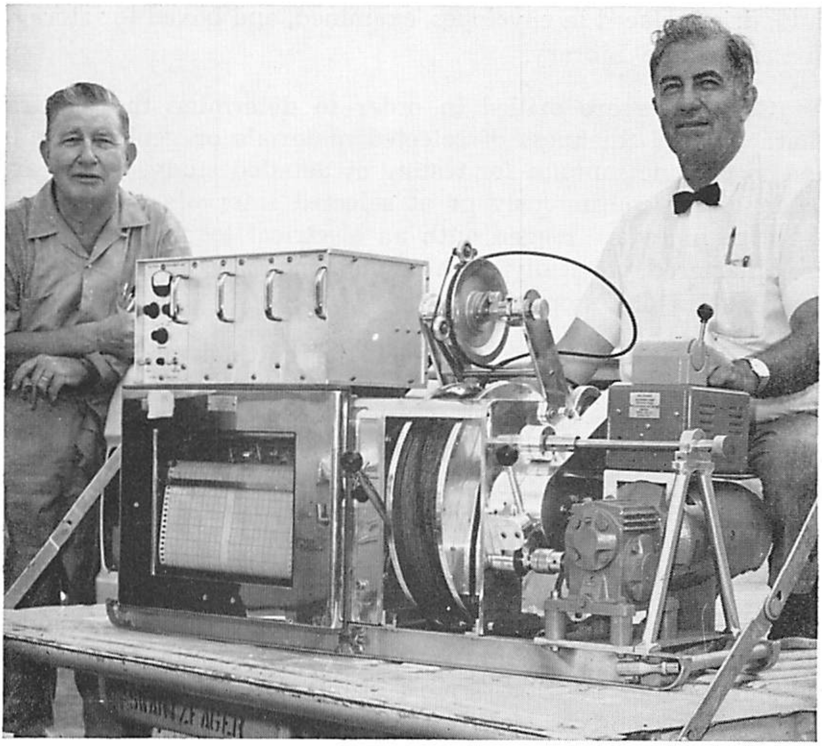

Figure 2.—Survey's new Neltronic 2 K electrical logger capable of making conventional two-curve logs (self potential and resistance) and also gamma ray logs up to depths of 3,300 feet. Claude Sutherland photo. August 19, 1964.

with a Widco electrical logger capable of making two-curve logs (self potential and resistance) to depths up to 950 feet. The Survey recently acquired a new Neltronic 2K logger capable of making the conventional two-curve logs and, also, gamma ray logs up to depths of 3,300 feet (Figure 2). This depth range will allow the Survey to log test holes, water wells, and oil test wells through the deepest known fresh water horizons in the State.

Drill holes are drilled to determine the stratigraphic and spatial position, the general character, and the thickness of geologic units. From each drill hole, cuttings are caught at 5-foot or 10-foot intervals, and the bore hole is logged with an electrical logger. The samples are washed to remove drilling mud, dried, placed in envelopes, examined, and boxed for storage in the Sample Library.

Core holes are drilled in order to determine the specific character and thickness of selected materials or geologic units and to provide samples for testing or detailed study. Cores are taken either continuously or at selected intervals. Several of the core holes are logged with an electrical logger. The cores are quartered vertically with a diamond saw and boxed for examination and storage.

A descriptive log is made of the cuttings and cores by examination of the reference samples under the microscope. From these preliminary examinations, evaluations are made as to the research potential of the materials. Representative sets of samples are distributed to the proper testing laboratory or to qualified research personnel.

TYPE LOCALITIES SAMPLED*

The Jackson and Vicksburg "groups", comprising a maximum of only 750 feet of sediments on the outcrop in Mississippi, contain some of the State's most useful mineral raw materials. The study of the type localities of these sediments will facilitate the prospecting of their outcrop areas for new deposits of materials now being developed and for new products still not being produced. The major industries are:

1. Filtrol Corporation, bleaching clay mined in Smith County.
2. Marquette Portland Cement Company in Rankin County.
3. Mississippi Valley Portland Cement Company in Warren County.
4. Miss-Lite Aggregate Division of Jackson Ready-Mix Concrete in Hinds County.

Lesser industries are:

1. Smith County Lime Company, Smith County.
2. Mineral Water and "acid-iron earth" produced by a number of small plants in Smith and Jasper Counties.

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*The basic geologic unit is the *formation,* and the *type locality* ". . . is the place at which a formation is typically displayed and from which it is named." [1]

3. Fresh water, largely for domestic use from:
    a. Moodys Branch marl
    b. Forest Hill sand
    c. Mint Spring marl
    d. Sands developed in the Glendon horizon
    e. Sands developed in the Byram and/or Bucatunna horizons.

Stratigraphy and geologic classification are the important scientific approaches to mineral resource discovery and development.

The Jackson (Eocene) and Vicksburg (Oligocene) type localities thus far sampled are summarized, in the order that they were drilled, to acquaint the researcher with the status of each locality and to show what materials are available for study. The Survey plans to publish detailed descriptions of each type locality at such times that the various research studies concerning a particular locality are completed. The general locations of the test holes are shown in Figure 3. The specific locations are shown on the log headings in the various Figures that show electrical logs of the drill holes.

YAZOO CLAY AT YAZOO CITY, YAZOO COUNTY

The Yazoo clay was named by Lowe[2] in 1915. His original description was from exposures in the bluff of the Yazoo River at Yazoo City. A suitable drilling locality was selected near these exposures in order to give as complete a section of the Yazoo clay as could be found along the Yazoo River bluffs. Continuous cores were taken to a depth of 46 feet. This coring was done with a thin-walled coring device, the Shelby tube, but the problem of ejecting the tough tenacious clay from the core barrel without ruining it caused continuous coring to stop. [Later holes were cored with a stronger, specially designed coring device which overcame this problem.] From the depth of 46 feet the hole was drilled, but the spot cores were taken at selected intervals. Figure 4 shows the electrical log of the hole with the cored intervals indicated. The test hole penetrated the loess, a thin gravel bed, the Yazoo clay, and the Moodys Branch marl and bottomed in the upper part of the Cockfield formation. The Yazoo clay was found to be 150 feet thick at

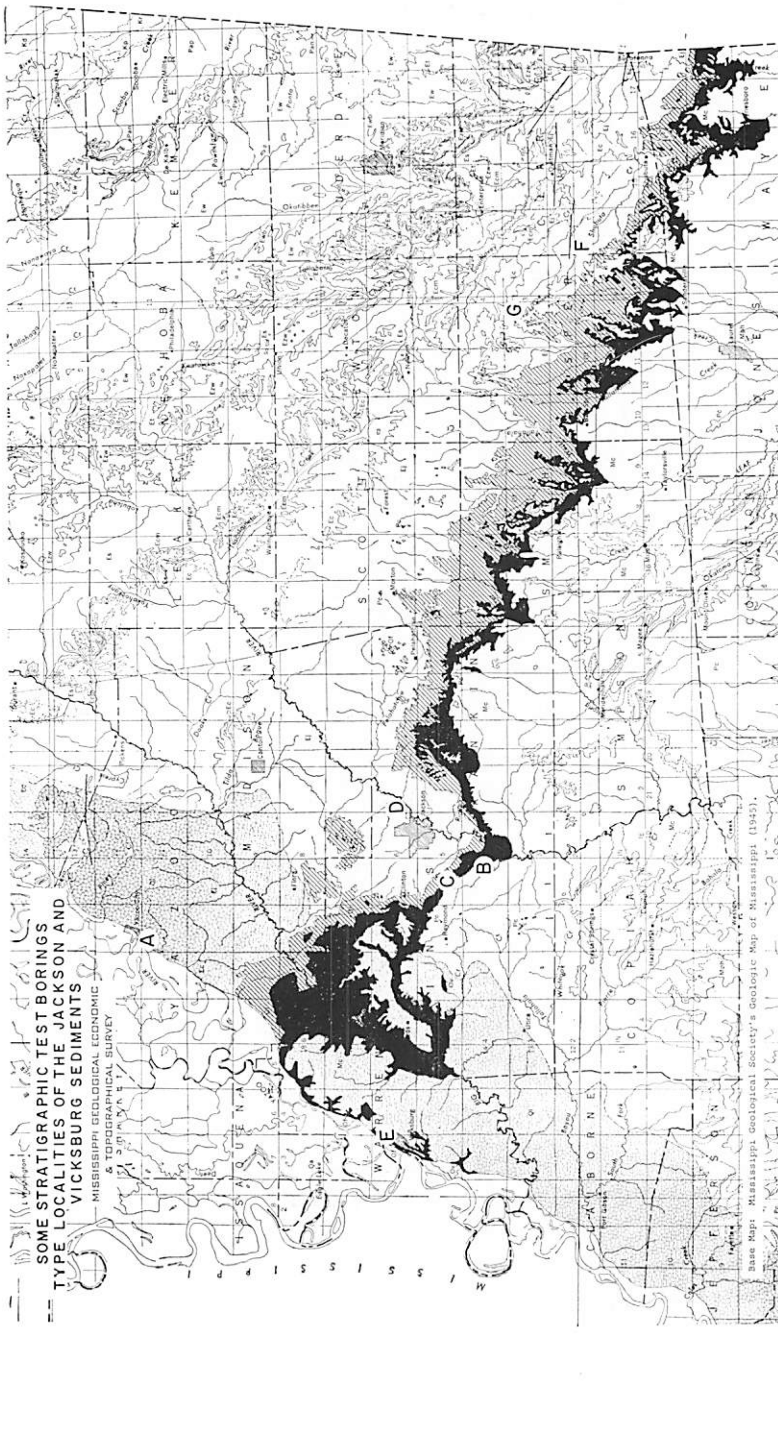

Figure 3.—Map showing the locations of holes thus far drilled to sample Jackson and Vicksburg type localities — (A) the Yazoo clay at Yazoo City, (B) the Byram marl at Byram, (C) the Forest Hill sand at Forest Hill, (D) the Moodys Branch marl at Jackson, (E) the Vicksburg "group" at Vicksburg, (F) the Pachuta marl at Barnett, and (G) the North Twistwood Creek clay near Rose Hill.

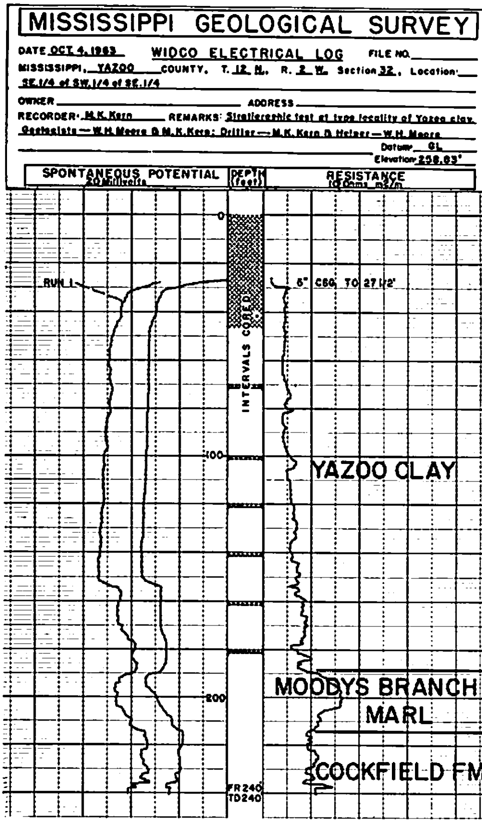

Figure 4.—Electrical log of the hole drilled to sample the Yazoo clay at Yazoo City.

the type locality where only the basal part is present. This compares with thicknesses as great as 400 to 500 feet for the entire unit in this area of the State.

BYRAM MARL AT BYRAM, HINDS COUNTY

The first accepted definition of the Byram marl is that of Cooke[3] made in 1918. His description was from exposures in the bank of the Pearl River at Byram, Hinds County (Figure 5). The term "Byram" originally was applied to the approximately 13 feet of marl exposed at Byram but later usage expanded the term to include the overlying Bucatunna clay and the underlying Glendon limestone.

The Bucatunna clay has been eroded along the Pearl River at Byram; therefore, in order to obtain a complete section, two holes were cored. One hole (AF-1), about a mile west of the River locality, penetrated 58 feet of Bucatunna clay and 12 feet of Byram marl. Coring was stopped at the top of the Glendon limestone, and the hole was drilled to a total depth of 260 feet into the upper part of the Yazoo clay. The second hole (AF-2), just above the River locality, penetrated 13 feet of Byram marl and was cored through the Glendon limestone, the Mint Spring marl and into the upper part of the Forest Hill. Figures 6 and 7 show electrical logs and the cored intervals of these two holes.

Figure 5.—Exposure of Byram marl in the bank of the Pearl River at the type locality near Byram, Hinds County. Perry Nations photo. September 27, 1964.

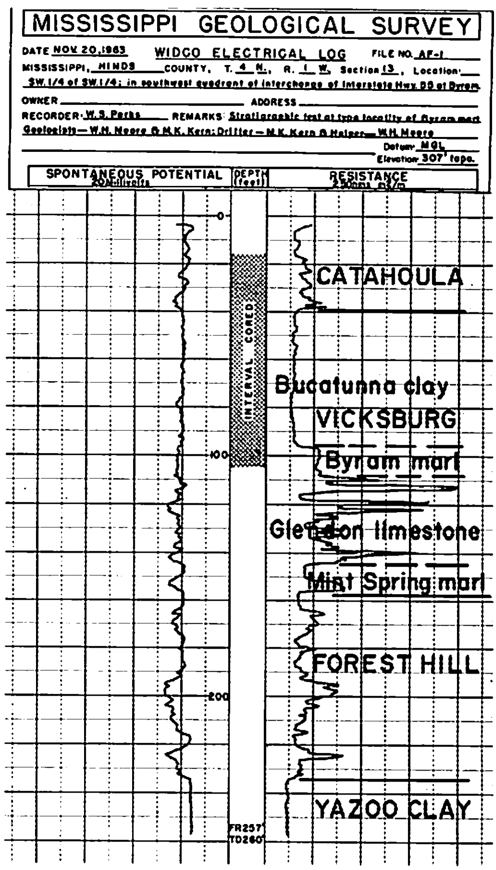

Figure 6.—Electrical log of the hole drilled to determine the stratigraphic position and the thickness of the Byram marl at Byram.

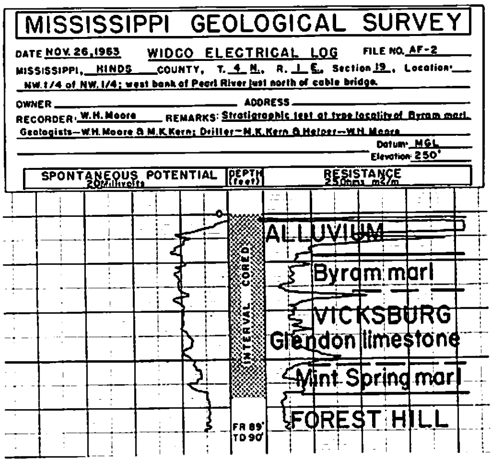

Figure 7.—Electrical log of the hole cored to sample the Vicksburg "group" near Byram.

FOREST HILL SAND AT FOREST HILL, HINDS COUNTY

The Forest Hill was described and named by Cooke[4] in 1918. His type locality is at Forest Hill, Hinds County. Some geologists consider the Forest Hill to be the basal unit of the Vicksburg (Oligocene) and others consider it to be uppermost Jackson (Eocene). The type locality at Forest Hill is badly weathered and slumped, making accurate descriptions of the lithology and measurements of the thickness difficult. A pilot hole was drilled to a depth of 100 feet at Forest Hill. A second hole was cored to a depth of 78 feet penetrating weathered Glendon limestone, Mint Spring marl, and the Forest Hill and bottoming in the upper part of the Yazoo clay. Figure 8 shows this core. The Forest Hill was found to be only 52 feet thick. The electrical log of the pilot hole shows relatively small amounts of sand in the Forest Hill (Figure 9).

MOODYS BRANCH MARL AND LOWER YAZOO CLAY AT JACKSON, HINDS COUNTY

Outcrops of marl along Moodys Branch were visited over 100 years ago by Hilgard.[5] This marl was named Moodys Branch by Lowe[6] in 1915. He incorrectly considered it to be above the Yazoo clay. Cooke[7] in 1918 recognized the correct stratigraphic position of the Moodys Branch as the basal unit of the Jackson. The type locality is just south of the intersection of Peachtree Street and Poplar Boulevard in Jackson. This exposure is in a residential area where coring is not feasible.

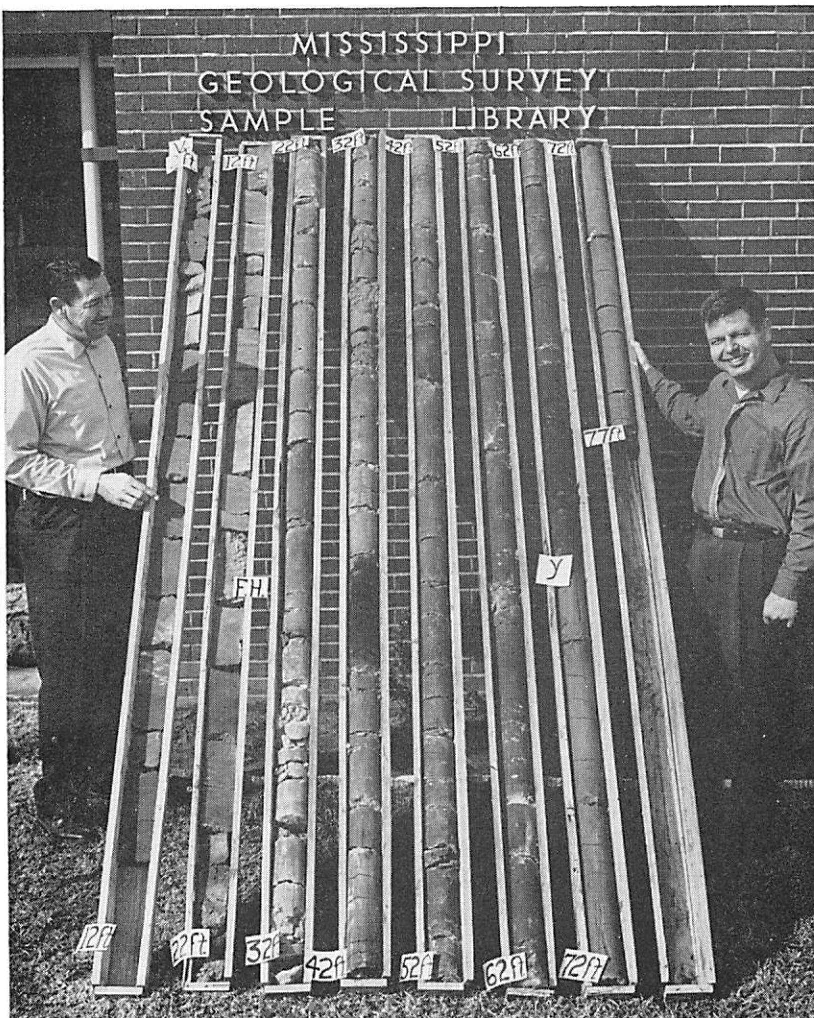

Figure 8.—Core taken at Forest Hill to sample the Forest Hill sand. Left to right and top to bottom — from Vx to F. H. is weathered Glendon limestone and marl; from F. H. to Y. is Forest Hill sand, silt, clay, and lignite; and from Y. to 77 ft. is uppermost Yazoo clay. Note two beds of lignite (dark-colored) in Forest Hill.

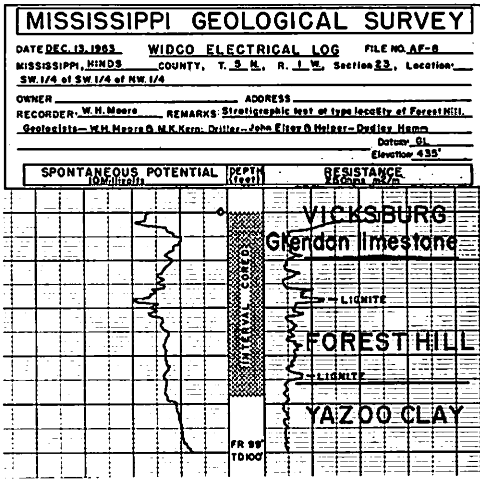

Figure 9.—Electrical log of hole drilled to determine the stratigraphic position and thickness of the Forest Hill sand at Forest Hill.

The alternate locality*, located at Riverside Park approximately one-half mile to the northeast, was chosen for sampling. This locality affords a better exposure of the marl than is now on Moodys Branch and also includes outcrops of portions of the overlying Yazoo clay and the underlying Cockfield formation. Continuous cores were taken from the surface to a depth of 69 feet. In descending order, the cores contained 6 feet of soil and subsoil, 3 feet of terrace sand, 35 feet of lower Yazoo clay, 13 feet of Moodys Branch marl and 12 feet of upper Cockfield formation. The hole was drilled to a total depth of 430 feet bottoming in the Wautubbee (Cook Mountain) formation. The electrical log and the cored interval are shown in Figure 10. This core hole proved to be located on one of the highest points on the well-known geologic structure, the Jackson Dome.

VICKSBURG "GROUP" AT VICKSBURG, WARREN COUNTY

The name "Vicksburg Group" was first applied to exposures at Vicksburg by Conrad[8] in 1856. (The name "Vicksburg" had

*The Riverside Park locality was designated an "Alternate Type Locality" of the Moodys Branch by E. H. Rainwater in "Unit I, Type Localities Project" (1960) sponsored by the Gulf Coast Section of the Society of Economic Paleontologists and Mineralogists.

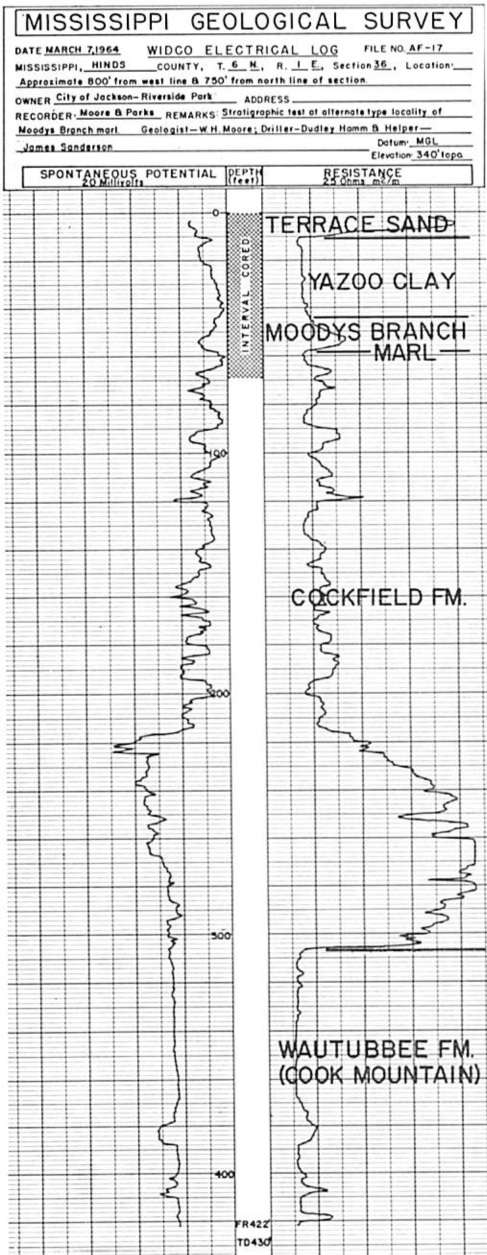

Figure 10.—Electrical log of the hole drilled to sample the lower Jackson Yazoo clay and Moodys Branch marl at Riverside Park at Jackson.

been mentioned by Conrad[9] in a publication in 1846.) The outcrops along the bluffs at Vicksburg also were described by Hilgard[10] in 1860. During the mineral survey of Warren County by Mellen[11] in 1941, hand auger holes were drilled through the Byram marl to the top of the Glendon limestone, and other holes through the Mint Spring marl into the Forest Hill. Figure 11 shows an auger hole being drilled at the type locality of the Mint Spring marl. The Mint Spring locality is now owned by the Federal Government and no sampling or fossil collecting is permitted except by special consent.

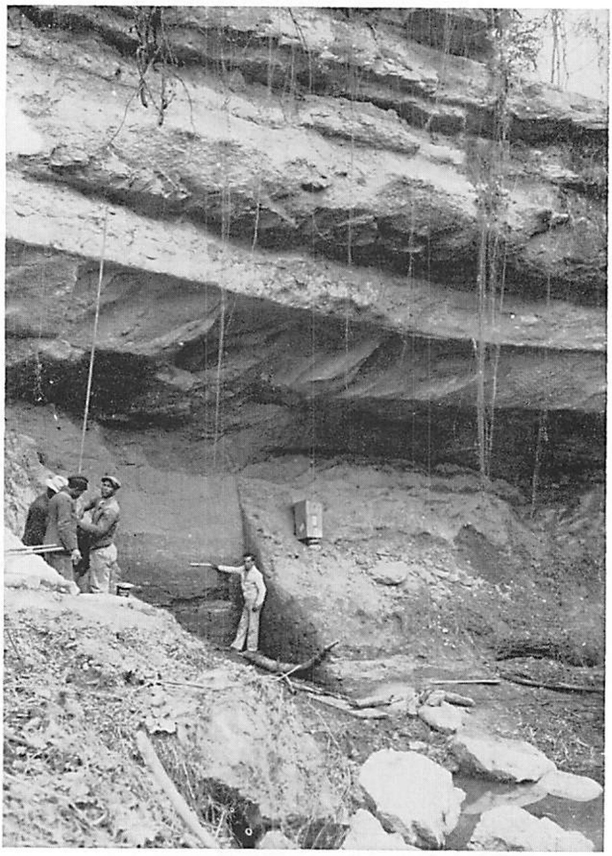

Figure 11.—View of the falls at Mint Spring Bayou showing the contact between the Jackson and Vicksburg units. Auger hole, where men are working, was drilled to 66.6 feet in Forest Hill materials (M.G.S. Bull. 43, Fig. 5). January 23, 1939.

To obtain a representative section of the Vicksburg "group" a location was selected on the bluffs, and a hole was cored continuously to a depth of 83.5 feet. This cored interval contained the Byram marl, the Glendon limestone, the Mint Spring marl, and the uppermost Forest Hill. In the writings of Conrad

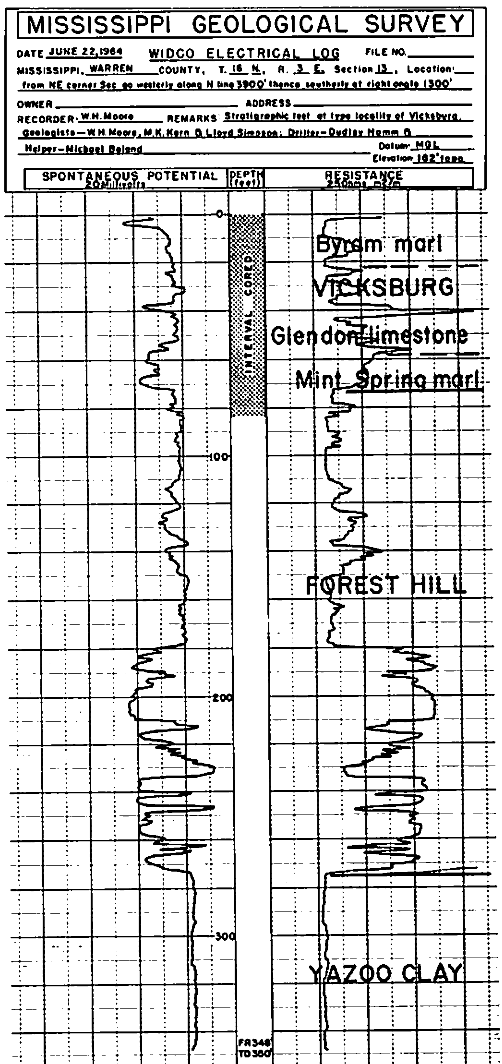

Figure 12.—Electrical log of the hole drilled to sample the Vicksburg "group" at Vicksburg.

