THE DEPARTMENT OF NATURAL RESOURCES

mississippi geology

Bureau of Geology
2525 North West Street
Jackson, Mississippi 39216

Volume 3, Number 2
December 1982

FOSSIL MICROALGAE (COCCOLITHOPHORIDS) IN THE YAZOO CLAY EXPOSURES AT THOMPSON CREEK, YAZOO COUNTY, MISSISSIPPI

Will H. Blackwell
Department of Botany and Department of Geology
Miami University, Oxford, Ohio

and

Martha J. Powell
Department of Botany
Miami University, Oxford, Ohio

Thompson Creek, long a favorite collecting haunt among "rockhounds," has become an increasingly well-known paleontological locality. Recent studies have turned up the exciting discovery of a fossil whale about 50 million years old (Frazier, 1980) as well as an abundance of identifiable fossil wood of Pleistocene age (Blackwell and Dukes, 1981), i.e., not more than one million years B.P. (before present). A third paleontological aspect which has received little notoriety is that Thompson Creek is also a good place to study microscopic fossil algae. The upper Eocene (45-50 million years B.P.) muds underlying the Pleistocene terrace gravels and loess (fig. 2) are an excellent source of a minute type of fossil algae known as coccolithophorids (figs. 1,3,4) as well as possibly related forms, the discoasters (figs. 5-10).

Some attention was accorded these interesting fossil algae in one previous study of the Yazoo Clay, exposed within the city limits of Yazoo City. This study by Levin (1965) provided rather extensive light microscopic descriptions of taxa new to science and some very excellent line

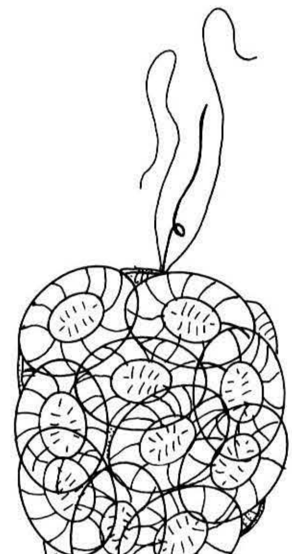


Figure 1. Line drawing of generalized coccolithophorid. The cell surface is covered with calcite plates (scales), the coccoliths. In fossils, these are usually found separated and scattered. When all together, as in the drawing, the unit is referred to as a coccosphere. The apical flagella, haptonemà (between), and other soft cell parts are not preserved as fossils.

drawings as well. Our study is in a sense an addition to this in that it looks at a similar exposure of the Yazoo Formation about 8 miles south of Yazoo City, along the banks of Thompson Creek, near Tinsley. In our study there is no formal attempt to describe new taxa, but rather the aim is to demonstrate the penetrating power of the microscope, especially the scanning electron microscope, in perceiving the delicate microstructure of these tiny organisms or parts of organisms. There is a growing opinion that certain identification to species may only be possible with the use of the electron microscope, and even then it is sometimes questionable due to structural variation associated even with a given representative organism (Bold and Wynne, 1978; Sieburth, 1979). The biostratigraphic value of coccolithophorids and related forms is also a point we attempt to stress in this discussion, as well as possible paleoenvironmental interpretations.

Methodology is fairly simple. Several samples of the bluish, semicompacted Eocene clays of the Yazoo Formation at Thompson Creek were collected into plastic bags and stored for later examination. Literally months later, it was possible to take a small pinch from a sample bag and make a smear on a glass slide for light or polarizing microscopic examination, or else upon a metal stub for examination under the scanning electron microscope. Light microscope slides are readily made permanent with epoxy. When examining through a microscope, the viewer is quickly engrossed by the beauty, variety, and fine details of these tiny organisms. Sample slides can be readily assayed for the presence of coccolithophorids because of their characteristic, swastika-like interference figures (fig. 11) under polarized light (Hay, 1965).

Some background information is perhaps in order. Coccolithophorids are small, one-celled algae (2-20 μm in size) which even at present form a significant component of the calcareous marine nannoplankton (small plankton), particularly in tropical seas. Some 200-300 living species are known (Sieburth, 1979; Tappan, 1980), and are most abundant to a depth of about 50 meters. Living specimens have one or two golden-brown chromatophores and store reserves of leucosin and lipid. Coccolithophorids are officially "haptophytes" (Class Haptophyceae), in reference to the fact that their motile stages, in addition to possessing two flagella per cell, sometimes have a third flagellum-like appendage, the haptonema. At least one stage in the life cycle may be covered by organic scales or else by calcareous plates composed of calcite (calcium carbonate) crystals (fig. 1). These tiny and often ornate calcite plates, the coccoliths, are usually formed within the endomembrane system of the cell before being deposited externally as a coat or "armour." Coccolith formation is light dependent and is known to be related to the photosynthetic process (Sieburth, 1979). The principle carbonate source is the bicarbonate ion of sea water. The deposition of the individual calcite crystals of each coccolith is very orderly, often producing an imbricated rosette (Black, 1965, and fig. 14). Coccoliths are the only part of fossil coccolithophorids known to be preserved, and are most often found separated from one another and scattered. Individual coccoliths are often no more than 1 μm in diameter. When, rarely, all the coccoliths surrounding one cell are found intact, the unit is referred to as a coccosphere (Bold and Wynne, 1978, and fig. 1). The often complex and unusual designs (figs. 12-15) of coccoliths make them very suitable objects for examination under the higher powers of the microscope. The viewer is visually rewarded by the kaleidoscopic array of forms seen.

As in the case of the Yazoo Clay at Thompson Creek, when such calcareous ultramicroplankton is found to be present in large numbers in "rock" or ancient muds, the usual interpretation is that the facies had a marine origin, perhaps deep in the open sea, and formed in a warm or at least temperate climate (Tappan, 1980). This bottom accumulation of planktonic organisms is the result of their postmortem downward drift or settling. There is thus an attendant general paleoenvironmental meaning to the discovery of the presence of these tiny creatures in a particular sediment. The content of such a formation as the clays at Thompson Creek compares well in general terms with that of certain modern deep sea muds and oozes. The favorable comparison of fossil coccolith muds with deep sea sediments has been known for many years. It was actually first noted by Sorby (1861) after comparison of coccoliths in the English Chalk with coccoliths of modern deep sea oozes. There is thus relatively little doubt as to the general paleoecological implication of such a formation as the Yazoo Clay.

Though small and inconspicuous, coccolithophorids have nonetheless been the subject of dynamic evolutionary processes through geologic time. They are sketchily known

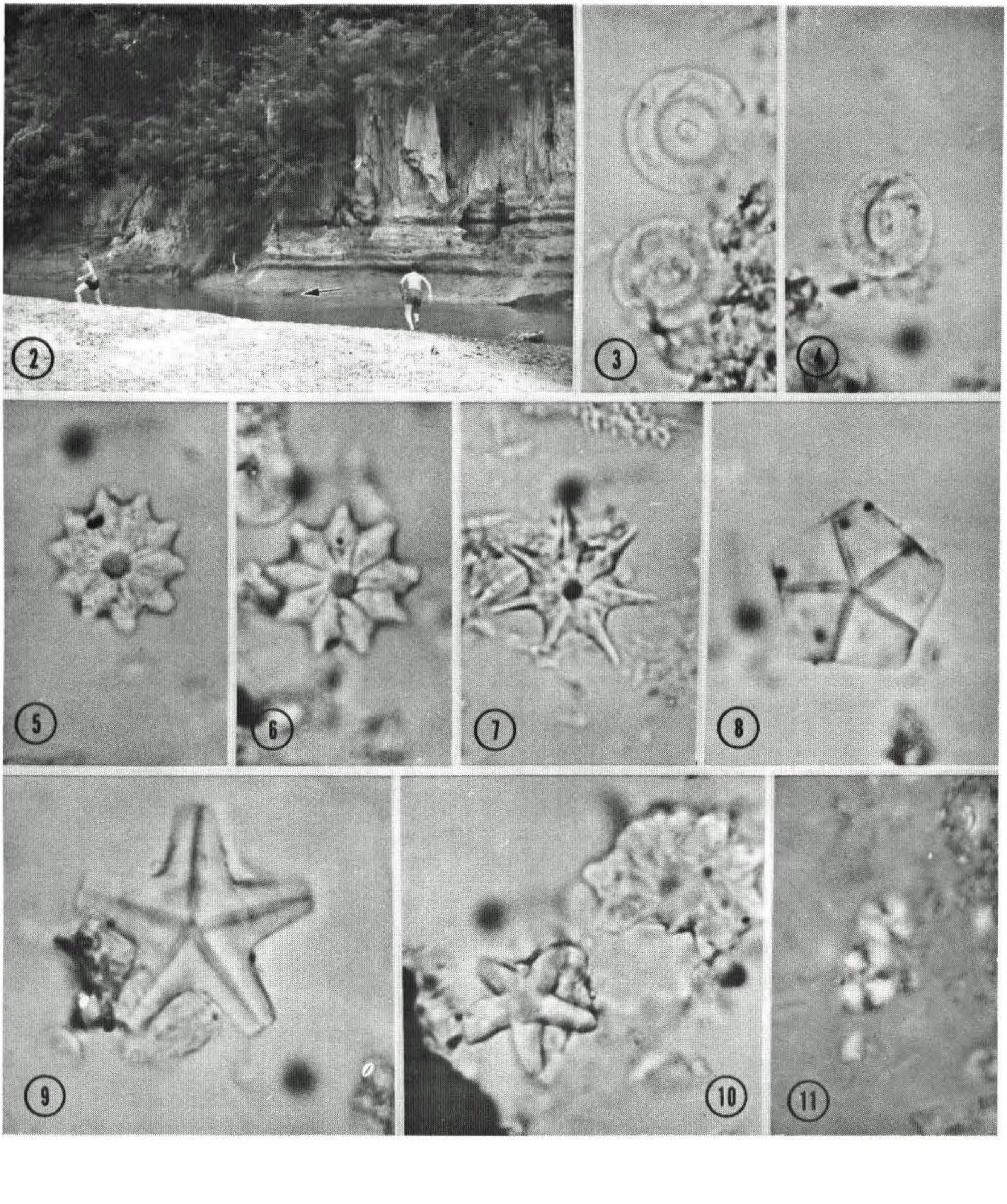
---

Figure 2. Locality photograph of Thompson Creek. Fossil coccoliths were extracted from lowest layer visible (arrow), the Yazoo Formation. Terrace material and loess, respectively, lie above the Yazoo Clay.

