MISSISSIPPI
STATE GEOLOGICAL SURVEY

WILLIAM CLIFFORD MORSE, Ph.D.
Director

BULLETIN 85

CRETACEOUS SHELF SEDIMENTS OF MISSISSIPPI

By

FREDERIC FRANCIS MELLEN, M.S.

UNIVERSITY, MISSISSIPPI
1958

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MISSISSIPPI GEOLOGICAL SURVEY

COMMISSION

STAFF

LETTER OF TRANSMITTAL

Office of the Mississippi Geological Survey
University, Mississippi

April 18, 1958

To His Excellency,
Governor James Plemon Coleman, Chairman, and
Members of the Geological Commission

Herewith is Bulletin 85, Cretaceous Shelf Sediments of Mississippi, by Frederic Francis Mellen, M.S.

According to the author these Cretaceous Shelf Sediments of Mississippi underlie or crop out over 99 percent of the State—the exceptions are the few small areas of Paleozoic rocks in Tishomingo County, the small stocks of rock salt, and the small piercement areas of volcanic rocks.

The Cretaceous had, up to January 1, 1957, produced 83 percent of all the oil and 95 percent of all the natural gas of the State.

From his extensive as well as intensive study of Mississippi, especially of the wide spread hardened asphaltic material, Mellen believes more oil will be found farther north in Mississippi than heretofore. Thus one of the best qualified geologists still remains optimistic.

Renewed prospecting will, no doubt, follow the appearance of this report. May it prove successful.

Sincerely,

William Clifford Morse
Director and State Geologist

CONTENTS

Page

Introduction 7

Background to the Cretaceous shelf deposition 10

Stratigraphic taxonomy of Cretaceous shelf sediments 19

The Coffee sand 22

The Annona chalk and its Coonewah bed 29

Discussion on the foraminifera—William S. Parks 40

Discussion on the ostracoda—Robert H. Shaver 44

Chiwapa sandstone member of Ripley formation 49

Economic Geology 55

Oil and gas in the Cretaceous shelf sediments of Mississippi 57

Conclusions 64

Acknowledgments 66

Suggested future studies of the Cretaceous sediments 68

Bibliography 72

ILLUSTRATIONS

FIGURES

Page

1. Depositional provinces of Gulf of Mexico 8
2. Diagrammatic cross section—south to north 10
3. Geologic structure section, eastern Mississippi 10
4. Stratigraphic diagram—Jackson Dome 12
5. Contact of the Little Bear residuum and Tuscaloosa formation 13
6. Gravel member of Tuscaloosa formation 14
7. Contact of Iuka chert . . . and Tuscaloosa formation 15
8. Structure map, Paleozoic floor 16
9. Schematic diagram . . . of outcropping upper Cretaceous in eastern Gulf Coast 18
10. Diagrammatic cross section . . . northwest to southeast 18
11. Unconformity between Tuscaloosa and Eutaw formations 21
12. Tombigbee sand member of Eutaw formation 22
13. Areal distribution of Coffee sand 23
14. Type locality of Coonewah bed [and other information] 25
15. Coffee sand overlain by Selma chalk [Annona] 26
16. Coffee sand and overlying oyster reef 27
17. Structure map of Coonewah bed of Annona chalk 31
18. Demopolis chalk 32
19. Insoluble residue chart—Stovall No. 1 core hole, Lee County 32
20. Insoluble residue chart—Natchez Trace No. 2-A core hole, Lee County 34
21. Gullies in lower Demopolis member of Selma chalk, Clay County 36
22. Cross section showing Coonewah bed 36

Page

23. Cross section showing Coonewah bed of Annona chalk 36
24. Isopachous map—Coonewah bed to top of Paleozoic 37
25. Isopachous map—base Midway shale to Coonewah bed 38
26. Foraminiferal chart (by William S. Parks) 40
27. Ostracodal chart (by Robert H. Shaver) 44
28. Chiwapa sandstone 2 miles east of Pontotoc 49
29. Lower opening of "The Caves," . . . Chiwapa sandstone, Union County 50
30. Upper opening of "The Caves," . . . Chiwapa sandstone 50
31. Type locality of the McNairy sand member of the Ripley formation 51
32. Geologic map of Pontotoc County 50
33. Type locality of Owl Creek formation . . . Tippah County 52
34. Habitat of oil . . . according to basin position in depositional basin 57
35. Habitat of oil . . . according to basin position in present structural basin 58
36. Seaboard Oil Company's core hole No. 2 (Roseborough), Tate County 60

Table I. Analyses of Lower Selma Chalks and Limestone in Lee County 34

CRETACEOUS SHELF SEDIMENTS OF MISSISSIPPI

FREDERIC FRANCIS MELLEN, M.S.

INTRODUCTION

The Cretaceous deposits of Mississippi are no doubt the most interesting sediments of the State. They occupy a large area of exposure in a wide crescentic band along the Alabama line in northeast Mississippi, whence they dip at slightly varying low rates, mostly around a quarter or a third of a degree, to the southwest, west, and west-northwest. Sediments of no other period of geologic time are so widespread in the State: the Cretaceous deposits underlie or crop out over 99 percent of the surface area. The rare exceptions are the few small areas of outcrop of Paleozoic rocks in Tishomingo County, and the very local structures where the buried Cretaceous deposits are pierced by stocks of rock salt or are locally intruded by volcanic rocks. As used throughout this report "Cretaceous" applies to those beds commonly referred to as "Upper Cretaceous" or "Gulf - Cretaceous." "Comanchean" is similarly used for those beds referred to by some as "Lower Cretaceous."

Geology in its broadest definition is the interpretation of the events of the past through evidences recorded in the rocks. These events can be reconstructed only by imagination that is guided by the physical processes that can be seen at work on every hand in the world today. The works of the agents of aggradation and degradation, the winds and waters, vulcanism, and the destructive and creative activities of plant and animal life were, in their principles, no different in Cretaceous times than they are today.

Specifically, the environs of Cretaceous shelf deposition in north Mississippi were at times very similar to present day depositional environs along the north of the Gulf of Mexico (Figure 1): the strand lines were essentially parallel, the prevailing winds and longshore and other hydrological currents are believed to have been similar, the types of sediments and their arrangements were similar, and although all the Cretaceous species of animal and plant life are long since extinct, many of the animal forms have closely related species living under similar environments in the marshes, around the beaches, free-swimming in the open waters, and on the floor of the continental shelf, just as they did during Cretaceous times. The angiosperms, modern-type trees, were abundant on the bordering shores of the Cretaceous sea as evidenced by the delicately preserved fossil leaves in some of the clays, by large and small logs and branches that have become lignitized or silicified after enclosure in the clays and sands, and by the chunks of *Teredo*-filled lignite that, as flotsam in the Cretaceous sea, sank to become incorporated in the deeper chalk and chalky marls. The chief difference between the modern and the Cretaceous environment is the much greater southwesterly distance to the active volcanoes of Central America than the volcanic islands at Jackson and the Monroe-Sharkey platform were removed from our Cretaceous shelf sediments.

Much research work in the field of marine biology, ecology and sedimentation has been done and is being pushed today. Hundreds of titles in this field could be searched for principles applicable to the present study. Only a few of the outstanding references that happened to be readily available were utilized; but in order to understand fully and to reconstruct the three-dimensional geology of the Cretaceous shelf deposition and its ecologies, it is fundamental to keep abreast of the findings of the researchers into modern sedimentation, oceanography, marine and littoral biology, and even meteorology.

In much of the area of north Mississippi, the Cretaceous sediments must be thought of as overburden through which it is necessary to drill in search for oil and gas in Paleozoic "hard" rocks. In drilling these Paleozoic wells much useful data on the Cretaceous sediments is uncovered. From these sediments may be learned the nature of the environment of their deposition, their probable sources, and the approximate depth of the sea at any specified time; the range of the fauna of the Cretaceous sea, laterally and vertically; the distribution of fresh and salt waters in their porous deposits; where the lands were in Cretaceous time; how much tilting there has been of essentially horizontal beds subsequent to deposition; where the deposits are of bentonite or of chalks or marls of certain required composition, or of sands or gravels, or of fresh water resources in sands that were deposited in a salty open sea. By pursuing these studies further than it has been the writer's pleasure or opportunity to do, the depositional breaks in the Cretaceous shelf sediments of Mississippi probably can be related intimately to diastrophic

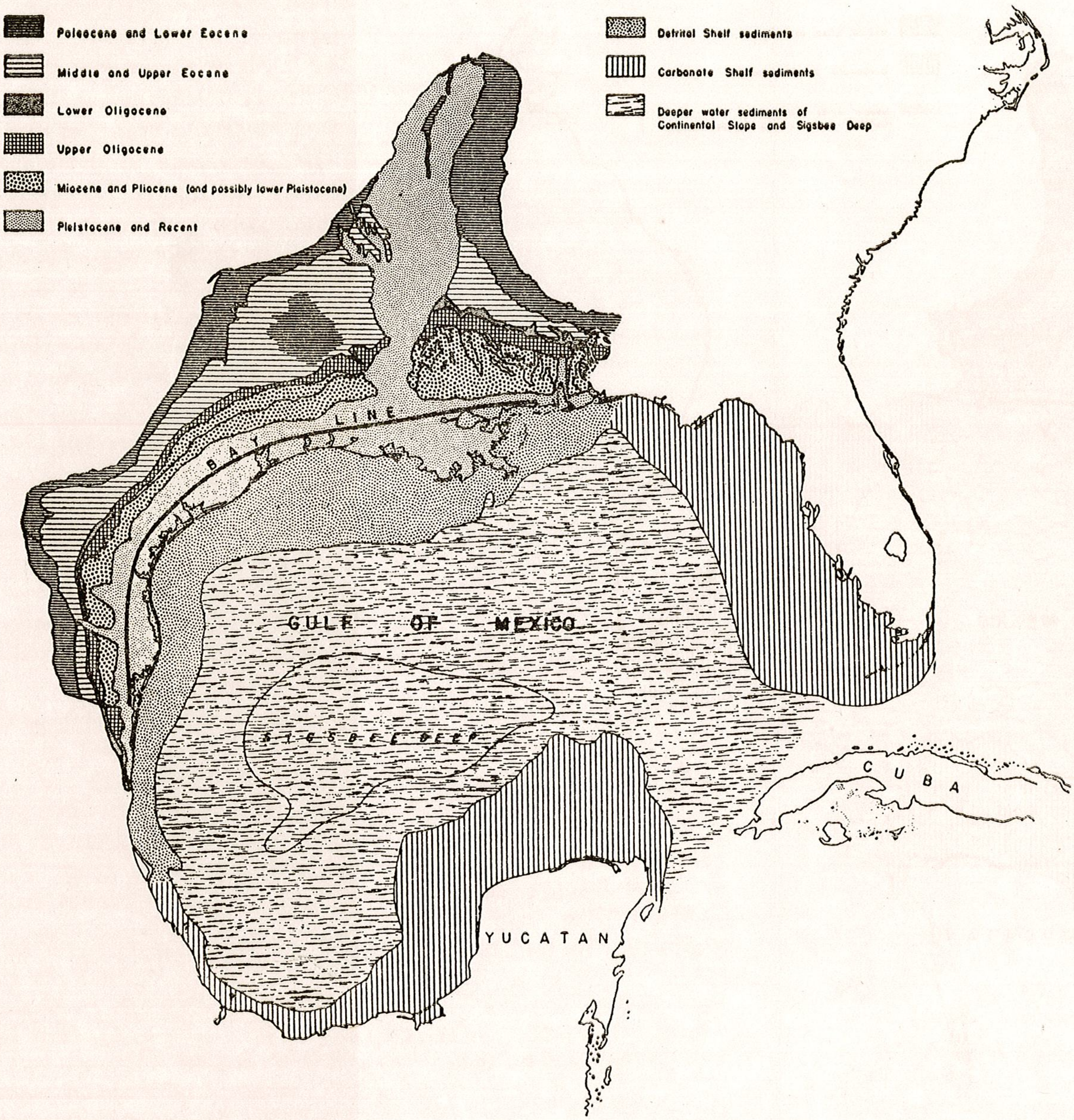

Fig. 1.—Depositional provinces of Gulf of Mexico and surface geology of northwestern Gulf Coastal Plain. Surface geology from Geologic Map of North America (Geological Society of America), compiled by George W. Stose, United States Geological Survey. Scale: 1 inch equals 250 miles. From S. W. Lowman, Bull. A.A.P.G., Vol. 33, No. 12, Fig. 1, p. 1943.

events, to the sharp down-warping at the hinge line on the inner limit of the Mississippi Interior Salt Basin, and even to the timing of the great volcanic eruptions which yielded bentonite, biotite mica and other volcanic debris to the Cretaceous sediments.

Electrical logging of wells has made possible subsurface geological work that could not even be attempted before its advent. The sensitivities of the electrodes record slight changes in formation texture and character that could not be discerned by ordinary visual inspection of the materials logged, and the measurements of depths and thicknesses reach accuracies heretofore unattainable. The basic fact remains, however, that lithologic samples are necessary to electrical log interpretation; it is inherent that the better and the more accurate the sample, the better interpretation can be had from the electrical log. Although well samples through the Annona do show increase in purity of the chalk, the stratigraphic position of the Annona and the Coonewah bed might never have been worked out with certainty with well-cutting analyses alone. With constant study and background data, the electrical log is also useful in the determination of fluid content of reservoir rocks. A study of these logs can reveal even the approximate or relative salinity of formation waters.

The present series of parallel and tangential studies, constituting, in the main, a review of published knowledge of Cretaceous geology, were begun as an investigation into the Paleozoic geology of oil and natural gas. Millions of dollars have been spent in north Mississippi since the 1952 discovery of Muldon Field* on geophysical exploration, core drilling, and deeper exploratory drilling. Because of this increased exploratory activity, much more data existed in the shallower geologic levels than in the deeper levels. With a considerable amount of these data

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* Muldon Gas-condensate Field, discovered by rework of Carter Oil Company's No. 1 J. T. Sanders, T.15 S., R.6 E., Monroe County, Mississippi, was an open hole completion from the Carter and Sanders sandstones of the Chester, upper Mississippian. It was completed by Union Producing Company in February, 1952. Although the first gas production in Mississippi was in the Carter sandstone of the Amory, Monroe County, Field, discovered in 1926, Paleozoic production of oil and gas was not looked upon as promising until the Muldon discovery. The combined open flow daily potential of the eight Muldon wells is 400,000,000 cubic feet of gas. The current monthly rate of production is in excess of 500,000,000 cubic feet of gas plus some 4500-5000 barrels of water-clear condensate.

available to him the writer set out to review the shallow Cretaceous data with the following objectives:

1) To determine the relation of Cretaceous structure to known Paleozoic structure;
2) To study the facies changes in the Cretaceous section in an effort to detect any obvious reason for abrupt velocity changes that would affect the accuracy of seismic computation;
3) To find the most useful structural mapping datum in the Cretaceous for general mapping;
4) To reconstruct, as much as possible, the pre-Cretaceous or early Cretaceous geomorphology as an aid in the search for Paleozoic oil or gas;
5) To determine whether or not the shelf sediments of the Cretaceous of northern Mississippi might be a favored habitat for deposits of oil and natural gas.

BACK-GROUND TO THE CRETACEOUS SHELF DEPOSITION

The Cretaceous deposits are interesting because they are dominantly of shallow marine origin, and the rich fauna contained therein helps in the correlation of these beds with Cretaceous beds hundreds or even thousands of miles away. They are also interesting because of the diversity in environment of deposition. Though some of Mississippi's Cretaceous sea may have been at its maximum northward advance, a hundred fathoms or more in depth, the great part of the sedimentary accumulation was in waters on the continental shelf, and the fossils and sediments we see on the outcrop and in wells in northern Mississippi were laid down on the landward shelf of the sea, perhaps on barrier islands, on beaches, in sounds and bays, and perhaps in lagoons and deltaic distributaries.

In the development of the oil and natural gas industry in Mississippi, a few thousand wells have been drilled, the deepest one to a depth of 20,450 feet. By combining the sedimentary section penetrated by these many deep wells, and by projecting additional indicated thicknesses, the State has some 50,000 feet, more or less, of sedimentary rock, ranging in age from Cambrian

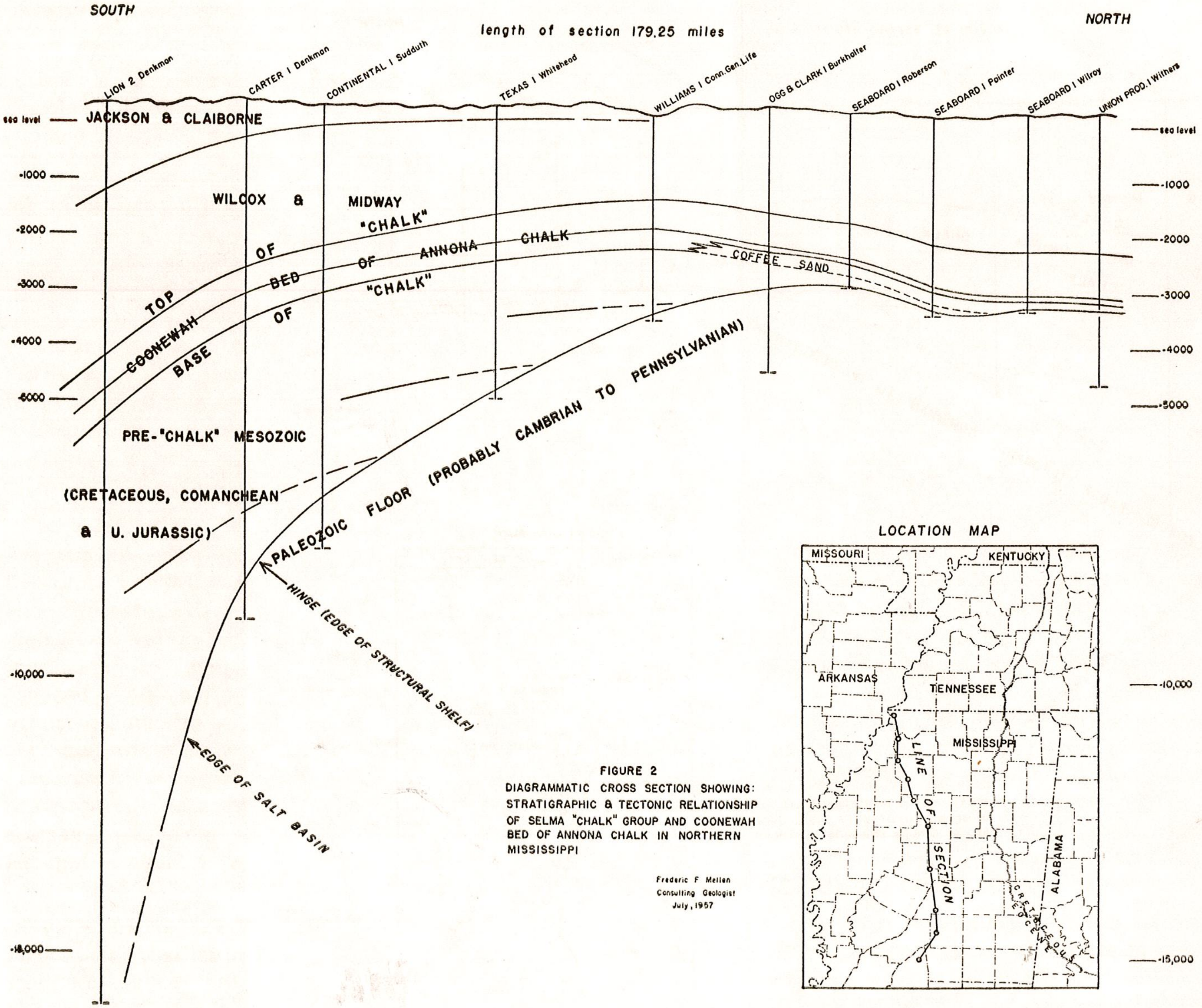


FIGURE 2

DIAGRAMMATIC CROSS SECTION SHOWING: STRATIGRAPHIC & TECTONIC RELATIONSHIP OF SELMA "CHALK" GROUP AND COONEWAH BED OF ANNONA CHALK IN NORTHERN MISSISSIPPI

Frederic F Mellen
Consulting Geologist
July, 1957

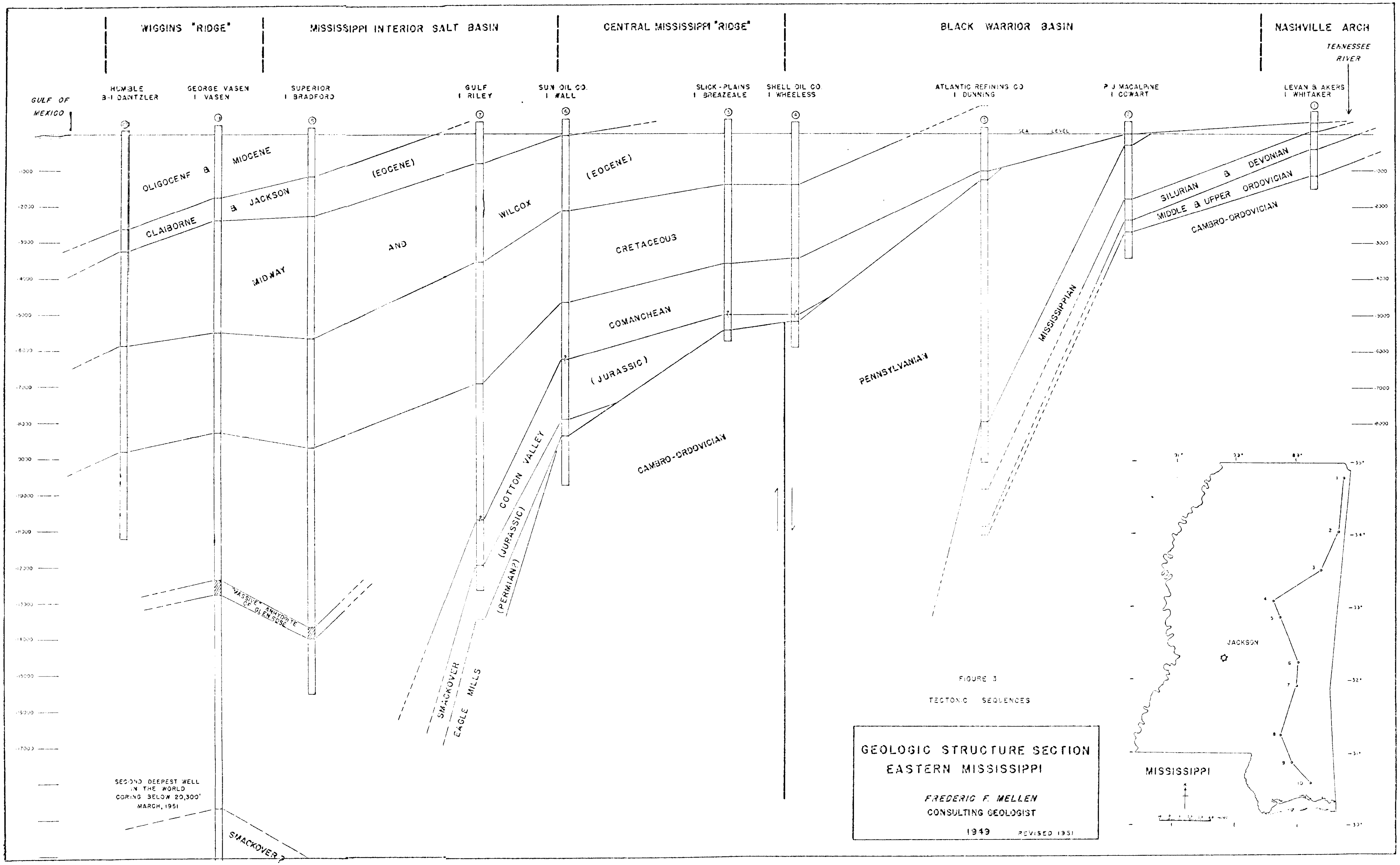


FIGURE 3

TECTONIC SEQUENCES

GEOLOGIC STRUCTURE SECTION
EASTERN MISSISSIPPI

FREDERIC F. MELLEN
CONSULTING GEOLOGIST

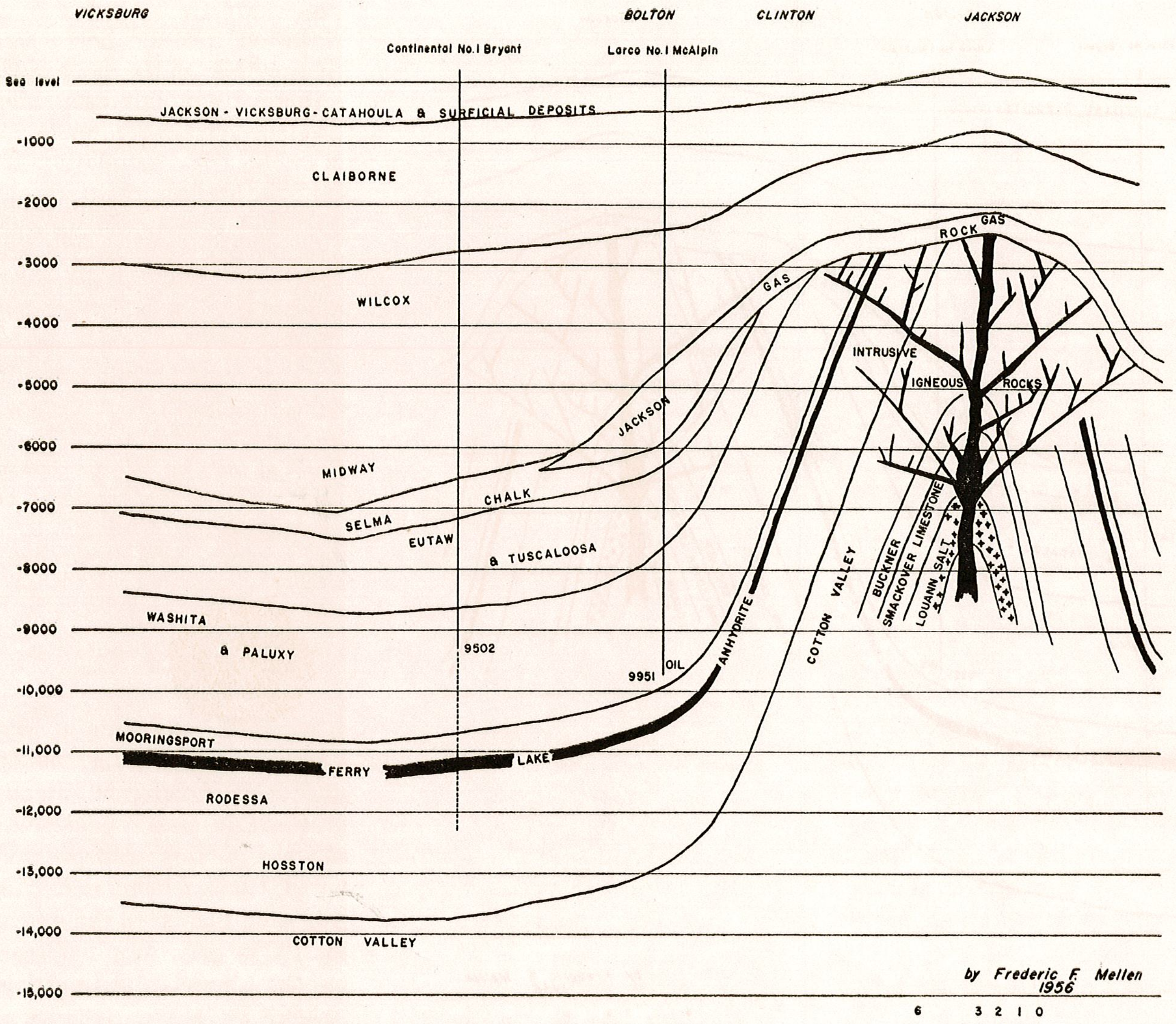
1949 REVISED 1951

to Miocene and Recent. Not all the geologic formations in the sedimentary section crop out. Nowhere in Mississippi, are the thick Pennsylvanian, the thick Comanchean (Lower Cretaceous), and the thick Jurassic strata exposed at the surface. Nowhere in Mississippi have the "basement" rocks been encountered. Our knowledge of these formations is at present limited to relatively few deep wells.