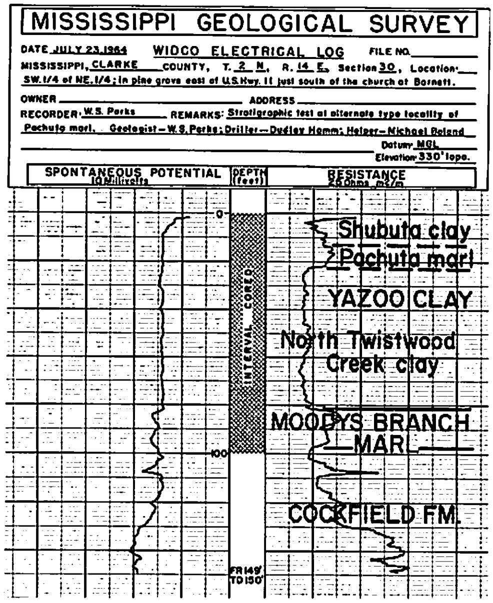

Figure 13.—Electrical log of the hole drilled to sample the Pachuta marl at Barnett.

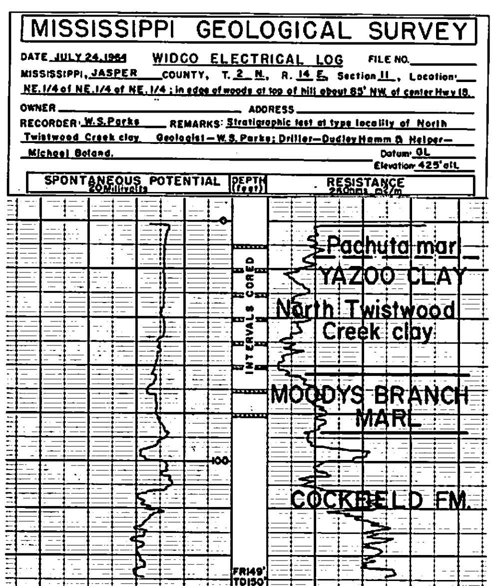

Figure 14.—Electrical log of the hole drilled to sample the North Twistwood Creek clay near Rose Hill.

and Hilgard, they mention a bed of limestone that was observed near the water's edge at the base of the bluffs. This limestone bed would be, stratigraphically, approximately 30 feet below the top of the Forest Hill. In order to ascertain whether this limestone is present in the Forest Hill or whether it is at its position as the result of slump, the hole was drilled to a total depth of 350 feet bottoming in the Yazoo clay. The limestone bed was not encountered in this hole. The Forest Hill was found to be much thicker than was expected, being some 200 feet thick. This compares with thicknesses of about 100 feet in holes drilled nearby. The electrical log of the hole with the cored interval indicated is shown in Figure 12.

PACHUTA MARL AT BARNETT, CLARKE COUNTY

The Pachuta marl member of the Yazoo clay was named by Murray[12] in 1947 from exposures on the south side of Pachuta Creek in Clarke County. A hole, located at Barnett a few miles south of this locality, was cored continuously to a depth of 100 feet. Coring started in weathered Shubuta clay and the hole penetrated the Pachuta marl, the North Twistwood Creek clay, the Moodys Branch marl and into the uppermost Cockfield formation. The hole was drilled to a total depth of 150 feet. Figure 13 shows the electrical log of the hole and the cored interval.

NORTH TWISTWOOD CREEK CLAY NEAR ROSE HILL, JASPER COUNTY

The North Twistwood Creek clay member of the Yazoo clay was named by Murray[13] in 1947 for exposures along the west side of what he took to be North Creek, two miles south of Rose Hill in Jasper County. Later work in Jasper County showed that Murray's type locality was actually on North Twistwood Creek rather than North Creek. In 1963 the member was formally renamed by Murray.[14]

A hole was drilled at the type locality to a depth of 150 feet and spot cores were taken at 10-foot intervals between the depths of 10 to 90 feet. These cores were from the Pachuta marl, North Twistwood Creek clay and Moodys Branch marl. The electrical log of this hole is shown in Figure 14. Figures 13 and 14 show that there is variation in the thicknesses of the Moodys Branch marl and North Twistwood Creek clay at this locality as compared with the previously described Pachuta marl locality.

STRATIGRAPHIC CONTRIBUTIONS

Perhaps the most important aspect of the type localities sampling program is the basic geologic information obtained from the academic research being conducted. Generally the development of the mineral resources of an area depends on the stage of development of geologic knowledge relative to that area. This means, how much reliable, useful, published information is available to the general public and to industry? The exception, of course, is when industry is attracted to an area by the discovery of commercial deposits of a much-wanted, spectacular mineral such as gold, iron ore, oil and gas, uranium, etc. In the exploration for these kinds of minerals, industry may spend very large funds far beyond the scope of expenditure of a governmental agency. Nevertheless, the reliable basic geologic information that governmental agencies provide facilitates these and other industries in their exploration and development efforts.

Early geological work in Mississippi dealt mostly with the study of surface formations and the search for surface minerals and rocks. In the early published reports, some of them more than one hundred years old, and in subsequent reports, the writers have applied names to the geologic formations that they recognized at the surface in the State. Some of these names originated in other states and were applied to units in Mississippi which were established to be, or thought to be, the equivalent to units already named. Also, many new names were used because of the inability of geologists to determine the stratigraphic equivalent of some units and because other units found in the State had not been recognized in other states. The geologic names derived from Mississippi localities have become widely known and are in use the world over. The classic localities have been visited, studied, and sampled by geologists from many countries for over 100 years. Fossils from several localities are displayed in museums throughout the United States and in other countries.

The original descriptions of the type localities have been used by geologists conducting work in other areas as a more or less standard for the units. As geological knowledge has progressed, much confusion and controversy has resulted from the usage of some names and as to the definitions of some units. Consequently, there has been a great need to re-examine the type localities and re-evaluate the status of many units.

It is hoped that the information gained from the type localities sampling program will help resolve many of the problems of nomenclature that now exist. The use of different names for equivalent units is commonly confusing to the experienced geologist and, of course, more so to the layman. The Survey is continually working towards a standardization of the nomenclature of the State. Its present policy in regard to stratigraphic nomenclature has been printed in the last several Bulletins (Figure 15). The standardization of nomenclature will eventually allow the making of larger-scale, more detailed geologic maps. The need for this kind of geologic map coverage is as important to the development of the mineral resources within the State as is the need for accurate, detailed transportation maps to the development of commerce. Geologic maps are not only used in geological work but also by the engineer, soil scientist, hydrologist and many others.

At the beginning of the search for oil and gas in Mississippi, there was an accelerated interest in the surface formations because they were used in mapping structures which, at depth, might be favorable for oil and gas accumulation. Also, the surface formations were closely studied so that they could be recognized when they were encountered in the subsurface. The Mississippi Geological Society, founded primarily for the professional and social activities of petroleum geologists, has from time to time sponsored field trips in the State and in neighboring states to study the geologic units and the geologic history of the area. The Society has a standing committee on type localities which has done limited and somewhat specialized work, most of which is not preserved in published form.

Even though the attention of oil geologists in recent years has been focused on the deeply buried subsurface formations which can be studied only by samples and electrical logs, a need still exists for an understanding of the surface deposits in order to reconstruct and to extrapolate geologic history and environmental conditions that affect oil and gas accumulation.

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

Figure 15.—Survey's policy on stratigraphic nomenclature published in several of the later Bulletins.

Many of the oil companies still assign new personnel to surface problems to acquaint them with the surface rocks and to search for surface structures. Most of this information, developed by private industry, remains confidential in the oil company files and is not available to the general public or to other oil operators.

The information gained by the present sampling program is important to mineral resources investigations by permitting a more accurate definition of the geologic units, by providing more information as to their lithologic character and thickness, and by giving additional clues as to depositional environments. This knowledge will aid geologists in their work with these formations whether engaged in the increasingly more difficult search for oil and gas or in the exploration for other rock and mineral deposits. Also, the continued refinement and expansion of geologic knowledge will no doubt, as in the past, result in the discovery of new rocks and minerals of economic value and in the finding of new uses for the materials already known.

MINERAL RESOURCES INVESTIGATIONS

The cores taken during the present sampling program provide excellent materials for testing to determine their suitability for various commercial uses. The type localities sampled, by definition, should represent the typical rock materials of these units as they are found in other parts of the State. Of course, this method of sampling by no means will provide a representative suite of all of the rocks and minerals present in the State because there commonly are facies changes within many of the units sampled and there are many other units that will not be sampled under this program. Also, it must be remembered that mineral concentrations are more commonly local features rather than being widespread. The sampling of the type localities will provide much general information about the economic potential of many of the more abundant materials such as clays, marls, sands, etc. Examples of the kinds of testing proposed are:

(1) Limestone and marl from Vicksburg and Byram are to be analysed for their calcium carbonate content to determine their suitability for use in making cement and as agricultural lime (Figures 12 and 7);

(2) Lower Yazoo clay from Jackson and Bucatunna clay from Byram have been tested to determine their suitability for use in making lightweight aggregates [These results are published in Bulletin 103] (Figures 10 and 6);

(3) Lower Yazoo clay from Jackson and marls from Vicksburg and Byram are to be analysed to determine their calcium carbonate content which will give some indication as to their suitability for use in making rock wool (Figures 10, 12 and 7); and

(4) Bucatunna clay from Byram, which is very pyritiferous, has been analysed chemically to determine its similarity to the so-called "acid iron earth" that is being produced commercially in the Bay Springs area (Figure 6).

GEOLOGICAL ENGINEERING STUDIES

Geology, as applied to engineering practice, involves the distribution and character of geological materials. Engineers are fast realizing the need for geological advice, especially in the fields of construction and water supply. The Survey has frequent requests for geological information to be used in conjunction with highway construction, airport planning, building sites, sewage disposal, water well drilling, etc. The Survey has published many reports that include information about the location of construction materials and about the distribution and character of the bedrock. Several reports prepared in cooperation with the Mississippi State Highway Department concern the geology along some of the State's highways. The information contained in these reports is to be used in repair work and in future highway planning. Several of the later county reports have sections dealing with water supply. Also, there are a few reports that concern local foundation problems that have application over large areas.

During the present sampling program, attention is given to the possibilities of utilizing some of the cores for testing in order to gain information that may have application in solving engineering problems. For example, the Yazoo clay which crops out in a belt about 130 miles long and varies from 5 to 35 miles wide across the State causes serious foundation problems in highway building and in other construction. This clay is very incompetent at the surface, and it slips or slides and expands or contracts depending on varying conditions. As yet, no completely satisfactory method has been found to stabilize this material.

Over several years, the State Highway Department has conducted extensive research on the Yazoo clay and other unstable materials that have been encountered in highway construction. Therefore, in sampling the Yazoo clay at Yazoo City, a set of samples from the cores were submitted to the

Highway Department for testing. These samples, taken at selected intervals, should be representative of unweathered Yazoo clays throughout the lower one-third of the thickness of the unit in the western part of its outcrop belt (Figure 4). Tests conducted include mechanical analyses and other determinations such as liquid limit, plastic limit, plasticity index, shrinkage limit, shrinkage ratio, and volume change. Also submitted for testing were samples of Moodys Branch marl, North Twistwood Creek clay, and Pachuta marl from Barnett (Figure 13).

These tests will add to the growing volume of data on the Yazoo clay and other incompetent materials. It is hoped that they will contribute to a more complete understanding of the behavior of these materials so that proper remedies can be found for the engineering problems associated with them. To resolve some of these problems will save the people of Mississippi millions of dollars.

AVAILABILITY AND USE OF MATERIALS

The cores and cuttings and electrical logs are on file at the Mississippi Geological Survey Sample Library, 2525 North West Street, Jackson, Mississippi. The Survey encourages the use of these materials by competent research personnel. The program is providing a wealth of working material for professors and graduate students in the geology departments of the various institutions of higher learning. Also, it provides opportunities for those many research personnel employed by industry in varied fields of geological endeavor to make further contributions to the geologic knowledge of the State.

The material collected in the drilling and coring of the seven type localities thus far completed is already being put to use. Aside from the invaluable stratigraphic and mineral resources information gained by the Survey Staff that will help in completing current projects, the following studies have been initiated or aided through this sampling program:

(1) Lloyd W. Simpson, *Foraminifera of the Vicksburg,* M. S. thesis, Mississippi State University;

(2) Martin Mumma, *Ostracoda of the Vicksburg,* Ph.D. dissertation, Louisiana State University;

(3) Kenneth Loep, *Foraminifera of the Jackson,* M. S. thesis, University of Houston;

(4) Ronald Greely, *Tertiary lunulitiform bryozoa,* Ph.D. dissertation, Missouri School of Mines;

(5) Norm Frederiksen, *Palynology of the Jackson,* Ph.D. dissertation, University of Wisconsin;

(6) William J. Huff, Ph.D. Rice University, *The Jackson Eocene Ostracoda of Mississippi,* manuscript now in preparation for publication; and

(7) Donald W. Engelhardt, Pan American Petroleum Corporation, *Plant microfossils from the Eocene Cockfield formation, Hinds County, Mississippi.*

The Survey requires that research be conducted on a cooperative basis inasmuch as the information is being developed largely at public expense. The Survey expects to be furnished the results of any studies and to have the right to publish them.

ACKNOWLEDGMENTS

The Survey expresses gratitude to the employees of the Mississippi State Highway Department for their help in this project. They established the elevation and assisted in the drilling and coring of the test hole at Yazoo City. Also, the Testing Division conducted various tests on samples from the holes drilled at Yazoo City and at Barnett.

Thanks are due Mr. E. H. Rainwater, Consultant for Tenneco Oil Company, for reviewing the manuscript of the present progress report and for making helpful suggestions. His remarks concerning the type localities sampling program are:

"Data already obtained on the Oligocene and Upper Eocene type sections more than justifies the type locality sampling project. The information to be gained from detailed paleontological, palynological and mineralogical studies and engineering tests of the samples will be most valuable in advancing the knowledge of the geological history of Mississippi. Just as entomologists must determine, from very detailed study, the life history of insects before they can be controlled, so geologists must understand the geological history of an area before its minerals can be scientifically explored and exploited. Your type locality project will aid significantly in determining the geological history of Mississippi; it will establish the upper and lower boundaries of the stratigraphic units; the samples obtained will make possible the development of criteria for correlation and zonation which are essential in mineral exploration. I believe that, if you will complete the project as planned, the stratigraphy of Mississippi will be better understood than that of most states. From such understanding, commercial geologists can better explore for the many minerals in the state."

Mr. Rainwater's criticism of the progress report and his support of the sampling program are greatly appreciated.

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HILGARD AS A GEOLOGIST

HENRY V. HOWE*

ABSTRACT

Dr. Eugene Waldemar Hilgard, native-born and educated in Germany, came to employment with the Mississippi Geological Survey in 1855. He served on two occasions as State Geologist in addition to other positions of responsibility. Hilgard's first great contribution was the development of a geological column in Mississippi. His second great contribution was the development of soil science.

Dr. Hilgard was a prolific researcher. An outline of his more prominent geological writings is given. Emphasis is placed on those works that have had far-reaching effects on thinking in Gulf Coastal Plain geology. Because of this work while in Mississippi, he is considered to be the "Father of Gulf Coast geology." This review of the many achievements of this remarkably versatile and adaptable man should be an inspiration to present-day geologists no matter what their field of endeavor or their area of study. Ed.

Eugene W. Hilgard is the "Father of Gulf Coast geology," and therefore must be looked on as the "Father of American Tertiary stratigraphy." As such he justly deserves a place among the truly great geologists of the last century. He was a remarkably versatile and adaptable man, whose great geological contributions were made under conditions present-day geologists would have difficulty in comprehending (Figure 1).

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Editor's note: From tenth edition *American Men of Science* we learn that the distinguished writer of this paper on Hilgard was born in Fulton, New York, received his A.B. degree from Oregon, his Ph.D. from Stanford in 1922. He has served in various positions of responsibility with the Louisiana State University from 1922 to the present, in the School of Geology, with the Louisiana Geological Survey and as Dean of the College of Arts & Sciences (1944-49). Evidence of his great ability in geological science and of the high esteem in which he is held by the Public is the fact that he was recently appointed and now serves as Chairman, Louisiana Mineral Board.

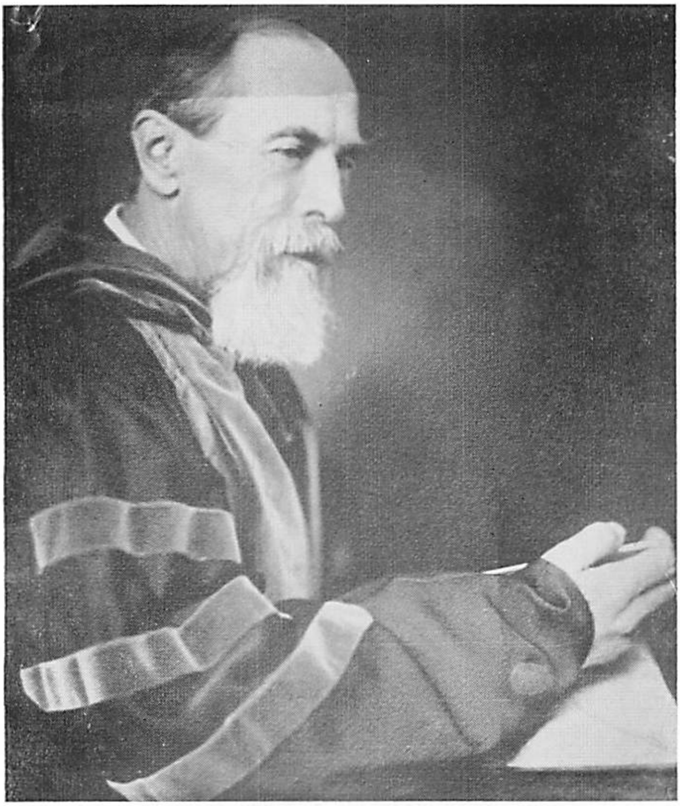

Figure 1.—Dr. Eugene W. Hilgard, twice officially State Geologist of Mississippi, World-renowned as the "Father of Agricultural Geology," the "Father of Gulf Coast geology," and the "Father of American Tertiary stratigraphy."

Hilgard, of course, was not the first geologist to examine the sediments of the Gulf Coastal plain. More than 30 years before, John Finch[1] had demonstrated these sediments to be fossiliferous. The classical studies of Conrad[2] and of Lea[3] had already made Claiborne Bluff America's most celebrated Tertiary fossil locality. There was also a large literature dealing with the remains of the well-known whale-like mammal *Zeuglodon*

[1]Finch, John (1824) Geological Essay on the Tertiary Formations in America; Amer. Jour. Sci., Vol. 7, p. 31-43.

[2]Conrad, T.A. (1833-1838)

[3]Lea, Isaac (1833) Contributions to Geology, 227 pp., 6 pls., Phila.

cetoides, whose bones occur in a narrow belt of clays across central Louisiana, middle Mississippi and Alabama. Even the eminent British geologist Sir Charles Lyell had paid two visits to America and had correctly diagnosed the sequence of sediments in the vicinity of Claiborne Bluff, and had described the loess bluffs at Natchez, Mississippi. Two great contributions had been made toward an understanding of Mississippi paleontology by Conrad,[4] the latter in a report on Mississippi by Wailes.[5] Numerous other smaller papers had been published which gave some information in regard to particular localities. There was, however, no established stratigraphic succession, and the Oligocene "Orbitoidal limestone" of Alabama had been confused with the Cretaceous.

Hilgard's first great contribution was the development of a geological column in Mississippi, particularly that of the Tertiary. It was on the foundation of this sequence of sediments that our American Tertiary nomenclature has been developed. To be sure many of Hilgard's formational names were descriptive, such as "Orange sand," and "Northern lignitic," and were replaced by later "locality" names, and some of his formations have been broken down into smaller units. His subdivisions nevertheless remain in sequence, and under his, or later names, form the major divisions of the Gulf Coast geological column. The rapidity with which Hilgard made order out of this succession after only a few field trips across portions of the State by horse and buggy, and without the aid of library facilities at the University, should be proof positive to anyone of his logical mind and astoundingly keen powers of observation.

Hilgard's second great contribution, the development of soil science, followed logically upon the results of his reconnaissance trips. Exposures were few, and the unweathered formations

[4]Conrad, T.A. (1847) "Observations on the Eocene Formation, and Descriptions of 105 New Fossils of that Period from the Vicinity of Vicksburg, Mississippi, with an Appendix," Proc. Acad. Nat. Sci., Philadelphia, Vol. 3, p. 280-99; also in Jour. Acad. Nat. Sci., Phila., Ser. 2, Vol. 1 (1848) p. 111-34, pls. 9-14.

[5]Wailes, B.L.C. (1854) "Report on the Agriculture and Geology of Mississippi;" embracing a sketch of the social and natural history of the State (with plates of Jackson Eocene fossils by T.A. Conrad).

were to be seen only in stream banks. In attempting to trace formations from one stream to the next, Hilgard quickly observed that in the case of some formations, the vegetation was so characteristic as to identify positively the underlying rocks in areas where exposures were unobtainable. Moreover, his hurried reconnaissance had shown him that Mississippi was lacking in metallic resources, and if the geological survey was to be justified, it would have to be of use to the rural population. Fortunately Hilgard's training in Chemistry fitted him for the soil studies that were to make him so famous.

After obtaining his Ph.D. degree from Heidelberg in 1853, Hilgard returned to Washington in 1855. Not finding a geological position immediately open, he started to make use of "an incipient chemical laboratory in the basement of the Smithsonian Institution" for research. He had hardly become settled, when word from his brother Julius called him to the Hartford meeting of the American Association for the Advancement of Science. There he met Dr. F. A. P. Barnard, then professor of physics at the University of Mississippi, who was looking for an Assistant Geologist to help Professor L. Harper, the newly appointed State Geologist of Mississippi. The remuneration was $1,000.00 per year, but Hilgard gladly accepted.

On his way south, Hilgard paid a visit of a few days to Dr. David Dale Owen at New Harmony, Indiana. Dr. Owen was preparing a geological report on Arkansas, and he took pains to impress on Hilgard that he should pay particular attention to soils and to any features that might be of use to agriculture. Hilgard[6] later wrote: "This visit was most important and fruitful in giving direction to my subsequent studies and methods." This advice was felt later by many of the southern states whose legislatures followed the example of Mississippi in establishing Agricultural and Geological Surveys. In Louisiana the survey, as the result of Hilgard's example was called a "*Soil* and Geological Survey" and operated under the auspices of the College of Agriculture until my arrival there in 1922, and I encountered considerable difficulty in getting geology freed from the clutches of agriculture so that our energies might be concentrated on the rapidly developing field of petroleum.

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[6]Hilgard, E.W. (1901) A historical outline of the geological and agricultural survey of the State of Mississippi. Am. Geol. Vol. 27, p. 289.

On his arrival in Mississippi, Hilgard found he belonged to a "Survey" which had had a brief and precarious history. It had first been created by an Act of the Legislature in March, 1850, and the first "State Geologist" was Dr. John Millington, professor of Chemistry at the University. Oscar M. Lieber of South Carolina was appointed Assistant Geologist in July, 1851, and made a reconnaissance trip through the Yazoo Delta of the State before resigning. He made no report and Professor B. L. C. Wailes of Jefferson College at Natchez accepted the position as Assistant. Wailes was a naturalist and had already made extensive collections of fossils and bones from the southern part of the State. By 1854 Wailes had completed and presented to the Board of Trustees of the University the manuscript of his "Report on the Agriculture and Geology of Mississippi." This report was largely historical and agricultural, rather than geological, but it made a favorable impression and money was provided for its publication, and the Legislature passed an Act under which the Survey was to operate for some years.

Under the new Act, Wailes had expected to become the State Geologist, but instead the Trustees of the University elected Lewis Harper,[7] a man singularly ill-fitted for the position. Harper had just returned from a rapid reconnaissance trip, and he and Hilgard started out together in a horse drawn ambulance with a camping outfit and negro driver. They crossed the eastern portion of the State as far south as Leakesville, Greene County, and thence west to the Mississippi at Natchez before rains made further field work impossible. The winter was devoted to arranging collections and making analyses, and the early spring was devoted to a study of the northeastern portion of the State. The field season of 1856 was spent in the northern half of the State for the most part and Hilgard ended up by visiting Michael Tuomey, State Geologist of Alabama for the purpose of comparing notes. This visit undoubtedly was a great help to both men.

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[7]Originally Ludwig Hafner, of Hamburg, Germany, who had fled first to France for political reasons, thence to America. From Hilgard's accounts it appears that he changed his name to Harper, made a living by traveling from place to place with a telescope for the viewing of stars and finally had taken a position teaching natural history in a small college near Greenville, Alabama.

Upon his return to the University, Hilgard discovered that Harper had aroused the Board of Trustees and was forced to resign. Hilgard was retained, however, with his salary increased to $1,500.00 per annum. At the January, 1857, session of the Legislature, however, Harper succeeded in getting the Legislature to pass an act separating the survey from the University, with the State Geologist to be appointed by the governor, and the Survey to be domiciled in the Penitentiary building at Jackson. It further provided for the publication of 5,000 copies of Professor Harper's report. The governor appointed Harper to the position with back pay from the time he resigned. Harper then left for New York to prepare his report for printing, apparently taking Hilgard's field notes with him. The report prepared in part from Hilgard's notes, which Harper lacked the training to understand is one of the most unusual curiosities of American geological literature, and was so absurd that it aroused a storm of protest, and only the strenuous efforts of Hilgard prevented the Legislature from abolishing the Survey.

Hilgard had accepted a position as chemist for the Smithsonian Institution, but returned to Mississippi when the position of State Geologist was offered to him. He found the resentment of the people of Mississippi still very great toward the Survey, and had to do much of his field work over, for lack of his previous notes. This time he started in the north and made a complete section of the formations of the State to the Gulf of Mexico, paying particular attention to the soils and vegetation, and to marls which might be used as fertilizers, and his great report of 1860[7] was the result. The first 201 pages of this remarkable report deal with geology; the remainder with agriculture and soils. The geological portion is of necessity a description of the succession of sedimentary rocks of which Mississippi is composed. In this description Hilgard departed from the customary order, in which the oldest beds are described first and the youngest last, and started with the "Orange Sand formation," devoting 41 pages to its delineation. This was done because the Orange Sand covered such a great percentage of the total land areas of the State. Many of Hilgard's later papers

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[7]Hilgard, E.W. (1860) Geology and agriculture of the State of Mississippi. State Report, Jackson, Miss. 391 pp., map and sections.

were devoted to problems connected with the Orange Sand in Mississippi, Louisiana and other southern states, and to the beds immediately overlying the Orange Sand. The development of Hilgard's ideas concerning the deposition and environment of various portions of the Gulf Coast section will be discussed in succeeding pages.

Before leaving this great Report, it should be pointed out that Hilgard accurately depicted the uplift of strata at Jackson, Mississippi, and when this uplift was drilled more than 70 years later, it turned out to be the noted "Jackson gas field."