Figures 3-4. Light micrographs of two different coccoliths. Figure 3 corresponds in general to the form identified as *Coccolithus eopelagicus* by Levin, 1965, from a similar exposure of the Yazoo Clay. X 830.

Figures 5-10. Light micrographs of various fossil discoasters (perhaps another type of coccolith) found in the Yazoo Clay. Figure 5 is probably *Discoaster barbadiensis*, a characteristic marker organism of the upper Eocene. X 830.

Figure 11. Polarized light micrograph of a coccolith showing the crossed or swastika-like interference figure caused by the orientation of calcite crystals. X 400.


2
3
4
5
6
7
8
9
10
11

from the upper Paleozoic Era. However, well-preserved coccoliths show up in the late Triassic record and become abundant in the Jurassic and Cretaceous (Tappan, 1980). These organisms apparently fell particular prey to the worldwide extinctions or near extinctions occurring in the Cretaceous/Tertiary hiatus some 70 million years ago (Bramlette, 1965). This near extinction of the entire group is thought to have been primarily related to low nutrient cycles at that particular time as well as to fluctuations in the carbonate compensation depth. Regardless, in the early Tertiary (Paleocene) these organisms began a "renewal" or reevolution of types which reached a peak, subsequently, in the Eocene. Coccolithophorid diversity declined drastically during the Oligocene, increased perhaps only slightly in the Miocene, and, with the exception of sporadic variation, has remained rather constant since (Tappan, 1980). As compared to the Cretaceous, forms found in the Eocene sediments are different taxonomically, and larger in size. The diversity during the Eocene (age of Yazoo Clay) was perhaps as great as at any time in geologic history. As indicated, there are numerous living representatives of coccolithophorids, occurring mainly in tropical waters. However, the taxa are not the same as those of the Eocene, they are smaller, and apparently somewhat less diverse. Thus, there is probably no better place to study coccolithophorids (or at least coccoliths) than in Eocene-age marine clays, such as those of the Yazoo Formation.

Possibly related to the coccolithophorids are the discoasters, sometimes known as ortholithid coccoliths (Tappan, 1980). These are often star-like in form (figs. 5-10) and somewhat simpler in structure. They do not show the cross-like interference figures characteristic of coccoliths under crossed nicols because of a different orientation of the axes of the calcite crystals. Discoasters are relatively simpler in that fewer calcite crystals are involved in their construction, and they are generally not so abundant as true coccoliths. These "asteroliths" may be conveniently classified (almost in a postage stamp fashion) by their general shape (e.g., pentaliths, prismatoliths, etc.). Discoasters are very useful tools in Tertiary biostratigraphy. The geologically rapid evolutionary fluctuations of this group have resulted in the fact that certain forms are rather specific markers of particular geologic time intervals. In fact, their distribution through Paleogene time (and Neogene for that matter) has been rather precisely subdivided into numbered zones (cf. Martini, 1970; Gartner, 1971). Discoasters are an entirely Tertiary phenomenon (Black, 1965). They did not evolve (apparently) until Paleocene times, say 60 million years ago. Like coccolithophorids, discoasters became particularly abundant in the Eocene, declining considerably during Oligocene time. After some resurgence during the Miocene, their numbers steadily fell off thereafter (Tappan, 1980). They were probably brought to extinction in the Pleistocene. There are no certain living representatives. Thus, unlike coccolithophorids, the discoasters are considered a basically extinct group. They are, in all probability, simply another type of coccolith. However, the absence of living, intact representatives leaves their true relationship a bit uncertain.

The various marine muds and rocks in Mississippi are undoubtedly a rich paleontological treasure, and most certainly hold an intriguing variety of types of fossil algae. Continuation of studies of this type would very likely be well worth the time of the investigator. For example, some fossil diatoms were seen in several of the coccolithophorid samples examined. These could well provide the subject of another investigation.

Acknowledgments

We thank Dr. Thomas N. Taylor and associates of Ohio State University for the use of their scanning electron microscope facility during this study.

References Cited

Black, M., 1965, Coccoliths: Endeavor, v. 24, p. 131-137.

Blackwell, W. H., and G. H. Dukes, 1981, Fossil wood from Thompson Creek, Yazoo County, Mississippi: Mississippi Geology, v. 2, no. 2, p. 1-6.

Bold, H. C., and M. J. Wynne, 1978, Introduction to the Algae, Structure and Reproduction: Prentice Hall, Inc., Englewood Cliffs, New Jersey, xiv + 706 p.

Bramlette, M. N., 1965, Massive extinctions in biota at the end of Mesozoic time: Science, v. 148, p. 1696-1699.

Frazier, M. K., 1980, Archaeocetes: whale-like mammals from the Eocene of Mississippi: Mississippi Geology, v. 1, no. 2, p. 1-3.

Gartner, Stefan, 1971, Calcareous nannofossils from the JOIDES Blake Plateau cores and revision of Paleogene nannofossil zonation. Tulane Stud. Geol. Paleont., v. 8, p. 101-121.

Hay, W. W., 1965, Calcareous nannofossils, *in* B. Kummel and D. Raup, eds., Handbook of Paleontological Techniques: W. H. Freeman and Co., San Francisco and London, p. 3-7.

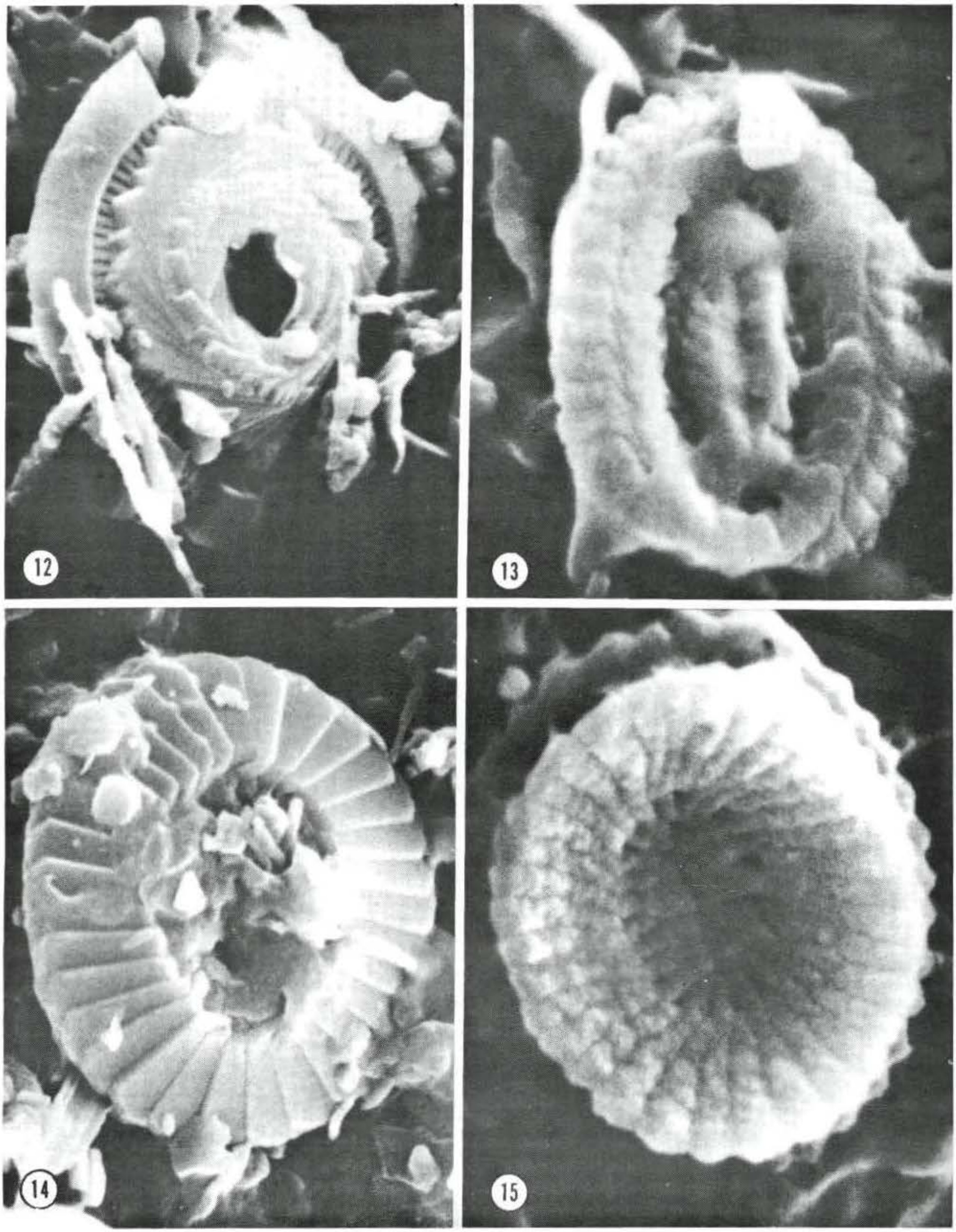
Levin, H. L., 1965, Coccolithophoridae and related microfossils from the Yazoo Formation (Eocene) of Mississippi: J. Paleontol., v. 39, no. 2, p. 265-272.

Martini, E., 1970, Standard Paleogene calcareous nannoplankton zonation: Nature, v. 226, no. 5245, p. 560-561.

Sieburth, J. M., 1979, Sea Microbes: Oxford University Press, New York, x + 491 p.

Sorby, H. C., 1861, On the organic origin of the so-called "crystalloids" of the Chalk: Ann. Mag. Nat. Hist., ser. 3, v. 8, p. 193-200.

Tappan, H., 1980, The Paleobiology of Plant Protists: W. H. Freeman and Co., San Francisco, xxi + 1028 p.



Figures 12-15. Scanning electron micrographs of various coccoliths. The coccoliths in figures 12 and 13, respectively, are the same as in figures 3 and 4. Figure 14 shows the imbricated rosette of calcite crystals often evident in coccoliths. fig. 12. X 22,500; fig. 13. X 37,500; fig. 14. X 14,250; fig. 15. X 37,500.

AN OVERVIEW OF OIL AND GAS POTENTIAL IN MISSISSIPPI*

Dora M. Devery
Placid Oil Company
1218 Capital Towers
Jackson, Mississippi

The history of hydrocarbon production in Mississippi began in 1926 with the discovery of natural gas in Monroe County, near the town of Amory for which the field was named (fig. 1). After the Amory Field discovery four years passed before a second natural gas discovery was made. This discovery, Jackson Field, produced from the Selma Gas Rock and was situated in Hinds and Rankin counties. The next discovery came nine years later in 1939; it was Tinsley Field.

