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PALEONTOLOGICAL INVESTIGATIONS IN THE VICINITY OF MONTGOMERY LANDING, RED RIVER WATERWAY

Louisiana State University
Baton Rouge, La. 70803

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16. Abstract (Limit: 200 words)

Field work at Montgomery Landing took place between August, 1979 and August, 1980, and consisted of collecting 138 samples at 2 kg each, spaced at 30 cm intervals along ten selected section lines. In addition, several large bulk samples were taken and the anterior third part of a toothed whale was recovered.

Paleontological investigation of the samples includes the study of nannofossils, foraminifera, ostracodes, corals, bryozoa, mollusks, crabs, echinoderms, otoliths and other vertebrate remains including one of the finest Eocene whale skulls known to science. Biostratigraphic study confirms assignment of these beds to the early Jacksonian (late Eocene). Biofacies studies suggest that they were deposited on a flat, shallow continental shelf during a slow transgression of the sea. Local variation and diversity of the faunas is caused mainly by changes in the influx of terrigenous and organic matter in suspension.

In view of the fact that part of the locality will become inundated, and the rest of the outcrop will deteriorate soon through weathering and vegetation cover, it is recommended that research and educational use of the site be facilitated while it is accessible through dissemination of data onthe site. Further testing is not recommended.

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PALEONTOLOGICAL INVESTIGATIONS
IN THE
VICINITY OF MONTGOMERY LANDING
RED RIVER WATERWAY

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The Principal Investigators would like to thank Mr. Thomas Ryan, Mr. Burt Rader, and Ms. Carol Kleinhans, who served as contract officers on this project for the Corps of Engineers, New Orleans District. Mr. Ryan and Mr. Rader served during the field work period. Both were able to come to Montgomery Landing and observe sampling in progress, and to experience the joys of work on a west-facing central Louisiana river bank in late afternoon in late summer. All three have been helpful in adapting procedures designed for archaeological research to a paleontological project and in answering our many questions.

Ms. Marsha Harrison and the Colfax Banking Company graciously permitted research on their land. Mr. William P. Fletcher treated our field crew to a fish fry on the day a rainstorm caught us on the outcrop, leaving spirits dampened. His daughter and son-in-law, Janet and Jimmy Dyson, both LSU graduate students and natives of Montgomery, provided invaluable advice.

Many LSU graduate and undergraduate students worked on the project. Without their participation, the work would not have been possible. David Dockery of the Mississippi Geological Survey and Dr. Ray Givens of Nichols State University visited us in the field, and they and Dr. Thor Hansen of the University of Texas at Austin and Mr. Gary Stringer of Monroe, Louisiana, Mr. Allen of Alexandria, and Mr. S. Breard of Amoco Production Company in New Orleans graciously shared data with us. Drs. Alan Cheatham, Warren Blow, Erle Kauffman, and Clayton Ray, and Mr. Robert Purdy of the Smithsonian were gracious hosts during our visit to compare specimens.

Paleoecoelogical reconstruction block diagrams are drawn by LSU graduate student Barbara Standhardt. Most photos in the field are by Judith Schiebout. SEM photography is by Woodson Godfrey of LSU Department of Geology except for the Bivalvia which were photograpned by James Ault, graduate student in Botany at LSU. School of Geoscience photographers Don Nugent and Dan Peace helped in photography, printing, and plate production.

Sections of the text for which no author is indicated are by the Principal Investigators with some student contributions. Dr van den Bold is responsible primarily for the microfauna and Dr. Schiebout is responsible for the megafauna, both vertebrate and invertebrate, and the sedimentology. The Principle Investigators have edited the work of all the other authors.

Joseph E. Boudreaux wishes to express the following acknowledgement for the nannofossil section: to the management of Texaco, Inc., appreciation and gratitude for encouragement and permission to publish. He is indebted to Mr. Al Traina, Laboratory Technician and operator of the SEM. Gratitude is also extended to James Terry Christian for constructive criticisms and to Jeannette Daste for typing the manuscript.

Chapter 1. NATURE AND HISTORY OF THE MONTGOMERY LANDING LOCALITY

A. INTRODUCTION

The cut-bank on the east side of the Red River near the town of Montgomery, Grant Parish, Louisiana, forms a cliff, Creola Bluff, of about 500 meters length, which in places attains heights of 14 meters (Figs. 1, 2, Plate 1). At low water a broad beach, composed of recent river deposits, covers the base of the cliff. During spring floods the water generally reaches about halfway up the cliff.

At the north end of the Montgomery Landing section, a less than 2 m. thick, very fossiliferous, glauconitic marl bed, topped by a thin calcareous ledge (ledge 1) forms the upper part of the cliff. Below this marl, dark gray lignitic clays are exposed. Their lower parts are covered by river mud during low water. The marl bed slopes down southward until it disappears below low-water level, but it appears again for a short distance on the other side of a minor fault. Above the marl bed and the lower calcareous ledge, the beds consist of greenish-gray clays, in places very fossiliferous. They contain two calcareous ledges, similar to the first one. The top ledge consists in places of 2 to 3 narrower ledges. These ledges can easily be followed all the way south along the cliff, except for a short interruption by a slumped area, till the lower ledge almost reaches low-water level at the south end.

This locality, especially the marl bed, has been known to geologists since the early 19th century (Table 1, Darby, 1816), and the first to describe the Montgomery Landing section in detail was Hopkins (1870). Since then the cliff has been described and sampled many times and macro and microfossils have been described from it, mainly from the marl bed. The overlying clays have never attracted that much attention, so that precise faunal distribution data are generally lacking. The lowermost lignitic clays belong to the Cockfield Formation of the Claiborne Group (Claiborne stage); the overlying marl belongs to the Moodys Branch Formation and the upper clays to the Yazoo Formation, both belonging to the Jackson Group (Jackson stage) (Fig. 3).

B. STRATIGRAPHY

Historical Review

The Cockfield, Moodys Branch, and Yazoo Clay formations are Eocene in age (Fig. 3). In Gulf Coast stratigraphy, the Eocene epoch is divided into the Wilcox, Claiborne, and Jackson stages. These are generally accepted as the equivalents of the lower, middle, and upper Eocene, respectively. The Cockfield Formation falls within the upper

FIGURE 1

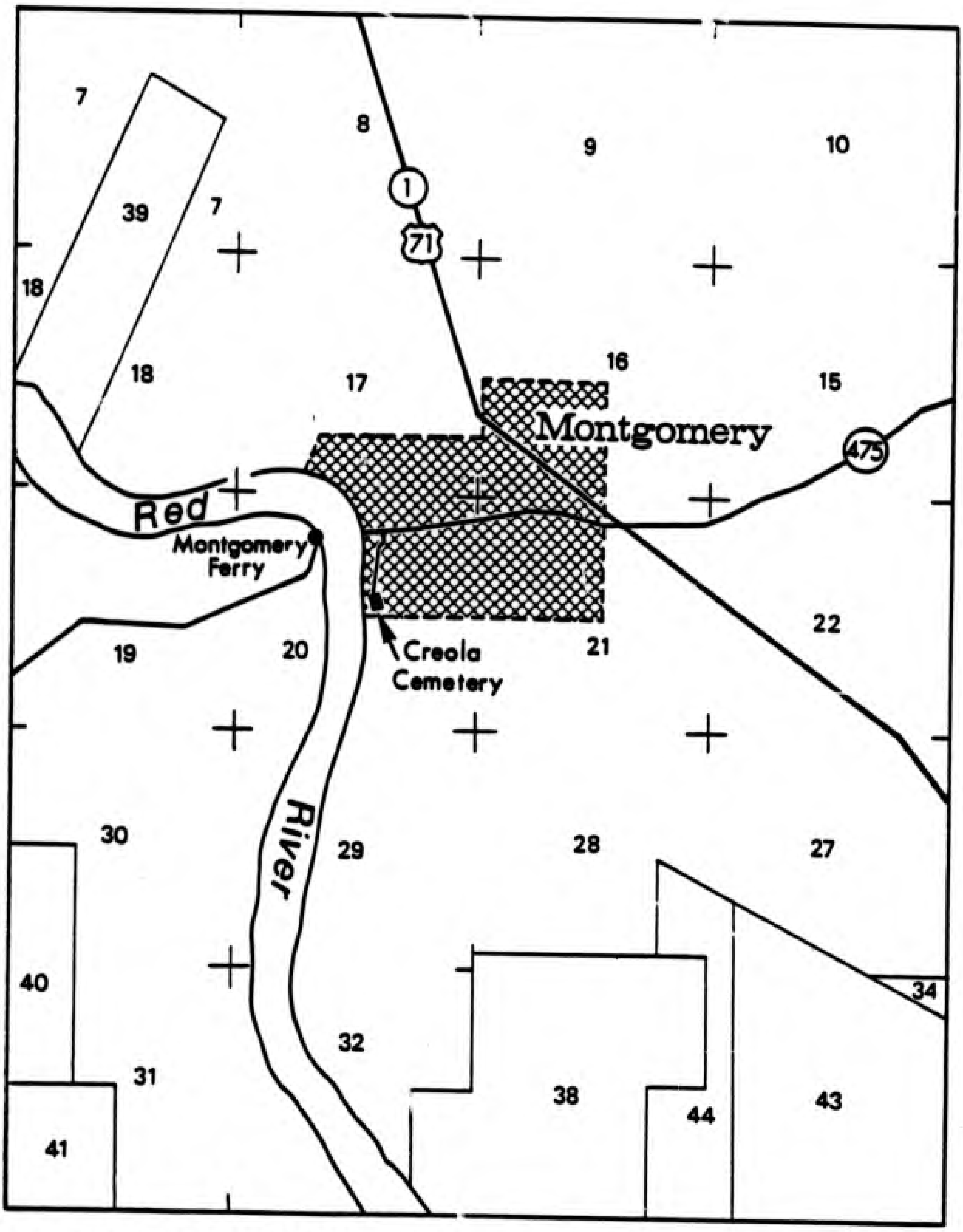


Figure 2 .Outcrop locality along the east bank of the Red River at Montgomery, Louisiana.

PLATE 1 . Aerial photo of Montomery Landing at the time research began. Former river courses and modifications planned in conjunction with the Red River Waterway Project are drawn over the photo. Photo courtesy of the Corps of Engineers, New Orleans District.

Claiborne stage; the Moodys Branch and Yazoo Clay formations fall within the Jackson stage. The unconformity between the Cockfield and Moodys Branch Formations corresponds to the Claiborne-Jackson contact.

Claiborne Stage, Conrad, 1847

Conrad (1847) first used the name Claiborne in a formal stratigraphical sense when describing the fossiliferous sands exposed at Claiborne Bluff and Claiborne Landing on the Alabama River. This term is now used "as a provincial division of the Eocene in the Atlantic and Gulf coastal province to include all strata which can be reasonably demonstrated to be equivalent to the type section and the typical subdivisions in the type area of western Alabama" (Murray, 1961).

Cockfield Formation, Vaughan, 1895

According to Fisk (1938), the lignitic beds along the Red River were originally placed by Hopkins (1870) in the upper Mansfield. These later (Lerch, 1893; Harris and Veatch, 1899) became known as the Lignitic beds. Vaughn (1895)applied the name "Cocksfield Ferry" to the lignitic beds exposed above the fossiliferous beds at St. Maurice and "Cocksfield Ferry" at Petite Ecore Bluff. Veatch (1906), however, pointed out that the bluff was adjacent to the plantation of two Cockfield brothers so corrected the name to "Cockfield."

The Cockfield Formation correlates with the Yegua Formation in Texas and the Gosport Sand of Alabama. The equivalent lignitic beds in Mississippi are referred to as the Cockfield Formation. For some reason, possibly because of Stenzel's work (1939), stratigraphers refer to these beds in Louisiana as the Yegua, Yegua (Cockfield), or Cockfield (Yequa). The type locality of the Yegua, however, is marine. Also, it is peculiar that the lignitic beds of Mississippi would be called the Cockfield Formation while the equivalent beds of Louisiana (which contain the type locality of the Cockfield) would not. Therefore, we suggest that these upper Claiborne beds in Louisiana be referred to as the Cockfield Formation.

Jackson Stage, Hilgard, 1860

Outcrops at Jackson, Mississippi contain typical sediments of this stage. According to Murray (1961), Wailes (1854), in describing the fossils of the "greensand marl of Jackson" was the first to use the term Jackson in a geological sense, although Huff (1970) notes that Lyell (1847) described fossils from Jackson several years earlier. Hilgard (1860) was the first to apply Jackson to a specific sedimentary sequence when he referred to the "Jackson Stage" in a report on the geology of

Mississippi, but used this term interchangeably with "Jackson Group" (Murray, 1961).

As Huff (1970) states, Lowe (1915) was the first to identify formations within the Jackson group, recognizing the Moodys Branch Green Marls along Moodys Branch (a tributary of the Pearl River) in Jackson, Mississippi, and the Yazoo Clay Marl for clays along the Yazoo River near Yazoo City, Mississippi. Cooke (1918), however, considered these both to be members of the Jackson Formation. Nomenclatural confusion continued until 1945 when the United States Geological Survey adopted the Moodys Branch Formation and Yazoo Clay Formation as subdivisions of the Jackson group (Huff, 1970).

Hilgard's (1860) observations were confined to the state of Mississippi, but in subsequent works "the name Jackson was applied to lithologically similar and dissimilar deposits in northern Mexico, in all states in the northern Gulf province where Jacksonian strata are known, and in the Atlantic segment of the Coastal province." Whether actually stated or implied, a time-stratigraphic usage may be inferred from these works (Murray, 1961).

The term Jackson is now used as a rock unit (Jackson Group = Moodys Branch + Yazoo Clay formations) and a time-rock unit (Jackson Stage). Murray and Wilbert (1950), Stuckey (1960), and Murray (1961) discuss the difficulties historically associated with this term. Hilgard (1869) first applied the term Jackson to the rocks of the Grant Parish area. Hopkins (1870) described the Montgomery Landing section in detail and separated the fossiliferous Jackson from the underlying lignitic beds (Fisk, 1938).

Moodys Branch Formation, Lowe, 1915

As previously discussed, Lowe (1915) first recognized the Moodys Branch Formation from outcrops along Moodys Branch in Jackson, Mississippi. The type locality is now covered, so Rainwater (1957) designated the section exposed at "Fossil Gulch" in Riverside Park at Jackson as the alternate type locality. The Moodys Branch is a widespread, persistent, mappable unit, extending from eastern Texas to eastern Alabama (Murray, 1961), which marks the base of the Jackson stage in these areas. In eastern Alabama and Florida, it grades into the calcareous facies of the Inglis and Williston Formations (Fig. 5).

Yazoo Clay Formation, Lowe, 1915

The Yazoo Clay conformably overlies the Moodys Branch. This formation was named by Lowe (1915) for the clay bluffs along the Yazoo River near Yazoo City, Mississippi, and included all Jackson clays above the Moodys Branch Formation (Fisk, 1938).

Fisk (1938) divided the Yazoo Clay in Louisiana into the Tullos and Verda members, separated by the Union Church Transition Phase. Overlying the Verda member were the Danville Landing beds, a series of fossiliferous clays and sands Fisk believed were post-Yazoo but pre-Oligocene.

The Tullos Member was named for the beds outcropping in the vicinity of Tullos, La Salle Parish, and were described as deep blue-gray clays containing little sand and leaving a washed residue composed almost entirely of microfossils. The Union Church Transition Phase was defined as the "upper concretionary, sandier phase of the Tullos member" (Fisk, 1938).

The Verda member was named for outcrops near Verda and New Verda, Grant Parish. These beds are described as a "series of sparingly fossiliferous, brackish-water, lignitic clays and interbedded silty sands, with intercalated lenticular marine sandstones, freshwater leaf-bearing silts and marine clays" (Fisk, 1938).

The Danville Landing beds have never been defined as a formal unit (Murray, 1961). As Stuckey (1960) states, Howe and Wallace (1932) published a report on the Jackson foraminifera from Danville Landing on the Ouachita River in Catahoula Parish. This was merely a faunal report of a particular locality and the authors never intended to introduce a stratigraphic unit. Hanna and Gravell (1934), however, referred to the uppermost Jackson as the Danville Landing group. Subsequent work has seen this term often used as a stratigraphic unit.

The nomenclatural state of the upper Jackson in Louisiana remains a point of confusion. As the term Danville landing has no definitive stratigraphic meaning, it has been used in several senses. Some workers place the Danville Landing beds as the uppermost member of the Yazoo Formation (e.g. Toulmin, 1977; Dockery, 1980). In a micropaleontological analysis, however, Stuckey (1960) concluded that the uppermost Jackson was missing from Danville Landing and that most of the section correlated to the Verda Member of Fisk.

Murray (1961) stated that the Danville Landing beds are a mappable lithologic unit with a distinct microfaunal sequence and implied they should be given formational status with the Danville Landing locality constituting the type section. Huff (1970) also referred to the Danville Landing Formation. The general consensus in the literature, however, appears to be the placement of the Danville Landing beds as the uppermost member in the Yazoo Clay Formation above the Tullos, Union Church Transition Phase, and Verda members.

The Yazoo Clay beds exposed at Montgomery belong to the Tullos Member (Fisk, 1938). These beds can be correlated with the North Twistwood Creek Clays, the lowermost Yazoo Clay member recognized in eastern Mississippi (Murray, 1947, 1963). In western Mississippi the Yazoo Clay is undifferentiated (Fig. 3).

Radiometric ages have been obtained for some Gulf Coast Claiborne and Jackson localities (Ghosh, 1972; Evernden, 1961), and are reported in Hardenboi and Berggren (1978). Ages of 37.3 and 39.0 MY are reported for Moodys Branch samples and 38.1 and 38.5 MY for Yazoo Clay (=Tullos?) samples. Comparison of these ages with those of European localities supports Frederiksen's (1980) hypothesis that part of the lower Jackson may be middle Eocene (Hardenbol and Berggren, 1978).

Paleobathymetry

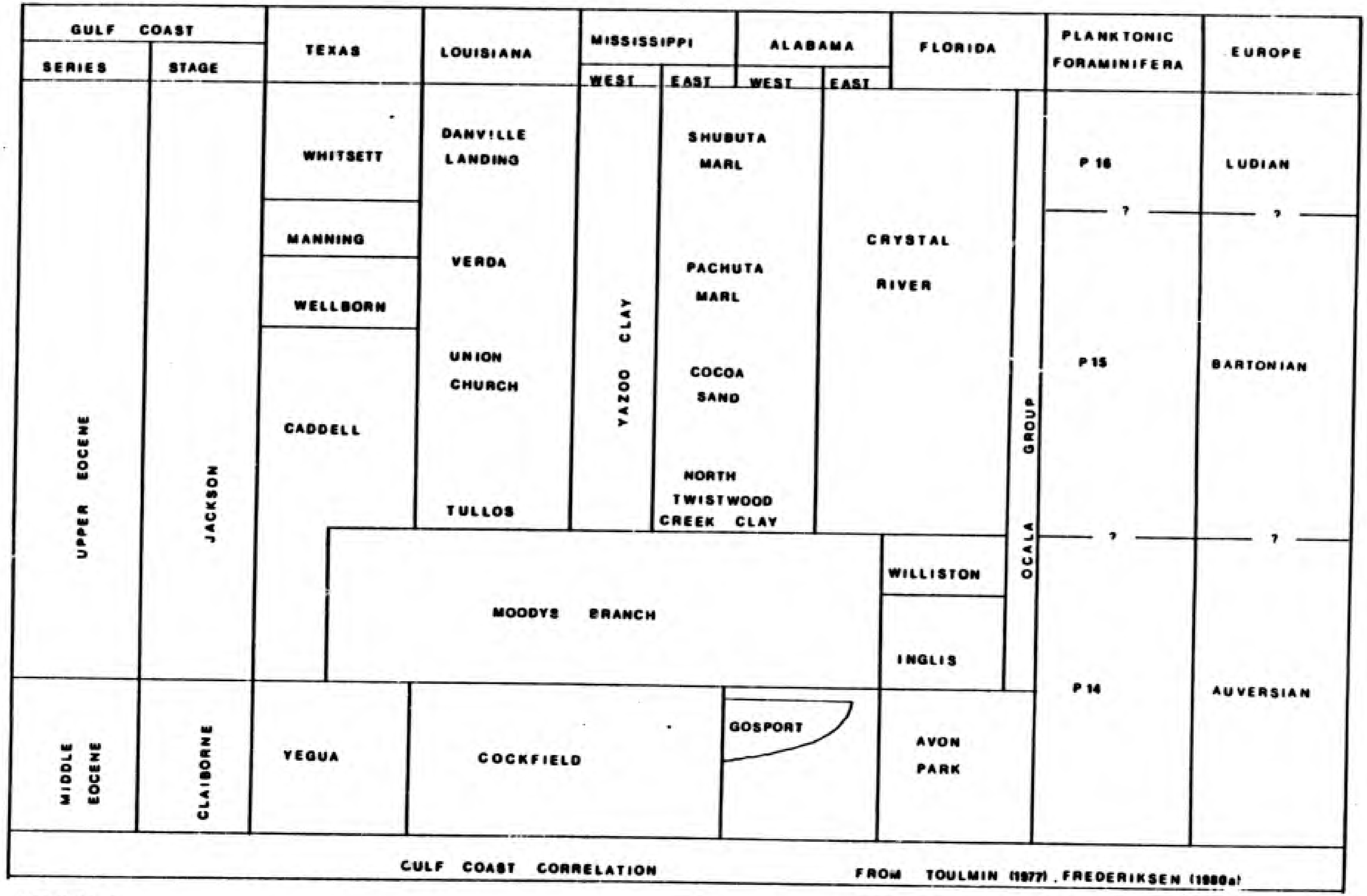
Cockfield Formation

Upper Claibornian deposition in the Gulf Coast was dominated by delta systems (Fig. 4, 5) and is characterized by chiefly non-marine to paralic sediments. The presence of elongate, high-constructive (fluvially influenced) deltas has been documented in eastern Texas (Fisher et al., 1969) and Mississippi (Dockery, 1976, 1977).

The complete sedimentary sequence deposited by a prograding delta into a marine basin is described by Miall (1979) and Dockery (1976). The initial deltaic sediments deposited over the fossiliferous marine sediments are the prodelta muds. As progradation continues, delta front silts and sands are deposited over the prodelta muds. These in turn are overlain by organic rich delta plain muds and sands.

As previously discussed, the Cockfield Formation at Montgomery Landing contains sands, silts, clays, and lignitic material. Fisk (1938) interpreted these sediments as having "been deposited at a position near sea level along a gradually subsiding coastal margin." In view of the above evidence, we believe they are deltaic plain deposits of a prograding upper Claibornian delta.

Naturally, the delta plain deposits of the Cockfield Formation at Montgomery Landing do not contain marine fossils. At several localities in Louisiana, however, a fossiliferous, glauconitic facies is developed in the upper Cockfield (Stenzel, 1939; Treadwell, 1954). Stenzel (1939) refers to this as the Creola Member, as he felt typical sediments of this type were well-exposed at Montgomery. These sediments could possibly represent either an interdeltaic or marginal marine facies deposited by a local advance of the sea upon abandonment of a distal deltaic lobe (Fisher et al., 1969). Although Stenzel (1939) named the Creola Member for Montgomery Landing, it must be emphasized that no trace of it was recognized in this study. As will be discussed, it is believed the Creola Member does not occur at Montgomery Landing, and that this stratigraphical term should be abandoned.



GULF COAST CORRELATION FROM TOULMIN (1977), FREDERIKSEN (1980a)

FIGURE 3

Moodys Branch Formation

If delta lobes are abandoned, the source of terrigenous material is removed, and progradation ceases. At this time, a delta enters the destructional phase which, in contrast to the constructional phase, is largely influenced by marine processes. Reworking and compaction of the deltaic sediments may allow marine transgressions to occur (Miall, 1977).

A modern example of this process is the St. Bernard delta of the Mississippi River, which Treadwell (1954) also used as an analog in his study of the Moodys Branch-Cockfield contact. The river has abandoned this delta lobe, thereby removing the sediment source and ending progradation. Marine processes then began an attack on the delta as it entered its destructional phase. A study of cores in this area revealed recent marginal marine deposits overlying deltaic organic silts and clays. Through this and other sedimentological observations, Treadwell (1954) believed the Moodys Branch-Cockfield transition represents a similar environment.

Paleontological evidence indicates the Claiborne-Jackson unconformity represents only a short time interval. As Treadwell (1954) reported, the microfauna (foraminifers and ostracodes) of the upper Claiborne are very similar to those of the Jackson. Frederiksen (1980) reached the same conclusion in his study of the sporomorphs and emphasized this point by stating "where the uppermost part of the Cockfield Formation contains marine interbeds, the megafaunas and microfaunas of these strata are distinctly Jackson and probably the only reason for any faunal change across the contact is the change of facies from brackish-water sediments below to normal marine strata above." Thus, paleontological evidence is compatible with the depositional model.

The Moodys Branch Formation constitutes a destructional shelf facies formed through reworking of the upper Claiborne deltaic sediments by marine processes. These sediments were deposited seaward of a retrograding shoreline in a shallow water, open marine environment (Dockery, 1976, 1977).

At Montgomery Landing, unquestionable marine sediments overlie unquestionable deltaic sediments. The transitional (marginal marine) environment appears to be missing. If the transgression had been rapid, the marginal marine environment would have been very short-lived and would have left little, if any, sedimentary record. The retrograding high-energy nearshore environment could easily rework such a deposit. Frederiksen (1980) believed that this is an example of Swift's (1968) ravinement process, as Swift stated that "in the ravinement process, the sea destroys part or all of its own marginal record." Frederiksen concluded "slightly deeper erosion probably accompanied the Moodys Branch transgression where marginal marine beds are lacking from the uppermost part of the Cockfield."

The basal Jacksonian transgression (Fig. 4) extended into northern Mississippi (Dockery, 1977) and southern Arkansas (Wilbert, 1953). These deposits are part of Dockery's (1977) northern terrigenous facies which is characteristic of a shallow water, near-shore, high energy environment. Montgomery Landing falls within Dockery's (1977) southern terrigenous facies. The nearshore environment is not preserved in these deposits as the sediments have been thoroughly reworked in the offshore environment by wave turbulence and burrowing organisms (Dockery, 1976, 1977).

Ophiomorpha, a fossil burrow, remains as an indicator of the near-shore environent (Plate 8). This burrow, thought to have been made by a callianassid shrimp-like animal, extends several feet down into the Cockfield Formation. Dockery (1976) stated that these burrows are common within shoreface environments. Weimer and Hoyt (1964) reported that the modern shrimp Callianassa major Say is confined to high-energy littoral and shallow neritic environments, as its burrows are restricted to the well-sorted sands of strongly wave-agitated waters.

All previous investigations indicate that the Moodys Branch was deposited in a shallow marine environment. Few studies, however, have attempted to assign absolute depths to the deposits. D. R. Andersen (1971) concluded that water depth ranged from sea level to about 60 feet. In a comprehensive study using many fossil forms, Breard (1978) concluded that sediments of the southern terrigenous facies were deposited in waters ranging from 30-60 feet deep.

In conclusion, then, the Moodys Branch Formation at Montgomery Landing, which is part of Dockery's (1977) southern terrigenous facies, represents shallow water sediments of a marine destructional shelf deposited seaward of a retrograding shoreline. Ophiomorpha burrows are remnants of the nearshore environment. The remaining sediments have been thoroughly reworked by wave agitation and burrowing organisms. Previous studies indicate these sediments were deposited at depths probably not greater than about 20 m.

Yazoo Clay Formation

The Yazoo Clay, like the Moodys Branch, was deposited in an open shelf environment. Most authors believe that the Yazoo Clay represents the deeper water, farther offshore facies of a normal marine transgression. Planktonic foraminifers, which are rare in the Moodys Branch, become fairly common in the Yazoo Clay.

Few studies have estimated water depths of Yazoo Clay deposition. Using both foraminiferal and ostracodal data, Huff (1970) estimated that the lower Yazoo Clays were deposited within the range of the mid-sublittoral to inner part of the outer sublittoral zone at depths of 20 - 100 meters. As reported by Huff (1970), Rainwater (1975) also suggested the depth range of middle to outer neritic. Breard (1978) concluded the Tullos member of the Yazoo Clay represents a gradually deepening sequence deposited in the middle neritic zone at depths of 20 - 100 meters.

According to Sen Gupta (1980, pers. comm.), the relationship between planktonic foraminifers and water depth is uncertain in Gulf Coast Eocene sediments. He states that an increase in planktonic species may be more indicative of greater distance from the shoreline than of a large increase in water depth. Fisk (1938) believed the Tullos Clay was deposited "in a shallow - water zone probably at considerable distance from the shore."

A prograding, constructional delta system was active at this time in eastern Texas (Fisher et al., 1970: Figs. 1-5). This delta system, known as the Fayette system, is the probable source of terrigenous material for the Tullos member. The Yazoo Clay in western Louisiana is chiefly non-marine clays with interbedded fossiliferous sands (H. V. Anderson, 1960).

As will be discussed more fully in the section on sedimentology, the limestone ledges in the Yazoo Clay at Montgomery represent a time of decreased terrigenous input and represent a calcareous, quiet-water facies. The cause for this decrease is unknown. Possibly the deltas briefly shifted further westward, or simply had periods of decreased output caused by changing continental climatic conditions. Possibly, a rise in sea level caused clastics to be trapped in estuaries (Givens, 1982, pers. comm.). Also, oceanic circulation may have changed during these periods and prevented deposition.

The Verda member of the Yazoo Clay, which is not present at Montgomery Landing, represents a series of nonmarine and paralic sediments reflecting close proximity to the deltas (Fisher et al., 1970). An eastward shift of deltaic depocenters left the Grant Parish area near the eastern margin of the delta where marine, brackish, and nonmarine processes were active (Fisk, 1938). Fisk (1938) stated that this was a rapid shift and left little transitional record. Breard (1978) agreed with this, stating that the Tullos member shows a gradual deepening and is a transgressional sequence throughout. He found no evidence of shallowing waters in the Tullos deposition caused by the eastward progradation of the Fayette delta system.

In conclusion, then, the Tullos member of the Yazoo Clay outcropping at Montgomery Landing was deposited in an open shelf environment in deeper waters and farther offshore than the Moodys Branch. Deposition occurred in the middle neritic zone in depths ranging from 20 - 100 meters. The source of terrigenous material was probably the Fayette delta system to the west. At times the influx of terrigenous material was greatly reduced, which allowed quiet-water, calcareous facies to develop. Although it is overlain by deltaic and paralic sediments deposited by an eastward-shifting delta, the Tullos member has been considered to be transgressional throughout by previous studies and to show no evidence of the encroaching delta.

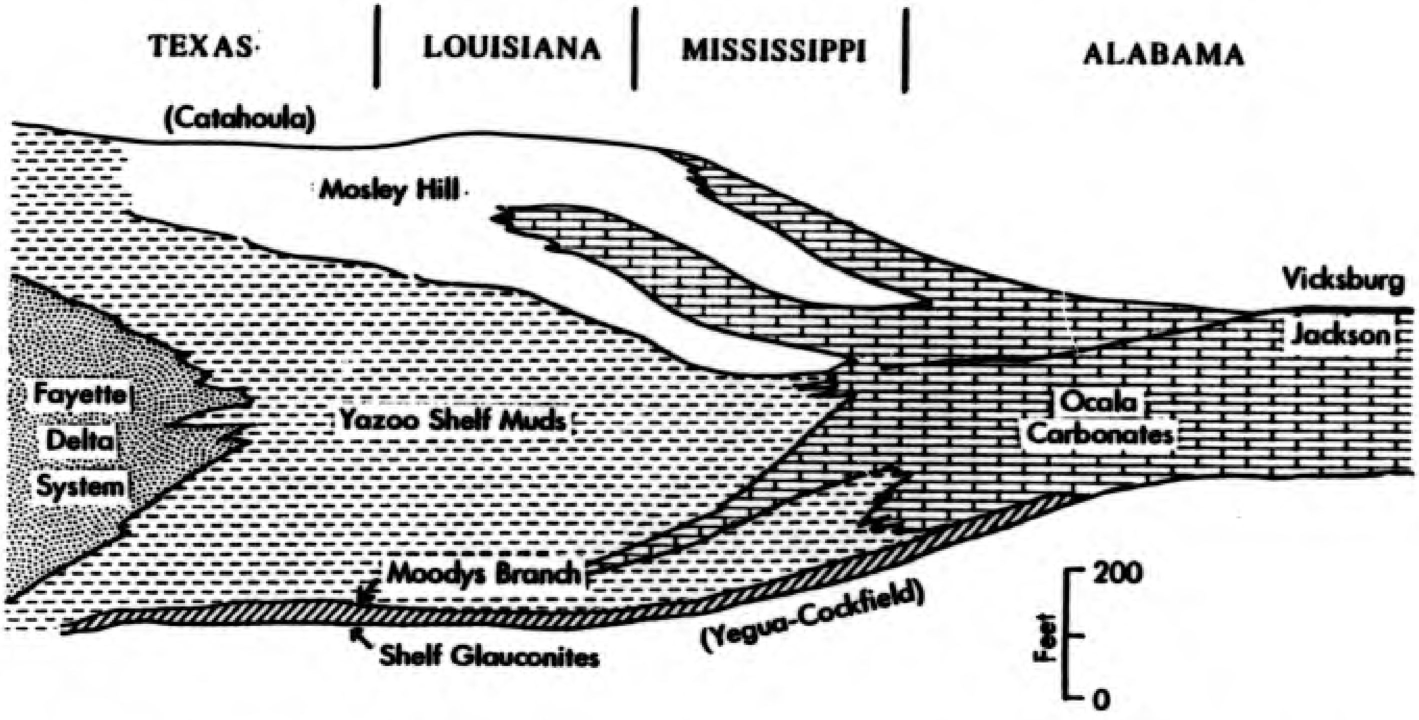


Fig. 4. Relationship of Fayette delta system to argillaceous and calcareous facies of the northern Gulf Basin, Jackson Group. From Fisher et al. (1970).

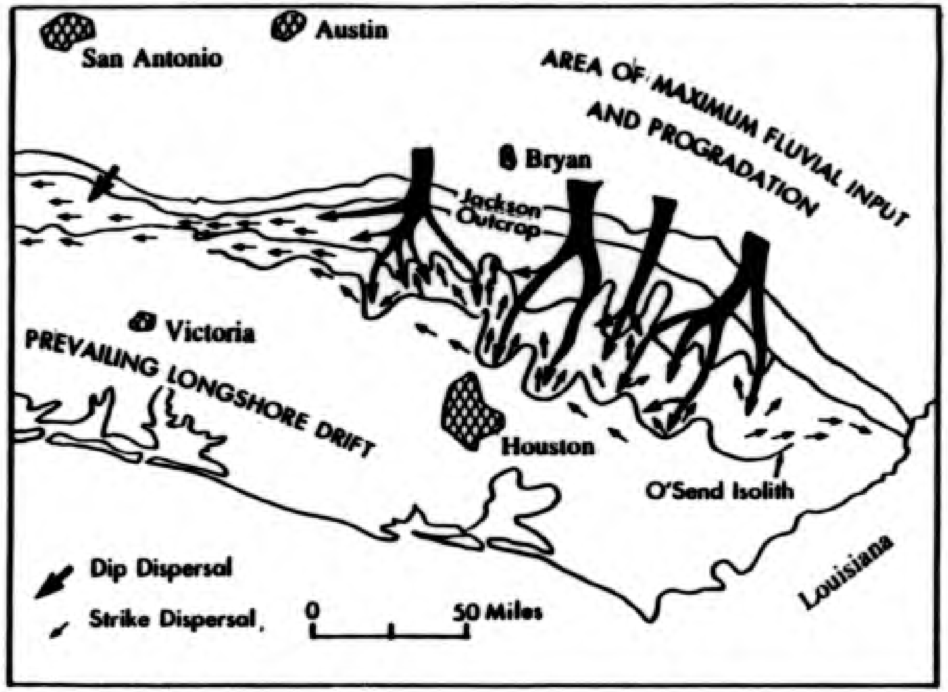


Fig. 5. Sediment dispersal pattern, Jackson Group, Texas. From Fisher et al. (1970).

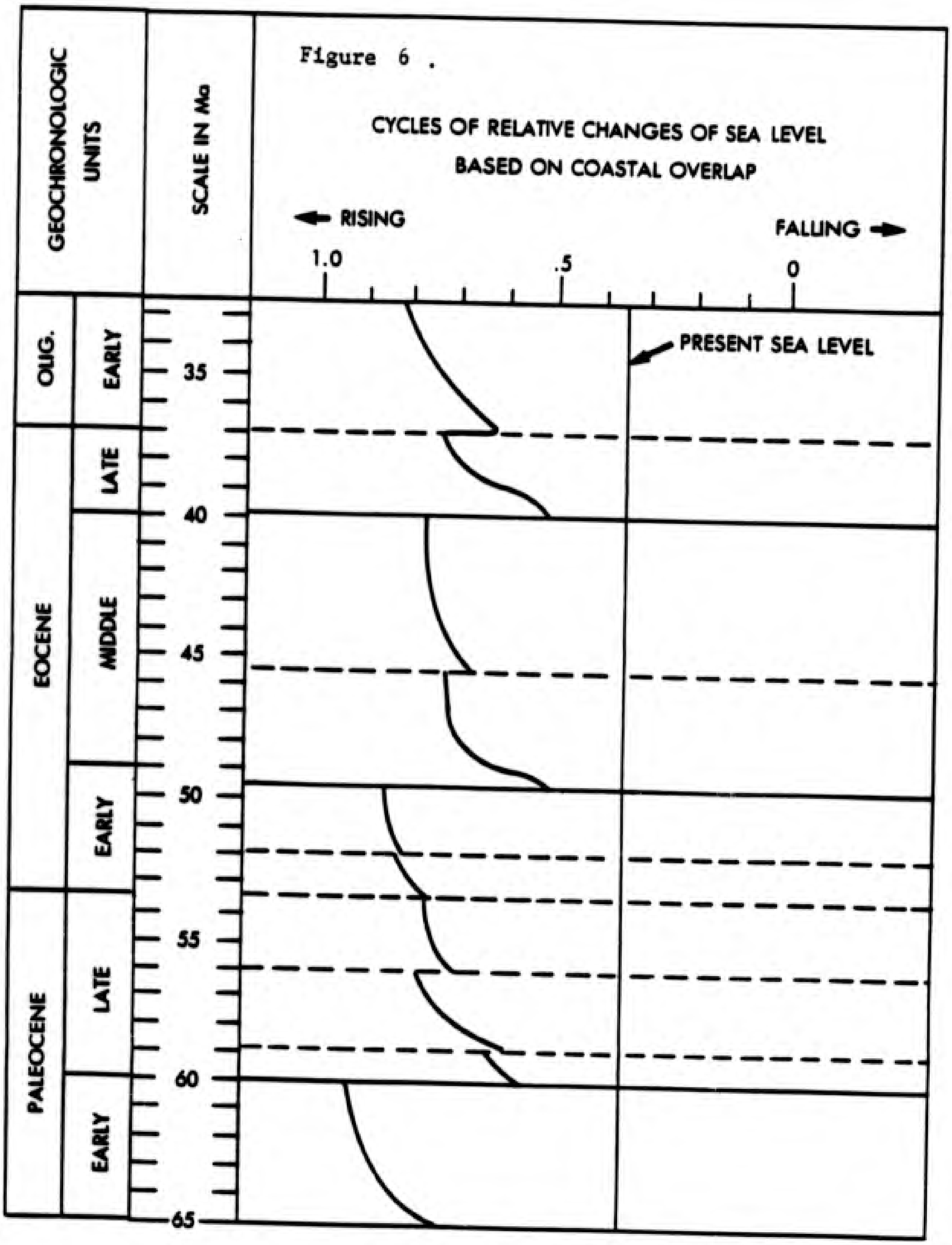


Figure 6 .

CYCLES OF RELATIVE CHANGES OF SEA LEVEL BASED ON COASTAL OVERLAP

After Vail and Mitchum (1979)

C. HISTORY OF THIS STUDY

In the fall of 1976, Dr. Judith Schiebout, a new faculty member of the LSU Department of Geology at Louisiana State University, took a group of student Geology Club members on a field trip which included the Montgomery Landing locality. Students expressed concern about the possibility of the Red River Waterway adversely affecting the site. Dr. Schiebout made inquiries of the Corps of Engineers, New Orleans District and discovered that others such as Dr. Leo Huff, former State Geologist, and LSU Department of Geology paleontologist, Dr. H. V. Andersen, had also made inquiries. All were reassured that the site was known and would be considered in surveys of the area to be impacted. The "Environmental analysis of the Red River Waterway, Louisiana, Texas, Arkansas, and Oklahoma (Design Memorandum 15 prepared by Gulf South Research Institute, Jan. 1975, for U. S. Army Engineer District, New Orleans)" did not list Montgomery Landing, however, increasing concern that it might be overlooked.

Dr. Schiebout contacted other scientists to learn how highly they ranked the site's scientific value and urging them to write the Corps of Engineers if they considered it to be of significance. She contacted all professional megafossil paleontologists in Louisiana and out-of-state workers with interests in the Gulf Coastal plain, such as Katherine Ann Palmer of the Paleontological Research Institution of Ithaca, New York.

When correspondence with Corps representatives indicated that the response of scientists on the locality's value had led them to consider seriously a proposal for a paleontologic survey there, Dr. Schiebout invited other LSU Department of Geology staff to participate, and Dr. Willem van den Bold joined the project, adding a needed dimension of microfossil expertise. A proposal was submitted in September of 1978, and, after negotiations and discussions in the spring and summer of 1979, field work began in August.

Several problems reared their heads early. In the original negotiations, field work was planned for the summer of 1979. The delay in awarding the contract brought the start of field work into conflict with university classes and near the late fall water rise in the Red River. The number of trips needed to accomplish the field work increased because the originally-planned long summer trip was impossible. Conditions vary from year to year, but summer and early fall low water are the usual times of best access to the Montgomery Landing fossil locality. In late fall or early winter the Red River rises, and it is no longer possible to sample the lower parts of the section until summer. LSU accepted the responsibility of obtaining landowner permission to work at the sites. Permission to work on the land was forthcoming from Mrs. Marsha Harrison, who owns the northern part of the site, and from Colfax Banking Company, which owns the south end of the outcrop. The central area is owned by the town of Montgomery and administered by the Cemetery Committee, which oversees Creola Cemetery on the bluff above the site. This section remains inaccessible to scientists to this day. Fear of erosion caused by sampling and its possible effect on the cemetery was the reason given by the town council for refusal to permit sampling, although at the time of their vote, winter, 1979, it could be seen that our sampling at other parts of the locality did not even leave changes visible after a few rains. The only excavation made in this project which had a lasting effect was that of the whale Basilosaurus. Fortunately, at the time of that excavation, Corps of Engineers work had begun at Montgomery Landing and the Corps had right-of-way access to the whale site. Later statistical analysis of the fossils proved that lateral variation at the location was not significant, so that the main result of the prohibition of research on town land was initial delay of work. The attitude of the townsfolk of Montgomery has a major bearing on final recommendations of this study, however (Chapter 6).

A brief listing of highlights of the work follows:

Fall 1979

Field work commences and ten sections are measured by the end of October. Access negotiations continue throughout fall with the Cemetery Committee. Washing and sorting of fossil samples begins. Four graduate students, Kevin Kilmartin, Thomas Klumpp, Winston Lancaster, and Woodson Godfrey join the project with the intent of producing masters' theses from their portions of the research. Peel methods are attempted and fail, as does pipette analysis of grain size. The high percent of calcium carbonate prevents penetration of peel mixtures and prevents disaggregation to a true sedimentary particle size. More thin sections are made, with Corps permission, to compensate for the lack of peels. In December, Winston Lancaster, Robert Guidry, and Bill Chauvin collected at the Basilosaurus site, finding four cervical vertebrae in a row. This find raises the possibility that the whale skull will be discovered.

Spring 1980

Washing and picking of samples are concentrated in this period. The Corps suggests that the principal investigators not respond to the Montgomery Town Council's refusal to allow us to work on town land. We cease efforts to communicate with council members. Herbert Martin joins the project, working on corals and bryozoa as his thesis research. Eleven samples are processed for pollen. Fish, shark, and otolith identification begins.

Schiebout and student workers travel to the Smithsonian for comparison of specimens and exchange of information. Dr. Alan Cheetham (Bryozoa), Dr. E. Fordyce (Cetacea), Dr. Robert Purdy (fish and sharks), and Dr. Earle Kauffman (mollusks) are especially helpful. Joe Boudreaux of Texaco, Inc., in New Orleans begins analysis of calcareous nannofossils. At the end of the spring semester, 80% of the mounted ostracodes are identified and Tom Klumpp has determined that most bivalve molluska are not juveniles, but are small species. A proposal for the salvage of the Basilosaurus, now clearly a major undertaking, is presented to the Corps of Engineers.

Summer, 1980

Statistical data on bivalve distribution is prepared for computer analysis. Writing up of ostracod results begins. Washing and picking of foraminifera, corals, and bryozoa continues. Negotiation of a modification to the contract to provide more funding for the excavation and preservation of the whale is completed.

Fall, 1980

The whale skull is excavated after a viewing of the skull in place by members of the broadcast media. The event is reported in newspapers across the U. S. and even reaches the Peking TV news. The first Masters thesis to be completed under the contract, that of Kevin Kilmartin on ostracodes, is completed and defended successfully. Preliminary faunal lists for mollusks, corals, bryozoa, arthropods, vertebrates, and foraminifera are complete. Thin section study by Jill Hartnell is completed. Janet Dyson joins the project to work for her masters thesis on gastropod ecology.

Spring 1981

Whale preparation is in full swing as is statistical work on bivalves. The principal investigators analyse the project to date and decide that the addition of the whale necessitates a longer working period.

Summer 1981 and Fall 1981

Data gathering and writing continues. Janet Dyson withdraws from work on the gastropods. They are given instead to Dr. Ray Givens of Nichols State in Thibodeaux, who is an expert on gastropods and is willing to work without pay. Thomas Klumpp successfully defends his thesis work on bivalves. Gathering of data from the several project lines continue. In fall, Schiebout becomes ill and is placed on half leave, but her supervision of students continues. Typing of results for the word processor occupies the holidays.

Spring 1982

Writing and compiling of data continue apace. Gastropod, foraminifera, and otolith data must be incorporated at this stage, as they have taken longer than other lines of inquiry.

Table 1. U.S.G.S. locality collections housed at the Smithsonian from Montgomery Landing and nearby localities.

2003	Montgomery Landing	L. C. Johnson	---
2638	Montgomery Landing	T. W. Vaughan	1894
4270	Montgomery Landing	T. W. Vaughan	1900
2005	Saline Bayou	L. C. Johnson	---
2916	Saline Bayou	T. W. Vaughan	1894
2919	Saline Bayou	T. W. Vaughan	1894
4272	Saline Bayou	T. W. Vaughan	1900
4271	Bell's Landing	T. W. Vaughan	1900

Fig. 2-1 Bell Bluff fossil locality on the east bank of the Red River, 6.4 kilometers S40 E of Montgomery Landing.

Fig. 2-2 Saline Bayou fossil locality, 12.8 kilometers N30 W of Montgomery Landing.

PLATE 2

Chapter 2. FIELD SAMPLING AND LABORATORY PROCEDURES

A. FIELD PROCEDURES, SECTION SAMPLING

Sample collecting along sections at Montgomery Landing took place during August and September, 1979. Sites for taking stratigraphic sections were chosen by examining the stratigraphic interval exposed at various sites along the outcrop so that, when sections were combined, a complete composite section could be constructed. Also, the varying amounts of stratigraphic overlap inherent in this method allowed for studies of lateral variation.

To picture how the environment at Montgomery Landing has changed through time, ten sections were measured from near the level of the Red River to the base of overlying Pleistocene deposits. An approximately 10 kilogram sample for microfossil analysis and one for megafossil analysis was taken every thirty centimeters (Plate 4). Each section began as a trench one meter wide, dug down around 15 cm in order to obtain fresh, unweathered material (Plate 3). Section lengths ranged from 1 to 6 meters. Samples needed to be closely spaced vertically, yet far enough apart so that they did not overlap, as looking at variation of the site through time was a prime objective. Some samples were taken within the sampling interval in order to examine unusual fossils or lithology. The exact point of each sample in a trench was selected by measuring 30 cm vertically with a meter stick and level from a previous site and then establishing a horizontal line with the level (Plate 3). Where this line intersected the surface of the bluff exposed in the trench was the next sample site. The point for the first sample in any section was chosen at the lowest exposed point close to the river.

Because the outcrop dips 10° degrees to the south, each formation at Montgomery Landing is not exposed to the same extent. Horizontal spacing of the trenches (referred to as sections in subsequent discussions) was made to get adequate sampling from the formations and to avoid small faults in the outcrop. Figure 7 shows the location of the sections. Nineteen samples were taken from the Cockfield Formation, 12 from the Moodys Branch Formation, and 107 from the Yazoo Formation. Samples were identified by both their section and number designations. For example, S3N12 would be the sample taken at the section three, number twelve locality.

B. FIELD PROCEDURES, EXCAVATION OF MONTGOMERY LANDING BASILOSAURUS COLLECTION HISTORY AND TECHNIQUES

The collection of the Montgomery Landing *Basilosaurus* began on 21 August 1979, and was completed in six field excursions. The site is located approximately 25 m north of the mouth of Dyson Creek and 8 m south of section six (Fig. 7). Stratigraphically, the site is at the

Fig. 3-1. Student Thomas Klumpp (l) and Curator Alvin Phillips (r) stand on limestone ledges 2 and 3 (the double ledge) on a small horst. Dark area near Klumpp is scree from section cleaning.

Fig. 3-2. Dr. van den Bold sights the 30 cm distance for a sample while Dr. Schiebout watches.

PLATE 3

Fig 4-1. Curator Alvin Phillips and Dr. van den Bold collect the megafossil sample 17 on section 5. Next they collect a microfossil sample at the same level.

Fig. 4-2. Students Thomas Klumpp(l) and Richard Teague(r) work a rope and pulley system hauling a burlap bag of samples up the bluff.

PLATE 4

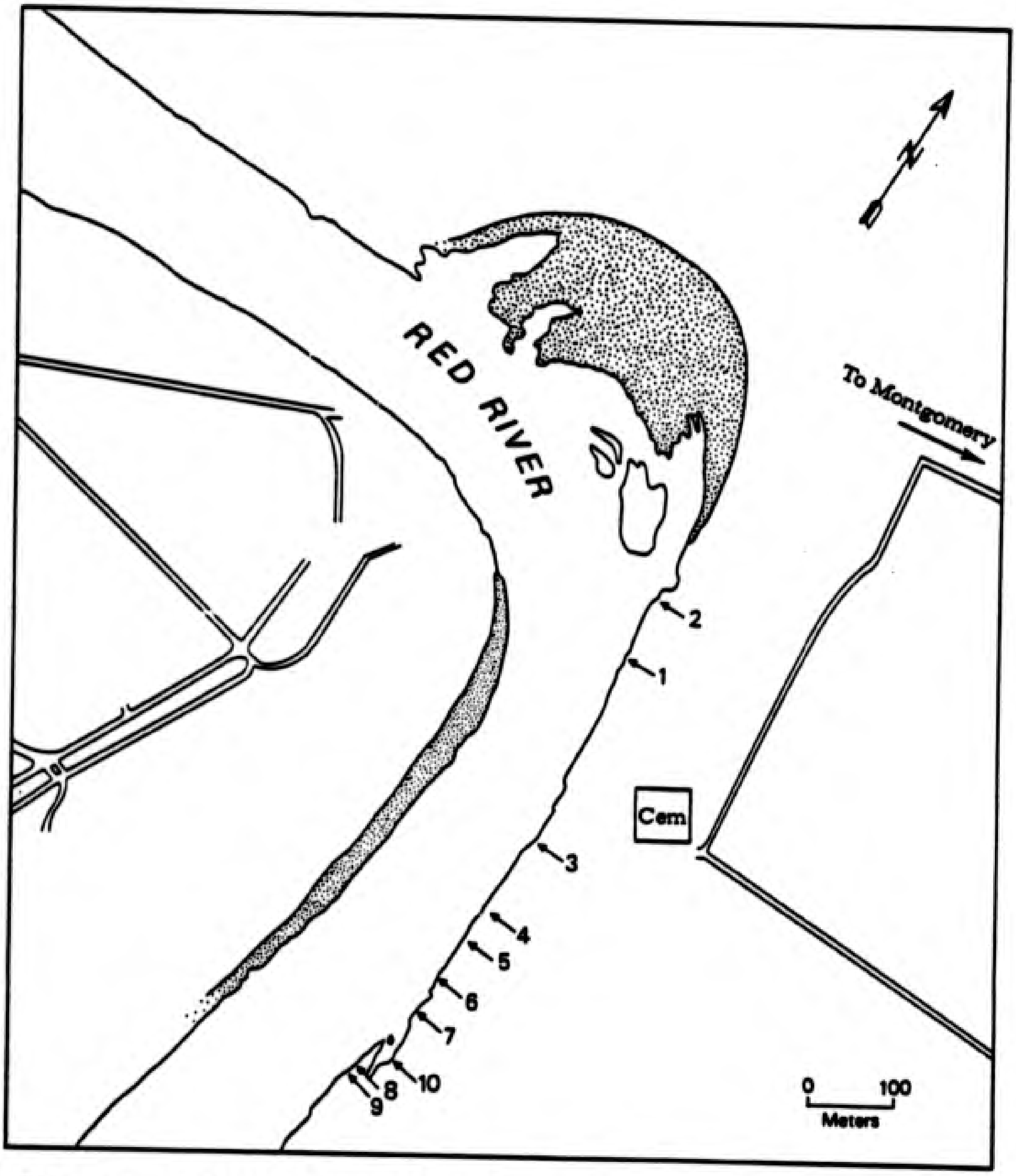


Figure 7 Location of stratigraphic sections sampled in this study.

level of sample 6-11, approximately 2.5 m below the uppermost (double) limestone ledge (Plate 7).

The first excavation removed one thoracic vertebra and ten ribs (Plate 5). The second excavation (1-2 September 1979) removed three vertebrae and ten ribs. The weekend of 17-19 November 1979, two thoracic vertebrae, numerous ribs, and the proximal end of the left radius were removed. Four articulated thoracic vertebrae, several ribs, and a sternal element were excavated from 13-14 December 1979. Also found on this trip was the proximal end of the left humerus, but this bone was not removed. The fifth, and most extensive excavation was made from 30 July to 6 August 1980. At this time the following bones were removed: 4 vertebrae, 2 humeri, 2 ribs, one scapula, and the skull. (Plates 5, 6) A trip made on 4-5 October 1980, to collect samples for paleomagnetic analysis led to the discovery of both mandibles, one metacarpal, the left scapula, and one ulna. These bones were removed on the final excavation made 18-19 October 1980. At this time it was believed that all the material that could be practically removed had been found, and the excavation was discontinued

The general collection methods varied depending on the condition and type of bones. Ribs were usually in good condition with clean breaks. These were removed, wrapped in paper, and labeled. Larger, more delicate bones were covered with paper and aluminum foil before being covered with plaster of Paris bandages, according to the procedure described by Hotton (1965). The positions of the bones were plotted in order to study the spatial arrangement.

C. LABORATORY PROCEDURES, MICROFOSSILS

Microfossils in general

The laboratory procedure began with removing approximately 2 kg. of sample from a bag and placing it in a copper bowl. The sample was then oven dried at 100°F for at least 24 hours. The dry weight of the sample was then determined. The sample was disaggregated by soaking in water for a variable length of time dependent on the ease with which it broke down. Many samples, especially those of the Yazoo Formation, required the addition of sodium bicarbonate ($NaHCO_3$) to completely disaggregate the clay.

Ostracodes

The sample material was then washed over a sieve with a 200-mesh screen. The screen was stained with methylene-blue before each washing for the identification of contaminant material. Most samples were thoroughly cleaned on their first washing, although some required redrying and/or resoaking in water and sodium bicarbonate before all the

Fig. 5-1. Basilosaurus rib in place at Basilosaurus site, August, 1979 reconnaissance.

Fig. 5-2. Clearing overburden from the Basilosaurus site as work progresses back into the cliff.

PLATE 5

Fig. 6-1. Cervical vertebrae in a row suggest that the skull could be near.

Fig. 6-2. Dr. van den Bold (l) and Corps of Engineers representative Rader (r) examine the skull in place.

PLATE 6

Fig. 7-1. Winston Lancaster's camp at the whale skull. He stayed with the skull a week until media viewing of the skull was over to protect it from vandals.

Fig. 7-2. The Basilosaurus site and view south showing revetment construction in the area of sections 9 and 10.

PLATE 7

< 200 - mesh material could be removed. The washed residue for each sample was placed in a copper bowl and oven dried at 100°F for at least 24 hours. This material was weighed, and the percent "coarse" material (or greater than 200 - mesh) for each sample was determined. The material was then placed in clean, labeled, Whirl-Pak storage bags.

Because the above procedure yielded a large amount of washed material, it was necessary to obtain subsamples of each sample. To do this, a small amount of sediment was scooped out of the washed sample material with a small plastic spoon. In some samples containing a relatively sparse fauna, it was necessary to remove up to three scoops of sediment. The weight of the subsample was determined to the nearest 0.1 g., and the sediment was placed in a clean, labeled, plastic vial.

The samples were picked for ostracodes by K. Kilmartin and three other student workers. Each sample to be picked was separated into five size classes through sieving to facilitate the picking procedure (the sieve sizes used were 20, 40, 60, and 80 mesh, and the pan). Each size fraction was picked of all ostracodes with a standard lined picking tray and an artist's (00) brush, and the specimens were placed in clean, labeled, micropaleontological slides. Upon completion of a sample, the picked ostracodes were transfered to a 60 - square micropaleontological slide covered with gum tragacanth, where the specimens were separated by species and glued down.

Because each sample was picked of all ostracodes, the picking procedure of the different workers should not be a factor. The workers were all given the same sample (S4N01) to pick, with the results checked statistically by a chi-square test. The test could not reject (at the 95% confidence level) the null hypothesis that the four distributions were the same (Table 2). In fact, the variance that was found is not all attributable to the picking procedure. Some indeterminable amount of it must be due to the variance inherent in any subsampling procedure.

The ostracode species occurrence data for each sample were recorded in absolute (number of specimens), normalized absolute (number of specimens per gram), and relative proportion form. Statistical analyses of the data were computed on an IBM 3033 computer.

Photomicrographs of ostracode specimens were taken with Kodak Tri-X Ortho film on Hitachi S-500 and Jeol JSM-2 scanning electron microscopes. Specimens were mounted on an aluminum stub covered with a layer of double-stick tape, then coated with 200 A of gold by a sputter coater. Thin-section photomicrographs were taken with Kodak Kodachrome film on a Nikon petrographic microscope.

Table 2. Chi-square analysis of variance between pickers.

SPECIES			**PICKER**		
	SL	**KK**	**BP**	**BR**	
EJAK	3.2	6.3	7.5	7.3	24.3
	5.2	5.4	7.1	6.7	
	.77	.15	.02	.05	
LCON	4.1	7.1	6.0	4.7	21.9
	4.7	4.9	6.4	6.0	
	.08	.99	.03	.28	
BSHU	9.1	12.7	16.5	14.0	52.3
	11.2	11.6	15.2	14.3	
	.39	.10	.11	.01	
HDOM	11.4	5.5	12.0	11.3	0.2
	8.6	8.9	11.7	11.0	
	.91	1.30	.01	.01	
CJAK	4.1	3.7	4.0	5.3	17.1
	3.6	3.8	5.0	4.7	
	.07	.00	.20	.08	
HMON	43.6	42.4	52.0	59.3	197.3
	42.1	43.8	57.3	54.1	
	.05	.04	.49	.50	
CPTM	5.9	7.6	13.5	10.7	37.7
	8.0	8.4	11.0	10.3	
	.55	.08	.57	.02	
CSPP	8.2	11.8	14.0	16.0	50.0
	10.7	11.1	14.5	13.7	
	.58	.04	.02	.39	
HFLO	5.5	7.8	14.0	7.3	3.6
	7.4	7.7	10.1	9.5	
	.49	.00	1.51	.51	
OTHERS	20.0	14.8	17.5	12.0	64.3
	13.7	14.3	18.7	17.6	
	2.90	.02	.08	1.78	
	115.2	119.8	157.0	148.2	540.2

SUM OF $(O-E)^2/E$ = 16.18
DF=(r-1)(c-1)=(9)(3)27
CHISQUARE with 27df and P=.05 = 49.6
DECISION: ACCEPT THE NULL HYPOTHESIS THAT THE DISTRIBUTIONS ARE THE SAME
OTHERS = LCRE+XSAR+PLIN+PFNQ+CYDM+ELOW+OBRD+CPCV+CINS+DRUS+TMON+AGIB +OCLD+APUR+BWAT+TGIB+BSMT+ASUB+LJCK+ESPA+?OCUL

Foraminiferida

Sections #1, #3, #4, and #9 were chosen for examination. Intervals between samples used were based upon the continuity of lithology; where rapid changes occurred, samples are tightly clustered.

About 250 grams of sediment were taken from each of the study samples and weighed to the nearest 0.1g. of a gram. The weighed samples were placed in as oven set at 85°F and allowed to dry for a minimum of 24 hours. Dry sample weights were recorded and the samples returned to the oven for another 24 hours immersed in water saturated with $NaHCO_3$. Virtually all samples were disaggregated without further treatment.

The disaggregated samples were washed over a #230 mesh screen, which retains particles greater in size than the 63 micron mesh opening. Between the sample washes, the screens were stained with methylene-blue to detect carbonate contaminants. After screening, the wash residues were redried and the weights recorded. Washed residues were stored in labeled plastic sample bags.

Prior to picking, the wash residues were fractioned by microsplitter. At the point when a fraction or "split" of wash residue represented only enough material to cover the surface of a picking pan, an estimate of the number of the benthic foraminiferida was made against a gridded surface to estimate which fraction or "split" would yield approximately 300 (250-350) specimens.

Once the fraction of the wash residue required to yield approximately 300 specimens (benthic foraminiferida) was determined, this fraction was picked of all benthic and planktonic foraminiferida using standard methods and equipment.

All specimens were placed on labeled, 60-square micropaleontology slides which had been previously covered with gum tragacanth. Specimens were sorted by species on these same slides.

Such statistical tests for variance as the chi-square test were deemed unnecessary as each operation in the handling of specimens (picking, sorting, etc.) was performed by one individual. Thus, any variance encountered between samples should not be attributable to variance in picking or other handling procedures.

Occurrence data for the species of foraminiferida encountered was recorded as follows:

1) number of specimens
2) normalized percentages of the residue fraction
3) estimated number of specimens per gram of unwashed sample.

All figured species were sputter-coated with 200A of gold-paladium and electron-micrographed with a Hitachi S-500 scanning electron microscope on Tri-X Ortho Sheet Film.

D. LABORATORY PROCEDURES, MACROFOSSILS

For section samples approximately 1.5 kg of material were taken from each sample. The material was dried thoroughly and weighed to obtain the dry weight. It was then soaked in $NaHCO_3$ to break it down into separate grains. Samples where this was difficult were processed in the ultra-sonic. Washing was done through a 200 mesh screen until only coarser material remained. This coarse-grained residue was dried and weighed. Before examination, the samples were put through a 40 mesh sieve. This sieve size allowed residual mineral grains and many microfossils to pass through, but trapped the macrofossil shell material.

Molluska

One hundred thirty-eight samples were prepared and examined under the microscope for bivalves. A specimen was picked and counted if at least half the shell was present with the hinge area intact and if it could be positively identified. Only shells with the hinge present were picked in order to avoid picking and counting different parts of a single shell, that is, to avoid over-counting the number of individuals of a given species present in a sample. Also, the hinge area is important for identification.

Dryden (1931), working with heavy mineral frequencies, showed that accuracy rises very slowly by counting more than three hundred grains. Kafescioglu (1975) showed that this concept also applied to foraminifera. These studies demonstrated that counting past 300 points does very little to increase statistical accuracy. To test procedure as far as bivalves at Montgomery Landing are concerned, three samples were selected for their diversity of species and numerical abundance. (Fig. 8, 9, 10). Figure 8 shows that five species were found in the first 100 specimens, no additional species in the second 100. One new species was found in the third 100 specimens and then no additional new species were found. Figure 9 shows that eight species were found in the first 100 specimens, and no additional species were found. Figure 10 shows six species in the first 100 specimens and no additional species in each successive one hundred specimens counted. These graphs show that this concept is valid for bivalves as well as for microfossils and thin section sedimentological analysis. Even though counting just one hundred valves could probably be considered statistically accurate in this case, the accepted standard of three hundred was followed.

Each sample was picked of every valve that met the established criteria. For specimens that were still articulated, each valve was counted separately. In those samples where there was a very large number of specimens, the sample was randomly split to where there were at least 300 specimens. The number of times a sample had to be split depended on the amount of bivalve material present. Two samples were split by one-half, five by one-fourth, eight by one-eighth and three by one-sixteenth. The rest were unsplit.