It is the history of the oil and gas industry in most provinces, closely geared to economics, that shallow production comes first, and that as time passes deeper and deeper drilling results in the areas of the early shallow production. To a certain extent this has been true in Mississippi, but less so than in other regions. As the first production of oil in Mississippi was from Cretaceous rocks (as was the first large gas production, at Jackson), most of the drilling in the State from 1930 to 1950 was in the search for Cretaceous oil. By far the larger percentage of these wells was in the Mississippi Interior Salt Basin where the gravity meter was the most successful exploration tool. Inasmuch as the Jurassic salt terminates abruptly just south of the hinge line (Figure 2) of the Cretaceous shelf, no gravity minimum anomalies on the shelf were believed to represent the type of structures productive within the salt basin. In other words, the shelf area is actually another province as far as oil and gas are concerned, and different types of exploration techniques are needed to locate the structures and traps favorable for the accumulation of commercial quantities of oil and natural gas. It is also true of the Cretaceous shelf that there is only a comparatively short section of prospective oil-or-gas-bearing formations in the Cretaceous and the thin underlying wedge of Comanchean clastic sediments above the "hard rocks" of Paleozoic age. Therefore, on the whole, the Cretaceous shelf has not been drilled extensively, and its stratigraphy and economic geology are not so well known as in the Mississippi Interior Salt Basin.

Through the construction of a cross section from the north edge of Mississippi to the Gulf of Mexico, are observed repetitious tectonic sequences, three in number, progressively younger to the south (Figure 3). In sequence are (1) the Black Warrior Basin, containing great thicknesses of Pennsylvanian sediments; (2) the Mississippi Interior Salt Basin with its great thicknesses of Jurassic and Comanchean, and where the Cretaceous deposits are thicker than elsewhere; (3) lastly, but lying for the most part south of Mississippi under the Gulf of Mexico and in south Louisiana, the Miocene basin whose enormous thicknesses of sediment have never been fully penetrated. On the north side of each of these three basins there is a stable platform or shelf area; on the south side of each basin there is a mobile basin rim, mobile during or shortly after its final period of greatest sedimentation. Each mobile rim served as the firm foundation for the stable shelf deposits of each next-succeeding basin to the south. The core of the Central Mississippi Ridge was uplifted during the Appalachian Revolution and, during Permian, Triassic and possibly early Jurassic times the structural and physiographic irregularities of the Paleozoic surface were worn down to a fairly regular land surface. The Wiggins Ridge was probably mobile during the approximate period of the Laramide Revolution, but subsequently has acted as a stable shelf for deposition of Tertiary and Quaternary sediments. The mobile rim of the Miocene Basin undoubtedly lies within the present Gulf of Mexico. This tectonic periodicity, although we can see it only imperfectly, reflects on a much grander scale the southward migration of the Gulf of Mexico that is so clear in the marine transgressions and regressions of the Cretaceous and Tertiary seas, and that is so obvious in the comparison herein of the Coffee sea (of middle Selma time) with the configuration, sedimentation and population of the present Gulf of Mexico.

Our present subject, the Cretaceous shelf sediments of Mississippi, is not too greatly concerned with the underlying Comanchean strata, most of which lie in the deep Mississippi Interior Salt Basin. Normal reworking of the coarsely clastic near-shore Comanchean sediments by the northward-moving transgressive Cretaceous sea, and re-incorporation of Comanchean materials into the basal Cretaceous conglomeratic sand furnished the quartz grains, granules and pebbles to deposits largely supplied from limestone and chert terrains to the north. Likewise, at intervals, uplift and erosion from the volcanic islands at Jackson (Figure 4) and the Sharkey-Monroe uplift permitted large bodies of quartz sand and other detritus to be stripped from slightly earlier Cretaceous deposits, from the Comanchean, and even from the uppermost Upper Jurassic, and to be swept back into the sea as depositional tongues of sand wedging out into the Cretaceous clays and



by Frederic F. Mellen
1956

STRATIGRAPHIC DIAGRAM OF BIG BLACK SYNCLINE AND JACKSON DOME FIG. 4

chalks, or as widespread shelf sands such as the Coffee, to be described later.

Cross sections and isopachous maps show that the Cretaceous rocks, on the whole, maintain fairly uniform thicknesses on the shelf, but that these thicknesses increase materially south of the hinge line in the northern part of the Mississippi Interior Salt Basin. The increases in thicknesses are, likewise, coincident with the sharp steepening of the dip in the Cretaceous rocks, even steeper in the Comanchean beds. The dips are not enough, however, to explain the increased thicknesses. It is presumed, for the present, anyway, that this tectonic hinge line was the continental shelf during most of Selma chalk deposition. The Cretaceous shelf deposits, as used herein, extend from the edge of the Mississippi Interior Salt Basin to the head of the Mississippi Embayment in the vicinity of Cairo, Illinois. Many of the beds in the northern part of the area are not, however, true shelf

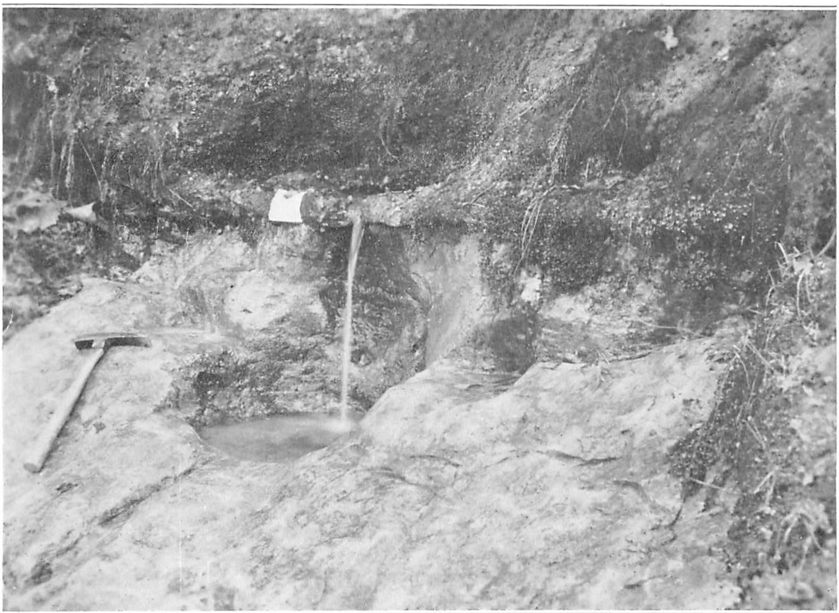


Figure 5.—Contact (paper) of the Little Bear residuum and the Tuscaloosa formation (Gordo formation) at the head (SW.¼, Sec.4, T.3 S., R.11 E.) of a small branch of Little Bear Creek, Tishomingo County, Mississippi. Type locality. April 2, 1937 (M.G.S. Bull.34, Fig.3).

deposits inasmuch as they were deposited under more landward environments.

A pre-Cretaceous regolith or soil mantle had been developed during the long period of time when the upper part of the shelf area, north Mississippi, western Tennessee, western Kentucky, southern Illinois, and perhaps other areas, was exposed as land (Figure 5). As is true of most terrestrial materials, this ancient soil was preserved only with difficulty because, on land surfaces, the dominant processes are degradational. Much of the old soil was reworked as clays and silts into the basal transgressive beds, for the most part gravelly, of the Cretaceous, losing its identity as a residual soil, but maintaining its mineralogical character and its lixiviated or oxidized colors of red, brown, yellow or white. In many places, the basal transgressive gravelly sand (Figure 6)

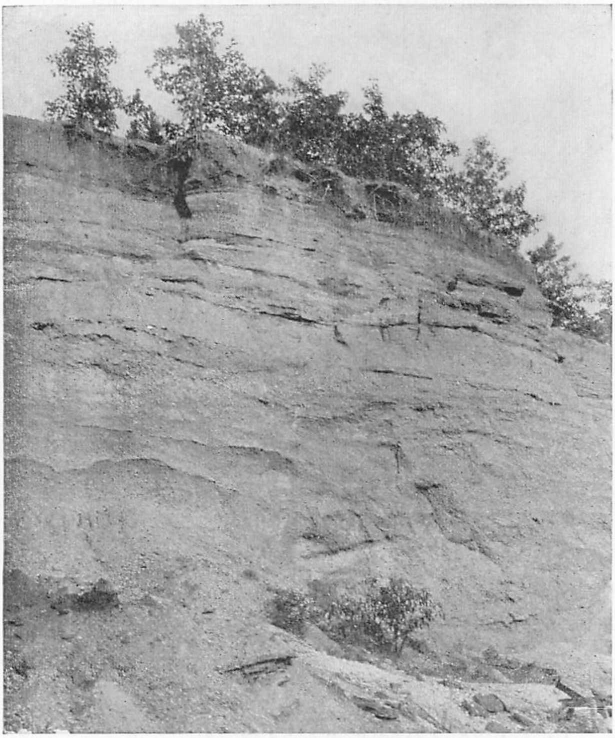


Figure 6.—Gravel member of the Tuscaloosa formation; abandoned pit north of the Southern Railway, 2½ miles southeast of Iuka, Tishomingo County, Mississippi (M.G.S. Bull.40, Fig.4) Photo by E. W. Shaw.

rests in sharp non-conformable contact upon the cleanly swept Paleozoic surface (Figure 7). In as many other places, however, the regolith intervenes. It is recognized, of course, that at the head of the Embayment, the soil is younger than it is farther south, because it was submerged by the advancing sea at a later time. The dating of soils is always difficult: they are normally without distinctive fauna or flora; in many cases they lie on weathered surfaces of various formations; the overlying strata

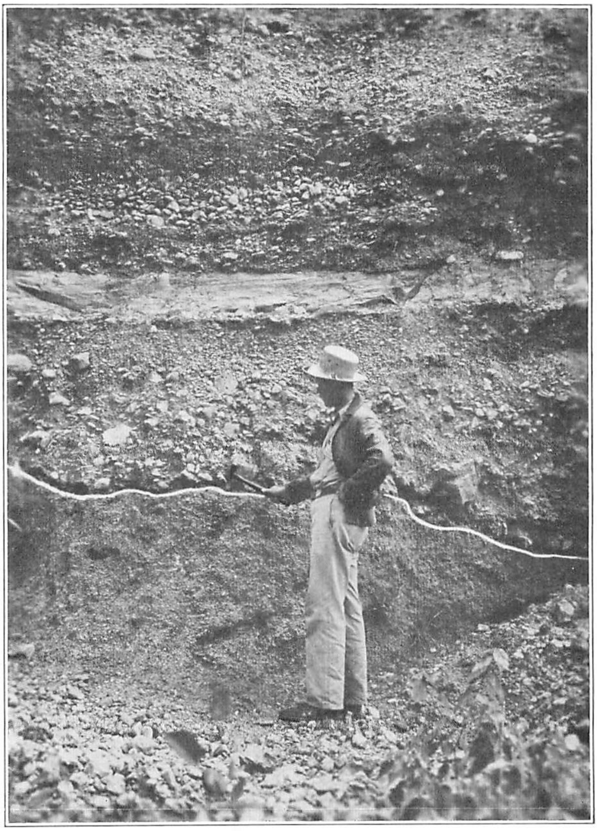


Figure 7.—Contact of Iuka chert (Lower Mississippian) and Tuscaloosa formation (Gordo formation) in a gravel pit (SE.¼, Sec.17, T.2 S., R.10 E., Tishomingo County) ten miles northwest of Iuka, Mississippi. The Little Bear residuum was swept away by the swift currents which rolled in the large chert blocks and pebbles of the Tuscaloosa; but Little Bear material from a nearby area was later reworked and redeposited here as the lens of clay (light color) in the Tuscaloosa gravel. April, 1937 (M.G.S. Bull.34, Fig.6).

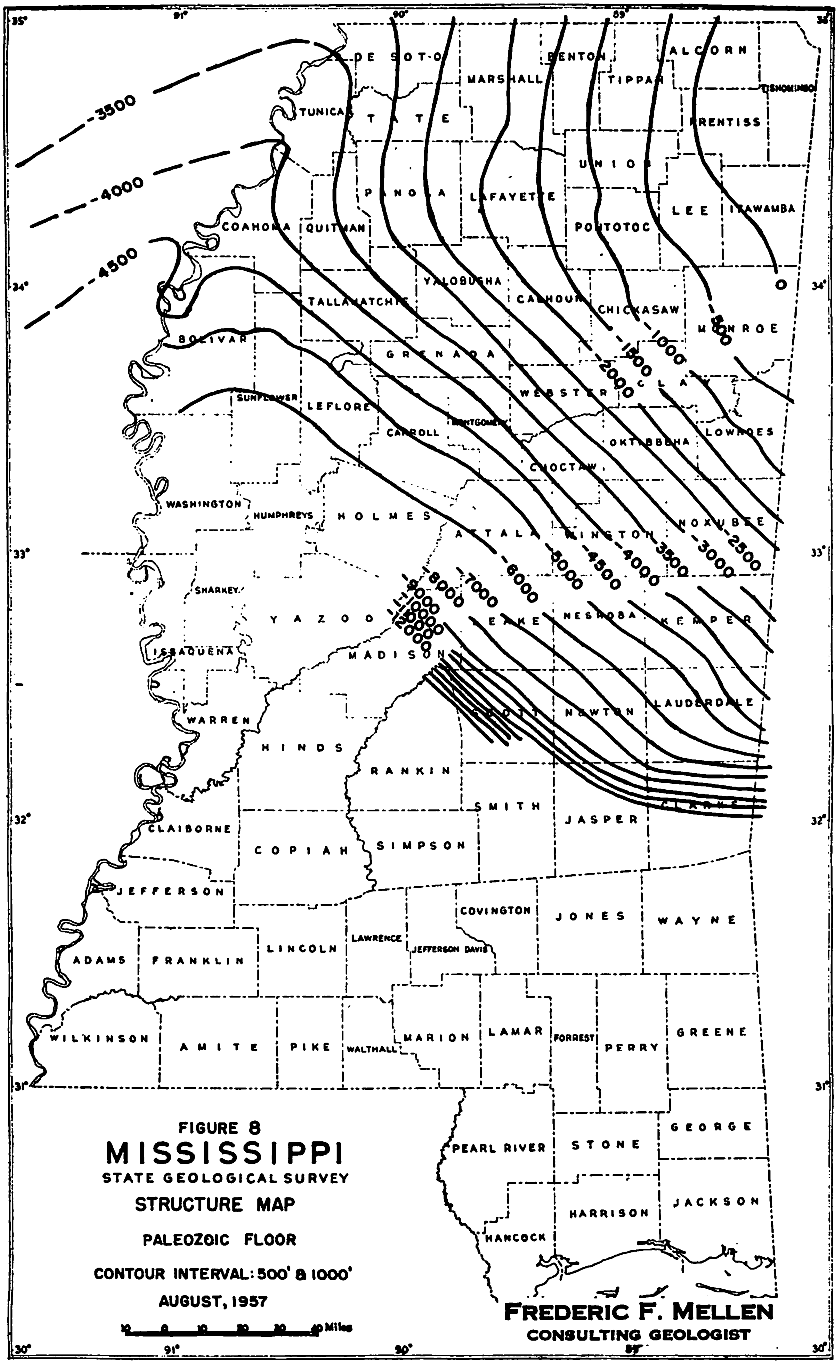


FIGURE 8
MISSISSIPPI
STATE GEOLOGICAL SURVEY
STRUCTURE MAP
PALEOZOIC FLOOR
CONTOUR INTERVAL: 500' & 1000'
AUGUST, 1957

are commonly heterogeneous and without distinctive flora or fauna; and, characteristic of soils, heterogeneity in composition is usual, which may or may not make correlation difficult. This soil mantle was named the Little Bear residuum in Mississippi Geological Survey Bulletin 34 in 1937 (Mellen, 1937). At that time, a complete resumé of the subject was presented, with a current bibliography. In 1954, Moneymaker and Grant described a sub-Cretaceous residuum at Shawnee Steam Plant, McCracken County, Kentucky. Here the residuum, at sea level, rested on partly leached limestone of Warsaw (Mississippian) age. They conclude in part as follows: "The surface on which the Upper Cretaceous sediments were laid down is irregular, at least locally; a basal Upper Cretaceous gravel is not everywhere present, and areas of unreworked regolith occur. Where a basal gravel does occur, it is much younger than the Tuscaloosa formation of Alabama and Mississippi. At the northern end of the Mississippi embayment, the gravel is believed to be of late Selma or early Ripley age." Since 1950, a good many wells in north Mississippi have been drilled through the Cretaceous and into the underlying Paleozoic. Some of these wells in Pontotoc County, and elsewhere, had relatively thin red and mottled clays lying on a surface of more or less weathered Paleozoic rock. Although well samples through this interval are nearly always poor, and although this interval is never cored, it is reasonable to conclude that locally, at least, the Little Bear residuum, the soil preceding the advance of the Cretaceous sea, is preserved on the Paleozoic floor of north Mississippi (Figure 8).

As the early Cretaceous sea advanced northward from what is now south Mississippi, the deposits left by it are progressively older to the south (Figure 9). The lowest (oldest) Cretaceous sediments on the Tennessee line in the vicinity of Memphis were deposited at the same time as were beds in the middle of the Selma chalk in the southern half of Mississippi. The farthest advance of the salty Cretaceous sea, so far as known from the sedimentary record, was to the vicinity of Cairo at the southern tip of Illinois and the Crowley's Ridge area of southeastern Missouri.

The northwesterly proximity of the Cretaceous land (source area) is indicated by the character of the basal transgressive sediments. These are usually coarse-grained pebbly sands in part

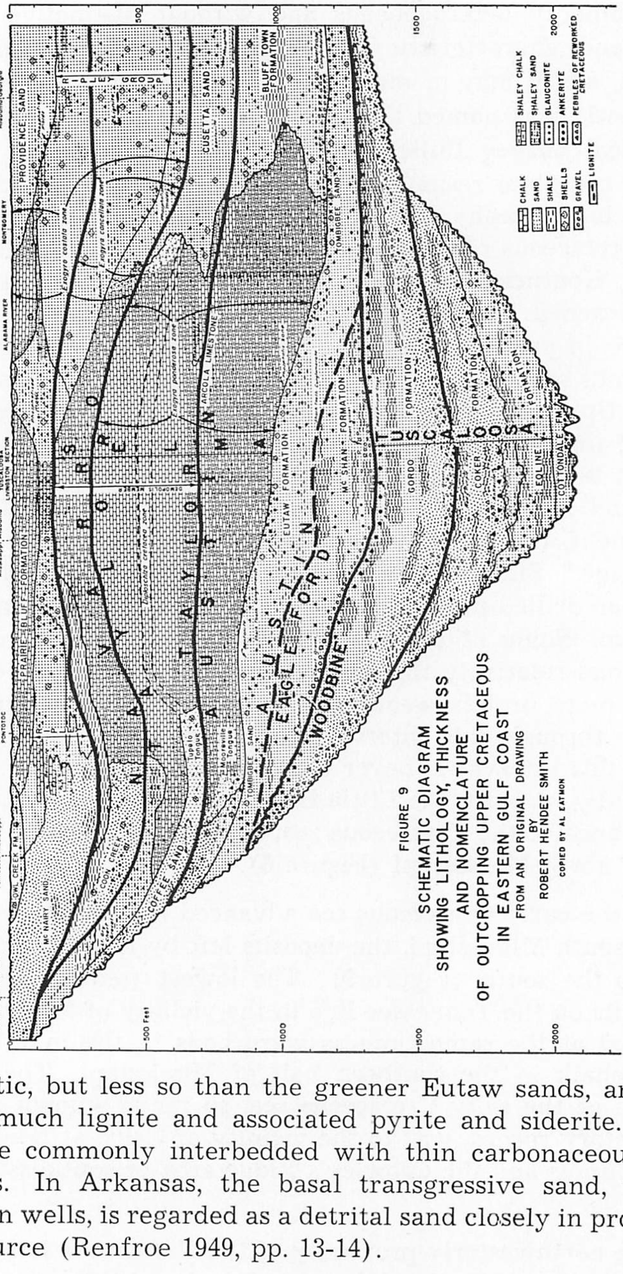


FIGURE 9
SCHEMATIC DIAGRAM
SHOWING LITHOLOGY, THICKNESS
AND NOMENCLATURE
OF OUTCROPPING UPPER CRETACEOUS
IN EASTERN GULF COAST
FROM AN ORIGINAL DRAWING
BY
ROBERT HENDEE SMITH
COPIED BY AL EATMON

glauconitic, but less so than the greener Eutaw sands, and they contain much lignite and associated pyrite and siderite. These sands are commonly interbedded with thin carbonaceous clays and silts. In Arkansas, the basal transgressive sand, usually present in wells, is regarded as a detrital sand closely in proximity to its source (Renfroe 1949, pp. 13-14).