Tinsley was a spectacular find, providing the State with its first oil production. Frederic F. Mellen, who at that time was a geologist with the Mississippi Geological Survey, recognized an enormous anticlinal structure from his surface mapping in Yazoo County. The Mississippi Geological Survey then issued a press release recommending that a commercial test well be drilled on the structural high in the vicinity of Tinsley. Union Producing Company (now Pennzoil) drilled the first well, and the boom was on. Within three years, from 1939 to 1942, production in Mississippi rose from zero to 28 million barrels of oil. Tinsley Field sparked a flurry of activity; leases were bought and wildcats drilled at an unprecedented rate throughout the Vicksburg-Meridian area. The exploration strategy of the day was, "drill along Highway 80".

Needless to say numerous luckless wildcats followed this strategy and by 1942 prices for land dropped to pre-Tinsley levels; companies closed their offices and left the State. From 1942 to 1943 exploration activity dropped, followed by obvious consequences -- a drop in oil production to 16 million barrels per year by 1944 (fig. 2,3). The State's oil fortunes changed in the war years of 1944 and 1945 when fourteen fields, such as Cranfield, Gwinville, East Heidelberg, Hub, Baxterville, Eucutta, Quitman, to name a few, were discovered, producing from Upper Cretaceous Tuscaloosa and Eutaw horizons. The exploration strategy now was to "localize with gravity and check with seismic". It was more sophisticated than the road map technique and considerably more successful. Production rose sharply for the next four years and peaked at 46 million barrels of oil in 1948. Mississippi was now firmly established as an oil producing state.

Today, two geological provinces in Mississippi are actively explored for hydrocarbons. These are the Mississippi Interior Salt Basin and the Black Warrior Basin. Of these two basins, the Interior Salt Basin is by far the more productive. The Salt Basin is situated in central and southern Mississippi and is bounded to the north by the buried Ouachita Mountains and by the Wiggins Anticline to the south (fig. 4). There are sixty-one identified salt domes in this basin as well as countless unidentified deep-seated salt diapirs; the latter are marked by deformation of surrounding and overlying strata. Salt tectonics are closely related to formation of structural traps for hydrocarbon accumulation within the Salt Basin. Currently within the Basin there are four major producing trends: Smackover, Hosston-Sligo, Lower Tuscaloosa, and Wilcox.

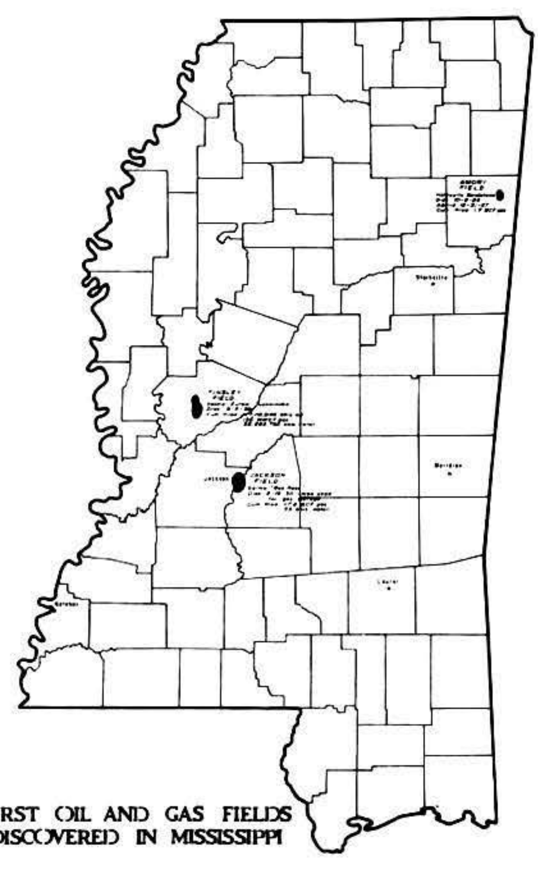


FIGURE 1

*This paper was originally presented at the University of Mississippi seminar on *Mississippi Lignite and Petroleum Resources*, May 1982

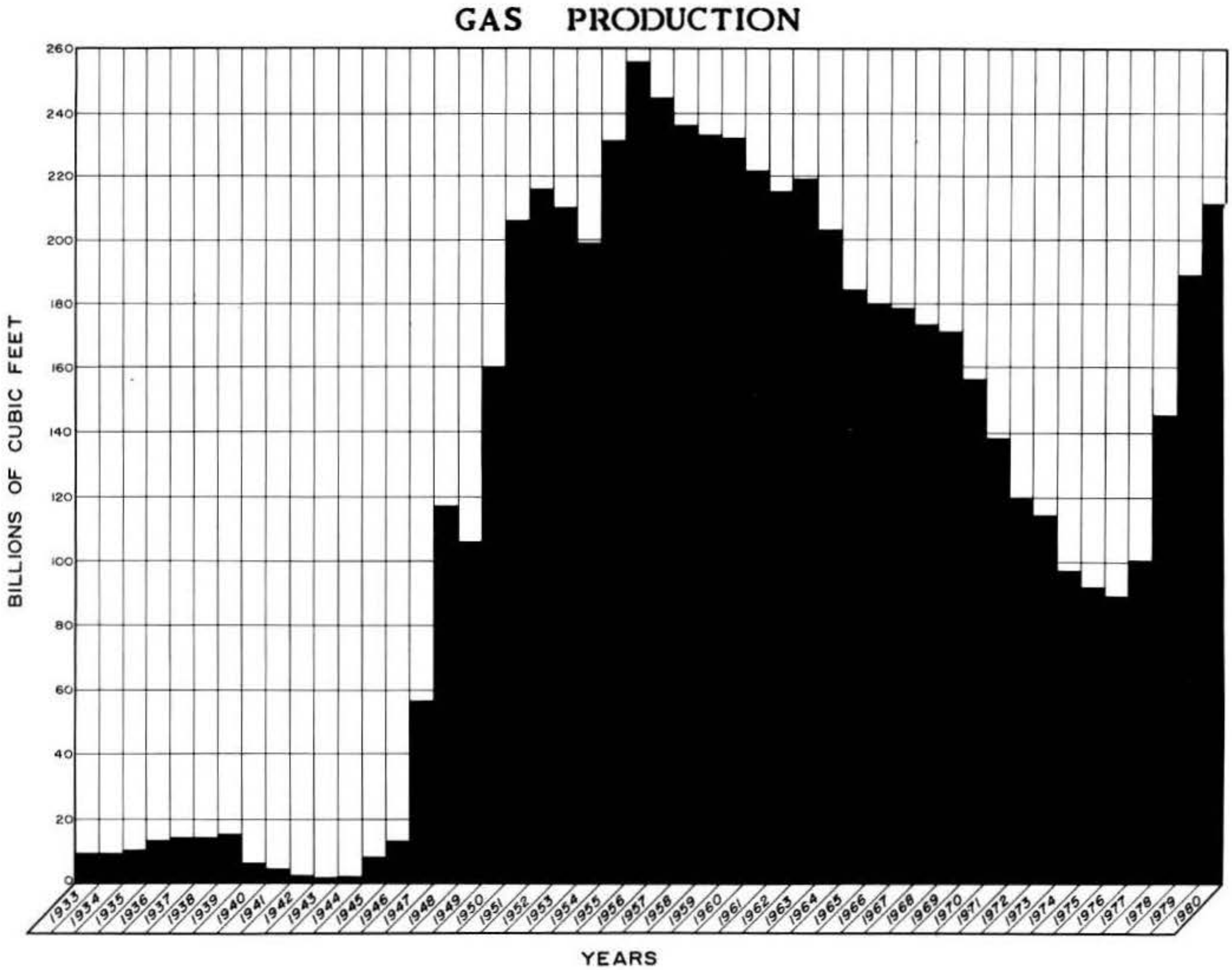


FIGURE 2

Interest in the Jurassic-age Smackover Formation as an exploration objective developed and intensified in the 1960's due to the discovery of oil at Bienville Forest Field in 1963 (fig. 5). Clarke, Jasper, Wayne, Smith, and Jones counties are the heart of Smackover production in Mississippi. Here Smackover carbonate rocks are reservoirs for oil and gas at depths of 11,000-15,000 feet. Another area of Smackover production is in Hinds, Rankin, and Simpson counties, where the producing section is sand found at depths of approximately 18,000-20,000 feet. At these greater depths the Smackover Formation is often under high pressure and contains sour gases (e.g. hydrogen sulfide) which can cause production problems if not handled cautiously. Technological advances over the years have made this type of drilling almost routine.

Lower Cretaceous Hosston oil production was first discovered at Virlillia Field in Madison County in 1951 (fig. 6). Learned Field in Hinds County was the site of the first Hosston gas producer in 1969. Currently Hosston-Sligo drilling activity is centered in the deeper part of the Interior Salt Basin where natural gas is sought. In 1974, Bassfield Field was discovered in Jefferson Davis County; this discovery intensified the search for Hosston sand objectives. Since 1974, Bassfield has produced a significant amount of hydrocarbons: from just the Booth Sand the 1980 annual production from 11 wells was 9.3 billion cubic feet of gas, 128,661 barrels of condensate, and 43,189 barrels of water. In the past few years twenty of the last twenty-nine Hosston-Sligo discoveries have occurred in Marion, Jefferson Davis, and Covington coun-