The geological column for Mississippi, which was Hilgard's greatest single geological contribution, was given in tabular form on page 3 of the Report and is reproduced below:

TABLE OF THE FORMATIONS OF MISSISSIPPI

Name of formation	NAME OF GROUP	PRINCIPAL MATERIALS	FOSSILS FOUND
Quaternary	ALLUVIUM	Soils, sand bars, etc.	Living plants and animals
	SECOND BOTTOM	Hommocks	?
	YELLOW LOAM	Brown and yellow brick clays	?
	BLUFF FORMATION	Calcareous silt	Terrestrial, part extinct
	ORANGE SAND	Sands, pebbles, clays	Those of underlying formations
Tertiary	COAST PLIOCENE?	Black fetid clays	Living marine shells, living trees
	GRAND GULF GROUP	Light colored clays, white sandstones	Plants partly extinct? Lignite
	VICKSBURG GROUP	Marls and limestones	Marine animals
	LIGNITIC	Black clays	Plants, Lignite
	JACKSON GROUP	Marls and soft limestones	Marine animals
	LIGNITIC	Black clays	Plants, Lignite
	CLAIBORNE GROUP	Marls and limestones	Marine animals
		Siliceous sandstones	Marine animals
	NORTHERN LIGNITIC	Black and gray clays; yellow sands	Plants partly extinct; Lignite
Cretaceous	RIPLEY GROUP	Marls and limestones, sandy	Marine animals
	ROTTEN LIMESTONE	Soft chalky limestones, clayey	Marine animals
	TOMBIGEE SAND	Greenish micaceous sands	Marine animals
	EUTAW GROUP	Dark colored clays, sand	Plants extinct, Lignite
CARBONIFEROUS	LIMESTONE	Fetid, crystalline limestone	Marine animals
	SANDSTONE	Siliceous sandstone and chert	Marine animals
	BLACK SLATE	Hydraulic limestone	?

Upon the completion of Hilgard's manuscript, he left for Europe, finding the report printed upon his return in 1860. The report was shipped to St. Louis for binding, but hostilities between the North and South prevented its return until 1866.

Despite the conflict, the Mississippi Legislature continued appropriations for the continuance of Hilgard's work. With the conflict approaching Oxford, the faculty was dissolved and the governor delegated Hilgard to look after the University's scientific equipment and collections, which he was successful in doing.

In resuming his Survey work, Hilgard appointed Dr. George Little as Assistant Geologist in July, 1866. Little immediately began a field investigation of the Loess deposits of Mississippi from the vicinity of Rodney to the Louisiana line and beyond. Little's report, done under the supervision of Hilgard was published in Memoir No. 268 of the Smithsonian Institution.

About this time Hilgard resigned as State Geologist to accept the Professorship of Chemistry at the University of Mississippi, and Dr. Little became State Geologist. Little was fortunate in obtaining Dr. Eugene A. Smith as Assistant Geologist in 1868, but in 1870 Little resigned to accept the Chair of Geology at the University. To prevent the Survey from being abolished, Hilgard, without compensation, again assumed the position as State Geologist. He had an understanding that he would not again have to take the field, and Dr. Smith was continued as Assistant for the field work.

Under Hilgard's direction Smith took to the field in the Yazoo Bottom, crossing it and recrossing it many times in the region between Vicksburg and Memphis. The results were presented by Smith at the Indianapolis meeting of the A.A.A.S., and were published in the volume of *Proceedings* for 1871. In succeeding field work Smith traced the "Siliceous Claiborne," Jackson, and Vicksburg across the State, with resulting refinements in the geological map. In September, 1871, Smith resigned to accept the Chair of Geology at the University of Alabama, and went on to create the Geological Survey of that State which has continued to this time. He was succeeded by R. H. Loughridge of Texas, who began a compilation of the results of the Survey since the 1860 Report, when in the fall of 1872, a ruling by the State Auditor of Public Accounts stopped the Survey entirely.

While Hilgard did little active field work himself in Mississippi after the war, his investigations led him outside the State, and particularly into Louisiana, and his geological writings were prolific. Several of these papers, which were largely restatements and refinements of portions of the 1860 Report, were printed in the American Journal of Science at the suggestion of Prof. J. D. Dana. In the first of these Hilgard[9] outlined his concept of the succession of Quaternary events, suggesting the name "Loam Period" for the Yellow Loam of the Report and "River Terraces Period" for his previous Hommocks or Second Bottoms. The paper is important in Hilgard's thinking as in it he outlined his concept of the Orange Sand delta, which he conceived of as filling the "Mississippi Embayment" with an apex within the confines of the "Northern Drift" of Illinois and Missouri. He made very clear his position that its formation was occasioned by glaciation.

In the second of these papers Hilgard[10] came to the defense of his stratigraphical section. He pointed out that Conrad had made a mental slip in referring the Orbitolite limestone at Vicksburg to the Jackson Eocene, and that his supposed *Ostrea georgiana* bed at Vicksburg must underlie the Vicksburg and overlie the Jackson, and thus occupy a similar stratigraphic horizon as Hilgard's previously suggested "Red Bluff group." The bed with *"Ostrea georgiana"* as given in the section by Conrad lies below the falls at Mint Spring Bayou near the national cemetary and is no longer visible due to slumping and fill made by road construction. Hilgard was, nevertheless, very right in what he had to say about the position of this bed.

In a third paper Hilgard[11] pointed out the great difference between drift in the New England area which is not stratified

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[9]Hilgard, E.W. (1866) On the Quaternary formations of the State of Mississippi: Am. J. Sci., *91*, p. 311-325.

[10]Hilgard, E.W. (1866) Remarks on the new division of the Eocene or Shell Bluff Group proposed by Mr. Conrad: Am. J. Sci., *92*, p. 68-72.

[11]Hilgard, E. W. (1866) Remarks on the Drift in the Western and Southern States, and its relation to the Glacier and Iceberg Theories: Amer. J. Sci., *92*, p. 343-347.

and that of many places in Illinois, Wisconsin, Iowa, and Missouri, which is described in the reports of those states. He compared the latter to the Orange Sand. Hilgard is here influenced in his thinking by Dana's Manual of Geology, and by Dana's address before the American Association in 1855 on the "Champlain Epoch." A depression of near 500 feet below the present level in the latitude of Montreal bothered Hilgard, particularly as he felt the Orange Sand extended to elevations as great as possibly 700 feet above sea level in Mississippi. He therefore at this time concluded that the Champlain Epoch of submergence must be connected with the formation of the "Second Bottoms."

In the succeeding year Hilgard[12] gave an able dissertation on the erroneous conclusions which may be drawn from "selected" fossil collections made by amateurs, in which he pointed out that the "Orbitoides limestone" of St. Stephens is Vicksburg in age, rather than Jackson as Conrad had claimed. He correctly placed the sediments at Red Bluff in Wayne County, Mississippi, between the Vicksburg and Jackson. He then went on to discuss variations in lithology along strike, and outlined very modern principles of stratigraphic correlation. He reaffirmed the lower Eocene age of his "Northern Lignitic," disposing of possible Pliocene fossil leaves reported by Lesquereaux, and reaffirmed that the regional dip is west in northern Mississippi and south in southern Mississippi. He was inclined to regard the reverse dips at Jackson as due to irregularities in the sea floor, rather than folding. As to Conrad's assertion that the bluffs at Grand Gulf and Fort Adams have *marine* beds at the base, he said that neither he nor Wailes had been able to find any trace of fossils, though the bedding shows deposition in quiet water. He was still correctly convinced that the Grand Gulf overlay the Vicksburg, though he had not been able to find the contact. Finally he concluded that the "Blue clay bottom" of the "Coast Pliocene?" was the same as the black clays with marine shells encountered in a well at New Orleans to a depth of 570 feet, and that it underlay the whole delta as far up as Port Hudson, where it carried cypress stumps. Hilgard had, however, not visited Port Hudson at this time.

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[12]Hilgard, E.W. (1867) On the Tertiary Formations of Mississippi and Alabama: Amer. J. Sci., vol. 93, p. 29-41.

Another brief note by Hilgard[13] at this time dealt with how to separate glacial till from stratified outwash deposits.

While these short papers were being written for the American Journal of Science Hilgard was working on samples from a well drilled at New Orleans in 1856. The invitation to work the well samples had come from General A. A. Humphreys of the U. S. Engineers at the suggestion of Sir Charles Lyell. Unfortunately the samples had been somewhat scattered during the war and some of the labels lost, but by 1870 Hilgard had made sufficient order out of them to submit a report. This report by Hilgard[14] correctly placed the strata and fossils encountered as younger than Orange Sand and below 108 feet as not river silt or true delta material, but marine and older than the present Mississippi River. The report is notable as being the first in America to make use of the microscopic shells of foraminifera for purposes of identification of well samples. It was not until 50 years later that the petroleum industry took up widespread use of these organisms for well correlation.

In 1867 Hilgard received from Prof. Jos. Henry an invitation to study the rock salt deposit of Petite Anse (Avery Island), Louisiana, under the auspices of the Smithsonian Institution. The invitation was enthusiastically accepted, and a trip was made by steamer down the Mississippi River, with stops at many points on the way to New Orleans. The stop at Port Hudson, Louisiana, impressed Hilgard most and resulted in a number of publications. Hilgard renamed his "Coast Pliocene?" of the 1860 Report for this place, because here he found the Port Hudson sediments, full of cypress logs and stumps, overlying his Orange Sands and was convinced that it lay beneath equivalents of the Bluff formation (or Loess).

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[13]Hilgard, E.W. (1867) Note on Dr. Andrews' paper on the Glacial Drift: Am. J. Sci., *93*, p. 241-242.

[14]Hilgard, E.W. (1870) Report on the Geological age of the Mississippi Delta; Rept. U.S. Engineers Dept., Washington, 16 pp.; *also*: Report of Examination of Specimens from the New Orleans artesian well of 1856: U. S. (War Dept.) Chief Eng. Ann. Rept. 1870 (U.S. 41st Cong., 3rd Sess., H. Ex. Doc. 1, pt. 2, V. 2, p. 352-365; U.S. Army Corps of Eng. P. P. 13, (1860) p. 636-646.

Arriving at New Orleans, Dr. J. S. Copes, President of the New Orleans Academy of Science, and other members arranged transportation for Hilgard to Pilottown and the Towboat Association thence took him on the Schooner *Varina* to the "mud-lumps" which were forming at the passes of the river. This portion of the trip likewise resulted in a number of subsequent papers on "mud-lumps."

On the trip west from New Orleans, Hilgard examined three of the famous "Five Islands," which are more or less circular mounds, up to two miles in diameter, rising from the coastal marsh of Louisiana to elevations approaching 200 feet. The first visited was Cote Blanche. One side of this "Island" faces Cote Blanche Bay and in the sea cliffs, he found cypress stumps at the base overlain by clays with concretions and fresh water shells, which convinced him that he was dealing with the same sequence of beds he had seen at Port Hudson. He found no exposures on the interior of the Island, however.

Weeks Island was examined next, and here Hilgard found ravines traversing the center of the island which exposed Orange Sand and on the edges of the island were again the Port Hudson clays, this time clearly inclined away from the center of the island. Curiously Hilgard was little impressed by the inclination of these beds away from a common center, and therefore missed the obvious implication of recent uplift.

At Avery's Island (Petite Anse) the story was more complete, but to Hilgard more confusing. Here again the Orange Sand formed the center, with rock salt exposed beneath it in the pits which had been dug during the war, and Port Hudson clays about the edges. Hilgard expressed his doubt of any uplift in spite of the evidence. In his first paper on Petite Anse[15] he concluded that the rock salt was Quaternary in age and that the Five Islands were but erosion remnants of Orange Sand. This conception forced him to the following strange conclusion in regard to the Loess which overlies the Orange Sand in western Mississippi:

[15]Hilgard, E.W., (1869) On the Geology of Lower Louisiana and the Rock Salt Deposit of Petite Anse: Am. Jour. Sci., 97, p. 77-88.

"There must have been such a depression of the whole country as to transform the immediate valley of the Mississippi as far as Keokuk, as well as valleys of larger tributaries into estuaries of the Gulf of Mexico, containing a mass of water too great to be sensibly affected by the variation now causing the annual overlows of the rivers (for otherwise the deposits must have shown lines of deposition), yet possessing a gental flow above (since the materials of the Bluff formation of Missouri and Indiana exhibit signs of fluviatile action); quite fresh in its upper portion (where fluviatile shells are found), but rendered unfit for the life of either a fresh or salt water fauna by an abundance of sea-water, in its lower or almost stagnant portion at tide level, and deriving vestiges of animal life only from the 'offscourings' of the adjacent unsubmerged lands."

Thus two concepts were formulated in Hilgard's mind which were elaborated and applied to other portions of the section in succeeding papers. The first, that of great eustatic changes of sea level in the later stages of the Earth's history, was adopted from Dana and was carried to greater extremes by McGee some 20 years later. The second, that of great bodies of marine water devoid of life, Hilgard himself carried to the ultimate extreme in papers dealing with the deposition of the Grand Gulf group.

During the winter of 1866-1867, through the efforts of the officers of the New Orleans Academy, funds were subscribed, and an allowance was obtained from the State Bureau of Immigration, to defray the expenses of a geological reconnaissance of Louisiana under Hilgard's guidance. Hilgard's visit to Petite Anse caused him to be anxious to explore the remainder of the State. The expedition was undertaken in May and June of 1869. The party consisted of three men, Hilgard, J. R. Walker and F. C. Miller, members of the New Orleans Academy. In addition to their horses, they took with them a large pack mule for the carrying of samples. Hilgard had allotted only 30 days to the expedition, but actually 39 days were consumed, of which 28 were spent in the saddle. Since they covered some 625 miles, averaging over 22 miles per day, it is remarkable that Hilgard was able to see so much and bring back so many samples.

On this trip Hilgard started at the Five Islands, going north to Opelousas and the Bayou Chicot salt dome, thence southwest to Lake Charles and the Sulphur Dome, thence north to Bayou Toro, Many, Sabinetown, Mansfield and on east to the salt dome area of northern Louisiana, visiting a number of domes including Kings, Drakes, Rayburns, Winnfield and Cedar, from whence he turned southeast to Harrisonburg and across the Mississippi to Natchez.

The results of this expedition were presented by Hilgard[16] in three separate papers, all covering the same material, but the last being by far the most complete. This was the last extensive geological reconnaissance made by Hilgard in the Gulf Coast and essentially fixed his ideas in regard to the geology of that region. A summary of his findings and conclusions is therefore justified.

First, as he had anticipated, he found Louisiana to be a western counterpart of Mississippi, and the formations which he crossed he unhesitatingly identified with the section he had established east of the river. He was thus able to put together a geological map of Louisiana, which was presented at the Chicago meeting of the A.A.A.S. This map was largely adopted and modified by Hopkins (then exploring Louisiana himself) and published under the auspices of the school which later became Louisiana State University. The map was remarkably accurate except in the northwestern part of the state.

Hilgard's physiographic description of the prairies of southwest Louisiana is admirable and accurate. He described how these prairies start with a surface elevation of around 70 feet near Opelousas and slope gradually south toward the Five Islands and southwest toward Lake Charles and Sulphur. He likewise gave a good description of the water courses which cross them, but failed to realize that the surface is a tilted one, crossed by the meander scars of Pleistocene streams. He also correctly correlated the sediments which underlie the prairies with the section he had seen earlier at Port Hudson.

These reports by Hilgard give the first accurate account of the famous Sulphur Mound, and the wells which were then

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[16]Hilgard, E.W. (1869) Preliminary Report of a Geological Reconnaissance of Louisiana: DeBow's Review, New Orleans, Sept. issue; extracted and published by the New Orleans Academy (1869) 15 pp.; Summary of Results of a late Geological Reconnaissance of Louisiana: Amer. Jour. Sci., *98*, p. 331-346. Supplementary and final report of a geological reconnaissance of Louisiana: New Orleans Acad. Sci. and the Bureau of Immigration (1873), 44 pp.

being drilled on it, together with an appraisal of the very great value of its discovery. The country north of Sulphur to Bayou Toro is correctly correlated with the section of southern Mississippi.

At Sabinetown, Texas, Hilgard made a small collection of fossils which he incorrectly identified with those he had obtained at Bayou Toro, and also with those at Vicksburg. He unfortunately was in too much of a hurry to take accurate dips along the Sabine River in this area, where the dip is in most places more than 150 per mile to the south, as against the 25 feet per mile he was accustomed to in Mississippi. He therefore assumed the beds to be nearly horizonal and even continued what he supposed to be the Vicksburg many miles to the north to the region of Mansfield, where he encountered numerous lignite beds. Hilgard realized that these sediments were lithologically different from the Vicksburg limestones of Mississippi, but assumed the difference was one of facies. He therefore proposed a new name for these lignitic sediments: the Mansfield group.

Had Hilgard stopped to record dips, as he had done earlier in Mississippi, he would have found that the thickness of Eocene sediments exposed between Bayou Toro and Sabinetown was as great or greater than he had allowed for the whole Tertiary section of Mississippi! Such a calculation would have forced a revision of his ideas of sedimentation in the Gulf Coast region, and might have led him to the concept of isostasy. Instead, Hilgard's figures of about 4,000 feet for the whole Gulf Coast section remained the accepted and quoted figures in American textbooks of geology until about 1930.

Hilgard's examination of the saltdomes of north Louisiana, following his brief visits to the Five Islands, Bayou Chicot and Sulphur, convinced him of the genetic similarity of all. The finding of Cretaceous fossils, *Gryphaea pitcheri* and *Exogyra costata* at the King's dome convinced him that each of these isolated spots represented peaks of a buried Cretaceous ridge, a concept which he retained to the end.

Finally, in the hills of Catahoula Parish, he found undoubted Vicksburg fossils overlying definite Jackson clays, and underlying Grand Gulf sandstone. This sequence was clearer than he had been able to find in Mississippi, and supplied the final proof of the correctness of his Mississippi section.

Returning to Oxford from his Louisiana expeditions, Hilgard was very active in presenting brief papers dealing with various features which he had seen. Some of these appeared in print only as abstracts. One of these read before the American Association by Dr. Andrews[17] of New Orleans outlined many of his previous ideas in regard to the Mississippi Embayment, discussed the New Orleans gas wells, and appealed for a well deep enough to reach the Orange Sand which he thought would carry suitable water for the city. This was accompanied by an abstract of the first of Hilgard's[18] "mud-lump" papers. Here he briefly described them as the cones of mud-volcanoes with gas emanating from their numerous craters. He indicated that they formed in the channel of the river inside the pass-bars. He suggested that the mud of which they are formed was the semi-liquid mass above the "blue-clay bottom" formed ahead of the river mouths by the action of sea water on the river's load. The weight of the advancing pass-bars caused this mud to be squeezed up in the deepest part of the channel immediately behind the bars.

These two papers were largely combined in an article published by Hilgard[19] the following year. In this article it is evident that Hilgard had confused the "back-swamp" clays of the Mississippi flood-plain with the Pleistocene cypress-stump bearing clays of the bluff at Port Hudson. He again appealed for a deep well at New Orleans.

In another paper presented at the Indianapolis meeting of the American Association, Hilgard[20] again reviewed the develop-

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[17]Hilgard, E. W. (1870) The Upper Delta Plain of the Mississippi. (abst.) Am. Nat., vol. 4, p. 638.

[18]Hilgard, E. W. (1870) On the mudlumps of the passes of the Mississippi: Am. Nat. vol. 4, p. 638-639.

[19]Hilgard, E. W. (1871) On the geology of the delta and the mudlumps of the passes of the Mississippi: Am. Jour. Sci., *101,* p. 238-246, 356-368, 425-435.

[20]Hilgard, E. W. (1871) On the geological history of the Gulf of Mexico: Proc. Am. Assoc. Adv. Sci.,-Indianapolis meeting; Am. Nat., vol. 5, p. 514-524 (with comments by many geologists); also in Am. Jour. Sci., vol. 102, p. 391-404, with a geologic map of the Gulf Coast.

ment of sedimentation in the Mississippi embayment, pointing out how the lignitiferous sediments of the upper embayment became marine farther south. He then went on to a discussion of the unfossiliferous nature of the Grand Gulf group and concluded that the Gulf of Mexico must have been nearly closed and so freshened as to kill marine life. The geologic map is more or less generalized and is accompanied by a stratigraphic column giving thicknesses. The map is grossly in error in north Texas and Indian Territory, where he placed the sands of the Cretaceous "Cross-Timbers" with his "Northern Lignitic" on hearsay evidence. This mistake was quickly rectified by him in later publications, however. The comments on this paper are most interesting, as A. Winchell agreed that the northern and southern drift were continuous, and Dr. G. Little, who had studied under Tuomey, maintained that Tuomey had traced the gravels from Tuscaloosa, Alabama, to Columbus, Mississippi, and thence northward through the Tennessee valley to Ohio.

Hilgard's[21] remarks on another paper at this meeting again proved the keenness of his observation. Inquiring of Prof. Swallow whether the Cretaceous shown bordering the Embayment in Missouri contained glauconite, black sand and gravel, and obscure casts of fossils, and receiving an affirmative reply, Hilgard went on to state that these were not characteristic of the Cretaceous of Arkansas, Tennessee, and Mississippi. Instead, they were characteristic of the very base of the Tertiary in these states. This bed is now placed in the Paleocene Midway group as the Clayton limestone.

In a discussion of the paper by Dr. Eugene A. Smith on the "Mississippi Bottom" prepared under his direction, Hilgard[22] remarked that his own observations in the Tensas bottom in Louisiana confirmed those of Dr. Smith. Much of the best land there is a genuine prairie soil, full of calcareous concretions — a feature entirely foreign to the true river alluvium as well as the modern paludal deposits. He concluded that there can be

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[21]Hilgard, E. W. (1871) Remarks on the geological map and section of the rocks of Missouri by Prof. G. C. Swallow: Am. Nat., 5, p. 541-542.

[22]Hilgard, E. W. (1871) On the origin of the alluvial lands of the lower Mississippi: Am. Nat. vol. 5, p. 606.

no doubt that a very large portion of the celebrated "alluvial" lands of the lower Mississippi are not alluvium at all, but substantially result from the disintegration of these older beds. Subsequent studies by the Mississippi River Commission under the direction of Dr. H. N. Fisk and his associates have not borne out these ideas of Hilgard, which appear to have come from his visit to the Port Hudson bluff.

In his next paper Hilgard[23] was obviously upset by his friend Hopkins having had the temerity to question in the Third Annual Report of the Geological Survey of Louisiana, some of the ideas Hilgard had come to cherish. He denounced Hopkins for doubting the great differences in elevation during the Drift Period. He violently protested the substitution of "Champlain Period" of Dana for Swallow's "Bluff Period," indicating that he doubted whether Hopkins could tell "Yellow Loam" when he saw it. Finally he was greatly provoked at the suggestion that Hilgard was rash in drawing conclusions about a closed Gulf of Mexico until something was known about the Grand Gulf of Texas. While exposures in Texas would not have done much to help Hopkins, subsequent drilling of wells has shown Hopkins to be right, as the Miocene beds which are largely unfossiliferous on the surface, all become abundantly fossiliferous and marine "down-dip" to the south of the outcrop.

In 1873 Hilgard accepted the Professorship of Geology and Natural History at the University of Michigan, where he was to remain until 1875. While there he published two papers. The first indicated that Hopkins' remarks had told on Hilgard[24] as after comparing the lignites of the Tertiary with the peat beds of the coastal marshes, he concluded that leaching had removed spots and other organic remains from the underclays. He then concluded that similar processes are responsible for the apparent absence of fossils in the Grand Gulf, rather than the closing of the Gulf of Mexico.

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[23]Hilgard, E. W. (1872) On some points in the geology of the Southwest: Am. J. Sci., (3) vol. 4, p. 265-270.

[24]Hilgard, E. W. (1874) Note on lignite beds and their underclays: Am. Jour. Sci., (3) vol. 7, p. 208-210.

In the other paper at this time, Hilgard[25] entered the realm of geophysics. Hilgard vigorously opposed the geological giants of this time, Dana and LeConte, and defended many points of Mallet's theory. The article was written, however, to show that Mallet's theory "leaves unexplained the numerous *oscillations* of level which we find the record down to our own time." He went on to point out that oscillations of the continent during the Quaternary may be told much better from the record of the Gulf of Mexico than in the center of the continent.

In his general discussion, his thinking led him almost to the threshold of isostasy: "Indeed it seems almost impossible to imagine a mechanism explaining satisfactorily fissure eruptions such as those of the Pacific Coast, on the basis of a slowly contracting *solid* crust with a rapidly contracting *liquid* layer or nucleus beneath. A more satisfactory explanation seems possible, if in accordance with Mallet's suggestion, and the intrinsic probabilities of the case, we assume the existence of a thickly viscid, igneo-plastic under crust layer. Such a layer, while barely, or very slowly obeying the laws of liquid equilibrium, would be capable of being liquified by a slight increase of temperature such as might be produced by squeezing or kneading. Portions of such plastic matter would occasionally become involved in the anticlinal folds of synclinoria; and thus supply the material for limited fissure eruptions, in this case literally "squeezed out." If Hilgard had only taken dip-measurements on the Sabine River section, he might have discovered that the great bulk of sediments lay parallel to the coast, not in the "Mississippi Embayment," and might then have taken the small additional step of postulating that the weight of sediments could cause movement in this viscous layer, instead of leaving it for McGee to point out that the Gulf of Mexico was the ideal place to measure the effects of isostasy.

Flood threats to New Orleans caused the (U.S.) Commission of Engineers to consider the advisability of constructing an artificial overflow outlet from the Mississippi into Lake Borgne, and a series of 14 borings were made along the course of the proposed outlet. Samples from these borings were placed

[25]Hilgard, E. W. (1874) On some points in Mallet's theory of vulcanicity: Am. Jour. Sci. (3) vol. 7, p. 535-546.

in 10 oz. bottles and shipped to Hilgard for examination. They reached him at Ann Arbor in February, 1875. Hilgard had then accepted the position which he was to fill with so much distinction at the University of California, and was arranging his belongings for the trip west. Moreover his eyesight had been somewhat impaired. He therefore arranged to have his friend, Dr. F. V. Hopkins, who had left Louisiana for financial reasons, do the necessary microscopic work on these samples, making determinations of only the larger organisms himself. The joint Report[25] of this investigation was completed after Hilgard reached Berkeley. This report was very carefully prepared and depicted accurately the relationship of recent river sediments to the underlying Quaternary marine clays in each boring. These borings fully substantiated Hilgard's earlier contention that the Mississippi River was a very recent arrival in the vicinity of New Orleans. The report was accompanied by excellent plates of drawings of the marine organisms encountered including the microscopic forms which had been studied so carefully by Hopkins. While Hilgard had previously mentioned the occurrence of foraminifera in samples from the New Orleans well of 1855, this report is the first properly illustrated report describing microfossils from well samples in this country.

The transfer of Hilgard's activities to the University of California, where he was to become Professor of Agricultural Chemistry, Director of the Agricultural Experiment Station, and Dean of the Faculty of Instruction, did not cause him to lose interest in geology. In fact the record of his publications after the move shows that much of his interest still remained in the problems of the deep South.

The origin of loess, particularly that of the lower Mississippi Valley is still being debated. Hilgard[26] was aroused by Prof. Pumpelly's paper in the American Journal of Science

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[25]Hilgard, E. W., and Hopkins, F. V. (1878) Report (on specimens obtained from borings between the Mississippi River and Lake Borgne, La.) U. S. (War Dept.) Chief Eng., Ann. Rept. 1878 (U. S. 45th. Cong., 3rd Sess., H. Ex. Doc. 1, pt. 2, v. 2, pt. 2, App. W, 2, p. 855-890.)