"Ankerite" pellets or spherules and amber-colored crystals of siderite are common above and below the Mesozoic-Paleozoic

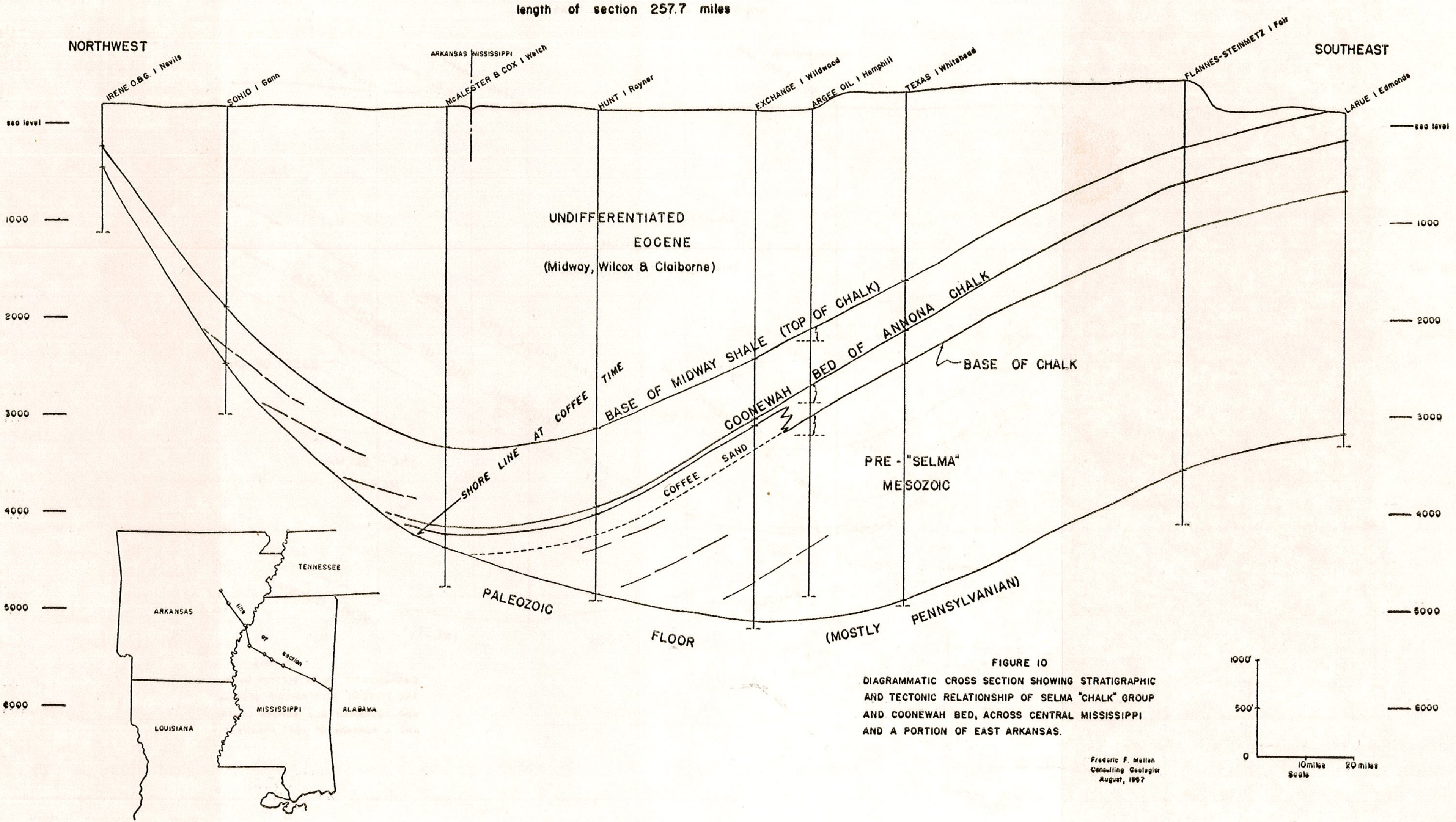


FIGURE 10

DIAGRAMMATIC CROSS SECTION SHOWING STRATIGRAPHIC AND TECTONIC RELATIONSHIP OF SELMA "CHALK" GROUP AND COONEWAH BED, ACROSS CENTRAL MISSISSIPPI AND A PORTION OF EAST ARKANSAS.

Frederic F. Mellen
Consulting Geologist
August, 1967

unconformity even north of the updip limit of Tuscaloosa. The presence of these materials is believed due to conditions developed during the period of unconformity rather than at a definite geologic time.

In a study of the Cretaceous shelf sediments of Mississippi, it is not always clear whether structural or depositional shelf sediments are involved. It is assumed that the edge of the continental shelf moved northward with the transgression of the Cretaceous sea. Certainly the oyster-bearing glauconitic sands and sandy limes of the Eutaw in the Maxie Field area (Forrest County) of extreme south Mississippi were deposited in very shallow marine water, well up on the continental shelf. In later, "Selma" times, the continental shelf may have coincided closely with the Pickens-Gilbertown fault system which is developed on the structural hinge line of the Cretaceous basin as it is known today. It is in the area north of this hinge line that present interest is centered. Although this region includes approximately half of the State of Mississippi no oil or gas has been produced from the Cretaceous beds therein.

STRATIGRAPHIC TAXONOMY OF CRETACEOUS SHELF SEDIMENTS

The Cretaceous deposits are interesting because their depositional and tectonic record presents one of the most unusual cases of stratigraphic onlap and subsequent tilting known in Geology (Figures 2, 10). Viewed in proper perspective, consideration should be given not only to the Cretaceous deposits of the Mississippi Embayment — Mississippi, Alabama, Arkansas, Missouri, Illinois, Kentucky and Tennessee — but to the Cretaceous deposits of other nearby States, Florida, Louisiana, Texas, and even the Atlantic coastal States.

One of the most important aspects of the geology of the Cretaceous sediments of the shelf area in Mississippi is its stratigraphic taxonomy, or the grouping and subdividing of the rock units and the assignment of names to the units recognized. Multiplicity of names should be avoided and lack of definition should not be condoned. It is fully recognized that definitions will be modified, expanded or restricted, as new paleontological and stratigraphical data are developed. These modifications should be made wherever possible in such a way as to permit the retention of useful names, and to reduce the introduction of unnecessary new names. The rule of priority is justly well-established, and should be observed in many instances, perhaps, where redefinition is needed.

The Cretaceous nomenclature of the Mississippi Embayment is complex and somewhat confusing. Like an old automobile that has been patched up from time to time with increasing frequency, it is badly in need of a general overhaul. The commercial paleontologists and stratigraphers have developed a great deal of information, much of which will never, per se, appear in print but exists only in the great colloidal mass of data in company reports, cross-sections, maps, and in the minds of the hundreds of workers whose objectives are not publication but economic discovery and exploitation. There is no attempt here to set up any hard and fast nomenclature. In general, the writer does not believe that the Texas terms Eagle Ford, Austin, Taylor and Navarro have any place in the stratigraphic nomenclature of the Mississippi Embayment except to denote time equivalency as established by fossils and lithologic similarities. In such manner these terms are commonly used by many stratigraphers and paleontologists. A need is felt for the establishment of usable taxonomic principles and a nearer approach to uniformity in nomenclature.

A conspicuous deficiency of the Cretaceous binomial system is the peculiar disposition of writers to refrain from assigning stratigraphic rank to chalk units. Prairie Bluff "chalk" is recognized as the exact equivalent of the Owl Creek formation and Selma "chalk" is rarely designated by stratigraphic rank, i.e., formation, series, or other unit. "Selma," itself, is used in a great variety of stratigraphic values. If the presently extended Annona (chalk) formation is accepted as a valid unit of formational rank, the Selma, in which the Annona would be included, would be of series or group rank. In general, if the sediments are heterogeneous, i.e., clays, sands, marls and gravels, the binomials usually do not contain a lithologic designation but a stratigraphic rank, such as formation (Figure 11).

The writer has for many years held to the principle that a unit name should carry across facies boundaries and that the facies should be designated as such rather than by synonymous nomenclatural designations. For example, the youngest unit of the Cretaceous, some 30 to 100 feet in thickness, has been known variously as the Prairie Bluff chalk, the Oktibbeha "tongue" of the Selma chalk, and the Owl Creek (marl) formation. Here, if priority alone should apply, the unit should be known as the Prairie Bluff (formation), including both the chalk and marl facies. The facies changes between the two formations as used by Stephenson and Monroe (1937) develop over a lateral distance of 30 miles or more in which the awkward hyphenated name Prairie Bluff-Owl Creek is most appropriately applied. The writer's objections to the use of Owl Creek (Figure 33) (other than as a facies name of the Prairie Bluff formation) were written to Stephenson and Monroe upon appearance of their paper.

Figure 11.—Unconformity between the Tuscaloosa and Eutaw formations on the southeastward-facing slope of Buttahatchie River Valley about 10 miles southeast of Aberdeen on a local road, Monroe County (M.G.S. Bull.40, Fig.10).

One of the principal purposes of this report is to aid in stratigraphic taxonomy of the Cretaceous deposits of the region, not by the introduction of new names but by pointing out the sources of sediments, methods of deposition and some of the more evident precise correlations within the Cretaceous system.

By obtaining a broader perspective of Cretaceous deposition, the stratigrapher can decide on better grouping of sediments into assigned stratigraphic units, and a nomenclatural house-cleaning can be accomplished (Figure 12).

THE COFFEE SAND

The Coffee sand, formerly considered to be an upper member of the Eutaw formation but now concluded to be equivalent to the lower "Selma" chalk, was named and described by J. M. Safford (1864) from Coffee Landing on the Tennessee River, 4 miles northwest of Savannah and 19 miles north of the Mississippi State line. Safford's description given in summary by Wilmarth (1938) follows: "Mostly stratified sands, usually containing mica scales. Thin leaves of dark clay often interstratified

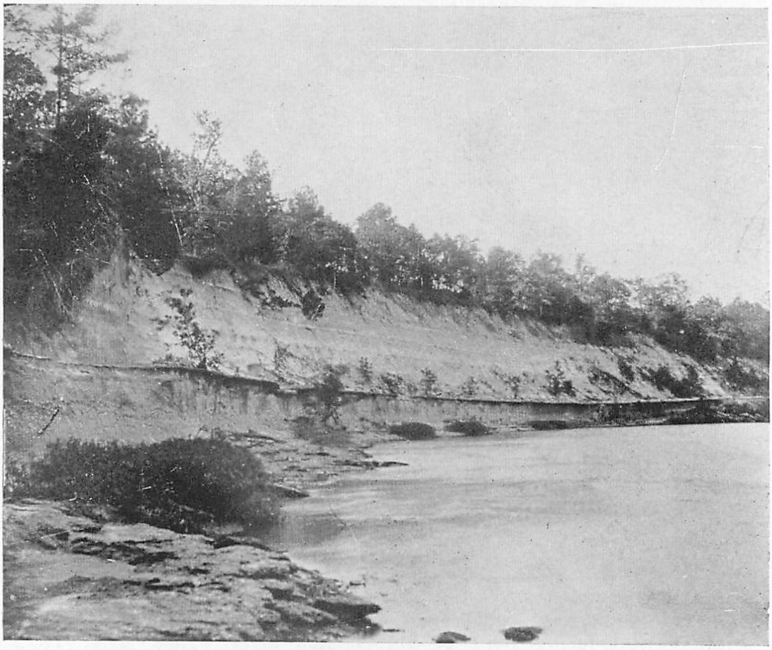


Figure 12.—Tombigbee sand member of Eutaw formation overlain by Selma chalk, Plymouth Bluff, Tombigbee River, Lowndes County, Mississippi. The Tombigbee-Selma contact lies well up toward the top of the bluff; the prominent ledge of bench-forming sandstone contains innumerable prints and molds of several large species of Inoceramus (M.G.S. Bull.40, Fig.11) Photo by L. W. Stephenson.

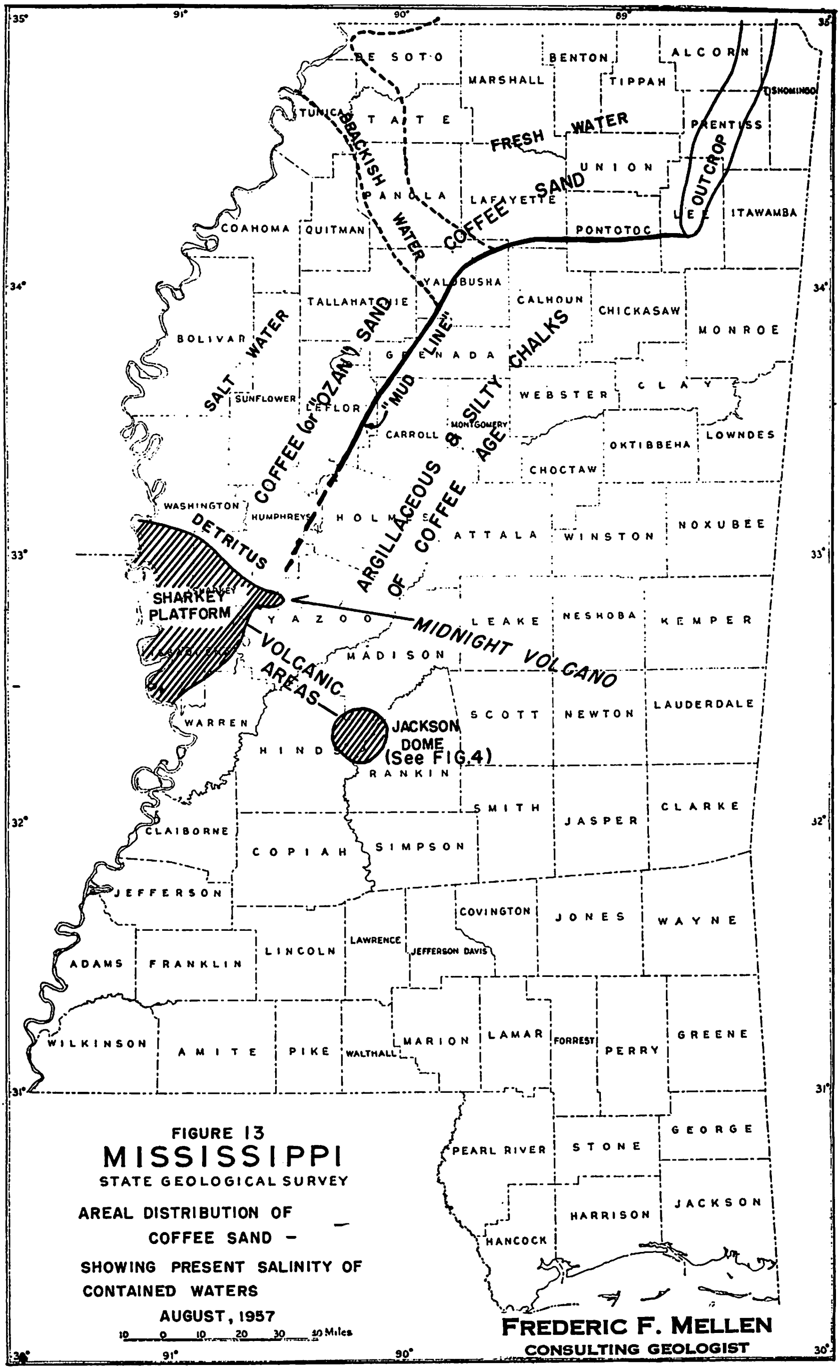


FIGURE 13

MISSISSIPPI

STATE GEOLOGICAL SURVEY

AREAL DISTRIBUTION OF COFFEE SAND – SHOWING PRESENT SALINITY OF CONTAINED WATERS

AUGUST, 1957

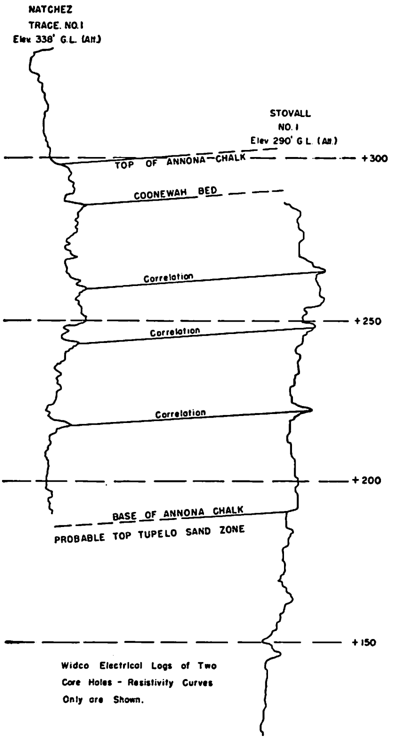
FREDERIC F. MELLEN

CONSULTING GEOLOGIST

with the sand, the clay leaves occasionally predominating. Sometimes beds of dark laminated or slaty clay 1 to 20 feet or more feet thick are included. Thickness probably 200 feet." Local details of the geology of the Coffee sand in the type area in Hardin County, Tennessee, are given by Jewell (1931, Pl. II, A & B. pp. 46-48, geologic map).

The Coffee sand (Figure 13) has been traced continuously south-southwesterly into Mississippi across its outcrop belt to a distance about 76 miles from its type locality, where, 3 to 4 miles south of Tupelo, Lee County, it gives way abruptly to deeper water deposits of argillaceous silty chalk or marl. This break in facies has been traced in the subsurface westerly to the northeast corner of Yalobusha County, thence southwesterly to approximately the Midnight Cretaceous volcano in southern Humphreys County. On the north flank of the Sharkey-Monroe platform the Coffee sand is represented by poorly sorted volcanic debris, or pyroclastic material, establishing fairly conclusively that at least some of the Coffee sand had its origin on the greatly elevated volcanic archipelego which we know now as the Sharkey-Monroe platform or uplift. Biotite mica is a common accessory mineral in the Coffee and in the overlying Annona chalk as far away from the probable source as Lee County, well over a hundred miles northeast. Bentonite has been mined from the Lower Coffee in Prentiss County (Vestal, 1936) and has been found in negligible amounts in Lee County (Vestal, 1946). It was also found in very small amount in the lower Coffee (160-180′) in Gulf's Core Hole No. 3, a mile northwest of Verona, but in the samples of three other core holes the bentonite was not found. The bentonite lies probably within 50 feet of the still deeper Arcola limestone.

The "mud line" between the Coffee sand and its lower "Selma" equivalent passes east-west through the approximate center of the fourth tier of Sections (19-24) of T.10 S., R.5 E., Lee County. Gulf's Core Holes 1 and 2, south of this line, did not have any sorted sand in the Coffee horizon but Core Holes 3 and 4, north of the line, had some sand and silts in the Coffee. The Stovall No. 1 Core Hole, discussed under the heading "Annona chalk", shows the break between the Coffee and the Annona on the Widco electrical log (Figure 14) and on the insoluble residue chart (Figure 19) even though it is located south of the "mud line" where the overlying lower Annona and the underlying



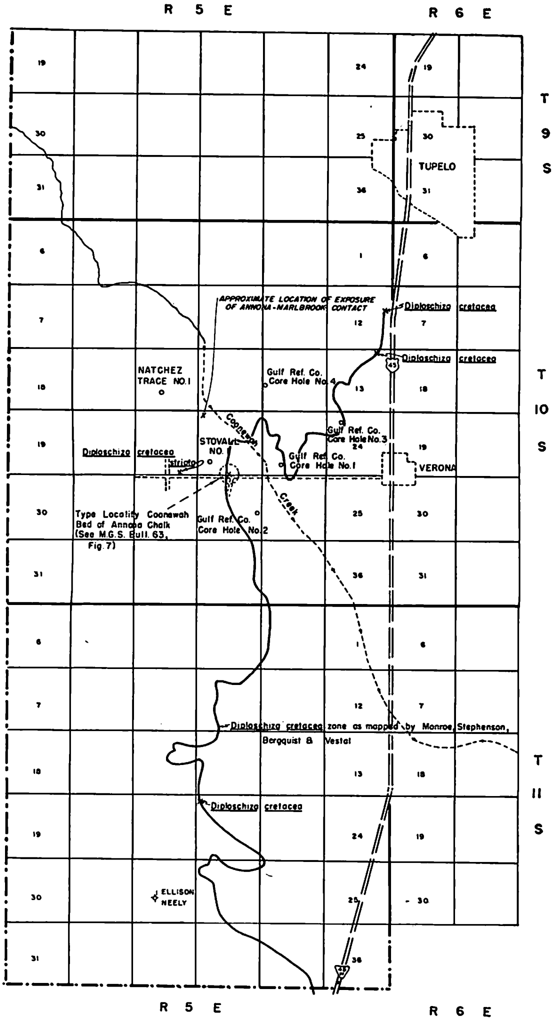


FIGURE 14

TYPE LOCALITY OF COONEWAH BED OF ANNONA CHALK

Lee County, Miss.

Frederic F. Mellen
1957

Coffee equivalent are lithologically similar. This break probably can be recognized far to the south by changes in color or texture of the outcrops.

As the distribution of the Coffee sand is mapped across north Mississippi, the top may not be a precise time or stratigraphic point by reference to the higher Coonewah bed of the Annona chalk. For example, in the Pontotoc-Union-Lee Counties area, the interval from the Coonewah bed to the Coffee is commonly 80 to 100 feet, but in Leflore County, the interval is commonly only 25 to 40 feet. This thinning of interval reflects a possible slight build-up in Coffee thickness in the direction of the Sharkey-Monroe platform, which, in turn, indicates the previously implied westerly and southwesterly source of the Coffee sediments. The alternative explanation is another sand member, likewise developing from the west or southwest, but pinching out in the Tallahatchie-Yalobusha Counties area where well control is lacking.

Figure 15.—Coffee sand overlain by Selma chalk (Annona), west side of U.S. Highway 45 a mile northwest of Saltillo, Lee County, Mississippi. The prominent bed of hard sandy chalk at the base of the Selma contains great numbers of Exogyra ponderosa Roemer and Gryphea convexa Say. (M.G.S. Bull.40, Fig.23) Photo by W. H. Monroe.

Actually, both explanations of the southwesterly thinning of this interval are essentially the same thing.

The Coffee sand (Figures 15, 16) is a fine to medium-grained quartz sand. It is locally slightly glauconitic and in the subsurface, at least, contains some thin beds of fossiliferous lime-cemented sandstone. Mica and pyrite are common accessory mineral impurities. Lignitic fragments are not uncommon. Following are several screen analyses of samples of Coffee sand:

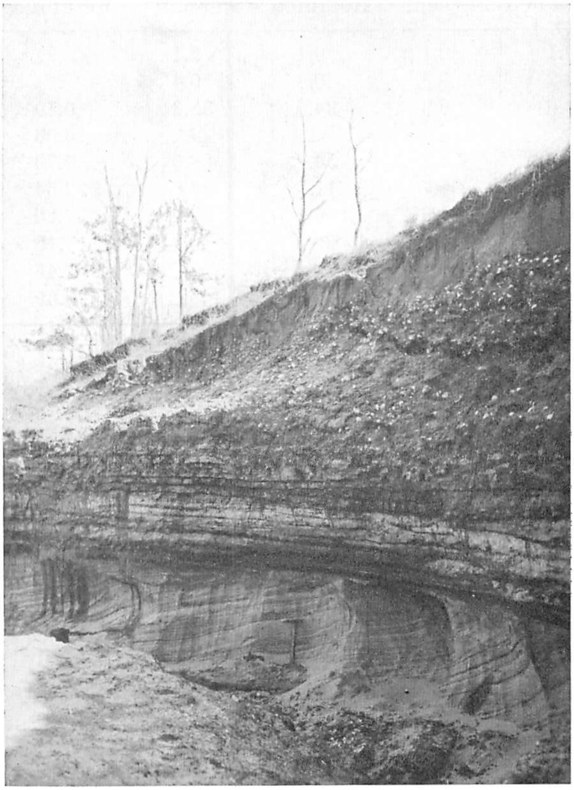


Figure 16.—Top of Tupelo tongue of Coffee sand and overlying oyster reef (mostly Gryphea convexa) in base of Annona chalk at a locality 6 miles southwest of Booneville on U.S. Highway 45 (SW.¼, SW.¼, Sec.1, T.6 S., R.6 E., Prentiss County, Mississippi). March 31, 1936.

GRANULARMETRIC ANALYSES OF COFFEE SAND

	Outcrop				Well	
	Sample 1		Sample 2		Sample 3	
Mesh	Percent Retained	Cumulative Percent	Percent Retained	Cumulative Percent	Percent Retained	Cumulative Percent
16	0.1	0.1	0.1	0.1	----------	----------
20	0.2	0.3	0.3	0.4	----------	----------
40	6.6	6.9	34.9	35.3	0.10	0.10
50	------	------	------	------	6.90	7.00
60	68.2	75.1	50.7	86.0	8.79	15.79
80	20.6	95.7	11.8	97.8	22.64	38.43
100	0.1	95.8	0.1	97.9	37.86	76.29
150	------	------	------	------	17.16	93.45
200	------	------	------	------	3.45	96.91
Pan	------	------	------	------	3.09	100.00

Sample 1: Coffee sand, Tupelo tongue, in Tupelo west of the lake and southwest of the fertilizer factory, from pockets of white and yellow sands near the top of a range of low hills. Logan (1911); see also Vestal (1946).

Sample 2: Reworked Coffee sand, washed down from the hills (sample) into a small creek valley. See Logan (1911) or Vestal (1946).

Sample 3: Coffee sand from deep well core, J. Willis Hughes No. 1 Kearney, Sec. 20, T.21 N., R.1 E., Leflore County, at 3204-3206.5; bulk porosity of this core was 29.5%, horizontally permeability 300 millidarcys. Well-core Company, Analyst, Aug. 22, 1957.

The upper part of the Coffee sand is characteristically more massive and less argillaceous and has been named the Tupelo tongue (Stephenson, 1917) of the Coffee sand. Stephenson and Monroe (1940, p. 144) describe it: "The Tupelo tongue of the Coffee sand is a body of dark-gray mostly massive calcareous, glauconitic sand extending southward from the Coffee sand of northern Lee County into the main body of the Selma chalk, being underlain by a corresponding tongue of the Selma chalk, the Mooreville tongue, which extends northward from the basal part of the Selma. The Mooreville tongue loses its identity by merging into and minor intertonguing with the chalk in southern

Lee County. * * * * The exposure in an abandoned portion of the Fulton road (U.S. Hwy. 78) 1.5 miles east of Tupelo, is considered the type section. * * * * The thickness of the Tupelo tongue, as shown by logs of wells at and near Tupelo, is approximately 100 feet."

The following references to nomenclature of the Cretaceous deposits of Coffee age indicate the priorities of names and their stratigraphic acceptabilities. The nomenclature is relatively complex.