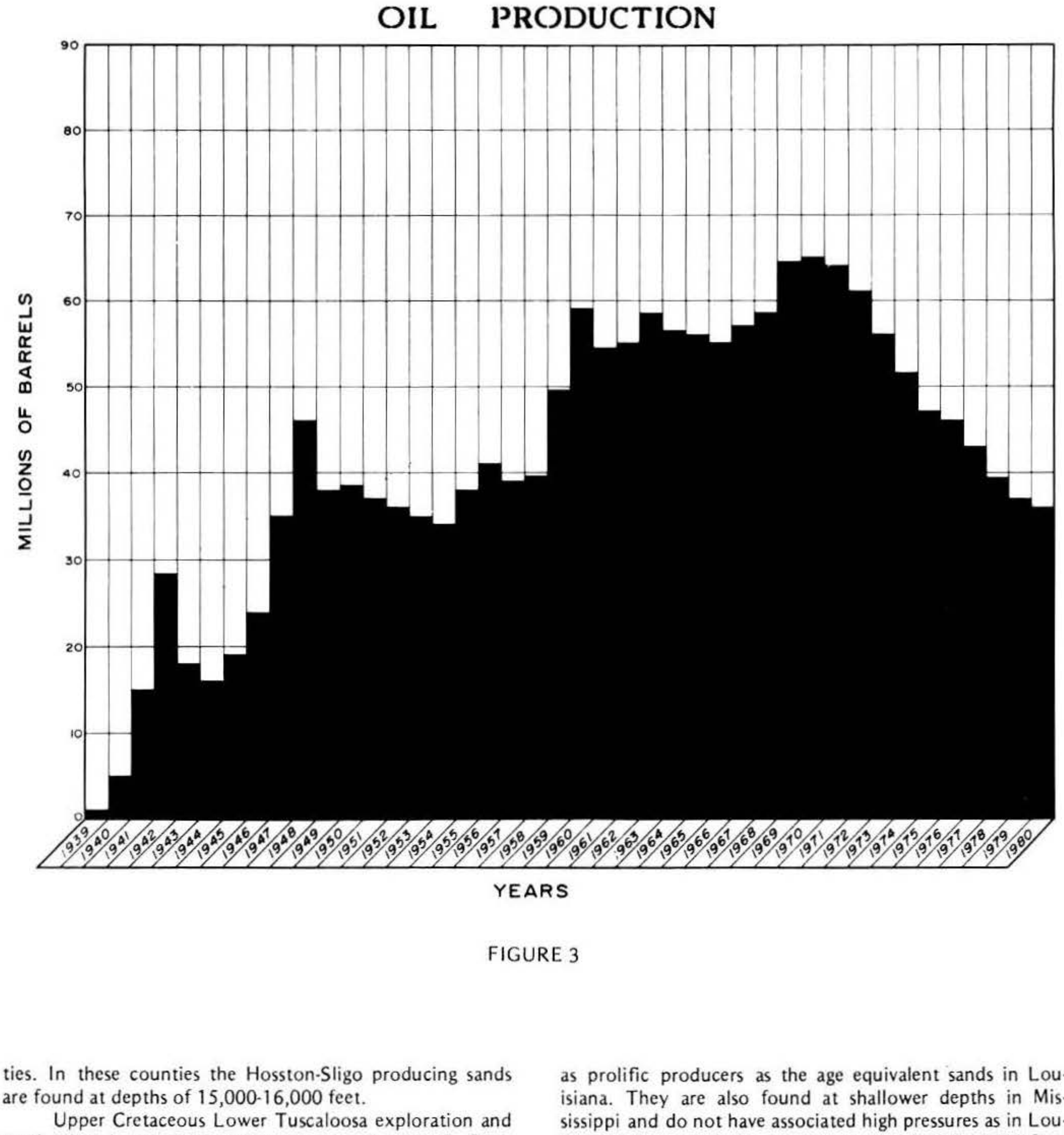


FIGURE 3

ties. In these counties the Hosston-Sligo producing sands are found at depths of 15,000-16,000 feet.

Upper Cretaceous Lower Tuscaloosa exploration and production is currently underway around Lincoln, Pike, and Amite counties (fig. 7). The upper unit of the Lower Tuscaloosa Formation is commonly the reservoir from which most of the oil production is obtained. This upper unit consists of alternating sands and shales, called the Stringer Sands, and is found at depths of 10,000-12,000 feet.

Lower Tuscaloosa objectives in southern Mississippi are different in character from the Lower Tuscaloosa in Louisiana. For the most part, Mississippi's sands are not as prolific producers as the age equivalent sands in Louisiana. They are also found at shallower depths in Mississippi and do not have associated high pressures as in Louisiana, where production depths are at 16,000-20,000 feet.

Southwestern Mississippi is Wilcox country (fig. 8). The Tertiary Wilcox Group consists of approximately 3,000-3,500 feet of sandstone section interbedded with gray to black shale and lignite. The first Wilcox oil production was at Cranfield Field in Adams County. The Wilcox sands are usually the exploration objectives of smaller independents because the wells are fairly shallow at 5,000-7,000 feet and can be drilled within a few days.