[26]Hilgard, E. W. (1879) The loess of the Mississippi Valley and the eolian hypothesis: Am. Jour. Sci. (3) vol. 18, p. 106-112.

which agreed with Richthofen's aeolian hypothesis. After citing David Dale Owen's description of loess in southern Indiana, and Winchell's description of its occurrence in Minnesota, he concluded: "Now, if the loess of the Mississippi trough is of aqueous origin at the heads, the sides, and the lower end of that trough, and is, moreover, covered, normally, by a deposit whose pebbles and sand streaks can leave no possible doubt of a general shallow submergence immediately following, and terminating, the loess period; it is not easy to see how the central portion of the deposit can have been in a subaerial condition as required by Richthofen's hypothesis." A condensed version of this paper appeared also under the title "The Mississippi Valley loess."[27] It was followed by another brief paper by Hilgard[28] on loess, but Richthofen's wind-blown hypothesis appealed to the writers of textbooks, and the origin of loess is so portrayed to most students to-day. The two men who have done the most study on the alluvial deposits of the lower Mississippi Valley, Dr. H. N. Fisk for the Mississippi River Commission, and Dr. R. J. Russell, Dean of the Graduate School of Louisiana State University, both consider the loess to be of aqueous origin. They consider it to be derived from clays of elevated Quaternary Mississippi River floodplains.[29]

Hilgard was now invited to take charge of the Tenth Census report upon cotton production. This he did with vigor, having Dr. Loughridge appointed a special investigator to cover the areas of Arkansas, Indian Territory, Georgia and Texas. In the latter state he made special investigations under Hilgard's direction. The first result of this work was a paper by Hilgard[30] in which he returns to the closed Gulf of Mexico hypothesis for the origin of the Grand Gulf group. The paper is accompanied by a generalized map of the floor of the Gulf with 3,000 foot

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[27]Science News, vol. 1, p. 216-218, (1879).

[28]Hilgard, E. W. (1884) The steep slopes of the western loess: Science, vol. 4, p. 302.

[29]see: Russell, R. J. (1944) Lower Mississippi Valley Loess, Geol. Soc. Amer., Bull., vol. 55, p. 1-40, and Fisk, H. N., (1951) Loess and quaternary geology of the lower Mississippi Valley, Journ. Geol., Vol. 59, No. 4, P. 333-356.

[30]Hilgard, E. W. (1881) The later Tertiary of the Gulf of Mexico: Am. Jour. Sci., (3) vol. 22, p. 58-65, map.

contours, and of the geology of the southern states which border the northern edge of the Gulf. The Texas and Florida portions were supplied to Hilgard by the investigations of Loughridge and Eugene A. Smith respectively. Still no fossils had been obtained from the Grand Gulf. The farsightedness of Hilgard is shown by this paragraph: (p. 62)

> "I cannot but express my regret that the latter portion of these data should thus far rest almost alone upon my personal observations and conclusions. It seems to me that as the only ocean basin not separated from the central part of the North American Continent by areas of disturbance and mountain making, the Gulf of Mexico deserves first and chief attention, as the reference plane from which the oscillations of that central portion must be measured; while its shores are the nilometers upon which these movements can alone be found recorded. It would seem as though the reading and exact understanding of that record should have been the first thing to be done in attempting to unravel the Tertiary and Quaternary history of the country lying between the Alleghenies and the Rocky Mountains; just as the measurement of a base line is the first in a geodetic survey. The stratified drift of the South alone renders intelligible the succession of events that must have occurred at the North; it is only on the shores of the Gulf, that the question whether the glacial epoch of the interior was one of elevation or depression, together with the measure of these, can be finally determined."

Many geologists in the South, particularly those who have worked at Louisiana State University fully appreciate the clarity and significance of the above paragraph and for more than 20 years have been laboring to supply the data which Hilgard called for so eloquently in this paper. Unfortunately, however, many geologists working in the interior of the Continent, to whom Hilgard addressed this paper, still do not realize the importance of the Gulf of Mexico to the solution of their everyday problems.

Before the publication of the Tenth Census, Hilgard was again called upon to describe the salt supplies of Louisiana.[31] This report is largely a repetition of his previous work, but from Hopkins he had learned that the ferruginous sandstone around the edges of the north Louisiana salines carried Clai-

[31]Hilgard, E. W. (1883) The salines of Louisiana: U.S. Geol. Survey, Mineral Resources (1882), p. 554-565.

borne fossils and was not a part of his Orange Sand. From William Crooks, General Manager of the American Salt Co. at Avery's Island he learned that a shaft had been sunk 190 feet in solid salt, with drifts extending 270 and 370 feet away from the shaft in opposite directions, and that surface exploration had outlined salt over an area of 144 acres, making available at least 28,000,000 tons. The mining operations had shown the salt to be banded, with the banding nearly vertical, but Hilgard still retained his former concept of buried Cretaceous hills.

The Cotton Report of the Tenth Census was published in volumes 5 and 6, and Hilgard personally wrote a surprisingly large portion. The large colored map, reviewed by Hilgard[32] shows the close relationship between the cotton soils and the various underlying sediments flanking the Gulf of Mexico.

In a brief chapter Hilgard[33] gave a simple and entertaining explanation of the structure and composition of the alluvial lands of the valley, with cross sections and terminology.

The larger contributions made by Hilgard[34-36] to this report were the descriptions of Louisiana, Mississippi, and California. In these chapters the geological portion was necessarily brief, but the physiographic description was extensive, and the soil discussion was in each case intimately related to the geology.

While the Cotton Report was being prepared for the press, Hilgard and Hopkins[37] were engaged in the study of samples

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[32]Hilgard, E. W. (1884) Review of the general soil map of the cotton States: U.S. 10th Census, vol. 5, p. 15-16, map.

[33]Hilgard, E. W. (1884) General features of the alluvial plain of the Mississippi River below the mouth of the Ohio: U.S. 10th Census, vol. 5, p. 73-76.

[34]Hilgard, E. W. (1884) Physico-geographical and agricultural features of the State of Louisiana: U.S. 10th Census, 5, p. 109-175, map.

[35]Hilgard, E. W. (1884) Physico-geographical and agricultural features of the State of Mississippi: U.S. 10th Census, 5, p. 209-345, map.

[36]Hilgard, E. W. (1884) Physico-geographical and agricultural features of the State of California: U.S. 10th Census, 6, p. 663-683, map.

[37]Hilgard, E. W. and Hopkins, F. V. (1884) Report upon the examination of specimens from borings on the Mississippi River between Memphis and Vicksburg: U.S. (War Dept.) Chief Eng. Ann. Rept. 1884 (U.S. 48th Cong. 2d. sess. H. Ex. Doc. 1, pt. 2, v. 2, pt. 4) App. T. T. p. 2885-2903.

from a series of borings made in the flood plain of the Mississippi between Memphis and Vicksburg. Again most of the microscopic work was done by Hopkins, who had moved to the West Coast. Plates illustrating the microscopic fossils encountered by Hopkins were prepared, but not published. The conclusions were by Hilgard, and he found the alluvium, which he had confused with the Port Hudson, to be much deeper (248 feet at Lake Providence, without reaching bottom) than he had expected. This report is notable for its use of Eocene microfossils for subsurface correlation. The age determination by Hilgard, based largely on a few larger shells was Claiborne, when it should have been Jackson, but was as accurate as the status of paleontology at that time permitted.

Hilgard's[38, 39] attention was now briefly attracted to the asphalt deposits of California. These reports were essentially informative descriptions of deposits which he had personally examined.

An article published by Otto Meyer[40] in three parts in the American Journal of Science aroused Hilgard's wrath, which increased with each part published, and he wrote immediate comments on each. In the first Hilgard[41] showed that Meyer had not read his 1860 Report on Mississippi when he accused Hilgard of blindly accepting the work of Lyell, Conrad and Tuomey. He pointed out that he had from the first used American methods of study and had checked personally all points mentioned in that report, and that if Meyer had gone to the trouble of taking dips he would not have placed the middle Eocene Claiborne above the Jackson and the Oligocene Vicksburg beneath it.

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[38]Hilgard, E. W. (1885) The asphaltum deposits of California: U. S. Geol. Surv. Min. Res. 1883-1884, p. 938-948.

[39]Hilgard, E. W. (1890) Report on the asphaltum mine of the Ventura Asphalt Company: Calif. St. Min. Bur., Ann. Rept. Vol. 10, p. 763-772.

[40]Meyer, O. (1885) The genealogy and the age of the species in the Southern Old Tertiary: Am. Jour. Sci. (3) vol. 29, p. 457-468; vol. 30, p. 60-72, 421-435.

[41]Hilgard, E. W. (1885) The old Tertiary of the Southwest: Am. Jour. Sci. (3), vol. 30, p. 266-269.

The second comment by Hilgard[42] shows agreement with Meyer that Conrad had created too many species, but ends up by suggesting pointedly that Meyer should do some field work himself before he attempt to turn the geological column of the Gulf Coast upside down on the basis of a supposed evolutionary sequence.

Since Meyer had not changed his views in the third installment Hilgard[43] expressed his disgust with great vigor and ended up with: "In the mean time, I commend Dr. Meyer's methods to the attention of ambitious young geologists as a conspicuous example of 'how not to do it.'" Being unable to defend his impossible contentions, Dr. Meyer returned to Germany, and Hilgard's stratigraphic succession has since remained intact.

Two brief notes by Hilgard[44, 45] were largely restatements of previous views held by him. A brief paper dealing with California by Hilgard[46] introduces a new viewpoint. This is an appeal to work out the Quaternary history of the great valley of California, where ancient drainage channels may be recognized by differences in soil and vegetation, before cultivation makes their interpretation largely impossible. His suggestion of a "bird's eye view" of the country is clearly an anticipation of present-day use of aerial photography.

The establishment of a set of rules to govern stratigraphic nomenclature by the U.S. Geological Survey placed several of Hilgard's Mississippi formational units in peril. These rules re-

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[42]Hilgard, E. W. (1885) The classification and paleontology of the U. S. Tertiary deposits: Science, vol. 6, p. 44.

[43]Hilgard, E. W. (1886) Dr. Otto Meyer and the southwestern Tertiary: Science, vol. 7, p. 11.

[44]Hilgard, E. W. (1887) The equivalence in time of American marine and intracontinental Tertiaries: Science, vol. 9, p. 535-536.

[45]Hilgard, E. W. (1888) *in* Smith, E. A. (and others including Hilgard) Report on the subcommittee on the Cenozoic (marine). *In* International Congress of Geologists, American Committee Reports . . . F: 19 pp. Phila. 1888. Am. Geol. vol. 2, p. 269-284. Int. G. Cong. IV, London 1888, C. R. App. A, p. 175-192 (1891).

[46]Hilgard, E. W. (1888) Agriculture and late Quaternary geology: Science, vol. 11, p. 241-242.

quired that to be valid, a formation must be named for a locality, and not be distinguished by color or other features. The first to be affected was the "Orange Sand," a term originally proposed by Safford in Tennessee and adopted by Hilgard. McGee had already applied the term "Appomattox formation" to deposits along the Atlantic coastal plain which Hilgard considered of equivalent age. A conference was therefore held between McGee, LeConte, Loughridge and Hilgard. Hilgard[47] then published a history of the terminology, and indicated that they all agreed to the use of the name Lafayette formation for Lafayette County, Mississippi. Safford appended a paragraph of approval of this name.

This was followed by a paper by McGee[48] before the American Association in which McGee considered the Lafayette to be marine and to be Pliocene. Hilgard was so shocked over concept that anyone could consider it marine, he devoted his comments to showing that the cross-bedded gravels and sands could only be stream laid deposits and overlooked the implications of McGee's Pliocene age. Instead of a depression of several hundred feet suggested by McGee, Hilgard called for an uplift of several thousand!

After publishing several brief papers,[49-51] the last of which dealt in a most interesting manner with ground water manifestations in the alluvial fans of southern California, Hilgard wrote his final article on the great graveliferous deposits of

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[47]Hilgard, E. W. (1891) Orange sand, Lagrange, and Appomattox: Am. Geol. vol. 8, p. 129-131.

[48]McGee, W. J. (1891) Neocene and Pleistocene continent movements (abst) with discussion by E. W. Hilgard, C. H. Hitchcock, and W. Upham: Am. Geol. vol. 8, p. 234-235. Am. Assoc. Pr. vol. 40, p. 253-254 (1892).

[49]Hilgard, E. W. (1891) Remarks on the value of fossil plants for correlation purposes: Am. Geol., vol. 8, p. 252.

[50]Hilgard, E. W. (1892) Observations on Eocene shells *in* James M. Safford's Note on the Middleton Formation of Tennessee, Mississippi, and Alabama: Geol. Soc. Amer. Bull. 3, p. 511-512.

[51]Hilgard, E. W. (1892) The cinegas of southern California: Geol. Soc. Amer. Bull. 3, p. 124-127.

the Gulf Coast.[52] It is a complete summary of his views in which he corrects certain mistakes he had made at particular localities cited in previous reports and in which he gives an excellent summary of the reasons for considering it Quaternary in age. Geologists with the U. S. Geological Survey continued to place it in the Pliocene and it is only within the past 20 years that many geologists have returned to Hilgard's views on the age of these graveliferous sediments.

Further minor papers were published by Hilgard[53-55] in the next few years. An opportunity to review the history of the Mississippi Survey was afforded him by the Mississippi Historical Society. The resulting article by Hilgard[56] must have shocked the people of Mississippi, for the Survey was re-established shortly afterward, and has continued effectively ever since. This brief history should be required reading for any young scientists of the present day who may think they are facing insurmountable difficulties!

The remaining papers published by Hilgard[57-] require only brief comments. It was most appropriate that he should have

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[52]Hilgard, E. W. (1892) The age and origin of the Lafayette formation: Am. Jour. Sci. (3) vol. 43, p. 389-402.

[53]Hilgard, E. W. (1893) Die Bodenverhaltnizze Californiens: Deut. G. Ges., Zs. vol. 45, p. 15-22.

[54]Hilgard, E. W. (1896) The geologic efficacy of alkali carbonate solution: Am. Jour. Sci. (4) vol. 2, p. 100-107 (Geochemistry).

[55]Hilgard, E. W. (1899) The subdivision of genera: Science, n. s. no. 253.

[56]Hilgard, E. W. (1900) A historical outline of the geological and agricultural survey of the State of Mississippi: Miss. Hist. Soc. Pub. 3, p. 207-234; Am. Geol. vol. 27, p. 284-311 (1901).

[57]Hilgard, E. W. (1901) An estimate of the life-work of Joseph LeConte; Univ. California Mag., Sept., 1901.

[58]Hilgard, E. W. (1901) Sketch of the pedological geology of California (abst.) Geol. Soc. Am. Bull., vol. 12, p. 499-500; Jour. Geol. vol. 9, p. 74-75; Am. Geol. vol. 27, p. 131.

[59]Hilgard, E. W. (1902) The debris fans of the arid region in their relation to the water supply (abst.) Science, n. s., vol. 15, p. 414.

[60]Hilgard, E. W. (1903) The Grand Gulf formation: Science, n. s., vol. 18, p. 180-182.

written the biographical memoir of the great California geologist Joseph LeConte, who had also visited and published on the geology of the Gulf Coast. The articles dealing with California and the far west are for the most part abstracts. The most vigorous of these papers was a reply to an article by Dr. W. H. Dall, who suggested that Hilgard's Grand Gulf dipped beneath Oligocene sediments in both Florida and Texas, and that perhaps the term should be restricted to the original use made of it by Wailes. Hilgard with great vigor and accuracy pointed out that Wailes had confused various strata with the beds exposed at Grand Gulf, and that he had been forced to redefine these sediments as a group. He very precisely outlined the stratigraphic position of the Grand Gulf group as he had defined it in the 1860 Report and subsequent papers, and his usage is still current in Louisiana and Mississippi. The final three papers dealt with the "Mud Lumps" at the mouth of the Mississippi River, and are largely restatements of his previous views in regard to these curious phenomena.

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[61]Hilgard, E. W. (1903) The valley of southern California (abst.) Jour. Geol. vol. 11, p. 96.

[62]Hilgard, E. W. (1905) The prairie mounds of Louisiana: Science, n. s., vol. 21, p. 551-552.

[63]Hilgard, E. W. (1906) The exceptional nature and genesis of the Mississippi Delta: Science, n. s., vol. 24, p. 61-866; (abst.) Geol. Soc. Amer., Bull., vol. 17, p. 731.

[64]Hilgard, E. W. (1906) Biographical memoir of Joseph LeConte: 1823-1901. Nat. Ac. Sci. Biog. Mem. 6, p. 147-218, portrait.

[65]Hilgard, E. W. (1906) Some peculiarities of rock weathering and soil formation in the arid and humid regions. Am. Jour. Sci. (4) vol. 21, p. 261-269.

[66]Hilgard, E. W. (1907) The causes of the glacial epoch. Int. Geol. Cong. X, Mexico, 1906 C. R., p. 431-436 (1907); Science n. s., vol. 25, p. 350-354.

[67]Hilgard, E. W. (1910) A new development at the mouth of the Mississippi (abst.) Science, n. s., vol. 32, p. 30; Geol. Soc. Amer. Bull., vol. 21, p. 791.

[68]Hilgard, E. W. (1911) The Mississippi Delta. (abst.) Assoc. Am. Geog., An. 1, p. 135.

[69]Hilgard, E. W. (1912) A new development in the Mississippi Delta. Pop. Sci. Mo., vol. 80, p. 236-245, map.

Inasmuch as a detailed study of these mud lumps has recently been made by Dr. Morgan,[70] I obtained from him the following outline of their formation:

"Mudlump islands are forced above water level by the static pressure of growing river-mouth bars upon plastic 'pro-delta' clays. The mudlumps originate on the steeper, seaward side of the bars and are generally elongate parallel to the periphery of the bar. They occur only at river-mouths where fine sediments predominate, where water depths are sufficiently great to allow thick bar deposits and where tidal conditions and littoral currents are negligible." It will be noted that Morgan's explanation of these phenomena differs from Hilgard's mainly in location of the place of origin, not in the forces involved. Morgan likewise does not assume that mudlumps are a major factor in the peculiar form which the Mississippi delta has assumed. After several years study of these mudlumps Dr. Morgan assured me that he was astounded that Hilgard had seen so much in the limited time he had to study them.

The discovery of oil at the Spindletop salt dome near Beaumont, Texas, followed quickly by a similar discovery at the Jennings dome in south Louisiana came more than 30 years after Hilgard had completed his Louisiana reconnaissance. Other discoveries followed in increasing numbers, but it was nearly 30 more years before geophysical exploration and the drilling of wells to depths of thousands of feet below the surface that geologists could agree on how these structures had been formed.

Since Hilgard's time the drilling of tens of thousands of wells, some of them to depths well in excess of three miles beneath the surface have made this region geologically the most explored portion of the earth's surface. To the hundreds of young geologists working in Texas, Louisiana, Mississippi, and Alabama, with all of the facilities and information oil companies place at their disposal, many of Hilgard's concepts may now appear absurd. They know now that the salt domes of north Louisiana, instead of being the summits of Cretaceous moun-

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[70]Morgan, James P. (1952) Mudlumps at the Mouths of the Mississippi River: Proceedings of the Second Conference on Coastal Engineering, 394 pp., Published by the Council on Wave Research, Univ. Calif., Berkeley, June, 1952.

tains, instead are nearly cylindrical plugs of salt rising through the thickest part of the north Louisiana syncline. They also know that the Five Islands have risen from the deepest part of the Gulf Coast geosyncline where the sedimentary section has a thickness nearer 40,000 feet than the 4,000 feet postulated by Hilgard.

This knowledge was not arrived at easily. As late as 1920 wells of 3,000 feet were "deep," and Hilgard's hypothesis was still being discussed. It was not until after 1930 that the prolific oil sands of the marine "*Discorbis, Heterostegina* and *Marginulina* zones of the salt dome section near the coast were correlated with the Catahoula sandstone, the basal portion of Hilgard's Grand Gulf group.[71] The development of other prolific oil sands from marine Miocene beds, younger than the Catahoula, at depths as great as 18,000 feet in the coastal Louisiana parishes is a development of only the last few years. We now know that the Grand Gulf group as described by Hilgard is essentially unfossiliferous on the surface, but rapidly changes in the subsurface, increasing in thickness prodigiously and becoming marine as one approaches the coast. This could only have been proven by the wells that have been drilled.

Likewise Hilgard's concepts of the "Orange Sand" and "Port Hudson" are for the most part good. No marine Pliocene has to this day been described from coastal Texas, Louisiana, or Mississippi, and everywhere the gravels lie unconformably upon materially older sediments. Hilgard's lithologic description of Orange Sand sections could scarcely be improved upon, and the distribution of these gravels within the "Mississippi Embayment" and Tennessee Valley will certainly stand the test of time. His generalized maps of the distribution of the Port Hudson clays along the Gulf coastal border likewise will for the most part stand, though he certainly confused these clays with recent "back-swamp" clays and with the filling of ancient cut-off river channels farther inland in the Mississippi valley proper.

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[71]Howe, H. V. (1933) Review of Tertiary Stratigraphy of Louisiana: Bull. Am. Assoc. Petrol. Geol., vol. 17, no. 6, p. 613-655.

The story of the Quaternary sedimentation in Mississippi and particularly in coastal Louisiana was much more complex than Hilgard realized. He certainly would have been astounded had he realized that these gravels extend to depths of 2,000 feet in the region between Baton Rouge and Lake Charles and to depths of near twice that amount east of New Orleans. Without detailed topographic maps of these states, which have been completed only within the past 20 years, Hilgard could not have made correlations between different flat-topped surfaces bordered by gravels which he described and thus have found them to be remnants of Pleistocene terraces. Four of these terraces have been described by Fisk.[72, 73] The two older terraces, Williana and Bentley, in general correspond with Hilgard's Orange Sand "delta." The two younger terraces, lie for the most part within the area depicted by Hilgard as "Port Hudson."

In conclusion, the record is clear that Hilgard was one of the finest, most accurate geological observers of all time. He was more than that. He was a trainer of men and many of those who worked under his guidance went on to greatness in their own right. This was particularly true of Alabama's great State Geologist Eugene A. Smith. To his eternal credit he was a fighter. Only a man with the greatest determination could have saved the Mississippi Survey after Harper's report, and gone on to establish the Gulf Coast section. This section he had to defend time after time in succeeding years. To no other man do the geologists of the Gulf Coastal region of this country owe so great a debt of gratitude.

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[72]Fisk, H. N.
[73]Fisk, H. N.

PLANT MICROFOSSILS FROM THE EOCENE COCKFIELD FORMATION, HINDS COUNTY, MISSISSIPPI

DONALD W. ENGELHARDT*

ABSTRACT

Five samples from the upper part of the Cockfield Formation in Riverside Park, Jackson, Mississippi were examined for palynomorphs. Thirty-six genera and fifty-six species of pollen and spores were identified from the sediments. The most abundant pollen species in the samples was *Momipites coryloides*. The paleoecology suggested by the palynomorphs identified in the samples is a tropical to subtropical climate at lower elevations and along the coast with a temperate flora present at higher elevations.

INTRODUCTION

This report is the result of a preliminary palynological investigation of the upper part of the Cockfield Formation (Claibornian) at Riverside Park, Jackson, Mississippi. The objectives of the study were: (1) to identify and describe palynomorphs recovered from the sediments; (2) to establish possible botanical affinities for the identified taxa; and (3) to interpret the possible paleoecology of the area. Thirty-six genera and fifty-six species of pollen and spores have been identified in the Cockfield sediments.

Correlation of most Tertiary sediments in the Gulf Coastal Plain of the United States is dependent upon marine foraminifera. In the nonmarine sediments, palynology can aid in the solution of time-stratigraphic and paleoecologic problems. Many fossil pollen grains and spores can be identified with extant plant groups and are useful in paleoecologic interpretations and stratigraphic zonation. Others, which are assigned to artificial taxa, can also serve as indices for stratigraphic zonation but are not as useful for paleoecologic studies. Hughes (1958) stated that palynology should prove of benefit in establishing age and sequence of the thick continental to deltaic deposits of the Gulf Coast geosyncline.

PROCEDURES

Five outcrop samples from the Eocene Cockfield Formation were collected at Riverside Park near the type locality of

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Moodys Branch Formation in Jackson, Mississippi (Miss. Geol. Soc., 1948, p. 23). The exposed section consists of the upper fourteen feet of the Cockfield Formation (Claibornian) which is disconformably overlain by the Moodys Branch Formation of Jacksonian age (Fig. 1). The Cockfield sediments at this locality are gray lignitic silty shales with light-gray siltstone partings, and one lignite bed.

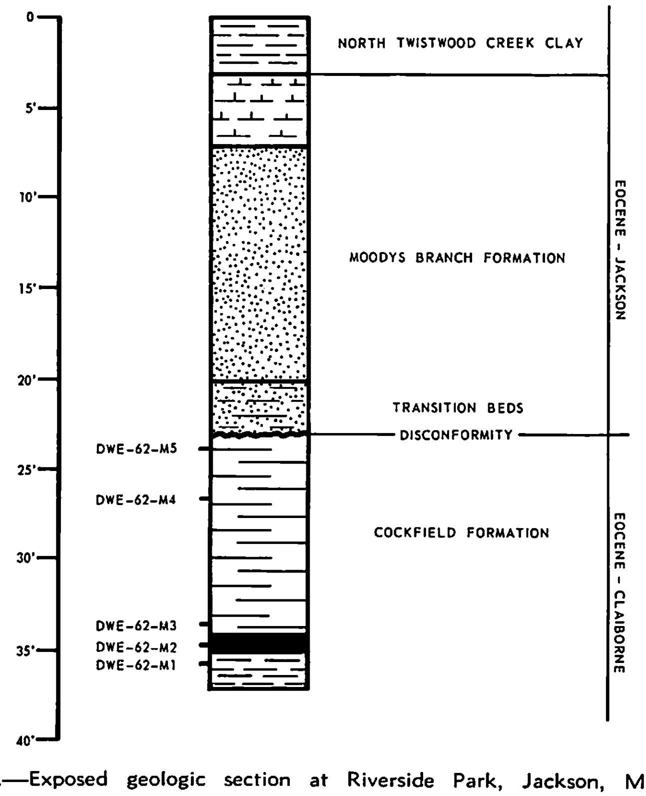

Figure 1.—Exposed geologic section at Riverside Park, Jackson, Mississippi, showing positions of samples studied.

The samples were first crushed and treated with 10 percent hydrochloric acid to remove any carbonates which might be present. Following a distilled water wash, 52 percent hydrofluoric acid was added to remove the silicates. The residues were washed several times with distilled water to remove any excess hydrofluoric acid. After washing, the palynomorphs were concentrated by heavy liquid separation in a zinc bromide solution with a specific gravity of 2.0. The "float" fraction was oxidized using cold Schulze's solution and 10 percent potassium hydroxide to remove the extraneous organic debris and to clear the palynomorphs. After several distilled water washes, the palynomorphs were stained with Safranin O and mounted on microscope slides using Clearcol as a mounting medium (Wilson, 1959).

Identification and photography of the specimens was done with a Leitz Ortholux microscope equipped with an Orthomat camera. The observed specimens were compared for identification with published photographs and descriptions of pollen and spores. The coordinates of the illustrated specimens are those of a Leitz Ortholux with a standard mechanical stage. The slide number refers to that assigned by the palynology research group of Pan American Petroleum Corporation.

The slide numbers are: P-7854, sample DWE-62-M5; P-7855, sample DWE-62-M4; P-7856, sample DWE-62-M3; P-7857, sample DWE-62-M2; P-7858, sample DWE-62-M1. The occurrences of the identified palynomorphs are classified as abundant (more than 50 specimens), common (25-50 specimens), scarce (5-25 specimens) and rare (1-5 specimens).

In this preliminary study, no new generic or specific names have been proposed.