Coffee —Safford, 1864 (Tennessee)
Tupelo —Stephenson, 1917 (Mississippi)
Wolfe City —Stephenson, 1918 (Texas) [possible exact equivalent of Tupelo]
Meakin —Schneider, 1924 (Arkansas) [considered basal Marlbrook] Mackay & McLaughlin, 1951, pp. 4, 5, 6 & 7 [considered upper part of Ozan]
Louann (sand) —Schneider, 1924 (Arkansas) [local name for Meakin]
Primm gas zone (sand) —Schneider, 1924 (Arkansas) [local name for Meakin]
Ozan —Dane, 1926 (Arkansas)
Buckrange —Dane, 1926 (Arkansas) [a sand lentil in base of Ozan]

Correlation of these deposits from the type areas in the eastern Embayment into Arkansas and Texas is based primarily upon the correlation (electrical, lithologic, stratigraphic, and paleontologic) of the overlying Annona chalk, together with correct downward stratigraphic successions. Both Coffee, as a formation (?) and Tupelo, as a member (?) or tongue have well-established published priority over any of the other names.

THE ANNONA CHALK AND ITS COONEWAH BED

The name Annona was first projected into Mississippi into a part of the Selma chalk by the Shreveport Geological Society. In stratigraphic cross-sections the projection was from the Desha Basin on the north side of the Monroe-Sharkey Uplift and also within the salt basin province south of the Monroe-Sharkey

Uplift. The nomenclature and usage are set out in the Gulf Cretaceous correlation chart (1945, Vol. II, pp. 480 481). In the present study, it was necessarily assumed that the stratigraphic studies and correlations of the Annona section by the Shreveport stratigraphers, Hazzard, Spooner, Blanpied and their assistants were essentially correct; and it was upon this premise that we have adopted the name Annona to apply to a certain portion of the lower part of the Demopolis chalk prior to the further proof of this correlation presented in the present report.

For a few years certain electrical characteristics in the Selma chalk were noted to maintain an unusual persistence throughout a large area of north Mississippi. As additional wells were drilled, the electrical characteristics and other geological correlations revealed that certain time lines within the so-called Selma chalk varied greatly in their positions within the Selma. Likewise in west Mississippi, beds beneath the "Selma" were called Eutaw, whereas it was apparent by the correlation of the superjacent beds that the sands were not Eutaw but were developed at a higher stratigraphic position, namely Coffee.

The Annona chalk, according to Wilmarth (1938) was described from the Upper Cretaceous of Northeastern Texas, Louisiana, Southeastern Oklahoma and Southwestern Arkansas. It was named by R. T. Hill (1894), a pure white chalk called White Cliffs chalk in Arkansas and Annona chalk in Texas. It was named for outcrops about two miles Northwest of Annona, Red River County, Texas. In many wells drilled in North Mississippi in recent years, the characteristic electrical log pattern shows two benches of chalk of higher self-potential and higher resistivity than the beds above and below. Samples through this section show the chalk to be lighter colored and less argillaceous than the chalks or chalky marls above and below. A two-foot bed in the upper part of the Annona chalk as used herein has been traced with reasonable accuracy over an area embracing all or part of more than 40 counties in Mississippi and covering an area of 20,300 square miles more or less (Figure 17). It is remarkable that a precise time-stratigraphic marker bed can be traced over such a widespread area. Its usefulness as a reference plane is much greater than that of any other bed in the Mesozoic or

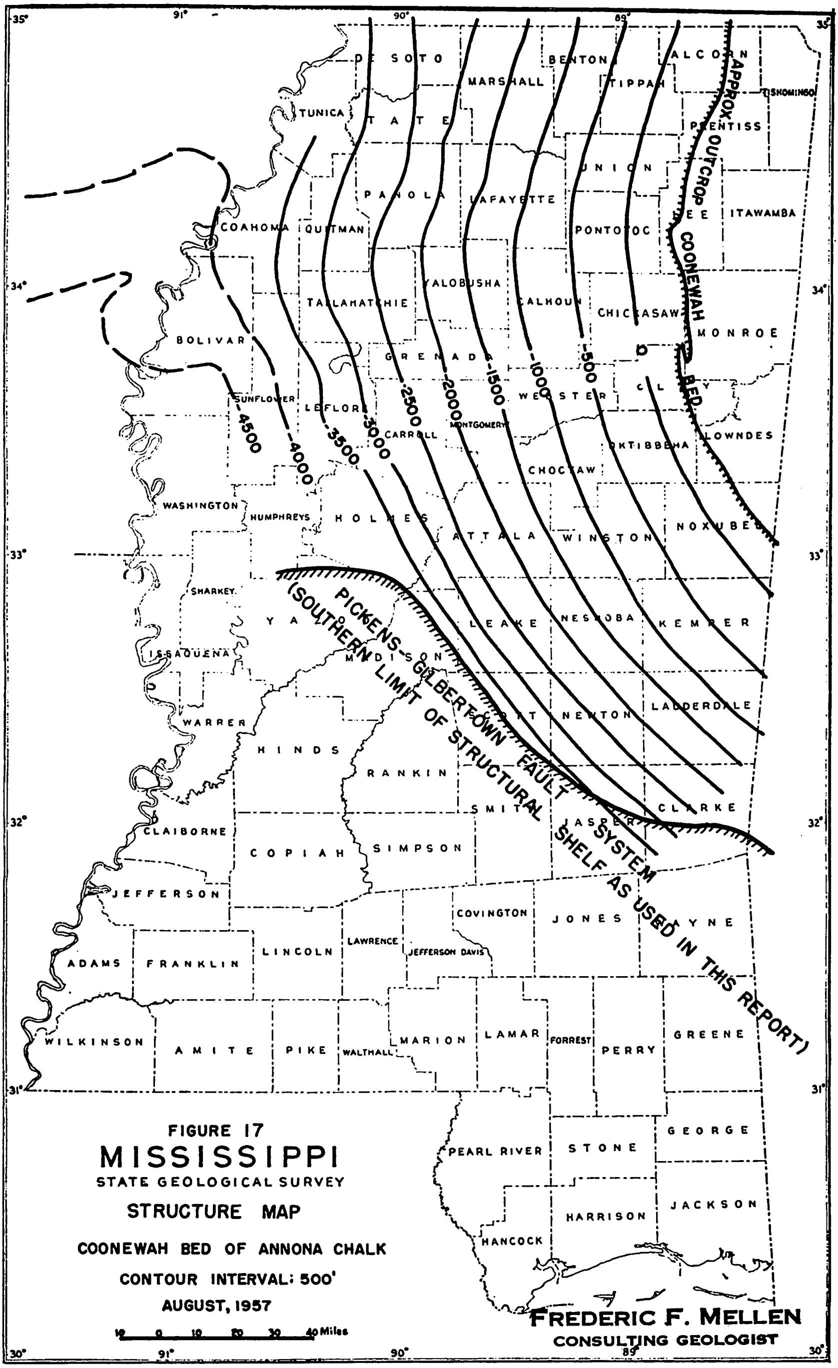


FIGURE 17

MISSISSIPPI

STATE GEOLOGICAL SURVEY

STRUCTURE MAP

COONEWAH BED OF ANNONA CHALK

CONTOUR INTERVAL: 500'

AUGUST, 1957

FREDERIC F. MELLEN

CONSULTING GEOLOGIST

Tertiary section in North Mississippi.* The only other precise time-stratigraphic reference plane of similar utility is the top of the lower Tuscaloosa (also called the base of the Marine Tuscaloosa shale of South Mississippi). It is doubtful that the Lower Tuscaloosa is useful over as much area as the Coonewah bed of the Annona chalk.

Figure 18.—Demopolis chalk, wall of road cut (SE.¼, Sec.22, T.10 S., R.5 E.) in the bluff of Coonewah Creek Valley 2½ miles west of Verona, Lee County, Mississippi. (As proposed in this report, this is the type locality for the Coonewah bed of the Annona chalk.) (M.G.S. Bull.63, Fig.7) Photo by F. E. Vestal, March 23, 1945.

The name Coonewah* is proposed for this two-foot bed of relatively pure chalk in the Annona. The name is taken from

---

* The "X point" used by Stearns (1957, 1082-1083) is apparently the shaly break between the two benches of purer chalk in the Annona. As stated elsewhere, and as can be seen on the electrical log sections, several of the electrical log characters in the Annona can be traced over wide areas.

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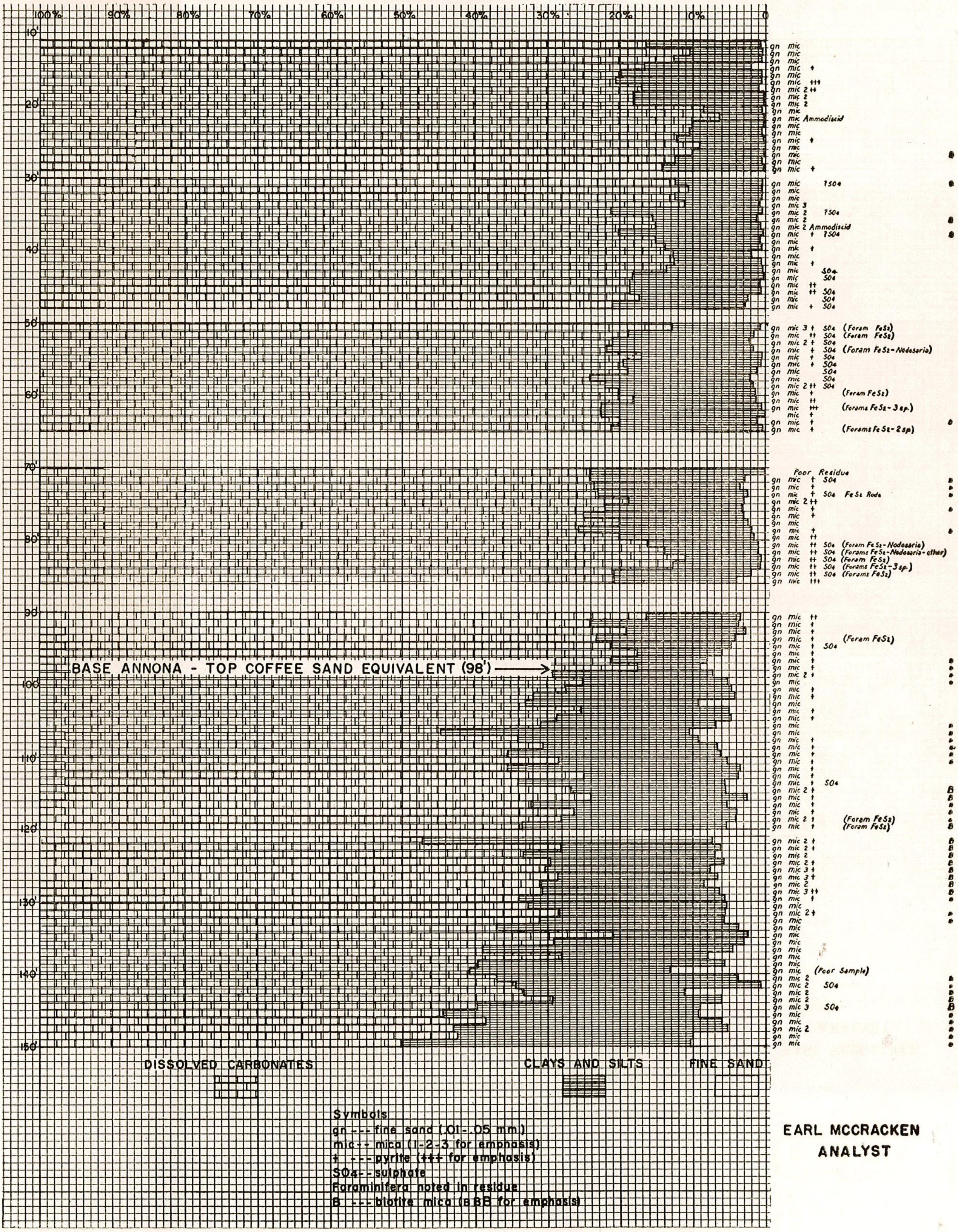
* Coonewah is not preempted as a stratigraphic name and has been reserved for the present usage (George V. Cohee, Chairman, Geologic Names Committee, U. S. Geological Survey, letter of July 17, 1957).

Figure 19

INSOLUBLE RESIDUE CHART

STOVALL NO. 1 CORE HOLE

(SW. 1/4, SEC. 22, T. 10 S., R. 5 E., LEE COUNTY, MISSISSIPPI)



Symbols
gn --- fine sand (.01-.05 mm)
mic -- mica (1-2-3 for emphasis)
+ --- pyrite (+++ for emphasis)
SO_4 -- sulphate
Foraminifera noted in residue
B --- biotite mica (BBB for emphasis)

EARL McCRACKEN
ANALYST

Coonewah Creek. The type locality (Figure 18) is on the west valley wall of Coonewah Creek approximately at the Southeast corner of Southwest quarter Section 22, T.10 S., R.5 E., Lee County, Mississippi, 2.5 miles west of the town Verona.

In order to determine the exact lithology of this two-foot bed that is so wide-spread through the Cretaceous and also to obtain material for paleontological, lithological and petrological studies, the State Geologist made available the services of members of the Mississippi Geological Survey staff and the use of a small rotary core drill and a Widco electrical logger. The area selected for this investigation was pointed out by previous core drilling of a Gulf Oil Corporation crew in T.10 S., R.5 E., Lee County, Mississippi, about six miles southwest of Tupelo and about two miles west of Verona (Figure 14). In this vicinity the zone of *Diploschiza cretacea* which had previously been mapped, was useful in helping to place the stratigraphic position of the beds being studied. Gulf Oil Corporation had drilled four core holes into the Paleozoic for structural control and had logged these holes almost to the surface. Gulf's geological department permitted use of their electrical logs and samples for this study. These logs revealed that the Coonewah bed lay somewhere at the surface — probably immediately west of the group of core holes. A preliminary inspection of the chalks showed that some layers were more massive and granular than others, that some were purer than others, and that some beds of the chalk contain fairly large oysters of the genus *Gryphea.*

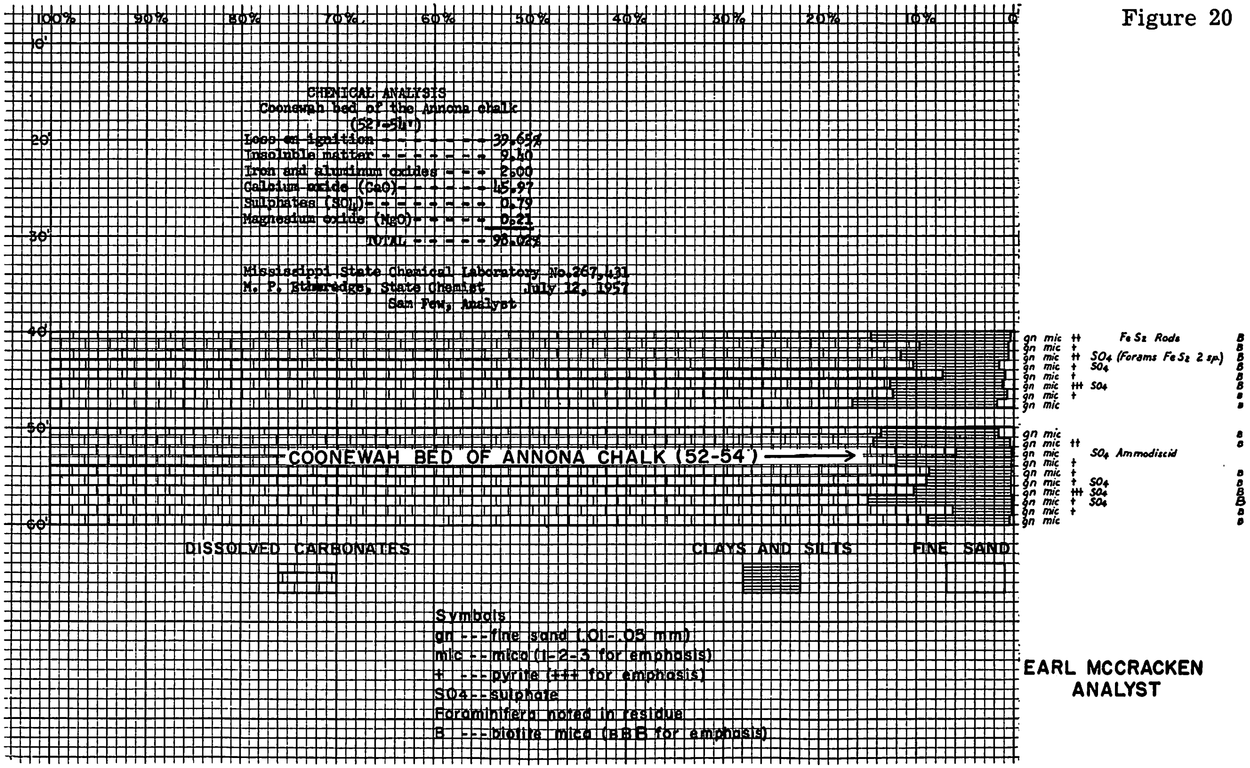
Due to property difficulty the first planned core hole could not be drilled and a second location was made, on the Stovall property. The cores from the Stovall core hole began immediately below the position of the Coonewah bed and continued to a depth of 150 feet, approximately 52 feet below the Annona chalk. Electrical logging extended to 170.5 feet, the total depth of the hole. The cores and log revealed that there was some type of stratigraphic break at the depth of 98 feet. This is shown on the insoluble residue chart (Figure 19) and is suggested by the paleontological studies as well as by simple lithologic examination of the cores. The highly argillaceous silty chalks below 98 feet are interpreted as being the deeper water equivalent of the Coffee sand immediately south of the "mud line", for the two

INSOLUBLE RESIDUE CHART

NATCHEZ TRACE NO. 2-A CORE HOLE

(NE 1/4, SW 1/4, SEC. 16, T. 10 S., R. 5 E., LEE COUNTY, MISSISSIPPI)

Figure 20



CHEMICAL ANALYSIS
Coonewah bed of the Annona chalk
(52'-54')

Loss on ignition - - - - - - - - - -	39.65%
Insoluble matter - - - - - - - - -	9.40
Iron and aluminum oxides - - - -	2.00
Calcium oxide (CaO) - - - - - - -	45.97
Sulphates (SO_4) - - - - - - - -	0.79
Magnesium oxide (MgO) - - - - -	0.21
TOTAL - - - - - -	98.02%

Mississippi State Chemical Laboratory No. 267,431
M. P. Etheredge, State Chemist July 12, 1957
San Few, Analyst

Symbols
gn - - - fine sand (.01-.05 mm)
mic - - mica (1-2-3 for emphasis)
\+ - - - pyrite (+++ for emphasis)
SO_4 - - sulphate
Foraminifera noted in residue
B - - - biotite mica (BBB for emphasis)

EARL MCCRACKEN
ANALYST

TABLE I
Analyses of Lower Selma Chalks and Limestone in Lee County, Mississippi, Area

Sample	1	2	3	4	5	6	7	8	9	10	11	12
Ign. loss	39.65	28.82	24.76	27.51	23.84	29.28	27.98	25.56	27.76	26.62	26.68	26.42
Insol.	9.40	......	......	......	......	......	......	......	......	......	......	......
SiO_2	......	25.13	32.69	24.73	24.70	23.15	25.06	30.45	25.40	31.02	29.82	31.16
R_2O_3	2.00	12.71	11.69	14.63	12.59	11.57	12.86	12.35	13.39	12.17	11.50	11.50
CaO	45.97	32.04	30.77	32.29	31.89	33.11	32.95	30.84	32.42	30.26	31.16	30.74
MgO	0.21	......	......	......	......	......	......	......	......	......	......	......
SO_3	......	1.30	0.89	1.23	0.79	0.0	0.81	0.94	0.99	0.0	1.02	0.0
SO_4	0.79	......	......	......	......	......	......	......	......	......	......	......
Misc.	......	1.30	0.09	0.79	1.98	2.89	1.15	0.80	1.03	......	0.84	0.18
$CaCO_3$	......	......	......	......	......	......	......	......	......	......	......	......

Sample	13	14	15	16	17	18	19	20	21	22	23	24
Ign. loss	27.68	25.61	26.63	24.48	27.24	32.58	17.83	17.22	16.42	24.31	14.64	28.01
Insol.	......	......	......	......	......	......	......	......	......	......	......	......
SiO_2	27.82	33.21	30.50	33.71	28.18	18.46	50.57	47.68	48.70	33.85	49.92	26.26
R_2O_3	12.02	11.83	12.00	12.58	14.01	9.24	10.27	14.84	15.62	12.91	10.38	10.98
CaO	31.70	29.27	31.15	28.73	31.30	37.72	20.78	17.92	17.17	28.87	20.12	33.67
MgO	......	......	......	......	......	......	......	......	......	......	......	......
SO_3	0.78	0.0	0.0	0.0	0.0	0.96	0.0	0.43	1.24	0.00	4.31	1.02
SO_4	......	......	......	......	......	......	......	......	......	......	......	......
Misc.	0.33	0.08	......	0.5	......	2.00	0.55	2.34	2.09	0.06	4.93	1.08
$CaCO_3$	......	......	......	......	......	......	......	......	......	......	......	......

Sample	25	26	27	28	29	30	31	32	33	34	35
Ign. loss	28.25	27.10	......	......	......	36.68	36.42	36.21	......	34.33	......
Insol.	......	......	......	......	......	......	......	......	......	......	......
SiO_2	22.76	14.84	......	......	......	10.10	10.94	11.21	......	13.16	......
R_2O_3	11.02	20.09	......	......	......	5.68	5.93	6.14	......	5.16	......
CaO	34.31	32.89	......	......	......	45.79	46.22	44.90	45.44	44.63	......
MgO	0.05	0.41	......	......	......	0.75	0.39	0.48	......	0.90	......
SO_3	0.43	3.30	......	......	......	0.36	0.31	0.49	......	0.95	......
SO_4	......	......	......	......	......	......	......	......	......	......	......
Misc.	......	......	......	......	......	0.82	0.55	0.78	......	0.26	......
$CaCO_3$	61.27	58.73	66.30	80.06	67.30	......	......	......	81.11	......	96.58

Sample

1. Coonewah bed of Annona chalk from 52-54 feet in Natchez Trace core hole Sec.16, T.10 S., R.5 E., Lee Co., Miss. Analyst: Sam Few, Miss. St. Cem. Lab. No. 267,431
2. M.G.S. Bull. 63, Spl 11, 25′-28′ above Coffee sand, Sec.25, T.8 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
3. M.G.S. Bull. 63, Spl. 10a, 10-15′ above Coffee sand, Sec.25, T.8 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
4. M.G.S. Bull. 63, Spl. 10b, 15-20′ above Coffee sand, Sec.25, T.8 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
5. M.G.S. Bull. 63, Spl. 10c, 20-25′ above Coffee sand, Sec.25, T.8 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
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18. M.G.S. Bull. 63, Spl. 12, 25-29′ above Coffee sand, Sec.36, T.8 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
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23. M.G.S. Bull. 63, Spl. 18, 4′-7′ above Coffee sand, Sec.13, T.9 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
24. M.G.S. Bull. 63, Spl. 18a, 17-20′ above Coffee sand, Sec.13, T.9 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
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31. M.G.S. Bull. 63, Spl. 5c-k, composite 19′,SW of Verona, SE/4, SW/4, Sec.35, T.10 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
32. M.G.S. Bull. 63, Spl. E-2-8, composite 14′,W. of Verona at type locality Coonewah bed, SE/4, Sec.22, T.10 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
33. M.G.S. Bull. 63, Spl. E-6, 2′ bed believed to be Coonewah bed, SE/4, Sec.22, T.10 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
34. M.G.S. Bull. 63, Spl. 9a-q, composite 34′SE of Belden, SE/4, NW/4, Sec.15, T.9 S., R.5 E., Lee Co., Miss. Analyst: Herbert S. Emigh
35. M.G.S. Bull. 46, Spl. V-1, 3′ Arcola limestone, Sec.13, T.12 S., R.6 E., Monroe Co., Miss., Collector, F. E. Vestal; Analyst, W. F. Hand, Miss. St. Chem. Lab. No. 172,523

northernmost core holes of Gulf contain small amounts of Coffee sand. The two southerly wells contain no sand.

A second core hole was drilled on the Natchez Trace property at a higher elevation, about 1.5 miles northwest of the Stovall core hole. An electrical log was run on this core hole. The Coonewah bed was identified at 52-54 feet and a third hole was drilled right beside No. 1 Natchez Trace, in order to core the Coonewah bed. The bed itself was found to be a light-gray, highly foraminiferal chalk of greater purity than the chalks above and below. This is indicated by the insoluble residue chart (Figure 20), and by the chemical analysis of a composite of this two foot bed. This analysis can be compared with the available analyses of the other chalks in this area presented in tabular form in this report.

During the course of the core drilling and the search of the outcrops in the area for *Diploschiza cretacea* and *Echinochorys texana,* a *Gryphea convexa* bed was found containing common left valves of the species having common adhering valves of *Diploschiza.* A few of the specimens of *Diploschiza* showed sufficient external markings that the surfaces were well-striated; these specimens fit the descriptions of *Diploschiza cretacea striata.* The position of these forms is geographically more than three miles west of definite *Diploschiza cretacea* without the striations and is some 40 to 50 or more feet higher stratigraphically. This higher position of the striate variety is difficult to reconcile with the statements of Monroe (1941, 67-68; 1946-b) wherein he states that the *Diploschiza cretacea striata* zone is in the base of the Demopolis chalk and that the *Diploschiza cretacea* zone is in the middle Demopolis. It is more nearly reconcilable with the statement of Stephenson (1935-b) that "the radial ornamentation of the variety *Diploschiza cretacea striata* is essentially like that of the present species (*D. melleni*) except that the costae are much finer and weaker; it seems likely that this variety is ancestral to *Diploschiza melleni* which is known only from a stratigraphically higher position." It would appear from the relationship of *Diploschiza cretacea* with its varietal form that the variety has either no individual status as an index fossil or that its stratigraphic position or identification in Alabama was incorrect.