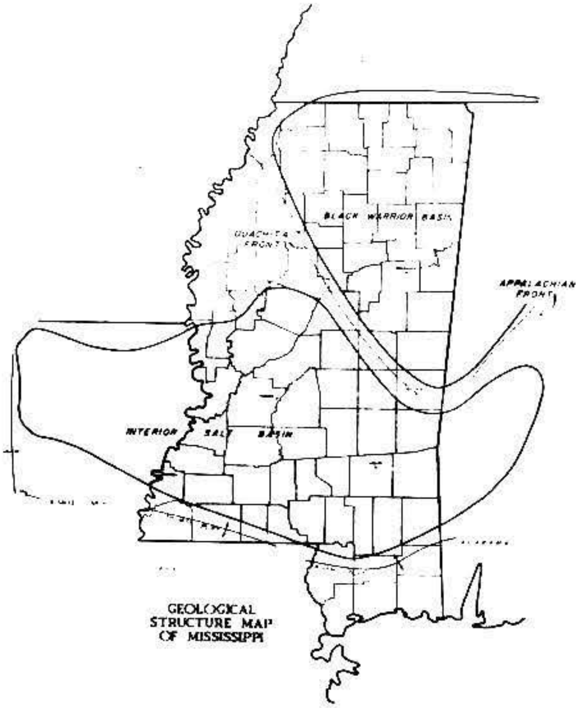


FIGURE 4

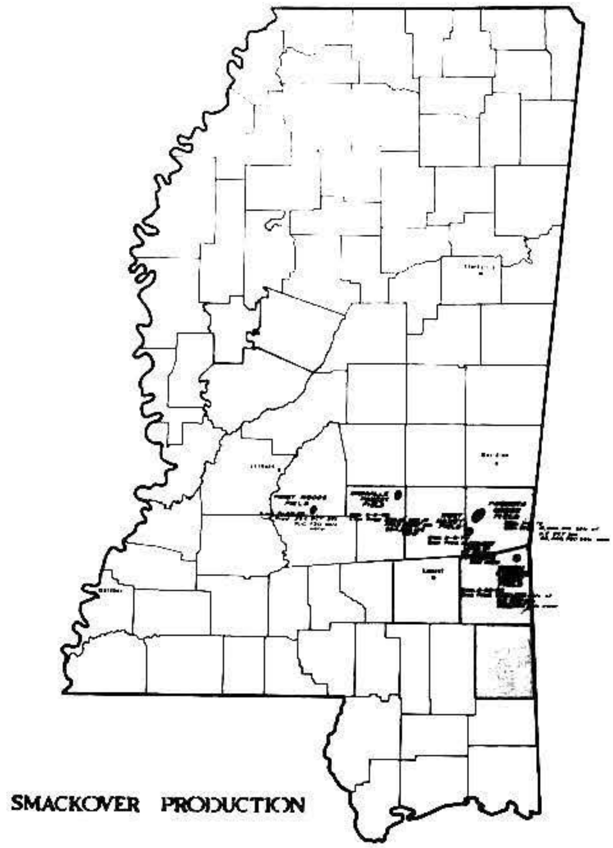


FIGURE 5

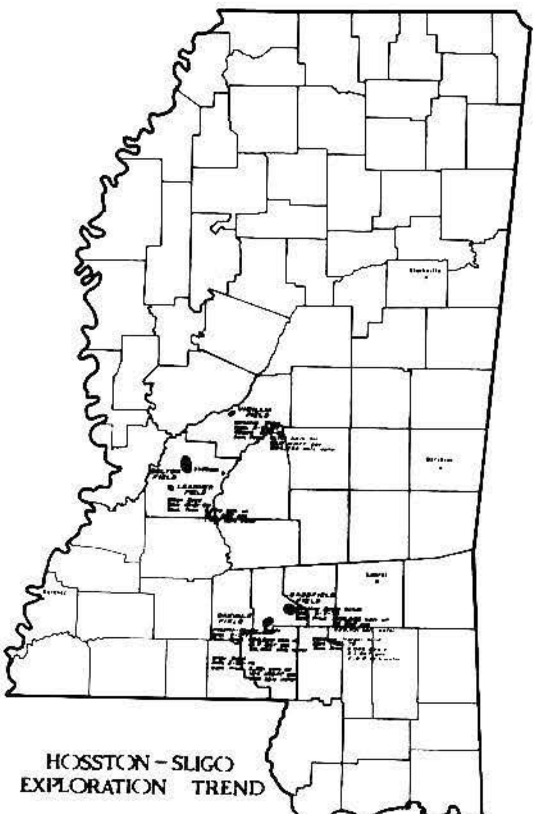


FIGURE 6

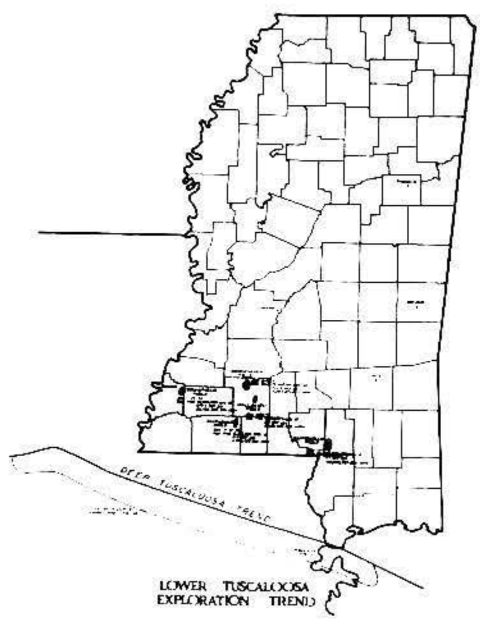


FIGURE 7

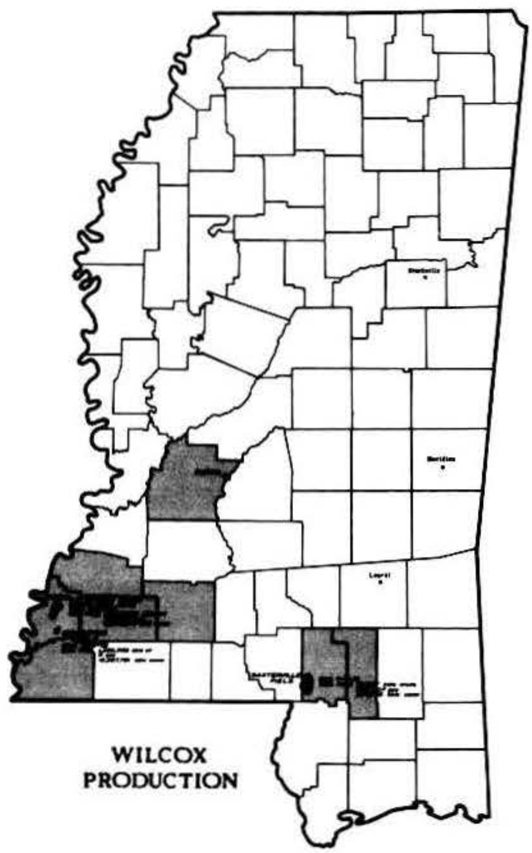


FIGURE 8

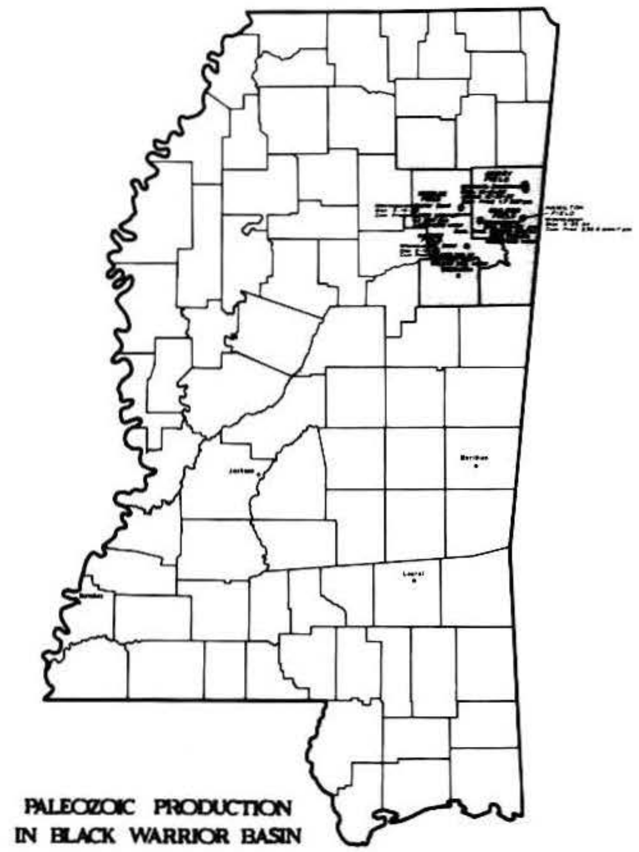


FIGURE 9

The second exploration province is the Black Warrior Basin, a Paleozoic structural feature bounded by the buried Ouachita Mountains to the southwest and the buried Appalachian Mountains to the southeast. Paleozoic rocks in the basin range in age from Cambrian to Pennsylvanian. Unconformably overlying the Paleozoics are Mesozoic and Cenozoic overburden. Natural gas production is predominant in the Warrior Basin. The main producing horizons are in the Mississippian-age section, which consists mostly of clastics. To date one zone, the Carter Sandstone, is the most productive unit and is generally found at shallow depths of 3,000-6,000 feet. Other productive Mississippian sands include the Sanders, Abernathy, Rea, Evans, and Lewis. Production is obtained to a lesser extent from Pennsylvanian sands, and limited production has been obtained from the Cambrian-Ordovician Knox dolomites. Most of the producing fields are centered around Monroe and Clay counties (fig. 9).

The full hydrocarbon potential of Mississippi has yet to be explored. There are several areas where deep objectives have not been tested. These areas include southeastern Mississippi (George, Jackson, Harrison, and Stone counties) where the Norphlet and Smackover formations may be prospective. These Jurassic reservoir rocks may also extend offshore to federal and state waters in the Mississippi Sound, where they would be found at depths in excess of 20,000 feet. Southwestern Mississippi (Wilkinson, Lincoln, and Franklin counties) has barely been tested at Norphlet, Smackover, and Cotton Valley levels. These objectives also require wells to be drilled in excess of 20,000 feet. In Warren, Hinds, and Copiah counties already a new Cotton Valley trend is developing led by exploration of Placid Oil Company at Bovina Field and Union Oil Company of California at Oak Ridge Field. The wells in this area are drilled to depths of 18,000 feet. And yet another large unexplored trend, which may become of interest to exploration companies, is the buried Ouachita Mountains, which are characterized geologically by complex folding and thrust faulting. Exploration for oil and gas will continue in Mississippi for some time to come, and with ever improving exploration techniques the challenge of finding the deeper objectives will be met.

Acknowledgments

The author thanks the management of Placid Oil Company for the time and materials necessary to prepare this presentation. Special thanks are due Hillary Wise for her technical assistance.

THE OLDEST LATE CRETACEOUS DINOSAURS IN NORTH AMERICA?

Kenneth Carpenter
University of Colorado Museum
Boulder, CO 80309

ABSTRACT

Dinosaurs have been collected from two sites in Late Cretaceous strata in northeastern Mississippi. A hadrosaur tooth from near Saltillo, Lee County, is the second record of a dinosaur from the Selma Group in Mississippi. Hadrosaurs, a theropod and an unidentifiable dinosaur have been recovered from the construction site of Lock A of the Tennessee-Tombigbee Waterway, Monroe County. The material is either from the basal Eutaw Formation or upper McShan Formation and may represent the oldest Late Cretaceous dinosaurs in North America.

Contrary to previous opinion, the Appalachian dinosaur faunas are dominated by endemic forms, with only two of the eight generically identifiable forms also known from the Western Interior. The presence of volcanic islands in the southern part of the epeiric seaway during the early and middle Late Cretaceous may have permitted limited east-west faunal migrations.

INTRODUCTION

Throughout most of the Late Cretaceous, North America was divided by a shallow epeiric sea that connected the Gulf of Mexico with the Arctic Ocean (fig. 1). This sea probably limited communication between the western (Cordilleran) and eastern (Appalachian) landmasses, producing endemic faunas (Lillegraven, 1974). Not until there was a partial regression of this sea during the late Maestrichtian could there have been any significant east-west exchange of vertebrates.

Over a century of collecting has revealed a detailed composite picture of the various vertebrate communities in the Cordilleran region. This includes the paleobiogeographical distribution of the dinosaurs (e.g. Sloan, 1969), foodwebs (e.g. Lucas, 1981), paleoecology of the dinosaur communities (e.g. Beland and Russell, 1978), and the composition and habitat distribution of the non-dinosaurian component of the vertebrate communities (e.g. Estes and Berberian, 1970). Unfortunately such studies have not been duplicated for the Appalachian region because of the paucity of specimens. This lack is due to the near absence of terrestrial sediments and to heavy vegetation cover which limits the extent of outcrops. All vertebrate fossils from the Appalachian region are from nearshore facies revealed in quarries, roadcuts and riverbanks. The scarcity of terrestrial sediments is primarily due to the Appalachian region being an area of degradation during the Late Cretaceous. Furthermore, terrestrial sediments which may have been deposited have mostly been eroded away, except in a few places (such as cited by Horner, 1979).

The scarcity of terrestrial vertebrates from the Appalachian region makes any additional material important. A search of the fossil vertebrate collection of the Mississippi Museum of Natural Science (MMNS) reveals several new records of dinosaurs from the southern Appalachian region. All specimens, except where noted, are from either the basal Eutaw Formation or upper McShan Formation (Dockery, personal communication) exposed during construction of Lock A of the Tennessee-Tombigbee Waterway near Amory, Mississippi (NW, NW, Sec. 29, and NE, NE, Sec. 30, T.12 S., R.8 E.).

SYSTEMATIC ACCOUNT

Class DINOSAURIA
Subclass SAURISCHIA
Order THEROPODA
gen. et sp. indet.
Pl. 1, figs. 1a,b; 2a,b

Material: MMNS VP103 proximal pes phalanx; MMNS VP113 partial caudal centrum.

Description: The phalanx (Pl. 1, figs. 1a,b) is incomplete proximally. However, the overall shape and curvature of the shaft indicate that it is the right first phalanx of digit II or III. Distally the bone measures 65 mm wide and 41 mm high.

The elongate, laterally pinched centrum identifies the partial centrum (Pl. 1, figs. 2a,b) as a theropod caudal. The absence of chevron facets ventrally indicates the portion preserved is the anterior half. Dorsally, sutures for the neural arch remain open indicating that the animal was young since the arch had not fused with the centrum.

Discussion: Late Cretaceous Appalachian theropods are not well known, although two species have been identified. These are *Dryptosaurus aquilunguis* and *Ornithomimus antiquus*. A third genus, *Albertosaurus*, may also be present (Baird and Horner, 1979), although the evidence is inconclusive. The MMNS toe bone is too broad and dorsally compressed to be that of an ornithomimid, but