GEOLOGY

The Cockfield Formation in Mississippi is a well-defined lithologic unit which has wide areal distribution. The lithology consists of gray argillaceous siltstone and silty shale with irregular siltstone partings. Lenses of gray lignitic claystone and lignitic to nonlignitic sandstone are interspersed in the siltstone (Thomas, 1942). Lignite beds are common in the Cockfield Formation. In Mississippi, this formation is a nonmarine unit or probable deltaic or flood plain deposition on the Gulf Coastal plain. The lower contact with the Wautubbee Formation (Cook Mountain Formation) is conformable and transitional (Thomas, 1942). The upper contact between the Moodys Branch Formation (Lower Jacksonian) and the Cockfield Formation (Upper Claibornian) is disconformable. There is a intermingling of the green sand facies of the Moodys Branch with underlying lignitic silts of the Cockfield at the disconformity.

PALEOBOTANY

The Eocene megaflora of the Gulf Coastal Plain has been extensively studied by paleobotanists including Berry (1914, 1916, 1924, 1930), Ball (1931), and Brown (1944). The microflora of the Gulf Coast Tertiary, however, has not been studied in detail. Jones (1961, 1962) described and illustrated some pollen and spores from the Lower Wilcox Group in Arkansas. Gray (1960) discussed and illustrated the presence of temperate pollen genera from the Claiborne Bluff locality in Alabama. These papers are the only published investigations concerning palynology of the Gulf Coast Tertiary which are available.

In other areas of the United States, the palynology of Lower Tertiary sediments is likewise relatively unknown. Wodehouse (1933) studied part of the microflora of the Eocene Green River Formation from Colorado. Paleocene palynology has been investigated by Wilson and Webster (1946), Gerhard (1958), and in part by Anderson (1960), Stanley (1960), and Newman (1961). Knowledge of the microfloras of the Lower Tertiary in the United States is meagre compared to that resulting from palynologic investigations of this time interval in Germany and other areas of the world by Potonie (1934, 1951), Potonie, Thomson and Thiergart (1950), Pflug (1952), Thomson and Pflug (1953), Krutzsch (1959), Couper (1953, 1960) and Kedves (1960).

PALYNOLOGY OF THE COCKFIELD FORMATION

In the preliminary investigation of five samples from the Cockfield Formation, 36 genera and 56 species have been noted. Of these, six are fern spore genera, three are gymnosperm and twenty-seven are angiosperm pollen genera. The microflora is predominantly angiospermous with triporate and tricolporate morphologic types dominant. Morphologic criteria and terminology used in this investigation are basically those of Potonie (1956, 1958, 1960).

DISPERSED PALYNOMORPHS — SPORES

Genus **CYATHIDITES** Couper, 1953

Genotype: *Cyathidites australis* Couper, 1953 (p. 27, pl. 2, figs. 11-12)

Cyathidites minor Couper, 1953 (p. 28, pl. 2, fig. 13)

Remarks: This species is common in the samples examined. Couper (1958) stated that these dispersed spores almost certainly belong to cyatheaeous or dicksoniaceous ferns. Similar forms also occur in Lygodium in the fern family Schizaeaceae. These fern families are predominantly tropical groups.
Illustration: Plate 1, figure 1, P-7854 B-1, 120.3 x 36.6.

Genus **GLEICHENIIDITES** (Ross, 1949) Delcourt and Sprumont, 1955

Genotype: *Gleicheniidites senonicus* Ross, 1949 (p. 31, pl. 1, fig. 3)
Gleicheniidites senonicus Ross, 1949
Remarks: This species is rare in the Cockfield sediments. It is probably related to the modern fern genus *Gleichenia* which is found predominantly in the tropics and subtropics.
Illustration: Plate 1, figure 2, P-7854 B-1, 121.1 x 30.9.

Genus **OSMUNDACIDITES** Couper, 1953

Genotype: *Osmundacidites wellmanii* Couper, 1953 (p. 20, pl. 1, fig. 5)
Osmundacidites wellmanii Couper, 1953
Remarks: This species is rare in the samples examined. It is probably related to the fern family Osmundaceae which is found in temperate to tropical swampy regions.
Illustration: Plate 1, figure 3, P-7854 B-1, 124.3 x 26.8.

Genus **CICATRICOSISPORITES** R. Potonie and Gelletich, 1933

Genotype: *Cicatricosisporites dorogensis* R. Potonie and Gelletich, 1933 (p. 522, pl. 1, fig. 1).
Cicatricosisporites dorogensis R. Potonie and Gelletich, 1933
Illustration: Plate 1, figure 4, P-7854 B-1, 123.2 x 37.
Cicatricosisporites cf. *C. paradorogensis* Krutzsch, 1959 (p. 172-173, pl. 35, figs. 366-371)
Remarks: This taxon is abundant in the Cockfield sediments. This genus is schizaeaceous, probably related to the modern fern genera *Anemia* or *Mohria*. The Schizaeaceae are mostly tropical and are rare in temperate regions.
Illustration: Plate 1, figure 5, P-7854 B-1, 115.6 x 27.

Genus **MICROFOVEOLATOSPORIS** Krutzsch, 1959

Genotype: *Microfoveolatosporis pseudodentatus* Krutzsch, 1959 (p. 212, pl. 41, figs. 463-466).
Microfoevolatosporis cf. *M. pseudodentatus* Krutzsch, 1959

Remarks: This species is rare in the Cockfield sediments. The spore is similar to the temperate region fern *Schizaea pusilla* Pursh in the Schizaeaceae.
Illustration: Plate 1, figure 6, P-7854 B-1 110 x 31.2.

Genus **POLYPODIISPORITES** R. Potonie, 1934

Genotype: *Polypodiisporites favus* R. Potonie, 1934 (p. 38, pl. 1, figs. 19-20).
Polypodiisporites cf. *P. favus* R. Potonie, 1934
Remarks: This species is common in the sediments examined. This spore type is found in the family Polypodiaceae. This fern family has wide distribution over most of the earth's land area in almost all floristic areas from the tropics to the arctic.
Illustration: Plate 1, figure 7, P-7856 B-1, 116 x 29.8.

GYMNOSPERMS

Genus **ABIETINEAEPOLLENITES** R. Potonie, 1951

Genotype: *Abietineaepollenites microalatus* (R. Potonie, 1934) R. Potonie, 1951 (p. 49, pl. 2, fig. 4).
Abietineaepollenites cf. *A. microalatus* (R. Potonie, 1934) R. Potonie, 1951.
Remarks: This species is rare in the Cockfield sediments. Modern *Pinus* pollen is similar to the form found in the samples examined. *Pinus* has a wide distribution at generally low elevation from cool temperate to warm temperate climates.
Illustration: Plate 1, figure 9, P-7855 B-1, 119.3 x 23.8.

Genus **GNETACEAEPOLLENITES** Thiergart, 1938

Genotype: *Gnetaceaepollenites ellipticus* Thiergart, 1938 (p. 307, pl. 24, fig. 10).
Gnetaceaepollenites eocenipites (Wodehouse, 1933) R. Potonie, 1958, (p. 495, fig. 16).
Illustration: Plate 1, figure 8, P-7854 A-1, 116.6 x 31.4.
Gnetaceaepollenites sp. (*Ephedra distachya* type) in Kuyl, Muller, and Waterbolk, 1955 (p. 63, pl. 1, fig. 3).
Remarks: This genus is common in the samples examined. The fossil genus *Gnetaceaepollenites* is most likely related to the modern Ephedraceae which has wide distribution in arid regions of the tropics and subtropics.
Illustration: Plate 1, figure 11, P-7854 B-1, 113.3 x 23.5.

Genus **TAXODIACEAEPOLLENITES** Kremp, 1949

Genotype: *Taxodiaceaepollenites hiatus* (R. Potonie, 1931) Kremp, 1949 (p. 5, fig. 27).
Taxodiaceaepollenites hiatus (R. Potonie, 1931) Kremp, 1949
Remarks: This species is probably related to modern *Taxodium* which grows in a swampy environment in temperate to subtropical climates. *Taxodiaceaepollenites* is common in the Cockfield sediments.
Illustration: Plate 1, figure 10, P-7854 B-1, 124.3 x 26.8.

ANGIOSPERMS

Genus **LILIACIDITES** Couper, 1953

Genotype: *Liliacidites kaitangataensis* Couper, 1953 (p. 56, pl. 7, fig. 97).
Liliacidites cf. *L. intermedius* Couper, 1953 (p. 56-57, pl. 7, fig. 100).
Remarks: The specimens from the Cockfield Formation are smaller (35-40 microns) than *L. intermedius* (44-53 microns).
Illustration: Plate 2, figure 12, P-7854 B-1, 127.3 x 30.4.
Liliacidites variegatus Couper, 1953 (p. 56, pl. 7, fig. 98-99)
Remarks: *Liliacidites* is abundant in the samples from the Cockfield. Couper (1953) established this genus for the reception of fossil pollen of liliaceous affinities that cannot be placed more accurately. Similar pollen morphology also occurs in the Palmae.
Illustration: Plate 2, figure 13, P-7855 B-1, 121 x 32.9.

Genus **SABALPOLLENITES** Thiergart, 1938

Genotype: *Sabalpollenites convexus* Thiergart, 1938 (p. 308, pl. 24, fig. 15).
Sabalpollenites cf. *S. convexus* Thiergart, 1938
Remarks: This species is rare in the samples examined. The fossil pollen is similar to the modern sabal palmetto, *Sabal.*
Illustration: Plate 2, figure 14, P-7856 A-1, 115.5 x 27.6.

Genus **QUERCOIDITES** Potonie, Thomson, and Thiergart, 1950

Genotype: *Quercoidites henrici* (R. Potonie, 1931) Potonie, Thomson and Thiergart, 1950 (p. 54, pl. B, fig. 22).
Quercoidites cf. *Q. henrici* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950.
Remarks: *Quercoidites henrici* is similar to modern *Quercus* pollen. The modern genus is found in temperate to subtropical

regions. The fossil grains are scarce in the Cockfield sediments.
Illustration: Plate 2, figure 15, P-7854 B-1, 120.5 x 31.2.

Genus **TRICOLPITES** (Erdtman, 1947, Cookson, 1947, Ross, 1949) Couper, 1953

Genotype: *Tricolpites reticulatus* Cookson, 1947 (p. 134, pl. 15, fig. 45).
Tricolpites thomasii Cookson and Pike, 1954 (pl. 2, figs. 93-94).
Remarks: This species is rare in the samples examined. The affinity of this taxon is unknown.
Illustration: Plate 2, figure 17, P-7854 B-1, 111.2 x 22.2.

TRICOLPITES SP. 1

Remarks: The affinity of this species is unknown but a similar pollen type occurs in the Rubiaceae. It is scarce in the Cockfield samples.
Illustration: Plate 2, figure 16, P-7857 A-4, 125.7 x 21.5.

TRICOLPITES SP. 2

Remarks: This species is scarce in the samples examined. The affinity is unknown.
Illustration: Plate 2, figure 18, P-7854 B-1, 122.5 x 22.6.

TRICOLPITES SP. 3

Remarks: This species is common in the Cockfield samples examined. The affinity is unknown.
Illustration: Plate 2, figure 19, P-7856 B-1, 122.1 x 36.1.

Genus **RETICULAEPOLLIS** Krutzsch, 1959

Genotype: *Reticulaepollis intergranulatus* (R. Potonie, 1934) Krutzsch, 1959 (p. 242, pl. 48, figs. 600-612).
Reticulaepollis cf. *R. intergranulatus* (R. Potonie, 1934) Krutzsch, 1959.
Remarks: This taxon is rare in the Cockfield sediments. The affinity is unknown.
Illustrations: Plate 2, figures 20 and 24, P-7856 A-2, 111.2 x 39.4.

Genus **CUPULIFEROIPOLLENITES** R. Potonie, 1951

Genotype: *Cupuliferoipollenites pusillus* (R. Potonie, 1934) R. Potonie, 1951, (pl. 20, fig. 69).
Cupuliferoipollenites cf. *C. insleyanus* (Traverse, 1955) R. Potonie, 1960 (p. 47, fig. 10, no. 39).

Remarks: This taxon is abundant in the Cockfield sediments. Modern *Castenea* from temperate regions is similar to this fossil type.
Illustration: Plate 2, figure 23, P-7858 B-1, 116.7 x 33.2.

Genus **ILEXPOLLENITES** Thiergart, 1937

Genotype: *Ilexpollenites iliacus* (R. Potonie, 1931) Thiergart, 1937 (p. 321, pl. 25, fig. 30).
Ilexpollenites cf. *I. iliacus* (R. Potonie, 1931) Thiergart, 1937.
Remarks: The specimens found in the samples examined are similar to modern *Ilex* in the Aquifoliaceae. *Ilex* is found in temperate to tropical regions. This fossil type is rare in the Cockfield sediments.
Illustration: Plate 2, figure 22, P-7857 A-1, 127.5 x 27.4.

Genus **TRICOLPOROPOLLENITES** (Pflug, 1952) Thomson and Pflug, 1953

Genotype: *Tricolporopollenites dolium* (R. Potonie, 1931) Thomson and Pflug, 1953 (pl. 12, figs. 112-117).
Tricolporopollenites dolium (R. Potonie, 1931) Thomson and Pflug, 1953.
Remarks: This taxon is similar to *Rhus* in the Anacardiaceae. This genus grows in temperate to subtropical regions. The fossil type is abundant in the samples examined.
Illustration: Plate 2, figure 21, P-7858 A-1, 122.3 x 36.2.

TRICOLPOROPOLLENITES SP. 1

Remarks: This species is similar to *Acer mullensis* Simpson, 1961, but is smaller. Simpson (1961) places the tricolporate striate grains he found in the Aceraceae. The identified species is common in the Cockfield sediments.

Illustration: Plate 3, figure 25, P-7857 A-3, 118.3 x 21.5.

TRICOLPOROPOLLENITES SP. 2

Remarks: Similar morphologic types occur in the Araliaceae. This taxon is scarce in the samples examined.
Illustration: Plate 3, figure 28, P-7857 A-3, 119.3 x 30.6.

TRICOLPOROPOLLENITES SP. 3

Remarks: The affinity of this species is unknown but similar pollen morphology occurs in the tropical tiliaceous genera *Belotia*, *Sparmannia,* and *Triumfetta.* It is scarce in the samples examined.

Illustration: Plate 3, figures 26 and 27, P-7857 A-3, 123.4 x 35.4.

TRICOLPOROPOLLENITES SP. 4

Remarks: The affinity of this species is unknown. It is rare in the Cockfield sediments.

Illustration: Plate 3, figure 29, P-7855 B-1, 120.2 x 30.3.

TRICOLPOROPOLLENITES SP. 5

Remarks: This species is similar to *Pollenites cingulum ovalis* R. Potonie, 1934 (p. 83, pl. 4, fig. 8). It is scarce in the samples examined. The affinity of this taxon is unknown.

Illustration: Plate 3, figure 30, P-7856 A-2, 125.3 x 24.1.

TRICOLPOROPOLLENITES SP. 6

Remarks: This taxon is rare in the Cockfield samples examined. The affinity is unknown.

Illustration: Plate 3, figure 31, P-7857 A-3, 119.6 x 30.4.

TRICOLPOROPOLLENITES SP. 7

Remarks: This species is common in the samples examined. It is possibly related to the tropical family Symplocaceae.

Illustration: Plate 3, figure 32, P-7857 A-1, 125.4 x 34.

Genus **NYSSAPOLLENITES** Thiergart, 1937

Genotype: *Nyssapollenites pseudocruciatus* (R. Potonie, 1931) Thiergart, 1937, (p. 322, pl. 25, fig. 32).

Nyssapollenites cf. *N. accessorius* (R. Potonie, 1934) R. Potonie, 1950 (pl. 21, fig. 121).

Remarks: This species is common in the Cockfield sediments examined. It is quite similar to modern *Nyssa* which grows in a swampy environment in temperate to warm temperate regions.

Illustration: Plate 3, figure 33, P-7857 A-4, 120.2 x 29.4.

Genus **CUPANIEIDITES** Cookson and Pike, 1954

Genotype: *Cupanieidites orthoteichus* Cookson and Pike, 1954 (p. 213, pl. 2, fig. 75).

Cupanieidites orthoteichus Cookson and Pike, 1954

Remarks: This taxon is rare in the samples examined. It is

quite similar to *Cupania* in the Sapindaceae. This genus is found in tropical and subtropical areas.
Illustration: Plate 3, figure 34, P-7854 A-1, 121.9 x 37.8.

Genus **GOTHANIPOLLIS** Krutzsch, 1959

Genotype: *Gothanipollis gothani* Krutzsch, 1959 (p. 232, pl. 47, figs. 546-590).
Gothanipollis sp.
Remarks: This species is scarce in the Cockfield samples examined. Its affinity is unknown.
Illustration: Plate 3, figures 35-37, P-7854 A-1, 115.1 x 30.4, P-7856 A-1, 109 x 32, P-7856 A-1, 116.4 x 32.

Genus **SYMPLOCOIPOLLENITES** R. Potonie, 1951

Genotype: *Symplocoipollenites vestibulum* (R. Potonie, 1931) R. Potonie, 1951 (p. 147, pl. 21, fig. 162).
Symplocoipollenites vestibulum (R. Potonie, 1931) R. Potonie, 1951.
Remarks: This taxon is similar to pollen grains of the tropical to subtropical family Symplocaceae. It is common in the samples examined.
Illustration: Plate 4, figure 38, P-7856 A-1, 109.6 x 25.8.

SYMPLOCOIPOLLENITES SP. 1

Remarks: This species is common in the Cockfield sediments. It is possibly related to the Symplocaceae.
Illustration: Plate 4, figure 39, P-7858 B-2, 119.7 x 28.8.

SYMPLOCOIPOLLENITES SP. 2

Remarks: This species is scarce in the samples examined. It is possibly related to the Symplocaceae.
Illustration: Plate 4, figure 40, P-7856 A-2, 119.4 x 24.

Genus **PROTEACIDITES** Cookson, 1950

Genotype: *Proteacidites adenanthoides* Cookson, 1950 (p. 172, pl. 2, fig. 21).
Proteacidites sp.
Remarks: This species is scarce in the samples examined. It is possibly related to the family Proteaceae.
Illustration: Plate 4, figure 41, P-7856 B-1, 120.8 x 29.4.

Genus **SAPOTACEOIDAEPOLLENITES** Potonie, Thomson, and Thiergart, 1950

Genotype: *Sapotaceoidaepollenites manifestus* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950 (p. 62, pl. B, fig. 62).
Sapotaceoidaepollenites cf. *S. manifestus* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950.
Remarks: This taxon is common in the Cockfield sediments examined. It is similar to *Manilkara* in the Sapotaceae. This family is a family of primarily tropical trees.
Illustration: Plate 4, figure 49, P-7854 B-2, 126.3 x 28.1.

Genus **TETRACOLPORITES** Couper, 1953

Genotype: *Tetracolporites camaruensis* Couper, 1953 (p. 64, pl. 8, fig. 126).
Tetracolporites sp.
Remarks: This taxon is rare in the samples examined. Its affinity is unknown. It is possible that this species is an aberrant form of the form genus *Nyssapollenites*.
Illustration: Plate 4, figure 50, P-7857 A-1, 127.6 x 29.1.

Genus **BETULACEOIPOLLENITES** R. Potonie, 1951

Genotype: *Betulaceoipollenites bituitus* (R. Potonie, 1931) R. Potonie, 1951 (pl. 20, fig. 43).
Betulaceoipollenites cf. *B. bituitus* (R. Potonie, 1931) R. Potonie, 1951.
Remarks: This pollen type is similar to that found in the Betulaceae and Myricaceae. It is scarce in the samples examined.
Illustration: Plate 4, figure 42, P-7854 B-1, 119.2 x 37.2.

Genus **MOMIPITES** Wodehouse, 1933

Genotype: *Momipites coryloides* Wodehouse, 1933 (p. 511, fig. 43).
Momipites coryloides Wodehouse, 1933
Remarks: This species is very abundant in the Cockfield sediments examined. Its affinity is unknown but it is similar to modern *Corylus*.
Illustration: Plate 4, figure 43, P-7857 A-3, 113.5 x 32.4.

Genus **ENGELHARDTIOIDITES** Potonie, Thomson, and Thiergart, 1950

Genotype: *Engelhardtioidites microcoryphaeus* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950 (p. 51, pl. B, fig. 8).

Engelhardtioides cf. *E. microcoryphaeus* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950 (p. 51, pl. B, fig. 8).

Engelhardtioidites cf. *E. microcoryphaeus* (R. Potonie, 1931) Potonie, Thomson, and Thiergart, 1950.

Remarks: This species is common in the Cockfield sediments examined. It is similar to *Engelhardtia* in the Juglandaceae which grows in temperate to subtropical regions.

Illustration: Plate 4, figure 44, P-7854 A-1, 110.1 x 25.8.

Genus **MYRTACEIDITES** Cookson and Pike, 1954

Genotype: *Myrtaceidites mesonesus* Cookson and Pike, 1954 (p. 205, pl. 1, fig. 36).

Myrtaceidites cf. *M. mesonesus* Cookson and Pike, 1954

Remarks: This species is similar to *Eucalyptus* in the tropical family Myrtaceae. It is scarce in the samples examined.

Illustration: Plate 4, figure 45, P-7856 A-1, 116.3 x 23.4.

Myrtaceidites cf. *M. eugeniioides* Cookson and Pike, 1954 (p. 204, pl. 1, figs. 21-26).

Remarks: This taxon is similar to *Eugenia* in the Myrtaceae. It is scarce in the Cockfield sediments examined.

Illustration: Plate 4, figure 46, P-7856 A-2, 126.2 x 26.3.

Genus **TILIAEPOLLENITES** (R. Potonie, 1931) Potonie and Venitz, 1934

Genotype: *Tiliaepollenites instructus* (R. Potonie, 1931) Potonie and Venitz, 1934 (p. 37, pl. 4, fig. 109).

Tiliaepollenites cf. *T. instructus* (R. Potonie, 1931) Potonie and Venitz, 1934.

Remarks: This species is rare in the Cockfield samples examined. It is similar to modern *Tilia* which is a temperate region genus but is also similar to the tropical genus *Berrya* in the Tiliaceae.

Illustration: Plate 5, figure 56, P-7855 B-2, 119.9 x 26.4.

TILIAEPOLLENITES SP.

Remarks: This taxon is scarce in the samples examined. Similar pollen type occurs in the tropical genus *Apeiba* of the Tiliaceae and also in the Bombacaceae.

Illustration: Plate 4, figure 48, P-7854 B-2, 117.6 x 25.7.

Genus **CARYAPOLLENITES** Raatz, 1937

Genotype: *Carapollenites simplex* (R. Potonie, 1931) Raatz, 1937 (p. 19, pl. 1, fig. 6).

Caryapollenites cf. *C. simplex* (R. Potonie, 1931) Raatz, 1937.

Remarks: This species is similar to the modern temperate zone genus *Carya*. It is common in the Cockfield sediments examined.

Illustration: Plate 5, figure 51, P-7854 A-1, 116.8 x 38.2.

Genus **TRIATRIOPOLLENITES** (Pflug, 1952) Thomson and Pflug, 1953

Genotype: *Triatriopollenites rurensis* Thomson and Pflug, 1953 (p. 79, pl. 7, fig. 95).

Triatriopollenites cf. *T. coryphaeus* (R. Potonie, 1931) Thomson and Pflug, 1953 (p. 80, pl. 8, figs. 15-37).

Remarks: This species is rare in the samples examined. It is very similar to modern *Platycarya* in the Juglandaceae. *Platycarya* is a temperate zone genus which is now restricted to eastern Asia (China).

Illustration: Plate 4, figure 47, P-7854 A-2, 117.2 x 27.4.

Genus **EXTRATRIPOROPOLLENITES** (Pflug, 1952)
Thomson and Pflug, 1953

Genotype: *Extratriporopollenites fractus* Pflug *in* Thomson and Pflug, 1953 (p. 69, pl. 6, fig. 2).

Extratriporopollenites cf. *E. fractus* Pflug *in* Thomson and Pflug, 1953.

Illustration: Plate 5, figure 53, P-7854 B-1, 115.3 x 29.9.

Extratriporopollenites terminalis Pflug *in* Thomson and Pflug, 1953 (p. 71, pl. 6, figs. 30-32).

Remarks: *Extratriporopollenites* is scarce in the Cockfield sediments examined. The botanical affinity of this taxon is unknown.

Illustration: Plate 5, figure 55, P-7854 B-1, 110. 1 x 34.7.

Genus **ANACOLOSIDITES** Cookson and Pike, 1954

Genotype: *Anacolosidites luteoides* Cookson and Pike, 1954 (p. 207, pl. 1, fig. 47).

Anacolosidites efflatus (R. Potonie, 1934) Erdtman, 1954 (p. 295, fig. 172B).

Remarks: This pollen is similar to the modern tropical genus *Anacolosa* in the Olacaceae. It is presently found from India to the western Pacific Islands. The fossil taxon is rare in the Cockfield sediments.

Illustration: Plate 5, figure 54, P-7854 A-1, 129.1 x 25.

Genus **ALNIPOLLENITES** R. Potonie, 1931

Genotype: *Alnipollenites verus* (R. Potonie, 1931) ex R. Potonie, 1934 (p. 58, pl. 2, fig. 17).
Alnipollenities cf. *A. verus* (R. Potonie, 1931) ex R. Potonie, 1934.
Remarks: This species is rare in the samples examined. It is very similar to modern *Alnus*.
Illustration: Plate 5, figure 57, P-7856 A-1, 117 x 31.5.

Genus **ULMIPOLLENITES** Wolff, 1934

Genotype: *Ulmipollenites undulosus* Wolff, 1934 (p. 75, pl. 5, fig. 25). *Ulmipollenites* cf. *U. undulosus* Wolff, 1934
Remarks: This genus is similar to the temperate region modern genus *Ulmus*. It is scarce in the samples examined.
Illustration: Plate 5, figure 58, P-7854 B-1, 120.9 x 22.1.
The following palynomorphs have been illustrated in publications by Potonie, 1934, Potonie and Venitz, 1934, and Thiergart, 1940 under the genus *Pollenites*. They should be placed in new or existing genera. *Pollenites ventosus* (R. Potonie, 1931) R. Potonie, 1934 (p. 77, pl. 4, fig. 10).
Remarks: This species is abundant in the Cockfield samples examined. The botanical affinity is unknown.
Illustration: Plate 5, figure 59, P-7854 A-1, 124.1 x 23.4. *Pollenites oculus noctis* Thiergart, 1940 (p. 47, pl. 7, fig. 1)
Remarks: This pollen type is similar to members of the Onagraceae. It is rare in the samples examined.
Illustration: Plate 5, figure 52, P-7854 A-2, 117.2 x 27.4. *Pollenites anulus* (R. Potonie, 1931) R. Potonie and Venitz, 1934 (p. 33, pl. 3, fig. 88).
Remarks: This pollen type is similar to modern *Celtis* in the Ulmaceae. It is scarce in the Cockfield samples examined.
Illustration: Plate 5, figures 60, 61, P-7854 B-1, 117.7 x 35.3. P-7854 A-4, 115.4 x 29.4.

QUANTITATIVE RESULTS

The Cockfield Formation sediments contain a large, varied palynomorph assemblage. A portion of this assemblage is described here. A triporate type, *Momipites coryloides*, is the dominant pollen grain in the five samples studied. A pollen count of the morphologic types in the lignite sample (DWE-61-M2) was made. All pollen and spore types were counted on one random traverse on four slides of the lignite sample. The results are as presented in Table 1.