The presence of beds of large *Grypheas* in the Annona chalk and overlying chalky marls of Marlbrook age indicate that much of the chalk deposition was in relatively shallow marine water which is contrary to the prevalent idea that warm deep waters are required for chalk deposition. It is far more logical to expect chalk deposition in relatively shallow waters than it is to expect the formation of oyster beds in deep waters. The wide distribution and the relatively easy identification of the Coonewah bed of the Annona chalk suggest that it was deposited on a relatively flat sea shelf that had a fairly great width. Similarly, the underlying Coffee sand as mapped herein was deposited on a certain belt of the continental shelf during Coffee times. The 5000-foot or more westward and southerly tilting that we now observe is interpreted as being subsequent to deposition. If this assumption be correct, there was no initial dip of these strata to the west or to the northwest as are now observed by the records of deep wells. The initial dip of these Cretaceous sediments as shown by the isopach maps was to the south and southeast (Figure 21).

Figure 21.—Gullies in lower Demopolis member of Selma chalk below Diploschiza cretacea zone, north-facing slope of Tibbee Creek (SE.¼, SE.¼, Sec.6, T.19 N., R.16 E.) ¼ mile east of Highway 45W, 4 miles south of corporate limits of West Point, Clay County, Mississippi. (Note by F.F.M.: The medium-gray chalky marl below the figure is probably the continental slope depositional equivalent of the Coffee sand. The overlying light-gray chalk is probably the basal part of the Annona, as used in this report.) (M.G.S. Bull.53, Fig.8) Photo by H. R. Bergquist, August, 1941.

The stratigraphic positions of the top and bottom of the Annona chalk are not precisely defined herein. A suggested limitation can be found by examination of the electrical log

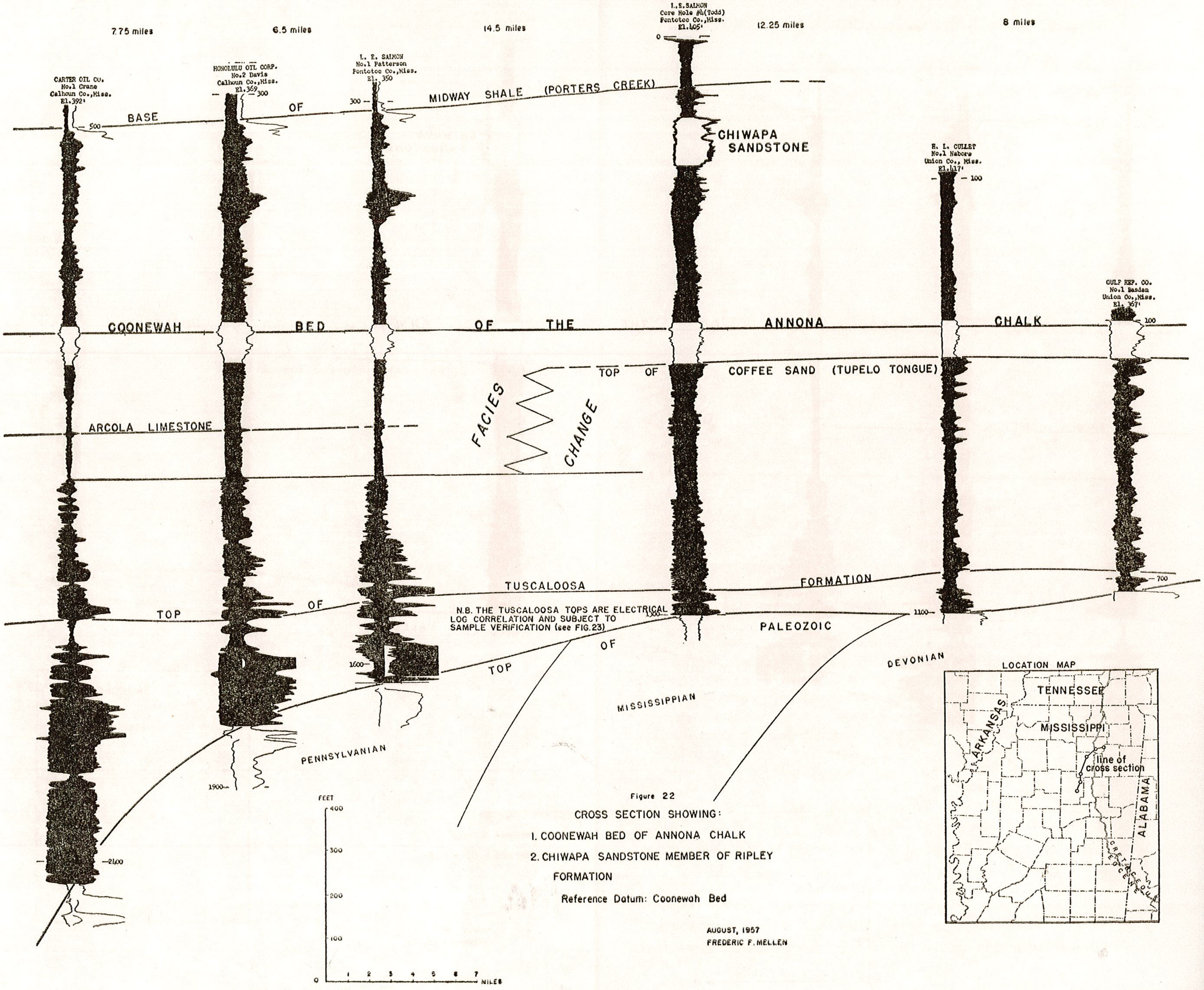


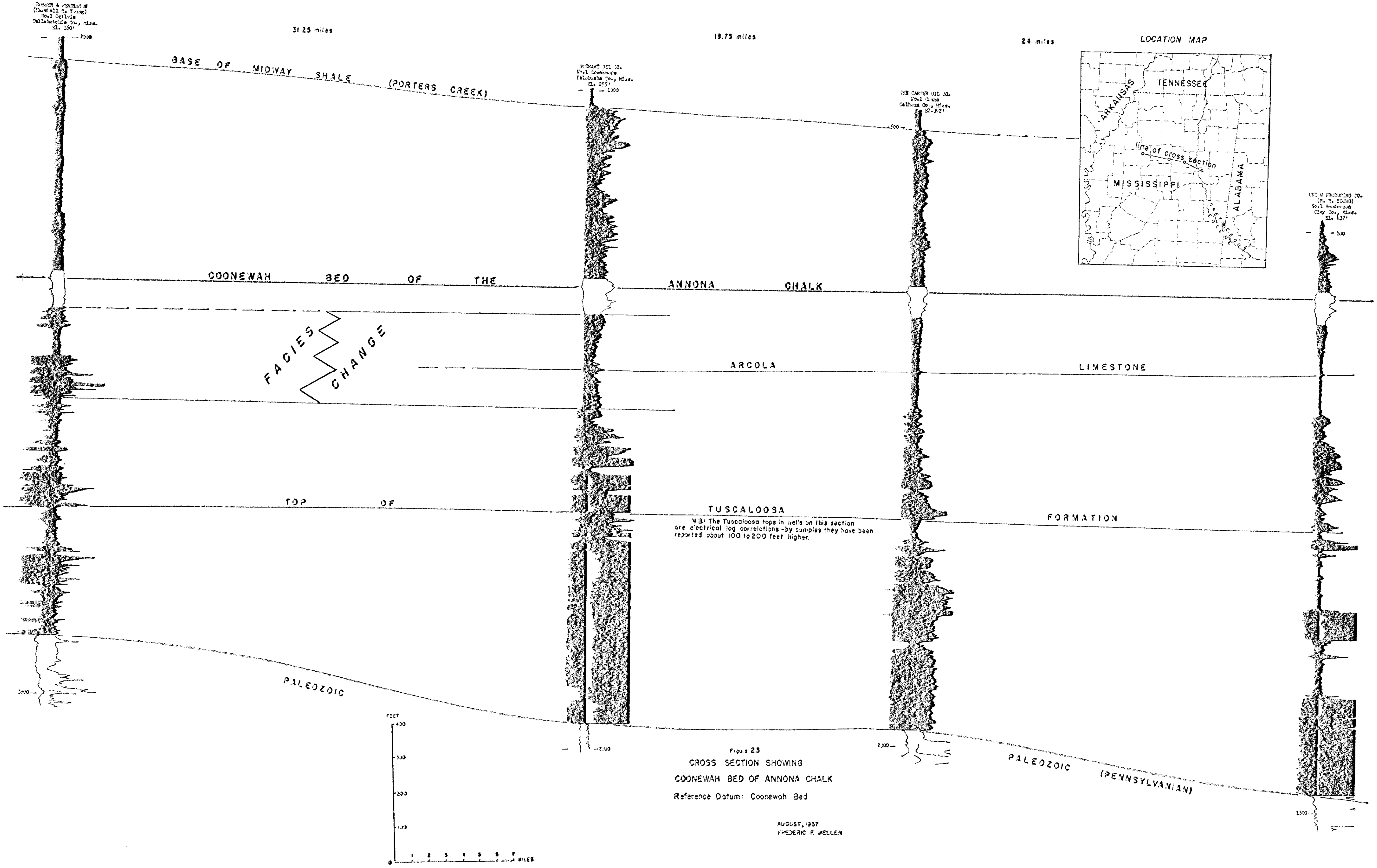
Figure 22

CROSS SECTION SHOWING:

1. COONEWAH BED OF ANNONA CHALK
2. CHIWAPA SANDSTONE MEMBER OF RIPLEY FORMATION

Reference Datum: Coonewah Bed

AUGUST, 1957
FREDERIC F. MELLEN



N.B: The Tuscaloosa tops in wells on this section are electrical log correlations - by samples they have been reported about 100 to 200 feet higher.

Figure 23
CROSS SECTION SHOWING
COONEWAH BED OF ANNONA CHALK
Reference Datum: Coonewah Bed

AUGUST, 1957
FREDERIC F. MELLEN

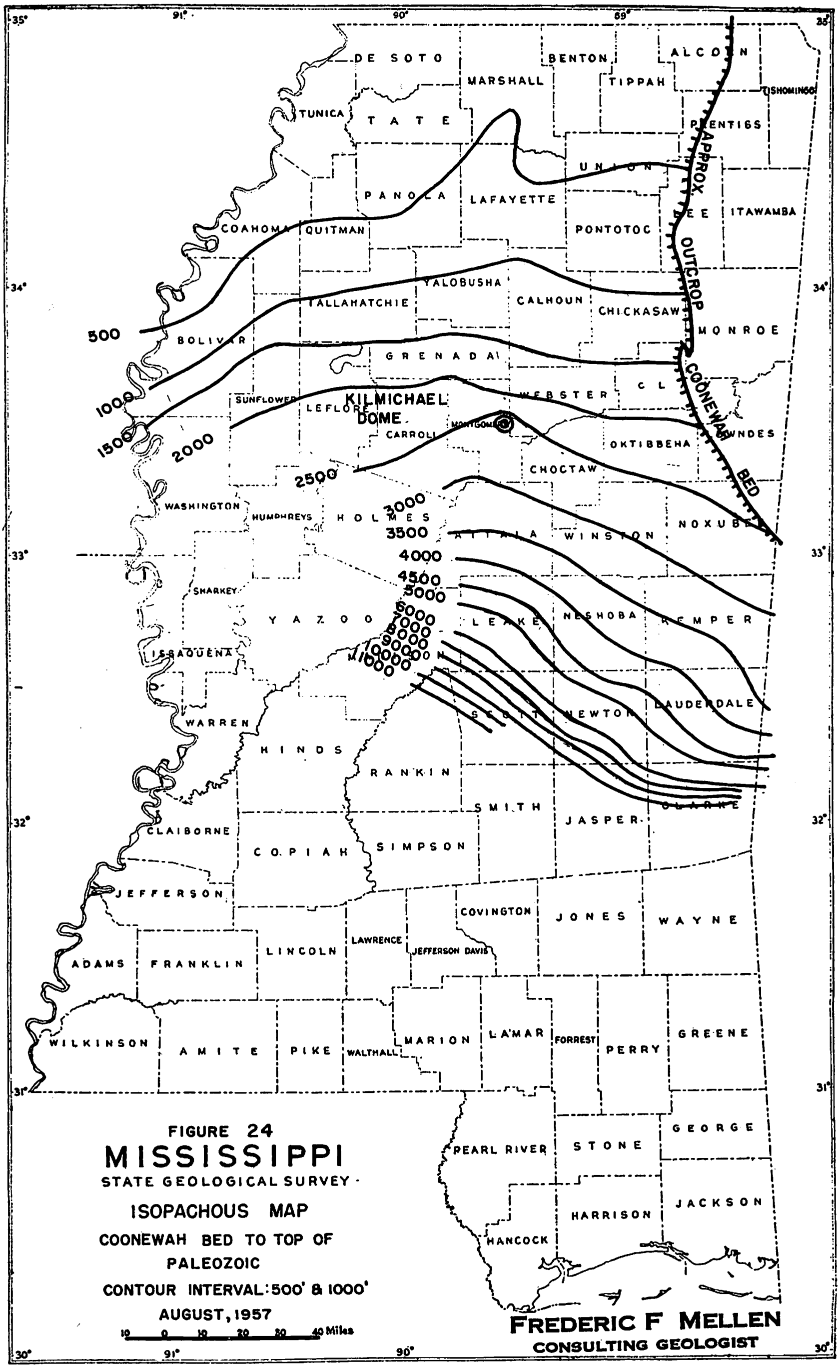


FIGURE 24
MISSISSIPPI
STATE GEOLOGICAL SURVEY
ISOPACHOUS MAP
COONEWAH BED TO TOP OF
PALEOZOIC
CONTOUR INTERVAL: 500' & 1000'
AUGUST, 1957

FREDERIC F MELLEN
CONSULTING GEOLOGIST

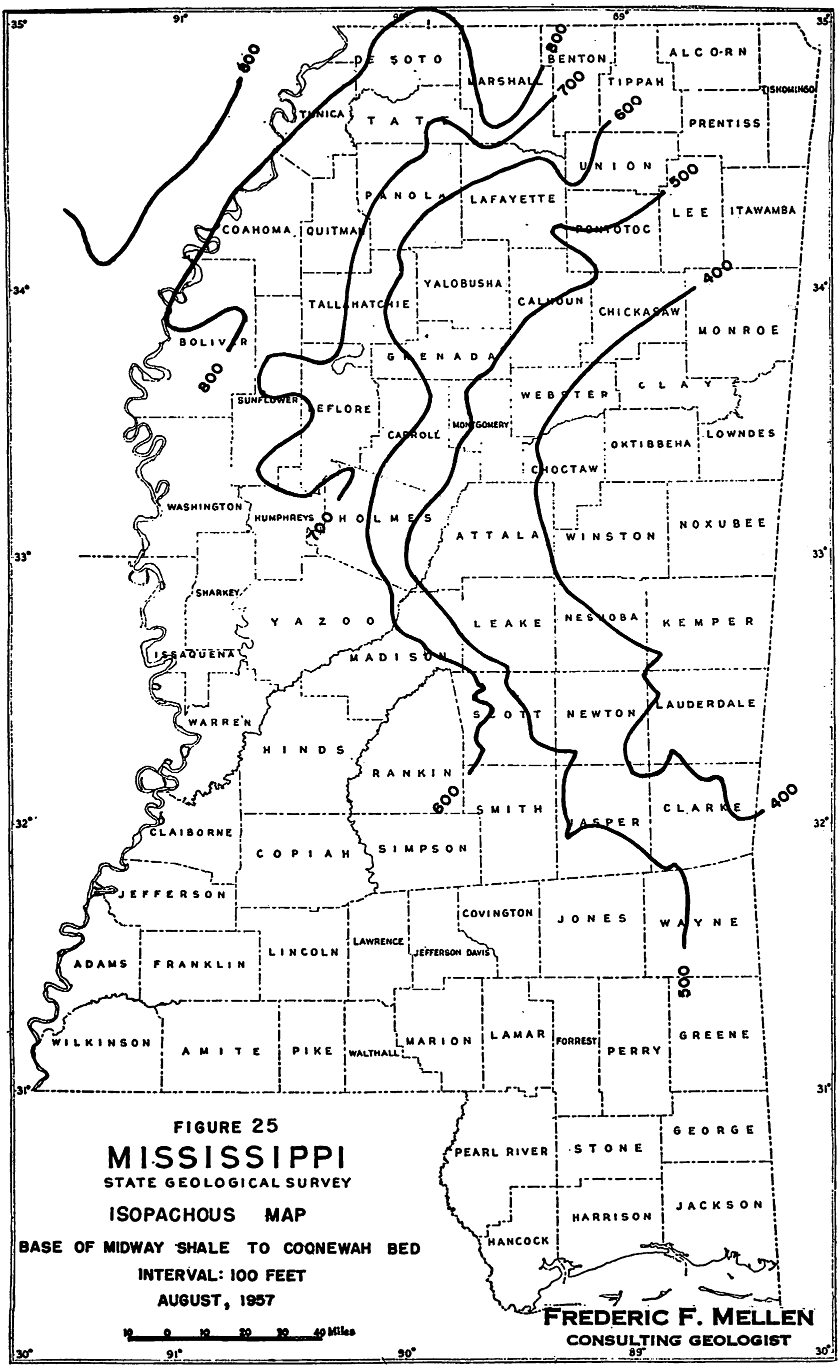


FIGURE 25

MISSISSIPPI

STATE GEOLOGICAL SURVEY

ISOPACHOUS MAP

BASE OF MIDWAY SHALE TO COONEWAH BED

INTERVAL: 100 FEET

AUGUST, 1957

FREDERIC F. MELLEN

CONSULTING GEOLOGIST

cross-sections (Figures 22, 23). The Coonewah bed lies usually within 10 to 20 feet of the top of the Annona and about 20 feet above Stearn's "X point" (Stearns, 1957). The total thickness of the Annona is 100 feet, more or less, and the base of the Annona is at the top of the Coffee sand or its equivalent beyond the "mud line".

The diagramatic cross-sections and the electric log cross-sections as well as the isopach maps (Figures 24, 25) show that the Annona chalk is in the upper part of the "Selma" in east-central Mississippi and is at the base of the "Selma" in northwestern Mississippi. The explanation for this phenomenon is multiple: for one thing the Navarro beds in east-central Mississippi are much more highly calcareous than they are farther northwest where they are very sandy, silty and marly and, because the rate of carbonate deposition is slower, the thicker sedimentation was obtained in the northwest part of Mississippi; also, the Navarro sea was deeper and farther from the source of sediments in east Mississippi than in northwest Mississippi. Another possibility for the thickening of the post-Annona Cretaceous rocks in the northwestern part of the state is that the initial development of the ancestral Mississippi Embayment took place in late Taylor and Navarro times north of the Monroe-Sharkey Uplift and roughly following the course of the present Mississippi River. The building up of the clastic material below the Annona to the northwest is simply an indication of approach toward the source of sediments.

The insoluble residue studies (Figures 19, 20) made on the core hole material in Lee County were done by Earl McCracken of the Missouri Geological Survey. These studies show that biotite mica is scattered through this section. The biotite is believed to be entirely detrital, having as its origin the volcanic rocks of the Sharkey-Monroe Uplift and the Jackson Dome.

The examination of micro-fossils was done on washed composite material representing 10-foot intervals in the core holes. These chalk samples were carefully washed by the Geological Department of Shell Oil Company in Jackson. The washed fossil material was delivered to William S. Parks of the Mississippi Geological Survey who studied the foraminifera and who picked out the ostracods. The slided ostracods were sent to Robert H. Shaver of the Indiana Geological Survey who had had previous experience in Mississippi. Neither Parks nor Shaver found anything to indicate that the chalk identified as Annona was not Annona. The foraminiferal assemblage is more definite in the conclusion that the section under study is of Annona age equivalent to the type locality in Texas. The detailed analyses and discussion of the micro-paleontological reports are covered in the sections prepared by Parks and Shaver.

The paleontological and insoluble residue studies may not be sufficient at this time for conclusive stratigraphic analysis. The foraminiferal studies by Parks, the ostracodal studies by Shaver, and the insoluble residue studies by McCracken all should be of great help in precise stratigraphic correlation. In addition, many lists of the megascopic fossils are published and stratigraphic zonation by the molluscs is better known at present. Following are the larger fossils noted in the Stovall No. 1 Core Hole:

Ostrea falcata Morton (24-25′)
Ostrea sp., frag. rt. valve med-sized thick-shelled smooth sl. striate (58-59′)
Paranomia scabra Morton (38-39′; 98-99′; 117-118′)
Inoceramus barabini Morton (92-93′), identified by Norman F. Sohl, U.S.G.S.
Corbula cf. *crassiplica* Gabb (35-36′)
Baculites sp. (119-120′)
Hamulus onyx Morton (61-62′; 113-114′)

The absence of the oyster bed (*Gryphea convexa,* etc.) and the associated bone and teeth fragments (of collophane) at the Annona-Coffee contact is noteworthy. It appears that the soft bottom sediments south of the "mud line" would not support the reef which developed north of the "mud line" at the close of Coffee time, or at the beginning of Annona time.

DISCUSSION ON THE FORAMINIFERA

WILLIAM S. PARKS, M.S.

The foraminifera chart (Figure 26) is a complete analysis of the foraminiferal population of the samples from the test holes. The chart shows also other references in the Cretaceous of the Gulf Coastal Plain and the relative abundance of the forms.