E. VERTEBRATE PREPARATION TECHNIQUES

Preparation consisted mainly of cleaning the bones of adhering sediments and repairing breakage. The sediment usually flaked off the surface of the bone easily, and only rarely was it necessary to scrape the surface of the bone. Portions of the bones that were hard enough were washed with soap and water, using a soft brush or sponge. Softer areas were cleaned with hydrogen peroxide, usually without brushing.

Exposed internal bone was saturated with gelva solution (polyvinyl acetate dissolved in acetone) before gluing with commercially available household cements (methyl-ethyl ketone base - also soluble in acetone). Fragmentary areas were cleaned as well as possible without dislodging pieces and then saturated with gelva or glue thinned with acetone. Areas broken into large pieces were dismantled, cleaned, and reassembled. A hypodermic syringe was used to inject gelva into cracks if the interior bone was powdery and required stablization. This method was also used to inject glue if the pieces were loose but too complex or fragile to dismantle. After the interior of the bone was hardened, the surface was painted with a thin coat of gelva.

Some small cavities were filled with hard carbonate. When necessary, this was physically removed with a percussion or rotary tip bit on a dental drill. The majority of the preparation was done by Winston Lancaster with assistance from Robert Guidry, Jeffrey Helmers, Keith Welsh, and William Chauvin.

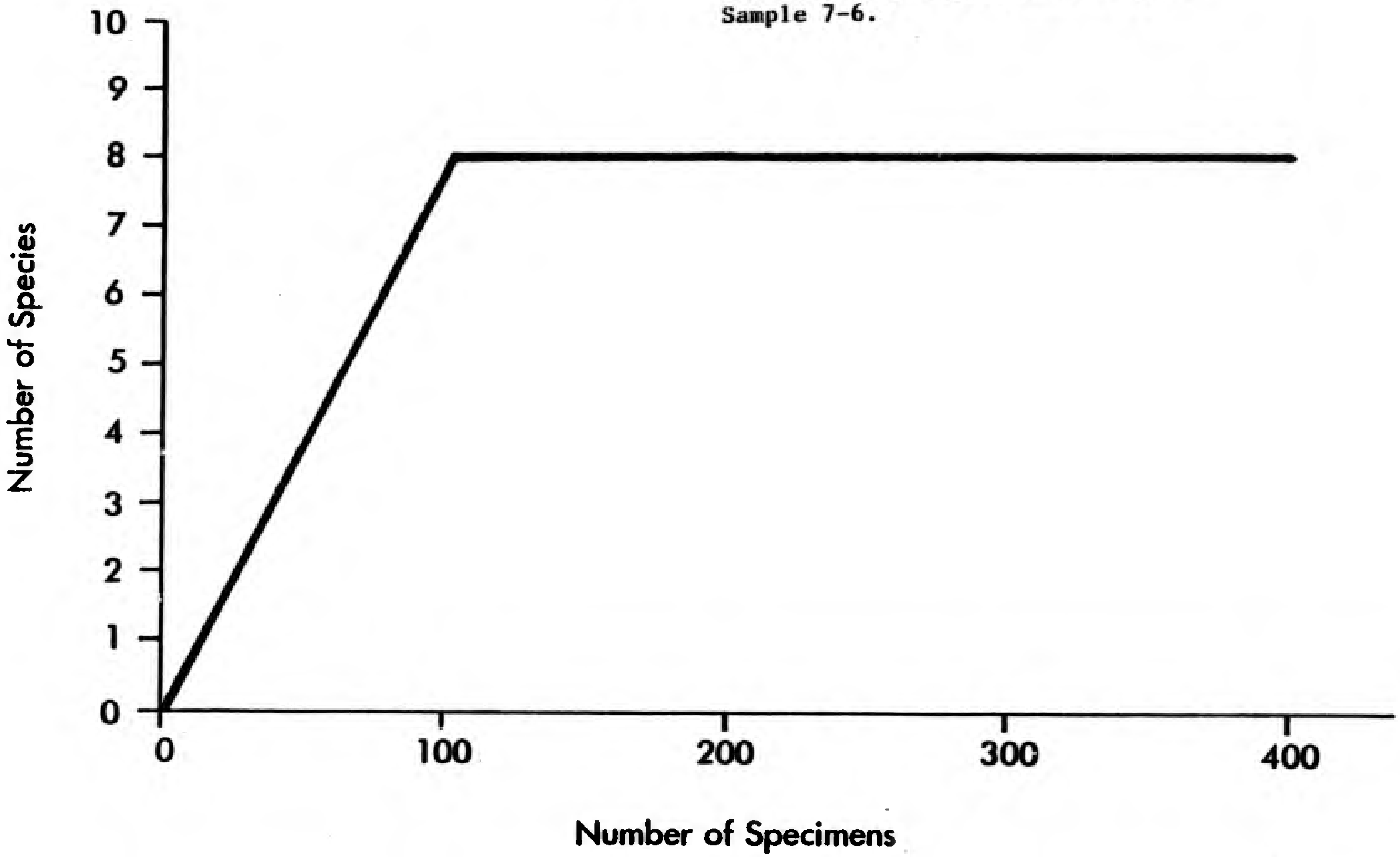
Sediment samples around the assemblage were collected to analyze the associated vertebrate and macroinvertebrate fauna. Sediment removed in the process of bone preparation was also examined for associated fauna.

The samples were treated with $NaHCO_3$ bicarbonate and disaggregated with a Branson model DHA-1000 ultrasonic cleaner. The treated samples were washed through a 40-mesh screen sieve and picked for all vertebrate remains (shark and fish teeth and scales, and otoliths) and macroinvertebrate fossils. The sediments from each major bone cast were treated and washed seperately in order that minor variation within the bone assemblage could be detected.

F. BULK WASHING

An industrial-ultrasonic machine (Bransonic) was used to disaggregate the clay matrix of Moody's Branch and Yazoo samples. About 4 inches of sample were placed into each of four wide-mouthed polyurethane jars. Water was added to each jar to within three inches of the top. The jars were then placed into the ultrasonic. Water was added to the ultrasonic to match the water level in the jars. Samples were run in the ultrasonic for approximately six hours.

Fig. 8. Test for number of specimens to have a statistically significant sample. Sample 7-6.



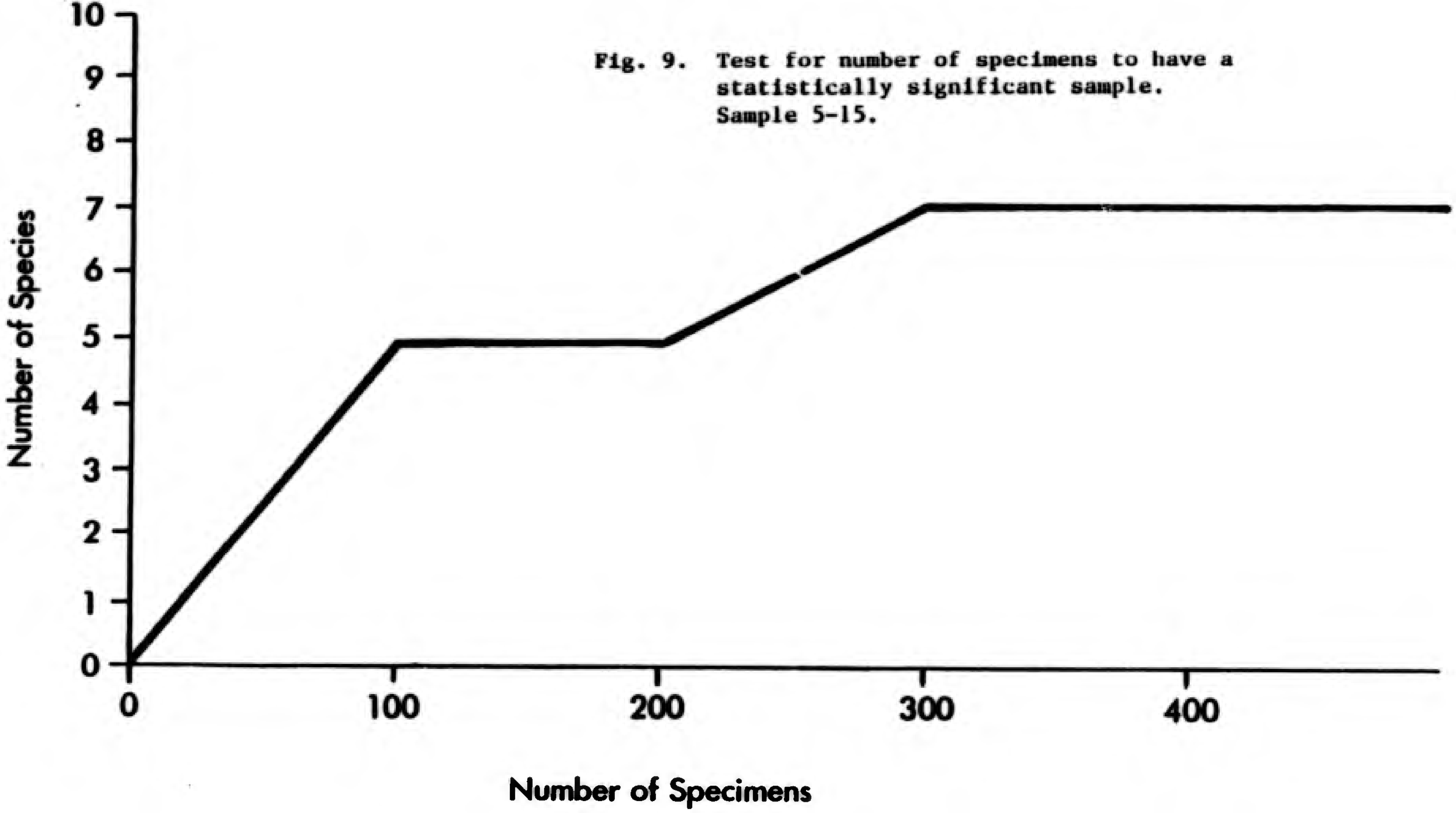
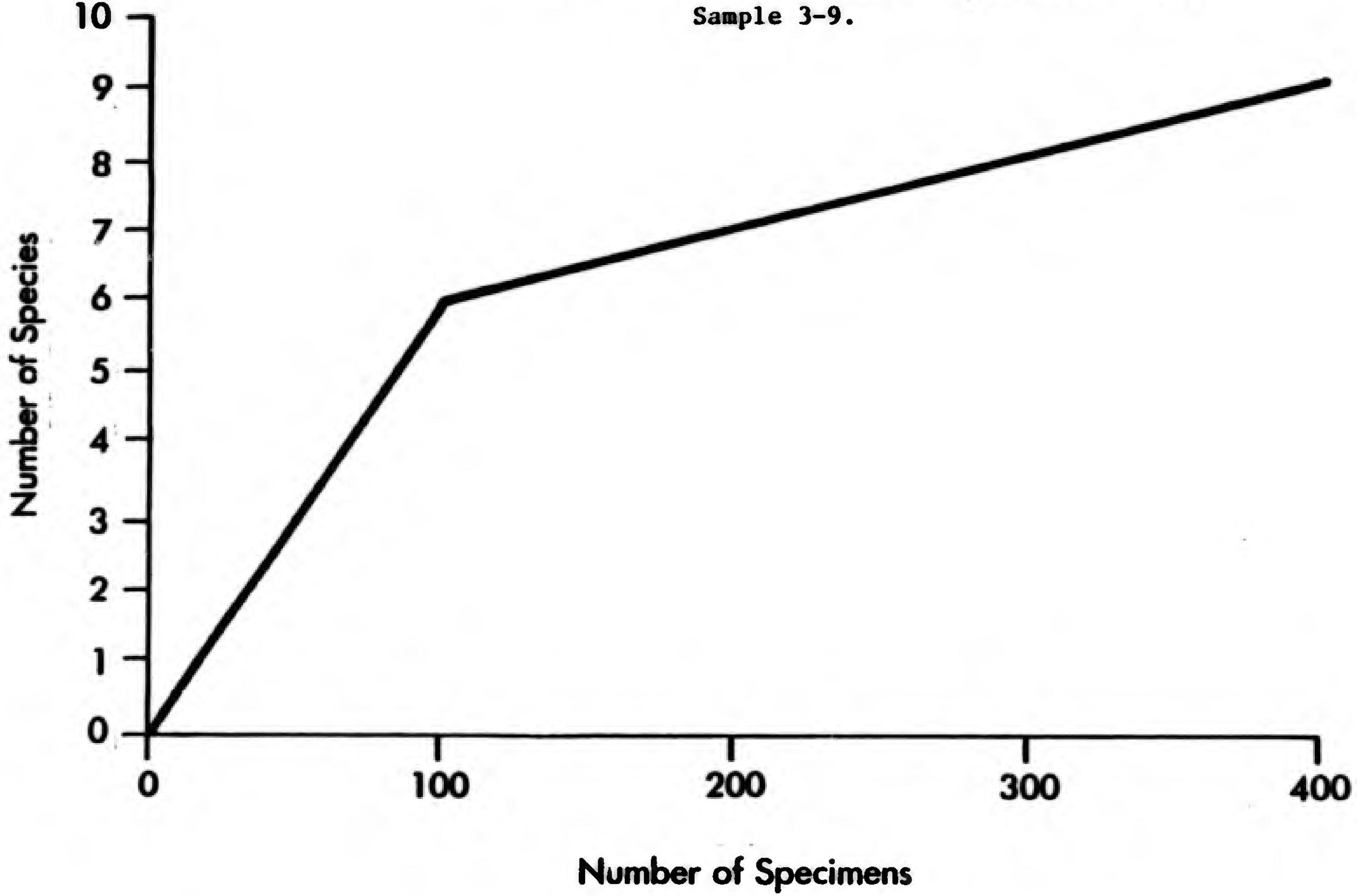


Fig. 9. Test for number of specimens to have a statistically significant sample. Sample 5-15.

Fig. 10. Test for number of specimens to have a statistically significant sample. Sample 3-9.



After breakdown of the matrix, the sample was washed through a 20-mesh sieve (20 wires to the inch). This size mesh was used instead of the more usual 18-mesh housing screen, to ensure retention of very small fossils on the screen. Once the sample had been washed clean of clay, it was oven dried, labeled and stored in large plastic bags for sorting.

3. SEDIMENTOLOGY

A. GEOGRAPHY

The transgression marking the beginning of the late Eocene covered the southern margin of North America. Most clastic sediments deposited during the Jacksonian Stage were provided by the Fayette delta system of eastern Texas, which is discussed in detail by Fisher et al. (1970). The sea floor was a broad, gently-sloping plain covered by relatively quiet waters. The latitude was about the same as at present, but the climate was probably warmer (Habicht, 1979).

Paleobotanical work done by Berry (1924) and Fredericksen (1980b) suggests that the prevailing climate of the late Eocene was winter-dry tropical to humid subtropical. Presence of *Nipa* (Palmaceae) pollen is indicative of a coastal environment free of killing frost (Fredericksen, 1980). Lagoons and estuaries were lined with *Rhizophora eocenica* (Eocene mangrove). Vegetation landward of mangrove thickets and along beaches was dominated by *Ficus*, *Mimosites*, and *Terminallia*, all indicative of a climate similar to the coasts of tropical America (Berry, 1924). Fredericksen (1980) suggests that the rainfall was greater than at present in the spring, summer, and fall, and substantially less than at present in the winter. Frakes and Kemp (1972) have postulated that monsoonal conditions prevailed during the late Eocene, with dry northwesterly trade winds in the winter and wet southeasterly monsoonal winds in the summer. They further postulate that the coastal waters were warmed by the Gulf Stream, which they feel existed at this time.

Jacksonian age outcrops of eastern Texas mark the westernmost extent of late Eocene seas. Jacksonian sediments of Texas, consisting primarily of lobate wedges of sand, mud, and lignite, were deposited in a wide delta which changed position through time, and fluctuated in the volume of sediment discharged (Fisher et al. 1970). Fisher et al. (1970) equate the Fayette delta to the present-day Mississippi delta (Fig. 4). This delta system is the probable source of clastics for the Yazoo Clay. To the east, these sediments grade into fossiliferous muds and marls in Louisiana and Mississippi, and into the fossiliferous limestones of the Ocala Group in Alabama, Georgia, and Florida. The lack of terrigenous material in the eastern (carbonate) facies is felt to be evidence that the southern Appalachians were lower than now, as they did not contribute a heavy sediment load to the upper Eocene seas of the Atlantic coastal plain (Fredericksen, 1980b). Figure 4 is a composite strike section illustrating the facies change in Jacksonian sediments from Texas to Florida.

B. DESCRIPTION OF SEDIMENTARY UNITS

Cockfield Formation

The Cockfield Formation (Yegua of many authors), is the lowest sedimentary unit exposed at Montgomery Landing. The water level of the Red River has a direct influence on the amount of sediment exposed. During annual spring high waters this formation is completely covered. The river level during sample collecting (late August through early September, 1979) was approximately at the 0 ft. stage as measured at Alexandria, Louisiana. This exposed the upper four meters of the formation for sampling.

The Cockfield Formation is typically a yellowish - gray (5Y7/2) to dark gray (N-3) mixture of clays, silts, and sands. The percentage of material retained by a 200-mesh sieve ranges from 2.3% (S2N02) to 61.6% (S2N12) and consists primarily of angular quartz grains, mica flakes, and lignite fragments. In fresh exposure the formation ranges from finely laminated to massive.

No calcareous macro- or microfossils are found within the Cockfield Formation. Organic remains such as lignitic material and leaf impressions are common. Palynological investigations have yielded fossil spores and dinoflagellates.

Ophiomorpha, which is a fossil burrow of a crustacean (Dockery, 1977), extends from the Cockfield - Moodys Branch contact downward through the upper two meters of the Cockfield Formation. The glauconitic, fossiliferous sand in these burrows both mineralogically and paleontologically identify it as Moodys Branch sediment that has filled in the burrows of a shrimp-like animal.

Cockfield - Moodys Branch Contact

The contact between the Cockfield and Moodys Branch formations is easily recognizable in the field and well exposed at Montgomery Landing. The contact is the sharp boundary between two very different lithologies - the unfossiliferous brown clays and silts of the Cockfield Formation and the very fossiliferous greenish-gray sands of the Moodys Branch. As previously discussed, Ophiomorpha burrows filled with Moodys Branch sediment extend below the contact into the Cockfield Formation (Plate 8).

Although its placement is fairly certain, the nature of the contact between the two formations has been the subject of some debate. All workers agree the contact is unconformable, but the magnitude of the unconformity is uncertain. Stenzel (1939) and Murray (1961) believed the contact marks a regional disconformity of possible long duration. Using both petrological and paleontological evidence, Treadwell (1954) concluded the break was of short duration, or diastemic. Frederikson (1980) utilized palynological evidence to conclude that "only a diastem or minor disconformity is present at the Claiborne - Jackson contact."

Moodys Branch Formation

The Moodys Branch Formation as exposed at Montgomery Landing is a massive, greenish - gray (5GY6/1), marly sand containing abundant glauconite, angular quartz grains, and a diverse macro- and microfossil assemblage. Foraminifers, ostracodes, pelecypods, gastropods, and corals are all abundant. The sediment is coarse at the base of the formation and fines gradually unwards.

Calcareous nodules are common in the basal Moodys Branch. Dockery (1977) believed these formed penecontemporaneously with early Moodys Branch deposition through the accretion of clay and sand about rolling masses of sediment.

Dockery (1977) divided the Moodys Branch Formation into northern and southern terrigenous facies on the basis of "fossil assemblages, sedimentary structures, lithology, and the thickness of the sedimentary sequence." The Montgomery Landing outcrop was placed in the southern terrigenous facies, which is characterized by a lower glauconitic sand and an upper glauconitic clayey sand, and a zone or reworking and burrowing into the Claiborne sediments.

The northern terrigenous facies, which is typical of the northern Mississippi and Arkansas outcrops, is characterized by a basal, sparsely fossiliferous clay which is overlain by coquina-like concentrations of *Glycymeris*, which in turn are overlain by beds containing abundant *Periarchus* (Dockery, 1977).

Moodys Branch - Yazoo Clay Contact

As it is throughout the Gulf Coast, the contact between the Moodys Branch and Yazoo Clay at Montgomery Landing is gradational (Plate 8).

Because of its nature, there has been uncertainty as to the placement of the contact. Fisk (1938) placed the contact at the uppermost level of glauconite occurrence, which he reported as seventeen feet above the base of the Moodys Branch. Subsequent analyses by many workers have shown that glauconite may occur, although rarely, much higher in the section. Therefore, the presence or absence of glauconite is not a useful criterion in defining the contact.

Stenzel (1939) placed the contact at the base of the lowest limestone ledge. Above this level the amount of glauconite in the sediment decreases sharply. The lithology also changes from a very glauconitic marly sand to a massive, blocky, bluish gray clay. The ledge is placed in the Yazoo Clay because it is lithologically similar to the ledges occurring in the upper Yazoo Clay section exposed at Montgomery Landing. Subsequent workers have followed Stenzel in their placement of the Moodys Branch - Yazoo Clay contact.

Yazoo Clay Formation

The uppermost unit exposed at Montgomery Landing is the Yazoo Clay, which throughout the exposed area constitutes the largest portion of the outcrop. The Yazoo Clay at Montgomery Landing occurs as two distinct lithologies. The most common form is a blocky, massive dark greenish - gray (5GY4/1) clay. Macrofauna fossils are not as abundant here as in the Moodys Branch. The microfaunas, particularly foraminifers and ostracodes, are abundant. These occur (1) distributed through-out the clay matrix, (2) concentrated in fossil-hash filled burrows, or (3) concentrated in bedding plane accumulations of fossiliferous material. Care was taken during field work to avoid sampling burrowed material.

Figure 8-1. View south along the Montgomery Landing outcrop. A cluster of students are standing on the Moodys Branch - Yazoo contact.

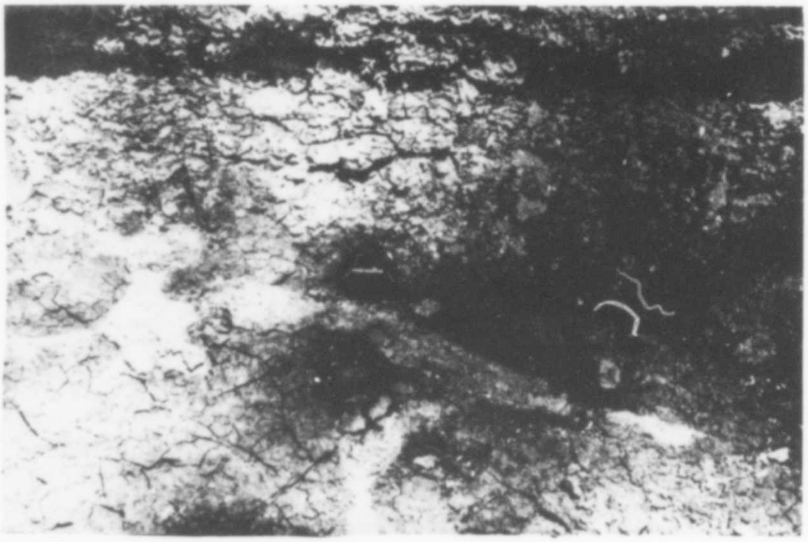
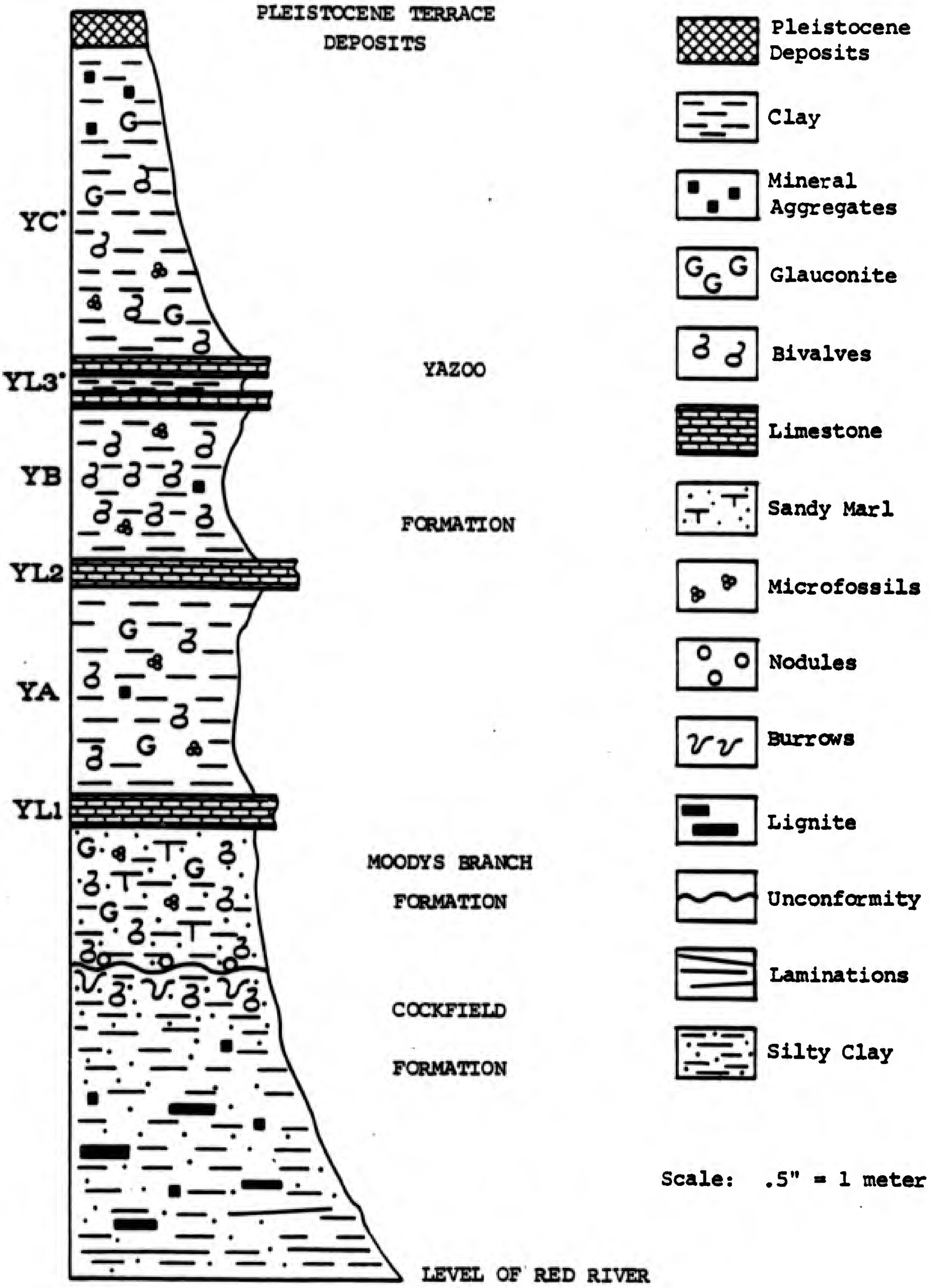


Figure 8-2. Burrows in the Cockfield which are filled with Moodys Branch sediment.

PLATE 8

Lithologic Section of Montgomery Landing
with Maximum Exposure of Each Unit



*Yazoo mudstone and limestone segments lettered and numbered for easy reference.

FIGURE 11

C. COMPOSITION, TEXTURE AND DIAGENESIS

The Cockfield Formation sediments are gray-brown to yellow-brown massive to finely laminated sands, silts, and clays. The Cockfield samples all contained abundant mica flakes and most contained fine grained, angular to subangular quartz grains. Mineralized lignitic fragments are abundant throughout the exposure, and fecal pellets are present in the upper portions, but are not common. Bivalve material is also found in the upper Cockfield but is probably carried down by burrowers from the overlying Moodys Branch Formation (Plate 8).

Along the zone of the Cockfield-Moodys Branch contact is a layer of phosphatic nodules. Nodules over an inch in diameter were found and many had shell material embedded in them. Dockery (1976) suggested that they were formed penecontemporaneously with deposition in the Lower Jackson. He said that they were probably formed by accretion of a rolling mass of clay and sand.

The Cockfield Formation has a higher percentage of coarse sediment (very fine sand or larger) than the Moodys Branch Formation or the Yazoo Formation. The sediment has a tendency to coarsen upward in the sections studied. There is 2 - 3% coarse sediment at the bottom which gradually increases to slightly more than 50% near the Cockfield-Moodys Branch contact.

The Moodys Branch Formation at Montgomery Landing is a highly fossiliferous, massive green-blue to gray sandy marl. The sediment fines upward. Near the contact with the Cockfield Formation nearly half the prepared sample is coarser than very fine sand. Near the contact with the Yazoo Formation the amount is reduced to sixteen percent. The wash residue consists of shell material, angular to subangular quartz grains, microfossils (foraminifers and ostracodes), and fecal pellets. Fecal pellets are extremely abundant in the Moodys Branch Formation and are one of its distinguishing characteristics.

The percentage of "coarse" residue (200 mesh) is very small for the Yazoo Clay samples. Typical values range from 1 - 4%. Microscopic examination of this material shows that nearly all of it consists of calcareous fossils. Glauconite occurs throughout the section but is very rare in the Yazoo Clay.

The Yazoo Clay at Montgomery also contains three highly calcareous layers that are more resistant than the surrounding clay and form prominent ledges upon weathering (Fig. 11). These are frequently referred to in the literature as limestone ledges.

The ledges are coarser than the surrounding clay, typically leaving a residue (200 mesh) of approximately 10% coarse material. Petrographic evidence, however, indicates this is a diagenetic phenomenon. The calcareous sediment of the ledges was originally a fine carbonate mud (micrite) that has been altered through aggrading neomorphism to a microspar (Folk, 1965). Plate 9(1) is a photomicrograph of a thin section from a ledge sample. Folk states that "microspar is not simply a coarser mechanically-deposited silt, but is definitely a product of neomorphism."

The X-ray diffractions were made on a Phillips APD-3500 Automatic Powder Diffractometer and were analyzed at 40 kv and 20 ma for the range of 4° - 32° 2 θ at a scanning speed of 0.02°/sec. The samples were powdered with a mortar and pestle, then spread on a standard glass mounting slide.

X-ray diffraction analysis (Fig. 12) shows that the clay intervals are rich in smectite and quartz, while the ledges are rich in calcite and do not contain much terrigenous material. A ledge sample that was dissolved in hydrochloric acid left a very small residue of clay and some glauconite grains. The ledges, therefore, represent periods of very low clastic input.

The Yazoo Formation is a blocky, bluish-gray clay in contrast to the massive sandy marl of the Moodys Branch. Shells occur in stringers throughout the clay, along bedding planes, and as shell hash filling burrows. Fecal pellets are found throughout the Yazoo Formation at Montgomery Landing but in varying amounts in the different clay layers, and they are not as common as in the Moodys Branch.

The Yazoo Formation at this site can be easily divided into three separate units for analysis based on the limestone ledges. For the purpose of discussion, the clay between the first and second ledges is designated zone A, that between the second and third is designated zone B, and that above the third ledge is designated zone C. As has already been mentioned, the first limestone marks the Moodys Branch-Yazoo contact. The second is 2.7 meters above the first and the third is a double layer, with a thin clay layer between, and is 2.4m above the second. The Moodys Branch will also be referred to as a zone in some later statistical discussions.

Fossil preservation is very good except in the limestone beds. Bivalve mollusks are mostly disarticulated, and they show little wear due to abrasion. Preservation in limestone ledges is exclusively as casts which make identification difficult.

The degree and mode of preservation for microfossils also differs between the ledges and clays. For example, the ostracodes recovered from the clays are well preserved and typically are found as disarticulated valves. In sample S3N18, 23 carapaces and 650 valves were recovered for a carapace/valve value of .04.

The ostracodes recovered from the ledge samples are not as well - preserved. Many specimens are encrusted by calcite overgrowth which often makes identification difficult. A large proportion of ostracodes recovered from the ledges occur as articulated valves, or carapaces. The carapace/valve value is 1.05.

Zone A washing residue is composed mostly of shell hash with varying amounts of fecal pellets. Microfossils become extremely abundant near the top of the layer. Crystal aggregates of pyrite or

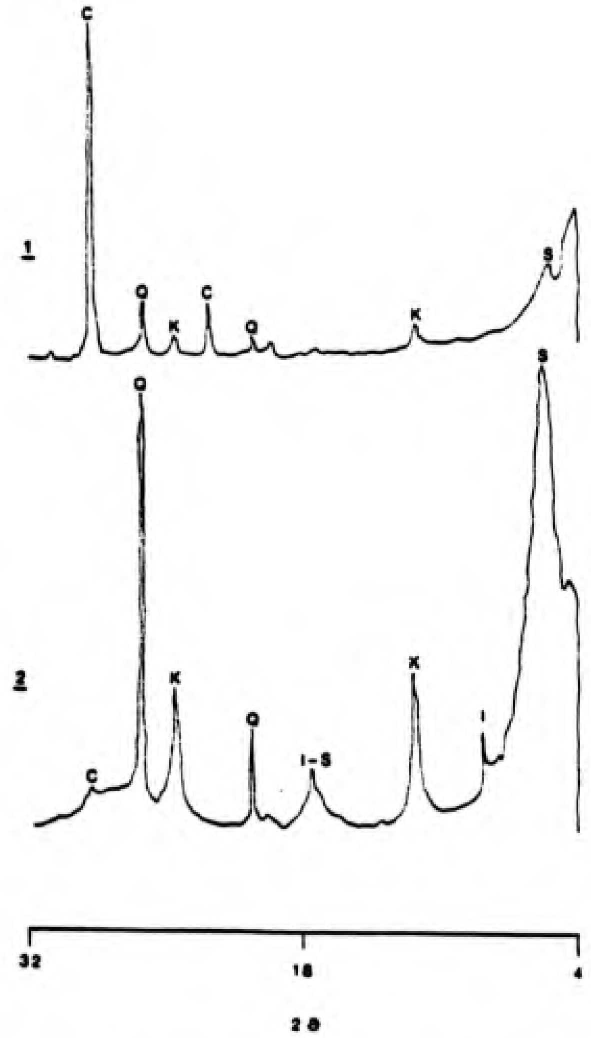


Figure 12 X-Ray diffraction analysis of (1) limestone ledge, and (2) argillaceous sample from the Yazoo Clay Formation.

Samples: 1 = S4N14 2 = S4N17
Minerals: C = calcite Q = quartz
K = kaolinite I = illite
S = smectite

marcasite are found in some of the samples, but they are not common. Zone B is similar to zone A. The washed samples are mostly shell hash with varying quantities of fecal pellets. Microfossils are more abundant in this zone and some samples are very rich. Near the base of the zone, the wash residue of the samples consists almost entirely of microfossils. Fecal pellets vary from small and sparse to large and numerous. The quantity of shell hash is also variable. As the top of the outcrop is approached, the abundance of microfossils decreases and the amount of shell material increases. Aggregates of mineral grains cemented with hematite are found in some abundance near the top. Lignite chips replaced with sulfide minerals are also found. The top of the outcrop, below the Pleistocene terrace deposits, has abundant quartz, mineral aggregates with hematite cement, abundant fecal pellets, and mineralized woody chips, but shell material is sparse. Hermatite was probably leached from Pleistocene sediments above.

In the Yazoo Formation no definite trends in sediment size were found; however, it is consistently higher in fine grained sediment (less than very fine sand) than the Moodys Branch or the Cockfield. Samples from the Cockfield averaged 82.21% fine grained sediment, the Moodys Branch averaged 78.2% fine grained sediment per sample, and the Yazoo averaged 97.3% for zone A, 94.6% for zone B, and 98.2% for zone C.

Table 3: Percentage of each sample of sediment of very fine sand or finer.

Cockfield

1-1	94.3%	2-1	97.7%	2-7	84.0%
1-2	80.3%	2-2	98.2%	2-8	77.9%
1-3	70.0%	2-3	98.1%	2-9	76.2%
1-4	73.3%	2-4	96.8%	2-10	86.3%
1-5	71.7%	2-5	98.1%	2-11	43.0%
1-6	85.4%	2-6	96.2%	2-12	44.0%
				2-13	90.0%

Average fine - 81.2%

Moodys Branch

1-7	63.1%	2-14	61.6%	4-1	78.0%
1-8	82.0%	2-15	69.4%	4-2	91.2%
1-9	84.5%	2-16	72.7%	4-3	82.9%
1-10	82.1%	2-17	85.0%		
		2-18	85.4%		

Average fine - 78.2%

Yazoo Zone A

3.1	100%	4-11	98.4%	5-9	95.8%
3-2	100%	4-12	96.7%	5-10	96.8%
3-3	98.3%	4-13	97.1%	6-1	97.8%
3-6	94.5%	5-1A	95.3%	6-2	97.8%
3-7	96.5%	5-2	93.2%	6-3	98.2%
4-5	93.3%	5-3	98.2%	6-4	98.5%
4-6	94.7%	5-4	98.8%	6-5	97.8%
4-7	94.7%	5-5	98.2%	6-6	95.8%
4-8	98.5%	5-6	98.6%	7-1	95.9%
4-9	98.1%	5-7	98.7%	7-2	95.8%
4-10	98.2%	5-8	98.2%	3-5	97.3%

Average Fine - 97.3%

* Designations such "1-1" indicate section number one and sample number one.

Yazoo Zone B

3-9	95.6%	5-13	96.4%	7-4	93.5%
3-10	93.8%	5-14	94.6%	7-5	90.1%
3-11	89.2%	5-15	92.4%	7-6	95.4%
3-12	91.7%	5-16	90.6%	7-7	91.3%
4-15	97.7%	5-17	84.6%	8-2	97.8%
4-16	98.9%	6-8	97.4%	8-4	96.4%
4-17	96.5%	6-9	98.8%	9-2	98.2%
4-18	93.3%	6-10	95.5%	9-3	98.5%
4-19	93.8%	6-11	95.2%	9-4	97.9%
4-20	90.5%	6-12	94.0%	9-5	95.5%
5-12	98.7%	6-13	93.3%	9-6	93.7%

Average fine - 94.6%

Yazoo Zone C

3-17	98.0%
3-18	99.2%
3-22	98.7%
3-24	98.2%
3-24	98.2%
3-25	99.2%
3-27	98.8%

Average fine - 98.2%

Table 4. Section Sample Descriptions

Section No. Sample No.	Formation Thin Section	Stratigraphic Position	Color	Sedimentary Structure, Comments
1-1	C	220 cm. below unconformity	10 YR 2/2 Dusk yellow brown	3 mm. crossbeds finely laminated, burrowed
1-2	C	190 cm. below unconformity	5 Y 4/1 Olive gray	Cross beds, burrowed unfossiliferous
1-3	CX	160 cm. below unconformity	5 Y 2/1 Olive black	Massive, lignitic unfossiliferous
1-4	C	130 cm. below unconformity	5 Y 4/1 Olive black	Mottled, unfossiliferous
1-5	C	100 cm. below unconformity	5 Y 4/1 Olive gray	Mottled, unfossiliferous
1-6	CX	90 cm. below unconformity	5 Y 3/2 Olive gray	Burrowed, fossiliferous (mollusks)
1-7	CX	40 cm. below unconformity	5 Y 5/2 Light olive gray	Fossiliferous
1-8	CX	10 cm. below unconformity	5 Y 4/1 Olive gray	Fossiliferous, shell hash; ledge
1-9	MX	50 cm. above unconformity	5 Y 6/1 Light olive gray	Fossiliferous
1-10	M	80 cm. above unconformity	5 Y 5/2 Light olive gray	Fossiliferous
1-11	Y	110 cm. above unconformity	5 Y 7/2 Yellowish gray	Fossiliferous ledge
1-12	Y	30 cm. above YL1	5 Y 5/2 Light olive gray	Fossiliferous
2-1	C	400 cm. below Moody's Branch (M.B.) unconformity	N-3 Dark gray	Finely laminated 1 mm. organic material unfossiliferous
2-2	CX	370 cm. below M.B. unconformity	N-3 Dark gray	Finely laminated; concretion layer present 5 cm. above 2-2 unfossiliferous
2-3	C	340 cm. below M.B.unconformity	N-3 Dark gray	Finely laminated unfossiliferous
2-4	C	310 cm. below M.B. unconformity	5 Y 2/1 Olive black	Unfossiliferous weathers buff-red
2-5	CX	280 cm. below M.B. unconformity	5 Y 2/1 Olive black	Finely laminated, sand pods, organic material unfossiliferous
2-6	CX	230 cm. below M.B. unconformity	5 Y 2/1 Olive black	Minor laminations, organic material, pods of finely carbonaceous shell
2-7	C	220 cm. below M.B. unconformity	5 Y 2/1 Olive black	Laminated, poorly fossiliferous, sand pods common; carbonaceous layer at 200 cm.

2-8	CX	190 cm. below M.B. unconformity	5 Y 2/1 Olive Black	Laminated, sand pods, silt-filled burrows, fossiliferous
2-9	C	150 cm. below M.B. unconformity	5 YR 2/1 Brownish black	Laminated, minor organics, poorly fossiliferous
2-10	CX	120 cm. below M.B. unconformity	N1 Black	Laminated, clay bodies and sand pods, stem and leaf fragments, black-yellow organic material
2-11	C	90 cm. below unconformity	5 YR 2/1 Brownish black	Very finely laminated, abundant organic speck poorly fossiliferous mollusk mold present
2-11A	C	90 cm. below M.B. unconformity	5 Y 6/1 Light olive gray	Finely laminated, organics present, unfossiliferous
2-12	C	60 cm. below M.B. unconformity	5 YR 2/1 Brownish black	Finely laminated, glauconite filled burrows, unfossiliferous
2-13	C	30 cm. below M.B. unconformity	5 Y 4/1 Olive gray	Laminated burrowed, sand pockets and organics common, fossiliferous
2-14	MX	30 cm. above M.B. unconformity	5 Y 4/1 Olive gray	Fossiliferous 16 cm. cobble found
2-15	M	60 cm. above M.B. unconformity	5 Y 6/1 Light olive gray	Fossiliferous
2-16	M	90 cm. above M.B. unconformity	5 Y 4/1 Olive gray	Fossiliferous, mottled
2-17	MX	120 cm. above M.B. unconformity	5 Y 4/1 Olive gray	Very fossiliferous
2-18	M	150 cm. above M.B. unconformity	5 Y 4/1 Olive gray	Very fossiliferous
2-19	YL1X	180 cm. above M.B. unconformity	5 Y 6/1 Light olive gray	Ledge, mollusk casts 45 cm. thick
3-1	Y	180 cm. below Ledge 2	5 Y 5/2 Light olive gray	Fossiliferous
3-2	Y	150 cm. below Ledge 2	5 Y 5/2 Light olive gray	Marly layer (?) fossiliferous
3-3	YX	120 cm. below Ledge 2	5 GY 4/1 Dark greenish gray	fossiliferous
3-4	Y	90 cm. below Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-5	YX	60 cm. below Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-6	Y	30 cm. below Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-7	YX	Just below Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-8	YX	Ledge 2	5 Y 5/2 Light olive gray	Fossiliferous

3-9	YX	40 cm. above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-10	Y	70 cm. above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-11	Y	100 cm. above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-12	YX	130 cm. above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
3-13	YX	Ledge A of Ledge 3	5 GY 6/1 Greenish gray	Fossiliferous
3-14	YX	17 cm. above Ledge A of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-15	Y	Ledge B of Ledge 3	5 Y 6/1 Light olive gray	Fossiliferous
3-16	YX	30 cm. above Ledge B of Ledge 3	5 GY 5/2 Dusky yellow green	Fossiliferous
3-17	Y	60 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-18	Y	90 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-19	YX	120 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-20	Y	150 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-21	YX	180 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous, sand-filled borings
3-22	Y	210 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous; sand-filled borings
3-23	Y	240 cm. above Ledqe B of Ledge 3	5 Y 4/1 Olive gray	Fossiliferous
3-24	Y	270 cm above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-25	Y	300 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
3-26	Y	330 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous; laminated
3-27	Y	360 cm. above Ledge B of Ledge 3	5 GY 4/1 Dark greenish gray	Fossiliferous
4-1	MX	60 cm. below Ledge 1	5 GY 6/1 Greenish gray	Very fossiliferous
4-2	M	30 cm. below Ledge 1	5 G 6/1 Greenish gray	Very fossiliferous; hash-filled burrows
4-3	MX	Right above Ledge 1	5 GY 6/1 Greenish gray	Fossiliferous; burrowed
4-4	YX	Ledge 1; 20 cm. thick	5 Y 6/1 Light olive gray	Very fossiliferous
4-5	YX	Ledge 1	5 G 6/1 Greenish gray	Very fossiliferous hash-filled burrows
4-6	YX	30 cm. above Ledge 1	5 G 6/1 Greenish gray	Fossiliferous; shell hash and sand pockets
4-7	YX	60 cm. above Ledge 1	5 G 6/1 Greenish gray	Fossiliferous; shell hash pockets, laminated
4-8	YX	90 cm above Ledge 1	5 G 6/1 Greenish gray	Fossiliferous; laminated

4-9	Y	120 cm above Ledge 1	5 G 6/1 Greenish gray	Fossiliferous
4-10	Y	150 cm above Ledge 1	5 GY 4/1 Dark greenish gray	Fossiliferous; sand pods, laminated
4-11	YX	180 cm above Ledge 1	5 GY 4/1 Dark greenish gray	Fossiliferous, sand pods, laminated
4-12	Y	210 cm above Ledge 1	5 GY 4/1 Dark greenish gray	Laminated, fossiliferous, burrowed
4-13	Y	240 cm above Ledge 1	5 G 6/1 Greenish gray	Laminated, fossiliferous, burrowed
4-14	YX	Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous, marly
4-15	YX	30 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Laminated, fossiliferous
4-16	Y	60 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Laminated, fossiliferous
4-17	Y	90 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Laminated, burrowed, fossiliferous
4-18	Y	120 cm above Ledge 2	10 YR 2/2 Dusky yellowish brn.	Fossiliferous, laminated
4-19	Y	150 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous, laminated
4-20	YX			
4-21	YX	Ledge A of 3	5 Y 4/1 Olive gray	Laminated marly, Fossiliferous
4-22	YX	Ledge B of 3	5 GY 6/1 Dark greenish gray	Laminated, marly, fossiliferous
4-23	Y	30 cm above Ledge A, C of 3	5 Y 4/1 Olive gray	Clay blebs, marly, fossiliferous
5-1	YX	Top of marly layer, Ledge	5 G 6/1 Greenish gray	Carbonaceous, fossiliferous
5-1A	YX	clay directly above marly layer		
5-2	Y	30 cm above Ledge 1	5 G 6/1 Greenish gray	Glauconitic lenses, fossiliferous
5-3	YX	60 cm above Ledge 1	5 GY 4/1 Dark greenish gray	Hash stringers, very fossiliferous
5-4	Y	90 cm above Ledge 1	5 Y 4/1 Olive gray	Very fossiliferous, laminated
5-5	Y	120 cm above Ledge 1	5 B 5/1 Bluish gray	Very fossiliferous
5-6	YX	150 cm above Ledge 1	5 B 5/1 Bluish gray	Sand-filled burrows, fossil layers, very fossiliferous (echinoids)
5-7	Y	180 cm above Ledge 1	5 G 4/1 Dark greenish gray	Silt pockets, fossiliferous
5-8	Y	210 cm above Ledge 1	5 G 4/1 Dark greenish gray	Fossiliferous; fossils aligned
5-9	Y	240 cm above Ledge 1	5 G 4/1 Dark greenish gray	Very fossiliferous, fossils aligned
5-10	Y	270 cm above Ledge 1	5 G 4/1 Dark greenish gray	Concretions, laminated, very fossiliferous (<u>Pinna</u>)

5-11	YX	Ledge 2	5 Y 4/1 Olive gray	Fossil layers
5-12	YX	30 cm above Ledge 2	10 Y 4/2 Grayish olive	Laminated, fossiliferous, oxidized to brown
5-13	Y	60 cm above Ledge 2	5 B 5/1 Medium bluish gray	Laminated, sand pockets, fossiliferous
5-14	Y	90 cm above Ledge 2	5 G 4/1 Dark greenish gray	Fossiliferous, fossil lenses
5-15	Y	120 cm above Ledge 2	5 G 4/1 Dark greenish gray	Fossiliferous, aligned fossils, burrowed
5-16	Y	150 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Laminated, fossiliferous
5-17	YX	180 cm above Ledge 2	5 Y 4/1 Olive gray	Laminated, fossiliferous
5-18	Y	210 cm above Ledge 2	5 Y 5/2 Light olive gray	Fossiliferous
5-19	Y	240 cm above Ledge 2		Fossiliferous, fossil lenses
6-1	YX	150 cm below Ledge 2	10 Y 4/2 Grayish olive	Shell hash stringers, echinoids 2 cm diam., small fish vertebrae
6-2	Y	120 cm below Ledge 2	5 Y 5/2 Light olive gray	oxidized zones, shell hash pockets, abundant echinoids
6-3	YX	90 cm below Ledge 2	10 Y 4/2 Grayish olive	Laminated, shell hash stringers, sand-filled burrows, echinoids
6-4	Y	60 cm below Ledge 2	10 Y 4/2 Grayish olive	Oxidized zones, shell hash stringers and pockets
6-5	Y	30 cm below Ledge 2	5 Y 5/2 Light olive gray	Oxidized zones, shell hash, dispersed shell fragments
6-6	YX	directly below Ledge	5 Y 5/2 Light olive gray	Fossiliferous mold, horizontal *Pinna* layers
6-6A	YX	directly below L2		
6-7	YX	Ledge 2 11 cm thick	5 Y 5/2 Light olive gray	
6-8	YX	30 cm above Ledge 2	5 Y 5/2 Light olive gray	Lignitic, very fine shell hash stringers, 2 cm bivalves, pinna
6-9	Y	60 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Faintly laminated, pinna-shell hash layers
6-10	Y	90 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Faintly laminated, scattered *Pinna*, shell hash, rust-colored weathered zone
6-11	Y	120 cm above Ledge 2	5 Y 4/1 Olive gray	Faintly laminated, prominent shell hash, whale bones found this layer 8 m to the south

6-12 Y	150 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Faintly laminated, fossiliferous
6-13 Y	180 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Extremely fossiliferous
6-14 YX	Lower part of Ledge 3; 20 cm thick	5 Y 5/2 Light olive gray	Extremely fossiliferous
6-15 YX	Middle of upper Ledge 3; 45 cm thick	5 Y 6/1 Light olive gray	
7-1 Y	60 cm below top of Ledge 2	5 GY 4/1 Dark greenish gray	Fine shell hash pods and stringers, scattered *Pinna*
7-2 YX	30 cm below top of Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous, red sand pods
7-2A YX	Ledge 2	5 GY 6/1 Greenish gray	Red sand pods
7-3 YX	30 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Red sand pods, shell hash, scattered *Pinna*
7-4 Y	60 mm above Ledge 2	5 GY 4/1 Dark greenish gray	Fossiliferous
7-5 Y	90 cm above Ledge 2	5 Y 4/1 Olive gray	Fossiliferous; shell hash, stringers and pods common
7-6 Y	120 cm above Ledge 2	5 GY 4/1 Dark greenish gray	2-3 cm shell and shell hash layer, finely disseminated shells
7-7 YX	150 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Shell hash and shell hash stringers, red sand pods
7-8 YX	Ledge 3	5 Y 5/2 Light olive gray	Fine shell hash common Double ledge 40+ cm thick, lower ledge 20 cm thick
8-1 YX	Ledge 2	5 GY 6/1 Greenish gray	Fossiliferous, glauconitic hash
8-1A YX			
8-2 Y	30 cm above Ledge 2	5 GY 5/2 Dusky yellow green	Fossiliferous; molluscs oriented along bedding
8-3 YX	60 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Shell hash
8-4 Y	90 cm above Ledge 2	5 Y 4/1 Olive gray	Burrowed, shell hash
8-5 YX	120 cm above Ledge 2	5 Y 6/1 Light olive gray	Fossiliferous
9-1 YX	Ledge 2	5 Y 6/1 Light olive gray	Pelleted, sparsely fossiliferous
9-1A YX	Ledge 2		
9-2 Y	30 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Very fossiliferous, finely laminated
9-3 YX	60 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Finely laminated, fossiliferous in layers

9-4	YX	90 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Finely laminated, fossiliferous in layers
9-5	Y	120 cm above Ledge 2	5 GY 4/1 Dark greenish qray	Very fossiliferous, pinnas common
9-6	Y	150 cm above Ledge 2	5 GY 4/1 Dark greenish gray	Very fossiliferous in layers, finely laminated, bioturbated
9-7	YX	Immediately above Ledge 3	5 B 5/1 Medium bluish gray	Laminated, fossiliferous
9-8	YX	Upper part of Ledge 3	5 Y 6/1 Light olive gray	Laminated, bioturbated,
10-1	YX		5 GY 6/1 Greenish gray	Sparsely fossiliferous
10-2	Y		5 GY 6/1 Light olive gray	Sparsely fossiliferous
				fossiliferous
10-3	YX	Ledge	5 Y 6/1 Light olive gray	Sparsely fossiliferous

Pipette Analysis

Pipette analysis of Moody's Branch and Yazoo samples was attempted. Preparation of the samples to prevent flocculation of the clays broke down the clays to such an extent that their original depositional size was not preserved. Also, the presence of zeolites as porefills (as seen in thin section) and the compaction of some of the fossil material shows that this area underwent post-depositional changes. These post-depositional events insured that any grain size analysis attempted would reflect post-depositional and not original depositional grain size. Use of a Coulter counter was investigated but previously mentioned problems made this technique impractical.

THIN SECTIONS

Cockfield

Cockfield samples, if lithified, would be considered graywackes. Grains are matrix-supported. Quartz, orthoclase, and albite are common. Accessory minerals include hematite, biotite, chlorite, granular micritic calcite rock fragments, and carbonate rock fragments.

Moody's Branch

Moody's Branch samples are fossiliferous and contain hash-filled burrows. X-ray diffraction of the clays shows that they are a smectite. Mollusks, forams, and echinoids are common. Corals are present but uncommon. Common minerals identified in thin sections include glauconite pellets and grains, quartz, orthoclase, and hematite. Zeolites are common and occur as radiating crystals in porefills.

Yazoo

Yazoo samples can be divided into two divisions; ledge and non-ledge smectites. Ledges consist of neomorphosed micrites or microspar. Forams, molluscs, and echinoids are common, although fossils are minor. Common thin-section-identified minerals include quartz, orthoclase, hematite, and glauconite pellets and grains. Pyroxene, biotite, and calcite crystals are present as accessory minerals. Only two out of eighteen ledge thin sections show zeolite porefills. Both ledge and non-ledge samples are iron stained. Non-ledge smectites are fossiliferous. Common fossils include forams, mollusks, and echinoids. Bryozoans, corals, and worm tubes are less abundant but are present. Common minerals identified in thin sections include glauconite pellets and grains, hematite, quartz, and orthoclase. Chlorite, biotite, and calcite crystals are also present. Iron-free pods are seen in thin section and correspond to the sand-filled pods seen in hand specimen.

TABLE 5. THIN SECTIONS
(By Jill Hartnell)

	Fossils	Minerals	Comments
1-3		hematite, orthoclase, quartz, microcline, albite, muscovite, chlorite, biotite	Protomatrix, sandy micrite rock fragments (r.f.), mudstone r.f., volcanic r.f.
1-6		Glauconite grains & pellets, orthoclase, microcline, quartz, albite, hematite, chlorite, biotite	Matrix-supported
1-7	Worm tubes, mollusks, forams, echinoids, coralline algae	Glauconite pellets, muscovite, granular micritic calcite (GMC)	Micrite r.f., carbonate r.f., oolites (?)
1-8	forams, echinoids, mollusks, coralline algae, bryozoa?	GMC, glauconite pellets, orthoclase, volcanic quartz, quartz, chlorite, albite, hematite	Some grains have been squashed
1-9	Mollusks, forams, echinoids, corals, worm tubes, bryozoa?	glauconite pellets, quartz, orthoclase, chlorite, biotite	Zeolite cement
1-12	Forams, mollusks, corals, bryzoa	Glauconite pellets, quartz, orthoclase	
2-2		Biotite, chlorite quartz, albite, glauconite, iron oxide, orthoclase	Matrix-supported pseudomatrix, zeolite cement, patches of areas of quartz grains with zeolite cement
2-5		Hematite, chlorite, glauconite, biotite, quartz, orthoclase, albite, iron oxide	Zeolite cement, matrix-supported, pseudomatrix
2-6		Hematite, chlorite, glauconite, biotite, quartz, orthoclase, albite, iron oxide	Zeolite cement, matrix-supported, pseudomatrix
2-8		Volcanic GMC, iron oxide, microcline, quartz, albite, orthoclase, chlorite, hematite, biotite, volcanic quartz	Zeolite cement, matrix-supported
2-10		Large quartz, orthoclase, and albite; microcline, chlorite	Hematite matrix, bimodal grain distribution, definitely matrix-supported

2-14	Forams, mollusks, echinoids, worm tubes, coralline algae, bryozoa	Glauconite pellets, quartz, feldspar	Oolites? Very unusual mineral assemblage
2-17	Forams, mollusks, worm tubes, corals, echinoids	Glauconite pellets and grains, quartz, hematite, orthoclase	Some rounded quartz, pockets of very broken (possibly bioturbated) fossils
2-19	Forams	Broken glauconite pellets, quartz, albite, orthoclase	
3-3	Echinoids, forams, mollusks	Biotite, disseminated hematite	Very iron stained, very bioturbated, "odd section"
3-5	Echinoids, forams, molluscs	Quartz, orthoclase, glauconite pellets	Zeolite pore fills
3-7	Forams, mollusks	Quartz, albite, glauconite pellets, hematite, orthoclase	Zeolite pore fill, bioturbated
3-8	Forams, mollusks	Broken glauconite pellets	
3-9	Mollusks, forams, echinoids, worm tubes	Quartz, biotite, glauconite pellets, chlorite, orthoclase	Zeolite pore fill
3-12	Forams, mollusks, echinoids, corals	Quartz, biotite, hematite, orthoclase	Zeolite pore fill, very bioturbated
3-13	Forams, mollusks, echinoids	Quartz, hematite, glauconite pellets and grains, orthoclase	
3-14	Very minor forams		
3-16	Forans, mollusks, echinoids, corals	Quartz, biotite, chlorite, hematite, glauconite pellets, orthoclase	Oolites? Very bioturbated
3-19	Forams, mollusks	Quartz, orthoclase, iron-free pods with quartz, orthoclase, chlorite, zeolite cement, iron oxide	Zeolite pore fill
3-21	Forams	quartz, orthoclase	Bioturbated
4-1	Forams, mollusks, echinoids, corals	Glauconite pellets and grains, quartz, hematite, orthoclase	Zeolite pore fill
4-3	Forams, mollusks, echinoids, corals	Glauconite pellets and grains, quartz, hematite, orthoclase	Zeolite pore fill
4-4	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, hematite, orthoclase	
4-5	Forams, mollusks, echinoids, corals	Glauconite pellets and grains, quartz, hematite, orthoclase	Zeolite pore fill

4-6	Forams, mollusks, echinoids, corals	Glauconite pellets and grains, quartz, hematite, orthoclase	Zeolite pore fill
4-8	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, orthoclase	Very bioturbated zones
4-11	Forams, mollusks, echinoids, corals	Glauconite pellets and grains, quartz, hematite, orthoclase	Zeolite pore fill
4-14	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, hematite, pyroxene, orthoclase	Zeolite pore fill, bioturbated zones
4-15	Forams, mollusks	Glauconite pellets and grains	
4-20	Forams, mollusks, corals	Glauconite pellets, calcite grains, quartz, hematite, orthoclase	Bioturbated zones
4-21	Forams, mollusk, ghosts	Glauconite pellets and grains, quartz, large calcite grains, hematite, orthoclase	
4-22	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, hematite, orthoclase	Bioturbated?
5-1	Forams, echinoids, corals	Glauconite pellets, quartz, hematite, biotite, orthoclase	
5-1A	Forams, mollusks, echinoids	Glauconite pellets, hematite	Odd texture
5-3	Echinoids, forams, mollusks, corals	Glauconite pellets and grains, quartz, biotite, hematite, orthoclase	
5-6	Forams, echinoids, corals, mollusks	Glauconite grains, hematite	Zeolite pore fill
5-11	Forams, mollusks	Large calcite crystals, hematite, glauconite pellets	
5-12	Forams, mollusks	Quartz, rare glauconite grains, orthoclase	Bioturbated zones
5-17	Corals, mollusks, forams	Glauconite pellets, hematite, quartz, orthoclase	Squashed oolites?
5-18	Forams, mollusks	Glauconite pellets, quartz	Odd assemblage
6-1	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, orthoclase	Bioturbated zones, geopetal structure

6-3	Echinoids, forams, mollusks, worm tubes	Rare glauconite pellets, quartz, hematite, orthoclase	Bioturbated zones
6-6	Forams, mollusks echinoids	Glauconite pellets and grains, quartz, orthoclase and grains, quartz, orthoclase	Very bioturbated
6-7	Forams, mollusks	Glauconite pellets	Neomorphosed micrite
6-8	Mollusks, forams, echinoids	Glauconite pellets and grains, quartz, biotite, orthoclase	
6-14	Forams, mollusks, echinoids	Quartz, hematite, glauconite pellets and grains, orthoclase	
6-15	Forams, mollusks, echinoids	Quartz, hematite, glauconite pellets (broken) and grains, orthoclase	
7-2	Mollusks, forams, echinoids, bryozoans	Glauconite pellets and grains, quartz, orthoclase	
7-2A	Forams, mollusks, echinoids	Glauconite pellets and grains, quartz, orthoclase, amphibole	Patch of quartz, hematite, glauconite grains, feldspar (possibly an infilled burrow); zeolite pore fill
7-3	Forams, mollusks	Glauconite pellets and grains, quartz, hematite, orthoclase	
7-7	Forams, mollusks, echinoids, bryozoans	Glauconite pellets and grains, calcite crystals	Bioturbated
7-8	Forams, mollusks, echinoids, bryozoans	Glauconite pellets, quartz, hematite, small calcite crystals, orthoclase	Bioturbated
8-1	Forams, mollusks, coralline algae	Glauconite pellets, quartz, hematite, orthoclase	Hematite replaces calcite in molluscs
8-1A	Forams, mollusks, echinoids	Hematite	Iron oxide mottled areas, pods of larger grains
8-3	Forams, mollusks, possible worm tube	?	
8-5	Forams, mollusks, echinoids, corals or Hryozoans	Quartz, hematite, glauconite pellets, biotite, orthoclase	
9-1	Forams, echinoids, corals	Glauconite pellets, quartz, orthoclase, biotite, amphibole, hematite	

9-1A	Forams, mollusks, echinoids, corals or bryozoans	Glauconite pellets and grains, quartz, chlorite, orthoclase, hematite	
9-3	Forams	Glauconite pellets, quartz, orthoclase	Thin section is too thick to be of much use
9-7	Corals, mollusks, forams, echinoids	Glauconite pellets and grains, quartz, biotite, hematite, orthoclase	
9-8	Forams, mollusks, echinoids	Broken glauconite pellets, quartz, orthoclase	Unneomorphosed areas
10-3	Forams, mollusks, echinoids	Quartz, amphibole, glauconite, hematite, orthoclase	Patches of larger grain development
10	Forams, mollusks, echinoids, coralline algae?	Glauconite pellets and grains, quartz, biotite, orthoclase, amphibole	Very bioturbated

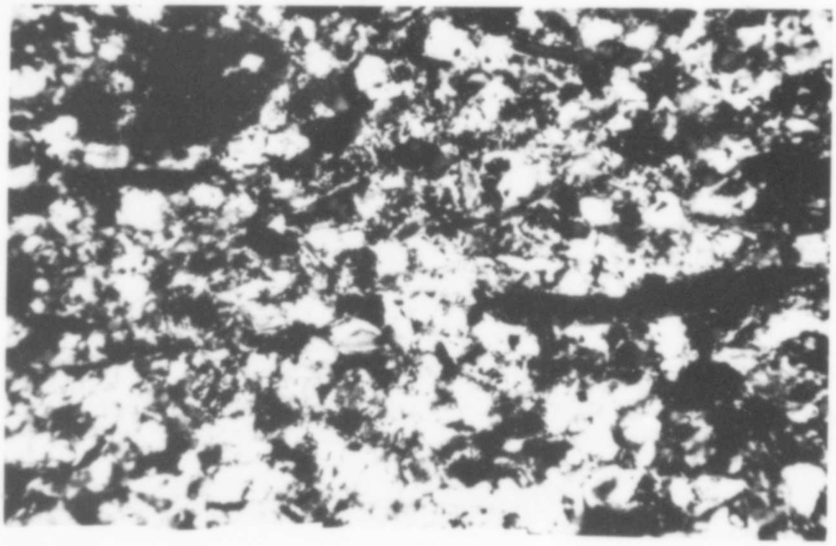


Figure 9-1. Thin section of Yazoo ledge 2 showing texture. Sample 5-11. 10 X. crossed nicols.