TABLE 1

TYPE	SLIDE				TOTALS
	A-1	A-2	A-3	A-4	
Momipites coryloides	256	201	141	198	796
Tricolporate	93	66	36	68	263
Tricolpate	38	33	9	14	94
Monocolpate	10	3	3	3	19
Inaperturate	4	3	5	3	15
Monolete	5	1	3	3	12
Triporate	5	3	0	0	8
Others	1	0	1	0	2
	412	310	198	289	1209

Approximately 66 percent of the pollen grains counted per traverse were *Momipites coryloides.* Tricolporate grains of various types accounted for about 20 percent of the total count on the traverses. The other 14 percent of the grains encountered were various other morphologic types.

PALEOECOLOGIC CONSIDERATIONS

Ecological conditions during the Eocene in the Gulf Coastal Plain have been a subject of high speculation. Berry (1916) considered the flora to be tropical since no strictly temperate genera were noted in the megaflora. Sharp (1951) interpreted the Wilcox Eocene flora as being temperate. In his comparison of the Wilcox fossil megaflora with modern floras of several regions, he found that 60 percent of the genera are present in the modern flora of the southeastern United States. In comparing the Wilcox flora with the eastern Mexican escarpment region, he found that 68 percent of the Wilcox genera are extant. This area in eastern Mexico shows a mixture of temperate and tropical conditions.

The genera identified palynologically in the Cockfield sediments suggest that the late Claiborne climate was similar to present day eastern Mexico. The fern groups represented by the genera *Cyathidites, Gleicheniidites, Osmundacidites,* and *Cicatricosisporites,* are predominantly subtropical and tropical fern families. *Microfoveolatosporis* and *Polypodiisporites* could be produced by ferns in warm temperate to subtropical regions. The fern genera may have grown on floodplain or deltaic surfaces near coastal areas in association with a predominantly tropical and subtropical angiosperm flora. The seed plant vegetation on the floodplain consisted of taxodiaceous trees (*Taxodiaceaepollenites*), palms possibly represented by *Liliacidites* and *Sabalpollenites*, the families Rubiaceae (*Tricolpites* sp. 1), Aquifoliaceae (*Ilexpollenites*), Anacardiaceae (*Tricolporopollenites dolium*), Tiliaceae (*Tiliaepollenites* and *Tricolporopollenites* sp. 3), Nyssaceae (*Nyssapollenites*), and the Sapindaceae (*Cupanieidites*). The tropical families Symplocaceae (*Symplocoipollenites*), Sapotaceae (*Sapotaceoidaepollenites*), Myrtaceae (*Myrtaceidites*), and Olacaceae (*Anacolosidites*) were also possibly represented in the floodplain flora.

Farther inland, possibly at higher elevation, a temperate flora consisting of oaks (*Quercoidites*), pines (*Abietineaepollenites*), chestnut (*Cupuliferoipollenites*), birch (*Betulaceoipollenites*), *Platycarya* (*Triatriopollenites coryphaeus*), *elm* (*Ulmipollenites*), and alder (*Alnipollenites*) could be found. Long distance transport of these pollen types would possibly account for their relative scarcity in the Cockfield samples studied.

Floral associations similar to those surmised from the palynology can be found today in the eastern Mexico forests where temperate genera exist at higher elevations and the lowlands are dominated by subtropical and tropical floral communities.

The paleoecologic conclusions of this investigation agree with those of Gray (1960). She concluded that there is a close parallel between the Claiborne climate and that of the eastern Mexico forest where communities of the tropical "tierra caliente" merge with those of the temperate "tierra templada" at elevations of about 3300 to 4000 feet. She noted the presence of several characteristically temperate genera including *Ilex*, *Nyssa*, *Alnus*, *Ulmus*, *Carya*, *Quercus*, and *Liquidambar* along with tropical and subtropical genera and families.

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PLATES 1-5

EXPLANATION OF PLATE 1

1. *Cyathidites minor* Couper, 54 microns.
2. *Gleicheniidites senonicus* Ross, 25 microns.
3. *Osmundacidites wellmanii* Couper, 37 microns.
4. *Cicatricosisporites dorogensis* Potonie and Gelletich, 60 microns.
5. *Cicatricosisporites* cf. *C. paradorogensis* Krutzsch, 48 microns.
6. *Microfoveolatosporis* cf. *M. pseudodentatus* Krutzsch, 70 microns.
7. *Polypodiisporites* cf. *P. favus* Potonie, 52 microns.
8. *Gnetaceaepollenites eocenipites* (Wodehouse) Potonie, 56 microns.
9. *Abietineaepollenites* cf. *A. microalatus* Potonie, 76 microns.
10. *Taxodiaceaepollenites hiatus* (Potonie) Kremp, 28 microns.
11. *Gnetaceaepollenites* sp. (*Ephedra distachya* type), 40 microns.

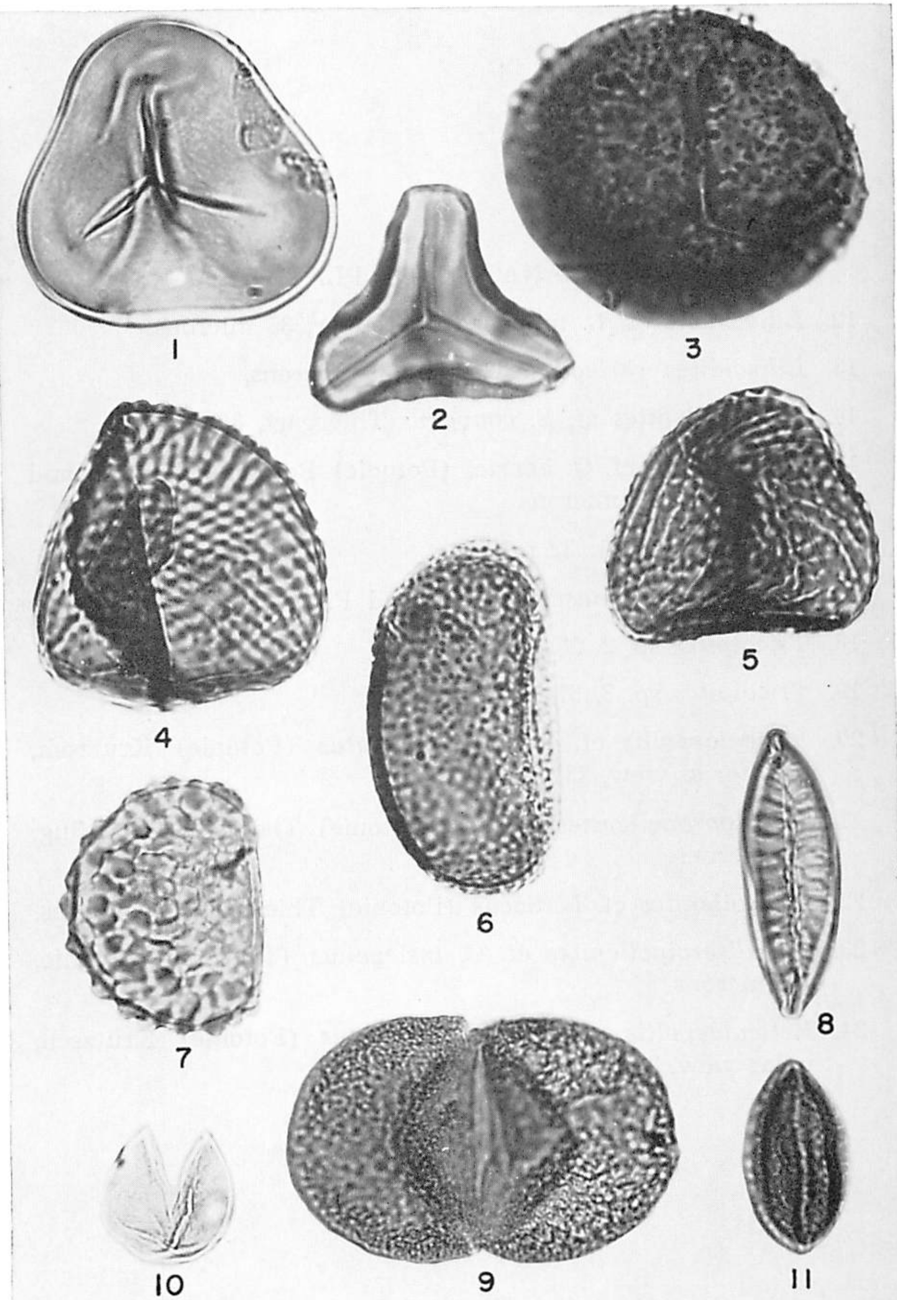


Plate I. Fern spores, 1-9; Gymnosperm pollen, 8-11.

EXPLANATION OF PLATE 2

12. *Liliacidites* cf. *L. intermedius* Couper, 35 microns.
13. *Liliacidites variegatus* Couper, 36 microns.
14. *Sabalpollenites* cf. *S. convexus* Thiergart, 38 microns.
15. *Quercoidites* cf. *Q. henrici* (Potonie) Potonie, Thomson and Thiergart, 27 microns.
16. *Tricolpites* sp. 1, 32 microns.
17. *Tricolpites thomasii* Cookson and Pike, 23 microns.
18. *Tricolpites* sp. 2, 28 microns.
19. *Tricolpites* sp. 3, 37 microns.
20. *Reticulaepollis* cf. *R. intergranulatus* (Potonie) Krutzsch, equatorial view, 23 microns.
21. *Tricolporopollenites dolium* (Potonie) Thomson and Pflug, 29 microns.
22. *Ilexpollenites* cf. *I. iliacus* (Potonie) Thiergart, 27 microns.
23. *Cupuliferoipollenites* cf. *C. insleyanus* (Traverse) Potonie, 18 microns.
24. *Reticulaepollis* cf. *R. intergranulatus* (Potonie) Krutzsch, polar view, 23 microns.

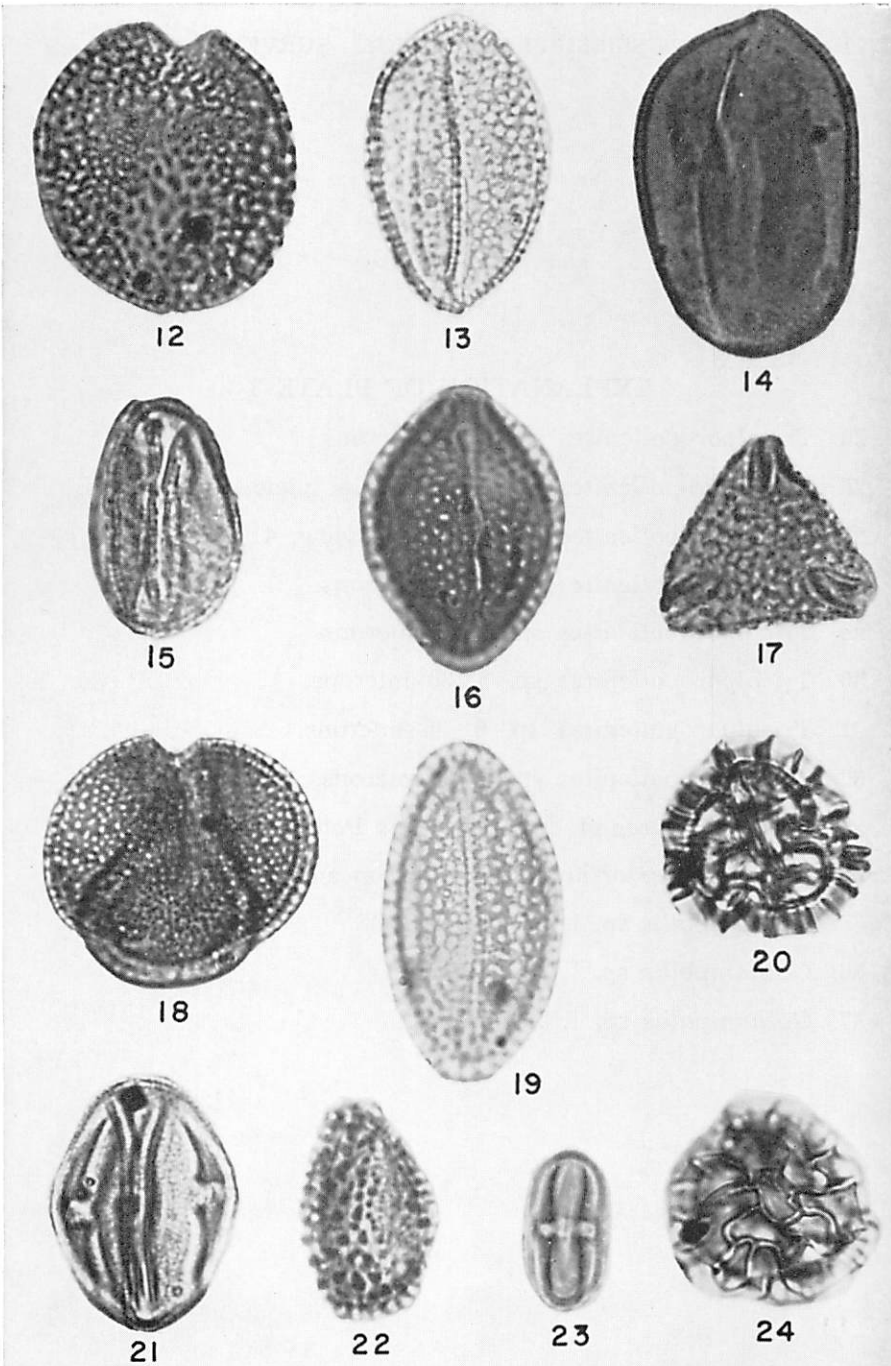


Plate 2. Angiosperm pollen.

EXPLANATION OF PLATE 3

25. *Tricolporopollenites* sp. 1, 23 microns.
26. *Tricolporopollenites* sp. 3, equatorial view, 41 microns.
27. *Tricolporopollenites* sp. 3, surface view, 41 microns.
28. *Tricolporopollenites* sp. 2, 30 microns.
29. *Tricolporopollenites* sp. 4, 40 microns.
30. *Tricolporopollenites* sp. 5, 30 microns.
31. *Tricolporopollenites* sp. 6, 35 microns.
32. *Tricolporopollenites* sp. 7, 30 microns.
33. *Nyssapollenites* cf. *N. accessorius* Potonie, 34 microns.
34. *Cupanieidites orthoteichus* Cookson and Pike, 26 microns.
35. *Gothanipollis* sp. 1, 25 microns.
36. *Gothanipollis* sp. 1, 20 microns.
37. *Gothanipollis* sp. 1, 22 microns.

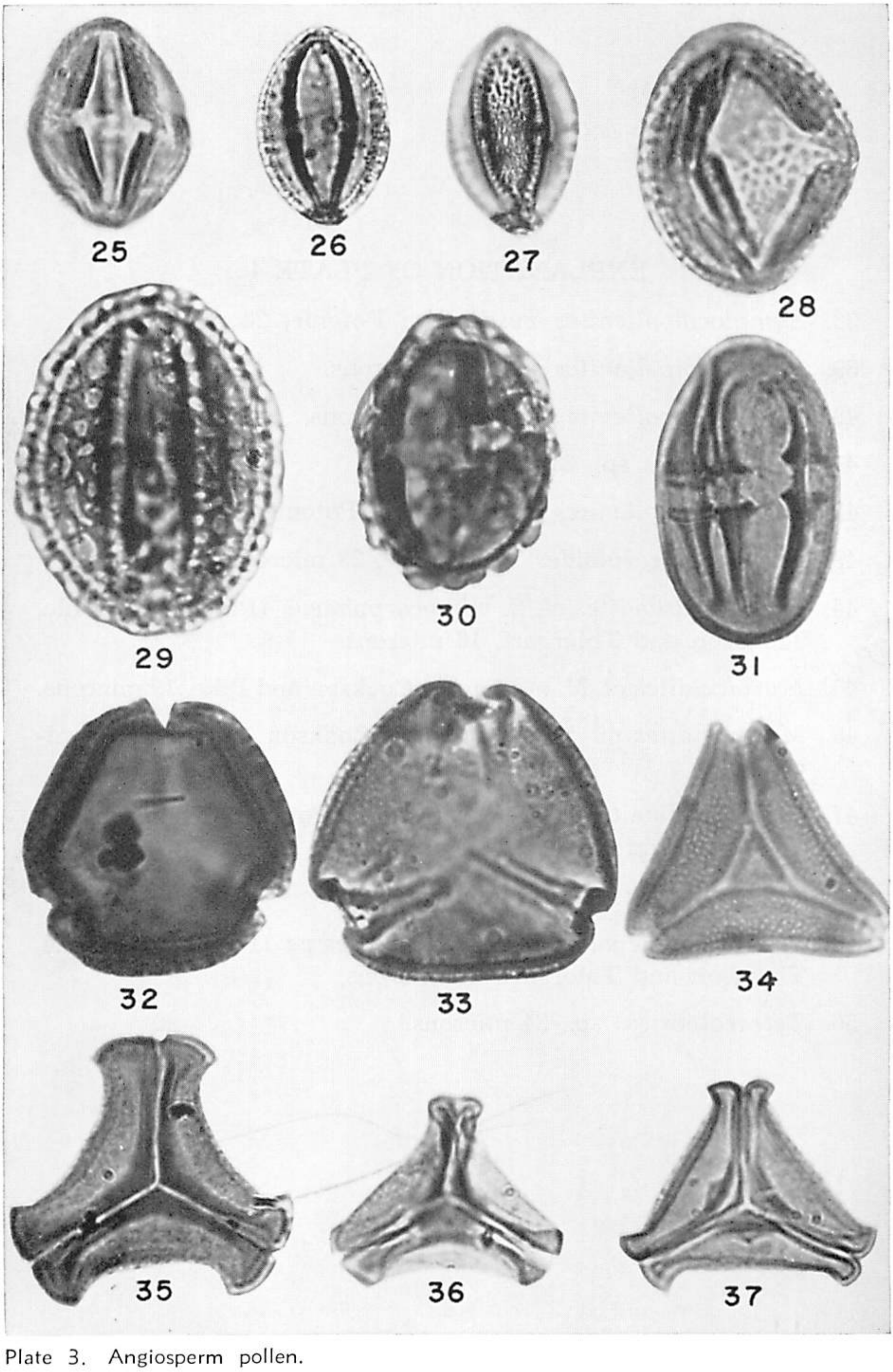


Plate 3. Angiosperm pollen.

EXPLANATION OF PLATE 4

38. *Symplocoipollenites vestibulum* Potonie, 28 microns.
39. *Symplocoipollenites* sp. 1, 31 microns.
40. *Symplocoipollenites* sp. 2, 30 microns.
41. *Proteacidites* sp., 28 microns.
42. *Betulaceoipollenites* cf. *B. bituitus* Potonie, 28 microns.
43. *Momipites coryloides* Wodehouse, 23 microns.
44. *Engelhardtioidites* cf. *E. microcoryphaeus* (Potonie) Potonie, Thomson and Thiergart, 16 microns.
45. *Myrtaceidites* cf. *M. mesonesus* Cookson and Pike, 19 microns.
46. *Myrtaceidites* cf. *M. eugeniioides* Cookson and Pike, 15 microns.
47. *Triatriopollenites* cf. *T. coryphaeus* (Potonie) Thomson and Pflug, 18 microns.
48. *Tiliaepollenites* sp., 26 microns.
49. *Sapotaceoidaepollenites* cf. *S. manifestus* (Potonie) Potonie, Thomson and Thiergart, 34 microns.
50. *Tetracolporites* sp., 34 microns.

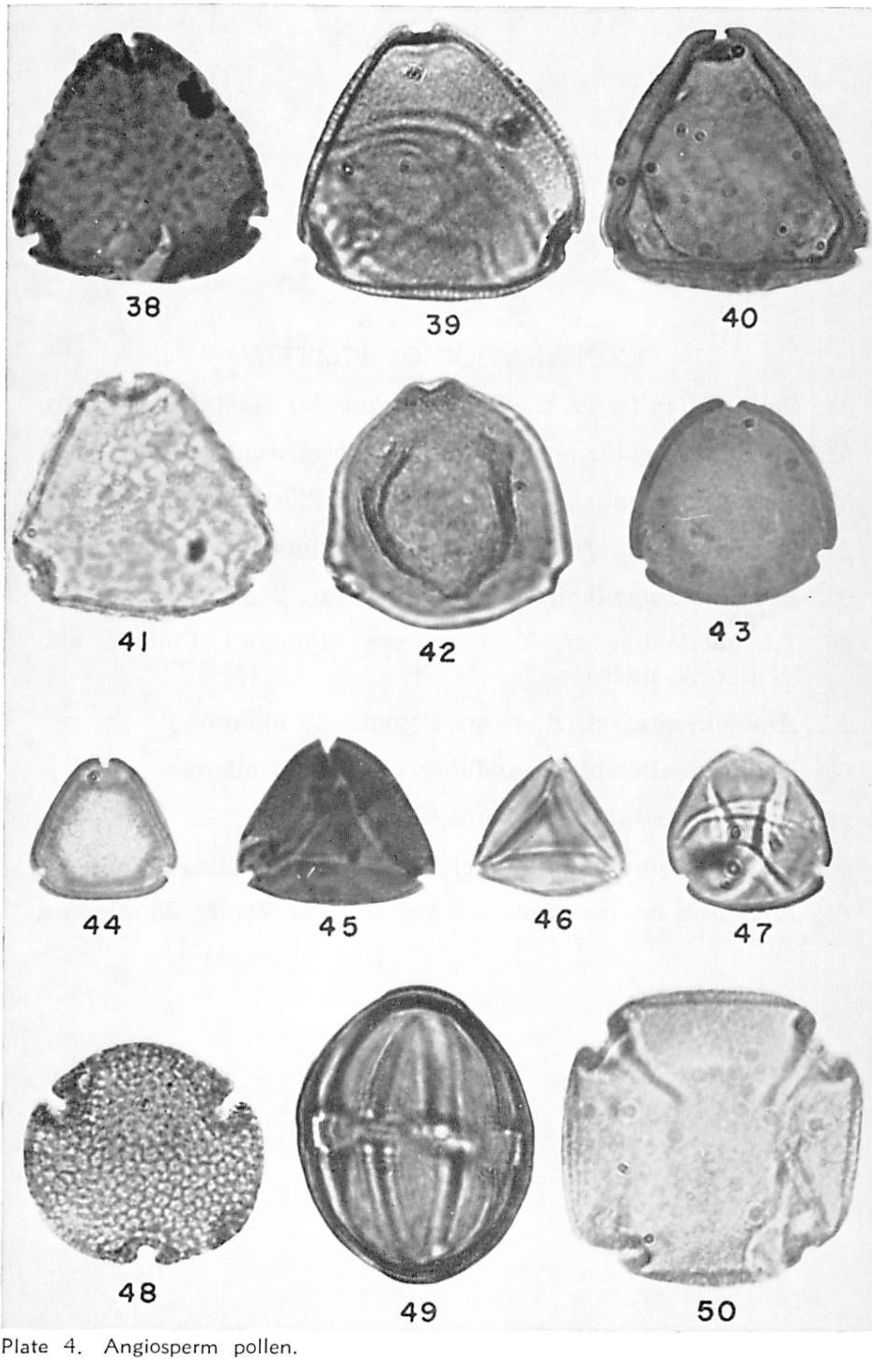


Plate 4. Angiosperm pollen.

EXPLANATION OF PLATE 5

51. *Caryapollenites* cf. *C. simplex* (Potonie) Raatz, 38 microns.
52. *Pollenites oculus noctis* Thiergart, 70 microns.
53. *Extratriporopollenites* cf. *E. fractus* Pflug, 28 microns.
54. *Anacolosidites efflatus* (Potonie) Erdtman, 16 microns.
55. *Extratriporopollenites terminalis* Pflug, 28 microns.
56. *Tiliaepollenites* cf. *T. instructus* (Potonie) Potonie and Venitz, 28 microns.
57. *Alnipollenites* cf. *A. verus* Potonie, 18 microns.
58. *Ulmipollenites* cf. *U. undulosus* Wolff, 30 microns.
59. *Pollenites ventosus* Potonie, 22 microns.
60. *Pollenites anulus* (Potonie) Potonie and Venitz, 32 microns.
61. *Pollenites anulus* (Potonie) Potonie and Venitz, 25 microns.

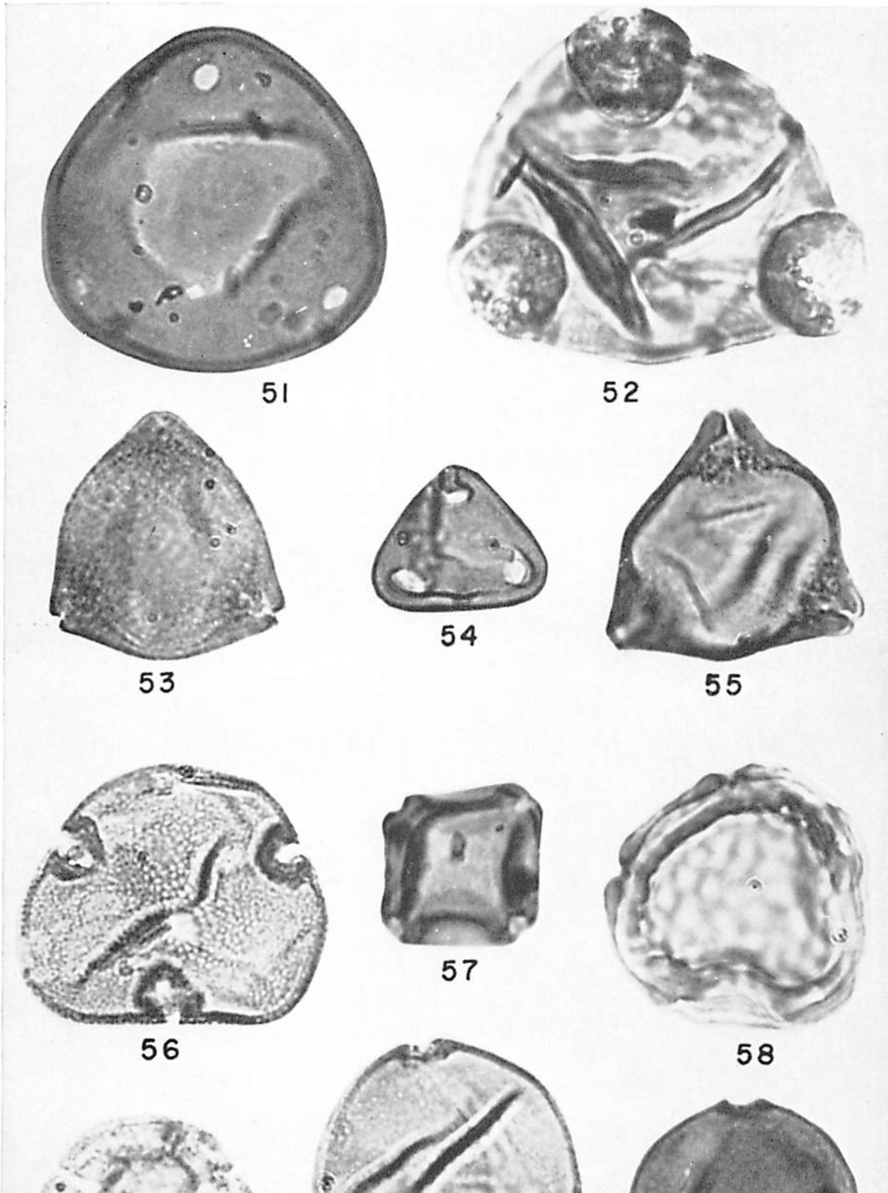


Plate 5. Angiosperm pollen.