The foraminifera are in general well preserved and several forms are represented in some abundance. However, the larger

Fig. 26

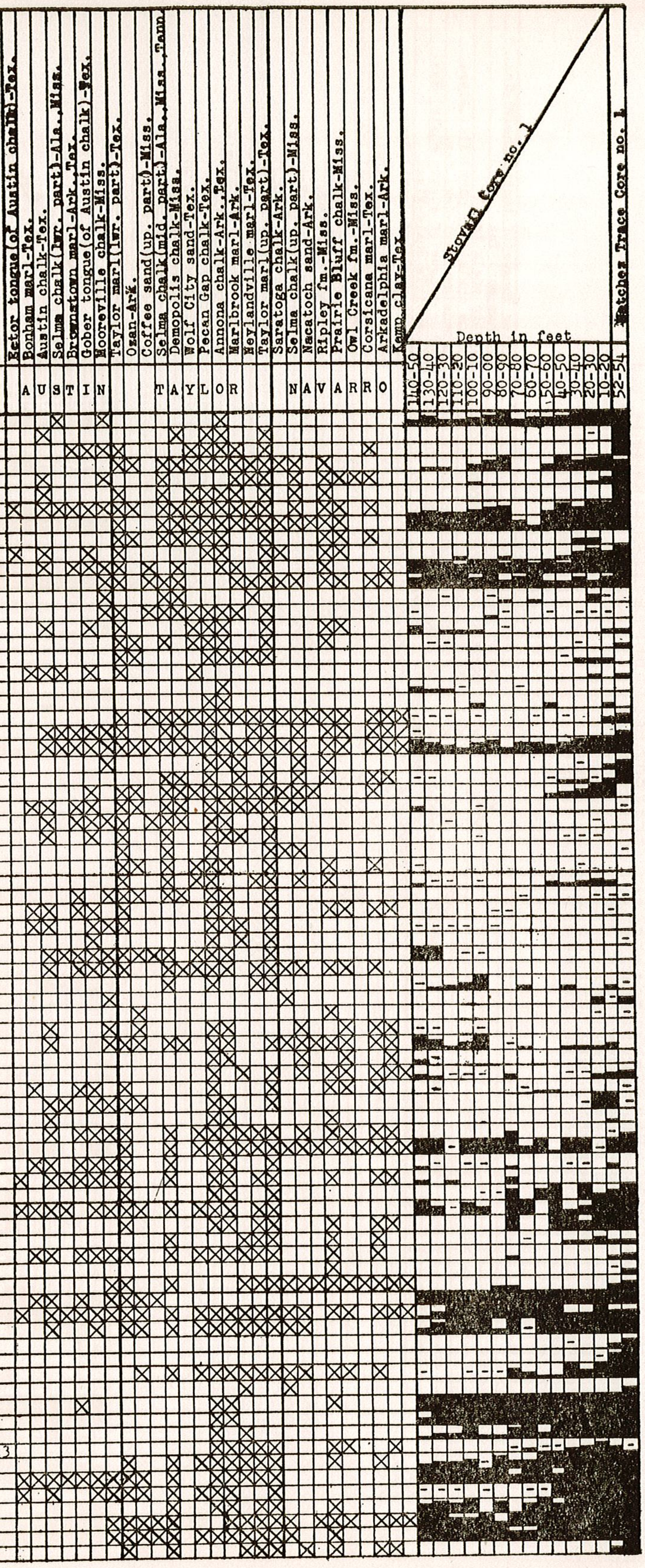
FORAMINIFERA

Identified by
William S. Parks

LEGEND

■ Abundant 10+
▆ Very Common 5-10
▄ Common 3-5
□ Present 1-3
⊟ Fragmental

	References
Reophax clavulinus (Reuss)	1,3
Lituola taylorensis Cushman & Waters ?	1,3,7
Spiroplectammina laevis cretosa Cushman	1,2,6,9
Textularia ripleyensis W. Berry	1,3
Gaudryina rudita Sandidge	1,3,9
G. stephensoni Cushman	1,7,9
Pseudoclavulina clavata (Cushman)	1,3,9.
Clavulinoides trilaterus concavus (Cushman)	1,3,8,9
Heterostomella americana Cushman	1,3.
Marssonella oxycona (Reuss)	1,11
Robulus münsteri (Roemer)	1,3,4,9
R. pondi Cushman	1,3,4,9,13
R. pseudo-secans Cushman	1,4,6
R. taylorensis (Plummer)	1,3,4,9
Saracenaria triangularis (d'Orbigny)	1
Marginulina bullata Reuss	1
M. cretacea Cushman	1,9
M. directa Cushman	1,2
M. dorsata Cushman	1
Dentalina aculeata (d'Orbigny)	1,8
D. basiplanata Cushman	1,4,9
D. legumen (Reuss)	1,3
Nodosaria affinis Reuss	1,3,4,9
N. obscura Reuss	1,2,6,9
Pseudoglandulina lagenoides (Olszweski)	1,2,3,9,13
Neoflabellina rugosa (d'Orbigny)	1,3,9
N. suturalis (Cushman)	1,4,5,9
Frondicularia cordata Roemer	1,4,5
F. goldfussi Reuss	1,9
F. watersi Cushman	1
Pseudofrondicularia archiaciana (d'Orbigny)	1
P. franki (Cushman)	1
P. intermittens (Reuss)	1,3,4,5
P. lanceola lanceola (Reuss)	1,12,13
P. linearis (Franke)	1,3,9
P. striatula (Reuss)	1,9
Kyphopyxa christneri (Carsey)	1,3,4
Lagena acuticosta Reuss	1,3
L. apiculata (Reuss)	1,2
L. Vulgaris Williamson	1,3
Guttulina trigonula (Reuss)	1
Globulina lacrima horrida Reuss	1,6
G. l. lacrima (Reuss)	1,2,3,6,13
G. prisca	1,7,13
Pyrulina cylindroides (Roemer)	1,2,3,9
Bullopora laevis (Sollas)	1,4
"Ramulina aculeata" Wright	1,6
R. globo-tubuloso Cushman	1
Bolivinopsis rosula (Ehrenberg)	1,3,4,9,13
Gümbelina globulosa (Ehrenberg)	1,3,7,12
G. pseudotessera Cushman	1,3
G. striata (Ehrenberg)	1,3,7,13
Bolivinoides decoratus latticeus (Carsey)	2,4
Buliminella carseyae carseyae Plummer	1,3,
Bulimina aspera Cushman & Parker	2,4
B. prolixa Cushman & Parker	1,4,9
Neobulimina canadehsis Cushman & Wickenden	1,3,9
Entosolenia marginata (Walker & Jacob)	1
Loxostoma plaitum plaitum (Carsey)	1,3,9
Valvulinera infrequens Morrow	1,3,4
Gyroidina depressa (Alth)	1,2,3,4,9,13
G. globosa (Hagenow)	1,9
Pulvinulinella ? sp.	
Allomorphina trochoides (Reuss) ?	1
Pullenia americana Cushman	1,3,9
P. coryelli White	1,4,9
Globigerina cretacea d'Orbigny	5,7,12
Globigerinella aspera (Ehrenberg)	7
Biglobigerinella multispina Lalicker	2,10
Globotruncana arca (Cushman)	1,3,7,8,9,11,13
G. fornicata Plummer	1,2,3,9,11
G. marginata (Reuss)	1,2,3,9
Globorotalites conicus (Carsey)	1,3,4
Anomalina henbesti Plummer	1,2,7
A. nelsoni W. Berry	1,3,4,9
Planulina dumbeli (Applin)	1,3,4,9
Cibicides coonensis (W. Berry)	1,2,9,13



forms are less abundant and most of them are poorly preserved. In comparison with other assemblages of the Gulf Coast Plain, there is a similarity in the faunal populations; the calcareous forms are predominant. There is a general trend of increase in abundance and of the introduction of new forms in the younger sediments of the samples examined, the Coonewah bed being the most prolific.

Taylor age is indicated through correlation by the greatest percentage of species. The abundance of typical Taylor forms such as *Planulina dumbeli* (Applin) [*P. taylorensis* (Carsey) Cushman], *Globorotalites conicus* (Carsey), and *Bolivinoides decorata latticeus* (Carsey) also leads to this conclusion. Further correlation by the greatest percentage of species method fails to show any significant difference in faunal populations within the Taylor, many of the forms ranging throughout the Taylor. An age younger than Annona cannot be favored, however, because of the absence of many typical upper Taylor forms. Braunstein et al (1950) state that the Texas-Austin equivalent in Mississippi is picked in the subsurface at the highest appearance of the Austin marker *Vaginulina texana* [*Citharina texana* (Cushman)]. There is no representation of this species in the core hole samples; therefore, the entire core hole section is considered Taylor in age.

Thomas and Rice (1932) state that both the top and base of the Annona are gradational and neither is the same age over the entire outcrop. They state further that over wide areas the change of the top or base is so gradual that its vertical (age) variation will be negligible. They also recognize a zone characterized by an abundance of *Bolivinoides decorata* and *Cibicides excolata* (*Stensiöina americana* Cushman and Dorsey). It is suggested by them that the base of this zone be used to determine the base of the Annona for the convenience of workers.

In the core hole samples *Stensiöina americana* Cushman and Dorsey is not present; however, *Bolivinoides decorata latticeus* (Carsey) is represented in some abundance, and first appears in abundance at the 80-90-foot level in the core hole samples, which will be considered the base of the Annona as suggested by Thomas and Rice (1932).

The distribution chart shows some break in abundance of forms centered at about the 90-110-foot level in the samples.

Some species are represented with little or no abundance below this level and some with little or no abundance above this level. Of course, they do not all break at the same level and there is variation in this respect.

Globorotalites conicus (Carsey), *Neoflabellina rugosa* (d'Orbigny), *Bulimina aspera* Cushman and Parker, *Bulimina prolixa* Cushman and Parker, *Globotruncana arca* (Cushman), and *Pullenia americana* Cushman appear for the first time in abundance above this 90-110-foot level and all except *Neoflabellina rugosa* (absent in the Coonewah bed) continue to increase in abundance in the younger sediments. *Pullenia americana* and *Bulimina asper* appear in abundance at the 80-90-foot level, as do *Bolivinoides decorata latticeus.* All the above genera and species seem to have a comparable range in the Cretaceous of Mississippi and may prove valuable in picking the base of the Annona. *Kyphopyxa christneri* is represented in some abundance below this level and is absent in the younger sediments; however, it is reported with variable range in Mississippi.

The variations in the foraminiferal population suggest a change in environment; and they somewhat parallel the changes in lithology as shown in the insoluble residue chart, the most evident change being the one centered at the 90-110-foot level which includes the "mud line" as defined in this paper.

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DISCUSSION ON THE OSTRACODA

ROBERT H. SHAVER, Ph.D.

The ostracod fauna consists of approximately 30 species, mostly in good preservation. Some species cannot be identified with those published earlier from the Gulf Coast; few are matched more nearly with Atlantic Coast forms with which, however, they are described only as having affinities. These species probably would be given new names in a systematic presentation. Evidently, Cretaceous ostracods from the Gulf Coast are not studied sufficiently, nor is their full value in correlation realized. Nevertheless, I conclude that the evidence presented herein indicates that the core hole strata are Taylor in age with middle Taylor preferred for most of the section.

Several ostracods are identified throughout the range of Stovall core samples between depths of 10 and 150 feet. The Chart (Figure 27), then, does not show a major faunal break at any point in the samples when the entire suite of species is considered. Indeed, when other published records are compiled for the species to which names are assigned, there is not convincing evidence that a Taylor age for the pertinent strata should be favored greatly over Navarro. Taylor species number 17 and Navarro, 15, but the Saratoga chalk of Navarro* age is shown to have more of the Stovall species than any other formation, with middle Taylor having the next greatest number. Therefore, the conventional method of correlation by greatest number of species does not offer decisive results.

During the course of this investigation, the new publication on Cretaceous ostracods from Louisiana salt domes (Butler and Jones, 6) became available. Without it, Saratoga species would number four and Navarro, 13. We appreciate then, how a timely or especially comprehensive paper may affect the greatest-number-of-species method of correlation, and we may speculate further upon similar effects produced by any miscorrelation in any of the sources involved, and by disregard of ecology.

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* Throughout this discussion and in the ostracod faunal chart Shaver has followed the usage of Stephenson and some others in placing the Saratoga in the Navarro. However, he concurs with the majority opinion in this region that Saratoga is uppermost Taylor and "believes that the ostracod evidence favors a Taylor age"—letter of March 20, 1958. According to a current review of the evidences by Mellen, Rice and Shaver they are in agreement that the Taylor in this area includes, in descending order, the following units: 1. Saratoga; 2. Marlbrook; 3. Annona; and 4. Coffee (Ozan).

Fig. 27

OSTRACODA

Identified by
Robert H. Shaver

		L. and M. Austin: Tex.	Eutaw, Tombigbee: Miss.	Niobrara, Ft. Hays: Kan., Neb.	Frontier: Utah, Wyo.	U. Austin, Gober: Tex.	Brownsport: Ark., Tex.	L. Taylor: Tex.	Ozan: Ark.	L. Selma, Mooreville: Miss.	Hilliard: Utah, Wyo.	M. Taylor, Wolfe City, Pecan Gap: Tex.	Annona: Ark., Tex.	L. Black Creek: N.C.	L. Pierre: Kan., Neb.	U. Taylor: Tex.	Marlbrook: Ark.	U. Selma, Demopolis: Miss.	U. Black Creek: N.C.	U. Matawan, Marshalltown, Wenonah: N. Atl.	L. Navarro, Neylandville: Tex.	Saratoga: Ark., La.	Ripley: Tenn.	L. Monmouth, Mt. Laurel: N. Atl.	M. Navarro, Nacatoch: Ark., Tex.	L. Pedee: N.C.	M. Monmouth, Navesink: N. Atl.	U. Navarro: Tex.	Arkadelphia: Ark.	Prairie Bluff: Ala., Miss.	U. Pedee: N.C.	Stovall Core no. 1														Natchez Trace Core no. 1
	References	A	U	S	T	I	N				T	A	Y	L	O	R							N	A	V	A	R	R	O			Depth in feet														
																																140-50	130-40	120-30	110-20	100-10	90-00	80-90	70-80	60-70	50-60	40-50	30-40	20-30	10-20	52-54
Cytherellidae																																														
Cytherella bullata Alexander	1,2,11,12,16,18			X	X	X		X				X														X				X		X			X		X	X	X	X	X	X		X		X
Cytherella ovata(Roemer)	1,2,10,13,18															X			X	X	X				X		X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cytherella parallela(Reuss)	1,11,12			X	X	X		X			X	X																				X	X	X	X			X		X	X	X		X	X	X
Cytherella sp.																																				X										
Cytherelloidea crafti Sexton	14																X																					X		X				X	X	
Cytherelloidea tollettensis Sexton	14								X																							X		X	X											
Cyprididae																																														
Paracypris spp.																																	X	X												X
Bairdiidae																																														
Bairdia-Bairdoppilata spp.																																X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bythocypris ? sp.																																														X
Cytheridae																																														
Brachycythere cf. B. ledaforma(Israelsky)	1,3,6,7,9,10,17																				X	X		X	X		X	X	X			X			X	X			X	X	X			X		
Brachycythere sphenoides(Reuss)	1,3,6,7,9,11,12,18	X		X		X	X	X	X		X	X	X	X	X		X					X			X				X											X	X					X
Brachycythere cf. B. taylorensis(Alexander) and	1,15		X			X				X		X																				X			X		X			X	X					
B. rhomboidalis(Berry)	1,5,6,10,13																				X	X		X	X	X	X	X																		
Cythereis austinensis Alexander	1,					X																																						X		
Cythereis communis Israelsky	1,6,9,10,13,17								X				X				X			X	X	X		X	X		X	X	X			X						X	X	X	X			X		X
Cythereis gapensis Alexander	1,12										?	X																				X	X													
Cythereis semiplicata(Reuss)	1,11					X		X				X			X																												X	X	X	X
Cytheridea ? sp.																																			X				X							X
Eocytheropteron sp.																																										X				
Haplocytheridea monmouthensis(Berry)	1,5,18													X										X	X			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Haplocytheridea plummeri(Alexander)	1,6							X				X				X						X																	X	X	X	X		X		
Haplocytheridea sp.																																		X												
Krithe cf. K. cushmani Alexander and	1,6					X		X				X										X										X	X	X	X	X	X	X		X	X	X	X	X	X	X
K. postprojecta Schmidt	13,18																			X						X					X															
Orthonotocythere hannai(Israelsky)	1,3,4,6,9,17							X	X							X					X	X			X				?								X	X		X						
Paracythereis cf. P. typicalis Jennings	10																										X								X		X									
Pterygocythere gulfensis(Alexander)	1,3,6,8,9,10	X				X		X			X	X				X	X	X			X	X	X		X		X	X		X											X					
Pterygocythereis thomasi(Israelsky)	3,6,7,8,9,12				X				X				X				X	X			X	X			X			X		X														X	X	
Veenia ozanana(Israelsky)	6,9,11			X					X				X		X		X					X										X	X		X	X	X	X	X	X	X	X	X	X	X	

Butler and Jones' work resulted in their conclusion (p. 6), based on the greatest number method, that the pertinent strata in Louisiana are correlatives of the Saratoga chalk. This correlation results in an upward extension of the ranges of several species or types of ostracods, which extension makes less convincing the conclusion offered herein that the Stovall section is considerably lower. These species include *Haplocytheridea plummeri, Krithe cushmani,* and *Veenia ozanana.* Further, their *Cytherelloidea* sp. (p. 10, pl. 6, fig. 4) is comparable with *C. crafti* Sexton (14, p. 813, pl. 117, figs. 7-10) from the Marlbrook; *Brachycythere rhomboidalis* (Berry) of Butler and Jones (p. 28, pl. 3, figs. 2a, b) when compared with Texas specimens, is nearer *B. taylorensis* (Alexander) (1, p. 82, pl. 7, figs. 3, 4) from the middle Taylor, than to Alexander's (p. 86, pl. 7, figs. 1, 2) *B. rhomboidalis* (Berry) of Navarro age. *Cythereis semiplicata* (Reuss) of Alexander (p. 80, pl. 6, fig. 15) and *Cythereis* cf. *C. filicosta* (Marsson) of Butler and Jones (p. 37, pl. 5, figs. 2a-e) are similar types of ostracods, as are *Cythereis austirensis* (Alexander) (p. 99, pl. 7, fig. 11) and *Cythereis verricula* Butler and Jones (p. 40, pl. 5, figs. 6a-c).

It has been decided to base the conclusion of a middle Taylor age of most of the Stovall section, on individual consideration of species, all too few of which have been studied with a view to determine directly their place in a developmental series of forms through time. Sexton (14) studied the complexly sculptured *Cytherelloidea* throughout its North American range. The Stovall samples contain *C. tollettensis* below 110 feet of depth and *C. crafti* above 90 feet. Based upon Sexton's work, the strata are correlated within the range of Ozan through Marlbrook. Sexton's *C. pecanana* from the intervening Annona equivalent, is not represented.

Brachycythere taylorensis is considered a good marker of the middle Taylor and lower strata in the Gulf Coast region. Our specimens have the prominent eyespot and shape of *B. taylorensis* (Alexander), but are coarsely punctate. In the latter respect, they resemble the Navarro species, *B. rhomboidalis* (Berry) of Alexander; Alexander's figure does not show an eyespot which is so prominent in the Stovall specimens. *Brachycythere sphenoides* is found no higher than Annona and Wolfe City in north Texas according to Alexander (3, p. 206). This evidence would place the Coonewah section no higher than the Annona of Texas. However, Alexander's (p. 205) placing of Israelsky's (9, p. 8) *Cytheropteron* sp. B in the synonymy of *B. sphenoides* is not compatible with his limitation of the range to Annona and below; Israelsky reported *Cytheropteron* sp. B ranges from Ozan through Arkadelphia. *Brachycythere* cf. *B. ledaforma* at first appears to offer contrary evidence inasmuch as *B. ledaforma* is known only as a Navarro species. Specimens below 70 feet in the Stovall core differ from the type specimens as described by having slight lateral keels and coarse punctae, and by lacking ventral striations; above 70 feet the specimens are nearer the type specimens but have punctae of moderate size and only suggestions of the ventral striations which characterize Navarro specimens. Alexander (3, p. 207) reported an unnamed and unfigured Taylor species with punctae.

Cythereis gapensis is a rare and complexly sculptured species known previously only from the middle Taylor of Texas and possibly from the Hilliard of Utah and Wyoming. The Stovall specimens compare perfectly with Alexander's (1, pl. 6, figs. 16, 17) specimens. *Cythereis austinensis* is similarly complex and presumably should have a short range. *Cythereis semiplicata, Haplocytheridea plummeri,* and *Veenia ozanana* support the assignment of a Taylor age to the core hole strata. *Cytherella ovata, Haplocytheridea monmouthensis* and *Paracythereis* cf. *P. typicalis* favor a higher correlation.

The specimens referred to *Krithe* show considerable variation but are nearer *K. cushmani* in elongation. Shorter forms like this Taylor species, are found consistently with longer Navarro forms approaching *K. postprojecta* Schmidt, which suggests a dimorphic relationship. Schmidt's (13, p. 409) Navarro species is characterized by a posterior projection, which feature is reduced in the Stovall specimens; Alexander (1, p. 67, pl. 4, fig. 11) did not figure or describe this feature in *K. cushmani,* but the specimens of Butler and Jones (6, p. 17, pl. 1, fig. 2) do have the projection.

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CHIWAPA SANDSTONE MEMBER OF RIPLEY FORMATION

The name Chiwapa is proposed for a sand or sandstone member of the Ripley formation throughout the outcrop belt of the unit in Clay, Chickasaw, Pontotoc, Union and Tippah Counties, and as far into the subsurface as it can be traced. It is characteristically a "bored" or "horsebone" limestone (Figures 28, 29, 30) or calcareous sandstone, an irregularly indurated stratum of shallow marine sediment approximately 80 feet in thickness at the top of the Ripley, and it can be traced for a north-south distance of 85 miles, more or less. Harper (1857) and Hilgard (1860) discussed the peculiar features of this rock, but confusion of this bed with the much younger "Turritella-rock" has resulted from their descriptions. The two similar rocks produce sink holes

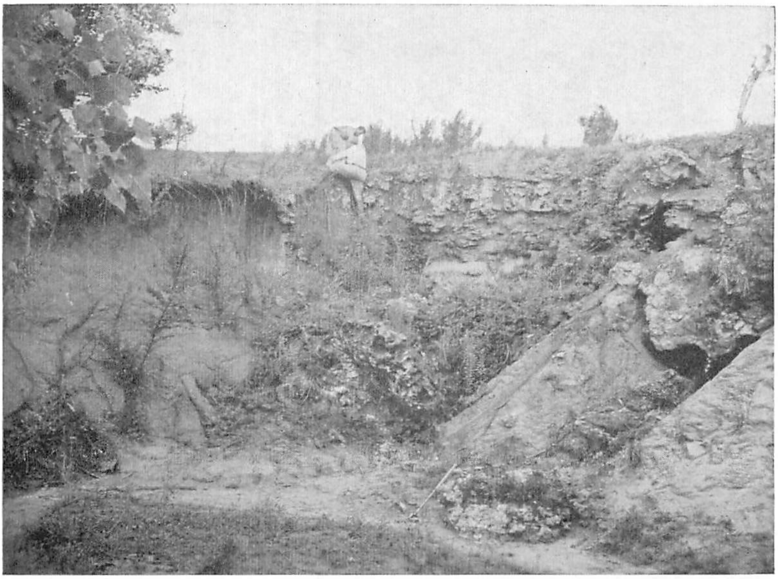

Figure 28.—Chiwapa sandstone 2 miles east of Pontotoc (N.pt. SW.¼, Sec.35, T.9 S., R.3 E., Pontotoc County, Mississippi); the leaching of the highly calcareous very fossiliferous sandstone to coarse-grained unconsolidated sand is characteristic. Common Hardouinia and Exogyra costata are freed from the rock in this leaching process. June 21, 1937.

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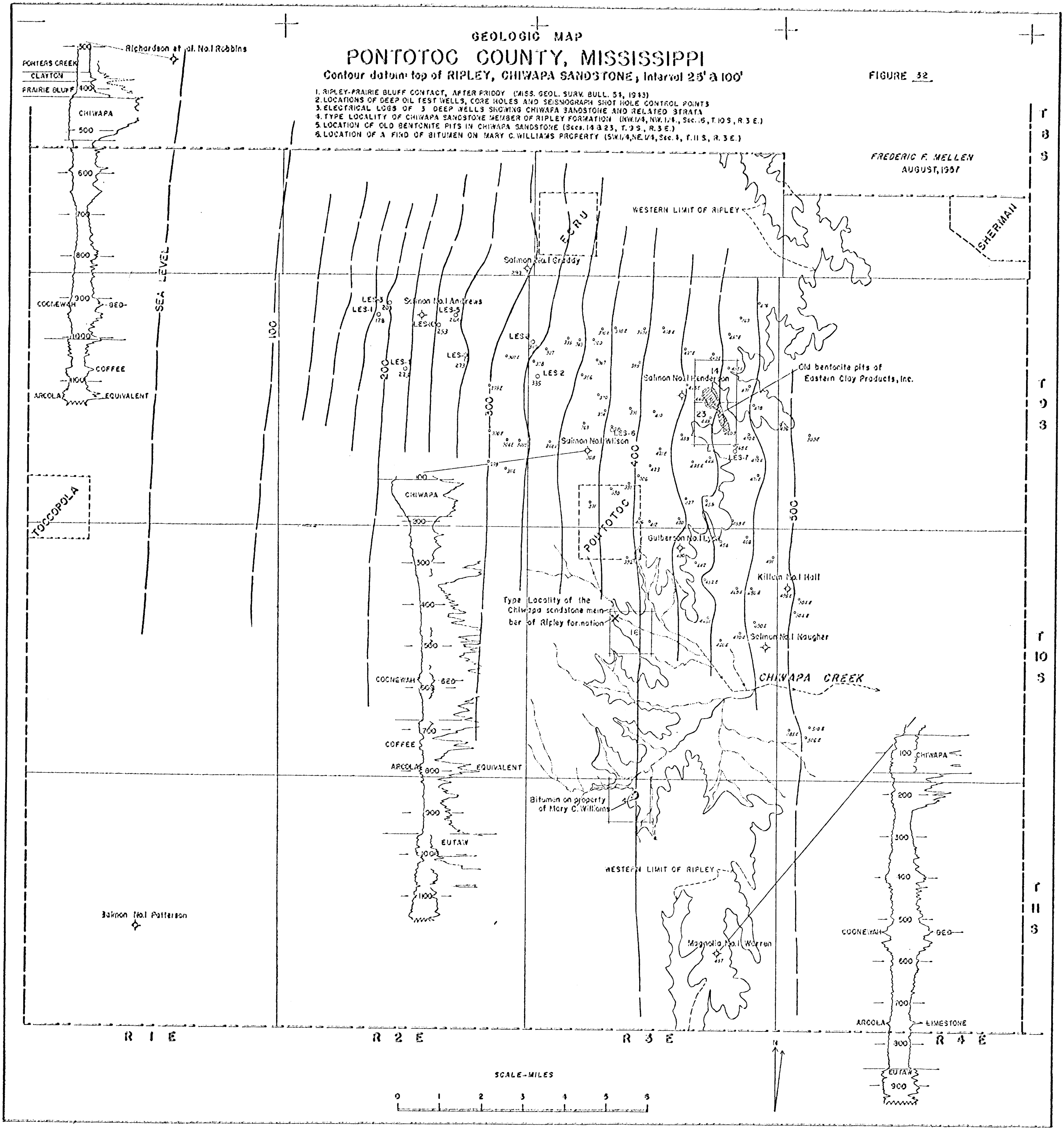
* Chiwapa is not preempted as a stratigraphic name and has been reserved for the present usage (George V. Cohee, Chairman, Geologic Names Committee, U. S. Geological Survey, letter of April 24, 1957.)

Figure 29.—Lower opening of "The Caves," developed in the Chiwapa sandstone (just N. of Highway 30, 4 miles NE. of New Albany, N.½, Sec.1, T.7 S., R.3 E., Union County, Mississippi) (see M.G.S. Bull.40, pp. 194-195; M.G.S. Bull.45, pp. 29-30) March 22, 1936.

Figure 30.—Upper opening of "The Caves," developed in the Chiwapa sandstone. (see notes under Figure 29) March 22, 1936.