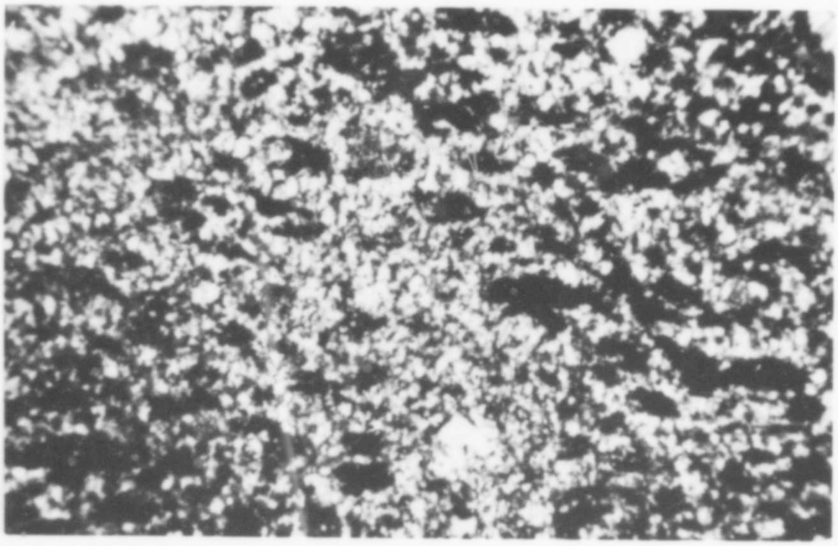


Figure 9-2. Thin section of Yazoo mudstone, zone C, showing texture. Sample 3-21. 10 X. crossed nicols.

PLATE 9

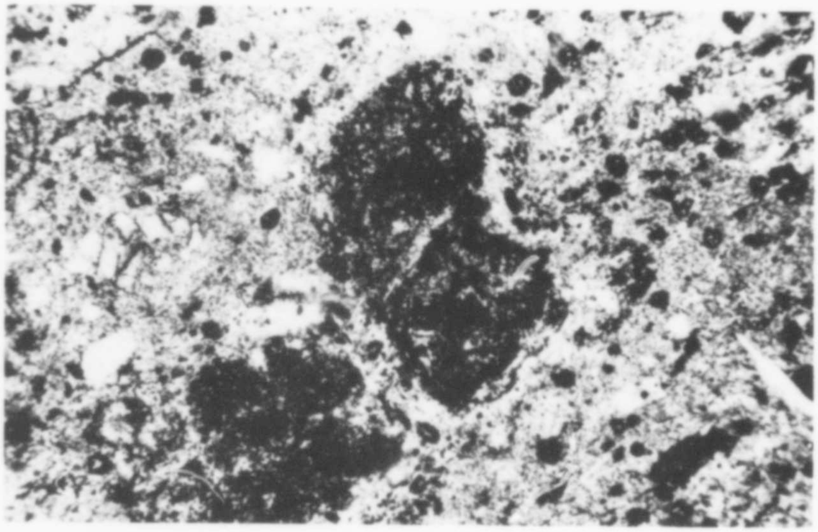


Figure 10-1. Thin section of Moodys Branch Formation, centered on glauconite grain. Sample 2-17. 10X. Crossed nicols.

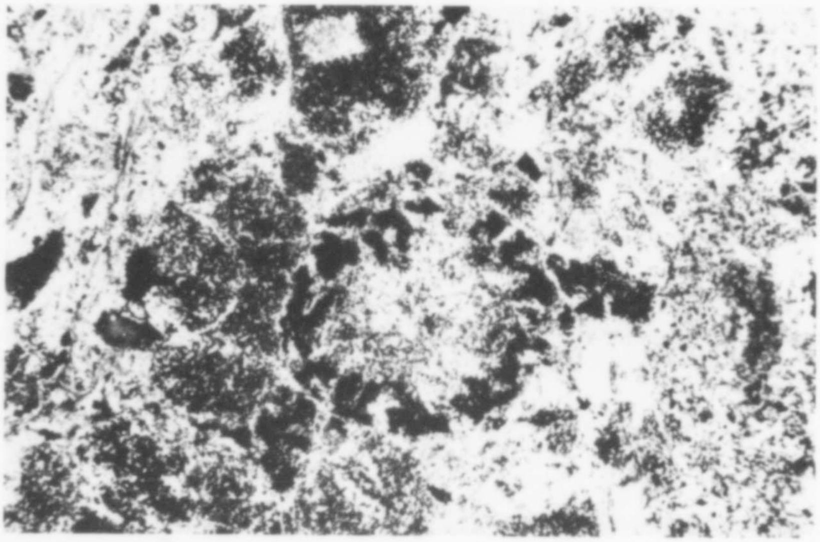


Figure 10-2. Thin section of Yazoo mudstone, zone B, centered upon a glauconite grain, probably a replaced fecal pellet. Sample 4-20. 20 X. crossed nicols.

PLATE 10

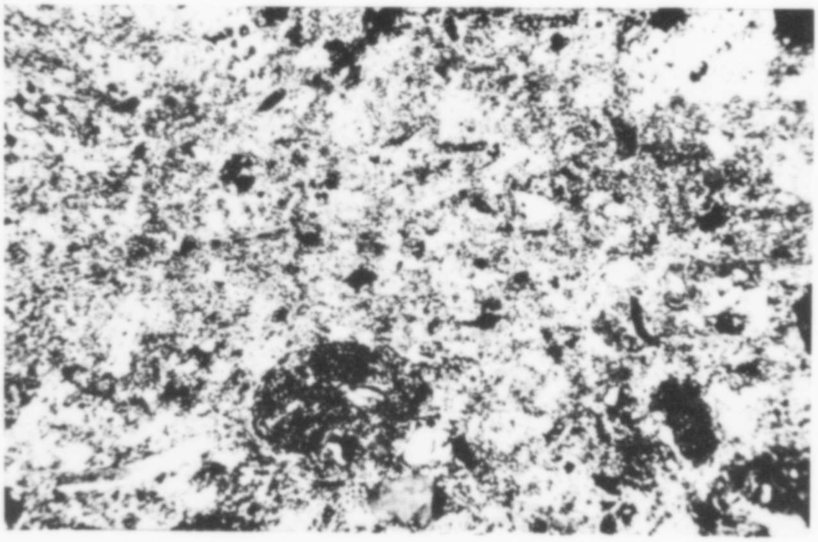


Figure. 11-1. Thin section of Moodys Branch Formation. Sample 2-14. 1. sand grain; 2. bryozoan; 3. mollusk fragment; 4. glauconite grain. 10X. Crossed nicols.

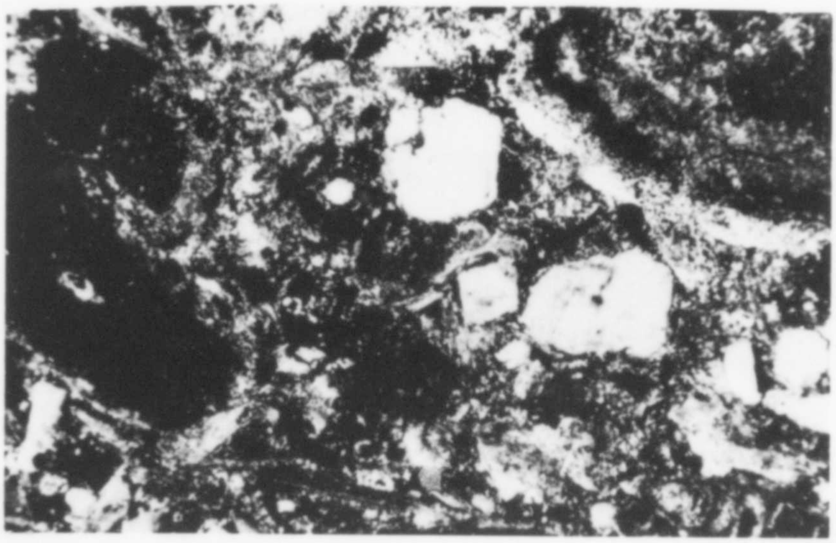


Figure. 11-2. Thin section of Moodys Branch Formation centered on quartz grains. Sample 2-14. 10X. Crossed nicols.

PLATE 11

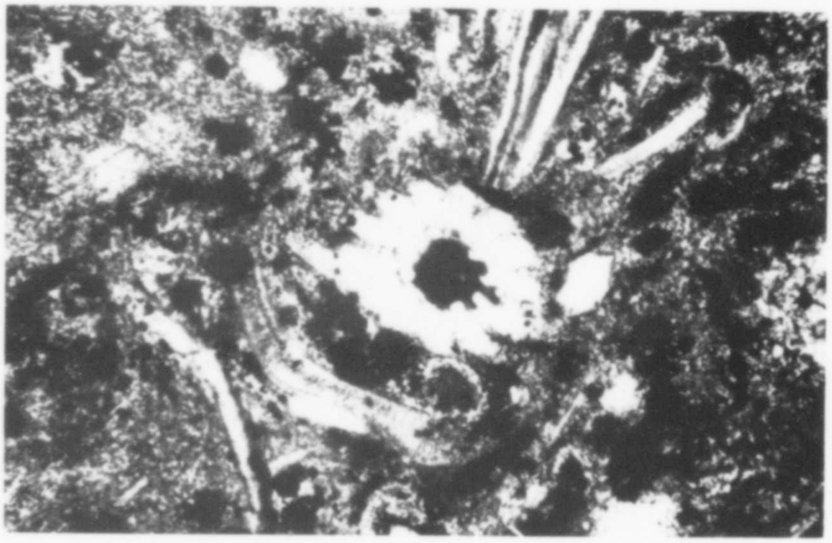


Figure 12-1. Thin section of Moodys Branch Formation, centered on echinoderm spine in cross section. Mollusk fragments and quartz grains prominent. Sample 2-17. 20 X. crossed nicols.

Figure 12-2. Thin section of Yazoo mudstone, zone A, centered upon foraminifer in cross section. Sample 5-6. 10 X. crossed nicols.

PLATE 12

Peels

Several peel techniques were attempted without producing suitable results. Methods tried include that of Ostler and Martini (1973), which involves affixing a plexiglass plate to the outcrop with marine polyester resin, and that of Bull (1977), which involves peeling polyurethane varnish from smoothed-out crop surfaces with matte adhesive tape. The Ostler and Martini process is being attempted in Figure13-1. The fine-grained nature of the sediments, the high percentage of carbonates in the clays, and the common presence of fossils that are substantially harder than the sediments prevented peel techniques from working well.

Figure 13-1. Students Richard Teague and Jill A. Hartnell affix a small sheet of plexiglass to the outcrop in the vicinity of a concentration of echinoids in an attempt to produce a peel.

Figure 13-2. Donna Teague and Dr. Judith Schiebout collect echinoids (*Schizaster*) which are concentrated in a layer near section five.

PLATE 13

D. CLAY ANALYSIS OF SEDIMENTS ASSOCIATED WITH BASILOSAURUS*

Studies of the clays were carried out to obtain more information about the environment in which they were deposited and to determine the nature of the differences between the layer of clays immediately surrounding the bones and the typical Yazoo. Surrounding the majority of the bones is a layer of tan clay averaging one centimeter thick. It occurs as a discrete layer and terminates abruptly away from the bone surface. This layer is designated as the periosteal layer. The terminus of the periosteal layer is succeeded by the typical Yazoo sediments with little or no transition. Variations in thickness of the periosteal layer are seen around irregularities and depressions in the bone. The typical Yazoo sediment is gray. Color is the most important distinguishing character. The periosteal layer surrounds the teeth, which are different in chemical composition from the bone. For unknown reasons, the right ulna and both thyrohyals did not exhibit a discolored periosteal layer.

Mineralogical analysis of the sediments associated with archaeocete remains at other localities within the Jackson Group could improve our understanding of the (sedimentary) environments in which early cetaceans lived.

Clay Mineralogy Materials and Methods

Clay samples collected at Montgomery Landing and other sites were analyzed for mineralogic composition. Of the five samples taken at Montgomery Landing for analysis, three (3-5) came from a vertical section 8m north of the bone site in order to insure that the sediments were not influenced by the different chemical environment of the bone assemblage. Sample 3 came from 30 cm below the bone assemblage, sample 4 was taken at the same level as the bones, and sample 5 was taken 30 cm above the bone level. The remaining two samples were taken within the bone assemblage. Sample 1 was taken from typical Yazoo sediments within the bone assemblage and sample 2 was taken from the periosteal layer of the mandibles of the whale. The samples from the vertical section were collected in August 1979 by a field party from Louisiana State University Department of Geology led by Drs. J. A. Schiebout and W. A. van den Bold. Sample 1 was collected by a field party led by Winston Lancaster to excavate the whale mandibles in October 1980. Sample 2 was collected in the laboratory during the preparation of the mandibles.

The samples were ground with a mortar and pestle and washed three times in sodium triphosphate solution to reduce the tendency to flocculation. The samples were centrifuged to separate two size fractions: > 2μ, and < 2μ (using the table compiled by Jackson (1979).

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*by Winston Lancaster, LSU

Oriented mounts were made of the < 2μ size fraction, and X-ray diffractograms were made of each from 2° 2θ to 40° 2θ . The equipment used was a Philips Electronics XRG X-ray generator (Cu K_α radiation at 40 KV and 20 ma) and an APD 3500 Data Display/control unit. The system includes a Texas Instruments Silent 700 Teletype unit. The 2θ increment was set at 0.02, chart speed at 30 inches per hour fixed time at 1.0 second, and full scale set at 1000.

After the initial run the slides were treated with ethelyene glycol overnight in a desiccation chamber, and X-ray diffractograms made from 2° 2θ to 40° 2θ. In addition to these, powder mounts were made of samples 1 and 2, and X-ray diffractograms were made from 2° 2θ to 70° 2θ. All diffractograms were qualitatively and quantitatively interpreted by the methods of Griffin (1971), and Carroll (1970).

Samples 1 and 2 were treated for the removal of iron oxide by the dithionate-citrate method buffered with $NaHCO_3$, as described by Mehra and Jackson (1960). Sample 1 was run as a control, and 2 to test if this process could remove the red color of the periosteal layer. Two fractions of both samples were treated. 1a and 2a were treated once, and centrifuged. The supernatants were reserved and oriented mounts were made from the residue. 1b and 2b were treated twice, boiled in $NaCO_3$, and centrifuged. As before, the supernatant was reserved and slides prepared from the residue. X-ray diffractograms were made from these slides from 2° 2θ to 40° 2θ. These slides were also treated with ethelyene glycol, and heated to 180°C.

The supernatants were analyzed for iron content by the colorimetric potassium thiocyanate method described by Jackson (1979). This procedure was done on supernatants 1 and 2, two iron solutions of known iron content, and one blank as a control. The reference solutions were 100 ppm and 10 ppm Fe_2O_3, and were run through the same procedure so that a known concentration of iron could complex with thiocyanate for colorimetric comparison. The blank was run with distilled water as a control. The five samples were analyzed for percent transmission against the blank (assumed to be 10% T) on a Bausch and Lomb Spectronic 20 spectrophotometer with a 490mm light (Jackson, 1979).

Clay Analysis Results

Qualitative analysis of the X-ray diffractograms was carried out using criteria for identification defined by Carroll (1970) and Griffin (1971). Peaks at 15Å from untreated slides that expanded to approximately 17Å after glycolation, and collapsed after heating were identified as smectite. The 10Å peak that showed no change with treatments was identified as glauconite or illite. Strong peaks at 7 Å and 3.57Å were identified as kaolinite. Wermund (1961) notes that chamosite will also show a 7Å peak and is a common constituent of Gulf Coast sediments. Differentation between these two minerals is beyond the scope of this investigation. Calcite showed peaks at 3.03Å in the same samples. Broad variation is seen between samples in the intensity of the 3.34Å quartz peak. This was sometimes masked by a broad band of peaks between 3.0Å and 3.4Å which is felt to indicate the presence of mixed layered clays.

The results of quantitative analysis of the diffractograms are presented in Table 6. Smectite is the major constituent of most samples, usually followed by kaolinite. The percentage of glauconite shows a wide range of variation. Chlorite is usually the constituent in lowest abundance.

The test for iron content of the periosteal layer was inconclusive. Periosteal clays treated with dithionate-citrate solutions showed no perceptible change in color after two treatments. Diffraction patterns show a large reduction in the percentage smectite in the treated samples (except for 2b), but this could be due to sampling error. The diffraction patterns of 2 and 2b are virtually identical, qualitatively. No qualitative changes were noted in the diffraction patterns between the dithionite-treated samples, and the samples that underwent treatment for quantitative analysis.

The reserved supernatants from the dithionite-citrate test had visible concentration of Fe 0. Sample 2 appeared to have more iron than sample 1 (as would be expected). The potassium thiocyanate test for colorimetric iron analysis was inconclusive.

Discussion

Mineralogical analysis of marine clays can yield information on the continental source of the detrital fraction of the sediments and the prevailing climatic conditions in the source area. The identification of the authigenic components can provide information on the physical and biological conditions of the environment of deposition. The validity of such interpretation as applied to ancient sediments hinges on the differentiation of authigenic from diagenetic changes. Chamley (1978), in an analysis of Mesozoic and Cenozoic clay sedimentation in the Atlantic, found smectite decreasing in abundance with time. He relates this to a diminution of chemical weathering, and an overall cooling trend through the Cenozoic. Chamley (1978) feels that most smectites in old sediments originate from a terrigenous supply (principally soil erosion) rather than a submarine volcanogenic origin as has been proposed. Well-crystalized Paleogene smectite from the Bay of Biscay to Cape Verde Basin was related to pedogenic smectite now forming in hot climates characterized by seasonal rainfall (Chamley, 1978).

Much has been written on the phenomenon of differential sedimentation of smectite in relation to other clay minerals. The often cited work of Whitehouse et al. (1960) demonstrated that illite and kaolinite show rapidly increased settling velocity at a chlorinity of less than 2 parts per thousand, while the settling rate of montmorillonite increased only slightly with an increased chlorinity (Fig. 13). This principle was experimentally confirmed and demonstrated to occur off the Niger River delta by Porrenga (1967a). In a mineral suite dominated by kaolinite and montmorillonite, Porrenga (1967a:55) found higher concentrations of kaolinite deposited nearshore and "relatively much

TABLE 6. RESULTS OF QUANTITATIVE ANALYSIS

SAMPLE	PERCENT COMPOSITION			
	Kaolinite	Chlorite	Illite	Smectite
1	24.4	13.5	18.3	43.8
2	28.7	12.2	27.2	31.9
3	28.2	14.9	39.4	17.5
4	28.3	8.1	57.8	5.81
5	34.0	10.5	47.6	7.95
1a	31.4	13.1	48.3	6.9
1b	28.9	12.8	49.6	8.7
2a	30.2	12.1	52.9	4.8
2b	28.1	11.3	40.0	19.6

montmorillonite in quiet-water environments, i.e. generally offshore in deeper water." He continues, "For most parts of the submarine delta, the distribution can be explained by differential sedimentation in moving water."

An increase in the abundance of montmorillonite and decrease in kaolinite and 10Å mica in the sediments moving away from the mouth of the Amazon River was seen by Gibbs (1977). He explained this as a phenomenon of differential sedimentation based on grain size rather than differential flocculation tendency. Gibbs (1977) claims that the experiments of Whitehouse et al. (1960) are inapplicable to natural systems because pure API clay samples were used. This assertion seems unfounded when the extensive list of samples tested by Whitehouse et al. (1960) is reviewed. He feels that metallic and organic coatings on naturally occurring clay grains negate the surficial electrostatic changes that Whitehouse et al. (1960) see as responsible for differential sedimentation. However, Porrenga (1967a), in his duplication of Whitehouse's experiments, used natural clays from the Niger River delta and came to the same conclusions. While Gibbs assertions seem intuitively valid, they do not appear to hold up. Despite this, it seems reasonable that both differential flocculation and grain size seggregation both contribute to the phenomenon of differential sedimentation.

It is probable that this phenomenon is responsible for the predominance of smectite in the sediments tested from Montgomery Landing and elsewhere in the upper Jackson Group. The environment of deposition of the Yazoo has been seen by most authors as quiet, continental shelf sea well offshore. An increase in kaolinite would be expected around the Fayette delta system provided that kaolinite was available as source material. Mineralogical analysis of the North Twistwood Creek Clay Member of the Yazoo Formation in Choctaw County, Alabama, yielded the following results: 50% montmorillonite, 30% quartz, 10% kaolinite, 5% illite, 2-3% iron oxide (Clarke, 1970). These data show that the mineralogical composition of the North Twistwood Creek member is similar to other Yazoo samples tested, but different from the samples analyzed by Buck (1956). In an X-ray diffraction analysis of samples from the upper Yazoo Clay in Hinds County, Mississippi, he reports 45% kaolinite group, 30% montmorillonoid, 15% illite, and 10% non clay minerals. This discrepancy could be due to an aerial or stratigraphic concentration of kaolinite. Most samples tested in this study were collected relatively low in the section. The X-ray diffraction analysis demonstrates that there is no mineralogical difference between the periosteal clay and the other samples tested. The differences in percent composition that are seen show no definable trend. Due to the lack of mineralogical difference, another source for the coloration must be researched. The test for iron oxide staining indicated that some iron oxide is present in the periosteal layer. The lack of significant color change in the treated sample could be due to tight binding, or more iron oxide present than the two treatments of dithionite-citrate could remove. It is certain that some iron oxide was removed, and more was removed from sample 2 than sample 1.

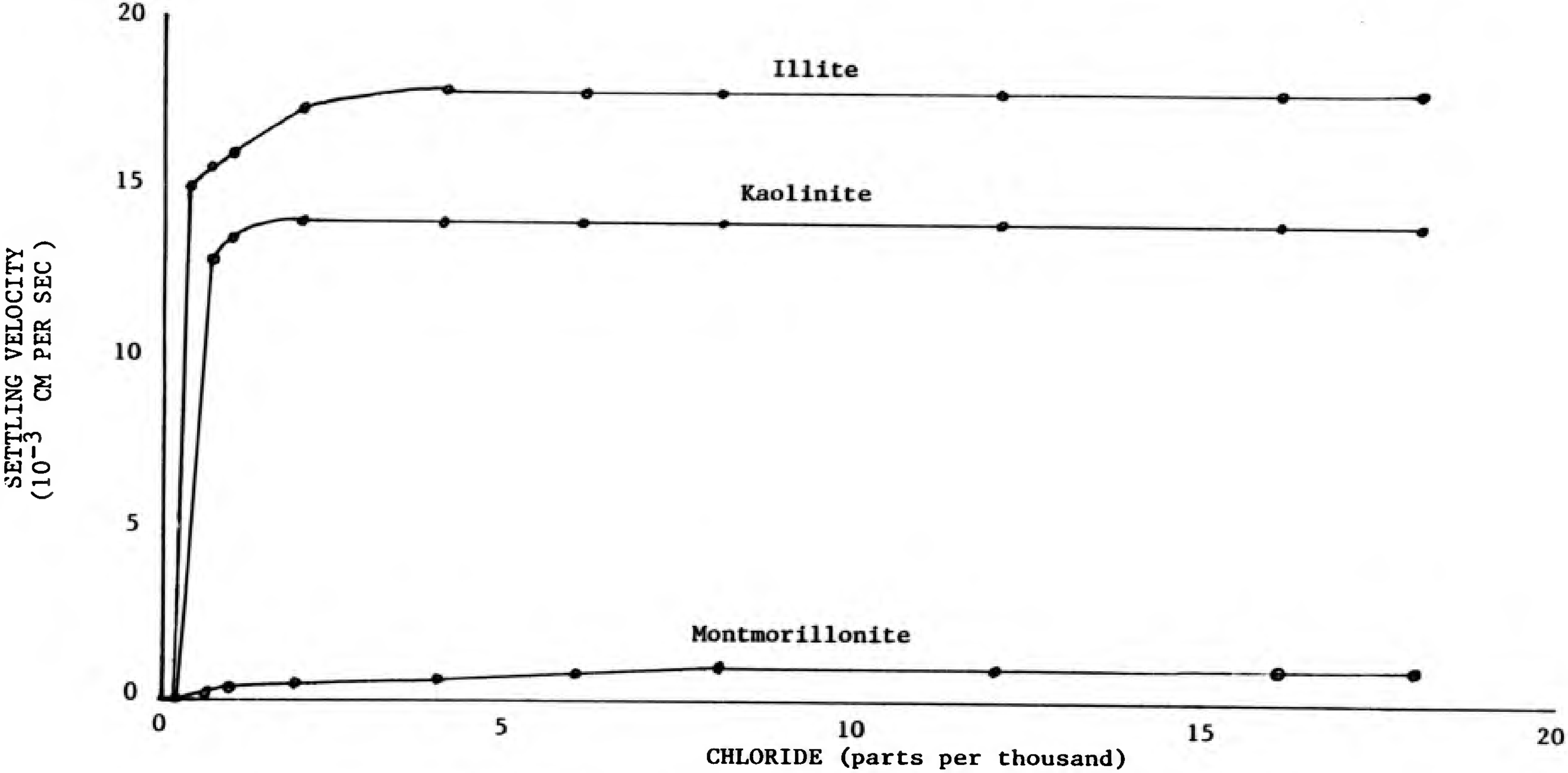

Fig. 13. Settling velocity for illite, kaolinite, and montmorillonite versus chloride concentration of the solution (after Whitehouse, et al., 1960)

Majilis (1967) found that the addition of iron to clays produced a red color. Montmorillonite was found to produce a redder color than kaolinite. It was also found that increasing pH with sodium hydroxide increased the redness further. The form of the iron was not mentioned. It was further reported that the initial iron uptake was in the form of a thin film chemically bound to the clay surface. As this film thickened, it became a surface coating independent of bonding to the clay surface. This process was not found to alter the clay structure (Majilis, 1967).

Absorption of amino acids and nucleotides was studied by Lailach, et al. (1968). It was found that absorption of these organic complexes was enhanced by a lower pH, and varied as to the type of montmorillonite involved. Absorption took place primarily by cation exchange. While it is unlikely that these organics remain, processes such as this could have been involved in the formation of the periosteal layer as it now exists.

The typical Yazoo bottom was probably a slightly reducing environment. The abundance of decaying organics surrounding the decomposing whale carcass on the sea floor would have produced a localized oxidizing environment. Much bottom life would have been attracted to this organic rich environment. Organic acids produced from protein breakdown would have lowered the pH, and facilitated the uptake of complex organic compounds. Brady (1974) summarized the reactions involved in organic decay as: (1) enzymatic oxidation, (2) release of nitrogen, phosphorus, and sulfur, (3) formation of compounds resistant to microbial breakdown. The enzymatic oxidation breaks down the complex organics, and frees the constituents. Many of these are absorbed by microbes, or they could be oxidized and form precipitates on the surface of the bone. The bone surface could provide a suitable surface for precipitation, as it was probably the only solid surface available.

The term glauconite has been used to describe a variety of different features observed mostly in sedimentary rocks of marine origin. Burst (1958) defined glauconite as iron-rich illite. Green heterogeneous pellets containing the mineral glauconite as well as other minerals will be referred to here as glauconitic pellets (after Hein, et al. 1974, and Griggs, 1974). Hein, et al. (1974), and Porrenga (1967a, and 1966f) investigated the occurrence and environmental significance of glauconite and glauconitic pellets in the marine environment. In studies on the sediments of Monterey Bay, California, Hein et al. (1974:p.569) found that the "abundance and diversity of glauconite pellets in bottom sediments is closely related to surrounding energy conditions and rates of sediment transport and deposition. Areas of high energy and sediment transport are poor in glauconite pellets. Lower energy environments show greater abundance and diversity of glauconite pellets. Hein et al. (1974) related the morphology of glauconite pellets to the parent material and mode of origin. Likely parent materials were found to be feldspar and biotite grains, fecal pellets, and clay minerals (Hein et al.,1974). The latter two are of most importance.

The environmental significance of authigenic glauconite was investigated by Porrenga (1967b). Analysis of continental shelf sediments near the Niger and Orinoco River deltas revealed glauconite developing in microfossil tests and from fecal pellets in waters 30-2000m deep. In shallower water (usually less than 40m) Porrenga (1967b) found brown and brownish-green pellets rather than the normal green glauconitic pellets. He identified these pellets as chamosite, an iron rich variety of kaolinite. Chamosite was found forming authigenically in shallow coastal waters off the deltas. This observation has importance in that pellets identified as glauconite could in many instances be chamosite and thus indicate a narrow range of environments. Also, in that chamosite is kaolinitic, reinvestigation could add to our knowledge of the provenance and climatic conditions in the source areas of some ancient marine-deltaic sediments.

The deposition of fine grain sediments is a complex process influenced by grain size, mineralogy, source environments, and environment of deposition. Small particles commonly have unsatisfied electrostatic charges on their surfaces and edges. This varies between the different clay minerals. They can also be coated with organic or metallic material from the source area which will affect their sedimentary behavior (Gibbs, 1977).

Physico-chemical flocculation, the formation of composite particles due to surficial electrostatic charges, affects clay mineral deposition. Flocculation usually occurs when the sediment is transported from fresh into saline water. It is triggered by the sudden change in ion concentration and varies depending on the type of clay involved. The phenomenon of differential sedimentation of clay minerals has been discussed above. Small charged particles bind with the dissolved ions in a sea water to satisfy the charge imbalance. The resultant aggregation of grains can settle out of suspension at the rate of fine sand. This process can increase the rate of deposition of fine grain sediments by an order of magnitude (Drake, 1976). Flocculation is most likely to occur under conditions of high sediment input and high sediment concentration.

Another process that can affect the rate at which fine sediments settle out of suspension is the agglomeration of sediments into fecal pellets by marine organisms. Filter feeding organisms filter suspended matter from the water to gather food. Most of the organic fraction is digested, and inorganic material is voided in a fecal pellet bound together with mucous, and it includes unused organic matter. These composite particles are regular in form, and like physico-chemical floccules have a higher fall velocity than individual grains. Clay minerals aggregated as fecal pellets have long been recognized as parent material for authigenic glauconite (Porrenga 1967b, Hein et al. 1974). Aggregation of grains into fecal pellets would not only be done by filter feeding organisms. Infaunal sediment feeders, along with marine invertebrates and vertebrates from all life zones make great contributions to the deposition of fine sediments. Drake (1976) cites examples where this process increased the deposition rate of fine sediments by several orders of magnitude.

Abundant pellets are present in the Moody's Branch, which accounts for early references to it as the Moody's Green Marl. The abundance of the pellets decreases up section (Fisk, 1938). Glauconitic pellets make up $< 0.01\%$ (by weight) of the sediments associated with the whale. This amount of pellets cannot account for the percentage of 10Å non-expandible clays in the sediments at the whale site. The remainder of this is probably detrital illite or non-pelletoid glauconite. The glauconitic pellets of the associated sediments appear to be mostly altered fecal pellets and infillings of microfossil tests. Low magnification examination of the pellets show few if any that exhibit cleavage traces characteristic of glauconitic pellets that originated from micaceous minerals.

4. PALEONTOLOGY

A. CALCAREOUS NANNOFOSSIL STUDY OF THE COCKFIELD FORMATION (CLAIBORNE, LATE MIDDLE EOCENE), THE MOODY'S BRANCH FORMATION AND THE YAZOO FORMATION (JACKSON, LATE EOCENE) OF MONTGOMERY LANDING, LOUISIANA*

Abstract

A study of the late Eocene (Jackson) marine sediments of the Moody's Branch Formation and the Yazoo Formation at Montgomery, Louisiana revealed the presence of about 54 species of calcareous nannofossils. The marine beds are rich in nannoflora and belong to the Discoaster tani nodifer Zone and the Isthmolithus recurvus Zone as defined by William W. Hay (1967). The extinction level of Chiasmolithus solitus (Bramlette and Sullivan 1961) may be significant.

Non-marine sediments of the late middle Eocene (Claiborne) Cockfield Formation are barren of nannofossils. The disturbed, burrowed section underlying the middle-late Eocene unconformity contains calcareous nannofossils common to the Moody's Branch Marl.

Introduction

Calcareous nannofossils, including coccolithus, discoasters, and associated planktonic algal remains, are abundant in most of the Eocene outcrop samples from Montgomery, Louisiana. Samples were collected at the classic locality on the east bank of the Red River at Montgomery Landing by Dr. W. A. van den Bold. Calcareous nannofossils from the Yazoo Formation of the late Eocene Jackson Group at the Montgomery Landing locality were originally studied by Stefan Gartner, Jr. and Lee A. Smith in 1967.

Nannofossils of similar character generally occur in Eocene marine sediments around the world. Similar nannoflora is present in the Yazoo of Mississippi (Levin, 1965), from the early Tertiary of Alabama (Levin and Joerger, 1967), from the early Tertiary of California (Bramlette and Sullivan, 1961), from Eocene sediments of northwest Germany (Haq, Bilal Ul, 1968), Tertiary of Saipan and Mariana Islands (Bramlette, 1957), late Eocene sediments from northern and central Italy (Roth, 1970), in the upper Eocene at Bath, Barbados (Bramlette and Riedel, 1954), late Eocene of Arabian Sea D.S.D.P. Leg 23 (Boudreaux, 1974), late Eocene of Australia (Rade, 1977), late Eocene of northwest Caucasus, U.S.S.R. (Hay, et al. and in many oil wells that penetrate the late Eocene section of the coastal plain of the Gulf of Mexico (personal observation).

The exposed stratigraphic section at the Montgomery Landing locality is approximately 14 meters in length and sampling extends from the

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upper Claiborne - Cockfield Formation through the lower Jackson -Moody's Branch Marl and middle to upper Jackson - Yazoo Clay Formation. Samples were obtained at 30 cm. intervals throughout the section. Samples 2-1 through 2-19 extend from the Cockfield Formation throughout the Moody's Branch Marl and the last sample (2-19) is at the base of the Yazoo Clay. Samples 4-6 through 4-23 and samples 3-16 through 3-26 are entirely within the Yazoo Clay. A sample in the short burrowed interval below the Cockfield - Moody's Branch unconformity is also included in the study.

Calcareous nannofossils are abundant throughout the sampled interval with the exception of the marginal marine Cockfield Formation. and the upper three samples in the Yazoo Formation. Burrow samples below the unconformable contact of the Cockfield and Moody's Branch formations contain abundant nannofossils of late Eocene age while the undisturbed sediments of the upper Cockfield Formation are completely barren of planktonic nannofossils. Fifty-four species of calcareous nannofossils are present in the study interval. The geological range of the study interval is relatively short, consequently only two time stratigraphic zones are represented among the many species of nannofossils. The SEM micrographs used in this study were made with an ETEC Autoscan electron microscope. Light micrographs were taken with a Zeiss Photoscope.

Previous Work On Late Eocene Nannofossil Zonations

Many nannofossil zonation schemes have been proposed for the late Eocene. One of the early proposals is that of Bronnimann and Stradner (1960), on work done in Cuba, in which the *Discoaster barbadiensis* Zone spans the entire late Eocene. *Discoaster barbadiensis* Tan Sin Hok is common throughout marine Eocene sediments of the Gulf Coast and becomes extinct at the top of the late Eocene. Hay et al. (1967) proposed two formal zones for the late Eocene and these include the *Discoaster tani nodifer* Zone and the *Isthmolithus recurvus* Zone. By Hay's definition, the *Discoaster tani nodifer* Zone includes the interval from the first occurrence of *Isthmolithus recurvus* Deflandre to the last occurrence of *Discoaster barbadiensis* Tan Sin Hok. Martini and Worsley (1970) proposed six nannofossil zones for the late Eocene and were designated NP16 - NP20. The *Discoaster tani nodifer* Zone (NP16) is at the base of late Eocene followed by *Discoaster saipanensis* Zone (NP17), *Chiasmolithus oamaruensis* Zone (NP18), *Isthmolithus recurvus* Zone (NP19), and *Sphenolithus pseudoradians* Zone (NP20).

Bukry's (1971, 1978) extensive experience with D.S.D.P. core studies from all oceans led to the establishment of still another zonal scheme for the late Eocene. The *Discoaster barbadiensis* Zone of Bukry covers the entire late Eocene and is similar to Bronnimann and Stradner's proposition, however, Bukry further subdivided the *Discoaster barbadiensis* Zone initially into two subzones, namely the *Discoaster tani tani* subzone (lower) and the *Cyclicargolithus reticulatus* subzone (upper). The *Discoaster barbadiensis* Zone is the only late Eocene nannofossil biostratigraphic zone which can be applied successfully on an international basis. The *Discoaster tani tani* subzone and the

Cyclicargolithus reticulatus subzone are reliable only in certain regions of the world. Bukry also believes that the five zones proposed by Martini and Worsley can not be successfully applied on a world wide basis because of provincialism of certain species and that his zonation scheme is the most useful one when applied universally. Bukry (1978) later revised his late Eocene subzones and substituted the Chiasmolithus oamaruensis subzone for the Discoaster tani tani Subzone and he substituted the Isthmolithus recurvus Subzone for the Cyclicargolithus reticulatus Subzone.

Stefan Gartner (1971) almost simultaneously proposed his own zonal scheme for the late Eocene. Gartner's zones, beginning with the oldest, include the Hayella situliformis Zone, the Isthmolithus recurvus Zone, the Discoaster barbadiensis Zone, and the Sphenolithus predistentus Zone. Gartner's work on the coccoliths of the Yazoo Formation of Louisiana in 1967 was predominantly taxonomic in nature and did not include biostratigraphic zonal assignments.

Late Eocene Calcareous Nannofossil Biostratigraphic Problems

It often becomes very difficult for the practical nannofossil biostratigraphers to decide on a particular zonal scheme to be utilized in a specific geological province. Six or more zonal schemes have been proposed for the late Eocene marine sediments of the world. Bronnimann's and Bukry's proposals of only one zone for the late Eocene are by far the easiest to apply on an international scale. The Discoaster barbadiensis Zone as originally described, encompasses the entire late Eocene and is the simplest to use. However, most workers desire greater stratigraphic resolution in their quest to solve correlation problems.

The five zones proposed by Martini and Worsley at first seemed to be the answer to the improvement of stratigraphic resolution in the late Eocene. Great problems exist when one attempts to use this scheme in the Gulf Coastal Province and the problems are compounded for petroleum paleontologists resorting on well cuttings for their investigations. Three of these zones, namely the tops of the Discoaster saipanensis Zone, the Chiasmolithus oamaruensis Zone, and the Isthmolithus recurvus Zone are based on the first (earliest) appearance of diagnostic nannofossil species C. oamaruensis (Deflandre), I. recurvus Deflandre, and Sphenolithus pseudoradians, Bramlette and Wilcoxon respectively. Earliest occurrences of marker species cannot be used accurately when working with ditch well cuttings because of down-hole contamination. The problem is further compounded, even when working with outcrop samples or cores, because all of the diagnostic markers are extremely rare in the Gulf Coast. Problems also exist in proper identification of various species of the Chiasmolithus lineage. The problematical, single, rare specimen of C. oamaruensis (Deflandre), illustrated in Levin and Joerger (Plate 1, Fig. 6a 1967), as noted in the Cocoa Sand at Little Stave Creek, Alabama, appears to be poorly preserved, possibly the result of reworking from older sediments.

A problem of great complexity exists with the *C. oamaruensis* Zone. As stated earlier, the boundary between the top of the *D. saipanensis* Zone and the base of the *C. oamaruensis* Zone is defined by the level of first (earliest) appearance of *C. oamaruensis* (Deflandre) and the boundary between the top of the *C. oamaruensis* Zone and the base of the *I.* Zone is defined by the level of first appearance of *I. recurvus* Deflandre. Levin and Joerger (Table 1, 1967) show the presence of *I. recurvus* Deflandre within most of the late Eocene and extending down within the Cocoa Sand where rare *C. oamaruensis* (Deflandre) is also noted. Gartner (1971), in a study of the JOIDES Blake Plateau cores, noted the rare occurrence of *C. oamaruensis* (Deflandre) in the early Eocene and rare sporadic occurrences of this species near the base of the late Eocene in his *Hayella situliformis* Zone and extending through his *Isthmolithus recurvus* Zone. Roth, et al. (1970) noted the earliest occurrence of *C. oamaruensis* at the base of the late Eocene in the Possagno section of Northern Italy and extended the upper range of this species throughout most of the early Oligocene. The type section for Martini's *C. oamaruensis* Zone is in Bavaria, Germany and due to the lack of and/or very rare and sporadic occurrence of this species in the Gulf Coast of North America, it becomes extremely difficult, if not impossible, to apply in the late Eocene section at Montgomery, Louisiana.

Okada and Thierstein (1979), provided further evidence for the invalidation of the *C. asmolithus oamaruensis* Zone in the western North Atlantic from work accomplished on Leg 43 of the Deep Sea Drilling Project. Investigations conducted on cores from Site 386 reveal concurrent or simultaneous first appearances of very rare *C. oamaruensis* (Deflandre) and *I. recurvus* Deflandre in sample (core) 12, CC, near the base of the late Eocene. It becomes obvious that without a distinct separation between the first occurrences of these two species, the *C. oamaruensis* Zone is nonexistent in the stratigraphic section of Site 386.

Calcareous Nannofossil Biostratrigraphy

Calcareous nannofossils are very abundant in most samples from the late Eocene marine section at Montgomery, Louisiana. Strew slides and a Zeiss Photoscope were used in the investigation for construction of a range chart and for age determinations. Many species of nannofossils are consistently present throughout the marine section and include *Reticulofenestra umbilica* (Levin), *Coccolithus pelagicus* (Wallich), *Coccolithus neogammation* (Bramlette and Wilcoxon), *Coccolithus eopelagicus* (Bramlette and Reidel), *Cyclococcolithina reticulata* (Gardner and Smith), *Zygrhablithus bijugatus* (Deflandre), *Blackites spinosos* (Deflandre), *Blackites tenuis* (Bramlette and Sullivan), *Discoaster barbadiensis* Tan Sin Hok, *Discoaster saipanensis* (Bramlette and Riedel), *Discoaster tani nodifer* (Bramlette and Riedel), *Cycloccolithus lusitanicus* (Black) (Hay, Mohler and Wade), *Reticulofenestra bisecta* (Hay, Mohler and Wade), *Helicopontosphaera seminulum* (Bramlette and Sullivan), *Helicopontosphaera compacta* (Bramlette and Wilcoxon) and *Transversopontis obliquipons* (Deflandre). Table 7 is a range chart which illustrates the distribution, abundance, and preservation of nannoflora in the sampled interval.

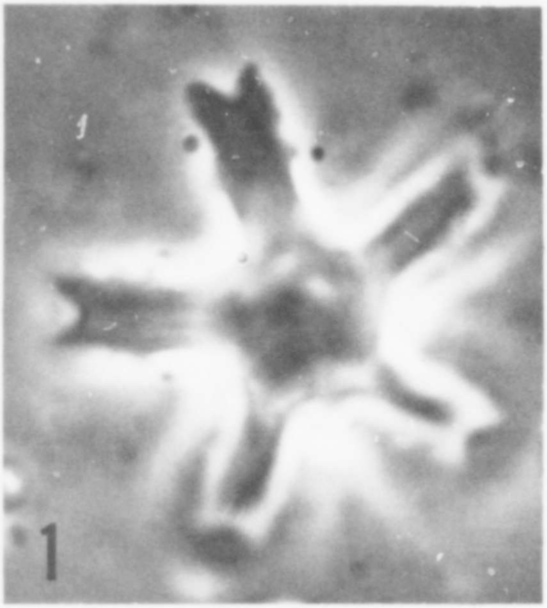
Samples 2-1 through 2-12 and the burrows sample were taken in the middle Eocene - Cockfield Formation. That portion of the Cockfield Formation is non-marine and cannot be zoned with calcareous nannofossils. The burrowed sediments within the Cockfield contain late Eocene nannofossils and are considered to be the disturbed sediments of the Moody's Branch Marl. Samples 2-13 through 2-19 and samples 4-6 through 4-12 belong to the *Discoaster tani nodifer* Zone as defined by William Hay, and these sediments are as old as the Moody's Branch Marl and the North Twistwood Creek Member of the Jackson. The boundary between the Moody's Branch Marl and the Yazoo Clay lies between samples 2-18 and 2-19. Samples 4-13 through 4-23 and samples 3-16 through 3-26 belong to Hay's *Isthmolithus recurvus* Zone as defined by the first occurrence of *I. recurvus* Deflandre. By definition, the *I. recurvus* Zone includes sediments as old as the Cocoa Sand Member, Pachuta Marl Member and Shubuta Clay Member of the late Eocene section at Little Stave Creek, Alabama. *Chiasmolithus solitus* (Bramlette and Sullivan) is a potentially useful nannofossil because it becomes extinct at a level in sample 4-12, which lies just below the first occurrence of *I. recurvus* Deflandre. *Discoaster tani nodifer* (Bramlette and Riedel) and *I. recurvus* Deflandre are illustrated in Plate 14.

PLATE 14

Figures 1, 2, & 3. Discoaster tani nodifer Bramlette and Riedel, Phase contrast, 5,000 X.

Figures 4 & 5. Isthmolithus recurvus Deflandre, SEM micrographs, 10,000 X.

Figure 6. Isthmolithus recurvus Deflandre, Phase contrast, 1,250 X.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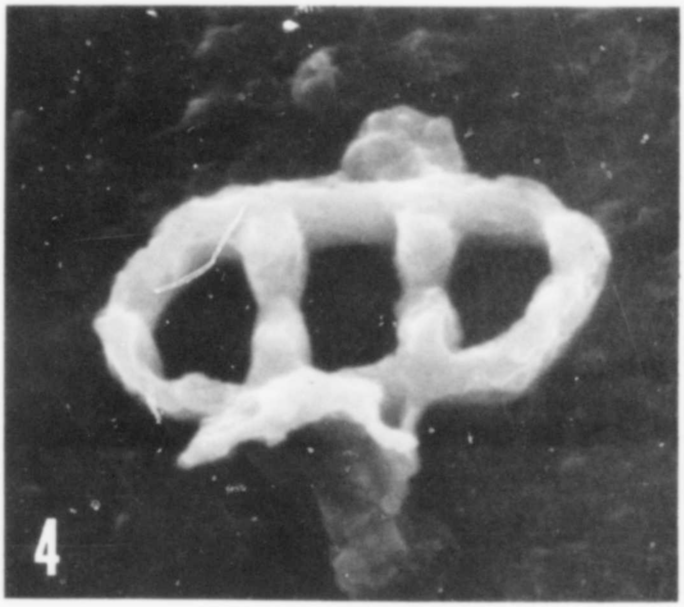
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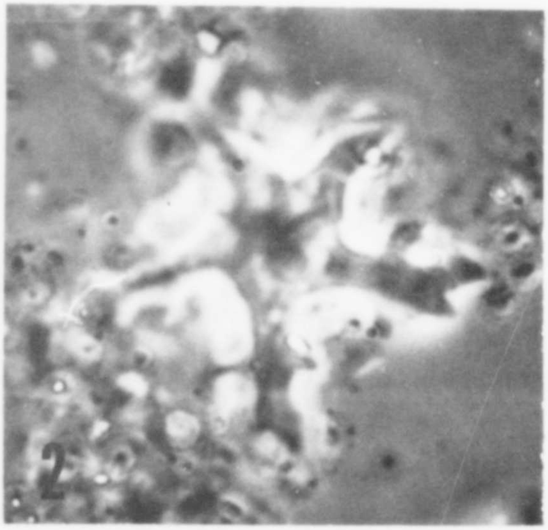
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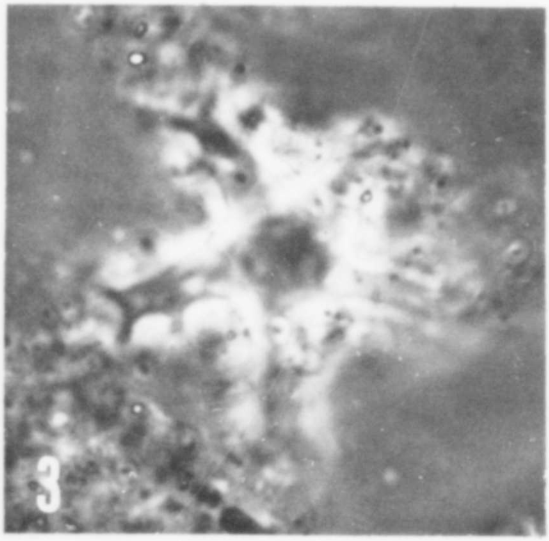
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6

SITE: Montgomery La. Red River Landing

AGE	M.E.			LATE EOCENE																																		
ZONE	Discoaster tani nodifer																Isthmolithus recurvus																					
ROCK UNIT	C.			M.B.					YAZOO																													
SAMPLE INTERVAL	2-1-12	Burrows	2-13	2-14	2-15	2-16	2-17	2-18	2-19	4-6	4-7	4-8	4-9	4-10	4-11	4-12	4-13	4-14	4-15	4-16	4-17	4-18	4-19	4-20	4-21	4-22	4-23	3-16	3-17	3-18	3-19	3-20	3-21	3-22	3-23	3-24	3-25	3-26
ABUNDANCE	B	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B
PRESERVATION		E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E		
Blackites sp.				.		.	.	.																														
Blackites spinosus		o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	●	o	o		o	o	o	.	.	●	o	o	o	o	o	o	o	o	o		
Blackites tenius		o	o	o	o	o	o	o	●	o	o	o	o	o	o	o	o	o	o	o		o	o	o	.	.	o	o	o	o	o	o	o	o	o	o		
Braarudosphaera bigelowi		o	o	.	.	●				●	●	.	.	.	.	.	.		.	.			.	.				o	.									
Braarudosphaera rosa			.		.	.										.												.										
Campylosphaera dela					.	.	.	.		.		.	.			.	.	.	.					.			.	.	.	.	.	.	.			.		
Chiasmolithus solitus		.	.	.	.	.	.	.				.		.	.	.																						
Clathrolithus ellipticus		.	.		.	.	.	.						.	.	.	.	.	.			.	.	.				.	.				.					
Coccolithus eopelagicus		o	o	●	.	.	o	o	o	.	.	●	o	o	o	o	●	.	.	.	.	o	●	o	.	.	o	o	o	o	o	o	●	o	o	o		
Coccolithus neogammation		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Coccolithus pelagicus		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	o	o	X	X	X	X	X	X	X	X	X	X		
Coccolithus sp.		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Cyclococcolithus cf. kingi		o	o	o	.	o	o	o	.	o	.	●	●	●	●	●	.	.	.	.		.	.					.	.	.	.	.	.	.	.	.		
Cyclococcolithus lusitanicus		o	o	●	.	.	o	o	o	o	o	o	o	o	o	o	o	●	.	o	.	o	o	.	●	.	o	o	o	o	o	o	o	.	.	.		
Cyclococcolithina reticulata		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Discoaster barbadiensis		●	●	o	.	.	o	o	.	o	X	o	o	o	o	o	o		.	.	.	●	o	o			.	o	o	.	.	.	o	.	●	●		
Discoaster deflandrei								.																														
Discoaster distinctus														.	.																							
Discoaster saipanensis		o	o	o	.	.	.	.	.	o	o	o	o	.	●	●	●		o	.	.	.	●	o				o	.	.	.	.	.	.	.	●		
Discoaster sp.			.												.							.	.															
Discoaster tani nodifer		.	o	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.		.		.				o	.			.	.		.	.		
Discoaster tani tani		.	o	.	.	.	.	.				.	.	.	.	.						.						.	.									
Discolithina distincta		●	.	.	.	.	.	.						.		.			.					.				.	.	.	.	.	.		.	.		
Discolithina macropora						.		.						.				.		.		.	.	.				.					.	.				
Discolithina multipora		X	●	.	.	.	.	.	.	.	.	.	.	.	.			.	.	.		.						.	.			.	.	.	.	.		
Discolithina planus		.	.	.	.	.	.	.							.	.	.		.	.					.				.			.						
Discolithina sp.		o	.	.	.	o	o	o	.	o	o	o	o	o	o	o	o	o	o	o	.	o	o	o	.	.	o	o	o	o	o	o	●	.	o	o		
Ericsonia fenestrata										.			.	.																						.		
Ericsonia subdisticha		.	.	.	.	.	.	.	.				●	.	.	.	.	.	.	.		.	.						.	.	.	●	.			.		
Helicopontosphaera compacta		.	.	.	.	.	o	o	.	.	.	.	●	●	●		.										.					.	.	.	.	.		
Helicopontosphaera reticulata																																		.		.		
Helicopontosphaera seminulum		o	o	o	o	o	o	o	●	o	o	o	X	X	X	o	o	●	o	o	.	o	o	.	.		.	o	.	.	●	●	o	o	o	o		
Isthmolithus recurvus																	.		.									.										
Koczyia wechesensis										.	.				.	.												.										
Lithostromation operosum			.				.	.	.			.	.	.			●		.	.		●	o					.	.	.	.	.	.	.	.	o		
Lithostromation perdurum		.	.				.					.	.				.						.							.	.			.	.			
Lithostromation simplex		●	.	.			.					●	.	.	.	.	.					.						.					.	.	.	.		
Markalius inversus		.	.	.														.																				
Micrantholithus attenuatus			.	.	.																		.															
Micrantholithus procerus				.		.																																
Neococcolithus dubius															.	.	.		.																			
Pemma angulatum										.																												
Pemma papillatum		.	●	.	.	.	.	.			.	.	.	.		.	.						.															
Pemma stradneri			.			.		.																														
Pentaster lisbonensis			.																																			
Reticulofenestra bisecta		o	o	●	.	.	o	o	.	.	.	.	.	.	.	.	.		.			.	.	.	.	.		.	.			.	.	.	.	.		
Reticulofenestra umbilica		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Rhabdosphaera vitrea		.	o	.	.	.	.	o	o	o	o	o	o	o	o	o	o	●	o	o		●	o	o			.	.	.	.	.	o	●	.	.	.		
Sphenolithus radians																											.											
Sphenolithus moriformis		.	.	.	.	.	o	.	.	o	o	o	o	o	o	o	.	.	o	o		●	o	●				.	.	.	.	.	.	.	o	o		
Thoracosphaera heimi			.																									.										
Transversopontis fimbriatus		.					.																													.		
Transversopontis obliquipons			●	●	.	o	o	o	.	●	o	o	o	o	o	o	.	.	.		.	o	o	●	.		●	o	o	o	o	o	o	●	o	o		
Zygrhablithus bijugatus		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		

Legend: X Abundant, o Common, ● Sparse, . Rare, A Abundant, B Barren, E Excellent preservation
C. Cockfield Formation, M.B. Moody's Branch Formation, M.E. Middle Eocene

Table 7 Distribution of nannofossils at Montgomery Landing

B. FORAMINIFERIDA

The Jacksonian Stage at Montgomery Landing is represented by a fauna in which small-sized individuals predominate. As most earlier workers examined only the larger sized wash-residues, whereas we have included in our counts all specimens that did not pass through the 230 mesh screen, this gives rise to a difference in opinion on which are the most common species. As a result of our procedure we have encountered numerous taxonomic problems, which have caused a delay in the finalizing of this work. No biostratigraphic, biogeographic, or bioecological study can be of value until we know with absolute certainty that every encountered species has received its correct name. The sheer number of species described or reported from the Jackson Eocene of Louisiana makes this task a very formidable one.

As mentioned above, most workers have described the larger and more conspicuous representatives of the foraminifera. A notable exception to this is the work by Howe and Wallace (1932) on the fauna of the Yazoo clay at Danville Landing. Because they realized the size-difference with other studies, they described many forms as new that showed only minor differences with earlier described forms. Many of these new forms have been found in the Tullos member of the Yazoo Clay Formation or Cook Mountain Formation, and now merit very careful consideration. Also they found many small forms that had been entirely missed by other workers, and that in many cases have also not been reported by later studies of the Yazoo clay. The result of this was that the Danville Landing fauna was considered as a "special case." The present investigation shows, however, that the Danville Landing fauna is almost identical to that of the Tullos member, and it turns out to be a typical Gulf Coast, shallow marine, late Eocene fauna.

Planktonic Foraminifera

Globorotalia cerroazulensis (Cole) has been reported as the dominant marker species of the upper Eocene of the Gulf Coast. Also in the present material it is one of the more common planktonic species. However, another common species *Globigerina danvillensis* has not been reported after its first description by Howe and Wallace and moreover turns out to present a taxonomic problem as it belongs to the genus *Truncorotaloides*. The small size of this species forces one to go to very high magnification in order to see the small supplementary apertures that give it its generic assignment. Whereas the two species mentioned are present throughout the outcrop at Montgomery Landing, *Porticulosphaera* semiinvoluta (Keyzer) accompanied by other species of *Porticulosphaera* and related genera, occur in the Moodys Branch and the lower part of the Yazoo Formation, indicating that these beds belong to the *Porticulosphaera semiinvoluta* zone, which is regarded on a world-wide basis as to the lowermost zone of the Upper Eocene. In Blow's letter classification of stratigraphic zones (Blow, 1969) it received number P 15.

Above the level of extinction of *Porticulosphaera semiinovoluta* to the level of extinction of *Globorotalia cerroazulensis* we find the

Globorotalia cerroazulensis zone, which comprises most of the upper part of the upper Eocene. Blow (1969) has replaced this zone by his Cribrohantkenina inflata zone, based on the total stratigraphic range of the nominate species. (zone P 16 of Blow). At Montgomery Landing, we do not find good representatives of C. inflata, but only large individuals with inflated last chambers, which may still belong to the population of Hantkenina alabamensis. Steineck (1971) presents a case for invalidation of the genus Cribrohantkenia, if we use phylogeny as the basis for taxonomic distinction. The supplementary apertures on the septal face, which give this genus its name, are a morphological novelty and are therefore not sufficient for establishing a new genus. However, at Montgomery Landing, where Hantkenina alabamensis occurs throughout the section, we find these specimens with inflated chamber, sometimes with circular depression on the septal face, but never with cribrate apertures, just above the extinction of P. semiinvoluta, but also, on one occasion, below this level (section 4 sample 5). We therefore believe that these are precursors of the real C. inflata, and that the upper part of the Yazoo Formation (Tullos member) could represent this zone. Nevertheless, we prefer to use the name Globorotalia cerroazulensis zone instead for this upper part of the outcrop. For distribution of the planktonic markers see Table 8. The planktonic foraminifera of Montgomery Landing form a "dwarfed" fauna in which small individuals predominate. This dwarfism is probably due to environmental conditions, but to a certain extent could also be an artifact of our procedure of using smaller screen size for washing samples than previous workers. Environmentally, it would mean that we are dealing with a protected bay fauna and not with one that was constantly in connection with open oceanic waters. Under those conditions planktonic foraminifera are washed in by tides, but are not living at optimal conditions. Although the fauna is strongly Jacksonian in character, a few characteristic Claiborne (middle Eocene) species persist, e.g., Pseudohastigerina cf. wilcoxensis and Cassigerinella winniana.

Benthic Foraminiferia

As can be seen from the list of species (Table 49) a great number of benthic foraminifera has been reported from the upper Eocene of Central Louisiana. Many of these actually are from Montgomery Landing. Again, it should be pointed out, that in most of the reports the emphasis was on the larger species. Also the generic name of many of these species has changed since the day of reporting as more precise diagnoses of the genera were published. It turns out that many of the Louisiana species did not conform exactly to the new generic descriptions as these genera were defined; for instance, by Loeblich and Tappan (1964) in the Treatise volume on Foraminiferida. As in the present study the emphasis is laid on the total fauna contained in the 230 mesh screen sieve, the number of small specimens greatly predominate over the larger ones. Thus, it happens that a count of 300 specimens fails to include some of the larger forms that have been reported previously from the same localities. As many of the Yazoo faunas abound in small specimens and species and, as the size of individuals has no bearing on their stratigraphic or ecologic importance, the latter approach is scientifically more valid and should be preferred over the classic approach, using only larger and more conspicuous species. However, it makes a direct comparison with earlier studies often somewhat hazardous.

Order FORAMINIFERIDA Eichwald, 1830
Suborder TEXTULARIINA Delage and Herouard, 1896
Superfamily LITUOLACEA de Blainville, 1826
Family TEXTULARIIDAE Ehrenberg, 1838
Subfamily SPIROPLECTAMMININAE Cushman, 1927
Genus SPIROPLECTAMMINA Cushman, 1927
SPIROPLECTAMMINA MISSISSIPPIENSIS (Cushman)
LSU Mus. No. 10400

Textularia mississippiensis Cushman, 1922, p. 90, pl. 14, fig. 4.
Spiroplectammina mississippiensis (Cushman)--Cushman and Todd, 1945, p. 80, pl. 13, fig. 1.

Subfamily TEXTULARIINAE Ehrenberg, 1838
Genus TEXTULARIA DeFrance in de Blainville, 1824
TEXTULARIA ADALTA Cushman, 1926
LSU Mus. No. 10401

Textularia adalta Cushman, 1926, p. 29, Plate 4, Figs. 2a, b.

TEXTULARIA DIBOLLENSIS Cushman and Applin, 1926
LSU Mus. No. 10402

Textularia dibollensis Cushman and Applin, 1926, p. 165, Plate 6, Figs. 12-14.

TEXTULARIA HOCKLEYENSIS Cushman and Applin, 1926
LSU Mus. No. 10403

Textularia hockleyensis Dumble (nomen nudum), 1924, p. 443.
Textularia hockleyensis Cushman and Applin, 192, p. 164, Plate 6, Figs. 3-6.

TEXTULARIA SPP.

Remarks: Under *Textularia spp*. are probable juvenile individuals of *Textularia cuyleri* (?) Davis of Bergquist (1942), *Textularia dibollensis* Cushman and Applin var. *humblei* Cushman and Applin, *Textularia* sp.

Bergquist (1942) and, perhaps, *Textularia danvillensis* Howe and Wallace.

Suborder MILIOLINA Delage and Herouard, 1896
Family MILIOLIDAE Ehrenberg, 1839
Subfamily QUINQUELOCULININAE Cushman, 1917
Genus QUINQUELOCULINA d'Orbigny, 1826
QUINQUELOCULINA SP. cf. Q. IMPRESSA Reuss
LSU Mus. No. 10404

Quinqueloculina impressa Reuss, 1851, p. 8ff, Plate f, Figs. 59 a-c. Specimens from Montgomery Landing are more inflated or rotund in appearance than the *Q. impressa* of Reuss.

QUINQUELOCULINA SP. A.
LSU Mus. No. 10405

Diagnosis: This species of *Quinqueloculina* has broadly rounded chambers (non-carinate), the test viewed dorsally is broadly triangular. No ornamentation has been observed; small pits occur sporadically on the test. The aperture is round, raised on a short neck and has a low, simple tooth. Maximum length is about 3 times the maximum width.

QUINQUELOCULINA SP. B
LSU Mus. No. 10406

Diagnosis: This species of *Quinqueloculina* is compressed, unornamented, with sharply angled chamber margins. The aperture is small and round; raised upon a long, tapering neck. The aperture has a small, bifid tooth. Maximum width is about 1/2 the total length of the test, giving it a broad appearance.

Genus MASSILINA Schlumberger, 1893
MASSILINA PRATTI Cushman and Ellisor
LSU Mus. No. 10407

Massilina sp. (?) Cushman and Applin, 1926, p. 185, Plate 10, figs. 25-27. *Massilina pratti* Cushman and Ellisor, 1931, p. 53, Plate 7, Figs. 4a-c. Remarks: *Massilina cookei* Cushman (1935) may be synonymous to *M. pratti*.

Genus TRILOCULINA d'Orbigny, 1826
TRILOCULINA TRIGONULA (Lamarck)
LSU Mus. no. 10408

Miliolites trigonula Lamarck, 18, p. 351.
Triloculina trigonula d'Orbigny, 1826, p. 299, Plate 1, Figs. 5-9.

Suborder LAGENINA Delage & Herouard, 1896
Superfamily NODOSARIACEA Ehrenberg, 1838
Family NODOSARIINAE Ehrenberg, 1838
Subfamily NODOSARIINAE Ehrenberg, 1838
Genus NODOSARIA Lamarck, 1812
NODOSARIA SP. cf. N. PYRULA d'Orbigny
LSU Mus. No. 10409

Nodosaria cf. *pyrula* d'Orbigny, 1826, p. 253.

Genus LAGENA Walker & Jacob, 1798
LAGENA GRACILICOSTA Reuss
LSU Mus. No. 10410

Lagena gracilicosta Reuss, 1858, p. 434 (nomen.).

LAGENA HISPIDA Reuss
LSU Mus. No. 10411

Lagena hispida Reuss, 1858, p. 434 (nomen).
Lagena concinna Reuss, 1858., p. 434 (nomen).
Lagena hispida Reuss, 1863, p. 335, Plate 6, Figs. 77-79.