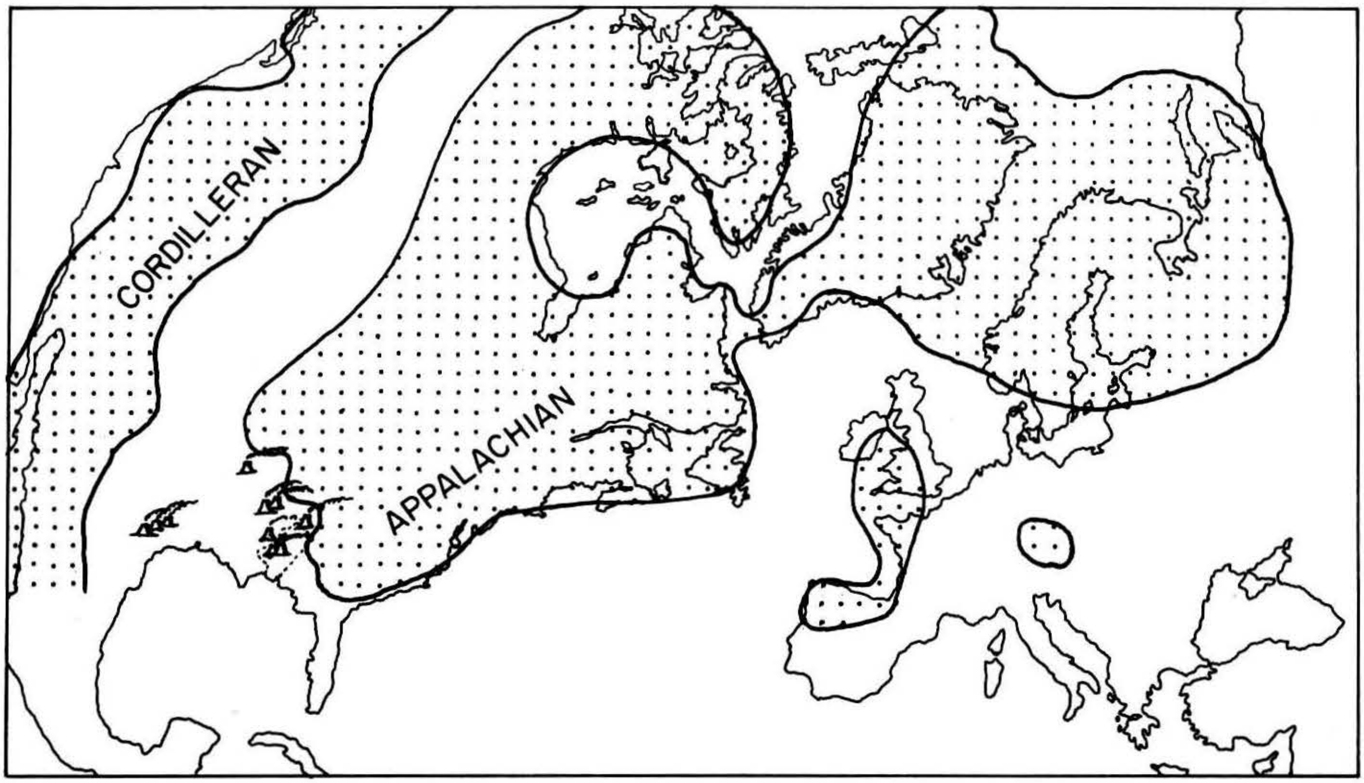


Figure 1. Reconstruction of North America and Europe during the Late Santonian. Possible volcanic islands shown with volcano symbol; terrestrial volcanoes not shown. Land shown in stipple. Data from Lonsdale (1927), Ross et al. (1929), Kidwell (1949; 1951), Moody (1949), and Williams and Stelck (1975).

compares well with *Albertosaurus*. Unfortunately, the feet of *Dryptosaurus* are too poorly known to be excluded as a possible alternative.

Subclass ORNITHISCHIA
Order ORNITHOPODA
Family HADROSAURIDAE
Subfamily HADROSAURINAE
gen. et sp. indet.
Pl. 1, figs. 3a,b

Material: MMNS VP118 a tooth from the Selma? Group near Saltillo, Mississippi. Exact locality unknown.

Description: The tooth (Pl. 1, figs. 3a,b) lacks the root and a small portion of the enamel crown near the base. The enamel face is 23 mm tall and 12 wide; the greatest buccal-lingual diameter is 10 mm.

Discussion: The nearly straight dentine face opposite the enameled surface identifies the tooth as from a maxilla. The overall appearance of the tooth is similar to the maxillary teeth of *Lophorhothon atopus* (see Langston, 1960), although slightly larger. Appalachian hadrosaurs are too poorly known to permit positive identification of the tooth.

Family HADROSAURIDAE
Subfamily indet.
gen. et sp. indet.
Pl. 1, figs. 4a,b; 5a,b,c

Material: MMNS VP111 distal caudal centrum; MMNS VP108 phalanx.

Discussion: The centrum (Pl. 1, figs. 5a,b,c) is abraded along its edges indicating transportation prior to burial. Sutures for the neural arch give no indication that the neural pedicles were coossified with the centrum; therefore the animal was young at the time of death. The centrum measures 45 mm long and 54 mm wide.

The phalanx (Pl. 1, figs. 4a,b) is well preserved and does not appear to have suffered transportation abrasion. The edges are not well ossified, suggesting a young animal. The phalanx is 68.5 mm long; the proximal joint face is 43 mm wide and 46.5 mm tall; and the distal joint condyles are 42 mm wide and 33 mm tall. The overall shape of the bone indicates that it is the right first phalanx of digit II.

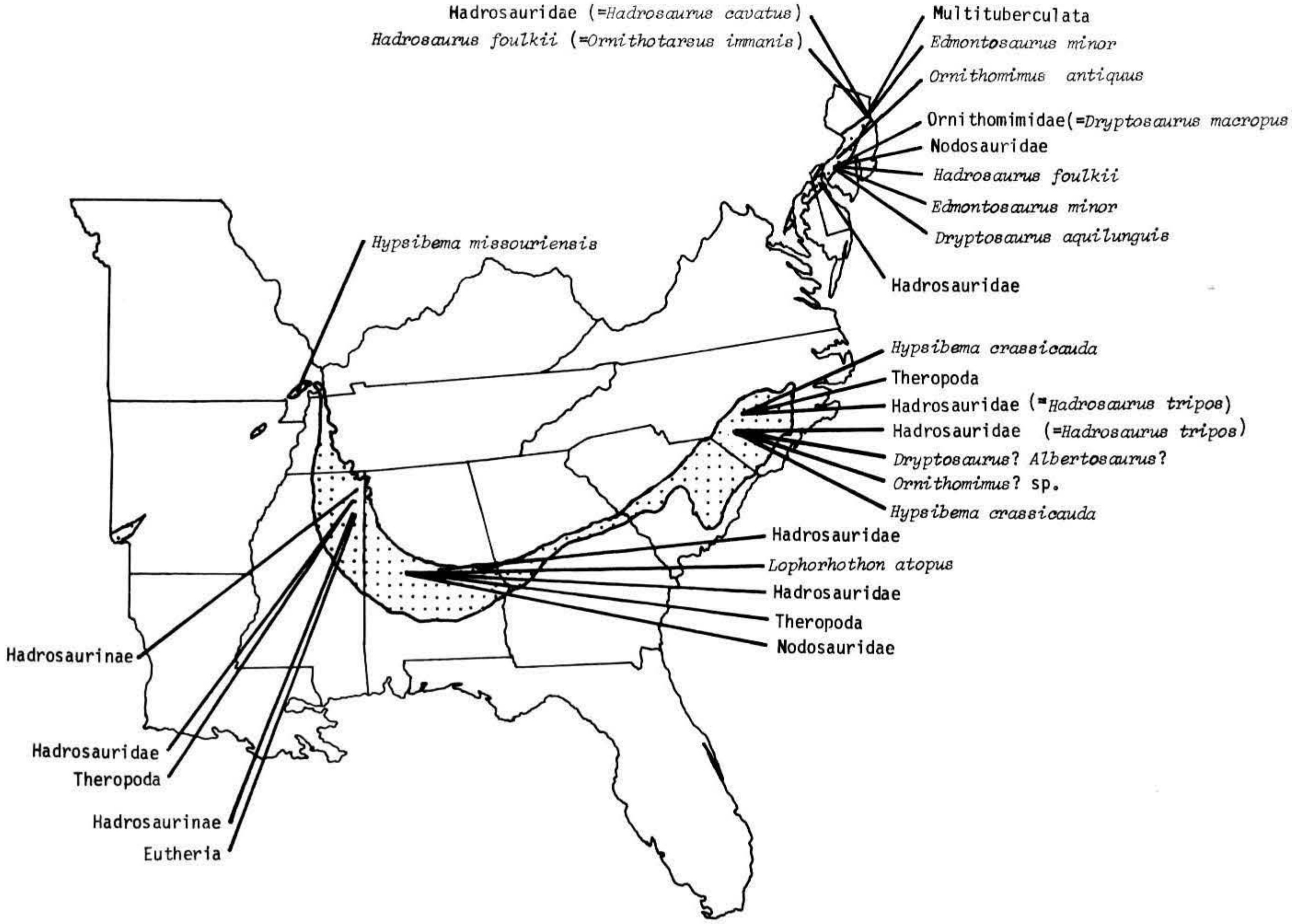


Figure 2. Distribution of Late Cretaceous dinosaurs along the East and Gulf Coast. Late Cretaceous deposits stippled.

DINOSAURIA *incertae sedis*
Pl. 1, figs. 6a,b

Material: MMNS VP104 sacrum.

Description: The sacrum is composed of three coossified vertebrae (Pl. 1, figs. 6a,b) which show a considerable amount of transportation abrasion. An unknown amount of the anterior part of the sacrum is missing; the portion preserved is believed to be the last three vertebrae. This conclusion is based on the sacrum becoming dorsoventrally thinner posteriorly(?) (from 26.5 mm to 19 mm) and because the centrum changes shape in cross-section from nearly circular anteriorly(?) to subrectangular posteriorly(?). The first vertebra is incomplete, but enough is present to indicate that the centrum was round with a weakly developed keel ventrally. The second vertebra is dorsoventrally compressed giving the centrum an oval cross-section; a ventral keel is very weakly developed. The third vertebra may have terminated the sacrum but abrasion of its posterior face prevents confirmation. The centrum is wider than high, and subrectangular in cross-section. Ventrally there is a shallow groove.

The overall length of the sacrum is 115.6 mm, with a greatest width of 56 mm. The first vertebra is too incomplete for measurements to have any value. The second vertebra is approximately 47.5 mm long and 29.5 mm wide at its narrowest point. The last vertebra is approximately 39 mm long and 27 mm wide at its narrowest point.

Discussion: The sacrum cannot be placed taxonomically with any certainty. It is unusual in that the centra become subrectangular in cross-section posteriorly, resembling the condition seen in dromaeosaurids (e.g. *Saurornithoides*, Carpenter and Paul, in preparation). However, unlike dromaeosaurids, the centra are not pneumatic. Until the Appalachian dinosaur fauna is better known, the sacrum cannot be identified more specifically.

DISCUSSION

Fossil vertebrates from northeastern Mississippi include some of the oldest Late Cretaceous dinosaurs in North America. Kaye and Russell (1973) described a partial Hadrosaurinae skeleton collected near Columbus, Lowndes County, as the oldest North American hadrosaur. The specimen was found about 27.5 m below the top of the Tombigbee Sand Member of the Eutaw Formation. Previously, *Claosaurus affinis* from the Smoky Hill Chalk Member of the Niobrara Formation, Kansas, was considered the oldest hadrosaur in North America (Lull and Wright, 1942). Kaye and Russell reasoned that since the upper part of the Smoky Hill Chalk, from which *Claosaurus* was found, was early Campanian and the Tombigbee Sand was Santonian, the Mississippi hadrosaur was older. Radiometric dates now place the upper part of the Smoky Hill Chalk in the Santonian (Obradovich and Cobban, 1975). There is presently a conflict as to the age of the Tombigbee Sand. Originally, Stephenson and Monroe (1940) placed the Tombigbee Sand in the Santonian based on the presence of the floating crinoid *Marsupites* and the ammonite *Muniericeras*. Recent work by Emry, Archibald and Smith (1981) places the Santonian-Campanian boundary within the Tombigbee Sand based on mega- and microinvertebrates and nannoplankton, while Russell et al. (1982) place most of the Eutaw Formation, including the Tombigbee Sand, in the Campanian based on pollen. This age conflict cannot be resolved at this time without additional study; however, it is certain that the hadrosaur described by Kaye and Russell is not the oldest hadrosaur in North America. It may be as old as *Claosaurus affinis*.