CURRENT PROJECTS OF THE MISSISSIPPI GEOLOGICAL SURVEY

FREDERIC F. MELLEN*

ABSTRACT

The Mississippi Geological Survey at Jackson, Mississippi has taken strong and progressive steps to reorganize its work and service programs, and to render a continuing improvement in its contributions to the economic welfare of the State. Some of the projects being encouraged, sponsored, or undertaken by the Survey are reviewed. The economic and cultural contributions to be expected from this work are summarized briefly.

INTRODUCTION

Following a general public demand and a specific need from the Petroleum Industry, the Mississippi Geological Survey Board ordered that all of the Survey's activities be centralized at Jackson. This was accomplished early in 1963 and the resulting increased efficiency of the Survey's work has been widely acknowledged. The Survey's extensive library of geological books, its collection of samples and cores from thousands of oil and water wells and other prospect holes, its collections of minerals and mineral substances, and its other facilities are now available to all of its staff, and are much more accessible to all of the people in the State than heretofore. Jackson is, of course, the Capitol City and is, incidentally, the headquarters or base of operations of most of the oil companies and of the geologists, geophysicists, engineers and others who are engaged in the development of our mineral resources. Our principal function is three-fold, 1) the development of scientific data on the geology of Mississippi, 2) the publication of those data, and 3) the

*An Address delivered:

July 21, 1964 to Desk & Derrick Club, Jackson, Mississippi;

August 15, 1964 to Mississippi Water Well Contractors Association, Biloxi, Mississippi;

September 24, 1964 to Jackson Chapter, Society of Professional Engineers, Jackson, Mississippi;

December 7, 1964 to Mississippi State University Union, Union Lecture Series, State College, Mississippi.

distribution of those data to the people who can use them in the economic development of our vast mineral resources.

The Survey's twenty-ninth biennium (July 1, 1962 through June 30, 1964) was spent largely in the completion of several field projects which had been underway for some time, and in a critical self-analysis, a review of the work of the Survey since its original establishment by the Mississippi Legislature in 1850. In this review we sought to determine objectively whether or not our work had paid dividends to the State, what type of studies had yielded the best results, and what new projects appeared economically justifiable.

The results of these studies have appeared in various forms, but are essentially complete in our Twenty-ninth Biennial Report to the Legislature, and in our Bulletin 100, *The Mississippi Geological Survey, A Centennial.*

The information about the Survey contained in these two reports must certainly have been convincing, for the Survey was recommended for a substantial appropriation increase by the Budget Commission and the 1964 Legislature made the largest grant to the Survey in history. The biennial budget was increased from $140,000 to $190,000, and an additional $32,000 was provided for an additional 4800 square feet of space to the Sample Library Building and for paving and shelving. In addition to these direct monetary appropriations for the Survey's authorized work, the Legislature made it possible for the Survey to receive other funds for its operations.

Since 1958 when the Survey was reorganized (General Laws of Mississippi, 1958, Chapter 477.) it has been actively governed by a 5-man Board. The Board is composed of two geologists, one professional civil engineer, and two business men, appointed on staggered terms by the Governor. The Board meets quarterly and more often if necessary. Credit for the more successful operation of the Survey in recent years is due, in large part, to the keen and dedicated interest that the men on this Board have in the work of the Survey, in the solution of its problems, and in the welfare of the State. They receive a complete monthly report on the operation of the Survey from the State Geologist and are frequently consulted by him.

PALEONTOLOGICAL STUDIES

Recognizing paleontology as one of the basic branches of geological science, and the importance of the paleontological tools in exploring for and mapping mineral resources, it is very evident that paleontology can be used with far greater effectiveness in the mineral development of Mississippi. In addition to the use of index fossils for correlation, largely in petroleum geology, the rapidly developing science of paleoecology can be important not only in petroleum geology, but also in the economic geology of deposition of clay, sand, gravel, lignite, marl, limestone, iron ore, and other mineral substances of Mississippi. A review of the publications of the Survey reveals that no single bulletin has been devoted to paleontology, and that significant paleontological work is included in only five of the 103 published Bulletins, in spite of the fact that Mississippi is noted for its highly fossiliferous collecting grounds. The recent availability of cored fossiliferous materials has, within the past 12 months, enabled the following projects to get underway:

1. Lloyd W. Simpson, *Foraminifera of the Vicksburg,* M.S. thesis, Mississippi State University.

2. Martin Mumma, *Ostracoda of the Vicksburg,* Ph.D. dissertation, Louisiana State University.

3. Kenneth Loep, *Foraminifera of the Jackson,* M.S. thesis, University of Houston.

4. Ronald Greeley, *Tertiary lunulitiform bryozoa,* Ph.D. dissertation, Missouri School of Mines, Rolla.

5. Norm Frederickson, *Palynology of the Jackson,* Ph.D. dissertation, University of Wisconsin.

6. William J. Huff, Ph.D. Rice University, has in preparation for publication his manuscript on *The Jackson Eocene Ostracoda of Mississippi.*

7. Donald W. Engelhardt, *Plant microfossils from the Eocene Cockfield formation Hinds County, Mississippi.*

In addition to these well-advanced studies, others in the field of palynology are underway. Still other investigations of our fossil materials are in the planning or beginning stages. It is anticipated that an increasing number of quality paleontological reports will be submitted to the Survey for publication, for the most part at no direct cost other than printing charges. Through cooperation with graduate students and their respective schools the Survey can make very great contributions to the sciences of paleontology and geology in Mississippi. It is obvious that the cores and electrical logs secured by the Survey with its drilling rig and logger have been responsible, in large part, for the increased scientific production in this field. In exchange for the raw samples of fossiliferous materials the paleontological students will furnish the Survey not only manuscripts of their work, but also type fossil material to be used in the building up of a fine paleontological reference library, too long, and too sadly, neglected.

MINERALOGICAL, PETROLOGICAL AND GEOCHEMICAL STUDIES

Although the Survey does not have a mineralogist or a geochemist and has very little specialized laboratory equipment in these fields, it has been able to secure valuable and useful information from time to time through cooperation with the State Chemist and others. Some limited, but very important studies now underway by others — with cooperation from the Survey — are:

1. Wendell Johnson of Millsaps College, mineralogy of Yazoo clay, Ph.D. dissertation, University of Missouri.
2. Richard R. Priddy of Millsaps College, physical, chemical, geological, and ecological characteristics of the loess, National Science Foundation.
3. Charles Milton, mineralogy and petrology of igneous rocks of Mississippi, U. S. Geological Survey.
4. Gene Collins, et al., composition of brines of Mississippi, U. S. Bureau of Mines.
5. M.G.S. Staff, composition, thickness, distribution and economic importance of the so-called "acid iron earths."
6. Mobile Oil Research Section is working on age-dating of intrusive igneous rocks from deep Mississippi wells.

7. Z. S. Altschuler, geochemistry of clays, U. S. Geological Survey.

8. Mississippi State Highway Department, physical properties of samples from cores taken on type localities program.

MISSISSIPPI GEOLOGICAL SURVEY SAMPLE LIBRARY

The Mississippi Geological Survey Sample Library building houses the Jackson Sample Cut, a private contractor, through whom the State receives automatically the cores and cuttings from oil and gas test wells over the State. Under a recent agreement, the Cut also prepares water well cuttings and the cuttings and cores from the Survey's test holes at no cost to the Survey.

The boxes of cuttings and cores are indexed, and the Survey provides an examination room which is being used with increasing regularity by persons interested in oil and gas, water or other minerals. Within fiscal year 1964 a greatly increased number of water well sample sets have been supplied by contractors and by the Groundwater Division, U.S.G.S.

WELL LOGGING

The Survey has two electrical loggers, a Widco logger having a 950-foot capacity, and a Neltronic logger having a 3300-foot capacity and a gamma ray logging attachment. Changes are being made in these instruments to insure better logging results. All of the Survey geologists are being instructed in the use of this equipment. Although these loggers are principally for use in test wells drilled by the Survey, they may be used in logging water wells which will yield geological information valuable to the State and which might otherwise be lost.

COUNTY MINERAL SURVEYS

The Mississippi Geological Survey has published reports on the geology and mineral resources of about thirty of the State's eighty-two counties. Experience has indicated that this is the most satisfactory method of studying the geology of the State. Although not to the exclusion of other approaches, plans are for the continuation and stepped-up activity in the county surveys. During the twenty-ninth biennium reports were published on Attala and Jasper Counties.

At the present time two of the largest counties of the State are being studied.

1. Hinds County, William H. Moore, principal investigator. Hinds County has agreed to contribute $7,500 of an estimated total cost of $37,500 for a complete study of the geology and mineral resources. Numerous drill and core holes have been drilled to maximum depths of 500 feet. In addition, many core hole logs have been contributed for use in this work by oil companies, and others. Assisting in the project are Alvin Bicker, subsurface geologist, and other members of the staff. Invitations to bid on ceramic testing of clays have been mailed out to numerous ceramic engineers. The successful bidder may also be used on additional projects. Perhaps no County has ever had the great mass of data available as has Hinds, and the Survey is very optimistic about the contributions this report will make. A great deal is being learned about the surface, the shallow and deep subface, and about the other geologic features. This report is scheduled for printing by June 1, 1965.

2. Rankin County, Marshall K. Kern, principal investigator. Rankin County has been asked for a contribution of $7,500 toward a total estimated cost of $37,500 for the complete study of the geology and mineral resources. As true in Hinds County, a great backlog of core hole data is available to which the Survey can drill supplementary test wells. It is estimated that a million dollars — or more — would be needed to redrill the holes in Rankin and Hinds Counties for which logs have been contributed for these surveys. The availability of these data is the principal reason these studies can be made at such reasonable costs. This report should be ready for publication, if Rankin County participates, by late summer, 1965.

In addition to these two counties now being surveyed several others have applications in various stages of preparation.

SURVEY OF LIGHTWEIGHT AGGREGATE MATERIALS

The Mississippi Geological Survey in cooperation with the Mississippi Research Commission has completed a statewide investigation of bloatable clays. The geological part was prepared by Survey Geologist William S. Parks, the economics part by Research Engineer Clyde A. McLeod, and the tests part by Dr. Allan G. Wehr, Head, Department of Metallurgical and Ceramic Engineering, Mississippi State University, assisted by the U. S. Bureau of Mines.

This report will be released around mid-August 1964 and is one of the most comprehensive studies of its type published by any State. Distribution of the report, M.G.S. Bull. 103, will be handled by the Survey. It is priced at $2.00 per copy.

GEOLOGIC RESEARCH PAPERS

The Survey has recognized the fact that many geologists working with the geology of the State would be able and willing to make important scientific contributions through submitting their works for publication. Practically the only cost involved is that of printing, but the economic benefits are undoubtedly many times greater. Thus far, two Bulletins of this type have appeared: Bulletin 97, "Mississippi Geologic Research Papers-1962" and Bulletin 102, "Mississippi Geologic Research Papers-1963."

Manuscripts for a third Bulletin in this series are being received. It is expected that this will become both a popular and useful outlet for serious contributions to Mississippi geology from geological scientists mostly outside the Survey organization.

TYPE LOCALITIES SAMPLING PROGRAM

The Survey Board has, from time to time, authorized the drilling, coring, and logging of some of the type localities in Mississippi when time and funds permitted. As many of the type localities of geologic units are in Mississippi where they were first described over a hundred years ago by Hilgard and others, a great many students of geology come to the State to see for themselves exactly what is exposed at the type localities and to collect materials for specialized study. The Survey staff, itself, needs to understand the sediments at their type exposures in order better to decide on proper nomenclature and unit definitions. Furthermore, these localities are in Mississippi and geologists throughout the World look to the Mississippi Geological Survey for re-descriptions and better definitions of our geologic units. Accordingly, the Survey has made abundant use of its core drill and electrical logger in the re-examination of the numerous type localities of the Vicksburg and Jackson groups in Mississippi. The materials and information secured in these studies are incorporated in current Survey reports and are available to competent research workers on cooperative basis.

The Survey has thus far cored and logged the following Jackson and Vicksburg type localities:

1. Yazoo clay at Yazoo City.
2. Forest Hill sand at Forest Hill.
3. Byram marl etc. at Byram.
4. Moodys Branch marl and lower Yazoo clay at Jackson.
5. Byram, Glendon and Mint Springs unit at Vicksburg.
6. North Twistwood Creek clay, etc. on North Twistwood Creek.
7. Pachuta marl, etc. near Pachuta.

As mentioned elsewhere, these materials are being studied cooperatively through a variety of lines of investigations.

TOPOGRAPHIC MAPPING

The Survey has been commissioned to work cooperatively on a matching fund basis with the Topographic Division of the U.S.G.S. Thus far no funds for this purpose have been provided. The Survey realizes that these maps are essential to rapid development of all of the natural resources of the State and is actively encouraging the enactment of a participating program to bring about complete topographic coverage of the State by 1970.

WATER RESOURCES

The Mississippi Geological Survey is commissioned to study and report upon the water resources of the State in a manner similar and coordinate to the functions of the U. S. Geological

Survey and of many other state surveys. Since 1956, however, the Survey has had no funds with which to conduct water studies.

The Survey does consult with public agencies and others in water problems of public interest. The Survey logs many water wells with its electrical loggers in cases where the geologic information that might be derived would be of use in developing the geology of Mississippi.

In the Survey's county mineral survey program it is established practice to include sections on ground water geology. This information is developed incidental to (and at little extra expense) the study of the geology of the counties involved. As has been said so often, "ground water and geology are inalienable."

The Ground Water Division of the U. S. Geological Survey has obligingly prepared reports for some of our county bulletins, but others have been prepared by our staff geologists and water analyses have been made for us by the Mississippi State Board of Health or the Mississippi State Chemical Laboratory.

The State Geologist is an *ex officio* member of the Water Pollution Advisory Council and of the A & I Board, and serves as a member of the latter's 4-man committee on city planning.

PENDING PROJECTS

The Survey has under consideration and discussion other projects dealing with the mineral natural resources of the State. These projects would be designed to supply information on particular resources for which inquiry has been made. For example, a Delta project has been drafted and is in planning. Also, an investigation of lignite resources of the State is in consideration. Other projects are discussed from time to time, but their approval depends upon the funds and manpower for handling the work as well as upon the probability for an important economic contribution to the State.

HOUSING

The need for adequate housing of the Survey's growing library, collections, equipment, and other facilities has never been more sharply felt.

In the Twenty-third Biennial Report written in July, 1951, Dr. W. C. Morse wrote: "Furthermore, it seems that recognition must now be given to the Survey's need of an adequate building where its various activities and materials, now scattered in parts of five separate and distinct buildings, can be gathered under one roof."

In the current biennium, some thirteen years later, the Survey has acquired thousands of additional books in its library, many thousands of additional bulletins of its own for distribution, and many tons of new well samples, cores, and collections, all requiring much better housing if they are to be used to maximum advantage in the development of our mineral resources.

It was for this reason that the Survey Board ordered and directed that all Survey equipment and materials be assembled at the principal office of the Survey, in the Sample Library at 2525 North West Street, Jackson, Mississippi. This was officially completed on May 31, 1963.

A modern Mississippi Geological Survey Building is badly needed to:

1. House adequately the present and expanded staff of the Survey.
2. House adequately the present large reference or research library collected by the Survey over a period of many decades by purchase, but principally by exchange; and to provide space for growth of this library, and for use of the library by geologists and others.
3. Provide a modest museum displaying for students, industrialists, and others the important fossils, rocks, minerals, and mineral products of Mississippi.
4. Provide space for the extensive reference collections of mineral samples, test pieces and other materials related to investigations of Mississippi's mineral resources; and adequate testing equipment with which to conduct research investigations on the oil and gas, clays, silts, sands, marls, chalks, limestones, lignite, ores and other raw materials sampled by the Survey's field men. The

equipment would include regular commercial-type geochemical, ceramic, aggregate and similar facilities for working with the more abundant raw materials of the State.

5. Provide a conference room for use of geologists, geophysicists, State Officials, or others interested in development of the State's vast mineral resources.

It has been suggested that such a building could be constructed as a first unit in a Research Center which has been authorized by the Legislature and is now being planned.

SUMMARY AND CONCLUSIONS

The true efficacy of the Survey's work is revealed by the case history review of the Survey's publications and subsequent developments. Whenever there has been any important developments in the mineral economy of Mississippi the record shows that the Mississippi Geological Survey had published its findings on that possibility, often immediately preceding and, in many cases, directly and solely responsible for the development.

The Board and Staff of the Survey are extremely proud of the legacy they, and the People of Mississippi, have received through the dedicated work involved in the preparation and publication of the many Bulletins of the Survey, and of Survey's history which commenced through act of the Mississippi Legislature of 1850, one hundred fourteen years ago! They recognize, too, in humility, the challenges and the opportunities, the hardships and the rewards, the responsibilities and the satisfactions that accompany them in carrying out their duties to the Mississippi Geological Survey, their obligations to the People of Mississippi, their reverence to those who have preceded, and their trusteeship to posterity.

The opportunities for further great increase in the mineral economy of Mississippi are as bright as they are for any other State in the Nation. Mineral industries not only contribute to the wealth of the communities in which they locate, but they tend to assist and supplement the beneficial effects of other mineral industries, a chain reaction within the economy. Similarly, funds wisely spent in research investigations, specifically in the field of geology and minerals technology, cannot fail to play an important part in the stimulation and establishment of existing and new industries, and continue to pay large monetary dividends, as has been true in the past.

Notes: Since presentation of the above discussion the following developments have been achieved:

1. **The Survey Board has approved the publication of the Simpson and Mumma reports jointly as a Bulletin of the Survey on the Paleontology of the Vicksburg, subject to final completion of the projects and their meeting editorial standards.**
2. **The Loep report is essentially complete and Mr. Loep plans an early trip to Jackson to discuss its form of final release.**
3. **The Huff report is in final stages of preparation.**
4. **The Engelhardt report is undergoing final review by research scientists of his company and is scheduled for inclusion in this Bulletin.**
5. **The Survey is increasing its activity in the cooperative study of the quality of water in Mississippi from all depths and all geologic formations.**
6. **Intensified effort has advanced the estimated completion date on the Hinds County report from June 1, 1965, to April 1, 1965. Much of the testing on raw materials has been completed.**
7. **The Survey cooperated with Millsaps College under a National Science Foundation grant and cored seven holes through the loess in Warren County.**
8. **The recent routine logging of a water well in Yazoo County with the Survey's new Neltronic logger resulted in a press release announcing a major structural discovery. This, undoubtedly, will result in leasing and drilling which will, in itself, immediately justify the acquisition cost of the logger. Had not this service been available, it may have been many years before this structural information would have been known to the petroleum industry, and to geological science.**
9. **Bulletin 103, SURVEY OF LIGHTWEIGHT AGGREGATE MATERIALS OF MISSISSIPPI, prepared jointly with the Mississippi Research and Development Center, has been distributed to points throughout the world and is considered to be one of the most comprehensive and useful reports of its type issued by any State.**
10. **The type localities sampling program and the progressive attitude of the Survey are two major contributing factors to the continuing success of the geologic research paper bulletin series which now is completing its third annual number.**

11. The Survey was a major influence in securing the topographic mapping of the Starkville quadrangle. Two of the four sheets have been released in advance print form, making available, for the first time, for teaching, research, planning and development adequate maps of the environs of Mississippi's largest school, Mississippi State University.

12. Contract has been let by the State Building Commission and work is in progress adding 4800 square feet of space to the Mississippi Geological Survey Sample Library Building. This will allow, for the first time in over thirty years, all of the Survey's collections, stocks, equipment and fixtures to be together under one roof.

WELL LOGGING BY MISSISSIPPI GEOLOGICAL SURVEY

A. R. BICKER, JR. and F. F. MELLEN

ABSTRACT

Well logging by electrical instruments has been a valuable tool used by the Mississippi Geological Survey for a number of years in conjunction with regular field work. Recently its role has been expanded in water well development in an effort to secure more subsurface geological information. Acquisition of new equipment enables the Survey to secure data from shallow and intermediate depths beyond the capacity of the original equipment.

INTRODUCTION

The Mississippi Geological Survey has been equipped to run electrical logs since late 1953. Previous to 1964 the equipment was used mostly to log core holes and test holes drilled by the Survey. Even though a few water wells were logged from time to time, personnel and funds were too limited to encourage actively logging of these wells. Consequently, many wells have been drilled and much invaluable data concerning the shallow formations, geologic structure and ground-water supplies that could have been obtained essentially have been lost.

In 1964, a program was initiated by the Survey to collaborate with the water well contractors in an effort to obtain more geological data, while aiding in the completions of their wells. A new logger, capable of logging to depths of 3,300 feet was acquired. This maximum depth allows investigations of deepest known fresh-water horizons in the State. Thus far, the program has been successful as evidenced by a large increase in the number of water wells logged.

Tabulation of logging records for a period of four months in 1964 exhibits an increase from 2,068 feet logged in July to 15,155 feet in October and a total footage of 26,890 feet (Table 1). These figures include footage of core hole and test hole logs that are part of the Survey's normal operation in the field of geological investigations. Besides the electrical log data, this program has added thousands of feet of samples to the Sample Library.

SURVEY LOGGING EQUIPMENT

The Survey presently operates two logging devices, both of which are capable of recording simultaneously the self potential curve and the resistivity curve. Also, one of these units is capable of recording a gamma ray curve.

The Widco logger is a portable two-curve instrument presently equipped to log bore holes to a maximum depth of 950 feet. The logging electrode attached to a neoprene cable is lowered and raised in the bore hole manually by means of a geared hand crank. Electrical power for the unit is supplied from a vehicle battery through the use of a rotary converter, which changes the 12 volt DC current to 115 volt AC.

The Neltronic 2K logger is a multipurpose instrument supplied with 3,300 feet of armored cable (Figure 1). The electrode may be raised or lowered either mechanically by means of a geared electric motor or manually by hand crank. Electrical power is supplied by a portable 2500 watt AC generator. This logging unit and its accompanying power supply presently are mounted in a carry-all.

Both loggers use one-inch diameter probes for the purpose of securing readings for electrical log curves. This allows the Survey to obtain results in bore holes of small diameters. In fact, results can be obtained in any size bore hole that can be drilled for practical purposes. Limiting factors to obtaining results are other physical conditions of the bore hole, such as mud conditions, cavings, etc. Since the acquisition of the one-inch electrode the Survey has logged water wells as small as 2-7/8 inches in diameter to a depth of 1,500 feet. This small diameter electrode has enabled the Survey to be far more successful in reaching total depth than in the past. To date the deepest log recorded by Survey equipment reached a total depth of 1,775 feet (Plate 1).

The gamma ray probe has an external dimension of two inches and is a much more delicate instrument; therefore, caution has to be practiced in its operation. Usual procedure is to log 100 feet below the casing seat in order to correlate the gamma ray log with the electrical log portion of the bore hole. To date the deepest log secured with this instrument has been

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF July 19 64 SHEET 1

No.	Date 1964	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
1	7/1	Byrd & Brown	Rankin	1-5N-2E	860'	-	-	330'	yes	Gordon & McNees Bridge at 330'
2	7/2	Test Hole AG-5	Rankin	21-5N-3E	310'	310'	-	304'	yes	Rankin County project
3	7/21	T.C. Brock	Hinds	28-4N-3W	475'	-	-	212'	yes	McNees Bridge at 212'
4	7/21	Town of Madison	Madison	8-7N-2E	596'	-	-	301'	yes	Layne Central Bridge at 308'
5	7/23	Pachuta Type	Clarke	30-2N-14E	150'	150'	100'	149'	yes	Type localities project
6	7/24	No. Twistwood Creek	Jasper	11-2N-14E	150'	150'	spot	149'	yes	Type localities project
7	7/27	Yarborough	Hinds	34-4N-2W	438'	-	-	240'	yes	McNees Bridge 240'
8	7/31	Shady Grove	Jones	13-9N-12W	384'	-	-	383'	yes	Griner
		Totals			3,363	610	100	2,068		

ADDITIONAL REMARKS: ___

Table 1.—Monthly well data tabulation, July through October 1964.

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF August 1964 SHEET 1 of 2

No.	Date 1964	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
1	8/6	Harmon	Hinds	8-4N-1W	880'	-	-	520'	no	Pitts & Sons Bridge at 520'
2	8/7	Hwy. Dept.	Rankin	21-5N-2E	100'	-	-	99'	yes	Materials prospect
3	8/10	Hwy. Dept.	Rankin	21-5N-2E	70'	-	-	69'	yes	Materials prospect
4	8/11	Goodsell	Rankin	1-3N-1E	230'	-	-	229'	yes	McNees
5	8/12	City of Columbia	Marion	4-3N-14E	255'	-	-	255'	yes	Griner
6	8/13	Hwy. Dept.	Rankin	21-5N-2E	100'	-	-	99'	yes	Materials survey
7	8/13	Hwy. Dept.	Rankin	21-5N-2E	80'	-	-	77'	yes	Materials survey
8	8/14	Hwy. Dept.	Rankin	21-5N-2E	82'	-	-	71'	yes	Materials survey
9	8/14	Test Hole AF-38	Hinds	7-7N-1W	490'	490'	-	488'	yes	Hinds Co. project
10	8/18	Test Hole AF-39	Hinds	27-6N-1E	360'	360'	-	350'	yes	Hinds Co. project
11	8/19	Cleveland Trailer	Rankin	14-5N-1E	600'	-	-	596'	yes	Gordon & McNees
12	8/19	Hwy. Dept.	Rankin	21-5N-2E	80'	-	-	80'	yes	Materials survey
13	8/19	Hwy. Dept.	Rankin	21-5N-2E	70'	-	-	53'	yes	Materials survey
14	8/20	Hwy. Dept.	Rankin	21-5N-2E	100'	-	-	92'	yes	Materials survey
15	8/21	Hwy. Dept.	Rankin	21-5N-2E	120'	-	-	93'	yes	Materials survey
		Totals								

ADDITIONAL REMARKS: _____

Table 1, continued.—Monthly well data tabulation, July through October 1964.

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF August 19 64 SHEET 2

No.	Date 1964	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
16	8/24	Hwy. Dept.	Rankin	21-5N-2E	120'	-	-	119'	yes	Materials survey
17	8/25	Mansfield	Yazoo	9-9N-3W	800'	-	-	796'	no	Creel & Cresswell
18	8/28	Town of Beaumont	Perry	5-2N-9W	660'	-	-	655'	yes	Griner
19	8/28	Test Hole AF-50	Hinds	23-5N-2W	400'	-	-	397'	yes	Hinds Co. project
		Totals			5,597	850	-	5,138		

ADDITIONAL REMARKS:

Table 1, continued.—Monthly well data tabulation, July through October 1964.

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF Sept. 19 64 SHEET 1

No.	Date 1964	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
1	9/3	Sebe Reynolds	Hinds	8-6N-1W	678	-	-	674	No	R.G. McNeece Drlg.Co.
2	9/5	J.T. Nosser	Warren	15-16N-4E	1027	-	-	1025	No	Dean Griner
3	9/17	E.E. Ely	Rankin	20-4N-3E	335	-	-	335	Yes	Elec.&Gamma-Ray logs Gordon & McNees
4	9/18	AF-51	Hinds	2-5N-2W	100	100	60	100	Yes	Hinds County project
5	9/18	Stanton Pre-Stressed	Hinds	23-4N-1W	1502	-	-	1485	Yes	Logged 3 runs- Gamma-ray to 800'.Delta Drlg. Co.
6	9/22	Dewey Myers	Rankin	20-4N-3E	330	-	-	329	Yes	Gordon & McNees
7	9/25	Hole 289	Warren	28-17N-4E	15	-	15	14.5	Yes	Gamma-Ray log Loess project
8	9/25	Hole 237	Warren	39-17N-4E	109	-	108.5	108.5	Yes	Gamma-Ray log Loess project
9	9/25	Hole 182	Warren	5-16N-4E	50	-	50	47.5	Yes	Gamma-Ray log Loess project
10	9/28	Escatawpa #3 Bd.ofSuper.	Jackson	9-7S-6W	409	-	-	411	Yes	Elec. & Gamma-Ray logs. Sutter Well Works
11	9/29	Hole (China)	Warren	16-16N-4E	48	-	48	NL	Yes	Loess project
12	9/29	Hole 519	Warren	13-16N-4E	28	-	28	NL	Yes	Loess project
13	9/30	Hole 125	Warren	20-16N-4E	60	-	60	NL	Yes	Loess project
14	9/30	S.R. Pooly	Madison	5-7N-1E	707	-	-	330	No	Forest Drlg. Service
		Totals			5,398	100	369.5	4,529.5		

ADDITIONAL REMARKS: No's 11-13 not logged as yet.