Genus LENTICULINA Lamarck, 1804
LENTICULINA ARTICULATA (Reuss) var. *TEXANA* (Cushman and Applin).
LSU Mus. No. 10412

Cristellaria articulata Reuss var. *texana* Cushman and Applin, 1926, p. 170, Plate 8, Figs. 1-2.

Lenticulina articulata (Reuss) var. *texana* Howe & Wallace, 1932, p. 31, Plate 5, Figs. 1-2.

Robulus articulatus (Reuss) var. *texanus* Ellisor, 1933, Plate 2, Fig. 3.

Robulus articulatus (Reuss) var. *texanus* (Cushman & Applin), 1935, p. 16, pl. 4, figs. 16-17.

LENTICULINA JUGOSA (Cushman & Thomas)
LSU Mus. No. 10413

Robulus jugulosa Cushman & Thomas, 1930, p. 36, pl. 3, figs. 4a-b.

LENTICULINA SP. A
LSU Mus. No. 10414

Diagnosis: This species has a thick, low keel; smoothly rounded apertural face. There are 5-6 chambers visible. Sutures are narrow and depressed; gently recurved. The periphery is mildly lobate. Umbilici are covered by a small, clear, stellar-shaped boss. Chambers have a slightly inflated appearance. Maximum diameter: Mm not yet determined.

LENTICULINA SP. B
LSU Mus. No. 10415

Diagnosis: Test of this species is small; 6 chambers separated by slightly thickened sutures. Umbilici covered by flush, stellar-shaped, translucent boss. There is a prominent, thin keel which terminates at the suture of the ultimate and penultimate chambers. Apertural face bordered by low carinae.

LENTICULINA SP. C.
LSU Mus. No. 10416

Diagnosis: This species is very similar in form to Lenticulina jugosa (Cushman and Thomas) except that it is very small and has a prominent, blade-like keel terminating at the suture of the ultimate and penultimate chambers. There is no ornamentation and only a poorly developed, stellar-shaped boss-like area over the umbilical areas. Also very similar to Lenticulina sp. B. (above), but broader.

Genus MARGINULINOPSIS Silvestri, 1904
MARGINULINOPSIS FRAGORIA (Gumbel) var. TEXASENSIS (Cushman and Applin).
LSU Mus. No. 10417

Cristellaria fragaria Gumbell var. texasensis Cushman and Applin, 1926, p. 171, Plate 8; Figs. 5-7.
Lenticulina fragaria (Gumbel) var. texasensis Howe and Wallac-, 1932, p. 32, Plate 5, figs. 3-5.
Marginulina fragaria (Gumbel) var. texasensis Ellisor, 1933, pl. 2, fig. 4; 1935, p. 19, Plate 7, Figs. 8-10.

Genus SARACENARIA DeFrance, 1824
SARACENARIA SP.
LSU Mus. No. 10418

Diagnosis: The test of this species is smooth, possesses six visible chambers and a boss flush with the test surface. There is a thick, short keel; the apertural face is carinate on its outer margins. This species is narrower than the concomitant *S. parva* Hussey.

Family POLYMORPHINIDAE d'Orbigny, 1839
Subfamily POLYMORPHINIDAE d'Orbigny, 1839
Genus GUTTULINA d'Orbigny in de la Sagre, 1839
GUTTULINA SP. cf. G. CONSOBRINA (Fornasini)
LSU Mus. No. 10419

Polymorphina sororia consobrina Fornasini, 1900-1902, p. 69, Fig. 21.

Globulina consobrina Cushman and Ozawa, 1930, p. 5, Plate 21, Figs. 6a-c.

Globulina ampulla Bergquist, not Jones, 1942, p. 55, Plate 6, Fig. 10.

Guttulina consobrina (Fornasini) - Bandy, 1949a, p. 69, Plate 1, Figs. 7a-c.

Remarks: Like the *Guttulina sp.* Bandy (1949a) this group of specimens are "...young form(s) which (have) not yet acquired sufficient adult characters to be determined."

Genus SIGMOMORPHINA Cushman & Ozawa, 1928
SIGMOMORPHINA JACKSONENSIS (Cushman)
LSU Mus. No. 10420

Polymorphina jacksonensis Cushman, 1926, p. 36, Plate 5, Figs. 5a-b.

Polymorphina compressa Nuttall (not d'Orbigny), 1928, p. 93, Plate 6, Figs. 18-19.

Sigmomorphina jacksonensis Cushman and Ozawa, 1930, p. 123, Plate 32, Figs. 2a-b.

Family GLANDULINIDAE Reuss, 1860
Subfamily GLANDULININAE Reuss, 1860
Genus GLANDULINA d'Orbigny in de la Sagra, 1839
GLANDULINA OCCIDENTALIS (Cushman)
LSU Mus. No. 10421

Glandulina laevigata occidentalis (Cushman) - Toulmin, 1941, p. 595, Plate 80, Figs. 12-13.

Glandulina occidentalis (Cushman) - Bandy, 1949a, p. 79, Plate 6, Figs. 14a-b.

Subfamily OOLININAE Loeblich & Tappan, 1961
Genus OOLINA d'Orbigny, 1839
OOLINA SP.
LSU Mus. No. 10422

Diagnosis: This species is small with a smooth, very thin test. The entosolenian tube is scarcely visible.

Suborder ROTALIINA Delage & Herouard, 1896
Superfamily ROBERTINACEA Reuss, 1850
Family ROBERTINIDAE Reuss, 1850
Genus ROBERTINA d'Orbigny, 1846
ROBERTINA MCQUIRTI Howe
LSU Mus. No. 10423

Robertina mcquirti Howe, 1939, p. 82, Plate 8, Figs. 23-24.

ROBERTINA PLUMMERAE Cushman & Parker
LSU Mus. No. 10424

Robertina plummerae Cushman and Parker, 1938, p. 75, Plate 16, Fig. 1.

Superfamily BULIMINACEA Jones, 1875
Family TURRILINIDAE Cushman, 1927
Genus TURRILINA Andreae, 1884
TURRILINA QUADRALOCULA (Bergquist)
LSU Mus. No. 10425

Rotaliatina quadralocula Bergquist, 1942, pp. 86, 134; Plate 8, Figs. 27-29.

TURRILINA ROBERTSI (Howe & Ellis)
LSU Mus. No. 10426

Bulimina robertsi Howe and Ellis in Howe, 1939, p. 63, Plate 8, Figs. 32-33.
Rotaliatina quadralocula Bergquist var. *elongata* Bergquist, 1942, p. 87, Plate 8, Fig. 30.
Buliminella robertsi (Howe & Ellis) Cushman & Herrick, 1945, 64, Plate 10, Fig. 15.

Turrilina robertsi: (Howe & Ellis) Todd & Knicker, 1952, p. 19, Plate 4, Fig. 8.

Subfamily BULIMINELLINAE Hofker, 1951

Genus BULIMINELLA Cushman, 1911
BULIMINELLA ELEGANTISSIMA (d'Orbigny)
LSU Mus. No. 10427

Bulimina elegantissima d'Orbigny, 1839, p. 51, Plate 7, Figs. 13-14.
Buliminella elegantissima (d'Orbigny) Cushman, 1911, p. 89.

Remarks: The species at Montgomery Landing is similar to *B. elegantissima* (d'Orbigny) forma B of Poag (1966) and *B. marylandica* Nogan *(1964)*.

Family BOLIVINITIDAE Cushman, 1927
Genus BOLIVINA d'Orbigny, 1839
BOLIVINA GRACILIS Cushman & Applin
LSU Mus. No. 10428

Bolivina gracilis Cushman & Applin var. *danvillensis* Howe & Wallace, 1932, p. 57, pl. 11, fig. 7.

Bolivina danvillensis Howe & Wallace, ibid, p. 56, Plate 11, Figs. 8a-b.

Remarks: Holotypes of *B. gracilis* var. *danvillensis* (LSU Museum no. 651) and *B. danvillensis* (LSU Museum no. 704) were examined and determined to be late growth stages of *Bolivina gracilis* Cushman and Applin. The early portions of the test of *B. danvillensis* are broken off.

BOLIVINA JACKSONENSIS Cushman and Applin
LSU Mus. No. 10429

Bolivina jacksonensis Cushman and Applin, 1926, p. 167, Plate 7, Figs. 3-4.

Remarks: The holotype of *Bolivina taylori* (LSU Museum no. 128) Howe has been examined and appears to be a small specimen of this species. The *B. jacksonensis* (USNM cc 5383) of Montgomery Landing are often less compressed than the holotype.

BOLIVINA PLICATELLA Cushman
LSU Mus. No. 10430

Bolivina plicatella Cushman, 1930, p. 46, Plate 8, Figs. 10a-b.

Bolivina thomsoni Howe, 1939, p. 68, Plate 8, Figs. 25-26.

Remarks: Holotype of B. thomsoni examined, LSU museum no. 133.

Genus BRIZALINA Coasta, 1856
BRIZALINA BEYRICHI (Reuss)
LSU Mus. No. 10431

Bolivina beyrichi Reuss, 1851, p. 83, pl. 6, figs. 51a-b.

BRIZALINA SP.
LSU Mus. No. 10432

Diagnosis: Test very finely porous; compressed slightly; chamber margins are rounded (non-carinate) and test sides become parallel in later stages. End is rounded. Sutures are thickened and distinct, thickest near central suture line. Very close to B. beyrichi in appearance, except for lack of spines. Length: 170 mm; width: 60mm.

BRIZALINA ? SP.
LSU Mus. No. 10433

Diagnosis: The texture of the test is finely porous; fine striae span the length of the test uninterrupted. The periphery is rounded and smooth (not lobate). Sutures are thickened but sometimes obscured by the test texture. The final chamber is rarely found intact. Test is long (about 4 times maximum width) and rapidly tapers. Length: 200 mm; Width: 50 mm.

Family ISLANDIELLIDAE Loeblich & Tappan, 1964
Genus CASSIDULINOIDES Cushman, 1927
CASSIDULINOIDES HOWEI Cushman
LSU Mus. No. 10434

Cassidulinoides brazilensis (Cushman) - Howe and Wallace, 1932, p. 72, Plate 10, Fig. 6.

Cassidulinoides howei Cushman, 1946, p. 36, Plate 7, Figs. 9-10.

Family BULIMINIDAE Jones, 1875
Subfamily BULIMININAE Jones, 1875
Genus GLOBOBULIMINA Cushman, 1927
GLOBOBULIMINA PYRULA (d'Orbigny)
LSU Mus. No. 10435

Bulimina pyrula d'Orbigny, p. 184, Plate 11, Figs. 9-10.

Genus STAINFORTHIA Hofker, 1956
STAINFORTHIA BIFORMATA (Bandy)
LSU Mus. No. 10436

Buliminella sp. Bergquist, 1942, p. 65, Plate 7, Figs. 1-6.
Buliminella biformata Bandy, 1949, p. 138, Plate 26, Figs. 2a-b.

Family UVIGERINIDAE Haeckel, 1894
Genus UVIGERINA d'Orbigny, 1826
UVIGERINA COCOAENSIS Cushman
LSU Mus. No. 10437

Uvigerina cocoaensis Cushman, 1925, p. 68, Plate 10, Fig. 12.

UVIGERINA DANVILLENSIS Howe & Wallace
LSU Mus. No. 10438

Uvigerina danvillensis Howe & Wallace, 1932, pp. 62-63; Plate 12, Fig. 5.

UVIGERINA GARDNERAE Cushman
LSU Mus. No. 10439

Uvigerina gardnerae Cushman, 1926, p. 175, Plate 8, figs. 16-17.

UVIGERINA JACKSONENSIS Cushman
LSU Mus. No. 10440

Uvigerina jacksonensis Cushman, 1925, p. 67, Plate 10, Fig. 13.

UVIGERINA YAZOOENSIS Cushman
LSU Mus. No. 10441

Uvigerina yazooensis Cushman, 1933, p. 13, pl. 1, fig. 29.

Genus SAGRINA d'Orbigny in de la Sagra, 1839
SAGRINA MAURICENSIS (Howe)
LSU Mus. No. 10442

Gaudryina sp. Cushman, 1922, p. 127, Plate 29, Fig. b.
Bitubulogenerina sp. Howe, 1934, p. 421, Plate 51, Figs. 6a-b.
Bitubulogenerina sp. Howe, 1934, Plate 51, Fig. 4.
Bitubulogenerina howei Cushman, 1935, p. 20, Holotype of *S. mauricensis* examined, LSU Museum no. 751.

SAGRINA MONTGOMERYENSIS (Howe)
LSU Mus. No. 10443

Bitubulogenerina montgomeryensis Howe, 1934, p. 421, Plate 51, Figs. 9a-b. Holotype examined, LSU Museum no. 752.

Genus TRIFARINA Cushman, 1923
TRIFARINA WILCOXENSIS (Cushman & Ponton)
LSU Mus. No. 10444

Pseudouvigerina wilcoxensis Cushman & Garret, 1932, p. 66, Plate 8, Figs. 18a-b.
Angulogerina wilcoxensis Cushman & Garret, 1939, p. 84, Plate 14, Figs. 24-25.
Trifarina wilcoxensis (Cushman & Ponton) - Bandy, 1949, p. 145, Plate 27, Figs. 11a-b.

Superfamily DISCORBACEA Ehrenberg, 1838
Family DISCORBIDAE Ehrenberg, 1838
Subfamily DISCORBINAE Ehrenberg, 1838
Genus EOEPONIDELLA Wickenden, 1949
EOEPONIDELLA MEYERHOFFI Seiglie
LSU Mus. No. 10445

Discorbis ? hemisphaerica Cushman - Howe, 1939, p. 73, Plate 10, Figs. 16-19.
Discorbis hemisphaericus Cushman - Bandy, 1949, p. 96, Plate 16, Figs. 2a-b.
Eoeponidella meyerhoffi Seiglie, 1964, pp. 7-8, Plate 2, Figs. 1-7.

Remarks: *Eoeponidella meyerhoffi* Seiglie may be an ecopheno-type of *Eoeponidella hemisphaerica* (Cushman). The prominent difference between Seiglie's figured specimens and that of Cushman is in the presence of umbilical bosses in the former. The umbilical boss is variable in size in Seiglie's syntypes. In the event that *E. meyerhoffi* and *E. hemisphaerica* are the same, Cushman's (1931) species has seniority.

Genus EPISTOMINELLA Husezima & Maruhasi, 1944
EPISTOMINELLA DANVILLENSIS (Howe and Wallace)
LSU Mus. No. 10446

Pulvinulina danvillensis Howe and Wallace, 1932, p. 71, Plate 13, Figs. 7a-c.

Genus PIJPERSIA
Thalmann, 1954
PIJPERSIA GLOBULPINOSA (Cushman)
LSU Mus. No. 10447

Discorbis globulo-spinosa Cushman, 1933, p. 14, Plate 2, Figs. 1a-c.
Discorbis (?) *globulo-spinosa* Cushman-Howe, 1939, p. 73, Plate 10, Figs. 23-24.
Asterigerinata globulospinosa (Cushman) - Bermudez, 1952, pp. 201-210, Plates 1-3.

PIJPERSIA PETALIFERA (Howe)
LSU Mus. No. 10448

Bulimina (?) *petalifera* Howe, 1939, p. 63, pl. 9, figs. 22-23.

Remarks: Holotype observed, LSU Mus. No. 136.

Family EPONIDIDAE Hofker, 1951
Genus NEOEPONIDES Reiss, 1960
NEOEPONIDES JACKSONENSIS (Cushman & Applin)
LSU Mus. No. 10449

Pulvinulina jacksonensis Cushman and Applin, 1926, p. 181, Plate 9, Figs. 24-25.
Eponides jacksonensis (Cushman & Applin) - Cushman, p. 46, Plate 19, Figs. 4-8.

Remarks: Holotype examined, USNM cc 5373.

Family SIPHONINIDAE Cushman, 1927
Genus Siphonina Reuss, 1850
SIPHONINA JACKSONENSIS Cushman & Applin
LSU Mus. No. 10450

Siphonina jacksoni Dumble, 1924, (nomen nudum), p. 443.
Siphonina jacksonensis Cushman & Applin, 1926, p. 180, Plate 9, Figs. 20-23.
Siphonina claibornesis Cushman, 1927, p. 4, Plate 3, Figs. 5a-c.
Siphonina lamarkana Cushman, 1927, ibid, p. 3, Plate 3, Figs. 3a-c.
Siphonina carltoni Cushman and Ellisor, 1932, p. 42, Plate 6, Figs. 5a-c.

Siphonina danvillensis Howe and Wallace, 1932, p. 70, Plate 13, Figs. 1a-b.

Remarks: Holotypes of *Siphonina danvillensis* LSU Museum no. 600, and *S. jacksonensis* USNM cc 5368 were compared for this study. J. B. Wharton (unpublished thesis 1935), examined holotypes of *S. jacksonensis* and *S. clairbornensis* and found them to be the same species.

Family CIBICIDIDAE Cushman, 1927
Subfamily CIBICIDINAE Cushman, 1927
Genus CIBICIDES de Montfort, 1808
CIBICIDES PSEUDOUNGERIANUS (Cushman)
LSU Mus. No. 10451

Truncatulina ungeriana Brady, 1884, Plate 94, Figs. 9a-c.
Truncatulina pseudoungeriana Cushman, 1922, pp. 97, 136; Plate 20 Fig. 9.
Cibicides pseudoungerianus (Cushman) - Cushman, 1935, p. 52, Plate 23, Figs. 1a-c.

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones, 1862
Family HETEROGELICIDAE Cushman, 1927
Subfamily HETEROHELICINAE Cushman, 1927
Genus CHILOGUEMBELINA Loeblich & Tappan, 1956
CHILOGUEMBELINA SPP.

Remarks: Abundant specimens of *Chiloguembelina* are found throughout the section at Montgomery Landing.

Family HANTKENINIDAE Cushman, 1927
Subfamily HASTIGERININAE Bolli, Loeblich & Tappan, 1957
Genus PSEUDOHASTIGERINA Banner & Blow, 1959
PSEUDOHASTIGERINA DANVILLENSIS (Howe and Wallace)
LSU Mus. No. 10452

Nonion danvillensis Howe & Wallace, 1932, p. 51, Plate 9, Figs. 3a-b.
Nonion wilcoxensis Cushman & Ponton, 1932, p. 64, Plate 8, Fig. 11.
Hasterigerina eocenica Berggren, 1960, pp. 85-91, Plate 5, Figs. 1-2; Plate 10, Fig. 2.
Pseudohastigerina wilcoxensis (Cushman & Ponton) - Berggren, Olsson & Reyment, 1967, pp. 278-280, Figs. 2-6.

Subfamily HANTKENININAE Cushman, 1927
Genus HANTKENINA Cushman, 1924
HANTKENINA ALABAMENSIS Cushman
LSU Mus. No. 10453

Hantkenina alabamensis Cushman, 1925, p. 3, Fig. 1, Plate 1, Figs. 1-6, p. 2, fig. 5.
Hantkenina brevispina Cushman, 1925, p. 2, Plate 2, Fig. 3.
Hantkenina alabamensis Cushman compressa Parr, 1947, p. 46, Figs. 1-7.
Hantkenia (Hantkenian) alabameusis Cushman - Bronniamann, 1950, p. 414, Plate 56, Figs. 10, 14-16.

Genus CRIBROHANTKENINA Thalmann, 1942
CRIBROHANTKENINA INFLATA (Howe)
LSU Mus. No. 10454

Hantkenina inflata Howe, 1928, p. 14, Fig. 2.
Hantkenina mccordi Howe and Wallace, 1932, pp. 55-56; Plate 10, Figs. 1a-b.
Hantkenina bermudezi Thalmann, 1942, p. 812, Plate 19, Figs. 7-10.
Cribrohantkenina mccordi (Howe and Wallace) - Cushman, 1946, p. 38, Plate 7, Figs. 18-22.
Cribrohantkenina bermudezi (Thalmann) - Postuma, 1971, pp. 134-135.
Cribrohantkenina inflata (Howe) - Stainforth et al., 1979, pp. 194, 196; Fig. 57; 1-10.

Remarks: The specimens examined from Montgomery Landing matched the holotypes of *Cribrohantkenina danvillensis* (LSU Mus. No. 599) *C. mccordi* (LSU Mus. No. 605) and *C. inflata* (LSU Mus. No. 585) in all details except for the inflated ultimate chamber and completed cribrae. Montgomery Landing *C. inflata* had incomplete cribrae which did not penetrate into the interior of the test. One specimen was broken; others may have been juveniles.

Subfamily CASSIGERINELLINAE Bolli, Loeblich & Tappan, 1957
Genus CASSIGERINELLA Pokorny, 1955
CASSIGERINELLA WINNIANA (Howe)

Cassidulina winniana Howe, 1939, p. 82, pl. 11, figs. 7-8.

Cassigerinella winniana (Howe) - Steineck & Darrel, 1971, p. 358, pl. 1, figs. 1a-b.

Family GLOBOROTALIIDAE Cushman, 1927
Subfamily GLOBOROTALIINAE Cushman, 1927
Genus GLOBOROTALIA Cushman, 1927
GLOBOROTALIA CERROAZULENSIS
(Cole, 1928) sensu lato.

This heading includes the subspecies:

Globorotalis *cerroazulensis* cerroazulensis &

Globorotalis *cocoaensis*

GLOBOROTALIA CERROAZULENSIS CERROAZULENSIS (Cole)
LSU Mus. No. 10455

Globorotalia *cerro-azulensis* Cole, 1928, p. 17, Plate 1, Figs. 11-13.
Eponides *cerro-azulensis* (Cole) - Nuttall, 1930, p. 274.
Globorotalia *bonairensis* Pijpers, 1933, p. 71, Figs. 107-110.
Globorotalia *cerro-azulensis* (Cole) - Bermudez, 1949, p. 285, Plate 22, Figs. 27-29.
Globorotalia *centralis* Cushman & Bermudez, 1937, as amended by Toumarkine & Bolli (1970, pp. 132, 144).
Globorotalia *cerroazulensis* (Cole) - Stainforth et al; 1979, pp. 256-258, Fig. 107; 1-13.

GLOBOROTALIA CERROAZULENSIS COCOAENSIS (Cushman)

Globorotalia *cocoaensis* Cushman, 1928, p. 75, Plate 10, Fig. 3.
GLoborotalia *(Turborotalia)* *cerro-azulensis* (Cole) - Blow & Banner, 1962, p. 118, figs. 12d-e, Plate 12, Figs. F.
Globorotalia *cerroazulensis* *cocoaensis* (Cushman) - Toumarkine & Bolli, 1970, p. 144, Plate 1, Figs. 28-33; pl. 2, figs. 6-8, 27.

GLOBOROTALIA INCREBESCENS (Bandy)
LSU Mus. No. 10456

Globigerina *increbescens* Bandy, 1949, p. 120, Plate 23, Fig. 3.
Globorotalia *(Turborotalia)* *increbescens* (Bandy) - Blow & Banner, 1962, p. 118, Plate 13, Figs. T-V.
Turborotalia *increbescens* (Bandy) - Bermudez, 1960, p. 1322, Plate 18, Figs. 3-4.
Globorotalia *increbescens* increbescens (Bandy) - Bandy, 1964, pp. 8, 13; Fig. 5.
Globorotalia *increbescens* (Bandy) - Nicora, 1971, p. 184, Plate 7, Fig. 6.

Subfamily TRUNOCOROTALOIDINAE Loeblich & Tappan, 1961
Genus TRUNCOROTALOIDES Bronniman & Bermudez, 1953
TRUNCOROTALOIDES DANVILLENSIS (Howe & Wallace)
LSU Mus. No.s 10398-10399

Globigerina danvillensis Howe & Wallace, 1932, p. 74, Plate 10, Figs. 9a-c.
Globigerina cretacea d'Orbigny (?) - Howe, 1939, p. 83, Plate 12, Figs. 16-17.

Remarks: Holotype examined, LSU Mus. No. 713.

Remarks: This species was found to have an aperture positioned as found in Globorotalia and to have minute, secondary sutural aperatures on the spiral side. Except for its small size (0.2 mm for the holotype, LSU Museum no. 712), the species very much resembles Truncorotaloides rohri Bronniman & Bermudez (1953).

Family GLOBIGERINIDAE Carpenter, Parker & Jones, 1862
Subfamily GLOBIGERININAE Carpenter, Parker & Jones, 1862
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA LINAPERTA Finlay
LSU Mus. No. 10457

Globigerina linaperta Finlay, 1939, p. 125, Plate 13, Figs. 54-57.
Globigerina ouachitaensis Howe & Wallace, 1932, p. 74, pl. 10, figs. 7a-b.

GLOBIGERNIA PSEUDOAMPLIAPERTURA Blow & Banner
LSU Mus. No. 10458

Globigerina pseudoampliapertura Blow & Banner, 1962, p. 95, Plate 12, Figs. A-C; Plate 17, Figs. A, E.

Remarks: This species differs from Globigerina ampliapertura in (1) lacking a granular texture, 2) having an asymetry of the test similar to Globigerina cerroazulensis cerroazulensis, (3) having a wider aperture than Globigernia ampliapertura, (4) being more loosely coiled.

"GLOBIGERINA" SP. A (Howe & Wallace)
LSU Mus. Nos. 10459-10461

Globigerina sp. A Howe & Wallace, 1932, p. 75, Plate 10, Figs. 8a-b.

Remarks: This species is small in size, perhaps taken as a juvenile by previous workers. Like Truncorotaloides, this species has sutural secondary apertures on the spiral side. No proper generic assignment has yet been determined for sp. A of Howe & Wallace. Figured specimen examined, L.S.U. Mus. No. 714.

Subfamily ORBULININAE Schultze, 1854
Genus PORTICULOSPHAERA Bolli, Loeblich & Tappan, 1957
PORTICULOSPHAERA INDEX (Finlay)

Globigerinoides index Finlay, 1939, p. 125, Plate 14, Figs. 85-88.
Globigerinoides macrostoma Hagn, 1956, p. 173, Plate 16, Fig. 11.
Glcgigerapsis index (Finlay) Blow & Banner, 1962, pp. 124, 125; Plate 15, Figs. g-h.
Globigerinatheka (Globigerapsis) index index (Finlay) -Jenkins, 1971, pp. 187-188, Plate 22, Figs. 641-645.
Globigerinathka index index (Finlay) - Bolli, 1972, p. 124, Figs. 51-57, 63-64; Plate 1, Figs. 1-4, 6-7.
Globigerinatheka index (Finlay) - Stainforth et al, 1975, pp. 194, 195; Plate 56, Figs. 1-8.

PORTICULOSPHAERA SEMIINVOLUTA (Keijzer)
LSU Mus. No. 10462

Globigerinoides semiinvoluta Keijzer, 1945, p. 206, Plate 4, Fig. 58.
Globigerapsis semiinvoluta (Keijzer) - Bolli, Loeblich & Tappan, 1957, p. 34, Plate 6, Fig. 7.
Globigerinatheka semiinvoluta (Keijzer) - Bolli, 1972, p. 131, Figs. 72-79; Plate 5, Figs. 1-27; Plate 6, Figs. 1-17.
Porticulosphaera semiinvoluta (Keijzer) - Blow, 1979, pp. 876-878.

Superfamily ROTALIACEA Ehrenberg, 1839
Family ELPHIDIIDAE Galloway, 1933
Subfamily ELPHIDIIDAE Galloway, 1933
Genus CRIBRONONION Thalmann, 1947
CRIBRONONION ADVENUM (Cushman)
LSU Mus. No. 10463

Nonionina advena Cushman, 1[illegible]2, p. 139, Plate 32, Fig.8.
Nonionina advena (Cushman) - Howe, 1928, p. 175 (list only)
Nonion advenus (Cushman) - Cole & Gillespie, 1930, p. 10, Plate 2, Fig. 15.
Nonion advenum (Cushman) - Cushman, 1935, p. 30, Plate 11, Figs. 1-4.
Cribrononion advena (Cushman) - Poag, 1966, p. 415, Plate 7, Figs. 9-10.

Genus PROTELPHIDIUM Haynes, 1956
PROTELPHIDIUM DECORATUM (Cushman & McGlamery)
LSU Mus. No. 10464

Nonion advenum (Cushman) - Cushman & McGlamery, 1938, p. 106, Plate 24, Fig. 23.
Nonion decoratum Cushman & Mclamery, 1939, p. 46, Plate 9, Fig. 4.
Protelphidium decoratum Poag, 1966, p. 416, Plate 7, Figs. 11, 12.

Family NUMMULITIDAE de Blainville, 1825
Subfamily NUMMULITIDAE de Blainville, 1825
Genus NUMMULITES Lamarck, 1801
NUMMULITES MOODYBRANCHENSIS (Gravell & Hanna)
LSU Mus. No. 10465

Camerina moodybranchensis Gravell & Hanna, 1935, pp. 332-333, Plate 29, Figs. 15, 22-24.

NUMMULITES VAUGHANI (Cushman)

Operculina vaughani Cushman, 1921, p. 128, Plate 19, Figs. 6-7.
Operculina oliveri Ellisor, 1933, pp. 1299-1301, pl.2, fig. 15.

Superfamily ORBITOIDACEA Schwager, 1876
Family LEPIDOCYCLINIDAE Scheffen, 1932
Subfamily LEPILOCYCLINDAE Scheffen, 1932
Genus LEPIDCYCLINA Gumbel, 1870
LEPIDOCYCLINA (PLIOLEPIDINA) MONTGOMERIENSIS Cole
LSU Mus. No. 10467

Lepidocyclina (Lepidocyclina) montgomeriensis Cole, 1949, p. 270, Plate 53, Figs. 2-8.
Lepidocylina mortoni Cushman, 192, pp. 70-71, pl. 27, figs. 1; Plate 28, Figs. 1-2.
Lepidocyclina (Lepidocylina) mortoni Cushman - Gravell & Hanna, 1935, pp. 337-339, Plate, Figs. 1-9; Plate 31, Figs. 1-11, Plate 32, Figs. 1-4.

Superfamily CASSICULINACEA d'Orbigny, 1839
Family CAUCASINIDAE Bykova, 1959
Subfamily FURSENKOININAE Loeblich & Tappan, 1961
Genus FURSENKOINA Loeblich & Tappan, 1961
FURSENKOINA ZETINA (Cole)
LSU Mus. No. 10468

Virgulina sp. (?) Cushman, 1922, p. 92, Plate 16, Figs. 2-3.
Virgulina mexicana Cole, 1927, p. 2, Plate 5, Figs. 14.
Virgulina Zetina (new name) Cole, 1929
Virgulina vicksburgensis Cushman, 193, p. 48, Plate 7, Fig. 6.
Virgulina dibollensis Bergquist (not Cushman & Applin), 1942, p. 68, Plate 7, Fig. 16.

Virgulina dibollensis Cushman & Applin - Bandy, 1949, p. 136, Plate 26, Figs. 9a-b.
Fursenkoina vickburgensis (Cushman) - Poag, 196, p. 422, Plate 8, Figs. 23-24.

Family Nonionidae Schultze, 1854
Subfamily Nonioninae Schultze, 1854
Genus PSEUDONONION Asano, 1936
PSEUDONONION SPISSUS (Cushman)
LSU Mus. No. 10469

Nonionella hantkeni var. spissa Cushman, 1931, p. 58, pl. 7. fig. 13.
Nonionella spissa (Cushman) - Bandy, 1949, p. 78, Plate 11, Figs. 2a-2c; 4a-c.

PSEUDONONION WINNIANUS (Howe)
LSU Mus. No. 10470

Nonionella winniana Howe, 1939, p.V, Plate 7, Figs. 26-27.

Remarks: most specimens are juveniles. Pseudononion is acknowledged as reestablished by Hansen and Rogel (1980).

Genus NONIONELLA Cushman, 1926
NONIONELLA JACKSONENSIS Cushman
LSU Mus. No. 10471

Nonionella jacksonensis Cushman, 1933, p. 10, Plate 1, Figs. 23a-c.

Family OSANGULARIIDAE Loeblich & Tappan, 1964
Genus GYROIDINOIDES Brotzen, 1942
GYROIDINOIDES DANVILLENSIS (Howe & Wallace)
LSU Mus. No. 10472

Gyroidina danvillensis Howe & Wallace, 1932, p. 69, Plate 13, Figs. 3a-c.
Valvulineria danvillensis (Howe & Wallace) - Bandy, 1949, p. 83.

Family GAVELINELLIDAE Hofker, 1956
Subfamily ANOMALININAE Cushman, 1927
Genus ANOMALINOIDES Brotzen, 1942
ANOMALINOIDES DANVILLENSIS (Howe & Wallace)
LSU Mus. No. 10473

Anomalina danvillensis Howe & Wallace, 1932, p. 76, Plate 1, Figs. 2a-b.

Remarks: Holotype observed; LSU Mus. No.

Genus HANZAWAIA Asano, 1944
HANZAWAIA MAURICENSIS (Howe & Roberts)
LSU Mus. No. 10474

Cibicides mauricensis Howe & Roberts, 1939, p. 87, Plate 13, Figs. 4-5.
Cibicides mauricensis (Howe & Roberts) - Bandy, 1949, p. 93, Plate 15, Figs. 3a-c.

Remarks: Holotype observed; LSU Mus. No.

HANZAWAIA YAZOOENSIS Cushman
LSU Mus. No. 10476

Cibicides yazooensis Cushman, 1931, p. 59, Plate 7, Figs. 12a-c.
Cibicides Jacob and Walker, 1798), 1942, pp. 100-101, Plate 10, Figs. 11-13.
Cibicidina yazooensis (Cushman) - Bandy, 1949, p. 95, Plate 15, Figs. 6a-c.

Genus MELONIS de Montfort, 1808
MELONIS PLANATUM (Cushman & Thomas)
LSU Mus. No. 10477

Nonion planatum Cushman & Thomas, 193, p. 37, Plate 3, Figs. 5a-b.

Truncorotaloides danvillensis	Pseudohastigerina sp.	Cribrohantkenina inflata	Hantkenina alabamensis	Globorotalia increbescens	Globorotalia cerroazulensis (s. l.)	Globigerinatheka spp.	Porticulosphaera semiinvoluta	Porticulosphaera index	Globigerina sp. (A) Howe and Wallace	Globigerina pseudoampliapertura	Globigerina ouachitaensis	Globigerina linaperta	
●		●			●				●			●	4/23
●		●	●		●				●		●	●	22
●					●				●			●	19
●				●		●	●	●	●	●	●	●	17
●			●		●	●	●	●	●	●		●	15
●					●				●			●	14
●				●	●				●	●	●	●	13
●					●	●			●	●		●	12
●	●			●	●	●			●	●	●	●	10
●				●	●	●	●	●	●	●	●	●	8
●		●	●		●				●	●	●	●	5
●	●				●	●	●		●	●	●	●	3
●				●					●		●	●	1

Truncorotaloides danvillensis	Pseudohastigerina sp.	Cribrohantkenina inflata	Hantkenina alabamensis	Globorotalia increbescens	Globorotalia cerroazulensis (s. l.)	Globigerinatheka spp.	Porticulosphaera semiinvoluta	Porticulosphaera index	Globigerina sp. (A) Howe and Wallace	Globigerina pseudoampliapertura	Globigerina ouachitaensis	Globigerina linaperta	
●					●				●	●		●	3/24
●					●				●				20
●		●		●	●				●	●	●	●	18
●	●		●		●				●	●			16
●		●	●	●	●				●			●	15
●			●	●	●	●			●				14
●			●		●				●			●	13
●			●		●	●			●			●	12
●						●		●	●		●		5
●				●	●	●	●		●			●	3
●					●				●	●	●		1

Truncorotaloides danvillensis	Pseudohastigerina sp.	Cribrohantkenina inflata	Hantkenina alabamensis	Globorotalia increbescens	Globorotalia cerroazulensis (s. l.)	Globigerinatheka spp.	Porticulosphaera semiinvoluta	Porticulosphaera index	Globigerina sp. (A) Howe and Wallace	Globigerina pseudoampliapertura	Globigerina ouachitaensis	Globigerina linaperta	
●	●			●	●		●		●	●			1/12
●			●	●	●				●			●	11
●			●		●				●	●	●	●	9
●									●				7

Table 8. Distribution of planktonic foraminiferida at Montgomery Landing

TABLE 9. Benthic species of foraminifera from Montgomery Landing.

Anomalinoides danvillensis
Bolivina gracilis
Bolivina jacksonensis
Bolivina plicatella
Brizalina beyrichi
Brizalina sp.
Brizalina sp.
Buliminella elegantissima
Cassidulinoides howei
Cibicides pseudoungerianus
Cribrononion advenum
Dentalina jacksonensis
Eoeponidella meyerhoffi
Epistominella danvillensis
Fursenkoina zetina
Globobulimina pyrula
Guttulina cf. G. consobrina
Guttulina spp.
Gyroidinoides danvillensis
Hanzawaia sp.
Hanzawaia yazooensis
Lagena gracilicosta
Lagena hispida
Lenticulina articulata var. texana
Lenticulina jugosus
Lenticulina sp. A
Lenticulina sp. B
Lenticulina sp. C
Marginulinopsis fragaria var. texana
Massilina pratti
Melonis planatum
Neoeponides jacksonensis
Nodosaria cf. N. pyrula
Nummulites moodybranchensis
Nummulites vaughani
Oolina sp.
Pijpersia globulo-spinosa
Pijpersia petalifera
Protelphidium decoratum
Pseudononion spissa
Pseudononion winniana
Quinqueloculina sp. cf. Q. impressa
Quinqueloculina sp. A
Quinqueloculina sp. B
Robertina mcquirti
Robertina plummerae
Sagrina mauricensis
Sagrina montgomeryensis
Saracenaria sp.
Sigmomorphina jacksonensis
Siphonina jacksonensis
Spiroplectammina mississippiensis
Stainforthia biformata
Textularia adalta
Textularia dibollensis
Textularia hockleyensis
Textularia spp.
Trifarina wilcoxensis
Triloculina trigonula
Turrilina quadralocula
Turrilina robertisi
Uvigerina cocoaensis
Uvigerina danvillensis
Uvigerina gardnerae
Uvigerina jacksonensis

SERIES (Hardenbol & Berggren, 1978)		Group or Stage	Formation	Benthic Foraminifera Guide Fossils	Planktonic Foraminifera Zones (Bolli, 1957)	Nannofossil Zones (Hay, 1967)
EOCENE	Upper (Priabonian)	Jackson	Yazoo Clay	*Bulimina jacksonensis*	*Globorotalia (Turborotalia) cerroazulensis*	*Istholithus recurvus*
				Textularia hockleyensis		
					—?— —?— —?—	
					Porticulosphaera semiinvoluta	
				Textularia dibollensis		*Discoaster tani nodifer*
			Moodys Branch	*Nummulites moodybranchensis*		
				(*Nonionella cockfieldensis*)		
	Middle	Claiborne	Cockfield	UNFOSSILIFEROUS		

Figure 14, Foraminiferal and nannofossil zonation of the Upper Eocene of Central Louisiana

C. OSTRACODA SYSTEMATICS*

Order PODOCOPIDA Mueller 1894
Suborder PODOCOPINA Sars 1866
Superfamily BAIRDIACEA Sars 1888
Family BAIRDIIDAE Sars 1888
Genus TRIANGULOCYPRIS Teeter, 1975
TRIANGULOCYPRIS GIBSONENSIS (Howe & Chambers), 1935
PL. 15, Fig. 1

Bythocypris? gibsonensis Howe & Chambers, 1935, p. 9, Plate 3, Fig. 10, Plate 4, Fig. 3; Howe and Law, 1936, p. 26, Plate 1, Figs. 34-37; Monsour, 1937, p. 89, 96; Howe, in Fisk, 1938, p. 122, 141; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 105, Plate 11, Fig. 3; Shimer & Shrock, 1944, p. 683, Plate 287, Figs. 64-66; Swain, 1946, p. 375, Plate 54, Figs. 4a-e; McLean, 1947, p. 9; Howe, in Treadwell, 1954, p. 2321; Puri, 1957, p. 190, Plate 1, Figs. 10-13; Marianos & Valentine, 1958, p. 365, Plate 1, Figs. 3a-c, text Fig. 2; Bold, 1965, p. 387, Plate 1, Fig. 9; Huff, 1970, p. 76, Plate 2, Figs. 1-3; Howe, R. C. and Howe, H. J., 1973, p. 634, Plate 1, Figs. 7-9; Howe, H. J. and Howe, R. C., 1975, p. 285, Plate 1, Figs. 10, 11; Poag, 1974b, p. 43, Plate 1, Fig. 4; Howe, 1976, p. 167, Plate 2, Fig. 6.

Bythocypris gibsonensis Howe & Chambers. Howe, 1942, p. 270; Bold, 1950, p. 108; Wilbert, 1953, p. 125; Deboo, 1965, Plate 11, Fig. 14; Howe, 1977, Tables 1, 2.

Bythocypris cf. *B. gibsonensis* Vernon, 1942, p. 71; Bold, 1946, p. 68, Plate 1, Fig. 13; Butler, 1963, p. 39, Plate 1, Fig. 1; Plate 6, Fig. g.

Macrocyprina gibsonensis (Howe & Chambers), 1935. Hazel et al., 1980, p. 382, Plate 1, Fig. 4.

Material: 284 valves.

Discussion: Teeter (1975) erected the genus *Triangulocypris* for *Bythocypris* - like species that differed from that genus "in having a triangulate rather than subquadrate lateral outline, and possessing a thicker carapace." He stated that *Triangulocypris* is a shallow-water genus, in contrast to the deeper-water genus *Bythocypris*, and suggests that *T. gibsonensis* (Howe & Chambers) probably should be placed in this genus.

Material: 6172 valves.

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* by Kevin Kilmartin

Superfamily CYPRIDACEA Baird 1850
Family CANDONIDAE Kaufmann 1900
Subfamily PARACYPRIDINAE Sars 1923
Genus PARACYPRIS Sars, 1866
PARACYPRIS FRANQUESI Howe & Chambers, 1935
Plate 15, Fig. 2

Paracypris franquesi Howe & Chambers, 1935, p. 10, Plate 3, Fig. 13; Plate 4, Figs. 15, 19; Garrett, 1936, p. 786; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Berquist, 1942, p. 105, Plate 11, Fig. 4; Vernon, 1942, p. 63; Bold, 1946, p. 66, Plate 1, Fig. 16; Bold, 1950, p. 107; Wilbert, 1953, p. 125; Brown, 1958, p. 57, Plate 1, Fig. 12; Krutak, 1961, p. 774, Plate 92, Fig. 1; Huff, 1970, p. 78, Plate 2, Figs. 4-7; Howe, 1977, p. 292, Table 1. Material: 218 valves.

PARACYPRIS LICINA Huff, 1970
Plate 15, Fig. 3

Paracypris Licina Huff, 1970, p. 79, Plate 2, Figs. 8-12. Material: 105 valves.

Family PONTOCYPRIDIDAE Mueller 1894
Genus ARGILLOECIA Sars, 1866
ARGILLOECIA SUBOVATA Huff, 1970
PL. 15, Fig. 4

Argilloecia hiwanneensis Howe and Law. Deboo, 1965, Plate 11, Fig. 17.
Argilloecia subovata Huff, 1970, p. 80, Plate 3, Figs. 1-6; Howe, R. C., and Howe, H. J., 1973, p. 637, Plate 3, Figs. 15-16; Howe, 1977, p. 292, Table 1.

Material: 64 valves.

Superfamily CYTHERACEA Baird 1850
Family TRACHYLEBERIDIDAE Sylvester-Bradley 1948
Subfamily BRACHYCYTHERINAE Puri 1954
Tribus BUNTONIINI Apostolescu 1961
Genus BUNTONIA Howe, 1935
BUNTONIA MORSEI (Howe and Pyeatt), 1935
Plate 15, Fig. 5

Cythereis (?) *israelskyi* var. *morsei* Howe and Pyeatt, in Howe and Chambers, 1935, p. 34, Plate 3, Figs. 11, 12; Bergquist, 1942, p. 108, Plate 11, Fig. 1.

Buntonia israelski var. morsei (Howe and Pyeatt). Howe, in Treadwell, 1954, p. 2321.
Buntonia israelskyi var. morsei (Howe and Pyeatt). Howe, in Treadwell, 1955, p. 269.
Buntonia morsei (Howe and Pyeatt). Huff, 1970, p. 158, Plate 10, Figs. 6-8.

Material: 256 valves.

BUNTONIA SHUBUTAENSIS Howe, 1935
Plate 15, Fig. 6

Buntonia shubutaensis Howe, in Howe and Chambers, 1935, p. 23, Plate 4, Figs. 4-5; Plate 5, Fig. 7; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Howe, 1947, p. 50; Wilbert, 1953, p. 270; Krutak, 1961, p. 783, Plate 93, Fig. 15; Morkhoven, 1963, p. 240, fig. 361; Huff, 1970, p. 156, Plate 20, Figs, 1-5; Howe, R. C. and Howe, H. J., 1973, p. 651, Plate 3, Figs. 19-22; Howe, H. J. and Howe, R. C., 1975, p. 284, Plate 2, Figs. 3, 4; Howe, H. J., 1977, p. 292, Tables 1, 3.
Cythereis? israelskyi Howe and Pyeatt, in Howe and Chambers, 1935, p. 33, Plate 1, Figs. 19-21; Plate 4, Figs. 7-9; Monsour, 1937, p. 90, 95; Bergquist, 1942, p. 107, Plate 11, Fig. 12.
Pyricythereis israelskyi Howe. Howe and Law, 1936, p. 65; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Vernon, 1942, p. 44.
Pyricythereis cf. P. israelskyi McLean, 1947, p. 8.
Buntonia israelskyi (Hose and Pyeatt). Deboo, 1965, p. 11, Plate 12, Fig. 7.

BUNTONIA SMITHI Huff, 1970

Buntonia smithi Huff, 1970, p. 161, Plate 20, Figs. 15-17.
Material: 257 valves.

Tribus BRACHYTHERINI Puri 1954
Genus BRACHYCYTHERE Alexander, 1933
BRACHYCYTHERE WATERVALLEYENSIS Howe & Chambers, 1935
Plate 15, Fig. 7

Brachycythere watervalleyensis Howe & Chambers, 1935, p. 46, Plate 3, Figs. 1, 2, 3, 5, 6, not Plate 3, Fig. 4; Plate 4, Fig. 1; Plate 6, Fig. 7; Garrett, 1936, p. 786; Bergquist, 1942, p. 109, Plate 11, Figs. 21-22; Vernon, 1942, p. 43; Murray & Hussey, 1942, p. 179, Plate 28, Figs. 2, 3; Wilbert, 1953, p. 124; Howe, in Treadwell, 1954, p. 2322; Brown, 1958, p. 60, Plate 2, Fig. 1; Krutak, 1961, p. 782, Plate 91, Fig. 1; Huff, 1970, p. 82, Plate 3, Figs. 8-11; Howe, H. J. and Howe, R. C., 1975, p. 284, Plate 1, Figs. 12-15; Howe, 1977, p. 292, Table 1.

Brachycythere (*Digmocythere*) *watervalleyensis* Howe & Chambers. Morkhoven, 1963, p. 215.

Digmocythere watervalleyensis (Howe & Chambers). Deboo, 1965, Plate 11, Fig. 4.

Material: 953 valves.

BRACHYCYTHERE RUSSELI Howe & Lea, 1936

Plate 15, Fig. 8

Brachycythere watervalleyensis Howe & Chambers, 1935, (part), p. 46, Plate 3, Fig. 4 (not Plate 3, Figs. 1-3, 5-6; Plate 4, Fig. 1; pl. 6, fig. 7).

Brachycythere russeli Howe & Lea, in Howe & Law, 1936, p. 41, Plate 2, Figs. 30-31; Plate 3, Figs. 23-25; Howe, in Fisk, 1938, p. 141; Murray & Hussey, 1942, p. 178, Plate 28, Figs. 1, 4, 5, 8; text Fig. 1, Figs. 19-24; text Fig. 2, Fig. 1; Howe, 1942, p. 270; Vernon, 1942, p. 53; Shimer and Shrock, 1944, p. 688, pl. 289, Figs. 23-27; Bold, 1946, p. 107, Plate 13, Figs. 8a-c; Stephenson, 1946, p. 333, Plate 44, Fig. 22, Plate 45, Fig. 19; Bold, 1950, p. 108; Hill, 1954, p. 812, Plate 97, Figs. 1a-b.

Digmocythere russeli (Howe & Lea). Mandelstam, 1959, p. 277; Howe, 1963, p. 18, Plate 1, Figs. 14-15; Deboo, 1965, Plate 11, Fig. 16; Pooser, 1965, p. 33, Plate 18, Figs. 3, 5-7; Bold, 1967, p. 8; Hufi, 1970, p. 86, Plate 4, Figs. 1-3; Howe, R. C. and Howe, R. J., 1973, p. 650, Plate 1, Figs. 12-13; Howe, H. J., 1976, p. 168, Plate 2, Figs. 24-26; Howe, H. J., 1977, p. 292, Table 1; Bold, 1972, p. 427, Plate 3, Fig. 12, Bold, 1978, Table 4, 5, Hazel et al., 1980, p. 390, Plate 5, Fig. 3.

Material: 286 valves.

Discussion: Mandelstam (1958) separated *Digmocythere* from *Brachycythere* based on hinge characteristics. *Digmocythere* is characterized by an anterior grooved socket in the left valve and corresponding anterior crenulate tooth in the right valve. Specimens of *B. water-valleyensis* from Montgomery Landing often have a crenulate anterior tooth in the right valve. Murray and Hussey (1942) note that in this species the right valve hinge "consists of a high, somewhat elongate often crenulate tooth." Therefore, it appears that the nature of the anterior tooth is variable and not a good criterion upon which to base a new genus. For this reason *B. russeli* has been returned to the genus *Brachycythere*.

Genus OPIMOCYTHERE Hazel, 1968

OPIMOCYTHERE MISSISSIPPIENSIS (Meyer), 1877

Cythere mississippiensis Meyer, 1877, p. 14, Plate 2, Fig. 20, 20a-b.

Brachycythere mississippiensis (Meyer). Krutak 1961, p. 781, pl. 91, fig. 10; Deboo, 1965, Plate 12, Fig. 16.

Opimocythere mississippiensis (Meyer). Hazel, 1961, p. 116; Huff, 1970, p. 88, Plate 4, Figs. 4-8.

Material: 1 valve.

Subfamily TRACHYLEBERIDINAE Sylvester-Bradley 1948

Genus ACANTHOCYTHEREIS Howe, 1963

ACANTHOCYTHEREIS FLORIENENSIS (Howe & Chambers), 1935

Plate 16, Fig. 1

Cythereis florienensis Howe, H. V. & Chambers, 1935, p. 28, Plate 1, Fig. 14; Plate 6, Figs. 14-15; Garrett, 1936, p. 786; Monsour, 1937, p. 89, 96; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 106, Plate 11, Fig. 8; Wilbert, 1953, p. 125, Plate 1, Fig. 16.

Cythereis deusseni Howe, H. V. & Chambers, 1935, p. 27, Plate 1, Fig. 15; Plate 6, Figs. 2, 3,; Howe, H. V. & Law, 1936, p. 58; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Howe in Treadwell, 1954, p. 2322.

Cythereis(?) *floriensis* Howe, H. V., and Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.

Cythereis(?) *florienensis* Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1955, p. 269.

Henryhowella florienensis (Howe & Chambers). Krutak, 1961, p. 784, Plate 91, Fig. 8; Deboo, 1965, p. 29, Plate 13, Figs. 8-9, 11-12; Huff, 1970, p. 153, Plate 19, Figs. 1-5; Howe, R. C. & Howe, H. J., 1973, p. 649, Plate 4, figs. 1-5; Howe, H.J. & Howe, R. C., 1975, p. 287, Plate 2, figs. 13-15; Howe, H. J., & Howe, R. C., 1975b, Plate 1, Figs. 7, 8,; Howe, H. J., 1977, p. 292, Table 1.

Henryhowella? florienensis (Howe, H. V. & Chambers, 1935. Bold, 1978, p. 130, Table 5.

Trachyleberis florienensis (Howe, H. V. & Chambers, 1935). Pooser, 1965, p. 53, Plate 21, Figs. 4, 6-7.

Acanthocythereis florienensis (Howe, H. V. & Chambers, 1935). Hazel et al., 1980, p. 394, Plate 7, Fig. 15.

Material: 1044 valves.

ACANTHOCYTHEREIS HOWEI Huff, 1970

Plate 16, Fig. 3

Trachyleberis n. sp. 1. Deboo, 1965, p. 30, Plate 14, Figs. 11-12.

Acanthocythereis howei Huff, 1970, p. 151, Plate 18, Figs. 7-11; Howe, R. C. & Howe, H. J., 1973, p. 645, pl. 5, figs. 9-15; Howe, 1977, p. 292, Table 1.

Material: 710 valves.

Acanthocythereis juveniles

Discussion: Juvenile specimens of the genus Acanthocythereis were commonly found in the Montgomery Landing sampels. As discussed by Howe, R. C. & Howe, H. J., (1975b), the specific determination of these molts is very difficult. As two species of Acanthocythereis co-exist throughout much of the stratigraphic section exposed at Montgomery, it was decided that a separate category should be made for the juvenile molts.

Material: 554 valves.

Genus ACTINOCYTHEREIS Puri, 1953
ACTINOCYTHEREIS GIBSONENSIS (Howe, H. V. & Chambers), 1935
Plate 16, Fig. 5

Cythereis gibsonensis Howe, H. V. & Chambers, 1935, p. 29, Plate 1, Fig. 22; Plate 6, Figs. 21-22; Garrett, 1936, p. 786; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939; Bergquist, 1942, p. 107, Plate 11, Figs. 9-10.

Cythereis(?) gibsonensis Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.

Actinocythereis gibsonensis (Howe, H. V. & Chambers), 1935. Puri, 1953, p. 182, Plate 2, Figs. 11, 12; Krutak, 1961, p. 782, Plate 91, Fig. 4; Deboo, 1965, Plate 14, Fig. 6; Huff, 1970, p. 144, Plate 16, Figs. 10-11; Plate 17, Figs. 1, 2; Howe, H. J. & Howe, R. C., 1975, p. 284, Plate 2, Figs. 16-21; Howe, 1977, p. 292, Tables 1, 2; Bold, 1978, p. 130, Table 5.

Actinocythereis boldi Huff, 1970, p. 147, pl. 17, figs. 6-10; Howe, R. C. & Howe, H. J., 1973, p. 648, Plate 4, Figs. 9-11.

Discussion: Huff(1970) recognized A. boldi as a separate species from A. gibsonensis based upon the number and arrangement of spines in the median and ventral rows and the configuration of the dorsal spines. Howe, H. J. & Howe, R. C. (1975) find that enough intermediate forms exist to suggest the two morphotypes belong to the same species.

Material: 557 valves.

ACTINOCYTHEREIS PURII Huff, 1970
Plate 16, Fig. 2, 4

Actinocythereis n. sp. 1. Deboo, 1965, Plate 14, Fig. 7.
Actinocythereis purii Huff, 1970, p. 150, Plate 18, Figs. 1-6; Howe, R. C., and Howe, H. J., 1973, p. 648, Plate 5, Figs. 1, 2; Howe, H. J., 1977, p. 292, Table 1.

Actinocythereis nodosa Huff, 1970, p. 149, Plate 17, Figs. 11-13.
Discussion: Huff (1970) distinguished *A. nodosa* from *A. purii* based upon: (1) the size, arrangement, and shape of the median nodes, and (2) the nature of the ventral nodes. *A. nodosa* has two large rounded elongate median nodes while *A. purii* has one large elongate node and two smaller posterior nodes. The ventral row of nodes coalesce in *A. nodosa* while they do not in *A. purii*.

Huff reports *A. nodosa* as more common in basal Jackson deposits and *A. purii* more common in younger Jackson deposits. Material used in the present study, plus examination of the H. V. Howe collection reference slides indicates many intermediary forms exist between these two end-members. Many specimens that would be attributable to *A. purii* have the two posterior median nodes showing some degree of fusion. On others, the ventral row of nodes coaslesce. In forms very similar to *A. nodosa*, a "splitting" of the median nodes may be seen. It is suggested these two species are actually morphological end-members of a continuous series.

Material: 149 valves.

Genus TRACHYLEBERIS Brady, 1898
TRACHYLEBERIS? GRIGSBYI (Howe, H. V., & Chambers), 1935
Plate 16, Fig. 6

Cythereis grigsbyi Howe, H. V., & Chambers, 1935, p. 30, Plate 1, Figs. 17-18; Plate 2, Fig. 20; Plate 6, Fig. 6; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 122; Wilbert, 1953, p. 124, Plate 1, Fig. 13.
Trachyleberis(?) *grigsbyi* (Howe, H. V., & Chambers), 1935. Puri, 1953, p. 176, Plate 1, Figs. 9-10.
Actinocythereis grigsbyi (Howe, H. V., & Chambers), 1935. Huff, 1970, p. 145, Plate 17, Figs. 3-5.

Material: 57 valves.

TRACHYLEBERIS? MONTGOMERYENSIS (Howe, H. V. & Chambers), 1935
Plate 16, Fig. 7

Cythereis montgomeryensis Howe, H. V., & Chambers, 1935, p. 37, Plate 1, figs. 13, 16; Plate 2, Figs. 22-23; Plate 6, Figs. 19-20; Garrett, 1936, p. 786; Monsour, 1937, p. 90; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 108, pl. 11, Figs. 15-16; Vernon, 1942, p. 43; Wilbert, 1953, p. 125, Plate 1, Figs. 15-16; Vernon, 1942, p. 43; Wilbert, 1953, p. 125, Plate 1, Fig. 12; not Bold, 1950, p. 108 (= Trachyleberis bermudezi bermudezi, see Bold, 1966).

Cythereis yazooensis Howe, H. V. & Chambers, 1935, p. 38, Plate 1, Fig. 6; Plate 6, Figs. 29-30; Garrett, 1936, p. 786; Monsour, 1937, p. 90, 96; Bergquist, 1942, p. 108, Plate 11, Fig. 17.

Archicythereis yazooensis Howe, in Howe, H. V., & Law, 1936, p. 57; Howe, in Fisk, 1938, p. 120; Howe, in Fisk, 1939, p. 1399; Wilbert, 1953, p. 124; Sylvester-Bradley, 1954, p. 561.

Archicytherais(?) yazooensis Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.

Archicythereis(?) yazooensis (Howe, H. V. & Chambers), 1935. Howe, in Treadwell, 1955, p. 269.

"Archicythereis" yazooensis (Howe, H. V. & Chambers), 1935. Krutak, 1961, p. 783, Plate 93, Fig. 17; Huff, 1970, p. 175, pl. 23, figs. 8-9.

Trachyleberis montgomeryensis (Howe, H. V. & Chambers). Puri, 1953, p. 176, Plate 1, Figs. 4-5; text Figs. A, B; Hill, 1954, p. 812, Plate 97, figs. 3a-b; Krutak, 1961, p. 784, Plate 91, Fig. 3; Deboo, 1965, Plate 14, Figs. 9-10, 13, 16; Huff, 1970, p. 141, Plate 16, Figs. 1-4; Howe, R. C. & Howe, H. J., 1973, p. 643, Plate 4, Figs. 12, 13, 16-18.

Trachyleberis? montgomeryensis (Howe, H. V. & Chambers), 1935. Howe, H. J. & Howe, R. C., 1975, p. 288, Plate 1, Figs. 1-6; Howe, H. J., & Howe, R. C., 1975, Plate 1, Figs. 9-10; Howe, H. J., 1977, p. 292, Tables 1 3.

Material: 1551 valves.

Subfamily ECHINOCYTHEREIDINAE Hazel 1967
Genus ECHINOCYTHEREIS Puri, 1954
ECHINOCYTHEREIS JACKSONENSIS (Howe & Pyeatt), 1935

Plate 17, Fig. 1

Echinocythereis jacksonensis (Howe & Pyeatt, in Howe & Chambers, 1935, p. 35, Plate 1, Figs. 23-24; Plate 6, Fig. 31; Monsour, 1937, p. 90; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 109, Plate 11, fig. 14; Vernon, 1942, p. 43; Howe, in Treadwell, 1954, p. 2322.

Cythereis jacksonensis Howe & Pyeatt. Garrett, 1936, p. 789; Wilbert, p. 125, Plate 1, Fig. 14; Bold, 1946, p. 89, Plate 10, Fig. 9.

Echinocythereis jacksonensis (Howe & Pyeatt). Puri, 1953, p. 260; Kurtak, 1061, p. 783, Plate 91, Fig. 9; Morkhoven, 1963, p. 173; Deboo, 1965, Plate 14, Fig. 18; Pooser, p. 58, Plate 15, Figs. 7, 10-13; Huff, 1970, p. 155, Plate 19, Figs. 8-9; Howe, H. & Howe, R. C., 1975, p. 286, Plate 1, Figs. 7-9; Howe, H. J., 1976, p. 168, Plate 2, Figs. 20-22; Howe, 1977, p. 292, Tables 1, 2; p. 293, Tables 4, 5;

Hazel et al., 1980, p. 383, Plate 1, Fig. 10.

Material: 987 valves.

Subfamily PTERYGOCYTHEREIDINAE Puri 1957
Genus ALATACYTHERE Murray & Hussey, 1942
ALATACYTHERE IVANI Howe, H. V., 1951
Plate 17, Fig. 2

Cythereis (*Pterygocythereis?*) *alexanderi* Howe, H. V. & Law, 1936, p. 42, Plate 4, Fig. 23; Plate 5, Fig. 5; Howe, in Fisk, 1938, p. 141; not *Cythereis alexanderi* Morrow, 1934, p. 203, Plate 31, Figs. 14a-c.

Alatacythere alexanderi (Howe, H. V., & Law), 1936. Murray & Hussey, 1942, p. 168, 171; Plate 27, Figs. 10-11; text Fig. 1, figs. 2, 10.

Alatacythere ivani Howe, 1951, p. 538, nom. nov.; Brown, 1958, p. 62, Plate 8, Fig. 4; Moore et al., 1961, p. Q260, Fig. 190, 4a-d; Coryell, 1963, p. 169, Plate 9, Fig. 15; Howe, 1963, p. 17, Plate 1, Figs. 8-9; Pooser, 1965, p. 32, Plate 18, Figs. 9, 11; Huff, 1970, p. 84, Plate 3, Figs. 12-14; Howe, R. C. & Howe, H. J., 1973, p. 652, Plate 1, Fig. 10; Howe, H. J., 1976, p. 166, Plate 1, Figs. 20, 22-24; Howe, 1977, p. 292,bles 1, 2; Hazel et al., 1980, p. 392, 396; Plate 6, fig. 13; Plate 8, Fig. 7.

Pterygocythereis ivani (Howe). Hill, 1954, p. 814, Plate 97, Figs. 4a-b; Plate 98, Fig. 4a; Plate 99, Figs. 3a-e; Deboo, 1965, Plate 12, Fig. 17.

Material: 9 valves.

Subfamily SPINOLEBERIDINAE Pokorny 1968
Genus OCCULTOCYTHEREIS Howe, 1951
OCCULTOCYTHEREIS BROUSSARDI (Howe, H. V. & Chambers), 1935
Plate 17, Fig. 3

Cythereis broussardi Howe, H. V. & Chambers, 1935, p. 24, plate 1, Fig. 12; 1. 4, Fig. 6; Monsour, 1937, p. 89, 94; Bergquist, 1942, p. 106, Plate 11, Fig. 7; Vernon, 1942, p. 49.

Cythereis(?) *broussardi* Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.

Trachyleberis broussardi (House & Chambers). Brown, 1958, p. 62., Plate 3, Fig. 9.

Occultocythereis broussardi (Howe, H. V. & Chambers). Howe, 1951, p. 20; Morkhoven, 1963, p. 197; Deboo, 1965, Plate 12, Fig. 2; Huff, 1970, p. 173, Plate 23, Figs. 1-5; Howe, R. C. & Howe, H. J., 1973, p. 649, Plate 3, Figs. 28, 30; Howe, 1977, p. 292, Tables 1, 3; Plate 2, Fig. 6.

Material: 101 valves.

OCCULTOCYTHEREIS sp.
Plate 17, Fig. 4

?Occultocythereis sp. Huff, 1970, p. 174, Plate 23, Fig. 6. Discussion: Only two right valves of this species were recovered from Moodys Branch Formation. This species is similar to Occultocythereis sp. reported from the Pachuta Marl by Huff (1970). Huff, however, recovered only one specimen, a left valve.

Several differences exist between the valves recovered in the present study and Huff's specimen. The right valves have a finely reticulate surface covering the entire valve. Huff's left valve is reticulate only in the mid-dorsal region. The prominent dorsal and posteroventral ridges are much more strongly developed on Huff's specimen. The preservation is better for the specimens recovered in the present study, but it is doubtful preservation differences led to the observed differences between the specimens.

The valves also are similar in several respects. Huff's specimen has an identical outline to the presumed female specimen of the present study, and they are the same length (.53 mm). Both specimens have a prominent sub-central node and an adjacent, smaller, antero-ventral node.