GEOLOGIC MAP

PONTOTOC COUNTY, MISSISSIPPI

Contour datum: top of RIPLEY, CHIWAPA SANDSTONE; Interval 25' & 100'

FIGURE 32

1. RIPLEY-PRAIRIE BLUFF CONTACT, AFTER PRIDDY (MISS. GEOL. SURV. BULL. 54, 1943)
2. LOCATIONS OF DEEP OIL TEST WELLS, CORE HOLES AND SEISMOGRAPH SHOT HOLE CONTROL POINTS
3. ELECTRICAL LOGS OF 3 DEEP WELLS SHOWING CHIWAPA SANDSTONE AND RELATED STRATA
4. TYPE LOCALITY OF CHIWAPA SANDSTONE MEMBER OF RIPLEY FORMATION (NW.1/4, NW.1/4., Sec.16, T.10 S, R.3 E.)
5. LOCATION OF OLD BENTONITE PITS IN CHIWAPA SANDSTONE (Secs. 14 & 23, T. 9 S., R. 3 E.)
6. LOCATION OF A FIND OF BITUMEN ON MARY C. WILLIAMS PROPERTY (SW.1/4, NE.1/4, Sec. 4, T. 11 S., R. 3 E.)

FREDERIC F. MELLEN
AUGUST, 1957

and caves in Union and Tippah Counties. They are separated by only 30 to 50 feet of the Prairie Bluff chalk or Owl Creek marl, at the top of which the Cretaceous-Tertiary unconformity is the greatest in the post-Comanchean sedimentary record of the Embayment. South from Pontotoc County, the Chiwapa (Terry, 1957) grades laterally into finer-grained better sorted unconsolidated sand (which Terry correlated with the middle Ripley McNairy Sand) (Figure 31).

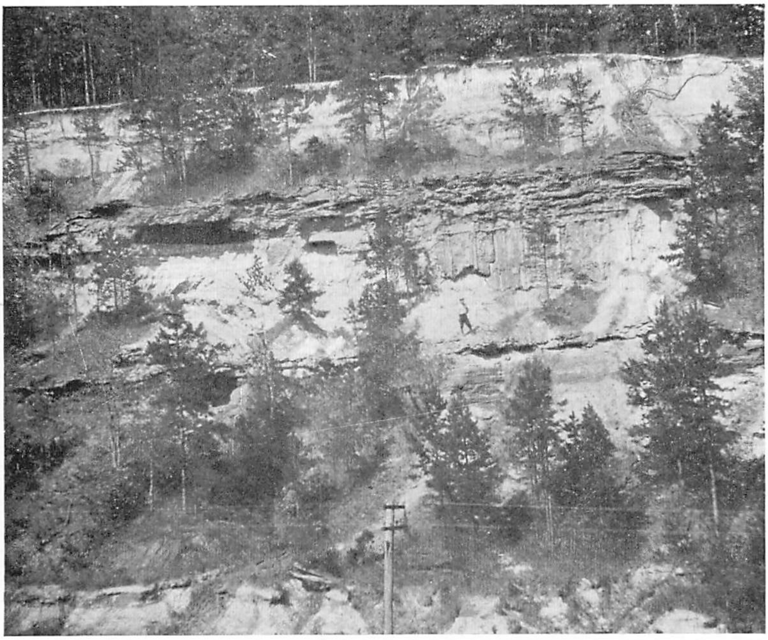


Figure 31.—Type locality of the McNairy sand member of the Ripley formation; cut of Southern Railway known as Big Hill, 1 ¼ miles west of Cypress, McNairy County, Tennessee. Photo by L. W. Stephenson.

The type locality of the Chiwapa sandstone member of the Ripley formation is on one of the main branches of Chiwapa Creek at the old CWA rock quarry 1.5 miles south of Pontotoc in NW.¼ of NW.¼ of Section 16, T.10 S., R.3 E., Pontotoc County, Mississippi (Figure 32). This locality is selected over better exposures of the typical material because of its accessibility and because of the excellent exposure of the overlying Prairie Bluff in the cut on Highway 15 several hundred yards west of the old quarry. Down-stream from the quarry, and on most of the other headwater tributaries of Chiwapa Creek there are excellent exposures of the typical lithology. Some of the exposures of the Chiwapa were figured by Priddy (1943) in his Pontotoc County report, figures 4 and 5; in this same report the above-mentioned outcrop of Prairie Bluff chalk is shown in figure 6.

Priddy points out that the highest (1 ft. to 2 ft.) layer of the Chiwapa contains the disc-shaped cephalopod *Sphenodiscus lenticularis* which commonly exceeds 15 inches in diameter, and that the underlying few feet of rock contain abundant sea urchins, *Hardouinia*, sp. and oysters, *Exogyra costata*, both among many other forms.

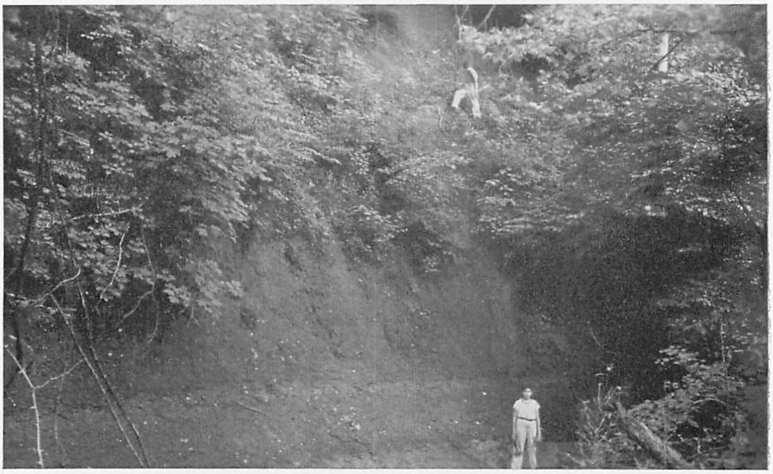


Figure 33.—Type locality of the Owl Creek formation, near Ripley, Tippah County, Mississippi. The boys are standing at the edge of the creek bed and at the Owl Creek-Clayton contact. Photo by L. C. Conant, July, 1938.

The base of the Chiwapa is thought to lie conformably upon the underlying Ripley marlstone, but the coarseness of the Chiwapa sands suggests the possibility of an unconformity. The Chiwapa is separated from the overlying Prairie Bluff-Owl Creek stratum by a sharp contact, regarded by some as marking an unconformity or a diastem. The base of the superjacent unit contains abundant phosphatic molds, some coarse sand and disseminated glauconite. Locally scattered quartz pea gravel is found. There is obviously no great break in time between the Chiwapa and the Prairie Bluff-Owl Creek (Figure 33) because the large, robust, short-lived, and free-swimming cephalopod genus *Sphenodiscus* is well-represented in the beds above and below the break, and the diminutive, fragile, but usually well preserved pelecypod, *Crenella serica,* is found in the Chiwapa as well as in the Prairie Bluff. Many fossil species transgress this contact. The basal part of the overlying Prairie Bluff-Owl Creek is one of the most fossiliferous intervals in the Cretaceous from the standpoint of variety of species of mcro-fauna and mega-fauna.

The Chiwapa possibly cannot be traced as a sand or sandstone throughout an area as great as that covered by the Coffee sand, or, at least, it cannot now be traced with as much certainty. Although it occupies a position approximately equivalent to the Nacatoch sand of Arkansas, the writer has no proof to offer of its precise equivalency. No doubt this can be proven paleontologically, one way or the other. In the event equivalency is established, the name "Nacatoch" should replace "Chiwapa" by the rule of priority.

In Pontotoc County, where the Chiwapa is the principal water reservoir for domestic and farm use, the writer saved and examined samples from many hundreds of seismograph shot holes, drilled by Oklahoma Geophysical Company during the course of oil exploratory work.* In addition to the seismic shot hole control, of which only a portion of the total data is used, Survey Drilling Company and Arrow Drilling Company drilled, respectively, a total of 10 core holes into the Paleozoic for strutural control, and 6 deep oil test wells, all for L. E. Salmon. The locations of the shallow structural data are shown on a geologic map of Pontotoc County, which shows, also, the western (downdip) outcrop limit of the Chiwapa member of the Ripley, the location of the bentonite deposit, the location of the selected type locality of the Chiwapa, and the location of a "find" of bitumen (grahamite), probably at the top of the Chiwapa (Figure 32). The sample and outcrop data show that the Chiwapa is characteristically most indurated and most highly fossiliferous at the top, that the usual thickness of the member is 80 feet, that no great variation in thickness exists over short distances, and that the bentonite in the Chiwapa was seemingly confined to the

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* These samples have been reposited with the Mississippi Geological Survey.

small hundred-acre (more or less) area where it was mined. Only rare traces of bentonite were found in 2 or 3 of the many shot holes, despite the careful taking of samples and the interest of the shot hole driller in attempting to find the bentonite. Where leached of its lime content, some of the coarse-grained Chiwapa is extremely permeable so that some difficulty was experienced in drilling. A few of the shot holes were drilled "blind", and wheat bran and drilling mud were always at hand to combat loss of circulation.

The deposit of bentonite on Bob Miller Creek, Secs. 14 and 23, T.9 N., R.3 E., that was mined by Eastern Clay Products, Inc. occupies a position about 20 or 25 feet below the top of the Chiwapa, and was normally underlain as well as overlain by calcareous fossiliferous sandstone. The deposit was somewhat lenticular in shape. Its maximum thickness in Sec. 14 was 9 feet, but a few hundred feet southwest in Sec. 23 it thinned sharply to less than 2 feet. The eastern edge of the deposit could never be observed, since it was removed by the erosion of Bob Miller Creek. In the pits a steep west dip was noticed coincident with thinning. This suggests that the bottom of the deposit was originally nearly flat and that the lenticularity of the bed was plano-convex, the convexity being at the top. If this is true, the bentonite bed might represent the accumulation of volcanic ash after a period of violent volcanic eruption, swept up into a spit or bar by current action, and buried by the shifting shallow marine sands toward the end of Chiwapa time. This would explain the very local nature of this bentonite, the youngest ash fall thus far reported in the Upper Cretaceous of Mississippi. A careful study of Chiwapa sedimentology might reveal the possibility or probability of other deposits of this bentonite, although none other has yet been found by careful and extensive outcrop search.

ECONOMIC GEOLOGY

The Cretaceous shelf sediments of Mississippi are interesting also because of their economic value to man. Fast-growing pine timber and fertile agricultural and pasture lands are found in the hills and prairies of the Cretaceous outcrop belt of northeast Mississippi. Millions of tons of chert gravel and bentonite have been dug and marketed from the outcropping edges of the Cretaceous strata in Tishomingo, Prentiss, Pontotoc, Itawamba and Monroe Counties. The sands, calcareous sandstones and ferruginous sandstones have been used for road topping and locally for building. The clays have been used locally for many years in a few small stoneware potteries. The chalks have been and are now being used intensively as agricultural lime, but have not yet been in demand for any other sizable product, such as portland cement, as they have been used in Alabama. Also in Alabama a subsurface storage reservoir for liquified petroleum gas has been excavated in the Demopolis chalk and is in commercial use.

The area in which these formations crop out is well known for the artesian water supplies of the Tuscaloosa and Eutaw sands which adequately supply many thriving industries, and for the lesser supplies of good waters in the Coffee sand and in the sands of the Ripley, both of which are developed only in the northerly parts of the State. The transgression of the Cretaceous sea onto the continental mass naturally buried local remnants of the pre-Cretaceous soil or regolith. These soils, the Little Bear residuum, are commonly variable deposits of ferruginous or highly leached clays which have been locally used or prospected. In the advance of the Cretaceous sea over the pre-existing regolith, conditions probably permitted the local entrapment of fresh water already present in the upper parts of the Paleozoic rocks beneath the soils. The large volume of fresh or nearly fresh water in the Devonian cherts of Prentiss, Union, Marshall, and DeSoto Counties (at 3874-3883 feet, NaCl 1,472 p.p.m., total solids 1,868 p.p.m.) suggest that these may be connate fresh waters, trapped in the leached out Devonian cherts beneath the advancing salt water of the Cretaceous seas.

The Cretaceous sediments of Mississippi, in toto, without respect to their depositional or structural position, have, at the present time, produced more mineral wealth than all other geologic systems combined. Oil, of course, is first in value, followed by natural gas. Up to January 1, 1957, about 83% of all oil produced in Mississippi was Cretaceous. Probably 95% or more of the natural gas was Cretaceous. The other mineral products mentioned in the preceding paragraph help to swell the economic worth of the Cretaceous far above any similar volume of other sedimentary rock in the State. In the last few years the annual values of raw mineral products from the Cretaceous have exceeded $100,000,000.

The economic products of the Chiwapa have been groundwater, bentonite, road material (crushed stone and sand topping) and rustic building stone.

Unfortunately, there are no available figures on annual production of the Ripley bentonite at Pontotoc. Although the writer was assured at various times that he might have such data, his request of August 15, 1957, brought, on August 20, a reply that "Old records of this type have been destroyed during the several moves since we have been acquired by International Minerals and Chemical Corporation." On checking with the Mississippi State Tax Commission, it was found that records of sales tax receipts of such products are destroyed after three years. On checking with the U. S. Bureau of Mines, which had annually received production figures, the reply of September 10 was tersely: "The Bureau of Mines is sorry to advise you that the data requested are not available." It is only a guess on the writer's part, based on his early exploration of the deposit, that approximately 150,000 short tons of dried and ground bentonite was marketed from this deposit on Bob Miller Creek between the years of 1938-1947.*

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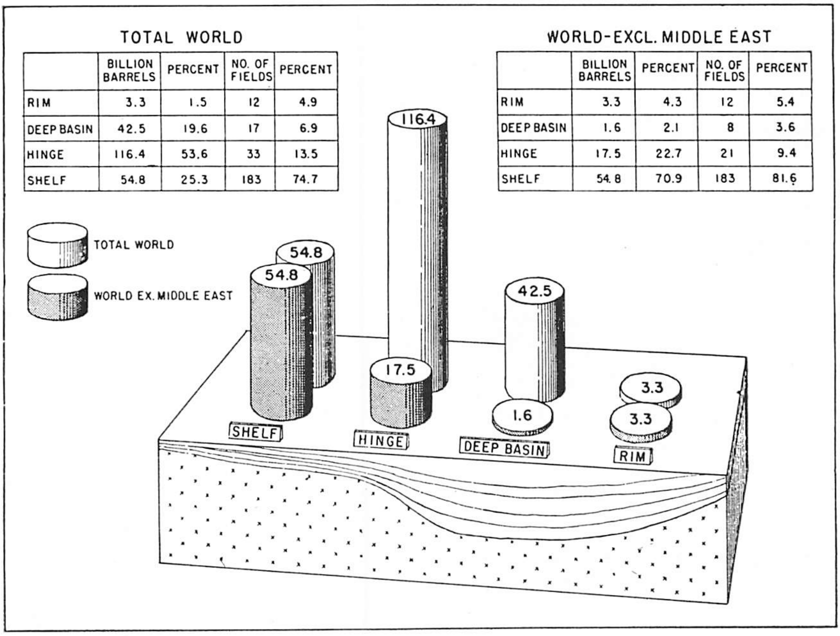
* It is a crime against posterity that such production records were not preserved. Inasmuch as minerals of this type (clays, chalks, sands, gravels, stone, etc.) are non-replaceable resources, producing or mining companies should be required to file production data with a state agency just as oil producers must do with the State Oil & Gas Board.

OIL AND GAS IN THE CRETACEOUS SHELF SEDIMENTS OF MISSISSIPPI

The principle of oil and gas accumulation in the hinge areas and on the shelf areas of sedimentary basins has been recognized for a relatively short time. The development of this concept was dependent upon deeper and deeper drilling and the availability of subsurface structural and stratigraphic data. Weirich (1953) wrote as follows (p. 2045): "The proposition that oil has originated, migrated, and accumulated over a moving shelf in the region (Oklahoma and Kansas) and rock section (Pennsylvanian) discussed is submitted to the petroleum geology profession as a principle. The repeated occurrence of oil in shale-enclosed sand bodies limited to the shelf validates such a conclusion. The abruptly diverging stratigraphy southeast of the hinge line in the adjoining basin performs no function in the process of oil generation; the hinge line merely marks the basinward limit of



TOTAL WORLD

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
RIM	3.3	1.5	12	4.9
DEEP BASIN	42.5	19.6	17	6.9
HINGE	116.4	53.6	33	13.5
SHELF	54.8	25.3	183	74.7

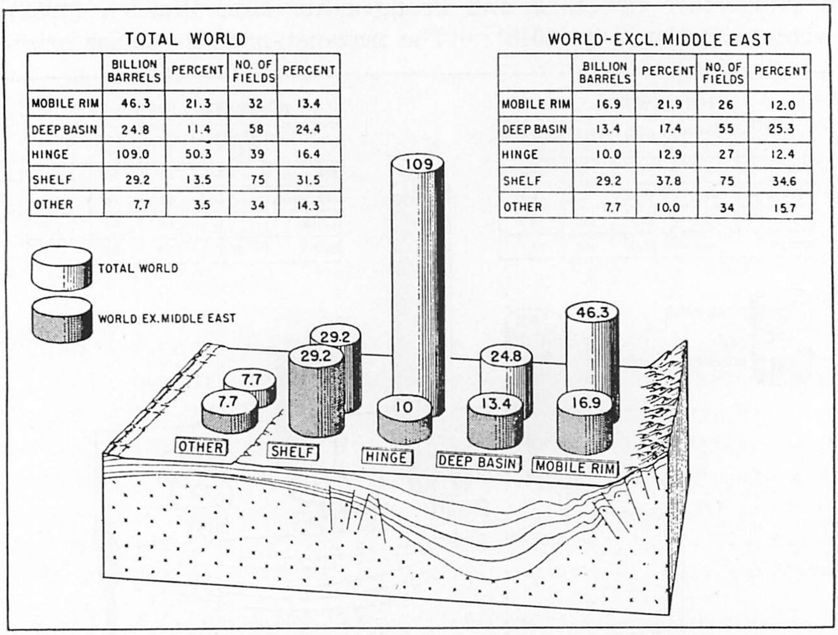
WORLD-EXCL. MIDDLE EAST

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
RIM	3.3	4.3	12	5.4
DEEP BASIN	1.6	2.1	8	3.6
HINGE	17.5	22.7	21	9.4
SHELF	54.8	70.9	183	81.6

Figure 34.—Habitat of oil in free-world's major oil fields according to basin position in depositional basin. From Knebel and Rodriguez-Eraso, Bull. A.A.P.G., Vol. 40, No. 4, Fig. 1, p. 550.

the productive shelf. Concepts induced from this study may be applicable to other oil-producing provinces and strata. Such studies, usually, must embrace wide belts which have onlapped cratonal regions."

Knebel and Rodriquez-Eraso (1956), in their statistical study of the 236 major oil fields of the free world, found that "the bulk of this oil occurs: (1) on the stable side of basins, (2) in anticlines, (3) in sandstone and carbonate reservoirs, (4) from formations of Mesozoic age or younger, and (5) from a depth range of 2,000-8,000 feet." These writers show the habitat of oil graphically in two striking illustrations, the first showing the distribution of the oil with respect to position in the depositional basin (Figure 34), and the second showing the position of these oil deposits with respect to present structural basin (Figure 35). As is true with the rest of the free world, the great percentage of Mississippi's oil is produced from anticlines (or faulted anticlines), from sandstone reservoirs, and from the depth range 2,000 to



TOTAL WORLD

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE RIM	46.3	21.3	32	13.4
DEEP BASIN	24.8	11.4	58	24.4
HINGE	109.0	50.3	39	16.4
SHELF	29.2	13.5	75	31.5
OTHER	7.7	3.5	34	14.3

WORLD-EXCL. MIDDLE EAST

	BILLION BARRELS	PERCENT	NO. OF FIELDS	PERCENT
MOBILE RIM	16.9	21.9	26	12.0
DEEP BASIN	13.4	17.4	55	25.3
HINGE	10.0	12.9	27	12.4
SHELF	29.2	37.8	75	34.6
OTHER	7.7	10.0	34	15.7

Figure 35.—Habitat of oil in free-world's major oil fields according to basin position in present (structural) basin. From Knebel and Rodriguez-Eraso, Bull. A.A.P.G., Vol. 40, No. 4, Fig. 2, p. 552.

8,000 feet. As far as the Cretaceous basin is concerned, oil is produced from the hinge, from the deep basin and from the mobile rim, but thus far there has been no production of oil or gas from the stable shelf of the Cretaceous basin (structural), although probably all of the oil and gas from these sediments are from beds deposited on a stable shelf of the transgressive sea.

Prior to the concept of the larger volumes of oil accumulating on the landward side of sedimentary basins there was a dominating concept that oil was found in structures within sedimentary basins, but the position within these basins was not considered important except for two things that were recognized only poorly until recent years. The first is that in the deeper parts of the structural basins (which may or may not coincide with the depositional basins) the greater depths often exceed the economic limits of exploration and development. The second is that reservoir rocks are much more prevalent on the landward side of basins.

Although many geologists do not think favorably of the North Mississippi area because of the lack of verifiable oil shows and gas shows, there have been definite evidences that liquid hydrocarbons have been present in the Cretaceous shelf area. The relatively few wells drilled in the area and other conditions, such as absence of good information as to well location, inadequate coring and testing, are some of the reasons, perhaps, why more definite information on "legitimate" shows is not available.

Solid hydrocarbon material, called under the general terms bitumen or asphaltum, usually specifically identified as grahamite, has been found in the Cretaceous beds of north Mississippi at various times for over 50 years. In the Prairie Bluff chalk and at other horizons of the Cretaceous, it is seen as a concentration on the outcrop like nut or slack coal. Indeed, it is entirely possible that many "finds" of grahamite are not recognized by the experienced geologist who thinks the material is actually a small amount of coal out of place. The first published reference to this, as far as the writer has been able to find, is by Logan (1904, p. 26) wherein he states: "Small deposits of asphaltum have been discovered in the Selma chalk in several localities in this (Oktibbeha) County. These deposits vary in amount from a few pounds to a ton. The quality also varies. In some places it is fairly pure;

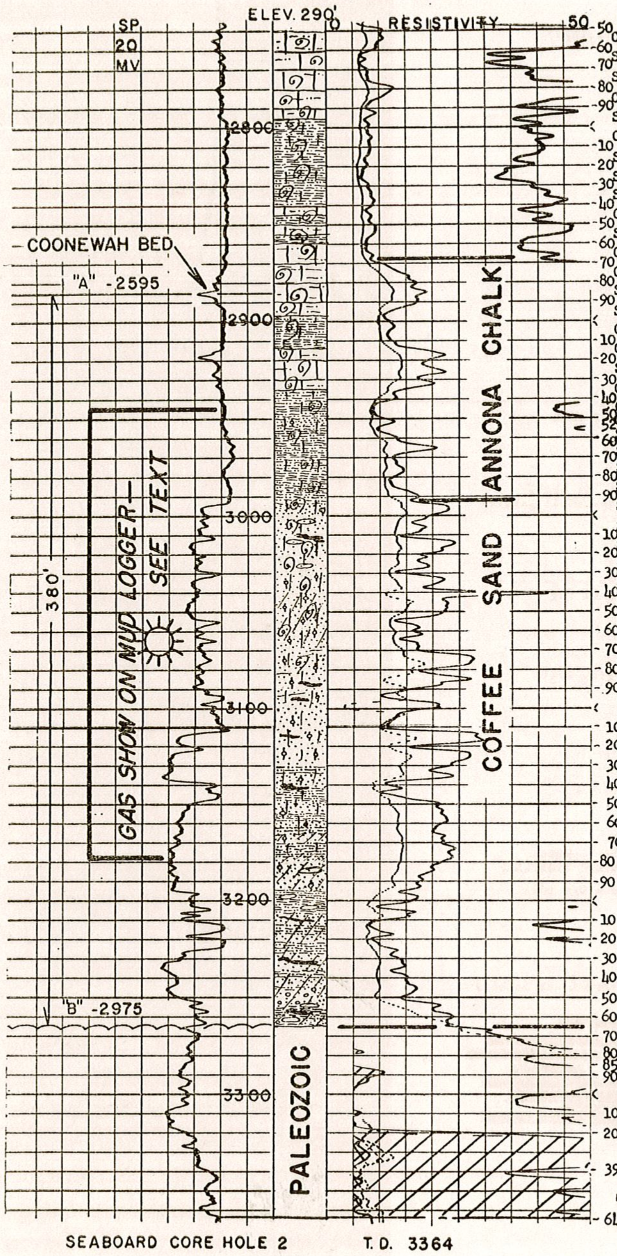
in others, it has the appearance of lignite while still retaining some of the properties of asphaltum."