Table 1, continued.—Monthly well data tabulation, July through October 1964.

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF October 19 64 SHEET 1 of 2

No.	Date	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
1	10/1	Test No.7, City of Vicksburg	Warren	2-16N-3E	200	-	-	195	Yes	Layne Central
2	10/1	Hadden No.1	Rankin	6-3N-2E	395	-	-	390	Yes	Gordon & McNees
3	10/1	F.T. Clark	Sunflower	11-2N-3W	614	-	-	587	614-TD No	Delta Drlg. Co.
4	10/5	Hole 125	Warren	20-16N-4E	60	-	*	58	Yes	Gamma-ray Loess project
5	10/5	Hole (China)	Warren	16-16N-4E	48	-	*	46	Yes	Gamma-ray Loess project
6	10/5	Test No.8 City of V'b	Warren	2-16N-3E	200	-	-	198	Yes	Layne Central
7	10/5	Test No.2 City of V'b	Warren	2-16N-3E	200	-	-	172	Yes	Gamma-ray Layne Central
8	10/5	Test No.6 City of V'b	Warren	2-16N-3E	200	-	-	168	No	Gamma-ray Layne Central
9	10/7	Test No.9 City of V'b	Warren	30-17N-4E	200	-	-	142	Yes	Layne Central
10	10/8	AF-52	Hinds	22-5N-2W	485	485	-	480	Yes	Test Hole Hinds Co. Report
11	10/9	AF-53	Hinds	24-5N-2W	404	404	-	401	Yes	Test Hole Hinds Co. Report
12	10/9	J.D. Green	LeFlore	5-19N-1W	1301	-	-	1301	Yes	Delta Drlg. Co.
13	10/12	AF-54	Hinds	10-7N-4W	120	120	-	118	Yes	Test Hole Hinds Co. Report
14	10/13	AF-55	Hinds	3-7N-4W	64	64	-	No log Lost Circ.	Yes	Test Hole, Hinds Co.**
15	10/14	Worrell	Rankin	18-5N-3E	784	-	-	255	Yes	Gordon & McNees
		Totals (carried forward)			5,275	1,073		4,511		

ADDITIONAL REMARKS: *Hole 125 & Hole (Rose Hill) entered previous month. **Two other holes drilled near. Lost circ.. Samples.

Table 1, continued.—Monthly well data tabulation, July through October 1964.

MISSISSIPPI GEOLOGICAL SURVEY MONTHLY WELL DATA TABULATION MONTH OF Oct. 19 64 SHEET 2

No.	Date 1964	Well designation	County	Location	Total depth	M.G.S. depth drilled	M.G.S. depth cored	Depth elec. log	Samples	Remarks
16	10/14	AF-56	Hinds	3-6N-4W	130	130	80-109	130	Yes	Test hole Hinds County report
17	10/16	AG-6	Rankin	4-3N-1E	170	170	0-67	170	Yes	Test hole Rankin County report
18	10/16	Bd.ofSuper. #3.Jackson Co.	Jackson	7-8S-5W	714	-	-	712	No	C.J. Switzer Well Co.
19	10/16	Bd. of Super. #6	Jackson	12-7S-6W	445	-	-	445	No	Sutter Well Works
20	10/19	AG-8	Rankin	12-3N-5E	140	140	-	140	Yes	Test hole Rankin County
21	10/20	AG-9	Rankin	25-4N-5E	120	120	-	120	Yes	Test hole Rankin County
22	10/21	AG-10	Rankin	3-3N-5E	180	180	-	180	Yes	Test hole Rankin County
23	10/23	B.L. Everett	Leflore	26-21N-1E	662	-	-	660	Yes	Gamma Ray 0-355 Delta Drlg. Co.
24	10/26	Holly Bluff #1	Yazoo	9-11N-5W	1116	-	-	1115	Yes	Gamma Ray 0-410 Layne Central
25	10/27	Love Pet. #2 Sowell	Rankin	18-5N-5W	1497	-	-	1497	No	Gamma Ray only
26	10/27	Hadden*	Rankin	6-3N-2E	1118	-	-	1114	Yes	Gordon & McNees
27	10/28	Chapman	Leflore	1-19N-1E	709	-	-	711	No	Delta Drlg. GRO-420 Chapman Subdivision
28	10/28	Brown Loam Exp.Sta.Test 1	Hinds	9-4N-3W	306	-	-	304	Yes	Forest Drlg. Service
29	10/29	Barns #1 Strain	Yazoo	11-13N-2W	1775	-	-	1773	No	Barns Drlg. Co. Meridian sand artesian
30	10/29	Int. Paper	Copiah	7-2N-1W	735	-	-	735	No	Griner
31	10/30	Lyon Inc.	Grenada	5-22N-5E	838	-	-	838	Yes	Robert Ratliff Drlg.Co.
		Totals			15,930	1,813	96	15,155		

ADDITIONAL REMARKS: *50'S of well logged 10-1-64

Table 1, continued.—Monthly well data tabulation, July through October 1964.

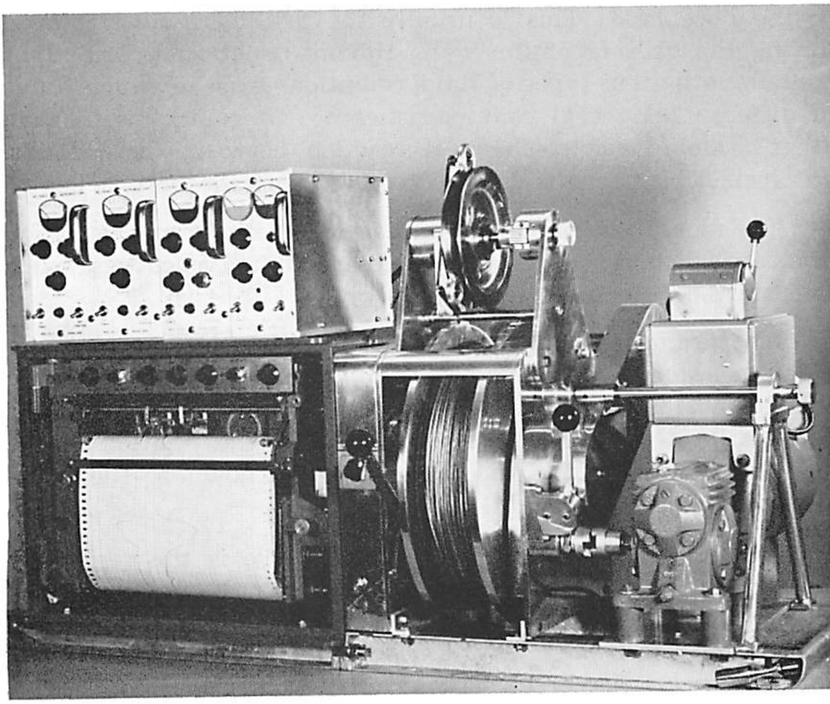


Figure 1.—Neltronic 2K Logger similar to the Survey's but equipped with additional panels that allow several more functions to be performed. The Survey logger is capable of making conventional two-curve electrical logs (self potential and resistivity) and gamma ray logs up to depths of 3,300 feet. The additional panels may be added as needed without modification of the instrument. Note electrical log tracing on chart. Photo provided by Neltronic Instrument Corporation.

1,500 feet in a cased hole. Open holes have been logged to depths as great as 800 feet.

ELECTRICAL LOGGING

A discussion of the methods of securing electrical logs must of necessity begin with an understanding of the medium to be investigated. The formations encountered in a bore hole are very resistive and by themselves conduct little or no electricity. It is the connate water and/or other formation fluids that may be filling the pore space of the strata that serve as conductor and provide for the measurement of the formation resistivity.

To obtain an electrical log there must be some type of fluid in the bore hole. This is usually the drilling mud employed during the drilling of the well. Having penetrated formations containing various types of fluid, conditions exist in which fluids of different electrical characteristics are in contact with each other. Due to electro-chemical reaction between these fluids, an electrical current is caused to flow along the bore hole.

The measurements of the formation resistivity and variation of electrical current in the bore hole are plotted as curves which constitute an electrical log.

Measurements of the electrical changes occurring in a bore hole are secured by an electrode traversing the well. As these changes are encountered they are recorded on a chart that has been calibrated for depth to correspond to the position of the logging electrode. This record is what is known as the spontaneous potential curve.

Basically a single point resistivity curve is the resistivity measurement of the opposition to the flow of an alternating current of low frequency between the logging electrode and the ground electrode. As the logging electrode traverses the bore hole, changes in formation resistivities cause changes in the electrode circuit. These changes are measured and plotted on a chart calibrated to correspond with the depth of the logging electrode. The resulting record is the resistivity curve.

The single-electrode method of resistivity measurement does not have as much lateral penetration as multi-electrode measurements, which are commonly used in oil well logging. Nevertheless, for obtaining correlations and bed thicknesses the single-electrode is as good, if not better than the multi-electrode. The lateral penetration of the single-electrode used by the Survey is approximately two feet. The resulting curve gives almost the same resistivity values that can be obtained with a short normal resistivity curve. The short normal curve is used by commercial logging companies as one of the resistivity measurements on their multicurve resistivity log.

Basic interpretation of electrical logs for correlation and lithologic determination requires no special knowledge when logs are obtained from an ideal section of rocks. Figure 2 illustrates the behavior of potential and resistivity curves in an ideal

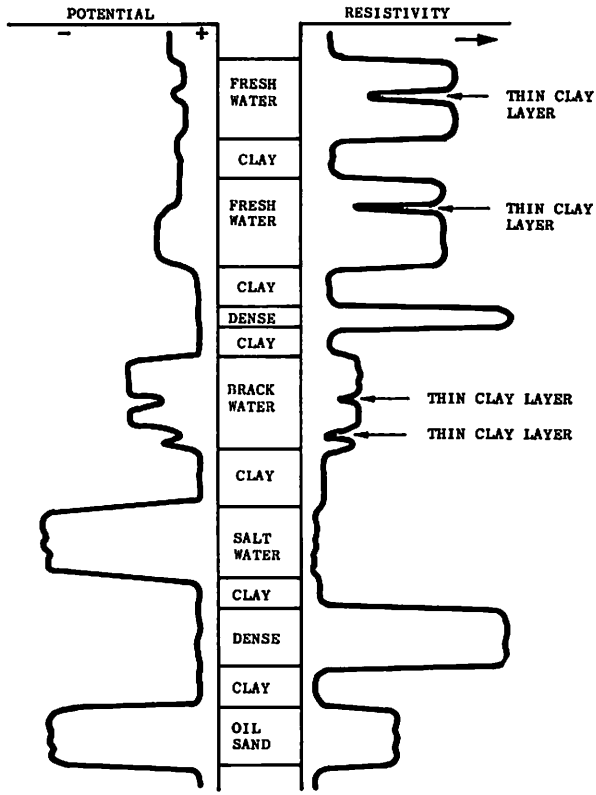


Figure 2.—Idealized electrical log. Note that the potential curve defines many of the boundaries of units and indicates the nature of many formations. Also, the resistivity curve shows that fresh water sands and dense formations have greater resistivity values than salt water sands, clays and shales. From the Widco Logger OPERATOR'S MANUAL published by Electro-Technical Laboratories.

medium. Ideal conditions do not always occur in nature and knowledge of the stratigraphic section can be helpful. The interpreter must consider the physical characteristics of the formations and their electrical responses. Other factors that may affect the log are bore hole conditions, porosity, permeability, bed thickness and mud conditions.

GAMMA RAY LOGGING

The radioactivity method of logging was first used commercially in 1940. After the close of World War II the Federal Government encouraged State agencies, oil companies, the mining industry and individual prospectors to use radioactive logging in their field investigations in order that unknown deposits of radioactive ores might not be overlooked.

Basically, gamma ray logging is the measurement of the natural radioactivity within a bore hole. This radioactivity is normally caused by minute traces of radium, uranium, potassium or other radioactive materials within the formations. Slightly radioactive material is concentrated in all types of vertebrate and organic residue so that normally sediments, such as shales and clays that commonly contain these residues, will exhibit a higher radioactivity than formations such as clean sand and carbonate rocks.

Most of the radioactive minerals are soluble to some degree. Therefore, ground water flow tends to transport and concentrate them as deposits in porous formations, resulting in possible erroneous measurements in respect to lithology. Accordingly, there is no hard and fast rule governing the amount of radioactivity of a given rock but, generally, shales, clays and marls are several times more radioactive than clean sand, sandstones and limestones.

There are several instruments used to measure the weak gamma ray intensity commonly emitted by the formations. Probably the best instrument to obtain a log in a reasonable operating time is the scintillometer, if the depth to be logged is above 5,000 feet. At greater depths heat adversely affects the scintillometer and other types of instruments are used.

Gamma ray logs have some distinct advantages in comparison to electrical logs. The most notable advantage is that of being able to secure logs in holes which are cased, as electrical logs cannot be run under these conditions. The absence of drilling fluids or the electrical characteristics of these fluids do not affect the quality of gamma ray logs, as is the case of electrical logs.

In the interpretation of gamma ray logs it must be remembered that in any given area only the relative radioactivity of the various strata is of significance. Rocks of low radioactivity include clean sands, sandstones, limestones and evaporites but their radioactivity increases as they become shaly.

For best results all radioactive logs should be correlated with a lithologic log in the area.

APPLICATION OF LOGS

Electrical logs are extremely valuable for many different geological studies, such as correlations between wells, subsurface mapping, location of fresh water bearing strata, determination of formation and bed thicknesses, lithology details, etc.

Presently the logging equipment is being used in the logging of core holes and test wells drilled by the Survey in the normal process of securing geological information. Although it is the policy of the Survey to secure statewide data, the logging of core holes and test wells is being concentrated in conjunction with the forthcoming bulletin on the geology and mineral resources of Hinds County.

Logging activity in the field of water well development is increasing monthly. It should be emphasized that electrical logs do not replace the water well contractor's local experience nor the driller's log, but provides an invaluable tool which enables him to see critical characteristics of the well. With the aid of the electrical log he can positively identify the fresh water formations. True thicknesses and depths of the formations are plotted to an accuracy of one foot. Nonproductive clays or dense rock lenses can be identified and avoided.

Clastic sediments, which are the objective of the contractor, are commonly highly susceptible to change from well to well even in a limited area. With the help of an electrical log the most productive portions of a water-bearing sand can be selected. Also the length of screen to be used and its position can be determined with great accuracy. Therefore, aided by the electrical log the contractor can eliminate faulty completions and the resulting wasted costs.

In addition to immediate assistance to the water well contractor in well completions, these electrical logs have another function in the never-ending search for ground water inasmuch as they are permanently filed for present and future use. They will be employed further for geological studies in preparation of more exacting structural, isopachous and lithofacies maps of the water-bearing strata of the State. At some future date, it will be possible to provide individuals, communities and industries with instant calculated predictions as to the water resources available for their immediate and future needs.

Recently the Survey logged a water well in Yazoo County which appears to indicate geologic structure of major proportions. Although some oil companies may have recognized this probability beforehand, the information was retained in their files and not available for general use. Public announcement of the log and structural possibilities may lead interested parties to additional geological work that may determine the presence of structure favorable for oil and gas accumulation (Plate 1).

MISSISSIPPI GEOLOGICAL ECONOMIC
& TOPOGRAPHICAL SURVEY

Frederic F. Mellen, Director & State Geologist

Jackson, Mississippi

For Immediate Release
November 3, 1964

Water Well Log May Indicate

Structure Favorable for Oil or Gas

On October 29 the Mississippi Geological Survey logged a water well in Yazoo County to the depth of 1775 feet. Although no samples were taken to confirm electrical log correlations, it appears that the geologic structure revealed by the well may be of major proportions. The well was drilled by John Barnes for Mr. Strain in the NW.¼ of SW.¼ of Section 11, T.13 N., R.2 W. The Survey logged the well electrically from the depths 143 to 1775 feet and has released this log today through L. L. Ridgway Company, Jackson, Mississippi, from whom copies may be purchased.

The well was drilled and completed as an excellent water well. However, due to the intense interest of the petroleum industry in the Smackover formation of Mississippi the immediate release of this log for geological study was considered advisable. According to State Geologist Fred Mellen, the well lies in an area characterized by graben faulting similar to many Arkansas producing structures. It is near the western end of the known extension of the Gilbertown-Pickens fault system. Additional geological work would be necessary before the information on the log could be fully evaluated and a determination made as to whether the structure of the area was favorable for oil and gas accumulation.

AVAILABILITY OF EQUIPMENT

The Survey is interested in logging any bore hole that will not otherwise be logged by commercial logging services and that will add materially to the geological information of the State. The equipment is available to any individual, contractor, or company on the basis of prior commitment and anyone desiring the services of the Survey equipment should make adequate arrangements beforehand.

To secure the services of the Survey equipment the following instructions have been transmitted to interested individuals and companies:

WELL LOGGING BY MISSISSIPPI GEOLOGICAL SURVEY
Instructions

October 1, 1964

HEADQUARTERS: The Mississippi Geological Survey's office is at 2525 North West Street in Jackson, Mississippi. The postal address is:

Mississippi Geological Survey
P. O. Drawer 4915
Jackson, Mississippi 39216

The telephone number is (Area Code 601) 362-1056.

INFORMATION DESIRED: The Mississippi Geological Survey wants samples caught at 10-foot or 20-foot intervals on wells throughout the State. Cloth sample bags will be furnished to the contractor by the Survey. The Survey believes that electrical logs (and/or gamma ray logs) should be run on all wells drilled within the State. This is a highly important source of information on the geology of Mississippi.

SURVEY WILL LOG: The Mississippi Geological Survey will log water wells or other drill holes THAT WILL NOT OTHERWISE BE LOGGED by commercial logging companies. This service will be limited by funds available, quality and quantity of information that might be derived, availability of equipment and operating personnel.

SURVEY'S EQUIPMENT: The Mississippi Geological Survey has a portable Widco electrical logger (2 curve) presently spooling 950 feet of neoprene cable.

The Survey now has a second logger, a Neltronic 2K instrument running 2 curves simultaneously. It is presently spooling 3300 feet of armored cable. This logger is mounted in a Chevrolet carryall and is powered in most cases by a 2500W generator which is carried with the logger. A gamma ray instrumentation permits logging through casing if necessary.

SURVEY'S STAFF: The Mississippi Geological Survey has 4 staff geologists who rotate in the operation of the logging equipment. The Survey may, in the future, secure the services of a specially trained operator for most of this work.

RECORDS: Since July 1, 1964 the Survey has kept a record of all wells logged with its instruments and such information is public information and may be inspected at the Survey's office.

COSTS OF LOGGING: At present there is no fee nor mileage charge for the logging of wells. When a well is logged the operator is under instructions to bring all tracings back to the Survey *office for completion of logs. The Survey will mail finished prints of these logs according to distribution instructions furnished. A charge of $1.00 per log copy is made to help the Survey take care of some of its reproduction costs. This was discussed with numerous contractors and others who agree that the charge is reasonable. Many contractors have standing requirements for copies ranging from 2 to 10 of each log. Logs are usually mailed from Jackson within 24 hours of running.*

LOGS ARE PUBLIC PROPERTY; SURVEY ASSUMES NO LIABILITY: *Logs run on wells with Survey equipment are public property and will be placed in the Survey's open file along with other thousands of logs in these files, subject to inspection by any contractor, geologist, engineer, or other person.*

The Survey assumes responsibility for damage or loss of its equipment unless through negligence or willful act of the contractor or his representative. The Survey assumes no liability for any damage that might result through the logging of any well or through the irretrievable loss of logging equipment in the contractor's well being logged.

These instructions and regulations are subject to review and to amendment, but are set down as guidelines to procedure.

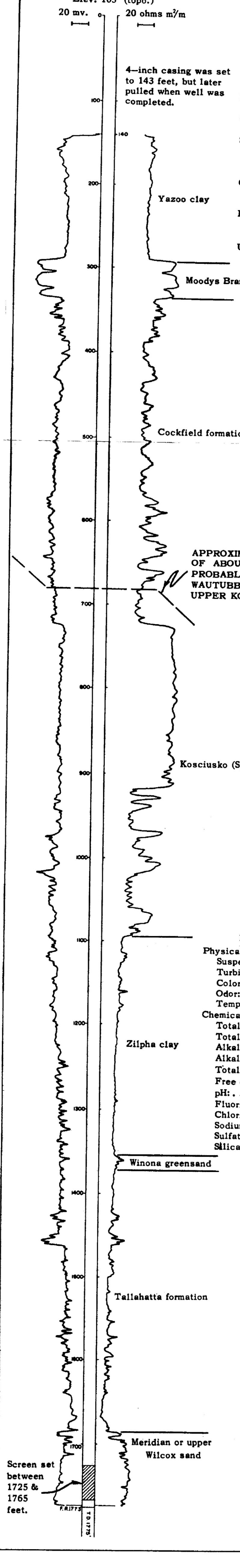
WHEN ORDERING LOGGER: *When ordering logger it would be desirable to let the Survey know in advance that the well will be started and the approximate date that logger would be needed. Also, an alert a day or two in advance would help in our work scheduling.*

When ready for logger call the Survey office FIRST (362-1056). If no answer, call State Geologist Fred Mellen at 372-3834; *if no answer call Mr. Alvin Bicker at* 372-8661. *All numbers dialed through Jackson.*

MISSISSIPPI GEOLOGICAL SURVEY

NELTRONIC ELECTRICAL LOG

Water Well
John G. Barnes
No. 1 G. C. Strain
Elev. 105′ (topo.)



COMPLETION DATA

Contractor : John G. Barnes, Water Wells Drilling & Supply, Tinsley, Miss.

Owner : Mr. G. C. Strain, Route 2, Yazoo City.

Location of well : Near Center SW ¼, Sec. 11, T. 13 N., R. 2 W., Yazoo Co.

Date logged : October 29, 1964.

Casing : 2—inch casing to 1725 feet.

Screen : 40 feet of stainless steel screen set between the depths of 1725 and 1765 feet.

Capacity : Well is reported to flow at about 80 g.p.m.

Pressure : Shut—in pressure 50 lbs./sq. inch.

Use : It is proposed that this well will supply a residence and at least two tenant houses.

WATER ANALYSIS

Mississippi State Board of Health

Physical characteristics:	
Suspended matter:	None
Turbidity:	Less than 2
Color:	25
Odor:	None
Temperature:	90 F.
Chemical characteristics (p.p.m.):	
Total solids:	438.96
Total hardness as $CaCO_3$:	Trace
Alkalinity (P):	28
Alkalinity (M):	370
Total iron:	0.2
Free carbon dioxide:	0
pH:	8.6
Fluoride:	0.6
Chloride:	13
Sodium & potassium as sodium:	191.45
Sulfate:	0
Silica:	4.4

RECENT BULLETINS

95. Jasper County Mineral Resources: David A. DeVries, et al. 101 pp., 21 figs., 8 pl., 2 tables, 1963. $1.00
This report is a study of the outcrop formations, their characteristics and their economic importance. It contains a section on oil and gas production by Hugh McD. Morse; a section on subsurface stratigraphy by William H. Moore, and a section on ground-water geology and subsurface structure by Marshall K. Kern.

96. The Tula Prospect Lafayette County, Mississippi: Frederic F. Mellen and William H. Moore. 30 pp., 7 figs., 2 pl., 1962. $1.00
A study of available geological and geophysical data on an area in Lafayette County thought to be favorable for the accumulation of commercial oil or gas deposits, and a review of the possibilities for Cambrian and pre-Cambrian oil and gas in northern Mississippi.

97. Mississippi Geologic Research Papers-1962; Contains, Economic Potential of Alumina-rich Clays and Bauxite in Mississippi, by Marshall K. Kern; Stratigraphic Implications from Studies of the Mesozoic of Central and Southern Mississippi, by William H. Moore; Land Snails from the Loess of Mississippi, by Leslie Hubricht; Pleistocene Land Snails of Southern Mississippi and Adjacent Louisiana, by Leslie Hubricht; Problem of Dessication Sinking at Clarksdale, by Tracy W. Lusk; and Geologic History and Oil and Gas Possibilities of Mississippi, by E. H. Rainwater. 106 pp., 50 figs., 1963. $1.00

98. Geologic Study Along Highway 25 from Starkville to Carthage: Tracy W. Lusk. 48 pp., 15 figs., 3 pl., 1963. $1.00
This is the fourth in a series of geologic studies made by the Survey along State Highways. Beds from Upper Cretaceous to Middle Eocene are profiled and described.

99. Attala County Mineral Resources: William S. Parks, et al. 192 pp., 32 figs., 6 pl., 12 tables, 1963. $2.00
The report contains additional sections: Attala County Ceramic Tests, by Thomas E. McCutcheon; Attala County Subsurface Geology, by William H. Moore; and Water Resources of Attala County, Mississippi, by B. E. Wasson.

100. The Mississippi Geological Survey, A Centennial: Contains, Report of a Geological Reconnaissance of Parts of the Counties of Yazoo, Issaquena, Washington, Holmes, Bolivar, Tallahatchie, Coahoma, Mississippi During the Months of October and November, 1870, by Eugene A. Smith; History of the Mississippi Geological Survey, by Ephraim N. Lowe; Memorial to Ephraim N. Lowe (1864-1933), by William C. Morse; Address at recognition dinner honoring Dr. W. C. Morse and Prof. F. E. Vestal, upon their retirements, by Frederic F. Mellen; Memorial to William Clifford Morse, by Franklin E. Vestal; Employment in the mining industry in Mississippi, by William T. Hankins; The Present Course of the Mississippi Geological Survey, by Frederic F. Mellen and William S. Parks; The Survey's enabling act; List of State Geologists; Index to Bulletins 1-99, by William S. Parks. 183 pp., 32 figs., frontispiece. 1963. $2.00

101. An Investigation of Iron Ore of Mississippi: Marshall K. Kern, 77 pp., 11 figs. 6 tables, frontispiece. 1963. $1.00
Numerous test holes were drilled and many chemical analyses were made. A summary is given of ore produced and sold in the past and of the one smelting operation in 1913 at Winborn.

102. Mississippi Geologic Research Papers-1963: Contains, Regional Stratigraphy of the Midway and Wilcox in Mississippi, by Edward H. Rainwater; Late Pleistocene and Recent History of Mississippi Sound Between Beauvoir and Ship Island, by Edward H. Rainwater; and Geology of Northeast Quarter of the West Point, Mississippi Quadrangle, and Related Bentonites, by Thomas F. Torries. 98 pp., 22 figs., 22 graphic logs, 3 tables, 1 plate. 1964. $1.00

103. Survey of Lightweight Aggregate Materials of Mississippi: Geology by William S. Parks; Economics by Clyde A. McLeod; and Tests by Allan G. Wehr. 115 pp., 18 figs., 10 tables. 1964. $2.00.

104. Mississippi Geologic Research Papers-1964: $2.00.

105. Hinds County Mineral Resources: IN PREPARATION.

order from

The Director

Mississippi Geological Survey

Box 4915

Jackson, Mississippi 39216