The specimens recovered in this study probably are the same as Occultocythereis sp. Huff. The observed differences could be in response to ecological changes. Because only a limited number of specimens are available for comparison, it is best to group the present specimens with the one of Huff.

Subfamily THAEROCYTHERINAE Hazel 1967
Genus HERMANITES Puri 1955
HERMANITES DOHMI (Howe, H. V. & Chambers), 1935
Plate 17, Fig. 6

Cythereis hysonensis var. dohmi Howe & Chambers, 1935, p. 32, Plate 1, Fig. 9; Monsour, 1937, p. 90, Howe, in Fisk, 1938, p. 122; Gooch, 1939, p. 580; Bergquist, 1942, p. 107, Plate 11, Fig. 11.

"Cythereis" hysonensis var. dohmi Howe, H. V. & Chambers. Laurencich, 1969, P. 497, Plate 1, Fig. 5.

Cythereis(?) hysonensis var. dohmi Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.

Cythereis(?) hysonensis var. dohmi Howe, H. V., & Chambers. Howe, in Treadwell, 1955, p. 269.

"Cythereis" dohmi Howe, H. V. & Chambers. Deboo, 1965, Plate 14, fig. 1.

Hermanites? dohmi (Howe, H. V. & Chambers) 1935. Krutak, 1961, p. 786, Plate 93, Fig. 14; Howe, R. C. & Howe, H. J., 1973, p. 637, Plate 3, Figs. 23, 24.

Hermanites dohmi (Howe, H. V. & Chambers). Huff, 1970, p. 164, Plate

21, Figs. 10-13, p. 166, Figs. 11, 12; Howe, 1977, p. 292, Table 1.

Material: 732 valves.

HERMANITES HYSONENSIS (Howe, H. V., & Chambers), 1935
Plate 17, Fig. 7

Cythereis hysonensis Howe, H. V. & Chambers, 1935, p. 31, Plate 1, Fig. 8; Plate 6, Figs. 23, 24; Garrett, 1936, p. 786; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399, Gooch, 1939, p. 580; Vernon, 1942, p. 43; Wilbert, 1953, p. 125.
Cythereis(?) *hysonensis* Howe, H. V. & Chambers, 1935. Howe, in Treadwell, 1954, p. 2322.
Cythereis cf. *C. hysonensis* Howe, H. V., & Chambers, 1935. Swain, 1948, p. 201, Plate 13, Fig. 10.
"Cythereis" hysonensis Howe, H. V. & Chambers. Deboo, 1965, Plate 14, Figs. 2, 3.
Hermanites(?) *hysonensis* (Howe & Chambers), 1935. Krutak, 1961, p. 786, Plate 92, Fig. 7.
Hermanites hysonensis (Howe & Chambers), 1935. Huff, 1970, p. 166, Plate 21, Figs. 14-17; Howe, H. V. & Howe, H. J. & Howe, R. C., 1975, p. 287, Plate 2, Figs. 5-7; Howe, 1977, p. 292.

Material: 3 valves.

Genus TROPIDOCYTHERE Huff 1970
TROPIDOCYTHERE CARINATA Huff, 1970
Plate 17, Fig. 5

Tropidocythere carinata Huff, 1970, p. 171, Text Fig. 20; p. 172, Plate 22, Figs. 12-18; Howe, 1977, p. 292, Table 1.

Material: 5 valves.

Family CYTHERETTIDAE Triebel 1952
Subfamily CYTHERETTINAE Triebel 1952
Genus CYTHERETTA G. W. Muller, 1884
CYTHERETTA JACKSONENSIS (Meyer), 1887

Cythere jacksonensis Meyer, 1887, p. 14, Plate 2, Fig. 19.
Cytheretta jacksonensis (Meyer). Deboo, 1965, Plate 11, Fig. 12.
Cytheretta alexanderi Howe, H. V. & Chambers, 1935, p. 45, Plate 5, Figs. 17-21; pl. 6, figs. 27-28; Garrett, 1936, p. 786; Monsour, 1937, p. 90, 95; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 109, Plate 11, Fig. 20; Simer & Shrock, 1944, p. 688, Plate 291, Figs. 2-6; Blacke, 1950, p. 177,

Plate 30, Figs. 1-3; Puri, 1952a,p. 208, Plate 40, Figs. 1-2; Wilbert, 1953, p. 125, Plate 1, Fig. 15; Howe, in Treadwell, 1954, p. 2321, 2322; Puri, 1957, p. 195, Plate 7, Figs. 1-4; Brown, 1958, p. 67, Plate 6, Fig. 14; Krutak, 1961, p. 785, Plate 91, Figs. 5, 6; Pooser, 1965, p. 37, Plate 12, Figs. 1, 2, 4-6; Huff, 1970, p. 92, Plate 5, Figs. 9-12; pl. 6, figs. 1, 2; Howe, H. J. & Howe, R. C., 1975, p. 285, Plate 1, Figs. 16-17; Howe, H. J., 1977, p. 292, Table 1; Bold, 1978, p. 130, Table 5.

Cythereis? catahoulana Howe & Pyeatt, in Howe, H. V. & Chambers, 1935, p. 25, Plate 3, Fig. 7; Plate 6, Figs. 25-26.

Cythereis? catahoulana var. pyeatti Howe, H. V. & Chambers, 1935, p. 26, Plate 3, Figs. 20, 21.

Cytheretta sp. cf. *C. alexanderi* Vernon, 1942, p. 43; Swain, 1951, p. 47, Plate 6, Figs. 23-25.

Material: 1097 valves.

Family CYTHERIDEIDAE Sars 1925
Subfamily CYTHERIDEINAE Sars 1925
Genus CLITHROCYTHERIDEA Stephenson, 1936
CLITHROCYTHERIDEA GARRETTI (Howe, H. V. & Chambers), 2935
Plate 18, Fig. 2

Cytheridea(?) garretti, Howe, H. V. & Chambers, 1935, p. 14, Plate 1, Figs. 4, 5; Plate 2, Figs. 11, 12; Plate 6, Figs. 10, 11; Vernon, 1942, p. 43.

Cytheridea (Clithrocytheridea) garretti (Howe, H. V. & Chambers), 1935. Stephenson, 1936, p. 702, Plate 94, Figs. 5, 6, 10; text Figs., 110, p; Stephenson, 1932, p. 105, 110, Plate 18, Fig. 1.

Cytheridea (Haplocytheridea) garretti Howe, H. V. & Chambers, 1935. Shimer & Shrock, p. 689, Plate 290, Figs. 15-17.

Cytheridea (Cleithrocytheridea) garretti Howe, H. V. & Chambers. Monsour, 1937, p. 89, 94.

Cleithrocytheridea garretti (Howe & Chambers). Wilbert, 1953, p. 125.

Clithrocytheridea garretti (Howe, H. V. & Chambers), 1935. Stephenson, 1944b, p. 449, Plate 76, Fig. 1; Stephenson, 1946, p. 327, Plate 42, Fig. 18; Blake, 1950, p. 175, Plate 29, Figs. 9-11; Howe, in Treadwell, 1954, p. 2321; Krutak, 1961, p. 778, Plate 92, Fig. 8; oore et al., 1961, p. Q275, Fig. 204, Figs. la-d; Morkhoven, 1963, p. 282, Fig. 440; Deboo, 1965, pl. 13, Fig. 5; Pooser, 1965, p. 39, Plate 8, Figs. 8-11; Huff, 1970, p. 93, Plate 6, Figs. 3-6; Howe, 1971, p. 352, Plate 1, Figs. 1-2; Howe, H. J., 1977, p. 292, Table 1.

Material: 8 valves.

Genus OUACHITAIA Howe, 1971
OUACHITAIA CALDWELLENSIS (Howe, H. V., & Chambers), 1935
Plate 18, Fig. 3

Cytheridea? *caldwellensis* Howe, H. V. & Chambers, 1935, p. 11, Plate 1, Fig. 7; Plate 2, Figs. 4-6; Vernon, 1942, p. 43.

Cytheridea caldwellensis Howe, H. V. & Chambers, 1935. Garrett, 1936, p. 786.

Cytheridea (*Cleithrocytheridea*) *caldwellensis* Howe, H. V. & Chambers, 1935. Monsour, 1937, p. 89, 93.

Cytheridea (*Clithrocytheridea*) *caldwellensis* Howe, H. V. & Chambers, 1935. Stephenson, 1937, p. 154, Plate 26, Fig. 13; Brown, 1958, p. 59, Plate 5, Fig. 16.

Cleithrocytheridea caldwellensis (Howe, H. V. & Chambers), 1935. Wilbert, 1953, p. 125.

Clithrocytheridea caldwellensis (Howe, H. V. & Chambers), 1935. Stephenson, 1946, p. 327, Plate 42, Fig. 13; Blake, 1950, p. 175, Plate 29, Fig. 12; Howe, 1951, p. 6; Howe, in Treadwell, 1954, p. 2321; Krutak, 1961, p. 777, Plate 92, Fig. 3; Morkhoven, 1963, p. 284; Deboo, 1965, Plate 13, Fig. 6; Laurencich, 1969, p. 496, Plate 1, Fig. 16; Huff, 1970, p. 95, Plate 6, Figs. 7, 8.

Clithrocytheridea cf. *C. caldwellensis* (Howe, H. V. & Chambers). Swain, 1951 p. 24, Plate 2, Fig. 28.

Ouachitaia caldwellensis (Howe & Chambers). Howe, 1971, p. 352, Plate 1, Fig. 3, 4; Howe, H. J., & Howe, R. C., 1973, p. 638, Plate 2, Fig. 5; Howe, H. J., & Howe, R. C., 1975, p. 288, Plate 2, Fig. 22-24; Howe, H. J., 1977, p. 292, Table 1.

Material: 17 valves.

Genus COCOAIA Howe, 1971

COCOAIA GRIGSBYI (Howe, H. V. & Chambers), 1935

Plate 18, Fig. 4

Cytheridea grigsbyi Howe, H. V. & Chambers, 1935, p. 15, Plate 1, Figs. 2, 3; Plate 2, Figs. 8, 10, 17, 18; pl. 6, fig. 1.

Cytheridea (*Cleithrocytheridea*) *grigsbyi* Howe, H. V. & Chambers, 1935. Monsour, 1937, p. 89, 93.

Cytheridea (*Clithocytheridea*?) grigsbyi Howe, H. V. & Chambers, 1935. Bold 1946, p. 80, Plate 7, Fig. 15.

Clithrocytheridea grigsbyi (Howe, H. V., & Chambers), 1935. Blake, 1950, p. 175, pl. 29, Figs. 13-15; Bold 1950, p. 108, in Treadwell, 1954, p. 2321; Krutak, 1961, p. 778, Plate 92, Fig. 12; Deboo, 1965, Plate 13, Fig. 4; Huff, 1970, p. 96, Plate 6, Figs. 9, 10; pl. 7, fig. 1.

Cleithrocytheridea grigsbyi (Howe, H. V., & Chambers), 1935. Wilbert, 1953, p. 125.

Cocoaia, *grigsbyi* (Howe, H. V. & Chambers), 1935. Howe, 1971, p. 353, Plate 1, Fig. 5; Howe, H. J. & Howe, R. C., 1975, p. 285, Plate 2, Fig. 8; Howe, 1977, p. 292, Table 1, not Poag, 1974b, p. 44, Plate 2, fig. 2 (=*C. grigsbyi chickasawhayana*).

Cocoaia grigsbyi grigsbyi (Stephenson). Bold, 1978, p. 130, Table 5.

Material: 19 valves.

Genus CYAMOCYTHERIDEA Oertli, 1956
CYAMOCYTHERIDEA CHAMBERSI (Stephenson), 1937
Plate 18, Fig. 5

Cytheridea *(Haplocytheridea)* *chambersi* Stephenson, 1937, p. 147, Plate 26, Fig. 2; text Figs. 13, 22.
Cyamocytheridea *chambersi* (Stephenson). Huff, 1970, p. 99, Plate 7, Figs. 5-9; Howe, 1977, p. 292, Table 1.
Material: 2 valves.

CYAMOCYTHERIDEA WATERVALLEYENSIS (Stephenson), 1937

Cytheridea *(Haplocytheridea)* *watervalleyensis* Stephenson, 1937, p. 154, Plate 26, Fig. 3; text Figs. 1, 2, 9, 11, 12; Bold, 1946, p.80.
Haplocytheridea *watervalleyensis* (Stephenson). Wilbert, 1953, p. 124.
Cyamocytheridea *watervalleyensis* (Stephenson). Kollman, 1960, p. 157, Plate 10, Figs. 1, 2, 13, 14; Krutak, 1961, p. 778, Plate 91, Fig. 2; Plate 93, Fig. 16; Deboo, 1965, Plate 12, Fig. 13; Huff, 1970, p. 101, Plate 7, Figs. 14, 15; Plate 8, Figs. 1-4; Howe, 1977, p. 292, Table 1; Bold, 1978, p. 130, Table 5.

Material: 8 valves.

Genus HAPLOCYTHERIDEA Stephenson, 1936
HAPLOCYTHERIDEA MONTGOMERYENSIS (Howe, H. V., & Chambers), 1935
Plate 18, Fig. 7

Cytheridea *montgomeryensis* Howe, H. V. & Chambers, 1935, p. 17, Plate 1, Fig. 1; Plate 2, Figs. 1-3, 7, 9; Plate 6, Figs. 17-18; Garrett, 1936, p. 786; Bergquist, 1932, p. 106, Plate 11, Fig. 5; Vernon, 1942, p. 44.

Cytheridea *(Haplocytheridea)* montgomeryensis (Howe, H. V. & Chambers), 1935, p. 700, Plate 94, Figs. 3-4, 9; Monsour, 1937, p. 89, Stephenson, 1937, p. 146, 153; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Stephenson, 1941, text Fig. 9; Stephenson, 1942, Plate 290, Figs. 12-14; Brown, 1958, p. 57, Plate 5, Fig. 4; Morkhoven, 1962, p. 179, Figs. 434-436, 438.
Haplocytheridea *montgomeryensis* (Howe, H. V. & Chambers), 1935. Stephenson, 1946, p. 322, Plate 42, Fig. 29, Blake, 1950, p. 176, Plate 29, Fig. 16; Swain, 1951, p. 20, Plate 1, Fig. 18; Plate 2, Figs. 1-4; Wilbert, 1953, p. 125, Plate 1, Fig. 18; Howe, in Treadwell, 1954, p. 2322; Krutak, 1961, p. 779, Plate 91, Fig. 7: Moore, et al., 1961, p. Q276, Fig. 204, 2a-c; Howe, 1963, p. 23, Plate 2, Figs. 6-9; Deboo, 1965, Plate 13, Fig. 1; Pooser, 1965,

p. 41, Plate 5, Fig. 10; Plate 6, Figs. 1-4; Huff, 1970, p. 102, Plate 8, Figs. 5-8; Howe, R. C. & Howe, H. J., p. 639, Plate 2, Figs. 7, 9; Howe, H. J. & Howe, R. C., 1975, p. 286, Plate 2, Figs. 9, 10; Howe, H. J., 1977, p. 292, Table 1.

Material: 10393 valves.

Subfamily EUCYTHERINAE Puri 1954
Genus EUCYTHERE Brady, 1868
EUCYTHERE LOWEI Howe, 1936
Plate 19, Fig. 1

Eucythere lowei Howe, 1936, p. 144, Figs. 4-6; Monsour, 1937, p. 90; Huff, 1970, p. 108, Plate 9, Figs. 7-10; not E. aff. *E. lowei* Howe, R. C., in Howe, 1963, p. 24, Plate 3, Fig. 1.

Material: 29 valves.

Subfamily NEOCYTHERIDEINDINAE Puri 1957
Genus CUSHMANIDEA Blake, 1933
CUSHMANIDEA GOSPORTENSIS (Blake), 1950
Plate 19, Fig. 2

Cytherideis gosportensis Blake, 1950, p. 179, Plate 29, Figs. 24-25.
Cushmanidea gosportensis (Blake). Huff, 1970, p. 112, Plate 10, Figs. 9, 10.

Material: 1 valve.

Family CYTHERIDAE Baird 1850
Subfamily CYTHERINAE Baird 1850
Genus CYTHEROMORPHA Hirschmann, 1909
CYTHEROMORPHA CALVA Krutak, 1961
Plate 19, Fig. 3

Cythermorpha calva Krutak, 1961, p. 781, Plate 93, Fig. 5; Huff, 1970, p. 139, Plate 15, Figs. 15-18; Howe, 1977, p. 292, Table 1

Material: 201 valves

CYTHEROMORPHA CF. C. ASPERATA Huff, 1970
Plate 19, Fig. 4

cf. *Cytheromorpha asperata* Huff, 1970, p. 140, Plate 15, Figs. 23-26
Discussion: This specimen resembles *C. asperata* Huff in that it

possesses a ventral ridge. The ridge, however, is very subdued, and *C. asperata* has a prominent ridge. Also, *C. asperata* is covered by an irregular pattern of reticles, and the specimen recovered in this study has a smooth surface except for very faint reticles in the extreme posterior portion of the valve.

Material: 1 valve.

Family LOXOCONCHIDAE Sars 1925
Genus LOXOCONCHA Sars, 1866
LOXOCONCHA COCOAENSIS Krutak, 1961

Plate 20, Fig. 6

Loxoconcha cocoaensis Krutak, 1961, p. 774, Plate 93, Fig. 2; Huff,1970, p. 131, Plate 14,.Figs. 7-10.

Material: 130 valves.

LOXOCONCHA CONCENTRICA Krutak, 1961

Plate 20, Fig. 3

Loxnconcha concentrica Krutak, 1961, p. 775, Plate 93, Fig. 6; Deboo, 1965, Plate 12, Fig. 8; Huff, 1970, p. 132, Plate 14, Figs. 11-13; Howe, R.C. & Howe, H.J., f973, p. 642, Plate 3, Figs. 11-12; Howe, 1977, p. 292, Table 1.

Discussion: Howe and Chambers (1935) find *Loxoconcha jacksonensis* at the Montgomery Landing outcrop but no *L. concentrica*. Examination of Howe and Chamberts' type material indicates *L. jacksonensis* is a very restricted form. It is characterized by a smooth to finely pitted carapace, with the pits showing no particular orientation. *L. concentrica*, as its name implies, is finely to coarsely pitted, with the pits arranged in concentric rows. As Howe & Howe (1973) state, finely pitted specimens of *L. concentrica* may be difficult to distinguish from *L. jacksonensis*, although the concentric pitting usually may still be seen in the postero-ventral portion of the valve. Also, *L. jacksonensis* is slightly larger and more ovate than *L. concentrica*. In most specimens recovered from Montgomery Landing the concentric arrangement of the pits is clearly evident. Therefore, these specimens must be placed in *L. concentrica*. Several smooth to finely pitted specimens that are nearly identical to Howe & Chambers' type material for *L. jacksonensis* were recovered, but, as stated previously, this is a much rarer form. It is suggested here that many of the reported occurrences of *L. jacksonensis* in the literature may have actually been *L. concentrica*. Since much of this information was reported in checklist form, however, there is no way of checking this assumption. Therefore, the reported occurrences of *L. jacksonensis* are left, with reservation, in the synonymy of that species.

Material: 1967 valves.

LOXOCONCHA CREOLENSIS Howe & Chambers, 1935
Plate 20, Fig. 1

Loxoconcha creolensis Howe & Chambers, 1935, p. 40, Plate 5, Fig. 13; Monsour, 1937, p. 90; Murray, 1938, p. 586; Wilbert, 1953, p. 125; Howe, in Treadwell, 1954, p. 2322; Brown, 1958, p. 66, Plate 6, Fig. 3; Krutak, 1961, p. 775, Plate 93, Fig. 1; Deboo, 965, Plate 12, Fig. 9; Huff, 1970, p. 133, Plate 14, Figs. 14-16; Howe, 1977, p. 292, Table 1

Loxoconcha cf. *L. creolensis* Howe & Chambers. Swain, 1948, p. 194, Plate 12, Fig. 13, Swain, 1951, p. 27, Plate 2, Fig. 15.

Material: 32 valves.

LOXOCONCHA JACKSONENSIS Howe & Chambers, 1935
Plate 20, Fig. 4

Loxoconcha jacksonensis Howe & Chambers, 1935, p. 41, Plate 4, Fig. 20; Plate 5, Fig. 14; Plate 6, Figs. 8, 9; Monsour, 1937, p. 90; Murray, 1938, p. 586; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 109, Plate 11, Fig. 18; Vernon, 1942, p. 44; Wilbert, 1953, p. 125; Howe, in Treadwell, 1955, p. 269; Brown, 1958, p. 66, pl. 6, Fig. 4; Krutak, 1961, p. 775, pl. 93, Fig. 9; Huff, 1970, p. 134, Plate 15, Figs. 1-4; Howe, 1977, p. 292, Table 1.

Loxoconcha jacksonensis Howe & Chambers. Howe, in Treadwell, 1954, p. 322.

Discussion: See *Loxoconcha concentrica*.

Material: 9 valves.

LOXOCONCHA WATERVALLEYENSIS Krutak, 1961
Plate 20, Fig. 5

Loxoconcha watervalleyensis Krutak, 1961, p. 775, Plate 93, Fig. 3; Huff, 1970, p. 136, Plate 15, Figs. 5, 6.

Material: 149 valves.

LOXOCONCHA sp.
Plate 20, Fig. 2

Description: The surface ornamentation is dominated by two prominent blade-like ridges. A ridge extends along and above the dorsal margin form the anterior cardinal angle to just anterior of the posterior cardinal angle, where it curves downward and dies out in the mid-posterior region. A second ridge extends from the anteroventral margin to the mid-ventral region, where it curves up sharply towards the mid-posterior region, and ends just anterior to the dorsal ridge. The valve is coarsely reticulate; no definite pattern in the reticulation is evident.

On the inside, the valve is shallow, with a broad anterior and posterior marginal area, and a less broad ventral marginal area. The inner margin is approximately parallel to the outer margin. A fairly wide anterior vestibule becomes in the ventral and posterior marginal area. The muscle scars are not visible. Hingement is gongylodont.

Discussion: This is probably a previously-undescribed species. This worker could find no similar species in the literature. As only one valve was recovered, however, a new species should not be named at this time.
Material: 1 valve.

Family CYTHERURIDAE G.W. Muller 1894
Subfamily CYTHERURINAE G.W. Muller 1894
Genus CYTHERURA Sars, 1866
CYTHERURA aff. C. ULTRA Blake, 1950
Plate 19, Fig. 5

aff. *Cytherura ultra* Blake, 1950, p. 182, Plate 30, Fig. 19.
Cytherura aff. *C. ultra* Huff, 1970, p. 115, Plate 11, Figs. 8-10.

Discussion: One right valve was recovered from the Moodys Branch Formation. As discussed by Huff (1970), this form differs from *C. ultra* Blake principally in the configuration of surface ridges.

Both forms have a prominent ventral ala. This form has a ridge extending from the mid-ventral alar region to the midanterior valve margin. A second, weaker ridge extends from the mid-ventral alar region to the caudal process. A series of three transverse ridges extend from the dorsal margin to the anteroventral ridge. These sigmoid ridges are anteriorally convex in the dorsal region and anteriorally concave in the ventral region.

C. ultra Blake has a pitted groove separating the anteroventral ridge and the ala. There also is a deep sulcus in the mid-ventral region immediately dorsal of the anteroventral ridge. The valve recovered in this study lacks both of these features.

Subfamily CYTHEROPTERINAE Hanai 1957
Genus CYTHEROPTERON Sars, 1866

CYTHEROPTERON MONTGOMERYENSIS Howe & Chambers, 1935
Plate 19, Fig. 6

Cytheropteron montgomeryensis Howe & Chambers, 1935, p. 19, Plate 3, Figs. 14-16; p. 4, Figs. 11-12, 16; Garrett, 1936, p. 786; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399;
Bergquist, 1942, p. 106, Plate 11, Fig. 6; Vernon, 1942, p. 49; Bold, 1946, p. 114, Plate 2, Fig. 12; Bold, 1950, p. 108; Wilbert, 1953, p. 125; Howe, in Treadwell, 1954, p. 2322; Bold, 1960, p. 177; Krutak, 1961, p. 777, pl. 93, fig. 12; Huff, 1970, p. 119, Plate 11, Figs. 19-21; Howe, H.J. & Howe, R.C., 1975, p. 286, Plate 2, figs. 1, 2; Howe, 1977, p. 292, Table 1.
Cytheropteron mongomeryense Howe & Chambers. Martin, 1939, p. 176; Shimer & Shrock, 1944, p. 693, Plate 292, Figs. 16-21.

Material: 1338 valves.

Family XESTOLEBERIDIDAE Sars 1928
Genus XESTOLEBERIS Sars, 1866
XESTOLEBERIS SARSI Howe & Chambers, 1935
Plate 21, Fig. 4

Xestoleberis sarsi Howe & Chambers, 1935, p. 48, Plate 3, Fig. 9; pl. 4, Fig. 10; Plate 6, Fig. 16; Monsour, 1937, p. 89; Wilbert 1953, p. 125; Howe, in Treadwell, 1954, p. 2322; Huff, 1970, p. 176, Plate 23, Figs. 113; Howe, 1977, p. 292, Table 1.

Material: 32 valves.

Suborder PLATYCOPINA Sars 1866
Family CYTHERELLIDAE Sars 1866
Genus CYTHERELLA Jones, 1849
CYTHERELLA spp.
Plate 21, Fig. 1

Cytherella sp. Howe & Chambers, 1935, p. 6, Plate 4, Figs. 17-18; Plate 5, fig. 11-12; Monsour, 1937, p. 89; Howe, in Fisk, 1938, p. 122; Howe, in Fisk, 1939, p. 1399; Bergquist, 1942, p. 105, Plate 11, Fig. 1; Bold, 1946, p. 60, Plate 2, Fig. 4; Bold, 1950, p. 108; Howe, in Treadwell, 1954, p. 2322; Huff, 1970, p. 182, Plate 25, Figs. 10-11.
Cytherella undetermined sp. A. Huff, 1970, p. 183, Plate 25, Figs.12-14.

Discussion: This worker recognizes that two different species may have been placed in this group, hence the spp. connotation. Howe and Chambers (1935) recognized two cytherellid forms and believed they were the male and female forms of the most common species. These were deposited in the H.V. Howe collection (#'s 829, 830). Huff (1970) described *Cytherella* undetermined sp. A., which in the left valve is characterized by "a weakly projecting flange in the posteroventral part which overlaps the right valve in that region." This feature is not apparent in either of Howe and Chambers' illustrations, but study of the original specimens indicates *Cytherella* sp. Howe and Chambers (HVH #829) has this flange and is the same as *Cytherella* undetermined sp. A. of Huff (HVH #'s 6194-6196). In many of the Montgomery Landing specimens the flange appears to be eroded, and most valves are disarticulated, making identification of the right valves very difficult. Therefor, this worker decided in this study to consider both forms as *Cytherella* spp. In actual numbers, the "flange-type" left valve is by far the most abundant.

Material: 1915 valves.

CYTHERELLA INSCULPTILLA Huff, 1970
Plate 21, Fig. 2

Cytherella insculptilla Huff, 1970, p. 181, Plate 25, Figs. 4-9; Howe, R.C. & Howe, H.J., 1973, p. 653, Plate 2, Figs. 16, 18.

Material: 93 valves.

Genus CYTHERELLOIDEA Alexander, 1929
CYTHERELLOIDEA MONTGOMERYENSIS Howe, 1934
Plate 21, Fig. 3

Cytherelloidea montgomeryensis Howe, 1934a, p. 31, Plate 5, Fig. 1; Howe & Chambers, 1935, p. 7, Plate 5, Fig. 4; Garrett, 1936, p. 786; Monsour, 1937, p. 94; Howe, in Fisk, 1938, p. 123; Howe, in Fisk, 1939, p. 1399; Sexton, 1951, p. 808, Plate 115, Fig. 21; Wilbert, 1953, p. 125; Krutak, 1961, p. 772, Plate 93, Figs. 7, 10; Pooser, 1965, p. 29, Plate 1, Figs. 1, 4, 5, 8, 11; Huff, 1970, p. 186, Plate 26, Figs. 9-12; Howe, 1977, p. 292, Table 1; Bold, 1978, p. 130, Table 5.

Cytherelloidea danvillensis Howe, 1934a, p. 31, Plate 5, Fig. 5; Wilbert, 1953, Plate 1, Fig. 17; p. 125.
Cytherelloidea danvillensis Howe, var. Howe & Chambers, 1935, p. 7, pl. 5, Fig. 5.

Discussion: There appears to be some question as to the validity of the species *C. danvillensis*. This species is characterized by a convex-upward ridge above its sub-central sulcus. Howe & Chambers (1935) note that a variety of this species differs from the type in not possessing this ridge. Krutak (1961) states that this form is actually the male of *C. montgomeryensis*. However, it is uncertain whether the form with the ridge should remain in C. danvillensis or be placed in C. montgomeryensis also. If C. danvillensis is actually a valid species, to this writer's knowledge the female form has never been described.

The male specimens recovered at Montgomery Landing are all similar to C. danvillensis variety of Howe (Howe & Chambers, 1935, p. 7, Plate 5, Fig. 5). These are actually the male form of C. montgomeryensis. No specimens possessing the ridge above the sulcus as in C. danvillensis were recovered.

Material: 1431 valves.

PLATE 15

Figure	
1	*Triangulocypris gibsonensis* (Howe & Chambers) Sample S2N14, X80
2	*Paracypris franquesi* Howe & Chambers Sample S4N05, X69
3	*Paracypris licina* Huff Sample S3N03, X138
4	*Argilloecia subovata* Huff Sample S2N18, X92
5	*Buntonia morsei* (Howe & Pyeatt) Sample S3N18, X115
6	*Buntonia shubutaensis* Howe Sample S4N13, X144
7	*Brachycythere watervalleyensis* Howe & Chambers Sample S4N15, X81
8	*Brachycythere russeli* Howe & Lea Sample S4N08, X58

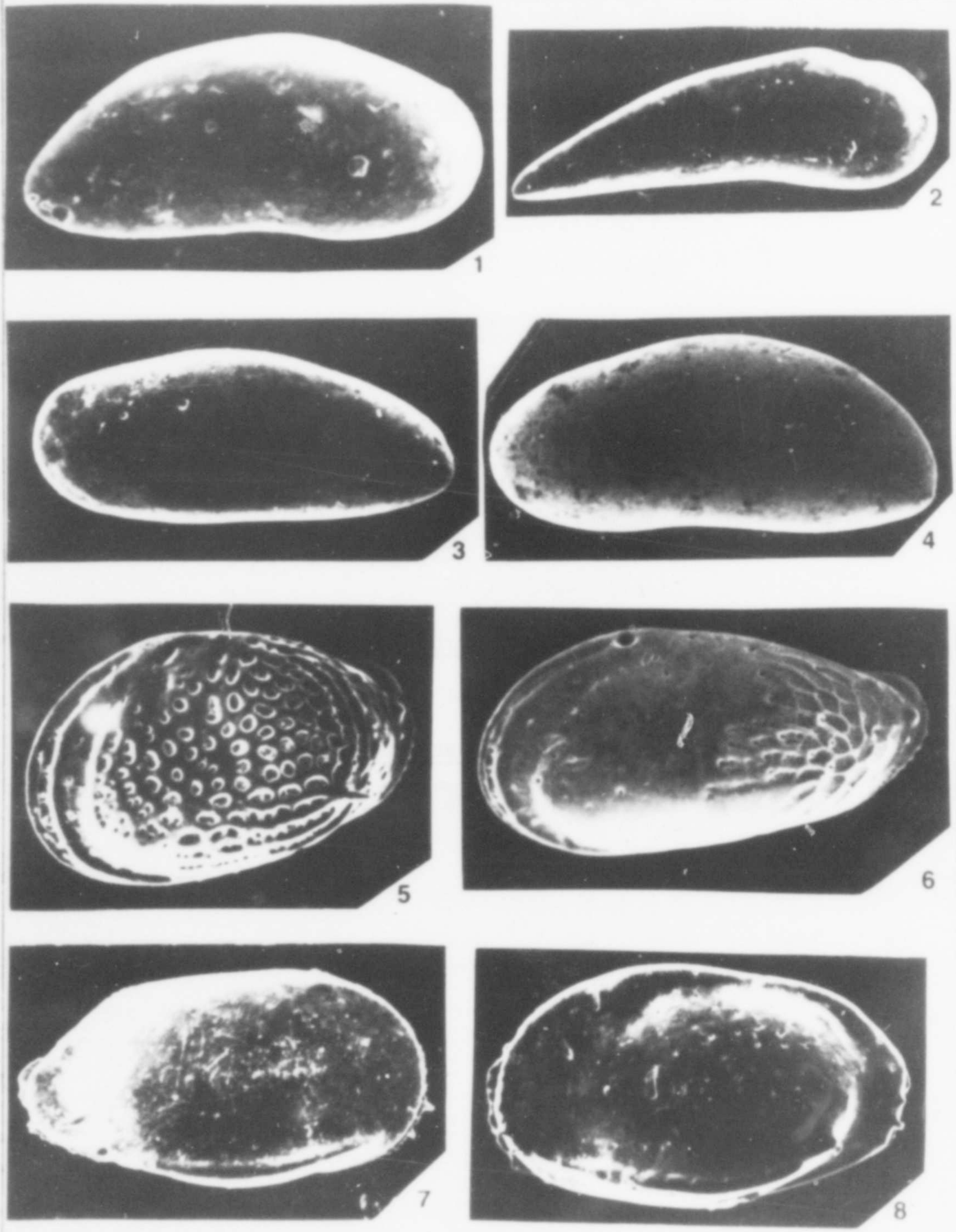


PLATE 15

PLATE 16

Figure

1. *Acanthocythereis florienensis* (Howe & Chambers)

   Sample S3N18, X 104

2. *Actinocythereis purii* Huff

   Sample S3N13, X 72

3. *Acanthocythereis howei* Huff

   Sample S4N08, X 86

4. *Actinocythereis purii* Huff (nodosa - type)

   Sample S4N23, X 67

5. *Actinocythereis gibsonensis* (Howe & Chambers)

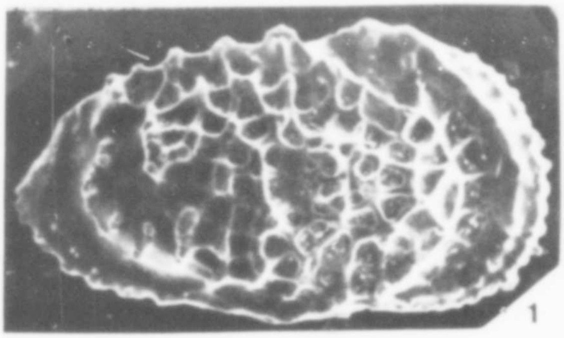
   Sample S4N05, X 96

6. *Trachyleberis*? *grigsbyi* (Howe & Chambers)

   Sample S9N03, X 81

7. *Trachyleberis*? *montgomeryensis* (Howe & Chambers)

   Sample S1N12, X 96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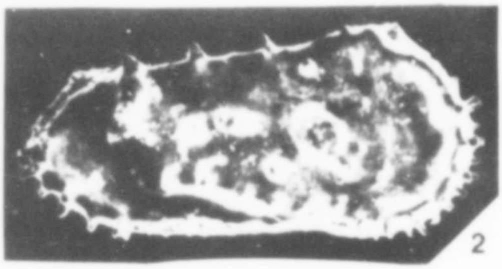
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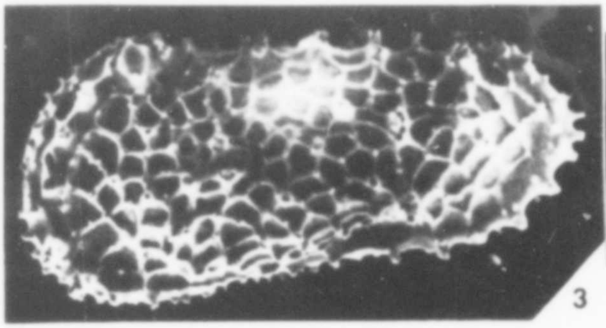
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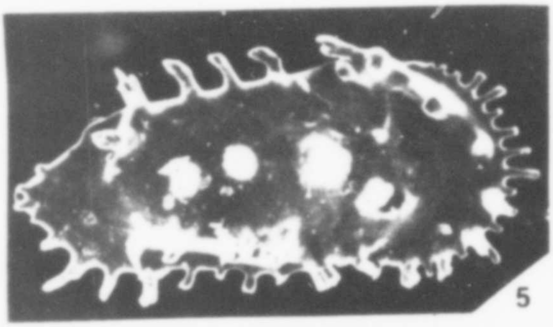
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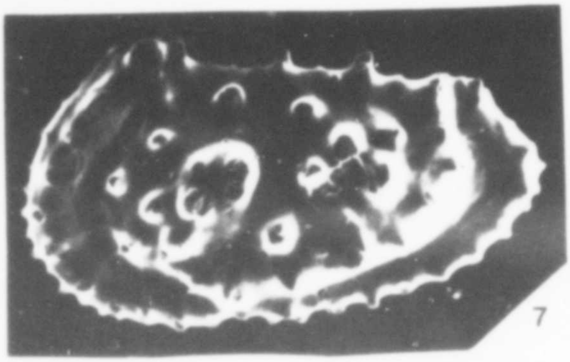
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Plate 16

PLATE 17

Figure	
1	*Echinocythereis jacksonensis* (Howe & Pyeatt) Sample S3N05, X86
2	*Alatacythere ivani* Howe Sample S1N09, X69
3	*Occultocythereis broussardi* (Howe & Chambers) Sample S1N09, X120
4	*Occultocythereis sp.* Sample S4N01, X121
5	*Tropidocythere carinata* Huff Burrow sample, X104
6	*Hermanites dohmi* (Howe & Chambers) Sample S4N05, X120
7	*Hermanites hysonensis* (Howe & Chambers) Sample S1N07, X92

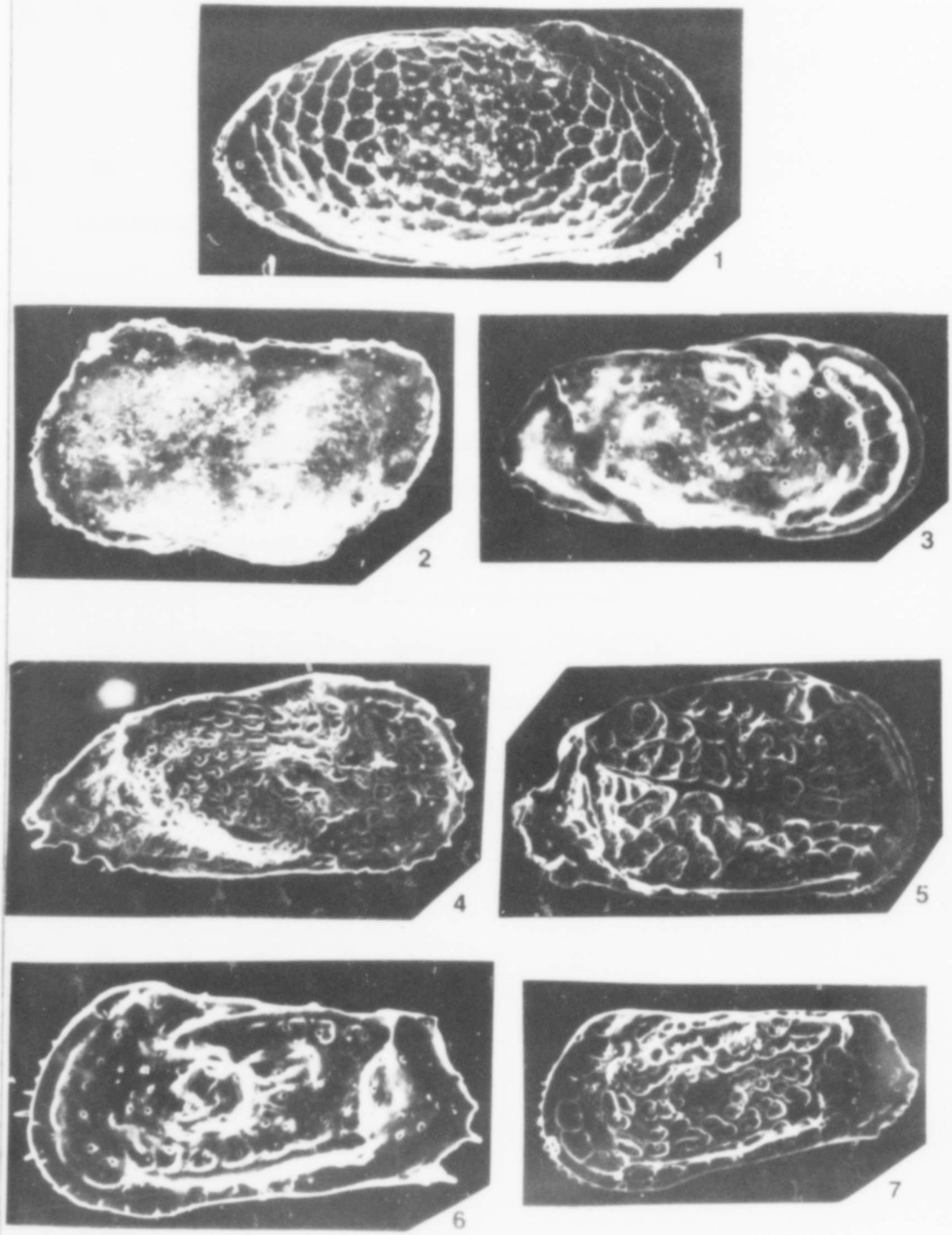


Plate 17

PLATE 18

Figure

1 *Cytheretta jacksonensis* (Meyer)

Sample S4N14, X86

2 *Clithrocytheridea garretti* (Howe & Chambers)

Burrow sample, X92

3 *Ouachitaia caldwellensis* (Howe & Chambers)

Burrow sample, X104

4 *Cocoaia grigsbyi* (Howe & Chambers)

Burrow sample, X127

5 *Cyamocytheridea chambersi* (Stephenson)

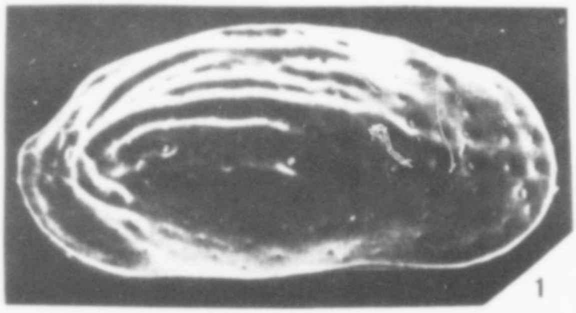
Burrown sample, X104

6 *Cyamocytheridea watervalleyensis* (Stephenson)

Burrow sample, X115

7 *Haplocytheridea montgomeryensis* (Howe & Chambers)

Sample S3N03, X81



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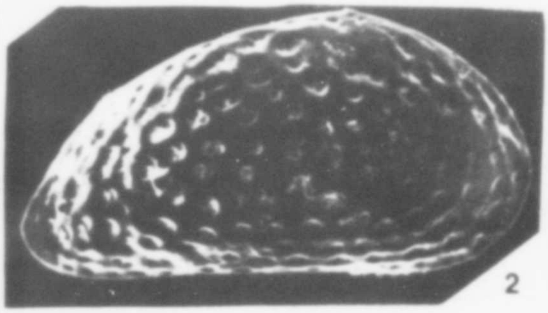

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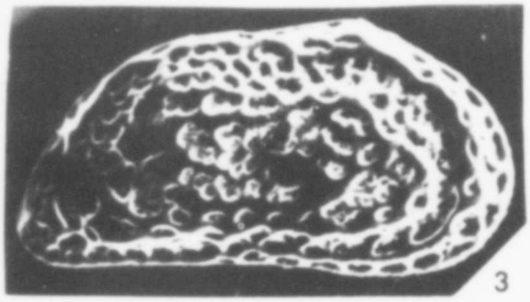

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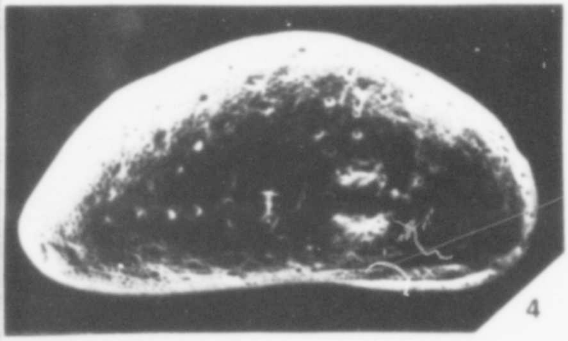

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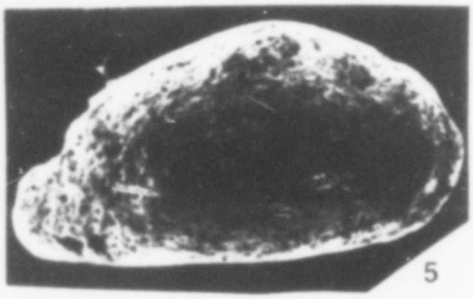

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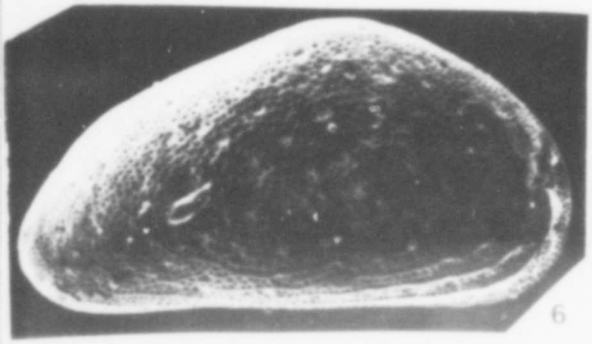

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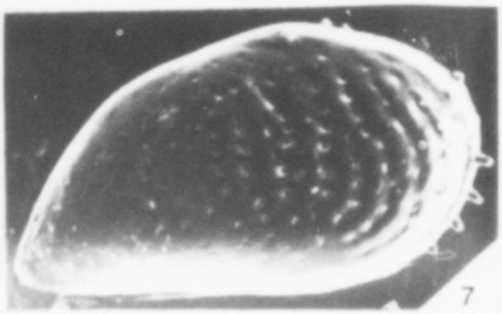

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Plate 18

PLATE 19

Figure

1 *Eucythere lowei* Howe

Sample S4N01, X127

2 *Cushmanidea gosportensis* (Blake)

Burrow sample, X92

3 *Cytheromorpha calva* Krutak

Sample S3N09, X127

4 *Cytheromorpha* cf. *C. asperata* Huff

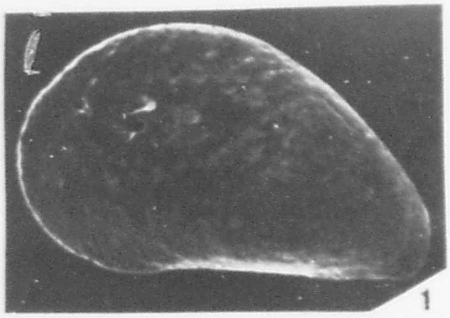
Sample S4N12, X150

5 *Cytherura* aff. *C. ultra* Blake

Sample S2N14, X127

6 *Cytheropteron montgomeryensis* Howe & Chambers

Sample S4N15, X150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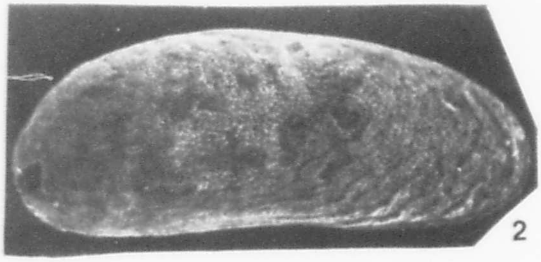
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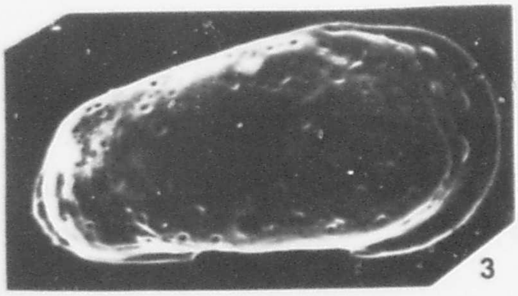
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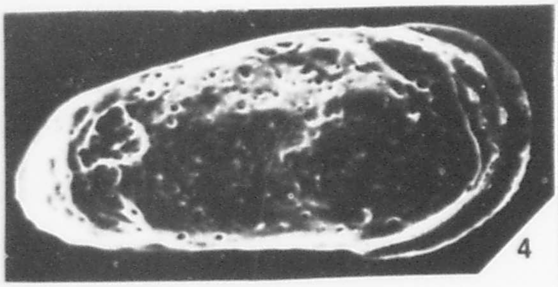
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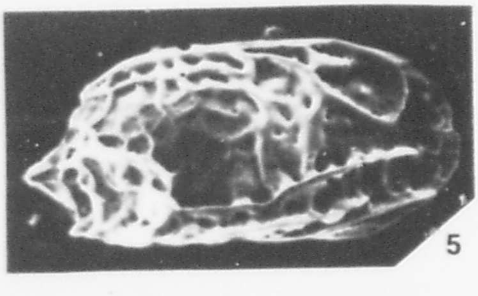
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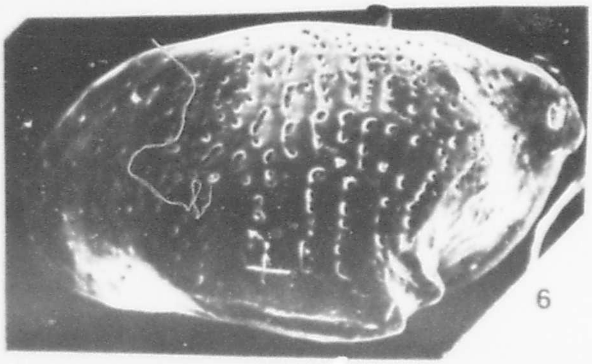
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Plate 19

PLATE 20

Figure

1 *Loxoconcha creolensis* Howe & Chambers

Sample S9N07, X150

2 *Loxoconcha sp.*

Sample S3N18, X161

3 *Loxoconcha concentrica* Krutak

Sample S4N08, X138

4 *Loxoconcha jacksonensis* Howe & Chambers

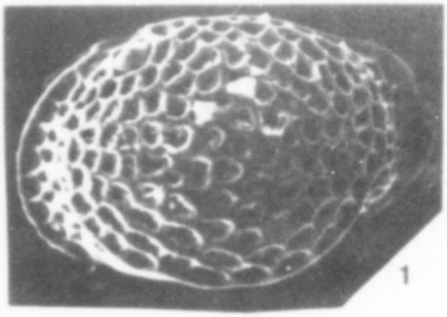
Sample S4N01, X115

5 *Loxoconcha watervalleyensis* Krutak

Smaple S3N09, X138

6 *Loxoconcha cocoaensis* Krutak

Sample S6N15, X127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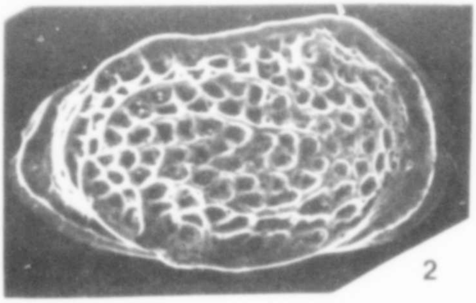
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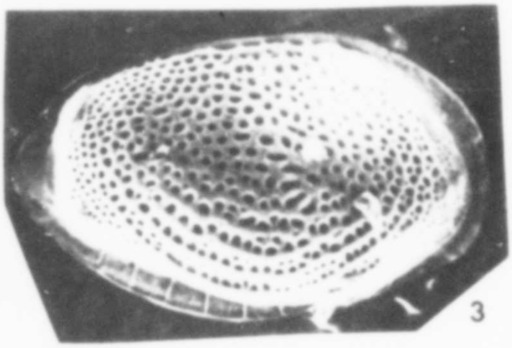
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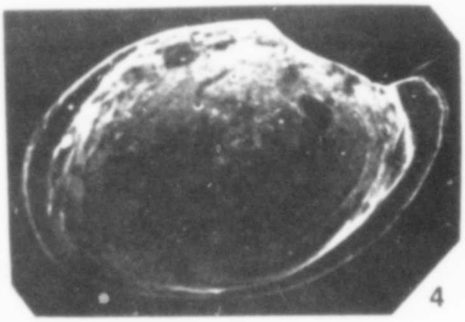
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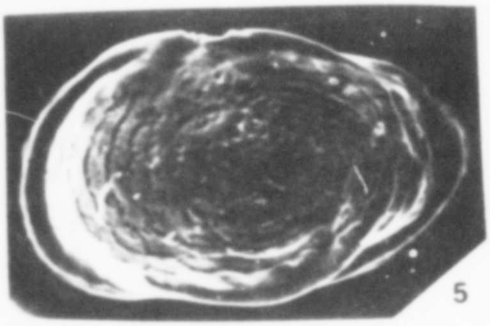
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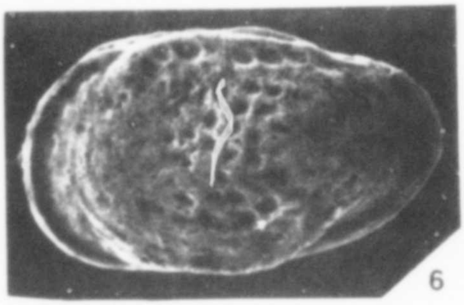
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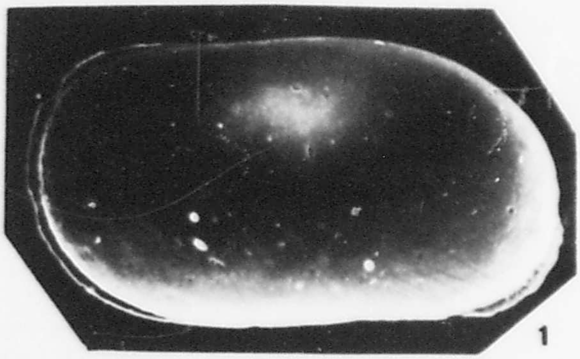
Plate 20

PLATE 21

Figure	
1	*Cytherella sp*. Sample S3N01, X92
2	*Cytherella insculptilla* Huff Smaple S3N01, X96
3	*Cytherelloidea montgomeryensis* Howe Sample S6N02, X104
4	*Xestoleberis sarsi* Howe & Chambers Sample S2N14, X138



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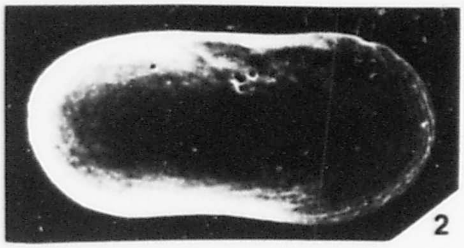

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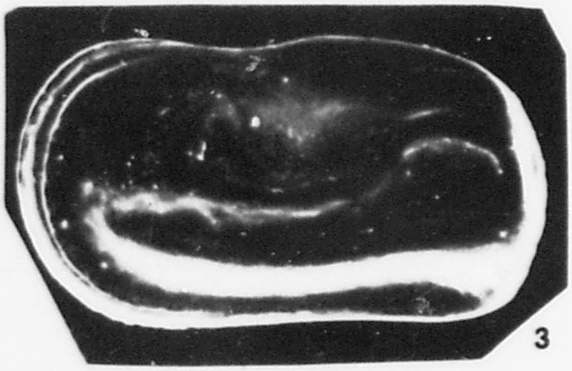

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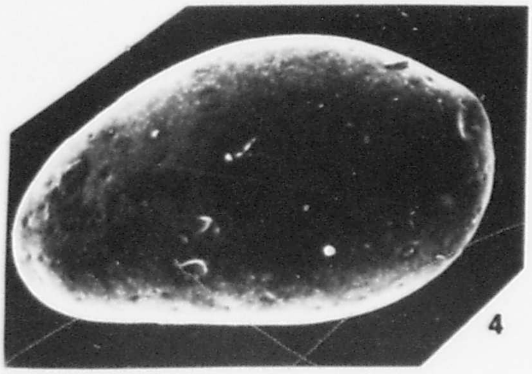

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Plate 21

D. BRYOZOA OF THE MONTGOMERY LANDING LOCALITY, EOCENE OF LOUISIANA*

Comments on the Classification of Bryozoa: This Report and in General

The classification presented in this report represents a fusion of classification schemes gleaned from a number of sources. This was necessary due to the lack of one recent, comprehensive and authoritative taxonomic reference dealing with the variety of bryozoans present at Montgomery Landing. McGuirt (1941) proved to be most useful, as it contains almost every one of the species of Bryozoa found at Montgomery Landing. However, this publication contains some taxonomic errors which were corrected after personal communication with Dr. A. H. Cheetham at the Smithsonian and work with more recent literature (Cook 1968; Ryland 1969; Cheetham 1963).

The cheilostome classification is based almost exclusively on the work of McGuirt, as it seems in agreement with the majority of other comparable material. A few generic and specific taxonomic changes have been made. Reptolunulites (D'Orbigny) has been grouped with the Lunulites types. Porella denticulifera has been considered a synonym of Porella jacksonensis. Canu and Bassler (1920) established Porella denticulifera as a species based on larger tremopores. However, both Canu and Bassler (1920) and McGuirt (1941) expressed some doubt as to the existence of the difference; that is, there appeared in some instances to be a variation in tremopore size. The Montgomery Landing samples contained a gradation in tremopore size, certainly not a bimodal distribution suggesting the existence of two species.

The classification of cyclostomatous bryozoa is even more inconsistent. The classification here is based solely on the current literature, as the Montgomery Landing material is too sketchy for sound anatomical analyses to be made. So instead, Ryland (1969) and Borg (1922), and the Treatise on Invertebrate Paleontology, Vol. G (1953), along with smaller recent papers (Hinks, 1975) were consulted and the taxonomy seen in this paper was produced.

Systematic Paleontology

Phylum BRYOZOA Ehrenberg, 1831
Subphylum ECTOPROCTA Nitsche, 1869
Class GYMNOLAEMATA Allman
Order CHEILOSTOMATA Busk, 1852
Suborder ANASCA Levinsen, 1909
Division MALACOSTEGO Levinsen, 1909
Family MEMBRANIPORIDAE Busk, 1854
Genus CONOPEUM Gray, 1848

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*by Herbert Martin, LSU

Lack an ovicell, an avicularium, and a dietella. Granulate mural rims are very characteristic.

CONOPEUM LAMELLOSUM Canu and Bassler, 1920

Typically an encrusting form, with a very smooth underside. The zoarium is commonly lamellar, with multiple lamellae growing back to back. The zooecia are very regular in shape, elliptical, usually entire mural rims.

Zooecial dimensions: length .4 - .5 mm., width .3 - .35 mm.

Genus OTIONELLA Canu and Bassler, 1917

Discoidal lunuliti form lacking ovicell and hydrostatic zooecia. Vibraculum (interzooecial chamber) asymmetrical and irregularly distributed. Usually one lip more prominent than the other on the vibracular margins.

OTIONELLA PERFORATA Canu and Bassler, 1917

Zoarium is discoidal (lunuliti form). The pattern and shape of the zooecia are characteristic. The zooecia are rounded, broad and distinct and separated by a distinct furrow. They are arranged in irregular radial and transverse lines. The opesium is rounded and bounded by a projecting lip or collar. The vibraculum is rather small (0.25 mm. average length), about the same size as the zooecia, and asymmetrical. The inner face is typically ribbed, with distinct radial furrows. The ribs are perforated by numerous pores.

OTIONELLA TUBEROSA Canu and Bassler, 1920

Zooarium is discoidal with a concave inner face. Two distinctive characteristics differentiate O. tuberosa from O. perforata: 1) the zooecia are joined by a shared mural rim rather than separated into rows and 2) the vibraculum is much larger (0.40 mm. average length) and larger than the zooecia.

The inner face is composed of ornamented ribs separated by clean furrows. The ribs are perforated by a few large pores.

Genus TROCHOPORA D'Orbigny, 1851

Lunulites (discoidal) form typical of the zooarium. The zooecia are aligned into distinct rows, alternating with rows of symmetrical vibracula. No ovicell.

TROCHOPORA BOUEI Lea, 1833

Zoarium normally a triangular lunulites with a slightly convex zoarium and a slightly concave inner face. The zooecia are sub-elliptical, flattened on one end, rather pear-shaped. The vibracula are small and narrow, and aligned into straight rows between the much larger zooecia.

Family ALDERINIDAE Canu and Bassler, 1927
Genus STAMENOCELLA Canu and Bassler, 1917

The few fragments of this material are not complete or common enough to allow identification to the specific level. However, the consistent rows of very symmetrical elliptical zooecia and the well-developed salient mural rims allow identification to the generic level.

Division COILOSTEGA Levinsen, 1909
Family MICROPORIDAE Hincks, 1880
Genus LUNULITES D'Orbigny, 1852

Typified by the convex discoidal lunulitiform zooarium with well-developed ovicell. The ancestrula region often includes enclosed zooecia. Growth accommodated by segments radiating from the center.

LUNULITES JACKSONENSIS (Canu and Bassler) 1917

Zooarium is a typical convex lunulites. The zooecia are distinct and aligned in radial and circular rows. The ancestrula region is well developed, typically composed of five to seven hydrostatic zooecia enclosed by a non-perforated olocyst (seal).

Typical _L. jacksonensis_ is differentiated from other _Lunulites_ by its zooecia size, the distribution of its vibracula, and small pores scattered on its inner surface.

Zooecia measurements: Length .3 - .4 mm., Width .25 - .35 mm.

The vibracula are in distinct rows, are symmetrical, and are marked by lateral condyles. These condyles are small and distally positioned.

LUNULITES FENESTRATA (De Gregorio), 1920

Very similar to L. ligulata. Typically a slightly convex, small lunulitiform with the zooecia and accompanying vibracula aligned in radial rows. The most distinctive character is the presence of hydrostatic zooecia perforated by four pores.

Zooecial measurements: Length .25 - .30 mm.; Width .15 - .25 mm.

LUNULITES BASSLERI (McGuirt), 1941

This species is usually a convex discoidal Lunulites, with radial and concentric rows of zooecia and vibracula. The zooecia are separated by a salient, though small, ridge. The inner face is marked by numerous pores and tubercles decorating the convex ribs. This ornamentation and the very large zooecia differentiate this species.

Zooecial dimensions: Length .5 - .6 mm.; Width .35 - .4 mm.

LUNULITES BASSLERI MONTGOMERYENSIS (McGuirt), 1941

This is a variety of the above species that is very common at Montgomery. It differs in its smaller zooecia and opesia, which result from an expanded cryptocyst not found in typical L. bassleri. In addition, the inner face has more distinct ribs and clear, large pores.

LUNUITES LIGULATA (Canu and Bassler), 1920

This species has a concave lunulitiform zoarium. The zooecia are disposed in distinct radial (but not circular) rows. The round to elliptical opesia are surrounded by a very strong collar. The concave zooarium and the much smaller zooecial and opesial dimensions allow differentiation of this species. The hydrostatic zooecia are partially or totally sealed by calcareous tongues or projections, but they are not perforated by any type of pores.

Zooecial dimensions: Length .2 - .25 mm.; Width .25 - .35 mm.
Opesial length .10 - .15 mm.

Suborder ASCOPHORA Levinsen, 1909
Division Typical Ascophora

Family STOMACHOSELLIDAE Canu and Bassler, 1917
Genus OCHETOSELLA Canu and Bassler, 1917

Branching, often anastomosing cylindrical zooaria marked by aligned areola on the zooecial frontal typify this genus.

OCHETOSELLA JACKSONICA Canu and Bassler, 1917

Typically a free, erect, branching zoarium. Each zooecia is distinct, bordered by a salient thread. The zooecia are elongate to oval, longer (.8 - 1.1 mm.) than wide (0.4 - 0.5 mm.). The frontal covering of each zooecia is normally slightly concave, and each zooecia is marked by a very distinctive set of areolae. These pores are aligned parallel to the salient rim and lead to the deep zooecial aperture located near the base of each zooecial frontal plate.

Family SCHIZOPORELLIDAE Bassler, 1934
Genus HIPPOMENELLA Canu and Bassler, 1917
HIPPOMENELLA c.f. H. MOODYSBRANCHENSIS M^{c}Guirt, 1941

The specimens are fragmentary and rare, containing distinct and elongate zooecia. The avicularia are distinct and well developed just below the aperture. Pores often accompany this avicularia. The zooecial dimensions: Length .9 - 1.3 mm., Width .3 - .6 mm.

Occurs in the Moody's Branch, lower Jackson.