The small collection of dinosaurs in the MMNS increases the total sample size of dinosaurs for Mississippi from two (Horner, 1979) to eight. The hadrosaurine tooth from the Selma Group is the second occurrence from that unit in the state. Horner (1979) erroneously assigned hadrosaur bones collected near Tupelo, Lee County, to the Eutaw Formation. All strata in the vicinity of Tupelo are the Coffee Sand and Selma Chalk (see Stephenson and Monroe, 1940, Pl. 1A). Furthermore, Lull and Wright (1942) clearly show that the specimen come from the Selma Group in their Plate 1.

The stratigraphic position of the dinosaurs from Lock A near Amory, Mississippi, is unknown since the contact between the Eutaw Formation and the underlying McShan Formation is uncertain (Dockery, personal communication). If from the basal Eutaw Formation, they are late Santonian or early Campanian, but if from the McShan Formation they are late Coniacian or early Santonian based on pollen (Russell et al., 1982). Thus, these bones may be the oldest Late Cretaceous dinosaurs in North America.

The lack of coossification of the neural arch with the centrum and the incomplete ossification of the hadrosaur phalanx indicate that many of the specimens were of young animals.

The Appalachian dinosaur fauna (fig. 2 and Table 1) is a mixture of endemic and pandemic forms. Baird and Horner (1977) and Horner (1979) have pointed out some of the similarities with the dinosaur faunas of the Western Interior; this was echoed by Krause and Baird (1979). This similarity, however, is less than they suggest. Of the six generically identifiable taxa (Table 1) only two, *Edmontosaurus* and *Ornithomimus*, also occur in the Western Interior. *Albertosaurus* may also be present in the Appalachian region, but its presence has not been confirmed. The alleged synonymy of *Kritosaurus* from the Western Interior with *Hadrosaurus* from the East Coast as suggested by Baird and Horner (1977, 1979) and Horner (1979) has never been substantiated. There are compelling reasons for accepting the two forms as distinct. In *Kritosaurus* the deltopectoral crest extends further down the humeral shaft than in *Hadrosaurus* (compare Lull and Wright, 1942, Pl. 6 with Fig. 47). Furthermore, Lull and Wright (1942) noted that the teeth of *Kritosaurus* have sparcely papillated margins if at all; this is in sharp contrast with *Hadrosaurus* in which the margins of the teeth have well-developed papillae.

There are some interesting problems posed by the high number of endemic dinosaurs from the Appalachian region. As yet no ceratopsians or non-hadrosaurian ornithopods are known. However, Horner (1979) failed to report either of these dinosaurs from his survey of marine occurrences of dinosaurs. Therefore, the apparent absence of ceratopsians and non-hadrosaurian ornithopods may be preservational and ecological (i.e. they did not live near the coast, but lived inland). Another interesting problem is that all hadrosaurs from the Appalachian region identifiable to subfamily are Hadrosaurinae, while all hadrosaurs from Baja California, Mexico, are Lambeosaurinae (Morris, 1973) and all hadrosaurs from central California are Saurolophinae (Morris, 1973). Only in the Western Interior do all three families occur together. A hypothesis that needs to be pursued further is that the hadrosaurines evolved in the Appalachian region and migrated to the Western Interior via a chain of volcanic islands in the southern part of the epeiric sea (see fig. 1). Presence of these volcanoes is indicated by pyroclastics, lava flows and breccia-filled plugs (see Lonsdale, 1927; Ross et al., 1929; Kidwell, 1949; Moody, 1949; and Kidwell, 1951, for details). Most of the evidence comes from wells; thus it is not certain if the lava flows are the characteristic pillow-type of underwater flows. The great volume of pyroclastics, especially ash, suggests that some of these volcanoes may have formed islands.

Plate 1. Fig. 1, Theropoda pes phalanx, a, dorsal view; b, lateral view. Fig. 2, Theropoda caudal centrum, a, proximal view; b, lateral view. Fig. 3, Hadrosaurinae tooth, a, buccal view; b, anterior view. Fig. 4, Hadrosauridae pes phalanx, a, lateral view, b, dorsal view. Fig. 5, Hadrosauridae caudal centrum, a, proximal view; b, dorsal view; c, lateral view. Fig. 6, Dinosauria, indeterminant sacrum, a, lateral view; b, ventral view. Heavy bar = 2 cm.

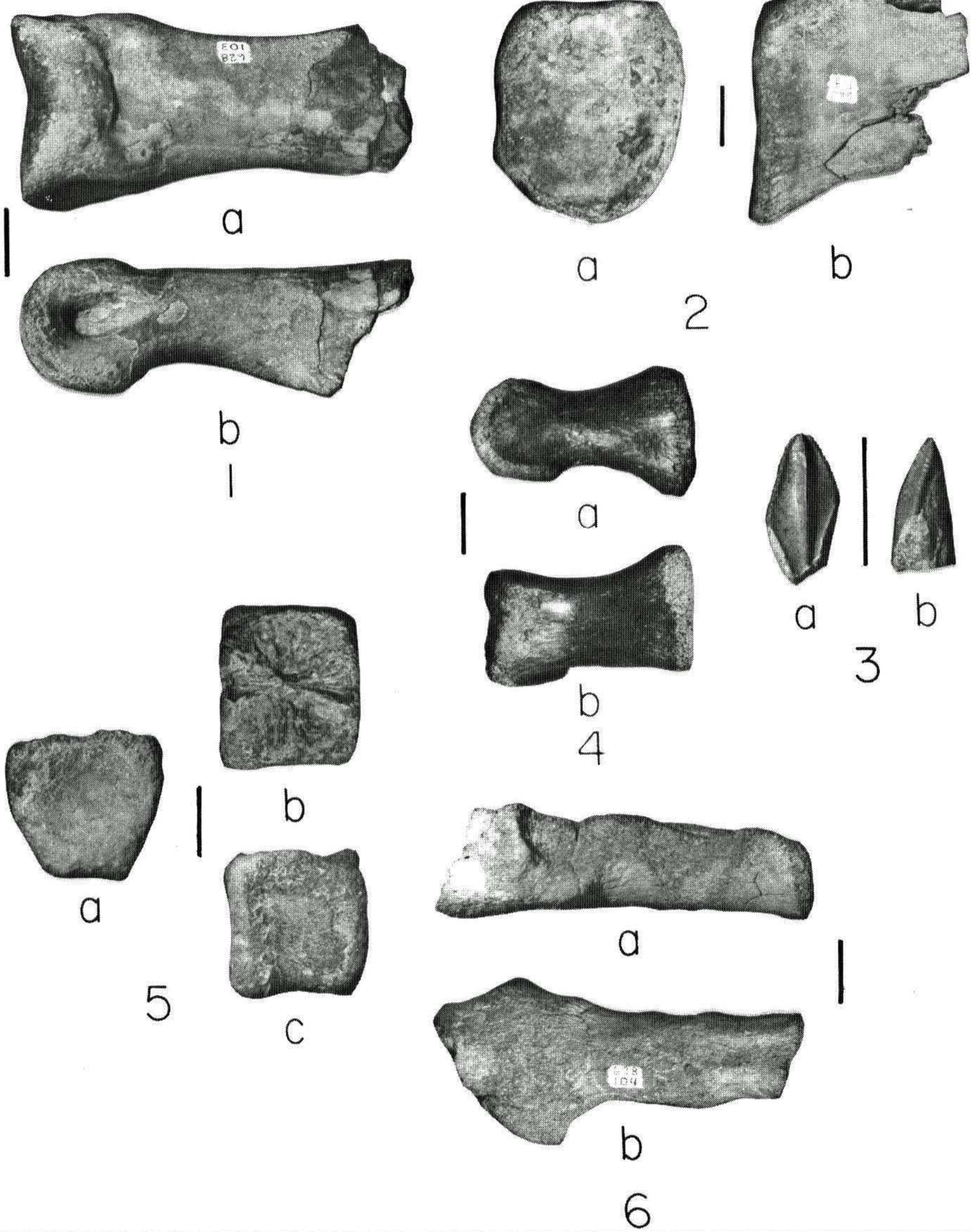

a
b
1
a
b
2
a
b
3
a
b
4
a
b
c
5
a
b
6

TABLE 1. GEOCHRONOLOGICAL DISTRIBUTION OF APPALACHIAN DINOSAURS.

AGE	TAXA	REFERENCE
Maestrichtian	*Hypsibema missouriensis*	Gilmore, 1945
	Ornithomimus antiquus	Horner, 1979
	Ornithomimidae	Horner, 1979
	Dryptosaurus aquilunguis	Horner, 1979
	Theropoda	Horner, 1979
	Edmontosaurus minor	Colbert, 1948; Horner, 1979
	Hadrosauridae	Horner, 1979
	Nodosauridae	Horner, 1979
Campanian	*Hypsibema crassicauda*	Baird and Horner, 1979
	Ornithomimidae	Baird and Horner, 1979
	Dryptosaurus? Albertosaurus?	Baird and Horner, 1979
	Theropoda	Langston, 1960; Baird and Horner, 1979
	Lophorhothon atopus	Langston, 1960
	Hadrosaurus foulkii	Baird and Horner, 1979
	Hadrosauridae	Baird and Horner, 1979
	Nodosauridae	Langston, 1960; Baird and Horner, 1979
Campanian? Santonian?	Hadrosaurinae	Kaye and Russell, 1973; This paper.
Campanian? Santonian?	Theropoda	This paper
Coniacian?	Hadrosauridae	This paper

CONCLUSION

Since the Late Cretaceous dinosaur fauna of the Appalachian region contains more endemic forms than previously thought by some, it becomes necessary to determine its source. Kielan-Jaworowska (1975) and Fox (1978) have commented on the similarities between the Late Cretaceous vertebrate faunas of Mongolia and the Western Interior. This was due to periodic east-west migrations across Beringia, which was repeatedly exposed during the Late Cretaceous. Similar east-west faunal migrations across North America were limited by the epeiric sea. The few taxa in common to both the Appalachian region and the Western Interior suggest that the volcanic islands functioned as filters selecting the immigrants that could cross.