In the Fall of 1935, P. H. Dunn and the writer found approximately a peck of grahamite in the Prairie Bluff chalk 3 miles northwest of the corporate limits of Starkville, Oktibbeha County, SW.¼ of NW.¼, Sec. 30, T.19 N., R.14 E. On August 10, 1957, M. E. Wiggins and the writer went on the property of Mary C. Williams in Pontotoc County, SW.¼ of NE.¼, Sec. 4, T.10 S., R.3 E. (Figure 32), from which her son, John J. Williams, dug approximately 8 pounds of grahamitic material, thinking that it was coal. A sample was submitted to Dr. Charles Milton of the U. S. Geological Survey, who, on August 16, 1957, reported as follows: "The tarry substance received with your letter of August 10, is quite soluble in carbon tetrachloride; but not at all in alcohol, which is a characteristic of grahamite. The nomenclature of the hydrocarbons is a difficult matter without extensive chemical and physical research; from the simple tests I have made, though, I see no reason to question your identification of the material as grahamite." This "find" was approximately at the top of the Chiwapa sandstone member of the Ripley (see section on Chiwapa, and related map) just below the impervious Prairie Bluff chalk. In 1942, the writer logged "pieces of bitumen" in Navarro chalk at 2510-20, approximately 200 feet below the Midway shale, in the C. L. Higgason et al., No. 1 Long-Bell, Sec.10, T.3 N., R.16 E., Clarke County, Mississippi. As this is north of the Quitman graben system, it is in the edge of the shelf area as used in this report. Possibly the detailed examination of cuttings from other wells will reveal a more wide-spread distribution of this inspissated residue of petroleum. In Arkansas, asphaltums are found in the Comanchean (Trinity) rocks where they come to the surface near the fall line north of the productive areas (see Hayes, 1902 and 1903, and Miser, 1918).

In the Southeastern States the writer has found asphaltum at other horizons: 1) in Paleozoic rocks of N. Mississippi and N. Alabama, 2) in the Clayton member of the Midway formation in NW. Wilcox County, Alabama, on Shell Creek, 3) at the top of the Cocoa sand in the lower Jackson formation at many localities in the vicinity of Melvin and Water Valley, Choctaw County, Alabama, 4) in the upper part of the Jackson formation in Yazoo County, Mississippi, and 5) in the Vicksburg formation on the

Fig. 36

SEABOARD OIL CO. - CORE HOLE NO.2 (ROSEBOROUGH)
TATE COUNTY, MISSISSIPPI



-50 Chalk, lt-med-gy sl argil sl silty fos (much Midway shale cavings)
-60 Same (also much Wilcox cavings)
-70 Same
-80 Chalk, med-gy v argil silty fos
-90 Same; also med-gy chalky silty fos clay
Clay, med-gy silty fos v calc fomica
-10 Same
-20 Same
-30 Same
-40 Chalk, dk-gy argil fos sl pyr; clay, as above
-50 Same
-60 Chalk, med-gy sl argil sl silty v fos
-70 Chalk, lt-gy f-silty f-mica v fos
-80 Same
-90 Same; also med-gy calcareous fos argil silt
Clay, med-gy f-mica silty v calc fos
-10 Chalk, lt-gy f-silty fos; clay, as above
-20 Same
-30 Chalk, med-gy argil silty; silt, med-gy calc argil mica
-40 Clay & silt, med-gy calc fos pyr sl sdy
-50 52 Circ - Same; also small amt hd f-med-gr calc sl glauc sl por sdst
Same
-60 Silt & silty clay (sample mostly Wilcox & Midway cavings)
-70 Same
-80 Same
/of collophane; silt, as above
-90 Sand, f-med-gr sl pyr lt-gy v por; dk-brn foecal pellets few small pebbles
Same; much pyrite and brn siderite; lignitic fragments
-10 Same (sample mostly Midway & Wilcox cavings)
-20 Same as 3010-20
-30 Sandstone, lt-gy hard f-med-gr calc common lt-grn glauc grs non-por to sl
-40 Same; also much pyr cement (much cavings) /por sl lignitic sl fos
-50 Same
-60 Same
-70 Same
-80 Same (sandstone, in part is v lignitic); tr snow-white f-gran chalk
-90 Same as 3080-90
Same; sandstone contains few v-large lt-grn glauc grains
-10 Same (much Midway & Wilcox cavings)
-20 Same; also dk-brn silty v lignitic clay
-30 Same (much cavings)
-40 Silt, med-gy f-mica lignitic; tr sdst, as above
-50 Same; incr in sdst
-60 Silt, as above; small amt pyr sdst
-70 Same
/lignite-covered calcite crystal
-80 Sandstone, f-gr f-glauc extremely pyritiferous; small amt brn siderite;
-90 Clay, v-dk-brn-gy v lignitic micaceous silty; much pyrite & pyr sdst
Same; also much brn siderite
-10 Silt and highly pyritiferous lignitic sandstone
-20 Same
-30 Same
-40 Sandstone, f-crse-gr extremely pyr lignitic; few small chert & qtz pebbles
-50 Same; also small amt v lig slty pyr clay & brn siderite
-60 Same; also 40% [redacted]
-70
-80
-85
-90
10
20
SKIP
-39
[redacted]
-64

south flank of the Jackson dome, Rankin County, Mississippi. Grahamite, bitumen or asphaltum is, therefore, not restricted to any specific stratigraphic horizon. It is one of the "tracks" that petroleum leaves behind during its genesis, fugacity and diagenesis.

One of the more important "shows" of gas was detected by a mud-logging unit on the Seaboard Oil Company's Core Test No. 2 (Roseborough) (Figure 36) just west of Senatobia, Tate County, Mississippi, Sec.26, T.5 S., R.8 W. No gas readings were noted above 2945, at which depth, 60 feet below the Coonewah bed and in the lower part of the Annona chalk, gas readings appeared immediately, reaching a maximum of 110 units in the drilling mud, and showing slight gas readings in the cuttings. Gas in the mud continued in lesser but measurable amounts until the depth of 3178 feet was reached at which point the readings returned to normal. Seven other core tests, similarly drilled and logged by Seaboard, did not have such a show. The Coffee sand, topped at 2993, indicated an immediate increase in gas readings.

Following are notes taken from various sources on reported shows of oil and gas, mostly unconfirmed, from the Cretaceous shelf sediments of Mississippi as used herein:

Attala County: Arkansas- Louisiana Pipeline Company No. 1 Moore, Sec.2, T.15 N., R.5 E.; drill stem test in Eutaw at 3240-68, recovered 1200′ gas-cut salt water.

Clint Crosby No. 1 Allen, Sec.32, T.13 N., R.5 E.; perforated 4018-20 in Eutaw sand with good electrical log "kick", ran drill stem test, recovered puff and odor of gas, 3000′ salt water.

Bolivar County: O. W. Killam No. 1 Dattel, Sec.18, T.23 N., R.7 W.; cored Coffee sand 4555-4565, reported slight gas odor by driller.

Carroll County: The Texas Company No. 1 Whitehead, Sec.22, T.18 N., R.5 E.; cored on basis of a mud logger show at 3175-3182 in basal sand of Eutaw, recovered sand with show of "dead" oil.
Clarke County: C. L. Higgason No. 1 Long Bell, Sec.10, T.3 N., R.16 E.; fragments of bitumen (probably grahamite) in chalk of Navarro age at 2510-20, 200′ below base of Midway shale.

Grenada County: Carter Oil Co. and Pace No. 1 Dubard, Sec.18, T.22 N., R.4 E.; reported show of gas in cuttings in basal sand of Eutaw at 2944-2966. Natives report that the well attempted to blow out at this depth and difficulty was experienced in controlling the well. A second well was drilled nearby and reported dry.

Papadakis No. 1 Holcomb, Sec.13, T.22 N., R.2 E.; at 2825-2835 (probably in lower Coffee) a show of oil and gas was reported on pits.

Womble and Williams No. 1 Connecticut General Life Insurance Company, Sec.28, T.23 N., R.5 E., as follows:

2370′ well blew out, blew gas and mud 20′-30′ up;
2705-2722 cored sand with strong odor of oil;
2820 show of oil on pits;
3145 show of oil and gas on pits;
3250-60 cored sand with good gas odor.

Holmes County: Hawkins and Howell No. 1 Ellis, Sec.18, T.14 N., R.4 E.; cored in Eutaw at 3913-3918, recovered 7 inches sand with very slight show of oil.

Humphreys County: Cities Service Oil Company No. 1 Jones Estate, Sec.19, T.15 N., R.1 W.; had heavy black oil in cuttings in upper Tuscaloosa and cored 5595-5605, recovered 6 inches sand with very slight show of oil; at 5612-30 had show of asphalt in cuttings.

Kemper County: R. M. Crabb No. 1 Land, Sec.12, T.10 N., R.14 E., at 2154 circulated scum of oil on pits from Eutaw (?), cored, no show.

A. E. Manning No. 1 Caldwell, Sec.25, T.9 N., R.15 E., cored in Tuscaloosa at 3265-72, recovered sand with very slight show of oil and gas; at 1458 reported questionable show of oil in upper Selma chalk.

A. E. Manning No. 1 McKelvaine, Sec.2, T.9 N., R.17 E.; cored 1403-07, recovered 1½ feet of sand with show of oil.

Lauderdale County: Lauderdale Oil and Gas Company No. 1 Gunn, Sec.13, T.7 N., R.16 E.; cored 2812-14, probably Tuscaloosa, recovered sand with show of oil and gas.

Lauderdale Oil and Gas Company No. 1 Lackey, Sec.2, T.7 N., R.16 E.; reported shows probably in Tuscaloosa, gas at 2805, gas and oil 2800-2914.

Leflore County: Sneed Brothers No. 1 Fitz Morgan, Sec.33, T.18 N., R.2 W.; questionable to dull fluorescence in sidewall cores in Tuscaloosa at 5228, 5231, 5238, 5244, 5274, 5275.

Montgomery County: Henderson No. 1 Columbian Mutual Life Insurance Co., Sec.36, T.21 N., R.5 E.; cored 2645-56, recovered sand with show of gas in Tuscaloosa.

Noxubee County: Price and Voss No. 1 Hadaway, Sec.18, T.15 N., R.19 E.; cored in Tuscaloosa as follows: 1120-27 silty sand with show of oil; 1150-55 hard sand with show of oil.

Panola County: Panola Oil and Gas Co. No. 1 Lamb, Sec.35, T.27 N., R.2 E.; reported sand with show of gas in Ripley at 2155-2300.

Sunflower County: Latex Gulf No. 1 Dockery, Sec.4, T.21 N., R.4 W.; ran drill stem test in Tuscaloosa (?) with straddle packers at 5002 and 5020, ¼-inch chokes, 1000-foot water cushion, open 16 minutes, top pressure 0#, recovered water cushion and 2174 feet salt water and 120 feet salt water cut mud with show of gas; shut in bottom hole pressure 2925 pounds.

Tallahatchie County: Neil Scroggins No. 1 Bardwell, Sec.32, T.26 N., R.3 E.; reported oil sand and water (in Coffee Sand) at 2637-57.

Tallahatchie Oil Co. No. 2 Bardwell, Sec.32, T.26 N., R.3 E.; reported shows in upper part of "Selma" and Ripley as follows: 2131-43, gas show; 2167-2219, sandy shale showing oil and gas; 2250-2255, sand showing oil and gas; 2261-2264, sand showing asphalt; and 2275-2291 sand, showing asphalt.

Tate County: C. Porter Johnson No. 1 Prichard, Sec.28, T.4 S., R.7 W.; reported show of oil in Coffee Sand in side-wall cores 2800-2850; production test made fresh water, 425 parts per million chloride.

Seaboard Oil Co., Core Hole No. 2 (Roseborough), gas shows on mud logger in lower Annona and Coffee at 2945-3178 (see discussion above).

Webster County: Cumberland Oil Company No. 1 Henley, Sec.15, T.21 N., R.11 E.; questionable scattered shows in Selma.

Winston County: Jack Vale No. 1 Moody, Sec.8, T.13 N., R.14 E.; reported sand with show of oil and gas in Eutaw at 2210-2225.

Yalobusha County: Collet and Carter Oil Company No. 2 Blackmur, Sec. 14, T.11 S., R.4 W.; sand in Ripley 1262-1300 with show of gas.

Sid Onyett No. 1 Austin, Sec.1, T.11 S., R.6 W.; at 1400-1592 asphalt and "dead" oil in Prairie Bluff chalk and upper Ripley; in core 2043-51 in Coffee Sand, recovered 2-feet fine-grained sand with slight show of gas.

Philip Brothers No. 1 James, Sec.20, T.11 S., R.5 W.; sand with show of gas in Selma or lower Ripley at 1648-1666; cored Coffee sand at 1995-2000 showing gas.

CONCLUSIONS

Some or all of the conclusions reached in the present treatise have been known or suspected for many years. The 2-foot bed of purer chalk in the Annona had been referred to by the writer as "Horizon A", but by tracing it to the outcrop on Coonewah Creek in Lee County, it can be dignified with the name "Coonewah bed." The upper member of the Ripley is a very coarse-grained highly fossiliferous sand locally cemented to calcareous stone. This 80-foot member was the subject of an unpublished paper over 20 years ago in which the presently proposed name "Chiwapa" was used, but in which the solution phenomena, sinks, caves and "horsebone" limestone, of the Ripley and of the "Turritella limestone" member of the Clayton were featured. The commercially exploited bentonite bed, 3 to 9 feet in thickness, lay in the upper half of the Chiwapa on Bob Miller Creek, Pontotoc County. The overstepping or transgressive onlap of the Cretaceous beds can be detected on the earlier geologic maps, but confusion has resulted in the reporting of "Eutaw" sands and "Tuscaloosa" gravels at latitudes or longitudes where they were never deposited, both on the outcrop on the eastern side of the embayment and in the subsurface of western Tennessee, eastern Arkansas and northwestern Mississippi. The onlap phenomenon has been recognized in eastern Arkansas in publications of its Geological Survey. It is pointed out in a guidebook of the Mississippi Geological Society, but has not been generally understood as a depositional principle of the Cretaceous shelf sediments. The paleontologist, whose working material is often much more limited than the stratigrapher's, can be effective in his work only so long as the stratigraphy he is using is correct. The facies changes illustrated on the cross sections, and the migration of the Coonewah bed from the upper part of the "chalk" in the Meridian area to the lower part of the "chalk" in the Memphis area, both show how time planes cross lithologic boundaries. Unless the faunas likewise cross these boundaries between facies, their usefulness as index faunas is limited.

Satisfactory conclusions were reached to some of the enumerated objectives of the present study. Other objectives were only partly satisfied.

1.) There is evidence, based on contouring and isopaching, that intense local structural deformation of the Paleozoic rocks is reflected slightly in the overlying Cretaceous sediments or younger beds. This is particularly noted in Marshall County (Shell No. 1 Johnson) and to lesser degree in Pontotoc County. Increased control, of course, is always needed. It is felt, however, that structural mapping on any Cretaceous datum is an uncertain method of locating a Paleozoic structure due to the great unconformity between systems.

2.) Interval velocities throughout north Mississippi might be helpful to the seismologist, as might the structural and stratigraphic information contained in this report. However, the relatively small variations in thickness and lithology over local areas would probably not cause serious velocity problems through the Cretaceous.

3.) Any one of a number of marker points within the Annona chalk, preferably the Coonewah bed, are exceptionally good mapping points, far better than the "top of the chalk", top of the Cretaceous, "base of the chalk", or top of the Tuscaloosa. As a precise time-stratigraphic marker bed there is probably no other datum in Mississippi so widespread as the Coonewah bed.

4.) Insufficient deep well control prevents reconstruction of pre- or early Cretaceous geomorphological maps. Many years of increased drilling activity and study of the data will be needed. The fixing of the transgressive shorelines and the principal of stratigraphic onlap will be helpful in reconstruction of a paleo-geomorphological map.

5.) There are definite evidences that liquid and gaseous hydrocarbons have been and are present in the Cretaceous deposits of north Mississippi. Unfortunately, many of the reported shows in wells are not verifiable. There appears to the writer no reason why, under proper conditions of entrapment, the Cretaceous rocks of the shelf area north of the Pickens-Gilbertown fault system should not produce commercial volumes of oil and gas.

ACKNOWLEDGMENTS

The writer is endebted to State Geologist W. C. Morse and to the staff of the Mississippi Geological Survey for encouraging the present study. The Survey's coredrill and electrical logger were used on core holes drilled in Lee County. Mr. Tracy Lusk assisted in the field and has helped in many ways during the preparation of this report. Mr. William S. Parks very capably made the study of the foraminifera.

Dr. L. W. Stephenson, retired, very graciously criticized the introductory portion of the manuscript.

Dr. G. Arthur Cooper and Dr. Norman F. Sohl of the U. S. National Museum and U. S. Geological Survey identified *Inoceramus* cf. *barabini.*

Dr. Charles Milton of the U. S. Geological Survey confirmed an identification as grahamite.

Dr. Robert H. Shaver, Indiana Geological Survey, formerly Chairman of Geology Department, University of Mississippi, prepared the chapter on ostracods.

Mr. Earl McCracken of the Missouri Geological Survey made the insoluble residue studies.

Dr. M. P. Ethridge, State Chemist, Mississippi State College, very kindly analyzed the Coonewah chalk.

Shell Oil Company obligingly washed the chalk samples to concentrate and clean the microfauna for the studies made by Parks and Shaver.

Gulf Oil Corporation, Seaboard Oil Company, and L. E. Salmon permitted the use of much of their coredrill data insofar as it applied to the Cretaceous sediments only.

The American Association of Petroleum Geologists has kindly consented to the use of illustrations from the Bulletin.

Mr. Leland Culligan of the California Company has been especially helpful in making suggestions. He spent many hours of his time reading and correcting the manuscript and discussing the subject with the writer.

Messrs. William R. Higgs, Tom McGlothlin and Ira J. Terry very kindly lent the writer unpublished manuscripts.

Mr. E. M. Rice reviewed the foraminiferal work of Mr. Parks and examined other portions of the manuscript and his suggestions were especially helpful.

The invaluable assistance of Mr. Marvin E. Wiggins, Jr. in the field and in the office is gratefully acknowledged.

As usual in a work of this kind it is not possible to cover adequately all of the cooperation that has been a part of the end result. I sincerely trust that there have been no serious omissions in my gratitude.

As this is probably the last report that the writer shall turn in to his teacher and supervisor, Dr. William Clifford Morse, it is fitting that the writer make special acknowledgments. Under Dr. Morse he studied Geology at Mississippi State College and under him he received his M.S. Degree at the University of Mississippi. In the Fall of 1937 when the writer was sent to Winston County to set up and put in operation the first county mineral survey project in Mississippi, it was with the admonition, "Above all map the geology of the County and measure the strata foot-by-foot and inch-by-inch, so that if anything happens to our testing project we will, at least, have accurate geology to report." Time after time Dr. Morse's reaction to the reporting of geological conclusions was simply—maybe exasperatingly—"Are you SURE?" Dr. Morse will retire from his position as State Geologist of Mississippi on June 30, 1958, the position he has held with credit and distinction for nearly 24 years, longer than any other man. He is retiring with great distinction for ethical conduct of his office and for credit in achievement. Largely through the efforts of the State Geologist, his staff and supporters, the value of mineral production in Mississippi rose from $3,846,104 in 1936 to $132,875,000 in 1956 or about 35 times, and the spiralling increase in mineral production is a lasting tribute to his administration. The writer will always appreciate the opportunities which Dr. Morse made for him, and the chance to study and work under his supervision.

SUGGESTED FUTURE STUDIES OF THE CRETACEOUS SEDIMENTS

The foregoing reports started out only to determine the age, lithology and the stratigraphic position of the Coonewah bed of the Selma chalk because it was found to be so wide-spread in the northern part of Mississippi and adjacent areas. As this study grew, its title was expanded to cover additional lines of investigation and to point out some features of the Cretaceous that appeared to warrant being reported. It is, of course, impossible and impracticable to cover all lines of investigation of the Cretaceous deposits that might appear to be necessary or desirable, and certainly the writer is not qualified to make many of these specialized studies. For what value there may be in such suggestions, the following studies are suggested as research projects that would in time contribute to the economic geology of the Cretaceous:

(1) The distribution of the Cretaceous volcanic vents should be mapped, and the nature of the intrusive and extrusive rocks should be studied as well as their role as sources of Cretaceous sediments. In connection with this, the synchroneity between volcanic activity, epeirogenic and orogenic warping and Cretaceous deposition could be studied. It appears that the stratigraphic positions of biotite concentrations, bentonite deposits, and sands might be related to the volcanic disturbances.

(2) The environments of deposition and respective locations of the continental shelf during the various minor subdivisions of Cretaceous time should be carefully studied throughout the vertical section and lateral extent.

(3) Faunal study techniques should be developed to understand the ecological conditions at various times and at various locations as an aid in producing a better defined stratigraphy. Good Cretaceous paleontological taxonomy will lead to determin-

ation of valuable index fossils and in the construction of a faunal zonation of the Cretaceous sediments. A particularly interesting paleontological study would be that of the range and distribution of the Cretaceous oysters. These mollusks are ecologically restricted, but many of them are widespread under certain environmental conditions and lived for relatively short times, and, therefore, appear to have a certain usefulness as stratigraphic markers.

(4) Useful subdivisions of the Cretaceous should be worked out through a long-range study of what constitutes a Cretaceous formation; a revision and redefinition of Cretaceous stratigraphic terminology would be effected.

(5) Grain size distribution and petrological studies of sands to determine sources, prevailing currents and other agents of distribution, and environments of accumulation would be helpful in economic geology of the Cretaceous.

(6) A study of the magnitude and distribution of disconformities within the Cretaceous would be useful in further reconstruction of Cretaceous paleogeography and sedimentation.

(7) A study of Cretaceous sediments and inferences from this study of the locations of the various depositional environments at different progressive stages of Cretaceous deposition might lead to the location of subsurface oil accumulation in offshore bars or other stratigraphic features favorable for the accumulation of oil, gas or other mineral deposits.

(8) The origin of hydrocarbons in the Cretaceous sediments of the shelf region should be studied. A search for additional localities at which asphalt, oil or gas are present should be made and the localities should be properly and permanently recorded. These studies may reveal much concerning the possibilities for commercial accumulations of oil and gas in this region.

(9) The porosity of chalk appears to be inverse to its argillaceous content and it should be studied as a possible oil and gas reservoir rock. Self-potential development on electric logs in the Annona chalk, particularly the Coonewah bed, and a microscopic study of the chalks are revealing how self-potential values indicate that much of the porous chalk is essentially a finely fragmental, calcareous and foraminiferal sand. The Annona chalk produces oil in commercial quantities in other areas

and it is entirely possible that production will result in North Mississippi from porosity in the Annona or from chalk in some other part of the Cretaceous section.

(10) The Cretaceous-Midway (Clayton) contact should be studied wherever possible on the surface and in the subsurface and criteria should be developed for determining this contact with greater accuracy in the subsurface than seems to be possible at present. Sample work is at present inadequate in many parts of the shelf area for conclusive determination of the exact contact.

(11) Further petrological study of igneous rock along the lines begun by Moody and Kidwell should be made and should be continued. All igneous rocks as they are found should be reported and catalogued in the effort to recognize and limit igneous provinces.

(12) The insoluble residue studies such as have been presented in this report on the Lee County core holes (Stovall & Natchez Trace) show great value in determining obscure lithologic breaks. There may be other stratigraphic or structural uses to which this type of study might be applied. Such work to have any lasting value would necessarily have to maintain a high degree of accuracy through all of its detailed stages.

(13) The role of the coccolithophores in the building of the chalk would be a worthwhile advanced research project.

(14) Recent techniques in determining paleo-temperatures through heavy isotopes of oxygen combined in calcium carbonate would, at the least, be an interesting line of investigation that might lead to economic conclusions.

(15) If the Coonewah-to-Paleozoic isopachous map were used as a guide and combined with careful lithologic and stratigraphic work, a useful palinspastic map could be prepared.

(16) An important economic geology problem would be the study of the Cretaceous bentonites and relation of all data concerning them, their petrography, their stratigraphic position, the nature of their deposition, the commercial utilization, and the probable reserves. At least 4 horizons of Cretaceous bentonites, basal Eutaw, upper Eutaw, basal Coffee and Chiwapa (upper

Ripley) have been exploited by at least 4 different mining companies.

(17) A critical phylogenetic study of the genus *Diploshiza* might prove it to be a valuable stratigraphic yardstick. The environment and paleo-ecology of these diminutive pelecypods may be important in restriction of the life span of the species. Because of this, they have been useful in correlation from central Alabama to central Texas. In view of the writer's experience with *D. cretacea striata* and its stratigraphic relationship to *D. cretacea,* contrary to the relationship previously reported, the phylogenetic study should commence with the Annona chalk and the overlying and underlying sediments.

In addition to the seventeen lines of investigative studies listed above, there might be others that are apparent to the worker who is keenly interested in the Cretaceous rocks of the shelf area of the Mississippi Embayment.

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COUNTY SOIL SURVEY REPORTS

UNITED STATES DEPARTMENT OF AGRICULTURE
CRETACEOUS AREA

A. MISSISSIPPI

1. ALCORN
2. CHICKASAW
3. CLAY
4. LEE
5. LOWNDES
6. MONROE
7. NOXUBEE
8. OKTIBBEHA
9. PONTOTOC
10. PRENTISS
11. TISHOMINGO

B. ALABAMA

1. ATAUGA
2. BARBOUR
3. BIBB
4. BULLOCK
5. BUTLER
6. CHILTON
7. COLBERT
8. COOSA
9. CRENSHAW
10. DALLAS
11. ELMORE
12. FAYETTE
13. FRANKLIN
14. GREENE
15. HALE
16. HENRY
17. LAMAR
18. LAUDERDALE
19. LAWRENCE
20. LEE
21. LOWNDES
22. MACON
23. MARENGO
24. MARION
25. MONTGOMERY
26. PERRY
27. PICKENS
28. PIKE
29. RUSSELL
30. SUMTER
31. TALLAPOOSA
32. TUSCALOOSA
33. WALKER
34. WILCOX
35. WINSTON