Family SMITTINIDAE Levinsen, 1909
Genus PORELLA Gray, 1848

Defined by a bilamellar, flat, irregular zooarium. The zooecia are elongate, covered with a highly porous tremocyst.

PORELLA JACKSONICA Canu and Bassler, 1920

Typically an undulose, flat, bilamellar zoarium containing elongate zooecia. A highly porous frontal (tremocyst) covers the zooecium and is bounded laterally by large mucro (projections). Large smooth avicularia are located between the oval to rounded apertures. The entire surface is covered with pores.

Zooecial dimensions: Length 0.6 - 0.8 mm.; Width .15 - 0.3 mm.

Family ADEONIDAE Jullien, 1903
Genus ADEONELLOPSIS MacGillivray, 1886

Typically a bilamellar zoarium, free and erect. In our few, fragmented samples, the overall aspect of the zoarium is difficult to discern. The peristome is protruding, complete and perforated by numerous ascopores.

ADEONELLOPSIS GRANDIS Canu and Bassler, 1920

The zoarium is bilamellar and the two lamellae are almost always both in place. It seems that the zooecia will disintegrate before the lamellae will separate. The zoecia are distinct and are separated by a furrow. The aperture is small, anterior distal, and basally crescent-shaped. Below the aperture is the peristomial avicularium.

Zooecial dimensions: Length .40 - .45 mm.; Width .20 - .25 mm.

ADEONELLOPSIS TRANSVERSA Canu and Bassler, 1920

Zoarium small, free and bilamellar, with the lamellae commonly separate. The zooecia are somewhat distinct, but not as clearly or regularly as in A. grandis. The zooecia are elongated, elliptical to pyriform. Well developed areolae usually surround each zooecium. The peristome is well-developed, thick and protruding. It often rises .15 mm. above the surface of the zoarium. A large pore is irregularly located on the peristome, possibly an avicularium. This irregularly positioned areola gives a rather disorganized look to this bryozoan, in contrast to the normally highly organized morphology of most bryozoans.
Dimensions: Length .4 - .45 mm., Width .15 .20 mm.

Family CELLOPORIDAE Busk, 1852
Genus HOLOPORELLA Waters, 1909

Apertures, areolae and avicularia are numerous and typically randomly distributed, giving a very disorganized appearance.

HOLOPORELLA FISSURATA Canu and Bassler, 1920

An encrusting form, differentiating it from most other Holoporella. The zooecia are indistinct, very difficult to delineate. The apertures are .10 to .15 mm. in diameter and virtually circular. They are bordered by occasional oval to lunate ovicells, and scattered small (.05 mm.) areolae. Prominent avicularia accompany most zooecial apertures, but the avicular position is variable.

Genus ACANTHIONELLA Canu and Bassler, 1917

Possesses a diagnostic lyrula, long (.01 mm) and strong within an oval to rounded aperture.

ACANTHIONELLA OECIPOROSA Canu and Bassler, 1920

The most diagnostic features are the very bumpy, gibbous surface of the zoarium and the distinctive proximal lyrula within the aperture. The rounded, convex olocyst frontal is perforated by numerous avicularia. The avicularia are often concentrated near the aperture. The zoarium is bilamellar, with the lamellae commonly separated. The interior view shows clearly the radiating fibers of the olocyst. The apertures are aligned in diagonal rows.

The zooecia are widely variable in size, ranging from 0.3 to 0.7 mm in length. This appears to be a growth feature, with younger specimens simply being smaller versions of the larger, older specimens.'

Genus KLEIDIONELLA - Cann and Bassler, 1917

The one fractured specimen found in the Montgomery Landing samples is highly worn and may have been transported considerably.

Typically the zoarium is very large, with numerous cumulate zooecia. This abudance of cuulate, heaped zooecia (and associated vibracula) give this genus a "disorganized" look which was important in identifying the specimen. In addition, Kleidionella is formed by the back-to-back fusion of two groups of zooecia. This character is also discernible on the Montgomery Landing specimen.

Division HEXAPOGONA
Family ORBITULIPORIDAE Canu and Bassler, 1923
Genus SCHIZORTHOSECOS Canu and Bassler, 1917

The zoarium is discoid and cupuliform. The zooecial aperatures are dispersed in radiating and concentric rows. Numerous smaller pores (zooeciules) are located between the apertures.

SCHIZORTHOSECOS INTERSTITIA Lea, 1833

Numerous features distinguish this very distinctive species. The zoarium is generally slightly cupuliform, discoid, often preserved intact. The individual zooecia are distinct, particularly distinguishable on the dorsal or lower surface. The numerous interzooecial pores likely served in the hydrostatic system or as avicularia. These zooeciules are more or less aligned into radiating rows.

The most distinctive characteristic is the presence on the inner face of distinct hexagons, each outlining one zooecium. These hexagons are perforated by large tremopores. The ancestrula region is readily apparent in this species, marked by large irregular zooecia and large protruding avicularia. Each zooecia averages .2 - .25 mm. in diameter. Each aperture is typically 0.1 mm. in width and .15 mm. in length.

The outer face of the zoarium is widely variable. On most specimens, the rimule is sharply salient. On other, presumably weathered and more mature specimens, the rimule and peristome are wide and rounded, often partially overgrowing the interzooecial pores.

SCHIZORTHOSECES GRANDIPOROSUM Canu and Bassler, 1920

The zoarium is discoid and cupuliform, usually flat to slightly concave. The zooecia are distinct on the outer face, with each aperture rather oval. The rimule (lip) of the aperture is rounded and slightly salient. Small rounded and irregularly spaced zooeciules are aligned in radial rows between the radial rows of apertura.

The back of the zoarium is once again the most distinctive characteristic. It is smooth and each zooecia is marked by one large and usually one small pore. However, the zooecia are indistinct on the back and the pores appear to be somewhat randomly placed.

The apertures average .08 mm. in widest dimension and range widely (.08 - .15 mm.) in length.

SCHIZORTHOSECOS DANVILLENSIS McGuirt, 1941

This species, like the other Schizorthosecos, is discoid and cupuliform, usually flat though occasionally concave on the inner face. Two features typically differentiate this species. One, the inner face is marked by radiating ribs perforated deeply by numerous small pores. Second, between the apertures are well-developed projecting rounded zooecial openings and irregular indentations. The indentations were likely avicularia (McGuirt, 1941).

The zooecia average .15 mm. in diameter, ranging from .10 - .17 mm. in length and .13 to .15 mm. in width. The apertures are irregular but rounded, with a typical diameter of .08 mm.

Class STENOLAEMATA Borg, 1926
Order CYCLOSTOMATA Busk, 1852
Suborder ARTICULATA Busk, 1859
Family CRISIIDAE Johnston, 1847
Genus CRISIA Lamouroux, 1817

A twig-like cyclostome with an erect zoarium and biserially arranged zooecia. The biserial aperture arrangement is the distinguishing characteristic.

Suborder TUBULOPORINA Milne-Edwards, 1838
Family TUBULIPORIDAE Johnston, 1838
Genus PLEURONEA Canu and Bassler, 1920

Typified by zooecia grouped in fascicles (groups of parallel zooecia), numerous dorsal tergopores and a lateral ovicell. The oecipore is often aligned with the fascicle, on one end.

PLEURONEA FENESTRATA (Busk) Canu and Bassler, 1920

The most outstanding characteristic of this species is the salient fascicles arranged uniserially. The fascicles are also somewhat scattered, depending on the bifurcations and reticulations of the zooarium. The fascicles usually begin at a median ridge and are present on one side of the crest. Four or five tubes per fascicle.

The zoarium is irregularly reticulating or bifurcating and oval to round in shape. Canu and Bassler (1920) refer to the overall shape as "idmoneiform."

McGuirt found the distance between fascicles to be .30 to .42 mm. The Montgomery Landing specimens are even more variable, ranging from 30 to as much as .50 mm. between groups of tubes, though on one specimen there is usually not more than .05 mm. variation.

Ovicells are located laterally on the opposite side of the median crest from the fascicles. Canu and Bassler in their original description described "tuberosities arranged in quincunx" on the ovicell these are not apparent on the Montgomery Landing specimens.

Suborder CANCELLATA Gregory, 1896
Family HORNERIDAE Gregory, 1899
Genus HORNERA Lamouroux, 1821

A branching cyclostome possessing zoecial apertures on one (frontal) side with the ovicell and smaller pores located dorsally.

HORNERA c.f. H. JACKSONICA Canu and Bassler, 1920

The one very weathered fragment present possesses a dorsal enlargement, potentially an ovicell, with evenly spaced apertures frontally bounded by some vacuoles.

Dorsally, the vacuoles are elongated and located within furrows.

The apertures present average .1 mm. in diameter, and are approximately .40 mm. apart.

Order CYCLOSTOMATA
Family ONCOUSOECIIDAE Cann 1918
Genus FILISPARSA D'Orbigny 1853

The zoarium is typically branching, erect, and flattened. Often the zoarium is flabellate. The zoarium is formed by the fusion of two to four tubes.

The zoecia are generally indistinct on the zoarial surface. The zooecial apertures are disseminated irregularly on only one side (the front side.) The dorsal side is often slightly concave and can be marked by convex to horizontal laminations.

Assignment to species was impossible due to the fragmentary nature of the few specimens present.

Family ENTALOPHORIDAE Reuss 1869
Genus ENTALOPHORA Lamoroux 1821

Zoaria in this genus are "slender, cylindrical and ramose" (Bussler, 1953). The zooecial apertures are irregularly dispersed over the entire surface of the cylindrical zoarium (i.e. no distinct front and back) with the peristomes rising distinctly off the surface of the zoarium. The zooecia are distinguishable, separated by a fine thread or line, though this line is often obscured. Entalophora are distinguished by (1) the cylindrical shape of the zoarial cross-section, and (2) the random placement, on all surfaces, of the zooecial apertures.

Family LICHENOPORIDAE - Smitt 1866
Genus LICHENOPORA - DeFrance, 1823

These fossils are very fragile. They are easily broken. On the fossils the visors are rarely preserved in their entirety. The determination of the species, even the recent ones, presents therefore much difficulty (Cann and Bassler, 1920).

The fragments present at Montgomery are typified by their mass of polgonal to subpolygonal, parallel tubes. These are known as cancellia.

The identification of these is made totally on the highly distinctive surface appearance, i.e.., the fascicles are little distinct and the entire zoarium takes on the appearance of a mass of parallel tubes.

Lichenopora c.f. L. boletiformis (Reuss) 1869.

This association is made due to the similarity in size and arrangement of the many tubes of this common species.

Bryozoan Paleoecology

The use of bryozoans in paleoecological determinations has just recently become a common practice. Bryozoans offer insight into the energy regimes, relative sedimentation rates, and bathymetry of their environment while offering little to knowledge of paleopressure, paleotemperature, and other environmental factors.

The pioneer bryozoan paleoecological work was done by Leo Stach (1936, 1937), working with Australian bryozoa. He established that the relative abundance of zoarial forms can be used to study paleoecology. This idea was used by many subsequent authors when considering bryozoan paleoecology. Other authors offered refinement to Stach's initial classification (Lagaaij and Gautier, 1965; Schopf, 1969) while showing growth form can be helpful in determining sedimentation rates, energy regimes, and thus, indirectly, bathymetry see Fig. 5. 15, 16, and 17).

Cheetham (1963a: p. 28) states that modern bryozoa are more euryhaline than some other sessile benthonics (i.e., corals), but maximum bryozoan development occurs in normally saline marine waters. Schopf (1969, p. 239) cited a few examples where salinity affects the zoarial growth habit of bryozoans. This occurs primarily in brackish estuarine, or hypersaline lagoons, and thus would not be of major importance in the Montgomery Landing normal marine units. The lack of significant bryozoan sensitivity to salinity limits the usefulness of bryozoa as paleosalinity indicators. None the less, it appears that the Eocene seas at Montgomery Landing were of normal marine salinities (32% - 37%).

Temperature tolerances are rather poorly documented. Cheetham (1963a: p. 28) made a few generalizations on living genera. Of the genera present at Montgomery Landing, only Conopeum and Smittina are considered by Cheetham. These two have been found in tropical, boreal and anti-boreal waters, seeming to be "truly eurythermal genera."

Rate of sedimentation, substratum consistency, and agitation of water are the factors which most strongly affect bryozoan growth and function. By studying the zoarial growth forms, one can learn much about these facets of the paleoecological scenario.

Agitation of the water is a broad category which here includes wave action, currents, and turbulence (upswelling, random water motion, etc.). Turbulence of the water is necessary to the bryozoa, for as filter feeders they must be exposed to large amounts of water containing planktics. In still water, however, many of the more highly integrated forms can create currents of their own. Thus many bryozoans can survive in relatively calm waters, and through the use of vibraculae (and vibracular setae) supply themselves with food and keep the zoarial surface clean (Cook, 1977 and 1980).

Water agitation often determines the growth form of polymorphic bryozoa. Stach (1937, p. 81-82) finds "A striking example ... Caleschana denticulata (Macgillivray, 1869), where according to the degree of motion of the bottom water, it may develop a membraniporiform (in the littoral zone), and eschariform (in deeper water subject to wave action and currents) or a vinculariform zoarium (in deeper sheltered waters)." This is one way water agitation can effect zoarial growth habit.

Strength of water movement also influences the initial habitat selection, i.e., the larval attachment and early ontogeny and astogeny. high wave energy will destroy fragile, erect, inflexible forms if they attempt to grow in littoral high-energy waters. Only flexible erect (eschariform, etc.), encrusting (menbraniporiform) and/or free (lunulitiform) types can resist the stress of high wave energy.

Erect forms (cellariiform, adeoniform, etc.) become more common with depth (Schopf, 1969: p.240) particularly at depths of one-half the normal wave length. At this depth, the influence of surface waves becomes negligible (Sverdrup et. al., 1942, p.536; Schopf, 1969, p. 240). Thomsen (1977) and Harmelin (1973) found that as water velocities decrease (normally associated with increased depth), the zoarial stems and walls were more thinly calcified, zooecia are less densely spaced, and zoaria tend to be less frequently branched. This may be in response to decreasing wave and water current engeries. However, Schopf et al. (1980) found that bryozoan colony branch diameters decrease gradually with increasing depth. This was found to occur despite highly variable current stress. It was thought that branch diameter was more closely tied to food availability (less light means less food in deep waters) than current strength. Thus it might appear that erect forms result in response to food competition, and soft thin walled types present two advantages: one, they allow earlier access to food than lower "shorter" forms, and two, tall ramose, thin colonies have a higher percentage of zooids removed from potentially damaging fine sediment (i.e., the substrate).

Substratum consistency is as important as any other factor in bryozoan growth and development. Bryozoans will grow on almost any firm substratum, typically occuring attached to or growing free above sand, shells, rocks, and packed sediments (marine "hard grounds"). Encrusting types can also flourish on algal fronds. Many free types (primarily the discoidal lunulitiform types) can live above loose sediments through the use of long peripheral and subperiphreal vibraculae (Cook, 1963). Cook (1979) and Cook and Chimonides (1981) found several types of cheilostome colonies living above loose sediments, and attached by rootlets. Therefore, though bryozoans are most successful on a firm substratum, colonies are highly adaptable and could hardly be excluded by substrate type from any normal marine assemblage.

Sedimentation rate is also quite significant when considering the growth and distribution of bryozoan colonies. Lagaaij and Gautier (1965), in studying bryozoan distribution in the Rhone delta distributary, found rate of sedimentaltion to be the factor controlling the distribution. Naturally, rate of sedimentation and substrate type are inseparably interdependent; areas of high sedimentation rate generally also present a substratum of soft, unconsolidated sediments. It was found that bryozoan populations and species diversity are greatest in areas of firmest sediment. Sediment rate and substratum are of primary importance. Off the northern coast of South America, sedimentation is high on the inner shelf, and bryozoans are absent. On the outer shelf where sedimentation is negligible, relict sand facies are present. Diverse bryozoan populations flourish in this environment of relatively clear water and coarse substratum.

There is currently no evidence to support ideas that pressure, dissolved gases or other minor constituents of marine waters have a significant influence on colony growth or specific population characteristics (Schopf, 1969; Cheetham, 1963).

Paleobathymetry is normally of utmost interest to the paleoecologist. Water depth does not directly affect bryozoan populations and colony structure. However, as depth does affect almost all other factors - food supply, temperature, competition, substrate type, sedimentation rate, agitation of water - it indirectly affects bryozoans and can be estimated.

Generally, bryozoans are most prolific in waters up to 200 m in depth (Ryland, 1970; Cheethamm 1963; Duncan, 1957 and many others), though they range from tidal zones (if protected from destructive waves) to the abyssal (8300 m) Galathea expedition.

Direct Correlation of Zoarial Types with Environmental Factors

Sedimentation rate, depth, food availability, available substratum, and agitation of water are factors which are correlatable to zoarial habit.

Sedimentation Rate

Interesting and occasionally conflicting results have been discovered concerning relationships between sedimentation rate and bryozoa. Cheetham (1963) and Lagaaij and Gautier (1965) found no bryozoan remains during periods (or at sites) of high clastic depostion. Lunulitiform and eschariform types seem to have advantages in conditions of fairly high deposition. Lagaaij (1963) found two lunulitiform genera, Discoporella and Cupuladria, occuring most closely to the mouths of the Mississippi distributary. The independent colony form and the possession of large vibracula to sweep the colony surface of settling sediment are the characters giving an advantage to the lunulitiform types. Lagaaij and Gautier (1965;p.36) found cellariiform types to occur most frequently in the Rhone delta region. They felt that since "... cellariform growth... combines erect growth with great flexibility and the inherent ability to shake off clay flakes," it was supremely adapted to handle moderately high desposition.

Decreasing sedimentation can be caused by different factors, and this is reflected by different bryozoan assemblages. If deposition is lowered by increased current and water agitation, encrusting (membraniporiform), cellariiform and lunulitiform (to a limited extent) are favored. Deposition reduction due to increased distance from the sedimentary source (normally accompanied by decreased water agitation) favors the development of eschariform colonies, though lunulitiform and cellariiform types remain a significant portion of the assemblage.

All forms are dependent upon a suitable substrate upon which to grow. Firm substratum is required by all forms except some encrusters (on algae), some lunulitiform types, and some rooted types.

Depth

As mentioned in the earlier discussion, depth per se has a very limited effect on bryozoan populations. It is the many factors associated with changing depth that so strongly affect bryozoan (and most other animal) assemblages.

Schopf (1969) found that among erect forms, only flexible (cellariiform) types are successful in shallowest waters, and that erect types become important rather suddenly at 35 m depth. He postulates (1968: p. 420) that this corresponds to long-period wave base. Askren (1968) found a very similar relationship in Eocene formations of Alabama.

Membraniporiform colonies seem most adapted to shallow, turbulent waters. Apparently they are outcompeted in calmer waters and are either eliminated or assume another colony form (usally eschariiform).

Lunulitiform types seem to be least affected by changes in depth, commonly occuring in any depth of water. Lunulitiform distribution is controlled more by substratum, although their growth is precluded in shallow water by high energy waters.

Food Availability

As mentioned earlier, Schopf et al. (1980) found food availability to be an important factor affecting colony branch diameters and calcification thickness. Food availability does not directly affect zoarial form; rather it will affect the robustness of the forms present. Thus it seems with increasing depth, food (planktonic productivity) decreases, thereby decreasing the raw materials used in bryozoan growth and development. Ultimately, the colony walls will be thinner and narrower as depth increases.

Substratum Controls

While many previous studies have stated that bryozoan morphology is primarily controlled by substrate, this has more recently been found to be a limited concept. It appears that the morphology is controlled by a system of factors (substrate, sedimentation, salinity, etc.), of which substratum is one important factor.

Encrusting, membraniporiform colonies are of two types; those attached to a hard substratum (Membraniporiform A) and those attached to a flexible substratum (Membraniporiform B). Membraniporiform A types encrust shells and stones, often in areas of maxmium water energies. Algal surfaces are the usual substratum of choice for Membraniporiform B types and algal distribution controls Membraniporiform B distribution.

Discoidal, lunulitiform types are most highly adapted to life on loose, coarse sediments (Greeley, 1967). Lunulitiform types appear to be the most adaptable of all forms, often adapted to life in environs of coarse sediments to deeper, fine grained sediments (Cook, 1963 and 1979; Greeley, 1967).

Erect forms are of two general types: fexible, cellariiform types and rigidly erect eschariform types. Joints between growth segments of cellariiform types allow the colony to give and move with wave and current action. This flexibility in turn allows cellariiform types to colonize hard substrates in shallower water. Eschariform rigidness (and thus fragility) forces it into calmer waters where it can flourish, provided there is sufficient firm or coarse (sand, shells, stones, etc.) substratum to colonize.

Agitation of Water

Movement and agitation of water is another influential factor in determining colonial morphology. The upper, shallow water limit of most growth types is determined by prohibitive, destructive energy.

Lunulitiform types again appear to be the most adaptive. The upper limit of lunulitiform distribution is determined by water agitation. It appears that free discoidal colonies have a stability advantage when wave energy is moderately high. Lunulitiform types are also able to survive in a region of low current, demonstrating colony-wide coordination in creating currents to bring in food and to sweep the colony surface. Lunulitiform types appear least effected by current variation.

Other forms are strongly affected by currents. Membraniporiform (encrusting) types are well adapted to encrusting firm substrata (rocks, shell, etc.) in highest energy environments. These types are usually outcompeted when the water is calm. The flexible nodes of cellariiform types allow survival in moderate to high energy regimes, though consistent pounding will eliminate any erect type. Erect, rigid eschariform types are excluded from high energy environments by the colony's fragility. As has been shown, colony form can be highly indicative of the energy regime.

Bryozoan Paleoecology at Montgomery Landing

A fairly diverse and well developed bryozoan fauna is found in the upper Eocene outcrops at Montgomery Landing. The Moodys Branch formation has a richer fauna than is found in the Yazoo. Tables 10, 11, and 12 list the bryozoa present at Montgomery Landing, their location and their growth forms.

In general, the bryozoan population is dominated by free, discoid to conical lunulitiform bryozoa, such as Schizorthosecos, Lunulites, and Otionella. Erect, rigid types (eschariform, adeoniform) compose an important secondary portion of the fauna, while cellariiform and membraniporiform types are fairly minor contributors to the faunal makeup.

To examine the bryozoan paleoecological implications, the bryozoa must be identified and placed in form categories. This was done for most of the Montgomery Landing bryozoa, though some were too fragmentary to identify zoarial habit and little or no literature published has assigned these bryozoa to form categories. Figures 15, 16, and 17 define zoarial growth types and show the Montgomery Landing bryozoa and their zoarial forms.

Lichenopora was not categorized for two reasons. First, though Lichenopora was very common in the Yazoo, all remains were fragmentary and hard to identify beyond generic level. Therefore, a previous author's designation of growth form could not be applied. Secondly, the fragments present do not fit any established category. However, Lichenopora is useful in paleoecological analysis. It is a very fragile form with many parallel tubes typically covered by a visor. This visor served as a sediment block and a food trap. The presence of Lichenopora indicates calm water with moderate to high deposition. Lichenopora possessess a broad, flat zoarial base, and it could live above soft sediments, provided a firm substate (i.e. a shell) was present for initial growth.

Cockfield Formation

The Cockfield samples are barren of any bryozoa except near the top of the unit. At the top, burrows and current-mixing placed some of the Moodys Branch material in the Cockfield. This fauna will be considered as Moodys Branch.

Moodys Branch

The Moodys Branch faunule is dominated by lunulitiform types. Lunulitiform bryozoa account for an average of 68% of the species in the Moodys Branch. The remainder of the faunule is composed of robust, erect adeoniform types, with very minor occurences of the membraniporiform Conopeum. Since whole colonies are rare, precise population statistics are difficult to derive. Gross population estimations show an even stronger dominance of the assemblage by lunulitiform types.

This faunal association suggests a number of ecological conditions. The dominance of lunulitiform types suggests a shelf (neritic) depositional setting where loose sand and shells were the dominant substratum. The presence of adeoniform and eschariform colonies indicates that wave and current energy, particularly later in Moodys Branch time, was low to moderate. All the colonies are robust and well developed, which implies fairly shallow waters, good availability of food and possibly intermittent strong wave energies. Sedimentation was slow, as indicated by the abundant, diverse bryozoan fauna and the presence of erect, rigid forms. Thus a neritic, low to moderate energy environment under clear, rich, normal marine seas is indicated by the bryozoa for deposition of the Moodys Branch. This would fit in with a geologic scenario in which the Moodys Branch was deposited early in a transgressive sequence.

Yazoo Formation

The bryozoa population is sparsely and inconsistently developed in the Yazoo. As in the Moodys Branch, the faunule is again a mixture of primarily lunulitiform and erect, rigid forms. The percentages of one type or the other vary abruptly and this would suggest an episocis occurrence of some factor controlling the bryozoan populations.

The presence of three "limestone" ledges in the Yazoo makes division of the unit for study convenient. For continuity's sake, this author will use the convention used by Tom Klump in his work. Therefore, the first "limestone" ledge marks the base of the Yazoo, zone a is between ledges 1 and 2, zone B is between ledges 2 and 3, and zone C is above ledge 3.

Zones A and C are similar in that both are rather impoverished with respect to bryozoans. Zone C is totally devoid of bryozoa. Since substrate availability (shells, coarse grains, etc.) and sediment type are about the same in zones A, B, and C, it would seem that some other factor was inhibiting growth and development of the bryozoa in zones A and C. As Rucker (1966) and Lagaaij and Gautier (1965) found high rates of fine grain sedimentation to be prohibitive to bryozoan life, it would seem that sedimentation rates were higher during deposition of zones A and C, particulary zone C.

The bryozoans present in zone A are a mixture of lunulitiform types (approximately 50% of the species), eschariform types (10), cellariform types (10%) and Lichenopora (3). This assemblage suggests conditions of moderate sedimentation, low to moderate current strengths and limited suitable substrate.

Zone B supports a more diverse and populous faunule. Though not as rich as the Moodys Branch faunule, the characteristics of the zone B association are similar to the Moodys Branch. Lunulitiform types make up around 60% of the faunule, while delicate eschariform types account for 29%, Lichenopora for about 15%, and occasional membraniporiform, cellariiform and adeoniform types the remaining 5%. This assemblage suggests reduced sedimentation, low current energies, and moderately good substrate availability. Lack of sufficient substrate probably limited the development of a richer fauna, as shells are the only available support present.

The limestone ledges have been postulated (Kilmartin, 1980) to be neomorphosed micrite, probably initially deposited during periods of very low terrigenous sediment input. This low sedimentaiton period would be the ideal time for a bryozoan bloom. Some sections within the ledges (9-7, 4-22) contain a diverse and rich bryozoan fauna of primarily delicate eschariform types (50%) lunulitiform types (40%) and Lichenopora (10%). Most ledge samples are devoid or very impoverished with respect to not only bryozoa, but most fossils. Some casts and molds are the most common remains. The ledges are much more porous than the rest of the Yazoo and probably serveral have been leached out. The fossils preserved suggest a stable sea bottom with little sedimentation and gentle current and wave action.

Just below and just above the ledges, there is often a proliferation of bryozoa (samples 4-25, 3-9, 7-7), particularly Lichenopora (4-13, 3-7, 9-17) just below the ledges. This is probably in response to decreasing sedimentation rates.

The Yazoo as a unit was deposited in slightly deeper water (on the average) than the Moodys Branch. The sedimentation was variable throughout the period, being most significant during upper Yazoo deposition.

The bryozoa indicate that the Jackson deposits at Montgomery Landing were deposited on a moderate to shallow (10 - 100 m) shelf, with a mild and fluctuating transgression recorded by these sediments.

Table 10. Montgomery Landing Bryozoa

SPECIES	MOODY'S BULK	GRID SAMPLE
Acanthionella oeciporosa	X	X
Adionellopsis transversa	X	X
Adionellopsis grandis	?	X
Conopeum lamellosum	X	X
Crisia sp.		X
Entalophora sp.	X	
Hippominella Moodysbranchensis	X	
Filisparsa sp.	X	
Holoporella montgomeryensis	?	X
Hornera jacksonica		X
Kleidionella ?	X	
Lichenopora c.f. *L. boletiformis*		X
Lunulites bassleri	X	X
Lunulites bassleri montgomeryensis	X	X
Lunulites fenestrata	X	X
Lunulites jacksonensis	X	X
Lunulites ligulata	X	X
Ochetosella jacksonica	X	X
Otionella perforata	X	X
Otionella tuberosa	X	X
Pleuronea fenestrata	?	
Polyascosoecia jacksonica		X
*Porella jacksonica**	X	X
Schizorthosecos danvillensis	X	X
Schizorthosecos grandiporosum	X	
Schizorthosecos interstitia	X	X
Stamenocella sp.	X	X
Trochopora bouei	X	X

* - Includes some differing types, named *P. denticulifera* by McGuirt, which are here considered as a variety of *P. jacksonica*.

Table 11. Occurrence of Bryozoa in samples from Montgomery Landing.

SPECIES	SECTION	SAMPLES
Acanthionella occiporosa	1	7
	3	9
Adionellopsis transversa	4	19
	6	12
Adionellopsis grandis	2	14
Adionellopsis sp.	1	10
	9	5, 6
Conopeum lamellosum	2	15
Conopeum sp.	1	12
	5	17
Crisia sp.	6	6, 6a, 14
	10	
Entalophora sp.	6	14
Filisparsa sp.	6	14
	a	7
	a	7
Holoporella montgomeryensis	1	9
Hippominella	4	3, 22
Hornera jacksonica	5	6
Kleidionella (?) sp.	1	10
Lichenopora sp. cf. *L. boletiformis* 20-22	4	20-22
	5	6
	7	3
Lichenopora sp.	3	7, 11, 14
	4	13, 19, 20, 22
Lichenopora sp.	5	3, 2, 10, 16, 17
	7	3,7
	6	2, 6a, 8, 14
	9	2, 7, 8
	10	
Lunulites bassleri	1	6, 8
	2	14, 16, 17, 19
	4	1, 2, 15
	5	8, 14
	6	4
	7	8
lunulites fenestrata	1	6, 9
	4	1
	2	14
lunulites jacksonensis	1	8, 9, 10
	2	14, 17
	4	1
Lunulites ligulata	2	14, 16
	4	1 (?)
Lunulites sp.	2	13, 17, 18, 14
	4	22, 23, 21, 17
	5	7

	3	9, 4
SPECIES	SECTION	SAMPLES
	6	3, 15
	7	5
	9	3
Ochetosella jacksonica	2	14
	5	2
	7	7
Otionella perforata	1	6
	2	14, 15, 18
	3	15
	4	15, 22, 17
	5	6
	6	4
	7	7
Otionella tuberosa	1	8
Otionella sp.	3	3, 9, 10
	4	1, 15, 18, 23, 17
	6	15
	5	7, 14
	9	5, 8
	8	4
Pleuronea fenestrata	4	2, 22
	5	17
	7	7
	10	
Porella sp.	1	7
	5	16
	9	7
_Porella jacksonica_*	1	1, 9
	2	13, 14, 16
	4	1, 20
Schizorthosecos danvillensis	1	7
Schizorthosecos interstitia	1	7, 8
	2	14-17
	3	9
	4	1, 15
	5	4, 15
	9	6
Schizorthosecos grandiporosum	4	1
	5	16
Stamenocella sp.	1	12
	5	5
Trochopora bouei	1	7-10
	2	14, 16-18
	3	3, 17, 9, 10
	4	1, 2, 5, 15, 18, 17
	5	7, 14
	6	4
	7	7
	8	7, 8

Table 12. Montgomery Landing bryozoan colony growth forms

Free, discoidal Lunulitiform
- *Lunulites bassleri*
- *Lunulites fenestrata*
- *Lunulites jacksonensis*
- *Lunulites ligulata*
- *Otionella perforata*
- *Otionella tuberosa*
- *Schizorthosecos danvillensis*
- *Schizorthosecos grandiporosum*
- *Trochopora bouei*

Erect, rigid forms *
- *Acanthionella oeciporosa*
- *Adeonellopsis transversa*
- *Adeonellopsis grandis*
- *Entalophora* sp.
- *Filisparsa* sp.
- *Hippominella moodysbranchensis*
- *Holoporella montgomeryensis*
- *Hornera jacksonica*
- *Kleidionella* sp.
- *Pleuronea fenestrata*
- *Porella jacksonica*

Erect, flexible cellariiform
- *Crisia* sp. c.f. *C. hornesi*
- *Stamenocella* sp.

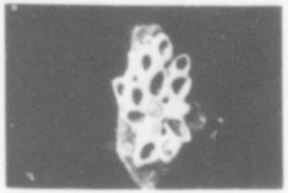
Membraniporiform
- *Conopeum lamellosum*

Uncategorized (see text)
- *Lichenopora* sp. c.f. *L. boletiformis*

* This includes types classified by other authors as adeoniform, eschariform or vinculariiform types. However, these are all firmly attached to the substrate, and many of the Montgomery Landing forms are free.

Fig. 15. Bryozoan Colony Forms. After Lagaaij and Gautier (1965)


1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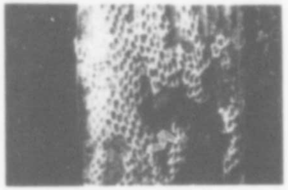
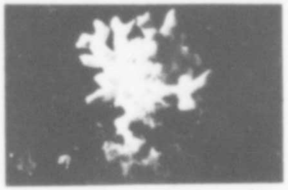
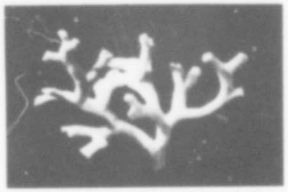
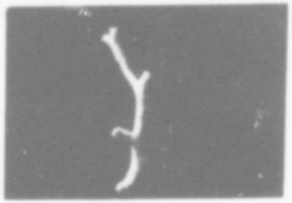

3


4


5

FIRMLY ATTACHED	encrusting a solid substratum	1	MEMBRANIPORIFORM (A)	Zoarium usually, but not necessarily, unilamellar, encrusting a solid substratum. Dorsal wall of zooecia entirely calcified
		2	SETOSELLINIFORM	Zoarium encrusting in spiral growth on small foreign objects which do not become incorporated in the adult zoarium. Usually a vibracular seta distal to each zooecium
	encrusting a flexible substratum	3	MEMBRANIPORIFORM (B)	Zoarium unilamellar, encrusting a generally flat flexible substratum. Dorsal wall of zooecia not or poorly calcified.
		4	CELLEPORIFORM	The zoarial habit in which the zooecia are heaped irregularly in multilamellar masses of variable shape, inherent with incrustation on or around a flexible substratum.
	erect, rigid	5	ADEONIFORM	Zoarium erect, rigid, bilamellar, lobate, firmly attached to a solid substratum by a calcareous base
		6	VINCULARIIFORM	Zoarium erect, rigid, consisting of dichotomous sub-cylindrical branches, firmly attached to a solid substratum by a calcareous base
		7	RETEPORIFORM	Zoarium erect, rigid, strongly calcified, fenestrate or reticulate, firmly attached to a solid substratum by a calcareous base
LOOSELY ATTACHED	encrusting	8	PETRALIIFORM	Zoarium unilamellar, attached by chitinous rootlets emanating from pores in the dorsal surface of the colony
	erect, flexible	9	CELLARIIFORM	Zoarium erect, flexible (jointed), calcareous, attached to the substratum by rootlets. Internodes consisting of numerous zooecia
		10	CATENICELLIFORM	Zoarium erect, flexible (jointed), calcareous, attached to the substratum by rootlets. Internodes consisting of few zooecia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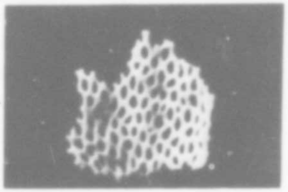
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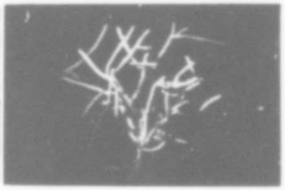
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10

MORPHOLOGICAL FEATURES OF ZOARIAL TYPES IN CHEILOSTOME BRYOZOANS

Zoarial Form	Mode of Attachment	Morphology	Arrangement and Shape of Zooecia
Cellariiform	Attached basally to substratum by chitinous fibers.	Erect; cylindrical or subcylindrical; branched or unbranched; jointed.	Zooecia in two or more longitudinal rows, generally alternating in position; zooecia hexagonal, rhombic, or rhomboidal.
Lunulitiform	Not attached.	Discoidal to conical; base hollow or filled; zoarium surrounds a small grain.	Zooecia in branching rows radiating from ancestrula; orifices on one side of the zoarium; zooecia rhomboidal.
Membraniporiform	Basal wall of each zooecium adherent directly to substratum or connected to substratum by fibers.	Encrusting	Zooecia arranged somewhat irregularly, often in branching rows radiating from ancestrula; orifices on one side of zoarium; zooecia hexagonal, rhomboidal, or rectangular.
Eschariform	Basal zooecia directly adherent to substratum.	Erect; cylindrical to compressed; branched or unbranched; anastomosing or not	Zooecia in vertical rows, alternating in position; orifices on one or both sides of the zoarium; zooecia usually rhomboidal or rectangular

Fig. 16

(From Cheetham, 1963 after Stach, 1936)

CORRELATION OF ZOARIAL FORM WITH HABITAT

Zoarial Form	Type of Substratum	Agitation of Water	Optimal Depth (in feet)
Cellariiform	*FIRM;* shells, test of larger foraminifers, algae; common only on algal substrata from which competitors have been excluded.	*QUIET TO AGITATED;* but more common in agitated water from which competitors have been excluded.	50-150
Lunulitiform	*FIRM OR LOOSE*– Common only on loose, granular substrata from which competitors have been excluded.	*QUIET TO AGITATED;* more conical in quiet water.	50-350
Membraniporiform	*FIRM;* shells, tests of larger foraminifers, algae.	*QUIET TO AGITATED;* more common in agitated water from which competitors have been excluded	5-600
Eschariform	*FIRM;* shells, tests of larger foraminifers.	*QUIET*	150-600

Fig. 17

(From Cheetham, 1963 after Stach, 1936)

PLATE 22

Figure 1 - *Conopeum lamellosum*, Canu and Bassler

Oral surface, 34 X. Elliptical, regular zooecia with well-developed mural rim are shown.

Figure 2 - *Otionella perforata*, Canu and Bassler

Oral surface, 60 X. The aligned zooecia and aligned, irregular vibraculae are visible.

Figure 3 - *O. perforata*, Canu and Bassler

Dorsal surface, 46 X.

Figure 4 - *Otionella tuberosa*, Canu and Bassler

Oral surface, 49 X; the large vibraculae are visible.

Fig. 1

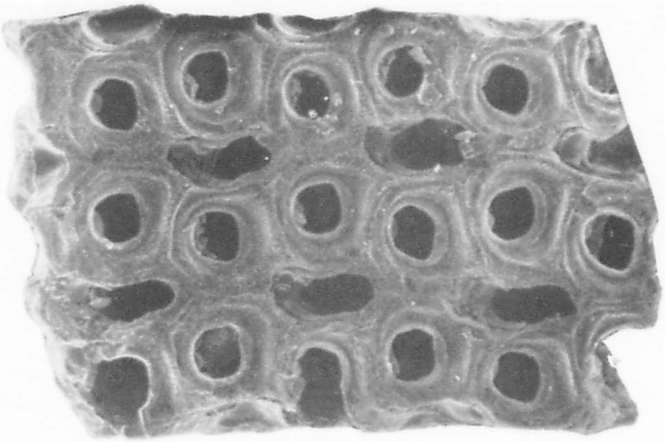


Fig. 2

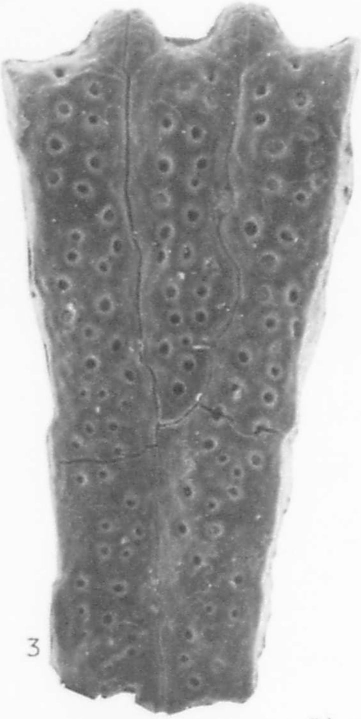


Fig. 3

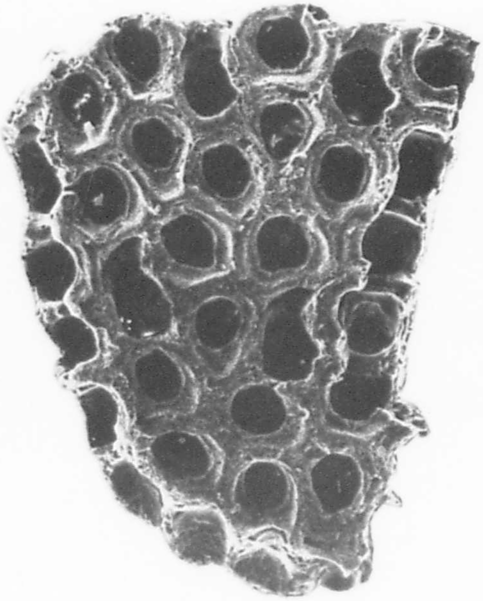


Fig. 4

Plate 22

PLATE 23

Figure 1 - Trochopora bouei, Lea

Oral surface, 25 X. Distinctive triangular zoarium showing aligned zooecia and interzooecial vibraculae.

Figure 2 - Stamenocella sp.

Fragment of bilamellar colony, showing well formed elliptical and highly symmetrical zooecia. 42 X.

Figure 3 - Lunulites jacksonensis,(Canu and Bassler)
Oral surface, 50 X, showing aligned vibraculae and zooecia.

Figure 4 - L. jacksonensis, (Canu and Bassler)

Dorsal surface, 68 X, showing random, scattered, tiny pores.

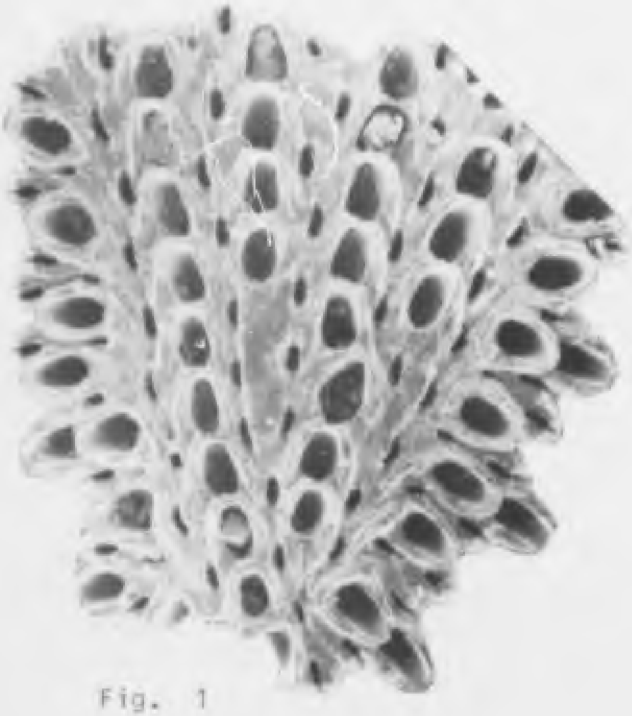


Fig. 1

Fig. 2

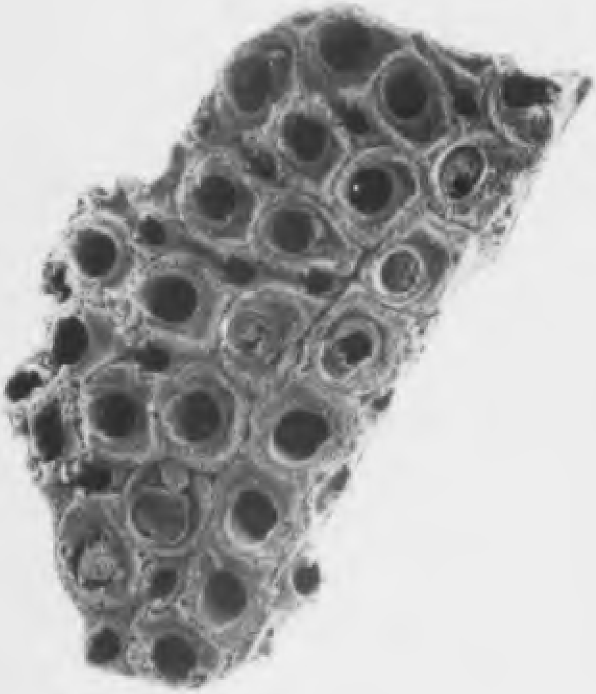


Fig. 3

Fig. 4

Plate 23

PLATE 24

Figure 1 - Lunulites fenestrata, (de Gregorio)

Oral surface, 50 X, showing aligned zooecia (primarily hydrostatic zooecia).

Figure 2 - L. fenestrata, (de Gregorio)

Close-up (50 X) of hydrostatic zooecia; covering plate perforated by four pores.

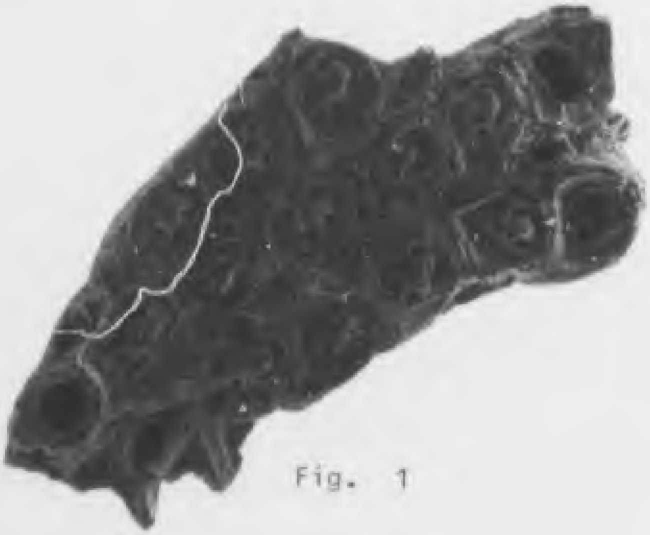


Fig. 1

Fig. 2

Plate 24

PLATE 25

Figure 1 - Lunulites bassleri, McGuirt

Dorsal surface, 69 X.

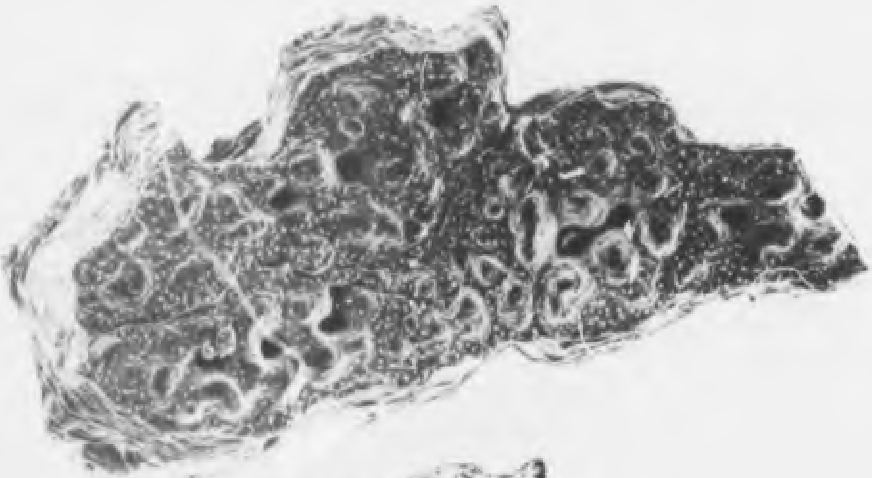
Figure 2 - L. bassleri, McGuirt

View of oral surface, 30 X. Large aligned zooecia and interzooecial vibraculae are apparent.

Figure 3 - L. bassleri, McGuirt

Close-up of a somewhat pyriform opesium, 300 X.

Fig. 1



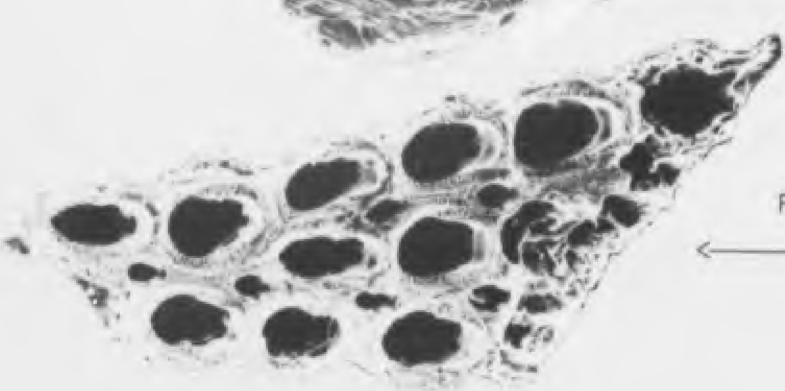


Fig. 2

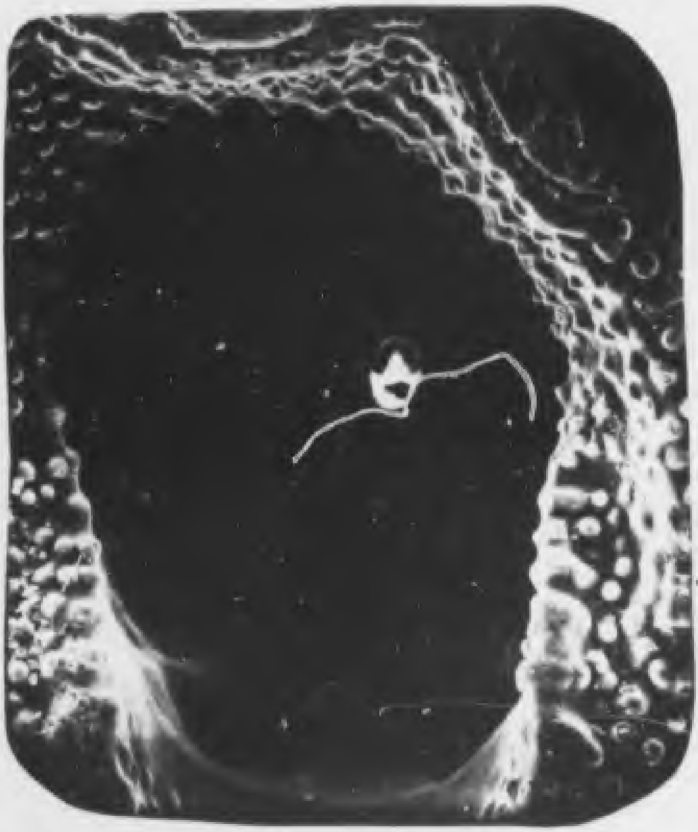


Plate 25

Fig. 3

PLATE 26

Figure 1 - *Lunulites ligulata*, (Canu and Bassler)

Oral surface, 29 X. Zooecia, rimmed by a strong collar, aligned in distinct radial rows.

Figure 2 - *L. ligulata*, (Canu and Bassler)

Close-up (400X) of one zooecia in which a calcareous projection extends completely across the opesium, creating tow "psuedopores".

Figure 3 - *Ochetosella jacksonica*, Canu and Bassler

View of a colony branch fragment, 40 X.

Fig. 1

Fig. 2

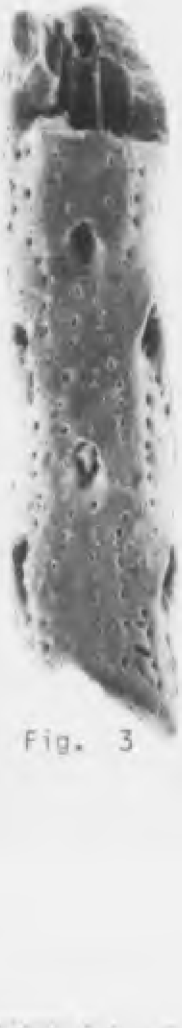


Fig. 3

Plate 26

PLATE 27

Figure 1 - Hippominella c.f. H. moodysbranchensis, McGuirt

View of one side of bilammellar zoarium, 50 X.

Figure 2 - Porella jacksonica, Canu and Bassler

View of one side of bilammelar zoarium, 39 X. Ovicells visible in some zooecia.

Figure 3 - P. jacksonica, Canu and Bassler

Close-up (220 X) of zooecial opening, showing the porous ovicell frontal and a small pore opposite the ovicell.

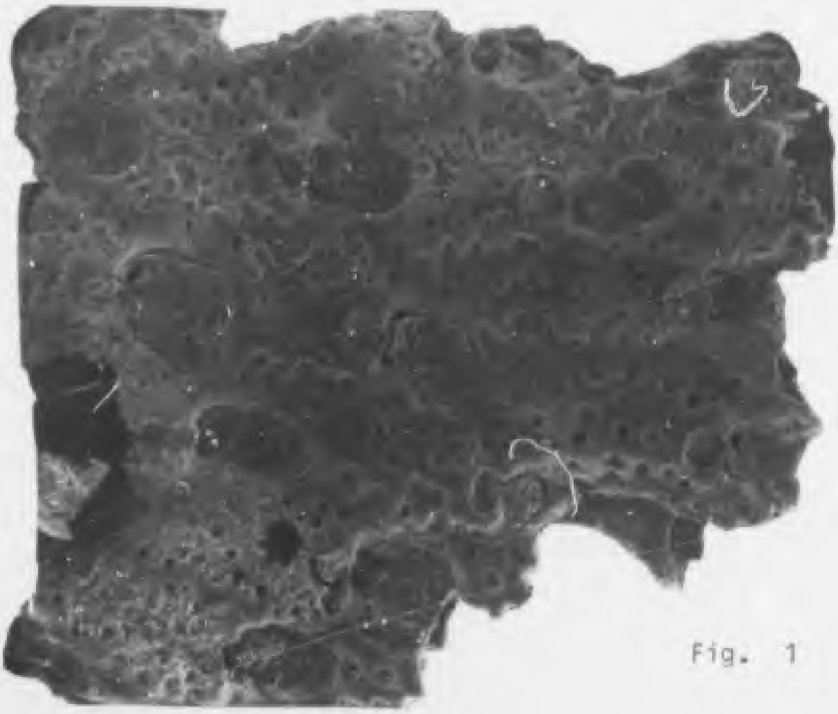


Fig. 1

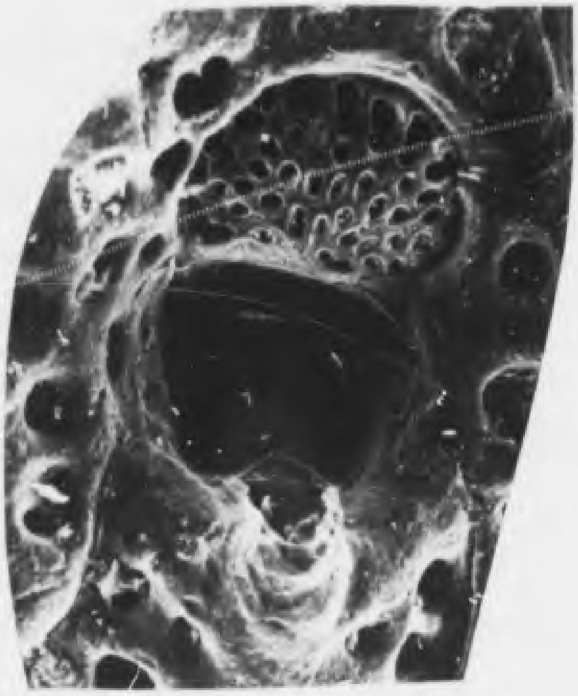


Fig. 3

Fig. 2

Plate 27

PLATE 28

Figure 1 - Adeonelopsis transversa, Canu and Bassler

View of bilammelar zoarium, 30 X. Areolae visible on interior surface of broken zooecia.

Figure 2 - A. transversa, Canu and Bassler

Close-up (80 X) showing the zooecial shape and the terminal avicularium.

Figure 3 - Holoporella sp. c.f. H. fissurata, Canu and Bassler

View of the incrusting zoarium, 34 X.

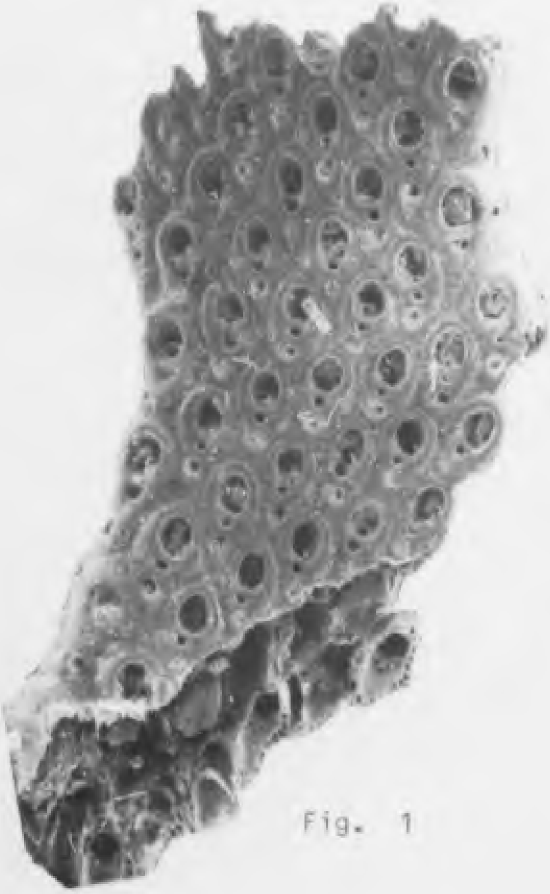


Fig. 1

Fig. 2

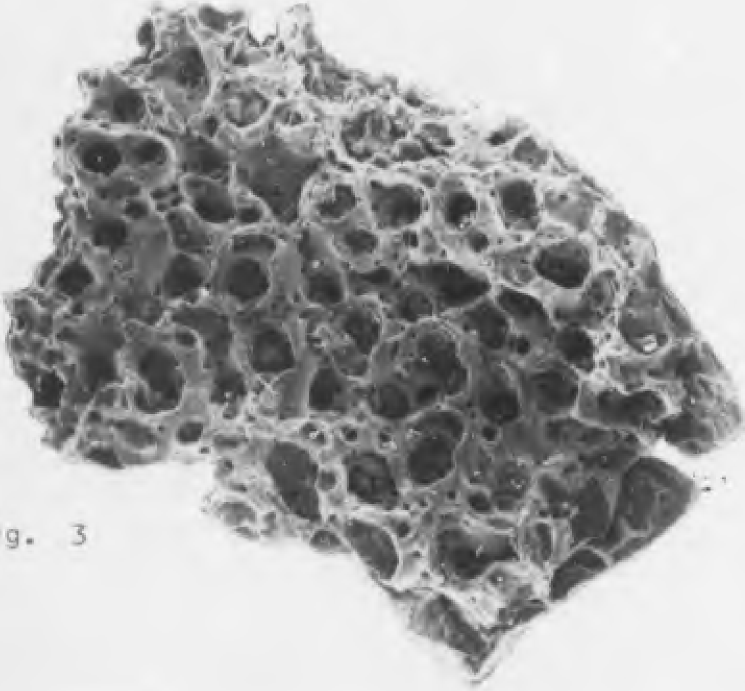


Fig. 3

Plate 28

PLATE 29

Figure 1 - *Acanthionella oeciporosa*, Canu and Bassler

Surface of fractured fragment of belamellar zoarium, 49 X.

Figure 2 - *Schizorthosecos grandiporosum*, Canu and Bassler

View of oral surface, 60 X

Figure 3 - *Schizorthosecos danvillensis*, McGuirt

View of oral surface, 30 X. The rounded opesia and interzooecial zooeciules are visible.

Figure 4 - *S. danvillensis*, McGuirt

View of dorsal surface, 39 X.

Fig. 1

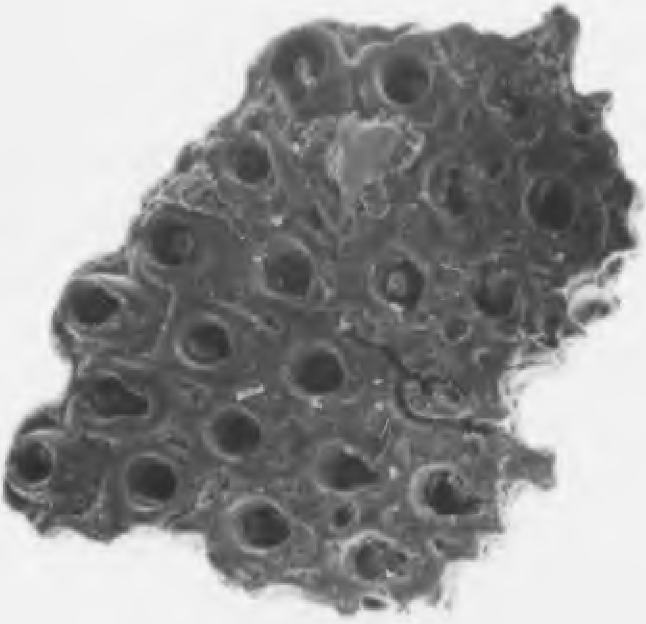


Fig. 2

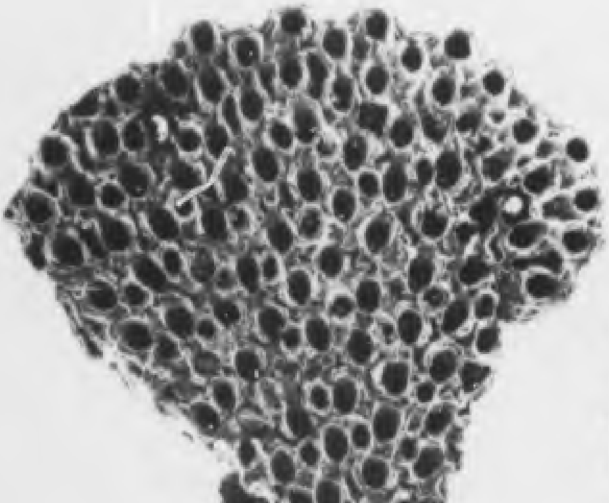


Fig. 3

Fig. 4

Plate 29

PLATE 30

Figure 1 - Schizorthosecos interstitia, Lea

View of the convex oral surface, 25 X.

Figure 2 - S. interstitia, Lea

View of the concave dorsal surface, 30 X. Hexagonal zooecial outlines visible.

Figure 3 - S. interstitia, Lea

Close-up (64 X) of oral surface.