It is possible that the Appalachian dinosaur fauna would show a high degree of similarity with the dinosaur faunas of Europe since the two regions were frequently joined during the Cretaceous (Williams and Stelck, 1975). Unfortunately, the Late Cretaceous dinosaur faunas of Europe are poorly known.

ACKNOWLEDGMENTS

I would like to thank Eleanor Daly, Mississippi Museum of Natural Science, for permitting me to study the dinosaur material in her care and for providing comments on an early version of this paper. I would also like to thank David Dockery, Mississippi Geological Survey, for bringing to my attention the presence of volcanoes in the southern part of the epeiric seaway and for data on the stratigraphy of Lock A, Tennessee-Tombigbee Waterway.

REFERENCES CITED

Baird, D., and J. Horner, 1977, A fresh look at the dinosaurs of New Jersey and Delaware (Abs.): New Jersey Acad. Sci. Bull. 22, No. 2, p. 50.

Baird, D., and J. Horner, 1979, Cretaceous dinosaurs of North Carolina: Brimleyana, v. 2, p. 1-28.

Beland, P., and D. Russell, 1978, Palaeoecology of Dinosaur Provincial Park (Cretaceous), Alberta, interpreted from the distribution of articulated vertebrate remains: Can. J. Earth Sci., v. 15, p. 1012-1024.

Colbert, E. H., 1948, A hadrosaurian dinosaur from New Jersey: Proc. Academy Nat. Sci., Phil., v. 100, p. 23-37.

Emry, R. J., J. D. Archibald, and C. Smith, 1981, A mammalian molar from the Late Cretaceous of northern Mississippi: J. Paleont., v. 55, p. 953-956.

Estes, R., and P. Berberian, 1970, Paleoecology of a Late Cretaceous vertebrate community from Montana: Brevoria, no. 343, p. 1-35.

Fox, R., 1978, Upper Cretaceous terrestrial vertebrate stratigraphy of the Gobi Desert (Mongolian Peoples Republic) and western North America, *in* C. R. Stelck and B. Chatterton, eds., Western and Arctic Canadian biostratigraphy: Geol. Assoc. Can., Special Paper 18, p. 577-594.

Gilmore, C., 1945, A new sauropod dinosaur from the Upper Cretaceous of Missouri: J. Paleont., v. 19, p. 23-29.

Horner, J., 1979, Upper Cretaceous dinosaurs from the Bearpaw Shale (marine) of south-central Montana, with a checklist of Upper Cretaceous dinosaur remains from marine sediments in North America: J. Paleont., v. 53, p. 566-577.

Kaye, J., and D. Russell, 1973, The oldest hadrosaurian dinosaurs in North America: J. Paleont., v. 47, p. 91-93.

Kidwell, A. L., 1949, Mesozoic igneous activity in the northern Gulf Coastal Plain: Unpubl. Ph. D. Thesis, University of Chicago, 317 p.

Kidwell, A. L., 1951, Mesozoic igneous activity in the northern Gulf Coastal Plain: Trans. Gulf Coast Assoc. Geol. Soc., v. 1, p. 181-199.

Kielan-Jaworowska, Z., 1975, Late Cretaceous mammals and dinosaurs from the Gobi Desert: Amer. Scientist, v. 63, p. 150-159.

Krause, D., and D. Baird, 1979, Late Cretaceous mammals east of the North American Western Interior seaway: J. Paleont., v. 54, p. 562-565.

Langston, W., 1960, The vertebrate fauna of the Selma Formation of Alabama, Part 6: The dinosaurs: Fieldiana, Geol. Mem., v. 3, p. 313-360.

Lillegraven, J., 1974, Biogeographical considerations of the marsupial-placental dichotomy: Ann. Review Ecol., v. 5, p. 263-283.

Lonsdale, J. T., 1927, The igneous rocks of the Balcones Fault region of Texas: Univ. Texas Bull. 2744, 78 p.

Lucas, S., 1981, Dinosaur communities of the San Juan Basin: A case for lateral variations in the composition of Late Cretaceous dinosaur communities, *in* S. Lucas, J. Rigby, Jr., and B. Kues, Advances in San Juan Paleontology: Univ. New Mexico Press, p. 337-393.

Lull, R., and N. Wright, 1942, Hadrosaurian dinosaurs of North America: Geol. Soc. Amer. Special Paper 40, 242 p.

Moody, C. L., 1949, Mesozoic igneous rocks of the northern Gulf Coastal Plain: Amer. Assoc. Petroleum Geol., v. 33, p. 1410-1428.

Morris, W., 1973, A review of Pacific Coast hadrosaurs: J. Paleont., v. 47, p. 551-561.

Obradovich, J. D., and W. Cobban, 1975, A time-scale for the Late Cretaceous of the Western Interior of North America, *in* W. Caldwell, ed., The Cretaceous System in the Western Interior of North America: Geol. Assoc. Can. Special Paper 13, p. 31-54.

Ross, C. S., et al., 1929, Water-laid volcanic rocks of early Upper Cretaceous age in southwestern Arkansas, southeastern Oklahoma, and northeastern Texas: U. S. Geol. Survey Prof. Paper 154F, p. 175-202.

Russell, E. E., D. M. Keady, E. A. Mancini, and C. E. Smith, 1982, Upper Cretaceous in the Lower Mississippi Embayment of Tennessee and Mississippi: Lithostratigraphy and biostratigraphy: Field Trip Guidebook, 1982 Annual Meeting of the Geological Society of America, 50 p.

Sloan, R., 1969, Cretaceous and Paleocene terrestrial communities of western North America: Proc. North Amer. Paleont. Convention, part E, p. 427-453.

Stephenson, L. W., and W. H. Monroe, 1940, The Upper Cretaceous deposits: Miss. State Geol. Surv. Bull. 40, 296 p.

Williams, G., and C. Stelck, 1975, Speculations of the Cretaceous paleogeography of North America, *in* W. Caldwell, ed., The Cretaceous System in the Western Interior of North America: Geol. Assoc. Can. Special Paper 13, p. 1-20.

CALENDAR OF EVENTS
1983 January - April

January 17-21 - Clastic depositional systems, short course, Houston. (Patrice Cunningham, Research Planning Institute, 925 Gervais St., Columbia, S.C. 29201. Phone: 803/256-7322)

March 3-4 - South-Central Section, Geological Society of America, meeting, College Station, Texas. (Melvin C. Schroeder, Dept. of Geology, Texas A & M Univ., College Station, Texas 77843. Phone: 713/845-2451)

March 16-18 - Southeastern Section, Geological Society of America, annual meeting, Tallahassee, Florida. (James F. Tull, Dept. of Geology, Florida State Univ., Tallahassee, Fla. 32306. Phone: 904/644-5860)

March 21-25 - Modern deltas, field seminar, Baton Rouge, Louisiana. (James Coleman, Coastal Studies Institute, Louisiana State Univ., Baton Rouge, La. 70803. Phone: 504/388-2395)

April 8-9 - Gulf Coast Section, Society of Economic Paleontologists and Mineralogists, 1983 Spring Field Trip, Upper Cretaceous Lithostratigraphy and Biostratigraphy of Northeast Mississippi, Northwest Alabama, and Southwest Tennessee. Leaders: E. E. Russell, Mississippi State Univ.; E. A. Mancini, Geological Survey of Alabama; D. M. Keady, Mississippi State Univ.; C. E. Smith, U.S.G.S., U. S. National Museum. (For further information contact John L. "Chip" Carney, Amoco Production Co., P. O. Box 50879, New Orleans, La. 70150. Phone: 504/586-6769)

April 17-20 - American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, annual meeting, Dallas. (AAPG headquarters, Box 979, Tulsa, Okla. 74101. Phone: 918/584-2555)

NEW BUREAU OF GEOLOGY PUBLICATION
Lower Oligocene Bivalvia of the Vicksburg Group in Mississippi

The Bureau of Geology announces the publication of Bulletin 123, "Lower Oligocene Bivalvia of the Vicksburg Group in Mississippi," by David T. Dockery III.

This bulletin reports on the bivalves and stratigraphy of the lower Oligocene Vicksburg Group in Mississippi. Fossil bivalves from seven formations are illustrated and their occurrences recorded. One hundred forty-four species are discussed systematically and forty-five new species are named. The sixty-two plates and numerous illustrations will aid in the comparison of the Mississippi fauna with Oligocene fauna from locations worldwide.

Fossils of the Vicksburg Group in Mississippi are unique in being the best preserved lower Oligocene fauna in North America. Many workers use the Mississippi Oligocene sequence as a standard for stratigraphic correlation. Many of the identified new species are of small size which should enable their use in subsurface correlation by the petroleum industry. This publication is the first major report on Vicksburg fauna since Conrad's work in 1848. Its use should contribute to geologic mapping and stratigraphic correlations and should be an important reference for professionals working in this field. Amateur collectors will also find the bulletin useful in the identification of their fossils.

This publication may be purchased from the Bureau of Geology at 2525 North West Street for $9.00 per copy. Mail orders will be accepted when accompanied by payment ($9.00, plus $1.00 postage and handling). Address mail orders to:

Bureau of Geology
P. O. Box 5348
Jackson, Mississippi 39216

PETROLEUM NEWS

MISSISSIPPI OIL AND GAS STATISTICS, SECOND QUARTER 1982

Oil

	Bbls. Produced	Severance Tax	Average Price Per Bbl.
April	3,286,042	$ 4,952,684.57	$ 25.11
May	2,790,185	4,752,290.34	28.39
June	2,793,192	4,726,102.21	28.20
Totals	8,869,419	$ 14,431,077.12	$ 27.11

Gas

	MCF Produced	Severance Tax	Average Price Per MCF
April	25,913,997	$ 5,322,310.90	$ 3.42
May	22,827,995	6,544,221.43	4.78
June	15,910,625	3,857,977.92	4.04
Totals	64,652,617	$ 15,724,510.25	$ 4.05

source: State Tax Commission

MISSISSIPPI GEOLOGY
Department of Natural Resources
Bureau of Geology
Post Office Box 5348
Jackson, Mississippi 39216

Mississippi Geology is published quarterly in March, June, September, and December by the Mississippi Department of Natural Resources, Bureau of Geology. Contents include research articles pertaining to Mississippi geology, news items, reviews, and listings of recent geologic literature. Readers are urged to submit letters to the editor and research articles to be considered for publication; format specifications will be forwarded on request. For a free subscription or to submit an article, write to:

Editor, Mississippi Geology
Bureau of Geology
P. O. Box 5348
Jackson, Mississippi 39216

Editors: Michael B. E. Bograd and David Dockery
Typesetter: L. Michele Morphis