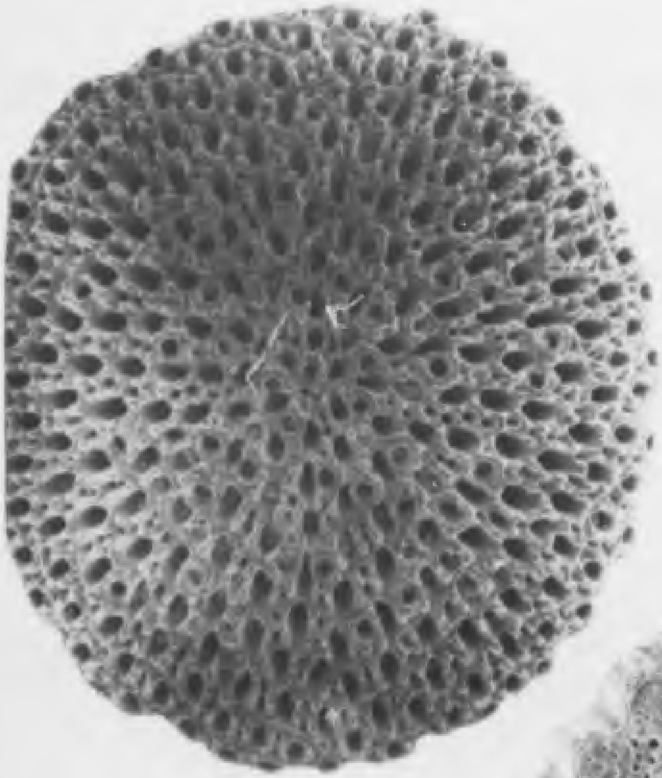


Fig. 1

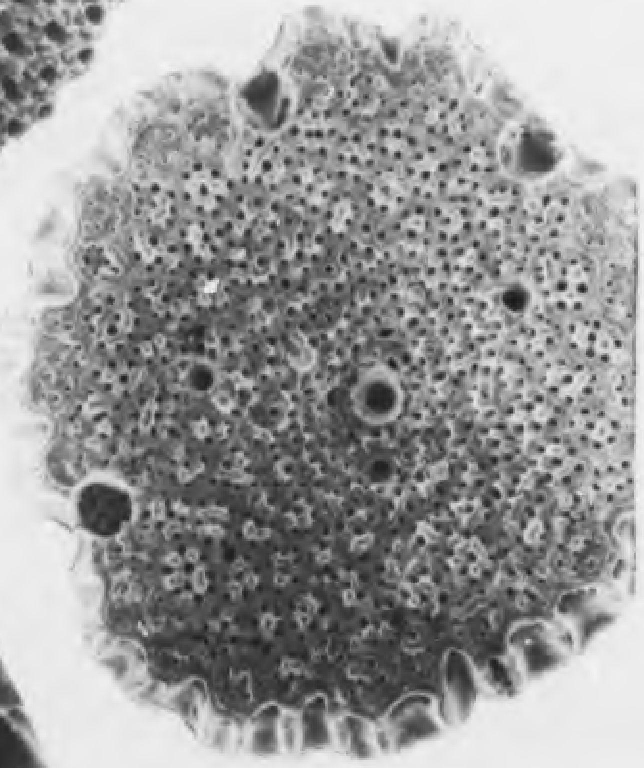


Fig. 2

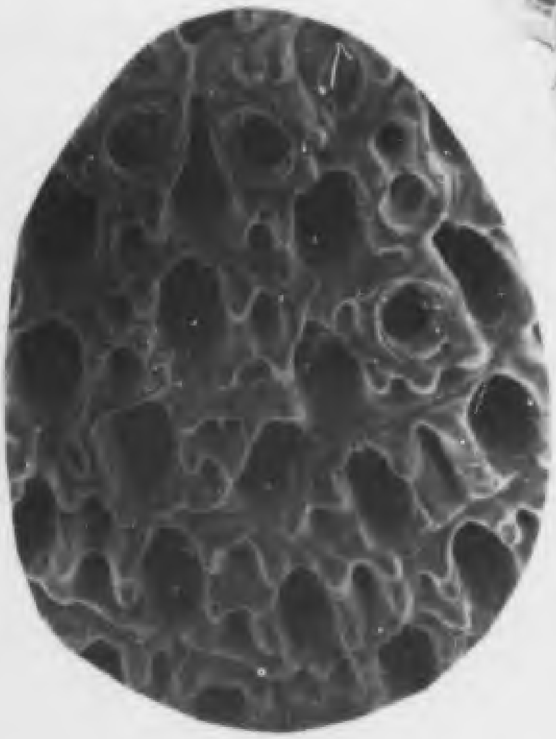


Fig. 3

Plate 30

PLATE 31

Figure 1 - Crisia sp.

View of the small biserial branch, 60 X.

Figure 2 - Pleuronea fenestrata, (Busk)

Oral surface (50 X) of a broken branch. The rectangular shape of the tubes in the fascicles is apparent.

Figure 3 - Filisparsa sp.

View of the oral surface of a colony fragment. 60 X.

Figure 4 - Entalophora sp.

Fragment of colony branch, showing zooecial apertures placed on all sides of the colony. 59 X.

Figure 5 - Lichenopora sp.

View of randomly oriented mass of parallel tubes, a fragment of a zoarium. 58 X.

Figure 6 - Kleidionella (?) sp.

Fragment of a worn zoarium, 40 X.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

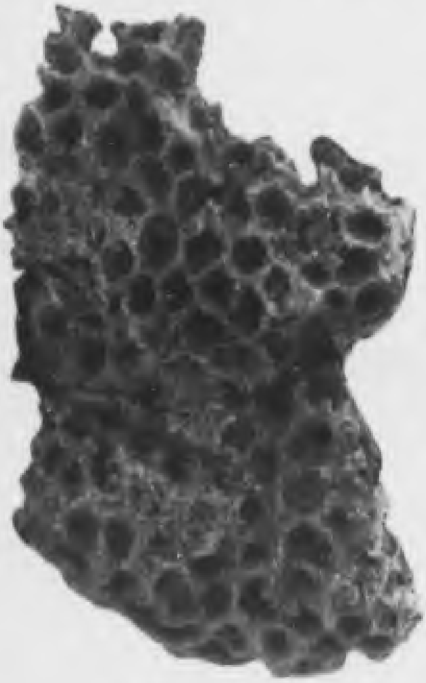


Fig. 5

Fig. 6

Plate 31

E. COELENTERATA OF THE MONTGOMERY LANDING LOCALITY, EOCENE OF LOUISIANA*

Systematic Paleontology

Phylum COELENTERATA
Class ANTHOZOA Ehrenberg, 1834
Subclass HEXACORALLIA Haeckel, 1896
Order SCLERACTINIA Bourne, 1900
Suborder FAVIIDA Vaughan and Wells, 1943
Family OCULINIDAE Gray, 1847

Typically dendroid colonies with protruding corallites. Corallites normally covered with peritheca and thus smooth. Some variation present.

Subfamily OCULININAE Vaughan and Wells, 1943

Possess solid peritheca and dendroid colonies.

Genus ARCHOHELIA, Vaughan 1919

Colonial, with subramose shape. Calices usually spiral around the branches. Dense smooth peritheca separates the protruding corallites.

ARCHOHELIA BURNSI (Vaughan), 1900

Astrohelia burnsi Vaughan, 1900, p. 115, Plate X, Fig. 3-3b
Archohelia burnsi Vaughan, 1919, p. 195

Range: Eocene - Bartonian, Jacksonian
Localities: Jackson, Mississippi and Montgomery, Louisiana

Surface of corallite commonly weakly striate. Corallites arranged in irregular spirals. Distance between corallites 2-4 mm. Very thin and weak septa, arranged irregularly. Usually 8 principal septa visible with up to 8 smaller associated septa.

Geologic occurrence: Jacksonian.

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*by Herbert Martin, LSU

Family ASTRANGIDAE Verrill, 1869

Calices usually low and often with well-developed costae. Colonial form typically stolonlike (placoid or reptoid). Septa usually irregularly distributed.

Genus ASTRANGIA Milne-Edwards and Haime, 1848

Typified by encrusting form and a thin peritheca connecting randomly oriented corallites

ASTRANGIA LUDOVICIANA Vaughan 1900

Astrangia ludoviciana Vaughan, 1900, p. 133, Plate XIV, Fig. 6-7

Range: Eocene Jacksonian
Localities: Montgomery, Louisiana

Suborder CARYOPHYLLIIDA Vaughan and Wells, 1943
Superfamily CARYOPHYLLIOIDAE Vaughan and Wells, 1943
Family CARYOPHYLLIIDAE Gray, 1847

Mostly solitary and typically with imperforate walls (except in some Turbinoliinae). Stereome not heavy. Always costate and usually with pali in upper corallite.

Subfamily CARYOPHYLLINAE Milne-Edwards and Haime, 1857
Genus TROCHOCYATHUS Milne-Edwards and Haime, 1848

Solitary, turbinate to ceratoid, fixed or free, nonepithecate corallum. Most septa have associated pali in two crowns. Columella not solid.

TROCHOCYATHUS LUNULITIFORMIS (Conrad), 1855

Turbinolia lunulitiformis Conrad, 1855, p. 263
Trochocyathus lunulitiformis Vaughan, 1895 , p. 223
Trochocyathus lunulitiformis Vaughan, 1900, p. 94, Plate VII

Range Eocene: Jacksonian
Localities: Jackson, Miss. and Montgomery, LA

Circular, subdiscoid corallum with a convex base, usually attached to achieve stability and to rise above the substrate. Well-developed costae correspond to all septal cycles and are distinct, granulate and alternate in size. Corallum usually 8-12 mm. in diameter and 3-6 mm. in height.

Geologic occurrence - Jacksonian.

Subfamily TURBINOLIINAE Milne-Edwards and Haime, 1857

Small, simple and free corallum generally trochoid, cuneiform or conical. Epitheca absent, with porous walls in some genera. Always costate.

Genus TURBINOLIA Lamarck, 1816

Corallum commonly trochoid-conical. Columella styliform or slightly compressed, formed by the fusion of the ends of six primary septa. Wall typically perforated by distinct pores. Septal arrangement is variable, ranging from tetrameral through pentameral to hexagonal.

TURBINOLIA PHARETRA Lea, 1833

Turbinolia pharetra Lea, 1833, Contributions to Geology, p. 196, Plate VI, Fig.,210
Turbinolia pharetra Milne-Edwards & J. Haime, 1848, 3 ser., Tome # 9, p. 238 (no illus.)
Turbinolia pharetra A. de Gregorio, 1890, p. 254, Plate 44, Figs. 12-19.
Turbinolia pharetra T. W. Vaughan, 1900, p. 86, Plate VI, Fig. 5-10.
Turbinolia pharetra Grabau and Shimer, 1909, p. 102, Fig. 167.
Turbinolia pharetra - Quayle, 1932, San Diego Soc. Nat. History Trans., vol. 7, no. 10, Plate 6, Fig. 17-19.
Turbinolia pharetra - Mounsour, 1944, vol. 18, #2, p. 115, Plate 21, Fig. 9 & 10.
Turbinolia pharetra - Shimer & Shrock, 1944, "Index Fossils of North America." MIT Press, New York. p. 121 pl. 45, Fig. 11-13
Turbinolia pharetra - Toulmin, 1977, p. 237, Plate 30, Fig. 15-16.

Range: Eocene - Claibornian through Jacksonian
Localities: throughout Alabama, Mississippi, Louisiana and Texas.

Identified by the true theca, covered by 24 costae of equivalent relief. Six of these costae extend to the base, six more rising near the base, and all 24 equal at the calicular opening. The intercostal furrows perforated by a characteristic double row of pores. Possesses

24 granulate and entire septa, in 3 cycles. A strong columella present, terminating in a well-preserved and distinctive protuberant hexagonal star.

Septal surfaces commonly ornamented with parallel rows of granules, sloping down from the wall to the columella at about a 45° angle. The granules stop about half the distance to the columella and are replaced by a swellinq on the septa. The swelling turns horizontal and continues to the columella. The granules and the swellings form continuums which are parallel.

The calicular diameter ranges from 2.0 to 3.5 mm, most commonly in the 2.2-2.7 mm range. Corallum height varies from 5.2-7.2 mm.

This is an extremely distinctive and well-preserved fossil typically found in waters of moderate to outer neritic depth.

Geologic occurrence: Claiborne and Jackson stages.

Subfamily PARASMILINAE Vaughan and Wells, 1943

Solitary, with a well-developed endotheca.

Genus PARASMILIA Milne Edwards and Haime, 1848

Solitary, simple trochoid corallum with a constricted shape. Columella spongy to absent.

PARASMILIA c.f. P. LUDOVICIANA Vaughan, 1900

Parasmilia n. sp. Vaughan, 1896, p. 51
Parasmilia ludoviciana Vaughan, 1900, p. 113, Plate IX, Fig. 6-13.

Range: Eocene - Jacksonian
Localities: Montgomery, Louisiana

The one loose specimen found resembles P. ludoviciana in a number of characteristics. First and most diagnostic is the correspondence between prominent costae and each septa, with 36 of each. The septa are commonly ornamented with small teeth, weakly aligned and growing more prominent near the columella.

This specimen would clearly be placed in P. ludoviciana except for one consideration: Vaughan described P. ludoviciana as having 32 septa, 3 complete cycles and a partial (8 septa) 4th cycle. The Montgomery Landing specimen contains 36 well-developed septa. This may represent a new species or possibly a subspecies of P. ludoviciana or an aberration.

Superfamily FLABELLOIDAE Vaughan and Wells, 1943
Family FLABELLIDAE Bourne, 1905
Genus FLABELLUM Lesson, 1831

Flattened turbinate to cuneiform shape of the corallum and the crowded numerous septa without columella typify this genus.

FLABELLUM CUNEIFORME Lonsdale, 1845

Flabellum(?) cuneiforme Lonsdale 1845. p. 512 (no illustration)
Flabellum cuneiforme Milne-Edwards and J. Haime, 1848, 3 ser., Tome IX p. 266 (no illustration)

Flabellum sp. A. de Gregorio, 1890, p. 257, Plate 44, Fig. 23 & 24
Flabellum cuneiforme Vaughan 1900, p. 60, Plate III, Fig. 10-12
Flabellum cuneiform Grabau and Shimer, 1909, p. 101, Text Fig. 164
Flabellum cuneiforme Shimer and Shrock, 1944, p. 122, Plate 4b, Fig 4
Flabellum cuneiforme Toulmin, 1977, p. 236, Plate 30, 10-11

Range: Eocene and Lower Oligocene units of Alabama, Vicksburg
Localities: Eocene and Lower Oligocene units of Alabama, Mississippi, Arkansas, Louisiana and Texas.

FLABELLUM CUNEIFORME WAILESI - (Conrad) 1855

Flabellum wailesi Conrad, 1855, vol. VII, p. 263 (not illus.)
Flabellum cuneiforme var. wailesi Vaughan 1900, p. 64, Plate III, Fig. 22 & 23, Fig. IV, Fig. 1-3.
Flabellum cuneiforme var. wailesi de Angelis, 1903, "Zoantari del Terziario della Patagonia" Paleontographia italica. IX p. 29, (11), Tav. X (1), fig. 5a-6, 6-9, 10-a-b.
Flabellum cuneiforme var. wailesi de Angelis, 1907, "Altri Zoantori del Terziario della Patagonia" Anales Mus. Nac. de Buenos Aires. XVI. p. 100, Tav. I.

Range: Eocene - Jacksonian & Vicksburgian
Localities: Jacksonian and Vicksburgian units in Mississippi, Arkansas, and Louisiana.

Features that help to identify F. cuneiforme include girdles (indentations that circle the corallum), which are growth features; "wings" (flattened lateral processes) near the base; and the abundant, crowded, almost anastomosing septa.

Vauqhan (1900) recognized and documented a succession of varieties of F. cuneiforme. As shown in Plate 35, F. cuneiforme wailesi (Conrad) is the typical Jacksonian form. This variety has thinner walls than normal F. cuneiforme. The corallum expands more rapidly (from base to top) and is more rounded than F. cuneiforme (typical). The numerous Flabellum from Montgomery Landing appear to fit in both typical Jackson categories (F. cuneiforme and F. cuneiforme wailesi). Also, some specimens are present which show a wide variety of features. These are mostly highly weathered and probably represent weathered F. cuneiforme.

Flabellum cuneiforme follows a regular succession of units, and F. cuneiforme wailesi is the Jacksonian form. This succession is well and confidently documented by Vaughan (1900) and is supported by the specimens found at Montgomery Landing.

Suborder DENDROPHYLLIIDA Vaughan and Wells, 1943
Family DENDROPHYLLIDAE Gray, 1847

Septal insertion follows Pourtale's plan. Septal and theca usually highly ornamented. Columella, if present, is usually spongy.

Genus BALANOPHYLLIA Wood, 1844

Well developed costae are found on a simple trochoid corallum. Septa are very numerous and inserted according to Pourtale's plan.

BALANOPHYLLIA IRRORATA (Conrad), 1855

Osteodes irroratus T. A. Conrad, 1855, vol. VII, p. 263 (no illustrations)
Balanophyllia irrorata Vaughan, 1900, p. 167, Plate XIX, Fig. 4-6
Balanophyllia irrorata Grabau and Shimer, 1909, p. 104, Fig. 171.
Balanophyllia irrorata Shimer and Shrock, 1944, p. 122, Plate 46, Fig. 10 & 11
Balanophyllia irrorata Toulmin, 1977, p. 307, Plate 52, Fig. 1, 2.

Range: Up. Eocene - Up. Claiborne (?) and Jackson
Localities: Montgomery, Louisiana; jackson, Mississippi, and Claiborne, Alabama.

The septa are highly crowded within the corallum. Laterally, the septa become a mass of synapticulae, and ordered septal insertion and arrangement often break down. Septa of the first and second cycle can often extend to the distal margin, there corresponding with a granulate costa. Other costae are present, but cannot be directly associated with a specific costa. These numerous and closely spaced costae cover the theca from base to calice, splitting to accommodate calicular expansion with growth.

The corallum is attached almost exclusively to shell (often gastropod) fragments, usually enveloping the shell. This attachment offered a number of advantages, including allowing the coral to grow on a soft substrate and lifting the juvenile above the substrate where competition might be.

The columella is very spongy, best described as a disorganized mass of septal fusions and calcification centers.

Geologic occurrence: Claiborne and Jackson.

Four varieties of B. irrorata have been documented. Of these, only typical B irrorata occurs at Montgomery Landing.

Genus ENDOPACHYS Lonsdale, 1845

More cuneiform in external shape, with well developed basal aliform processes. The external surfaces are usually strongly ornamented.

ENDOPACHYS MACLURII (Lea), 1833

Endopachys maclurii (Lea) 1833
Turbinolia maclurii I. Lea, 1833, Contributions to Geology, p. 193, Plate VI, Fig. 206 (not seen).
Endopachys alatum Lonsdale, 1845, vol. I., p. 514, Fig. 9.
Endopachys maclurii Milne-Edwards & Haime, 1848, 3 ser, Tome X, . 82, Plate I, Fig 1 & la.
Endopachys expansum Conrad, 1855, vol VII, p. 263 (no illustration).
Endopachys alticostatum Conrad, Ibid, p. 163 (illustration)
Endopachys triangulare Ibid, p. 263, (no illustration)
Endopachys maclurii de Gregorio, 1890, p. 258, Plate 45, Figs. 23-30.
Endopachys alticostatum Ibid., p. 258 (no illustration)
Endopachys expansum Ibid, p. 258, (no Illustration)
Endopachys maclurii Vaughan, 1900, p. 186, Plate XXI, Fig. 14-16, pl. XXII, Fig. 1 & 6
Endopachys maclurii Grabau & Shimer, 1909, p. 106, text Fig. 175.
Endopachys maclurii Shimer and Shrock, 1944, p. 122, Plate 46, Fig. 20, 21.
Endopachys maclurii Toulmin, 1977, p. 235, Plate 30, Fig. 7-9.

Range: Eocene - Claiborne and Jackson
Localities: Exposures of Eocene in Alabama, Mississippi, Louisiana, and Texas.

This species is typically subelliptical, with two faces and two rounded ends. The corallum is strongly compressed at the lateral extremes (particularly basally) to form "wings". Toward the calice, two tubercles rise off each face, near the middle. The outer surface is covered with coarse granules. The wall is thick, porous, vesiculated, and perforated.

Septa occur in four or five cycles and are granulated on their surface. The cycles are difficult to differentiate. Septa are inserted according to Pourtale's plan. The columella is highly vesiculate and elongated laterally (in the direction of the wings and perpendicular to the tubercles).

Geologic occurrence: Claiborne through Jackson

E. maclurii triangulare (Conrad) is a subspecies of *E. maclurii* that is found in the Jackson at Montgomery Landing. It is identified by its more rounded shape, described as an isosceles triangle with its apex truncated (Vaughan, 1900). This shape difference and more distinct external costae typify *E. maclurii triangulare*.

Coelenterate Paleoecology

A number of factors affect the growth and distribution of corals. Much is known about modern hermatypic (reef) corals; less is known about ahermatypic types. Unfortunately, all of the corals at Montgomery Landing are ahermatypic.

Ahermatypic corals may be solitary or colonial, though most (two thirds) are solitary, non-colonial types (Wells, 1956). All ahermatypic types lack the symbiotic zooxanthellae (algae) so vital (and limiting) to all hermatypic types. This is the primary reason ahermatypic types are more adaptable and wide ranging. Wells (1956 p. 354) felt that the ahermatypic habit was derived and allowed scleractinians "deployment away from the ancient, ancestral, and most fitted hermatypic environment, into all other possible environments."

As mentioned earlier, and as seen in many other organisms, a group of factors control the growth and distribution of corals. Water temperature, salinity, light, air, water movement, substratum, and depth all ahve an effect on coelenterate development. Table 13 shows the temperature and bathymetric range of modern ahermatypic genera also present at Montgomery Landing.

Though much remains uncertain concerning temperature controls on ahermatypic corals, it is apparent that temperature exerts a strong influence on coral growth and distribution. These solitary corals are best developed in sub-tropical to sub-temperate waters, but are not excluded from any waters by temperature.

Salinity

Corals are sensitive to changes in salinity. Most salinity research has been done with hermatypic types. This study has found corals to be best adapted to normal marine salinities (around 36%, but tolerable of a range of 27 to 40 parts per thousand (Wells, 1956; Vaughan and Wells, 1944). Fresh input damages corals but has a lesser affect than increased salinities. Hyper-salinity has a severe harmful impact, with salinities above 45% fatal to most corals within a few hours.

Though no direct studies of ahermatypic corals (like those of Montgomery Landing) have been encountered, it would seem that these types would have similar salinity tolerances as hermatypic types. As the main physiological difference between the hermatypic and ahermatypic corals is the zooxanthellae symbiotically present in hermatypic types, and the salinity damage to hermatypic types is not related to the zooxanthellae, it is here assumed that salinity changes would similarly affect both ahermatypic and hermatypic corals.

Thus, it would appear that the diverse coral assemblage (particularly in the Moodys Branch) was developed in seas of near normal (30 - 36 parts per thousand) salinity.

Light

Light has a strong affect on the growth and development of hermatypic corals. This is to be expected, as the zooxanthellae (algae) must have light to be productive, and the corals are interdependent with the algae.

Ahermatypic types, on the other hand, live virtually free of any influence of light, occurring in photic to non-photic zones. Best developments of only ahermatypic corals is in zones of partial to total darkness (Wells, 1956).

Air

As would be expected of marine organisms, corals are damaged by exposure to air, though most types are able to withstand temporary exposure to air. This allows growth above the low-tide level (Vaughan and Wells, 1944).

Water Movement

Water agitation is necessary both to supply fresh nutrients and to cleanse the corals of sediment (Wells, 1956, p. 353). This is particularly true of reef corals, but ahermatypic types also need a fresh food and oxygen supply and a clean feeding surface.

Water movement also influences growth forms of corals. Strong agitation (rough water) produces massive, short, thick, and encrusting forms, while thinly branched and columnar forms are typical of calm waters.

Substratum and Sedimentation

Coral larvae need a firm substratum for initial growth. Thus, corals are found in areas of shells, rocks, and skeletal debris, but are virtually excluded from areas of loose fine sand, silt, or mud (Wells, 1956).

Rapid sedimentation excludes the presence of virtually any coral development, as sediment clogs the feeding and respiratory activities of coral polyps.

Depth

As discussed in the section on bryozoan distributions, depth per se does not strongly affect coral distribution. Rather, the changes in sedimentation rate, temperature, light penetration, substratum availability, and water agitation associated with changing depth determine the distribution of corals. Nonetheless, corals are found in specific depths and can be useful bathymetric indicators.

Ahermatypic corals (as found at Montgomery Landing) have been studied in a number of regions to determine depth relationships. Wells states, "Ahermatypic corals live at all depths down to a maximum of 6000 m, but mostly between the surface and 500 m." Vaughan and Wells (1944: p. 57) studies of several suites of tropical and sub-tropical ahermatypic corals indicated that maximum ahermatypic diversity occurs in waters 180 to 360 meters in depth. They also noted that the greatest number of species occur just at the edge of the continental shelf at the uppermost edge of the continental slope. This is a zone of increased organic precipitation and serves as an excellent suspension feeding ground. It is below the light penetration zone, so hermatypic coral are excluded. See Table 13 for distributions of modern relatives of Montgomery Landing Jacksonian corals.

Coral Paleoecology at Montgomery Landing

The seas in which the Jackson at Montgomery Landing were deposited were of normal salinity and probably of sub-tropical to temperate temperatures. This is indicated by the regional fauna and by paleoclimatological studies (Dilcher, 1973, and others).

Corals are best developed, with respect to both diversity and individual growth, in the Moody's Branch. This is likely due to the availability of substrata (shells, coarse sands, skeletal debris), lack of competition for high-level suspended food, and the low sedimentation rate. See Table 15 for the distribution of Montgomery Landing corals.

The depauperate nature of the Yazoo with respect to corals is related to two obvious factors. One, the rain of fine sediment during

Yazoo deposition would likely have prohibited or inhibited coral growth. Second, the available firm substrata were rather scarce. This lack of suitable substrata would explain the absence of corals during the formation and deposition of the "limestone" ledges when sedimentation was reduced. Some Flabellum sp., represented by casts of some coralla, were able to survive during the "ledge time." Other coral remains in Yazoo samples are normally fragmentary and few in number. These corals (mostly Endopachys septal fragments) probably are remnants of a scattered Yazoo fauna or are fragments carried in by currents.

The lack of hermatypic corals in the Jackson samples is an interesting phenomenon. Light penetration and water temperature, naturally associated with depth, are the factors which most often prevent cohabitation of hermatypic and ahermatypic corals. The absence of hermatypic corals at Montgomery Landing indicates depth great enough to limit the penetration of light and to cause cold temperatures.

Jacksonian deposits at Montgomery Landing appear to have been deposited under warm, normally saline marine waters. The Moody's Branch and Yazoo both probably accumulated on the middle to outer shelf. Sedimentation (fine sediment) was greatest during the Yazoo, except for the periods of the "limestone ledge" deposition. During these periods, deposition was negligible. No significant changes in depth through the section are indicated by the coral fauna, though a change from middle or outer neritic to upper bathyal would not cause a significant alteration of the coral fauna.

Coral Morphologic Characteristics and Trends

Only in the Moody's Branch formation do corals occur intact and in quantities significant enough to consider any physical trends and the paleoecological implications of such development.

Jim Lucas (independent research, LSU, 1977; unpublished) measured and analyzed over 2000 corals from the Moody's Branch formation. He found trophic competition, mechanical sorting, mud content (of the sediments) substrate consistency and content, and nutrient supply to be pertinent factors affecting the coral morphologies and distributions. Considering these factors, Lucas found: (1) A decrease in the size of the corallite up the section; (2) A decrease in the variability of the groups studied up the section; (3) The percentage of corals in the overall biomass increased up the section; and (4) A trophic interrelationship he termed a "nutrient umbrella."

The predominance of larger forms near the base of the section is probably a reflection of mechanical sorting. The low mud percent would indicate a rather turbulent, high energy environment, in which currents would carry away the smallest corals. A mild transgression is recorded in the Moody's Branch, which explains the increase in both mud percent and the proportion of smaller corals in the assemblage.

Both the decrease in variability and the increase in coral percent of the biomass can be explained by a moderate environmental stress. A reduction in food availability or a reduction in the number of available niches could account for these phenomena. The decrease in individual variability (as compared to the average) through a section is commonly known as a "telescoping" effect. This is a very definite trend in the Moody's Branch, and is most likely related to a moderate decrease in food availability.

Lucas postulated that the higher weight percent of corals in the upper portion of the section was tied to higher efficiency in feeding or better versatility among the corals. This appears to be reasonable, as ahermatypic corals are well adapted to life in a wide variety of littoral environments and might therefore have an advantage over other benthic fauna.

The last of Lucas' major points was the trophic competitive relationship he termed the "nutrient umbrella" or "nutrient shadow." He felt that the tallest corals and those with the largest feeding structures would clear the water of nutrients as they rained down, thus limiting food availability to corals of lesser stature. This would certainly be true if there were a large, densely crowded population of ahermatypic corals. An overcrowded population of ahermatypic corals is unusual in the modern and certainly does not appear to exist in the Eocene sediments at Montgomery.

Therefore it seems that decreasing food availability and possibly an environmental shift accompanied a mild transgression during the deposition of the Moody's Branch, as indicated by the "telescoping" effect, the decreasing size of the corals, the increase in corals as a percent of the total biomass, and the increasing preservation of smaller, lighter coral types.

TABLE 13

Bathymetric and Temperature Ranges of Recent Representatives of Montgomery Landing Eocene Genera

	Bathymetric Range		Temperature Range	
GENUS	Meters	Feet	Celcius	Fahrenheit
Astrangia	0 - 110	0 - 360	8.3 - 27.7	47 - 82
Balanophyllia	0 - 1145	0 - 3750	6.7 - 27.7	44 - 82
Endopachys	37 - 602	120 - 1974	5.8 - 26.7	42.5 - 80
Flabellum	0 - 3188	0 -10452	1.7 - 27.6	35 - 82
Parasmilia	313 - 366	1026 - 1200	8.8 - 12.5	48 - 54.5
Trochocyathus	13 - 1473	45 - 4830	4.7 - 26.7	40.5 -80
Turbinolia	185 - 567	600 - 1860	11.6 - 21	53 - 70

Factors Controlling Ahermatypic Coral Development Water Temperature

The absence of symbiotic zooxanthellae enables ahermatypic corals to inhabit a wider range of environments than hermatypic types. This is certainly reflected in the temperature range of all ahermatypic genera (-1.1 C to 29 C, Wells 1956, p. 353) and in Table 4-E-j.

Maximum development occurs between 5"C and 20,C. Maximum number of genera occurs between 5"C and 10"C (Hawaiian Islands, Vaughan and Wells, 1949; also Wells, 1956), while maximum number of species occurs between 9°C and 20°C (Vaughan and Wells, 1944, p. 57).

Table 14

Occurence of the Subspecies of *Flabellum cuneiforme* (Lonsdale)

During the Eocene (from Vaughan, 1900)

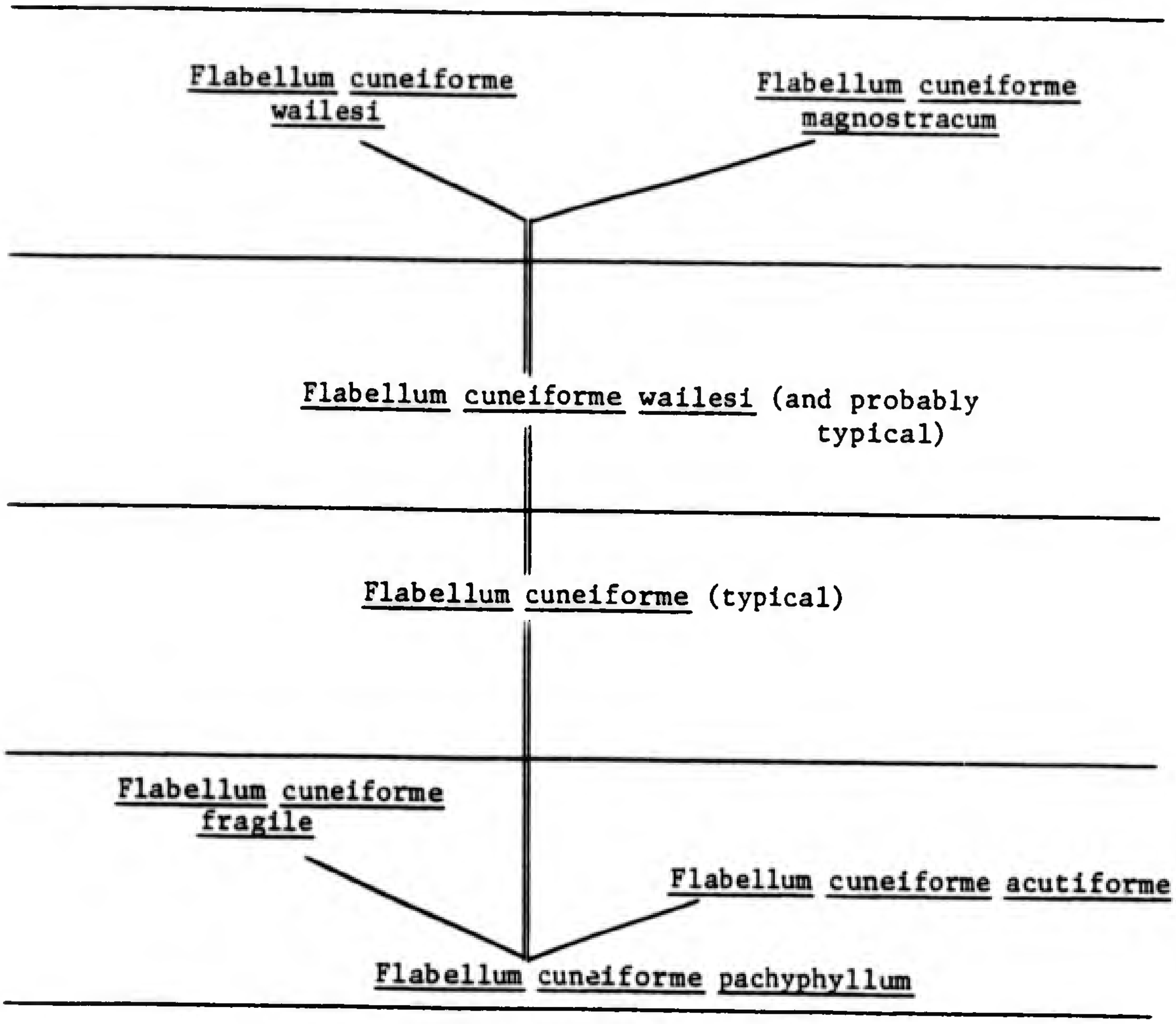

Table 15. Montgomery Landing Coelenterata

FAMILY	SPECIES
Oculinidae	*Archohelia burnsi*
Astrangidae	*Astrangia* cf. *A. expansa*
Caryophylliidae	*Trochocyathus lunulitiformis*
	Turbinolia pharetra
	Parasmilia ludoviciana
Flabellidae	*Flabellum cuneiforme*
Dendrophyllidae	*Balanophyllia irrorata*
	Endopachys maclurii

Table 16. Occurrence of Coelenterates in Samples from Montgomery Landing.

SPECIES	SECTION	SAMPLES
Trochocyathus lunulitiformis	1	6-10
	2	13-18
	3	3
	4	1-3, 5
Turbinolia pharetra	1	7
	2	14
	4	1
Flabellun cuneiforme	4	1-4
Flabellum sp.	1	7-11
	2	14-18
	3	13
	4	5, 21-23
	5	1
	6	15
Endopachys maclurii	1	6-10
	2	15-18
	3	10, 12, 14
	4	1-3, 5, 10, 11, 18
	5	7, 8, 13-15, 18
	6	3, 4, 10
	7	4, 8
	8	4
	9	3, 4

Other corals known to occur at Montgomery Landing were either picked from Moody's Branch Bulk Samples or were collected by hand from the Moody's Branch.

PLATE 32

Figure 1 - Turbinolia pharetra, Lea

Later view of the entire corallite showing the prominent columella, double row of pores perforating the intercostal rows, and the alternate length of the costa. 28 X.

Figure 2 - T. pharetra, Lea

Close-up (72 X) of the calicular end of the corallite, showing clearly the double row of pores (partially occluded by sediment), and the star-shaped columella.

Figure 3 - Trochocyathus lunulitifomis, (Conrad)

View of the oral surface showing the well developed pali before some of the septa. 30 X.

Figure 4 - T. lunulitiformis, (Conrad)

Septal detail (110 X) illustrating well developed and aligned granulations.

Fig. 1

Fig. 2

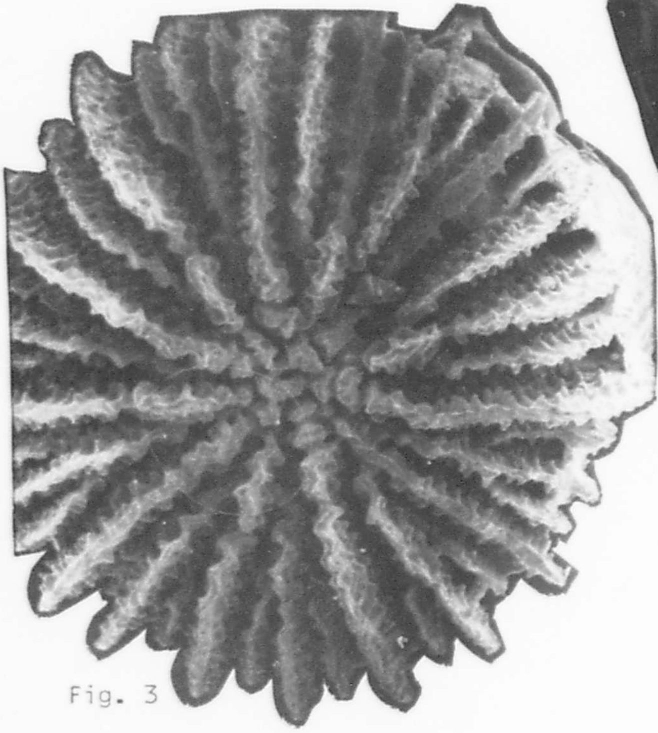

Fig. 3

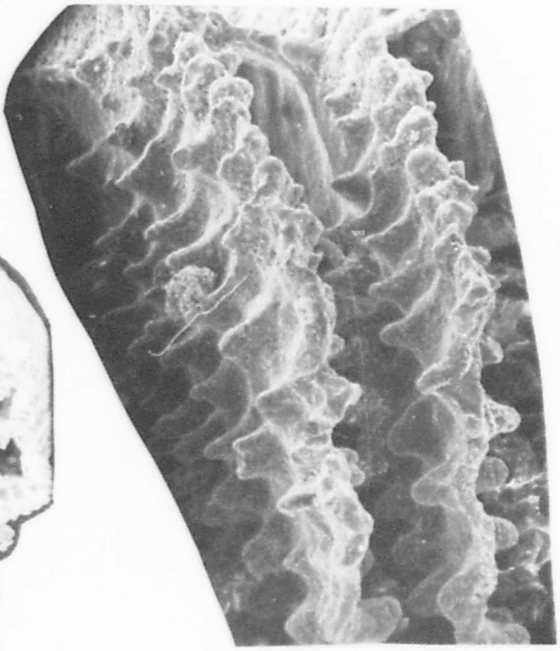

Fig. 4

Plate 32

PLATE 33

Figure 1 - Balanophyllia irrorata (Conrad), 1855

a)Lateral view. Attachment to gastropod is plainly visible. 2.5 X.
b) Calicular view. Anastomosing septa visible. 2.5 X.

Figure 2 - Balanophyllia irrorata (Conrad), 1855

Another lateral view of same specimen as in Figure 1 (a). 2.5 X.

Figure 3 - Archohelia burnsi Vaughan, 1900

Colony view. 1.4 X.

Figure 4 Archohelia burnsi Vaughan, 1900

Close-up of same specimen. Some calicular detail visible. 3 X.

Figure 5 - Astrangia ludoviciana

Colony view. 3 X.

a b

Figure 1

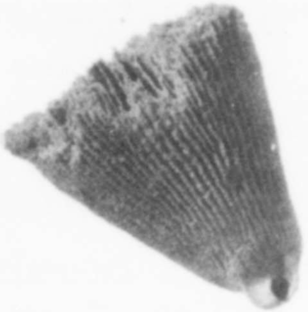

Figure 2

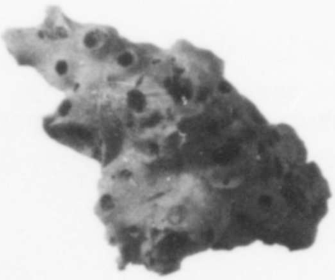

Figure 3

Figure 4

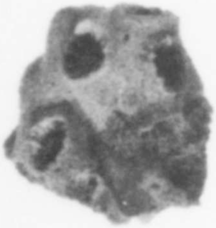

Figure 5

Plate 33

PLATE 34

Figure 1 - Parasmilia c.f. P.ludoviciana Vaughan, 1900

Lateral view, with costae visible. 5.5 X.

Figure 2 - Parasmilia c.f. P. ludoviciana Vaughan, 1900

Calicular view of same specimen. Septa with corresponding costae can be seen. 2.3 X.

Figure 3 - Parasmilia c.f. P. ludoviciana Vaughan, 1900

Basal view of same specimen. 3 X.

Figure 4 - Endopachys maclurii (Lea), 1833

Lateral view of a small specimen. Lateral alate processes and basal attachment process are visible. 1.4 X.

Figure 5 - Endopachys maclurii (Lea), 1833

Lateral view of a larger specimen. 1.4 X.

Figure 6 - Endopachys maclurii (Lea), 1833

Calicular view of the same specimen as in Fig. 5. Alate processes, septal structure, mid-facial tubercles, and synapticulotheca are all visible. 2.8 X.

Figure 1

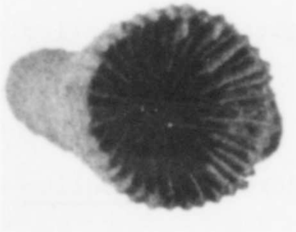

Figure 2

Figure 3

Parasmilia ludoviciana

Figure 4

Figure 5

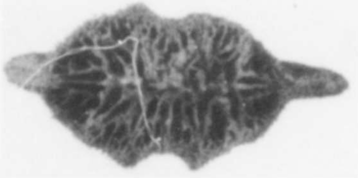

Figure 6

Endopachys maclurii

Plate 34

PLATE 35

Figure 1 - Flabellum sp.

Lateral view. Smooth epitheca and other signs of wear (transport) are visible. 2.6 X.

Figure 2 - Flabellum sp.

Calicular-lateral view of another specimen, showing septal and thecal thickening. 2.6 X.

Figure 3 - Flabellum sp.

Basal view. Smooth rounded base at bottom of picture. 2.6 X.

Plate 35

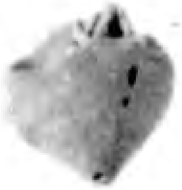

Figure 1

Figure 2

Figure 3

Flabellum sp.

PLATE 36

Figure 1 - *Flabellum cuneiforme wailesi* (Conrad), 1855

Lateral view. Wall is broken away and shows four cycles of thin septa. 1.5 X.

Figure 2 - *Flabellum cuneiforme wailesi* (Conrad), 1855

Lateral view showing calicular compression. 1.5 X.

Figure 3 - *Flabellum cuneiforme wailesi* (Conrad), 1855

Basal view. Flattened attachment visible near the bottom of the specimen. 1.5 X.

Figure 4 - *Flabellum cuneiforme wailesi* (Conrad), 1855

Calicular view. 1.5 X.

Plate 36

Figure 1

Figure 2

Figure 3

Figure 4

Flabellum cuneiforme wailesi

F. ARTHROPODA OTHER THAN OSTRACODA*

Fossil Arthropoda at Montgomery Landing are composed primarily of skeletal fragments of decapod crustaceans. Some interesting trace fossils are present, some of which are certainly produced by crustaceal activity, and others potentially so.

By far the most common arthropod remains found at Montgomery Landing are fragments of the chela of crabs of the genus Calappa. The dactylus and propodus of crabs are generally the most common of these parts among the samples at Montgomery Landing. Washing and sieving would eliminate all but the most resistant and stable elements. Other remains present include unidentifiable fragments of crustacean carapaces, legs, and chelae, and ichnofossils. The ichnofossils are of two general types: gastropod shells stripped to the columella by crab activity; and burrows considered to have been produced by crustaceans.

The gastropod columellae and the specialized chela are evidence of a specialized, unusual, and interesting type of crab. These are crabs of the genus Calappa (Schoup, 1968; Forster, 1979). This genus is characterized by a large tooth on the dactyl and a pair of protuberances of the propodus of one chela, usually the right one. These adaptations allow the crab to grasp a shell and, using the special claw, to roll the shell, breaking it as it is rolled. This in effect "peels" the shell open, allowing access to the edible internal soft parts (Schoup, 1968; Warren Blow, Smithsonian Institution, personal communication). This activity could account for the unusual number of "naked" gastropod columellas found in the Montgomery Landing samples.

Crabs of the genus Calappa are the dominant arthropods at Montgomery Landing, though other epifaunal and burrowing crustacea certainly lived contemporaneously with these more easily preserved crabs.

Systematic Paleontology

Phylum ARTHROPODA
Superclass CRUSTACEA
Class MALACOSTRACA, Latreille, 1806
Subclass EUMALACOSTRACA, Grobben, 1892
Superoder EUCARIDA, Calman, 1904
Order DECAPODA, Latreille, 1803
Suborder PLEOCYEMATA, Burkenroad, 1963
Infraorder BRACHYURA, Latreille, 1803
Section OXYSTOMATA, Milne-Edwards, 1834
Superfamily CALAPPOIDEA, de Haan, 1833
Family CALAPPIDAE, de Haan, 1833
Subfamily CALAPPINAE, de Haan, 1833
Genus CALAPPA, Weber, 1795

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*by Herbert Martin, LSU

Remarks: The members of this genus are strongly predatory, as the adaptation of one (usually the right) chela attests. The dactylus of this claw posseses a strong tooth, which in the Montgomery Landing samples articulates with two protuberances on the propodus. These tuberosities are used in the opening of molluscan shells usually gastropod).

Table 17. Montgomery Landing samples containing fossilized crab remains (claws).

SECTION	SAMPLES
1.	9, 10
2.	14, 15, 17, 18
3.	1, 4, 6-8, 10, 12, 16
4.	1-3, 5-9, 11-13, 15, 17-23
5.	1, 1a, 2-10, 14-17
6.	3, 5, 6, 6a, 9, 10, 12, 14
7.	2, 3, 7, 8
8.	2, 4
9.	2
10.	1

G. ECHINODERMATA*

Introduction

Among the Eocene fossils collected at Montgomery Landing is an echinoid species which is preserved as complete individuals in the lowermost part of the Tullos Member of the Yazoo Clay. While echinoderm fragments are scattered throughout the Yazoo, these whole specimens are limited in extent to a stratigraphic interval of between 50 and 260 cm above the base of the Yazoo and laterally to two adjacent sample sites seperated by 80 m. They occur mainly as lenses and pods a few meters wide composed of dense concentrations of complete individuals; a lesser number of individuals are scattered nearby in the sediment, which is a blocky, blue-gray micaceous clay. (Plate 13). The purpose of this section is to describe and identify this echinoid species and to make some suggestions regarding its unusual preservation.

Systematic Paleontology

Phylum ECHINODERMATA
Class ECHINOIDEA Leske, 1778
Subclass EUECHINOIDEA Bronn, 1860
Superorder ATELOSTOMATA Zittel, 1879
Order SPATANGOIDEA Claus, 1876
Suborder HEMIASTERINA Fischer, 1966
Family SCHIZASTERIDAE Lambert, 1900
Genus SCHIZASTER L. Agassiz, 1836
Species SCHIZASTER ARMIGER Clark, 1915

Description

Most of the shell material is leached away, leaving internal casts and external molds with a few fragments of plates attached. The specimens have been greatly compressed, generally to less than 5 mm in thickness. They show varying orientations: although many rest roughly normally with aboral surface uppermost, they often show some degree of rotation sideways so that the flattened portion includes part of the oral surface. At least one individual is oriented precisely on its side, the flattened test thus preserving a lateral view, as seen in Plate 37, Figure 1. The best preserved feature is the petal area (Figure 2); oral and aboral plates are also visible (Figure 3), but the periproct and the peristome are not discernble.

There is little variation in the size of the specimens--length varies from 21 to 28 mm, but some of that variation can possibly be attributed to tests having been compressed in different orientations. Measurements of the most symmetrically flattened individuals show a length of 27-28 mm, width of 21mm, and height (of laterally compressed specimen) of 19 mm. The measurements may be slightly exaggerated due to

*by Janet Dyson, LSU

compression; however, they do indicate an ovoid test shape. Petals are depressed with the anterior pair longer than the posterior pair and the central anterior petal extending to the edge of the test. Plates are generally rhomboid in outline; interambulacrals are considerably larger than ambulacrals.

Discussion

Two echinoids were previously reported from Montgomery Landing -- *Periarchus lyelli*, a clypastroid sand dollar, and *Schizaster armiger*, a spatangoid heart urchin; both were reported from Moodys Branch (Toulmin, 1977). Clearly these specimens are not *Periarchus lyelli*, which is circular, flatter, and larger (around 60-75 mm diameter), and lacks depressed petals (Toulmin, 1977). However, the observed features of this echinoid do correspond closely to those of *Schizaster armiger*, most notably the ovoid shape, interambulacral plates larger than ambulacrals, depressed petals, anterior petals longer than posterior ones, and overall dimensions. The figured specimen of Toulmin (1977) is 40 mm long, 37 mm wide, 27 mm high. Futhermore, while the range of *P. lyelli* is restricted to Moodys Branch, *S. armiger* occurs throughout the Jackson stage, including the Yazoo in numerous localities in Mississippi, Alabama, and Georgia (Toulmin, 1977), and one occurrence of a whole specimen of *S. armiger* has been reported from the Tullos Member of the Yazoo Clay in Copenhagen, Louisiana, about ninety miles northeast of Montgomery (Breard, 1978). Thus it is feasible that *S. armiger* could occur at this location. More information than these poorly preserved specimens can provide would be needed to make identification certain (The fascioles characteristic of *S. armiger*, for example, are not evident), but available evidence does support identification of this echinoid as *S. armiger*.

Paleoecology

There is no reason to doubt that *S. armiger* could have inhabited the area as the Yazoo Clay was being deposited. The Yazoo represents muddy bottom deposition in deepening water during a transgression, the lowermost portion being transitional from the outer part of the inner neritic to the inner part of the middle neritic zone (Kilmartin, Chapter 4-C of this report). Mollusk studies at Montgomery Landing indicate that the higher amount of suspended material in the nearshore Moodys Branch favored suspension feeders, while the quieter waters of the Yazoo allowed more nutrients to settle to the substrate, thus favoring deposit feeders (Chapter 5 of this report). These conditions are suitable for spatangoids, which are commonly soft-bottom burrowers living several centimeters below the sediment surface in subtidal to abyssal environments. As deposit feeders, they may either ingest the sediments, from which they digest organic material, or, if they have well-developed food-gathering tube feet, they may select organic material for ingestion. (Moore, et al., 1952). Thus the Yazoo Clay environment was suitable for the typical life mode of this spatangoid sea urchin.

Taphonomy

The occurence of these echinoids is unusual in this sequence for two reasons: their dense concentrations in aggregates and the preservation of whole individuals. These conditions suggest that the echinoid lenses represent life assemblages which have been preserved relatively intact.

Large concentrations of individuals can reflect either a living community assemblage or a sorting process. Mechanical sorting is not likely in this case because the muddy sediments and the echinoid tests are not hydraulically equivalent. However, many echinoderms are gregarious and tend to aggregate into densely populated stable communities which may be widely separated from one another. For example, 1300 specimens of the urchin _Strongylocentrotus_ were collected from an area of three square meters in Maine, and sand dollars are locally a major constituent of some Cenozoic beds in California (Moore, 1966). Thus the lenses of echinoids are probably preserved communities.

Preservation of whole sea urchins of this type requires rather special circumstances. On the basis of ecological studies in the North Sea, Schafer (1972: p. 103) states "Irregular sea urchins in the shallow sea are therefore preserved as complete fossils only when the animals are not displaced after burial; otherwise they are broken up and reduced to small fragments." Preservation of undisturbed animals in the sediments could be due to burial by storm deposits and subsequent death or merely to the animal's dying in their burrows from other causes in an area where scour was insufficient to work them out. Schafer (1972) observes that mass mortality by burial of echinoid communities during storms is fairly common in the North Sea, where a storm can deposit as much as 60 cm of sediment. While the Eocene Gulf probably did not have such fierce storms as the modern North Sea, a much smaller amount of sediment deposited by a storm could be sufficient to trap the sea urchins in their burrows, or the surge and pull from the storm waves may have simply disarranged the sediment and the burrows in such a manner that the animals were unable to dig out, without the storm's actually having deposited much sediment. The presence of clay blebs near the echinoid lenses does indicate more disturbance by currents here than elsewhere in the Yazoo. This might be expected since the lower Yazoo represents shallower water deposition than upper parts. The rotation of many individuals slightly out of life position could have been caused by storm surges or by later water escape.

Another possibility is that the animals simply died in their burrows in an area with a low level of scour. Finding such concentrations however, suggests that large numbers of them died in relatively short periods of time, possibly a time when food was scarce. Klumpp's mollusk study (Chapter 4-H of this study) recognizes more rigorous and less rigorous zones in the Yazoo and interprets the lowermost part-- Zone A-- as a more rigorous zone. Whether death of the community was by quick burial or by more gradual starving off, it is clear that current and wave activity did not reach deeply enough or were not strong enough to disturb them.

The limited occurrence of such communities in the Yazoo is not surprising. Even living echinoid communities are often widely separated, and only a minority of them are likely to escape disturbance by reworking or bioturbation after death. As noted earlier, the effects of storms or of a more rigorous environment are more likely in the lower Yazoo than in some of the overlying portions. Failure to find other assemblages of this type at the same level in the sequence can be explained by the wide spacing of the samples, but, on the other hand, this site may be unique--perhaps a more protected area along the coast where day-to-day currents were too weak to rework the sediments.

Thus the occurence of dense concentrations of complete fossils of Schizaster armiger at Montgomery Landing is probably due either to catastrophic kills by storms or to more gradual dying off of communities by starvation. Whatever the cause, clearly these entire communities remained buried after death, thus preserving a life assemblage quite different from other fossil remains found at Montgomery Landing.

Plate 37

Fig. 1 A fragment of the Yazoo Clay containing fossils of the echinoid *Schizaster armiger*. On the left is an external mold showing an aboral view; on the right is a specimen which was compressed on its side, as can be seen by petals radiating from the top. X2

Fig. 2 A view of the mold in Fig 1, showing petal area of mold. X2

Fig. 3. Internal cast of *Schizaster armiger*, showing plates and a portion of the petal area. X2

Plate 37

Fig. 1

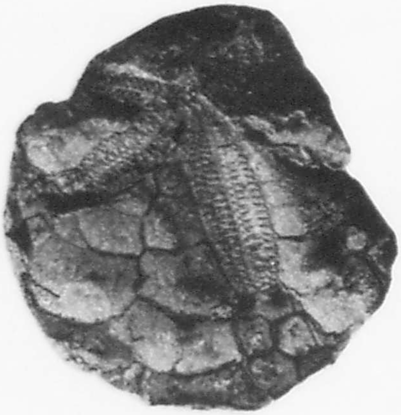

Fig. 3

Fig. 2

H. BIVALVE MOLLUSKA OF THE MONTGOMERY LANDING LOCALITY, EOCENE OF LOUISIANA*

More than twenty thousand valves were counted and identified. In all there were nineteen species from thirteen different families (Table 18). Shell morphology and comparison to recent forms were used to gain some insight into what might have been the life modes of these animals. Table 19 shows the areas in the outcrop where specimens of each species were found.

An animal can change its mode of life through the course of geologic time, so drawing absolute conclusions about ancient life based on observations in the modern environment can be risky. This is especially true if the animal is extinct and we are comparing it with living species within its genus or even higher levels of classification. However, looking at closely related modern species and at shell morphology as it relates to life styles in the modern environment should increase the chance of drawing accurate conclusions about fossil specimens. Stanley (1970) and the Treatise of Invertebrate Paleontology give good discussions concerning shell morphology and life habits.

The classification used in this study closely follows that used by Dockery (1977, 1980). Although his work was done in Mississippi, the species found at Montgomery Landing, Louisiana were included by him. His classification is therefore considered to be the most current for these species.

*Thomas Klump, LSU.

Table 18. Families and Species found at Montgomery Landing

FAMILY	SPECIES
Arcidae	*Barbatia* *(Cucullaearca)* *ludoviciana*
Astartidae	*Lirodiscus* *(Lirodiscus)* *pretriangulata*
Carditidae	*Pleuromeris* *inflatir* *jacksonensis*
	Pleuromeris *quadrata*
	Venericardia *(Rotundicardia)* *diversidentata*
Corbulidae	*Caestocorbula* *wailesiana*
	Corbula *(Caryocorbula)* *densata*
Crassatellidae	*Bathytormus* *flexurus*
	Crassinella *pygmaea*
Glycymerididae	*Glycymeris* *filosa*
Kelliellidae	*Alveinus* *minutus*
	Kelliella *boettgeri*
Limopsidae	*Limogsis* *(Pectunuculina)* *radiata*
Lucinidae	*Lucina* *(Callucina?)* *curta*
	Lucina *(Callucina?)* *subcurta*
Mactridae	*Spisula* *jacksonensis*
Nuculanidae	*Hilgardia* *multilineata*
Nuculidae	*Nucula* *spheniopsis*
Verticardiidae	*Verticordia* *(Verticordia)* *cossmanni*

Table 19. Bivalve occurrence at Montgomery Landing by formation

	COCKFIELD	MOODYS BRANCH	YAZOO (ZONES)		
			A	B	C
Barbatia (Cucullaearca) ludoviciana		X			
Lirodiscus (Lirodiscus) pretriangulata		X			
Pleuromeris inflatir jacksonensis	X	X	X	X	
Pleuromeris quadrata		X	X	X	
Venericardia (Rotundicardia) diversidentata		X			
Caestocorbula wailesiana	X	X	X	X	X
Corbula (Caryocorbula) densata	X	X	X	X	X
Bathytormus flexurus		X	X	X	
Crassinella pygmaea		X	X	X	X
Glycymeris filosa		X			
Alveinus minutus	X	X	X	X	X
Kelliella boettgeri		X	X	X	X
Limogsis (Pectunuculina) radiata		X			
Lucina (Callucina?) curta		X	X	X	X
Lucina (Callucina?) subcurta		X	X	X	X
Spisula jacksonensis		X			
Hilgardia multilineata		X	X	X	X
Nucula spheniopsis		X	X	X	X
Verticordia (Verticordia) cossmanni		X	X	X	X

Systematic Paleontology
Family KELLIELLIDAE Fischer, 1887
Genus ALVEINUS Conrad, 1865

Plate 38, Fig. 1-2
ALVEINUS MINUTUS Conrad, 1865

Alveinus minutus Conrad, 1865, p. 138, Plate 10, Fig. 2.
Alveinus minutus Conrad. Dall, 1900, pt. 5, p. 1166.
Alveinus minutus Conrad. Harris, 1919, no. 31, p. 110, Plate 37, Fig. 15.
Alveinus minutus Conrad. Harris, 1920, no. 2, p. 8, Place 17, Figs. 11-15.
Alveinus minutus Conrad. Harris and Palmer, 1946, no. 117, pt. 1, p. 83, Place 19, Figs. 5,5a.
Alveinus minutus Conrad. Brann and Kent, 1960, no. 184, p. 989.
Alveinus minutus Conrad. Olsson, 1964, p.44.
Alveinus minutus Conrad. Palmer and Brann, 1965, no. 218, pt. 1, p. 27.
Alveinus minutus Conrad. Keen, 1969, N635, Fig. E1 30,11.
Alveinus minutus Conrad. Dockery, 1977, p. 131.
Alveinus minutus Conrad. Dockery, 1980, p. 182, Plate 71, Figs. 8A, 8B.

Range: Middle and Upper Eocene (Palmer and Brann, 1965)

Remarks: When Conrad described this species in 1865 he did not attempt to place it in a family (Harris, 1920). Dall (1899) put it in the family Kelliellidae and the superfamily Leptonacea. He said that this super-family has a general habit of commensalism or parasitism. The Treatise of Invertebrate Paleontology describes this superfamily as marine byssiferous, with three apertures in the mantle. Harris (1920) hinted that the genera *Lutetia*, *Alveinus*, and *Kelliella* should be in the Kelliellidae. Gardner (1926), in describing the molluscan fauna of the Alum Bluff Group of Florida, placed the family Kelliellidae in the superfamily Leptonacea. However, Gardner (1957) described *Alveinus* as a Leptonid, and she suggested that it indicated the presence of plant growth. Members of the Leptonidae are often found living attached to other marine organisms including vegetation, and others are crawlers (Morris, 1973). Morris also included the genus Kelliella in this family. Recent workers (Treatise; Dockery, 1977 and 1980) have placed *Alveinus*, *Kelliella*, and *Lutetia* in the family Kelliellidae and the superfamily Arcticacea, whose adult forms do not have a byssal gland. Microscopic examination of *Alveinus* failed to show any gapes in the shell, and the pallial line is entire. Because this is a fossil species, known only from the Eocene of Louisiana and Mississippi in North America, it is difficult to know with certainty its life habits. But, because of its suboval shape and entire pallial line, it is probably a shallow burrower. Its relationship, if any, to plant growth could not be determined. This is by far the most common species found at Montgomery Landing in this study, making up 79.07% of all specimens found. The most likely life mode for this species is that of a shallow burrowing, infaunal, suspension feeding opportunist. Elder and Hansen (1981) also indicate it as an opportunist. It displays some of the features often seen in opportunistic species enumerated by Levinton (1970). It is very common throughout the outcrop at Montgomery Landing. Different parts of the outcrop are characterized by different groups of species, but *Alveinus* is always abundant. This indicates some degree of eurytropism. In zone B, *Alveinus* comprises more then 95% of all specimens. Dominance of this magnitude results from a continuous or series of successive invasions into an area not totally occupied by other species. *Alveinus* is not distributed uniformly throughout the zone but is concentrated in thin stringers.

Alveinus minutus is an extremely small form and Casey (1901) described it as "literally swarming throughout the Jackson Stage" and as being one of the most characteristic upper Eocene species.

Genus KELLIELLA M. Sars
KELLIELLA BOETTGERI Meyer

Plate 41, Fig. 3

Kelliella? boettgeri Meyer, 1886, in Smith, p. 83, Plate 3, Figs. 15,15a.
Kelliella boettgeri Meyer, Harris, 1920, No. 2, p. 10, Plate 17, Figs. 16-18.
Kelliella boettgeri Meyer, Harris and Palmer, 1946, pt. 1, p. 83, Plate. 19, Figs. 6,6a.
Kelliella boettgeri Meyer, Palmer and Brann, 1965, p.162.
Kelliella boettgeri Meyer, Dockery, 1977, p.131.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: Morris (1973) placed this genus in the family Leptonidae, which live attached to other marine organisms including vegetation, but it shows no sign of a byssus. Other workers have placed it in the family Kelliellidae with *Alveinus minutus* which Gardner (1957) Described as a leptonid. Harris (1920) said that in the Jackson bed of Mississippi this species is not commonly found in association with *Alveinus minutus*. This species was found in every zone of the outcrop (except the Cockfield) but was only 0.25% of all specimens picked.

Family ARCIDAE Lamark, 1809
Genus BARBATIA Gray, 1842
Species BARBATIA (*Cuculloides?*) LUDOVICIANA (Harris)

Plate 40, Fig. 1-2

Arca (Cuculloides?) ludoviciana Harris, 1919, p. 54, Plate 22, Figs.8-16.
Arca (Barbatia) cuculloides ludoviciana Harris. Barry, 1942, p. 49, Plate 2, Fig. 14.

Barbatia ludoviciana (Harris). Gardner, 1945, p. 53.
Barbatia ludoviciana (Harris). Harris and Palmer, 1946, p. 46, pt. 1, Plate 11, Figs. 6-8.
Barbatia (Cucullaeara) ludoviciana (Harris). Stenzel, Krause, and Twining, 1957, p. 58.
Barbatia ludoviciana (Harris). Brann and Kent, 1960, Vol. 40, No. 184, p. 116.
Barbatia (Cucullaearca) ludoviciana (Harris). Palmer and Brann, 1965, p. 46.
Barbatia (Cucullaearca) ludoviciana (Harris). Toulmin, 1977, p. 184, Plate 13, Figs. 1,2.
Barbatia (Cucullaearca) ludoviciana (Harris). Dockery, 1980, Miss. p. 149, Plate 21, Figs. 6A, 6B, Plate 62, Figs. 1A, 1B,2A,2B.

Range: Lower Eocene to Upper Eocene (Palmer and Brann, 1965)

Remarks: According to Stanley (1970) Barbatia is a byssally attached genus and characteristically lives wedged among coral colonies or rocks, being attached to them by its byssus. Corals are fairly common at Montgomery Landing but they are not colonial types. Rock material is also not present. This species makes up only a very small percent of the species found at Montgomery Landing.

The Treatise describes the genus Barbatia as a byssate, epifaunal nestler, and filter feeder. These forms inhabit nearshore, shallow-water environments, predominately at depths less than 30m, and prefer depressions in firm substrate for attachment to exposed surfaces. On reefs they are often found in crevices between coral heads, or within coral branches. They are common in wavecut depressions in limestone benches, on the roots of marine plants, attached to the protected sides of vegetation and hard reef blocks (Treatise). This species was 0.22% of all shell picked and was found only in the Moodys Branch Formation.

Family CORBULIDAE Lamarck, 1818
Subfamily CORBULINAE Gray, 1823
Genus CAESTOCORBULA Vincent, 1910
CAESTOCORBULA WAILESIANA Harris in Dall
Plate 38, Fig. 3-4

Corbula bicarinata Conrad in Wailes, 1854, p. 289, Plate 14, Fig. 3. Not C. bicarinata G. B. Sowerby I, 1833.
Corbula wailesiana Harris in Dall, 1898, pt. 4, p. 846.
Corbula wailesiana Harris (MS). Dall, 1946, pt. 1, p. 113, Plate 23, Figs. 27-28, Plate 24, Figs. 1,3,4, 5,7,8.
Caestocorbula wailesiana (Harris in Dall). Palmer and Brann, 1965, pt. 1, p. 57.
Caestocorbula wailesiana Harris in Dall. Dockery, 1980, p. 188, Plate 71, Figs. 1A,1B,3A,3B.

Range: Upper Eocene (Palmer and Brann, 1965).

Remarks: This is an inequivalve species. Stanley (1970) indicates that members of this family are unusual in that their commissure is vertical. In most inequivalve bivalves the life position is with the commissure at some angle to the vertical, usually about forty-five degrees. He cites Yonge (1946) who suggested that the overlap of the valves could improve the ability of the animal to effect pseudofeces in a muddy environment. These animals are sluggish shallow burrowers in a soft substrate.

This is one of the more common species at Montgomery Landing. It makes up 1.19% of the shells picked and was found throughout the whole outcrop.

Genus CORBULA Bruguiere, 1797
Subgenus CARYOCORBULA Gardner, 1926
CORBULA (CARYOCORBULA) DENSATA (Conrad)
Plate 39, Fig. 1-2

Corbula densata Conrad in Wailes, 1854, p. 289, Plate 14, Fig.9.
Corbula (*Caryocorbula*) *densata* Conrad. Harris and Palmer, 1946, pt. 1, p. 115, Plate 24, Figs. 11-15, 17-21.
Caryocorbula densata (Conrad). Palmer and Brann, 1965, p. 76.

Corbula (*Caryocorbula*) *densata* (Conrad in Wailes). Dockery, 1980, p. 187, Plate 71, Figs. 4,5A,5B,7A,7B.

Range: Middle and Upper Eocene (Palmer and Brann, 1965)

Remarks: This is also an inequivalve species, although not to the degree of *Caestocorbula wailesiana*. At Montgomery Landing this species is more common than *C. wailesiana*, comprising 4.48% of the specimens picked. Stanley (1970) points out that the corbulas have a thickened shell, yet they inhabit a muddy environnent where bouyancy is important in order to prevent clogging. He says that apparently they are small enough so that shell thickness is not an important factor in bouyancy. He reported that *Corbula caribaea* could suspend itself above the substrate by means of byssal threads. It can probably anchor itself in the substrate by this same means. His species was found in every zone at Montgomery Landing.

Family CRASSATELLIDAE Ferussac, 1822
Subfamily CRASSATELLINAE Ferussac, 1822
Genus BATHYTORMUS Stewart, 1930
BATHYTORMUS FLEXURUS Conrad
Plate 39, Fig. 3-4

Crassatella flexura Conrad in Wailes, 1854, p. 289, Plate 14, Fig.7.
Crassatellites flexurus (Conrad). Harris, 1919, no. 31, p. 100.
Crassatella flexura Conrad. Harris and Palmer, 1946, pt. 1, p. 81, Plate 18, Figs. 22-29,35-38, Plate 19, Figs. 1-4.
Bathytormus flexurus (Conrad). Palmer and Brann, 1965, p. 50.
Bathytormus flexurus (Conrad). Dockery, 1977.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: Abbott (1968) states that modern members of this family have no siphons and hence the pallial line lacks a sinus. Breard (1978) indicated that this is composed of shallow, sand-burrowing clams. This species made up .41% of the specimens picked at Montgomery Landing. It was not found in the Cockfield Formation nor in the upper portion of the Yazoo.

Genus *CRASSINELLA* Guppy, 1874
CRASSINELLA PYGMAEA (Conrad, 1865)

Gouldia pygmaea Conrad, 1865, p. 139.
Crassatellites (Crassinella) pygmaea (Conrad). Dall, 1903, p. 1475.
Crassinella pygmaea (Conrad). Harris and Palmer, 1946, pt. 1, p. 79, Plate 18, Figs. 17,18.
Crassinella pyqmaea (Conrad). Palmer and Brann, 1946, pt. 1, p. 111.
Crassinella pygmaea (Conrad). Dockery, 1980, p. 177, Plate 66, Figs. 1A,1B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: Modern representatives of this family have no siphons (Abbott, 1968). At the present, bivalves of this genus are known only from the temperate and tropical regions of the Atlantic and Pacific shores of the American continents (Harry, 1966). Harry worked with a modern species, *C. lunulata*, in the northwestern Gulf of Mexico off the Texas coast. His figured specimens are very similar to *Crassinella pygmaea*. He found that *Crassinella lunulata* was able to attach itself above the substrate with delicate byssal threads. They spend most of their time, however, on top of the substrate. They are also capable of shallow burial with just the posterior top exposed. This species was found in all zones of the Montgomery Landing outcrop except the Cockfield Formation. It comprised 0.06% of all specimens picked.

Family GLYCYMERIDIDAE Newton, 1922
Genus GLYCYMERIS da Costa, 1778
Subgenus GLYCYMERIS da Costa, 1778
GLYCYMERIS (GLYCYERIS) FILOSA (Conrad in Wailes)

Glossus filosus Conrad in Wailes, 1854, p. 289, Plate 14, Fig.8.
Glycymeris filosa (Conrad). Dall, 1898, p. 607.
Glycymeris filosa (Conrad). Harris and Palmer, 1946, p. 49, Plate 12, Figs.1-3.
Glycymeris filosa (Conrad). Palmer and Brann, 1965, p. 151.
Glycymeris (Glycymeris) filosa (Conrad in Wailes). Dockery, 1980, p. 152, Plate 61, Figs. 7A,7B, Plate 62, Figs. 4A,4B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: Members of this species are sluggish burrowers that crawl for considerable distances before becoming buried. They are shallow burrowing forms in a soft substrate (Stanley, 1970). Abbott (1968) states that Glycymeris is generally found in sandy, shallow areas and some species are found at depths of 100 to 300 feet. According to Thomas (1975), modern Glycymeris is a mobile shallow-burrowing bivalve that is found at shallow to intermediate depths on the continental shelf. It lacks siphons but is a suspension feeder, so it lies just below the substrate surface. He says that large patches of them are found on clean sandy coarse bottoms. Paleoecological evidence indicates it has always lived in a similar environment as an opportunistic form. This species was found only in the Moodys Branch Formation and was only 0.02% of all specimens picked.

Family NUCULANIDAE H. and A. Adams, 1858
Genus HILGARDIA Harris, 1946
HILGARDIA MULTILINEATA? Conrad
Plate 42, Fig. 3-4

Leda multilineata Conrad. Wailes, 1854, p. 289, Plate 14, Fig. 4.
Nuculana (Hilgardia) multilineata (Conrad). Harris and Palmer, 1946, p. 59, Plate 14, Figs. 2-6.
Nuculana (Hilgardia) multilineata (Conrad). Palmer and Brann, 1965, p. 221.
Hilgardia multilineata (Conrad). Puri. 1969, Figs. A7,7a,7b,7c.
Hilgardia multilineata (Conrad). Dockery, 1980, Plate 20, Figs. 3A,3B,4A,4B.
Hilgardia multilineata (Conrad). Dockery, 1980, p. 147, Plate 44, Figs. 4A,4B, Plate 61, Figs. 3,5,6A,6B.

Range: Middle and Upper Eocene (Palmer and Brann, 1965)

Remarks: This genus is described in the Treatise as a shallow burrowing deposit feeding bivalve like Nucula. It is a moderately fast burrower, faster than Nucula, and shows a strong affinity for a soft, fine-grained substrate. This species was found in every zone in the outcrop (except the Cockfield) and was 0.6% of all specimens picked.

Family ASTARTIDAE d'Orbigny, 1844
Subfamily ERIPHYLINAE Chavan, 1952
Genus LIRODISCUS Conrad, 1869
Subgenus LIRODISCUS Conrad, 1869
LIRODISCUS (LIRODISCUS) PRETRIANGULATA (Dockery)

Astarte sp. Harris, ?1946, plate 18, Figs. 15,16.
Astarte pretriangulata Dockery, 1977, p. 124, Plate 24, Figs. 3,5.
Lirodiscus (Lirodiscus) pretriangulata (Dockery), 1980, p. 174, Plate 65, Figs. 3A,3B,4A,4B,5A,5B,6A,6B.

Remarks: Members of this family are infaunal filter and detritus feeders and have a strong preference for fine-grained substrate (Treatise). Stanley (1970) characterized members of this group as lacking siphons or having short siphons and being slow shallow burrowers in a soft substrate. This species was only found in the Moodys Branch Formation and was 0.004% of the specimens picked. Only one specimen was found.

Family LIMOPSIDAE Dall, 1895
Genus LIMOPSIS Sassi, 1827
Subgenus PECTUNUCULINA d'Orbigny, 1843
LIMOPSIS (PECTUNUCULINA) RADIATA Meyer

Limopsis radiatus Meyer, 1885, p. 459.
Limopsis radiata Meyer. Harris and Palmer, 1946, p. 51, Plate 12, figs. 13-15, Plate 13, Figs. 1,2.
Limopsis radiata Meyer. Palmer and Brann, 1965, p. 1.
Limopsis (Pectunuculina) radiata Meyer. Dockery, 1977, p. 113, Plate 21, Figs. 2A,2B.

Remarks: These are possibly shallow burrowers like *Glycymeris*. Gardner (1957) said that *Limopsis* usually indicates deep water. Ten specimens of this species were found, but only in the Moodys Branch Formation. It was 0.04% of all specimens picked.

Family LUCINIDAE FLEMING, 1828
Genus LUCINA GRUGIERE, 1797
Subgenus CALLUCINA Dall, 1901
LUCINA (CALLUCINA?) CURTA (Conrad)
Plate 40, Fig. 3-4

Cyclas curta Conrad, 1865, p. 138,212, Plate 20, Fig.14.
Lucina (Myrtea?) curta (Conrad). Harris, 1946, p. 89, Plate 19, Figs. 19-23.

Myrtea? curta (Conrad). Palmer and Brann, 1965, p. 202.
Lucina (Callucina?) curta (Conrad). Bretsky, 1976, p. 258260.
Gonimyrtea curta (Conrad). Dockery, 1977, p. 119, Plate 23, Figs. 3A,3B,4A,$b4B.
Lucina (Callucina?) curta (Conrad). Dockery, 1980, p. 163, Plate 64, Figs. 3A,3B,4A,4B.

Range: Upper Eocene (Palmer and Brann, 1965)

LUCINA (CALLUCINA?) SUBCURTA (Harris)

Lucina (Myrtea) subcurta Harris, 1946, p. 89, Plate 20, Figs. 1-5
Myrtea? subcurta Harris. Palmer and Brann, 1965, p. 202.
Lucina (Callucina?) subcurta (Conrad). Bretsky, 1976, p. 258-260.

Gonimyrtea subcurta (Harris). Dockery, 1977, p. 119, Plate 23, Figs. 1A,1B.
Lucina (Callucina?) subcurta (Harris). Dockery, 1977, p. 164, Plate 63, Figs. 6A,6B, Plate 64, Figs. 1A,1B,2A,2B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: According to the Treatise the Lucinidae have no inhalant siphon, but draw in a current through an inhalant tube which is driven through the sediment by an up-and-down motion of the end of an extensile vermiform foot, and is lined with hardened mucus. This tube projects from the shell at its anterior end, which points obliquely upward, buried perhaps to a depth of 6 - 8 cm. The animal is considered to be a shallow burrower in sandy sediment. Yonge and Thompson (1976) said that lucines in modern environments are able to live where there are extremes in food and oxygen. They are also common in shallow sand patches within West Indian coral reefs where the eel grass Thalassia is abundant. Lucina (Callucina?) curta was found in every zone of the outcrop except for the Cockfield Formation. One hundred and twenty-four specimens were found making up 0.61% of all shells picked. Lucina (Callucina) subcurta was also found in every zone (except the Cockfield) and comprised 4.2% of the shells. Eight hundred and fifty-three specimens were picked. The most readily observed difference between these two species is that L. subcurta has peripheral crenulations along the ventral margin and L. curta does not.

Family NUCULIDAE Gray, 1824
Genus NUCULA Lamarck, 1799
Subgenus NUCULA Lamarck, 1799
NUCULA (NUCULA) SPHENIOPSIS Conrad
Plate 42, Fig. 1-2

Nucula sphenopsis Conrad, 1865, p. 140, Plate 10, Fig. 13.
Nucula spheniopsis Conrad. Harris and Palmer, 1946, p. 63, Plate 14, Figs. 24-27.
Nucula (Nucula) spheniopsis Conrad, Palmer and Brann, 1965, p. 215.
Nucula (Nucula) spheniopsis Conrad. Dockery, 1977, p. 146, Plate 61, Figs. 1A,1B,2A,2B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: This species shows no signs of a pallial sinus and the Treatise describes this genus as one that burrows so shallowly that the inhalant current is drawn between its anterior margins. It is described as a sessile detritus feeder and a slow burrower in soft substrates. Stanley (1970) points out that it collects particles of food from sediments with appendages of the labial palps called proboscides. He considers four bivalve families to be shallow-water deposit feeders, Nuculidae, Nuculanidae, Semelidae, and Tellinidae. This species was found in every zone of the outcrop (except the Cockfield) and accounted for 6.56% of all specimens found. It was the second most common species behind Alveinus minutus.

Family CARDITIDAE Fleming, 1820
Subfamily CARDITAMERINAE Chavan, 1969
Genus PLEUROMERIS Conrad, 1867
PLEUROMERIS INFLATIOR JACKSONENSIS (Meyer)

Venericardia inflatior var. *jacksonensis* Meyer, 1885, p. 460.
Venericardia (Pleuromeris) inflatior Meyer. Harris and Palmer. 1946, p. 75, 76, Plate 17, Figs. 18,18b.
Venericardia inflatior jacksonensis Meyer. Palmer and Brann, 1965, p. 332.
Pleuromeris inflatior jacksonensis (Meyer). Dockery, 1977, p. 122, Plate 23, Figs. 7,8.
Pleuromeris inflatior jacksonensis (Meyer). Dockery, 1980, p. 167, Plate 67, Figs. 4A,4B,5A,5B,6.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: Dockery (1977) placed this species in the genus *Pleuromeris* rather than the genus *Venericardia* as done by Palmer and Brann (1965). This family has forms that are free burrowers into the sediment and others which live infaunally but are attached to roots and stems. Divergence of the carditidae into bysally attached and free burrowing groups has resulted in convergence with the arcidae family in which the same divergence is seen. *Pleuromeris* was placed as a subgenus of Venericardia which is not an attached form. This species is probably a shallow burrower. Park (1968) suggested that the optimum environment for *Pleuromeris* seems to be a fairly shallow inner shelf environment where the sedimentation rate is relatively low. He said that *Pleuromeris* showed some degree of ecologic heterogeneity and therefore cannot be considered to indicate any sharply delimited environment. This is one of only four species found in the Cockfield Formation at Montgomery Landing. It was also found throughout the rest of the outcrop except for the upper portion of the Yazoo. It makes up 0.11% of the specimens picked.

PLEUROMERIS QUADRATA Dockery

Venericardia parva var. Jacksonensis Meyer, 1185, p. 460.
Venericardia (Pleuromeris) parva var. *jacksonensis* Meyer. Harris and Palmer, 1946, p. 75, Plate 17, Figs. 19-21.
Venericardia (Pleuromeris) sp. Palmer and Brann, 1965, p. 348.
Pleuromeris sp. Dockery, 1977, p. 122.
Pleuromeris quadrata (Meyer). Dockery, 1980, p. 167, Plate 67, Figs. 2A,2B,3A,3B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: This is a new name proposed by Dockery (1980). It was previously known as *Venericardia (Pleuromeris) parva*. var. *jacksonensis* (Harris, 1946), and Dockery placed it in the genus *Pleuromeris* (Dockery, 1977). As with *Pleuromeris inflatior jacksonensis*, this species is probably a shallow burrower in soft substrate. This species was found throughout the outcrop (except the Cockfield Formation) and composed 0.74% of all specimens picked.

Subfamily VENERICARDIINAE Chavan, 1969
Genus VENERICARDIA Lamarck, 1801
Subgenus ROTUNDICARDIA Heaslip, 1969
VENERICARDIA (ROTUNDICARDIA) DIVERSIDENTATA Meyer
Plate 43, Fig. 1-2

Cardita tetrica Conrad, Wailes, 1854, p. 289, (name only).
Venericardia diversidentata Meyer. Harris and Palmer, 1946, p. 69, Plate 16, Fig.10, Plate 17, Figs.1-3, 5-9, 10-17a.
Venericardia diversidentata Meyer. Palmer and Brann, 1965, p. 328.
Venericardia (Rotundicardia) diversidentata Meyer. Heaslip, 1968, p. 95, Plate 23, Figs.3-8.
Venericardia (Rotundicardia) diversidentata Meyer. Dockery, 1977, p. 123, Plate 23, Figs. 6,9,10A,10B,11A,11B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: This species is rounded in outline and very similar in shape and features to *Venericarida rotunda*. Toulmin (1977) states that *V. diversidentata* has more ribs than *V. rotunda* but the nodes are not as flared. According to Stanley (1970), there is an association between upright byssal attachment and elongation. The living *Venericardia* are free-burrowers and lack a byssus (Abbott, 1954). This species is commonly found with both valves together (Breard, 1977) although no specimens were found in this condition at Montgomery Landing. *Venericardia* is usually absent from limestones and shales and is most commonly found in glauconitic and very shelly sediments (Park, 1968). This species was only found in the Moodys Branch Formation and represents 0.3% of the specimens picked.

Superfamily PANDORACEA Rafinesque, 1815
Family VERTICORDIIDAE Stoliczka, 1871
Genus VERTICORDIA J. de C. Sowerby, 1844
Subgenus VERTICORDIA J. de C. Sowerby, 1844
VERTICORDIA (VERTICORDIA) COSSMANNI (Dall)
Plate 43, Fig. 3-4

Verticordia (Trigonulina) cossmanni Dall, 1903, p. 1512.
Verticordia (Trigonulina) cossmanni Dall, Harris and Palmer, p. 112, Plate 23, Fig.23.
Verticordia (Trigonulina) cossmanni Dall. Palmer and Brann, 1965, p. 350.
Verticordia (Verticordia) cossmanni Dall. Dockery, 1977, p. 139, Plate 28, Figs.2A,2B.

Range: Upper Eocene (Palmer and Brann, 1965)

Remarks: This species is oval in outline and is probably a shallow burrower. Morris (1973) indicates that modern members of this family are found mostly in deep water. This species was in every zone at Montgomery Landing except for the Cockfield Formation. It made up 0.96% of all specimens picked.

Superfamily MACTRACEA Lamarck, 1809
Family MACTRIDAE Lamarck, 1809
Subfamily MACTRINAE Lamarck, 1809
Genus SPISULA Gray, 1837
SPISULA JACKSONENSIS Cooke

Spisula jacksonensis Cooke, 1926, p. 137, Figs. 14a,b,c.
Spisula jacksonensis Cooke. Harris and Palmer, 1946, p. 107, Plate 23, Figs. 7-10.
Spisula jacksonensis Cooke. Palmer and Brann, 1965, p. 298.
Spisula jacksonensis Cooke. Dockery, 1977, p. 127, Plate 25, Figs. 4,5.
Spisula jacksonensis Cooke. Dockery, 1980, p. 178, Plate 68, Figs. 4A,4B,5.

Range: Middle and Upper Eocene (Palmer and Brann, 1965)

Remarks: Stanley (1970) indicates that this genus is a rapid but shallow burrower and inhabits high energy environments. It lives in an unstable, shifting, coarse grained substrate where rapid burial is a necessity. Only one specimen of this species was found at Montgomery Landing. It was in the Moodys Branch Formation. Because it is so rare it is not considered useful as an environmental indicator.

Table 20. Total actual count and total adjusted count for each bivalve mollusk species.

	Actual Totals	Adjusted Totals
Barbatia (*Cucullaearca*) *ludoviciana*	46	185
Lirodiscus (*Lirodiscus*) *pretriangulata*	1	4
Pleuromeris inflatior jacksonensis	24	117
Pleuromeris quadrata	151	410
Venericardia (*Roundicardia*) *diversidentata*	75	308
Caestocorbula wailesiana	241	878
Corbula (*Caryocorbula*) *densata*	906	3516
Bathytormus flexurus	83	360
Crassinella pygmaea	14	25
Glycymeris filosa	5	21
Alveinus minutus	15991	81190
Kelliella boettgeri	52	165
Limopsis (*Pectunuculina*) *radiata*	10	44
Lucina (*Callucina?*) *curta*	124	381
Lucina (*Callucina?*) *subcurta*	853	2711
Spisula jacksonensis	1	4
Hilgardia multilineata	123	476
Nucula spheniopsis	1326	3152
Verticordia (*Verticordia*) *cossmanni*	196	241
Totals	20222	94188

Table 21. Actual count and asjusted count for each bivalve mollusk species in the Cockfield Formation.

	Actual Count	Adjusted Count
Barbatia (Cucullaearca) ludoviciana	0	0
Lirodiscus (Lirodiscus) pretriangulata	0	0
Pleuromeris inflatior jacksonensis	3	17
Pleuromeris quadrata	0	0
Venericardia (Rotundicardia) diversidentata	0	0
Caestocorbula wailesiana	1	6
Corbula (Caryocorbula) densata	2	11
Bathytormus flexurus	0	0
Crassinella pygmaea	0	0
Glycymeris filosa	0	0
Alveinus minutus	16	91
Kelliella boettgeri	0	0
Limopsis (Pectunuculina) radiata	0	0
Lucina (Callucina?) curta	0	0
Lucina (Callucina?) subcurta	0	0
Spisula jacksonensis	0	0
Hilgardia multilineata	0	0
Nucula spheniopsis	0	0
Verticordia (Verticordia) cossmanni	0	0

Table 22. Actual count, adjusted count, and average per sample for each bivalve mollusk species in the Moodys Branch Formation

	Actual Count	Adjusted Count	Ave./fossiliferous sam.
Barbatia (Cucullaearca) ludoviciana	46	185	15.41
Lirodiscus (Lirodiscus) pretriangulata	1	4	.33
Pleuromeris inflatior jacksonensis	19	83	6.00
Pleuromeris quadrata	89	299	24.91
Venericardia (Rotundicardia) diversidentata	75	308	25.66
Caestocorbula wailesiana	174	724	60.33
Corbula (Caryocorbula) densata	683	2820	235.00
Bathytormus flexurus	75	347	28.91
Crassinella pygmaea	8	18	1.50
Glycymeris filosa	5	21	1.75
Alveinus minutus	963	5789	482.41
Kelliella boettgeri	36	111	9.25
Limopsis (Pectunuculina) radiata	10	44	3.66
Lucina (Callucina?) curta	38	145	12.08
Lucina (Callucina?) subcurta	13	45	3.75
Spisula jacksonensis	1	4	.33
Hilgardia multilineata	35	113	9.40
Nucula spheniopsis	19	58	4.83
Verticordia (Verticordia) cossmanni	23	58	4.80

Table 23. Actual count, adjusted count, and average per fossiliferous sample for each bivalve mollusk species in the Yazoo Formation

	Actual Count	Adjusted Count	Ave./foss-liferous sam.
Barbatia (Cucullaearca) ludoviciana	0	0	0
Lirodiscus (Lirodiscus) pretriangulata	0	0	0
Pleuromeris inflatior jacksonensis	2	17	.2
Pleuromeris quadrata	62	111	1.5
Venericardia (Rotundicardia) diversidentata	0	0	0
Caestocorbula wailesiana	66	148	2.1
Corbula (Caryocorbula) densata	221	685	9.6
Bathytormus flexurus	8	13	.2
Crassinella pygmaea	6	7	.1
Glycymeris filosa	0	0	0
Alveinus minutus	15012	75310	1060.7
Kelliella boettgeri	16	54	.7
Limopsis (Pectunuculina) radiata	0	0	0
Lucina (Callucina?) curta	86	236	3.3
Lucina (Callucina?) subcurta	840	2666	37.5
Spisula jacksonensis	0	0	0
Hilgardia multilineata	88	363	5.1
Nucula spheniopsis	1307	3094	43.5
Verticordia (Verticordia) cossmanni	173	183	2.5

Table 24. Adjusted count for each bivalve mollusk species in the Moodys Branch and each zone of the Yazoo Formation

	Moodys Br.	Yazoo Formation A	B	C
Barbatia (*Cucullaearca*) *ludoviciana*	185	0	0	0
Lirodiscus (*Lirodiscus*) *pretriangulata*	4	0	0	0
Pleuromeris inflatior jacksonensis	83	1	16	0
Pleuromeris quadrata	299	45	58	8
Venericardia (*Rotundicaria*) *diversidentata*	308	0	0	0
Caestocorbula wailesiana	724	5	126	17
Corbula (*Caryocorbula*) *densata*	2820	28	626	31
Bathytormus flexurus	347	5	8	0
Crassinella pygmaea	18	3	3	1
Glycymeris filosa	21	0	0	0
Alveinus minutus	5789	1394	73763	133
Kelliella boettgeri	111	10	43	1
Limopsis (*Pectunuculina*) *radiata*	44	0	0	0
Lucina (*Callucina?*) *curta*	145	41	193	2
Lucina (*Callucina?*) *subcurta*	45	34	2596	36
Spisula jacksonensis	4	0	0	0
Hilgardia multilineata	113	25	322	16
Nucula spheniopsis	58	402	2650	42
Verticordia (*Verticordia*) *cossmanni*	58	167	8	8

Table 25. Average bivalve mollusk species abundance per fossiliferous sample in the Moodys Branch and each zone of the Yazoo.

	Moodys Br.	Yazoo Formation A	Yazoo Formation B	Yazoo Formation C
Barbatia (*Cucullaearca*) *ludoviciana*	15.41	0	0	0
Lirodiscus (*Lirodiscus*) *pretriangulata*	.33	0	0	0
Pleuromeris inflatior jacksonensis	6.00	.04	.45	0
Pleuromeris quadrata	24.91	1.73	1.65	.88
Venericardia (*Rotundicaria*) *diversidentata*	25.66	0	0	0
Caestocorbula wailesiana	60.33	.19	3.60	1.88
Corbula (*Caryocorbula*) *densata*	253.00	1.07	17.88	3.44
Bathytormus flexurus	28.91	.19	.22	0
Crassinella pygmaea	1.50	.12	.08	.11
Glycymeris filosa	1.75	0	0	0
Alveinus minutus	482.41	53.61	2107.00	17.00
Kelliella boettgeri	9.25	.38	.12	.11
Limopsis (*Pectunuculina*) *radiata*	3.66	0	0	0
Lucina (*Callucina?*) *curta*	12.08	1.57	5.51	.22
Lucina (*Callucina?*) *subcurta*	3.57	1.30	74.17	4.00
Spisula jacksonensis	.33	0	0	0
Hilgardia multilineata	9.40	.96	9.20	1.77
Nucula spheniopsis	4.83	15.46	73.80	4.66
Verticordia (*Verticordia*) *cossmanni*	4.80	6.42	.22	.88

Table 26. Five most common bivalve mollusk species in each zone at Montgomery Landing and percentage of specimens found.

Moodys Branch

Caestocorbula wailesiana

Corbula (*Caryocorbula*) *densata*

89.37%

Bathytormus flexurus

Vernericardia (*Rotundicardia*) *diversidentata*

Alveinus minutus

Yazoo - *A*

Lucina (*Callucina?*) *curta*

Nucula sphenioposis 94.86%

Pleuromeris quadrata

Verticordia (*Verticordia*) *cossmanni*

Alveinus minutus

Yazoo - *B*

Alveinus minutus

Corbula (*Caryocorbula*) *densata*

99.43%

Lucina (*Callucina?*) *subcurta*

Nucula spheniopsis

Hilgardia multilineata

Yazoo - *C*

Alveinus minutus

Caestocorbula wailesiana

Corbula (*Caryocorbula*) *densata*

88.57%

Lucina (*Callucina?*) *subcurta*

Nucula spheniopsis

Plate 38 Fig. 1,2 Alveinus minutus, left valves, outer & inner view. X 20.

Fig. 3,4 Caestocorbula wailesiana, left valves, outer & inner view. X 20.

FIG. 1

FIG. 2

FIG. 3

PLATE 38

FIG. 4

Plate 39

Fig. 1,2 *Corbula* (*Corbula*) *densata*, right valves, outer & inner view. X 20.

Fig. 3,4 *Bathytormus flexurus productus*, left valves, outer & inner view. X 40.

FIG. 1

FIG. 2

FIG. 3

PLATE 39

FIG. 4

Plate 40

Fig. 1,2 *Barbatia* (*Cucullaearca*) *ludoviciana*, 1-left valve. X 20, 2-right valve. X 30.

Fig. 3,4 *Lucina* (*Callucina?*) *curta*, 3-left valve, 4-right valve. X 20.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

PLATE 40

Plate 41 Fig. 1,2 *Lucina* (*Callucina*?) *subcurta*, right valves, outer & inner view. X 40.

Fig. 3 *Kelliella boettgeri*, left valve. X 40.

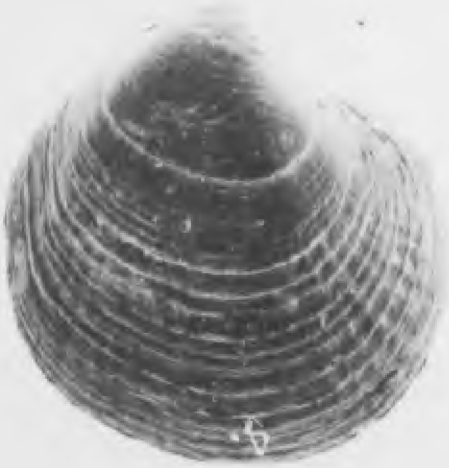

FIG. 1

FIG. 2

PLATE 41

FIG. 3

Plate 42

Fig. 1,2 Nucula spheniopsis, right valves, outer. X 70 & inner view. X 50.

Fig. 3,4 Hilgardia multiliheata, right valves, outer & inner view. X 40.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

PLATE 42

Plate 43

Fig. 1,2 Venericardia (Rotundicardia) diversidentata, 1-left valve, 2- right valve. X 40.

Fig. 3,4 Verticordia (Verticordia) cossmanni, 1-left valve, 2-right valve. X 20.

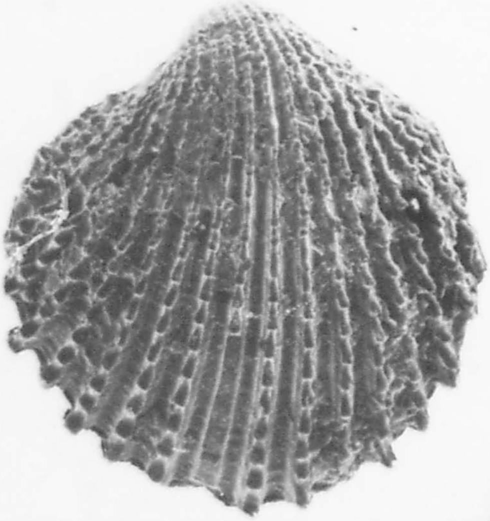

FIG. 1

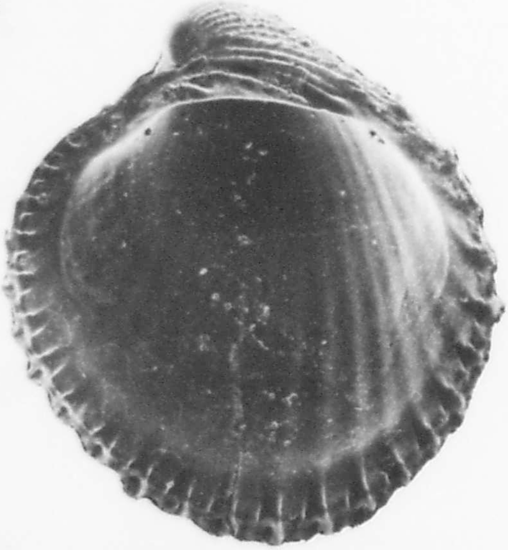

FIG. 2

FIG. 3

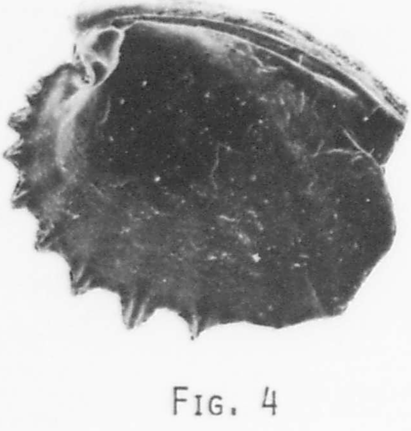

FIG. 4

PLATE 43

I. ANALYSIS OF MONTGOMERY LANDING EOCENE GASTROPOD FAUNA*

On the basis of modern representatives or close relatives, the genera represented by the common gastropod species can be categorized as follows according to mode of feeding (data from Keen, 1958; Emerson and Jacobson, 1976; and Stanton and Nelson, 1980):

HERBIVORES: (?) Bittium

Carnivores

A. Predators

Euspira - preys on bivalves, gastropods, and scaphopods
Natica - " " " "
Tritonoatractus

B. Predators and/or parasites (on mollusks, echinoderms, coelenterates, and polychaetes)

Pyramidella
Turbonilla
Melanella
Odostomia
Acteon

Suspension feeders

A. Sedentary

Turritella

B. Pelagic

Clio

Deposit feeders

Cadulus

(?) Bittium (may be herbivore)

Many of the less common (rare or scarce) gastropods are too poorly preserved for generic determination. For those that have been confidently or questionably identified to genus, the following modes of feeding are suggested by comparison with living relatives:

---

*by C. R. Givens, Earth Science Department, Nicholls State University

Carnivores

A. Predators and/or scavengers

- Athleta
- Caricella
- Hexaplex
- Levifusus
- Architectonica
- Cochlespira
- Agaronia
- Tritiara
- Cornulina
- Polinices
- Sinum
- Mnestia
- Cyclichnina
- Eopleurotoma
- Coronia
- "Turricula"
- Scobinella
- Mitrella

B. Predators and/or parasites

- Cirsotrema
- Acirsa

Herbivores

- Solariella
- (?) Circulus
- (?) Solariorbis
- (?) Tornus
- (?) Teinostoma

Sessile suspension feeders

- Calyptraea
- Hipponyx
- Capulus

Table 27 Gastropod Distribution, Selected Samples

Code for relative abundance:
A - (abundant) - more than 20 specimens
C - (common) - more than 6-20 specimens
S - (scarce) - 2-5 specimens
R - (rare) - 1 specimen

TAXA, by sample	RELATIVE ABUNDANCE
Section #1:	
Sample 1-6 (M)*	
Hexaplex? cf. *H.* *marksi* (Harris)	R
Sample 1-11 (YL 1)	
1-11a *Euspira*? cf. *E.* *jacksonensis* Palmer	A
1-11b *Sinum*? sp. indet. S	
1-11c *Mnestia* *meyeri* (Cossman)	S
1-11d *Rissonia* *mississippiensis* meyer R	
1-11e indeterminate gastropod	S
1-11f indeterminate gastrppod	R
Section #2	
Sample 2-13 (M)	
Architectonica *(Stellaxis)* *alveata* (Conrad)	R
Section #3	
Sample 3-2 (YA)	
Cadulus sp. indet.	S
Sample 3-8 (YL 2)	
3-8a *Euspira*? cf. E. jacksonensis Palmer	S
3-8b *Acteon*? sp./indet.	R
3-8c *Turritella*? sp. indet	R
Sample 3-12 (YA)	
Cadulus sp. indet.	S
Sample 3-13 (YL 3)	
3-13a *Euspira*? sp. indet.	S
3-13b *Turritella* sp. indet.	R
3-13c indeterminate gastropods: at least 2 species	S

Sample 3-15 (YL 3)

3-15a *Euspira* sp. indet.	C
3-15b *Turritella* sp. indet.	R
3-15c *Lanistes?* new species?	S
3-15d indeterminate gastroped	R

Sample 3-17 (YL)

3-17a *Turritella arenicola danvillensis* Stenzel & Turner	S
3-17b *Cadulus (Polyschides) margarita* Palmer	A
3-17c *Turritella* cf. *T. clevelandia* Harris	R
3-17d *Euspira jacksonensis* Palmer	S
3-17e *Polinices weisbordi* Palmer	R
3-17f *Tritonoatractus* cf. *T. pearlensis* (Aldrich), s.l.	S
3-17g *Hexaplex?* cf. H. supernus (Palmer)	R
3-17h *Athleta* so. indet.	R
3-17i *Eopleurotoma?* cf. E. carya Harris, variety	R

Sample 3-18 (YC)

3-18a *Euspira jacksonensis* Palmer	R
3-18b indeterminate gastropod	R

Sample 3-19 (YC)

3-19a *Cadulus (Polyschides) margarita* Palmer	A
3-19b *Turritella arenicola danvillensis* Stenzel & Turner	R
3-19c *Tritonoatractus* cf. *T. pearlensis* Aldrich, s. l.	S
3-19d indeterminate gastropod	R
3-19e *Athleta* sp. indet.	S
3-19g *Euspira jacksonensis* Palmer	C
3-19j *Mnestia* cf. *M. meyeri*	R
3-19k *Cylfchnfna* cf. *C. jacksonensis* (Meyer)	R
3-19l *Natica (Naticarius)* permuda Conrad	R
3-19m *Odostomia?* cf. *O. jacksonensis* Dockery	R

Sample 3-20 (YC)

3-20a *Euspira jacksonensis* Palmer	S
3-20b *Natica (Naticarius) permunda* Conrad	S
3-20c *Euspira* or *Natica* sp., indeterminate	S
3-20d *Tritonoatractus?* sp. indet.	R
3-20e *Levifuscus?* sp. indet.	R

Sample 3-21 (YC)

3-21a	*Cadulus* (*Polyschides*) *margarita* Palmer	A
3-21b	*Natica* (*Naticarius*) *permunda* Conrad	R
3-21c	*Euspira jackonensis* Palmer	S
3-21d	*Turritella arenicola danvillensis* Stenzel and Turner	S
3-21e	*Cirsotrema*? sp. indet.	S
3-21f	*Athleta* sp. indet.	S

Sample 3-22 (YC)

3-22a	*Cadulus* (*polyschides*) *margarita* Palmer	C
3-22b	*Cadulus* (*polyschides*) cf. *C*. (*P*.) *jacksonensis* Meyer	C
3-22c	*Turritella arenicola danvillensis* Stenzel and Turner	R
3-22d	*Melanella jacksonensis* (de Gregorio)	R
3-22e	*Pyrimidella* (*Syronla*) meyeri (Cossman)	R
3-22f	*Acteon* idoneus Conrad	R
3-22g	*Tritonoatractus* *cf*. *T*. *pearlensis* Aldrich, s.l.	C
3-22h	*Calyptraphorus* cf. *C*. *velatus stamineus* (Conrad)	R
3-22i	*Cirsotrema*? sp. indet.	R

Sample 3-23 (YC)

3-23a	*Natica* (*Naticarius*) *permunda* Conrad	C
3-23b	*Tritonatractus* cf. *T*. *pearlensis* (Aldrich), s.l.	R
3-23c	*Caricella*? sp. Indet.	R
3-23d	*Coronia* cf. C. conjuncta (Casey)	R
3-23e	*Cadulus* (*Polyschides*) *margarita* Palmer	A

Sample 3-24 (YC)

3-24a	*Cadulus* (*Polyschides*) *margarita* Palmer	A
3-24b	*Tritonoatractus*? Sp. indet.	R

Sample 3-25 (YC)

3-25a	*Cadulus* (*Polyschides*) *margarita* Palmer	C
3-25b	*Turritella arenicola danvillensis* Stenzel & Turner	S
3-25c	*Turritella* cf. *T*. *cleveleandia* Harris	S
3-25d	*Natica* (*Naticarius*) *permunda* Conrad	S
3-25e	*Euspira jacksonensis* Palmer	R

Section # 4

Sample 4-2 (M)

Turritella cf. *T*. *clevelandia* Harris	R

Sample 4-4 (YL 1)

4-4a	Euspira? and/or Natica? species indeterminate	A
4-4b	Acteon sp. indet.	C
4-4c	Circulus? cf. C. ottonius Palmer	C
4-4d	Tornus cf. T. infraplicatus (Johnson)	S
4-4e	Cyclichnina? sp. indet.	C
4-4f	Sinistrella? cf. S. america (Aldrich)	R
4-4g	Calyptraea cf. C. aperta (Solander)	C
4-4h	Lanistes? new species?	S
4-4i	Hexaplex? cf. H. supernus (Palmer)	C
4-4j	Tritiara? cf. T. albirupina (Harris)	C
4-4k	indeterminant gastropods: at least 15 species	
4-4l	Solariella? sp. indet.	C
4-4n	"Verconella"? sp. indet.	C
4-4o	Cadulus (Polyschides) margarita Palmer	C
4-4p	Architectonica sp. indet.	R
4-4q	Xenophora? sp. indet.	R
4-4r	Cochlespira? sp. indet.	R
4-4s	Odostomia cf. O. jacksonensis Dockery	R
4-4t	Scobinella? sp. indet.	R
4-4u	Levifusus? sp. indet.	R
4-4v	Hipponix cf. H. pygmaeous Lea	R
4-4w	Capulus? sp. indet.	R
4-4x	Cadulus cf. C. (Polyschides) jacksonensis Meyer	R
4-4y	Cadulus (Polyschides) sp. indet.	A
4-4aa	Eoclathurella? sp. indet.	R
4-4bb	Asthenotoma? sp. indet.	R
4-4cc	Melanella? sp. indet.	R

Sample 4-11 (YA)

Cadulus sp. indet.	C

Sample 4-12 (YA)

Cadulus sp. indet.	S

Sample 4-14 (YL 2)

4-14a	Cadulus sp. indet.	A
4-14b	Euspira? and/or Natica?, species indet.	C
4-14c	Sinum? sp. indet.	S

Sample 4-18 (YB)

4-18a	Cadulus (Polyschides) jacksonensis Meyer	A
4-18b	Cadulus (Polyschides) margarita Palmer	R
4-18c	Clio (Creseis) simplex (Meyer)	A

Sample 4-21 (YL 3)

4-21a	*Cadulus* sp. indet.	A
4-21b	*Odostomia*? sp. indet.	R
4-21c	*Cyclichnina*? sp. indet.	S
4-21d	*Euspira*? and/or *Natica*?, sp. indet.	A
4-21e	*Tornatellaea*? sp. indet.	S
4-21f	indeterminate gastropods: at least 10 species	

Sample 4-22 (YL 3)

4-22a	*Cadulus* sp. indet.	A
4-22b	*Euspira*? and/or *Natica*?, sp. indet.	A
4-22c	*Odostomia* cf. *O. jacksonensis* Dokery	S
4-22d	*Sinum* sp. indet.	S
4-22e	*Architectonica* sp. indet.	R
4-22f	*Acteon*? sp. indet.	R
4-22g	*Cirsotrema* cf. *C. nassulum creolum* Palmer	R
4-22h	indeterminate gastropods: at least 8 species	

Sample 4-23 (YL 3)

4-23a	*Euspira*? and/or *Natica*?, sp. indet.	A
4-23b	*Cadulus* sp. indet.	A
4-23c	indeterminate gastropods: at least 4 species	

Section 5:

Sample 5-5 (YA)

Solariorbis? sp. indet.	R

Sample 5-9 (YA)

5-9a	*Euspira* cf. *E. jacksonensis* Palmer	R
5-9b	*Lanistes*? new species?	R

Sample 5-11 (YL 2)
Euspira? and/or *Natica*?, sp. indet.

Sample 5-13 (YB)

5-13a	*Bittium koeneni* Meyer	
5-13b	*Turbonilla (Strioturbonilla) major* Meyer	A
5-13c	*Euspira jacksonensis* Palmer	C
5-13d	*Natica (Naticarius) permunda* Conrad	A
5-13e	*Circulus ottonius* Palmer	S
5-13g	*Acteon idoneus* Conrad	C
5-13h	*Eopleurotoma*? sp. indet.	C
5-13i	*Turritella arenicola danvillensis* Stenzel & Turner	C
5-13j	*Pyramidella (Syrnola) meyeri* (Cossmann)	S

5-13k *Odostomia jacksonensis* Dockery	A
5-13l *Cadulus* (*Polyschides*) *margarita* Palmer	C
5-13m *Cadulus* sp. indet.	A
5-13n *Clio* (*Creseis*) *simplex* (Myer)	A
5-13o *Tritonoatractus* cf. *T. pearlensis* (Aldrich), s.l.	A
5-13p *Coronia?* sp. indet.	S
5-13q "*Turricula*" cf. "*T*" *plutonica weisbordi* Harris	S
5-13r *Agaronia* sp. indet.	S
5-13s *Microdrilla?* sp. indet.	R

Sample 5-15 (YB)

5-15a *Cadulus* sp. indet	S
5-15b *Bittium* koeneni Myer	R
5-15c *Turritella* cf. *T. arenicola danvillensis* Stenzel & Turner	R
5-15d *Odostomia jacksonensis* Dockery	R
5-15e *Calyptraea?* sp. indet.	S
5-15f *Euspira* cf. *E. jacksonensis* Palmer	S
5-15g *indeterminate gastropod*	

Sample 5-18 (YL 3)

Euspira? and/or *Natica?*, sp. indet.

Section #6:

Sample 6-7 (YL 2)

6-7a *Euspira?* and/or *Natica?*, sp. indet.	C

Sample 6-12 (YB)

6-12a *Melanella jacksonensis* (de Gregorio)	R
6-12b *Odostomia jacksonensis* Dockery	S
6-12c *Pyramidella* (*Syrnola*) *meyeri* (Cossmann)	R
6-12d *Turritella* cf. *T. arenicola danvillensis* Stenzel & Turner	S
6-12e *Athleta* cf. *A. petrosa symmetrica* (Conrad)	S
6-12f *Calyptraea* sp. indet.	R
6-12h *Natica* (*Naticarius?*) sp. indet.	S
6-12i *Tritonoatractus?* sp. indet.	R
6-12j *indeterminate gastropod*	R

Section #7:

Sample 7-2 (YA)

7-2a *Teinostoma?* cf. *T. moodiense* Palmer	R
7-2b *Solariorbis?* cf. *S. subangulata* (Meyer)	R

7-2c	indeterminate gastropod	R

Sample 7-8 (YL 3)

7-8a	*Natica* (*Naticarius*) *permunda* Conrad	A
7-8b	*Bittium* *koeneni* Meyer	C
7-8c	*Odostomia* *jacksonensis* Dockery	A
7-8d	*Acteon* *idoneus* Conrad	R
7-8e	*Melanella* *jacksonensis* (de Gregorio)	S
7-8f	*Pyramidella* (*Syrnola*) *meyeri* (Cossmann)	S
7-8g	*Pyramidella* *new* *species* A?	S
7-8h	*Turbonilla* (*Strioturbonilla*) *major* (Meyer)	S
7-8i	*Pyramidella* new species B?	S
7-8j	*Acirsa*? *solumcostata* Dockery	R
7-8k	*Turritella* *arenicola* *danvillensis* Stenzel & Turner	C
7-8l	*Euspira* *jacksonensis* Palmer	C
7-8m	*Tritonoatractus* cf. *T.* *pearlensis* (Aldrich), s.l.	C
7-8n	*Athleta* sp. indet.	S
7-8o	*Levifusus*? sp. indet.	C
7-8p	*Eopleurotoma*? sp. indet. A	R
7-8q	*Agaronia* sp. indet.	S
7-8r	*Tritiara*? sp. indet.	S
7-8s	*Eopleurotoma*? sp. indet.B	S
7-8t	"*Turricula*"? cf. "*T.*" *plutonica* Casey, S.l.	S
7-8u	indeterminate gastropods: 4 species	

Section #9

Sample 9-3 (YB)

9-3a	*Turritella* *arenicola* *danvillensis* Stenzel&Turner	C
9-3b	*Bittium* koeneni Meyer	A
9-3c	*Pyramidella* (Syrnola) *meyeri* (Cossmann)	C
9-3d	*Melanella* *jacksonensis* (de Gregorio)	S
9-3e	*Odostomia* *jacksonensis* Dockery	A
9-3f	*Acteon* *idoneus* Conrad	S
9-3g	*Natica* (*Naticarius*) *permunda* Conrad	A
9-3h	*Euspira* *jacksonensis* *Palmer*	C
9-3i	*Turbonilla* (*Strioturbonilla*) *major* Meyer	R
9-3j	*Acteon* *annectens* Meyer	R
9-3k	*Pyramidella* new species C?	R
9-3l	*Acirsa*? *solumcostata* Dockery	R
9-3m	*Calyptraea* sp. indet.	S
9-3n	unidentified gastropod: new species?	R
9-3o	*Tritonoatractus*? cf. *T.* *pearlensis* (Aldrich) s.l.	A
9-3p	*Eopleurotoma*? sp. indet.	S
9-3q	*Agaronia* sp. indet.	S
9-3r	*Athleta* sp. indet.	S
S-3s	indeterminant gastropod species	S
9-3s	indeterminant gastropod species	S
9-3t	*Eopleurotoma*? sp. indet.	R
9-3u	indeterminate gastropod species	S
9-3v	"*Turricula*" cf. "*T.*" *plutonica* Casey s.l.	S

9-3w	indeterminate gastropod species	R
9-3x	indeterminate gastropod species	R

Sample 9-4 (YB)

9-4a	Bittium koeneni Meyer	A
9-4b	Acteon idoneus Conrad	S
9-4c	Natica (Naticarius) permunda Conrad	C
9-4d	Euspira jacksonensis Palmer	A
9-4e	Odostomia jacksonensis Dockery	A
9-4f	Turbonilla (Strioturbonilla) major Meyer	S
9-4g	Pyramidella (Syrnola) meyeri (Cossmann)	C
9-4h	Melanella jacksonensis (de Gregorio)Meyer)	C
9-4i	Turritella cf. T. arenicola danvillensis Stenzel & Turner	S
9-4j	"Turricula"? cf. "T." plutonica Casey s.l.	S
9-4k	Tritonoatractus? cf. T. pearlensis (Alsrich) s.l	C
9-4l	Agaronia cf. A. media (Meyer)	S
9-4m	Athleta sp. indet..	R
9-4n	indeterminant gastropod species	R
9-4o	Cornulina? cf. C. dalli (Harris s.l.	R
9-4p	Pyramidella new species B?	R
9-4q	Architectonica sp. indet.	R
9-4r	Agaronia media (Meyer)	R
9-4s	Eopleurotoma? sp. indet.B	S
9-4t	Coronia? sp. indet.." plutonica Casey, S.l.	R
9-4u	Cochlespira cf. C. columbaria (Alsrich)	R
9-4v	Mitrella? sp. indet.	R
9-4w	indeterminate gastropods:at least 10 species	

Sample 9-5 (YB)

9-5a	Odostomia jacksonensis Dockery	C
9-5b	Euspira jacksonensis Palmer	C
9-5c	Natica (Naticarius) permunda Conrad	A
9-5d	Bittium koeneni Meyer	A
9-5e	unidentified cerithiid? gastropod: new species	R
9-5f	Melanella jacksonensis (de Gregorio)	C
9-5g	Turritella arenicola danvillensis Stenzel&Turner	S
9-5h	Pyramidella (Syrnola) meyeri (Cossmann)	S
9-5i	Turbonilla (Strioturbonilla) major meyer	R
9-5j	Tritonoatractus cf. T. pearlensis (Alsrich) s.l.	C
9-5k	Cochlespira cf. C. columbaria (Aldrich)	S
9-5l	Pyramidella new species B?	S
9-5m	Solariorbis? sp. indet. C?	R
9-5n	Acirsa? cf. A.? solumcostata Dockery	R
9-5o	Eopleurotoma? sp. indet.	R
9-5p	Coronia? sp. indet.	R
9-5q	Cirsotrema? sp. indet.	R
9-5r	Cochlespira? cf. C. bella polita Harris	R
9-5s	indeterminate gastropods: 3 species	R

Sample 9-6 (YB)

9-6a	*Odostomia jacksonensis* Dockerys	R
9-6b	*Melanella jacksonensis* (de Gregorio)	R
9-6c	*Turbonilla (Strioturbonilla) major* Meyer	R
9-6d	*Euspira jacksonensis* Palmer	R
9-6e	*Turritella* cf. *T. arenicola danvillensis* Stenzel & Turner	R
9-6f	indeterminate gastropods: 3 species	R
9-6g	*Pyramidella* new species C?	R

TABLE 28. Montgomery Landing gastropod species from section samples.

Euspira jacksonesis Palmer
Natica (Naticarius) permunda Conrad
Bittium koeneni Meyer
Odostomia jacksonensis Dockery
Pyramidella (Syrnola) meyeri (Cossmann)
Melanella jacksonensis (de Gregorio)
Turbonilla (Strioturbonilla) major Meyer
Acteon idoneus Conrad
Turritella arenicola danvillensis Stenzel & Turner
Tritonoactractus cf. *T. pearlensis* (Aldrich)
Clio (Creseis) simplex (Meyer)

In addition to the gastropds, the scaphopod *Cadulus (Polyschides) margarita* Palmer is also abundant and, in fact, is the most abundant species in the Yazoo samples.

Plate 44

Figure 1, 2 *Odostomia jacksonensis*, X 80.

Figure 3 *Turbonilla major*, X 50.

Figure 4, 5 *Natica permunda*, X 50.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

PLATE 44

Plate 45

Figure 1, 2 *Bittium koeneni*, X 50.

Figure 3 *Clio simplex*, X 35.

Figure 4 *Tumitella arenicola danvillersis*, X 50.

Fig. 1

Fig. 2

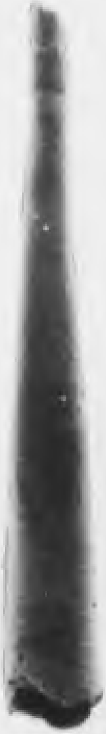

Fig. 3

Fig. 4

PLATE 45

J. PALEOPALYNOLOGY*

After the samples were mounted onto microscope slides, observation found no statistically significant pollen or spores. The palynomorphs that were present were badly torn and distorted. This could have been the result of post-depositional deformation or procedure deformation. However, several dinocysts were observed in the samples. These specimens were in good shape, whereas the pollen and spores were in a poor condition. This could be the result of the more durable character of the dinocysts relative to the pollen or that the dinocysts were indigenous to the samples and the spores and pollen were reworked into the sediment.

It is recommended that further work on dinocysts be pursued in the Montgomery Landing area. The potential for further study success appears good.

Table 29. Samples for pollen analysis at Montgomery Landing were taken from the following sections.

Sample 1: Yazoo - Sec. 3-20 (22.12 gms)
Sample 2: Yazoo - Sec. 4-23 (22.51 gms)
Sample 3: Yazoo - Sec. 4-14 (25.14 gms)
Sample 4: Yazoo - Sec. 3-14 (21.65 gms)
Sample 5: Yazoo - Sec. 4-5 (23.20gms)
Sample 6: Yazoo - Sec. 4-10 (24.55 gms)
Sample 7: Cockfield - Sec. 2-8 (23.13 gms)
Sample 8: Yazoo - Sec. 3-3 (24.00 gms)
Sample 9: Moodys Branch - Sec. 2-16 (22.57 gms)
Sample 10: Moodys Branch - Sec. 4-1 (23.35 gms)
Sample 11: Moodys Branch - Sec. 2-9 (22.43 gms)

Treatment Method

Preliminary Treatment

Scrape the exterior of the sample with a clean knife or spatula. Discard all scrapings. This provides a clean, uncontaminated surface on the sample.

Mechanically break down the sample with a clean mortar and pestle. (A grinding motion should be avoided so as not to crush the fossil pollen grains.)

*by Linda L. Rice, Union Oil Company of California, Lafayette, Louisiana

Place each sample into individual polyurethane 250 ml beakers. Label each test sample beaker. Add a little distilled H_2O to each beaker.

Removal of Carbonates

Add enough 10% HCL to each sample so as to cover the sample. When the sample is sufficiently disaggregated, decant 1/2 of the fluid. Add distilled H_2O to the sample. Place samples into polyurethane test tubes with screw-on tops. Centrifuge for approximately 15 minutes. Decant the fluid and add more 10% HCL to the sample. Repeat this procedure until no reaction to the HCL occurs and all of the samples are disaggregated and washed. Wash, centrifuge, and decant repeatedly until the pH of the sample is 7.

Removal of Silicates

Using only polyurethane test-tubes or beakers, add concentrated HF slowly to the samples. Stir continuously. Let this stand for 24-48 hours under a closed fume hood. Small amounts of HF can be added later--as long as there is no violent reaction. Decant the HF into a refuge HF bottle and add a small amount of distilled H_2O to the samples. Stir and centrifuge. Repeat procedure one more time. Decant HF again into a refuge HF bottle. Wash, centrifuge, and decant the samples until the samples have a pH of 7.

Removal of Organics

Add normal Schultze's solution to each sample, cold. Let stand for approximately 10-15 minutes.

The samples should be centrifuged, decanted, and washed. Cover sample with cold 20% potassium carbonate for approximately 5 minutes. Centrifuge, decant, and wash repeatedly.

K. CHONDRICHTHYES ASSOCIATED WITH THE BASILOSAURUS SPECIMEN.*

Class CHONDRICHTHYES
Subclass ELASMOBRANCHII
Order SELACHII
Suborder GALEOIDEA
Family CARCHARINIDAE
Genus HEMIPRISTIS Agassiz 1843
HEMIPRISTIS WYATTDURHAMI White 1956

The teeth of Hemipristis wyattdurhami were found in greatest abundance near the mandibles of the whale. Breard (1978) reported the teeth of Hemipristis from Montgomery Landing, as well as from Jackson exposures in Caldwell Parish, Louisiana, and Yazoo Co., Mississippi. White (1956) named this species from teeth collected from the Jackson Group in Choctaw Co., Alabama, and believed it to be conspecific with teeth described by Stromer (1905) from the Fayum of Egypt.

The only living species of this genus, H. elongatus is a species of warm shallow waters (Garrick and Schultz, 1963).

Genus GALEOCERDO Muller and Henle, 1847
GALEOCERDO CLARKENSIS White, 1956

Galeocerdo teeth were found concentrated around the large bones. Breard (1978) found Galeocerdo teeth at Montgomery Landing, in Caldwell Parish, Louisiana, and in Yazoo and Hinds Counties, Mississippi. White (1956) discussed several species of Galeocerdo from Eocene deposits of North America. This species was common in the Jackson seas (Thurmond and Jones, 1981).

The closest living relative of this species G. cuvieri (the Tiger shark) is found worldwide in temperate and tropical waters, and is common in the western Atlantic from Cape Cod to Uruguay (Hoese and Moore, 1977). This species is reported as a carrion feeder (Springer, 1967) but is known to frequently prey on sea birds (Hoese and Morre, 1977). This species probably represents the largest shark found in the whale bone assemblage.

Genus NEGAPRION Whitley, 1940
NEGAPRION cf. N. GIBBESI (Woodward, 18)

Less common than other species in the assemblage, many teeth of Negaprion were concentrated around the fifth thoracic vertebra. Breard (1978) reported Negaprion teeth from the same localities as Hemipritis and Galeocerdo. White (1956) sites the distribution of Negaprion

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*by Winston Lancaster, LSU

gibbesi as upper Eocene of Clarke and Choctaw Counties, Alabama, and middle Eocene of Monroe County, Alabama. A living representative of this genus common in the Gulf of Mexico is *N. brevirostris*, the Lemon Shark. *N. brevirostris* ranges in the temperate and tropical Atlantic from New Jersey to Brazil (Hoese and Moore, 1977). Like *Galeocerdo*, *Negaprion* is reported to feed on carrion and has been observed engaged in feeding frenzies off the east coast of Florida (Springer, 1967). Moss (1967) studied tooth replacement in *Negaprion*.

Family ORECTOLOBIDAE
Genus GINGLYMOSTOMA, Muller & Henle, 1837
GINGLYMOSTOMA SERRA (Leidy)

By far the most common species of shark represented (by teeth) in the bone assemblage is *Ginglymostoma serra*. Stringer (1977) and Breard (1978) reported this species to be uncommon in their surveys of the Jackson Eocene. Thurmond and Jones (1981) considers *G. serra* to be synonymous with *G. obliquum* which was reported from Clarke County, Alabama, by Leriche (1942), and discussed by White (1956).

One species, *G. cirratum* (the nurse shark), presently inhabits the Atlantic. Tropical in distribution, *Ginglymostoma* is considered by Lineaweaver and Backus (1970) to be "decidedly inshore animals" feeding on echinoderm, crustaceans, squid, and small fishes, but is said to commonly inhabit "offshore reefs" by Hoese and Moore (1977).

Family ODONTOSPIDAE
Genus ODONTASPIS Agassiz 1836
ODONTASPIS sp.

A single tooth of this genus was found near the mandible. Specific identification was not attempted due to the small sample size. Breard (1978) does not support this species from Montgomery Landing, but did find it in Caldwell Parish, and in Yazoo County, Mississippi. Stringer (1977) reports few specimens of *Odontaspis* from Caldwell Parish, and relates this to the lack of appropriate habitat. White (1956) and Thurmond and Jones (1981) discuss several species of *Odontaspis* that lived in the upper Eocene seas of Alabama.

The only extant species known in the Western Atlantic, *O. taurus* is most common in northern waters, but is seen in the Gulf of Mexico (Hoese and Moore, 1977). Lineaweaver and Backus (1969) describe *Odontaspis* as a shallow water form.

Order BATOIDEA
Suborder PRISTOIDEA
Family Pristidae
Genus PRISTIS Linck 1790
PRISTIS sp.

Found around the mandibles and scapula, *Pristis* is among the less common associated vertebrates. Breard (1978) found *Pristis* at Montgomery Landing, in Caldwell Parish, and in Yazoo County, Mississippi. White (1956) mentions *Pristis* but does not site a locality. Thurmond and Jones (1981) reported *Pristis* from the middle Eocene of Clark and Monroe Counties, Alabama. Living representatives of the genus *Pristis* are tropical in distribution found as bottom feeders in coastal waters (Hoese and Moore, 1977).

Suborder MYLIOBATOIDEA
Family MYLIOBATIDAE
Genus MYLIOBATIS, Dumeril, 1817
MYLIOBATIS sp.

Myliobatis is represented by a single symphysial plate and a partial bar found near the mandibles. Breard (1978) found abundant *Myliobatis* material at Montgomery Landing, as well as all sampled localities. White (1956) mentions *Myliobatis* as being present in the Jackson, but does not discuss its abundance or range. Teeth of *Myliobatis* are among the most common vertebrate fossils in the middle and upper Eocene sediments of the Gulf Coast (Thurmond and Jones, 1981).

Breard (1978) does not state which formation at Montgomery Landing yielded the abundant *Myliobatis* fauna. Stringer (1977) found abundant tooth plates and spine fragments in the Yazoo in Caldwell Parish, but did not elaborate on their stratigraphic position within the Yazoo. The benthic mollusks of the Yazoo were generally smaller than those of the Moody's Branch, and may not have been suitable food for *Myliobatis*. The depth of the Yazoo could have been outside the normal range of *Myliobatis*. The collecting techniques of Breard (1978) could have biased his abundance figures for this species.

Extant species of *Myliobatis* live in the Gulf of Mexico and Caribbean. They live in shallow water and feed on mollusks and crustaceans (Hoese and Moore, 1977).

Family DASYATIDAE
Genus DASYATIS Rafinesque 1810
DASYATIS sp

One tooth of *Dasyatis* sp. was found in the sediments associated with the *Basilosaurus* mandibles. Stringer (1977) found one tooth of

Trigon (a synonym of Dasyatis) in the Yazoo in Caldwell Parish. Thurmond and Jones (1981) report teeth of Dasyatis in the middle Eocene Gasport Formation of Clarke County, Alabama.

Modern species of this genus, the sting rays, are mostly bottom dwellers in shallow coastal waters and estuaries (Hoese and Moore 1977).

L. OSTEICHTHYES OF THE MOODYS BRANCH FORMATION AND YAZOO CLAY AT THE MONTGOMERY LANDING LOCALITY*

Remains of teleost fishes at Montgomery Landing other than otoliths, include scales and small bones of the peripheral skelton and vertebrae. Of the available remains, the systematics of the otoliths are best known although not complete. Some genera are correlated to living forms but for others the habits of the extinct genus or genera are almost totally unknown.

Introduction

Preliminary investigations of the approximately 20,000 otoliths collected from the Moodys Branch Formation and the overlying Yazoo Clay (Upper Eocene, Jackson Group) at the Montgomery Landing locality indicate a prolific and diversified ichthyological fauna. Preliminary identifications of the otoliths seem to indicate the presence of at least 40 species of teleosteans. This report discusses the preliminary identifications and the significance of the teleostean otoliths at the Montgomery Landing locality. It should be noted that identifications and paleoecological implications based on otoliths for this report are subject to revision with further study.

Previous studies

Although numerous studies have been completed on the paleontology of Montgomery Landing, only a few studies that deal exclusively with otoliths have been conducted at the locality. These include studies by Frizzell and Lamber (1961) on myripristid otoliths and by Frizzell (1962) on congrid-type otoliths. Fitch (1980: personal communication) has done extensive taxonomic work on the otoliths from Montgomery Landing, but this data is not yet published. Numerous paleontological studies mention the presence of otoliths at the locale, but very few of the studies specifically identify teleosts based on otoliths. One exception is a study by Breard (1978) in which otoliths from Montgomery Landing were utilized to identify teleostean remains.

General characteristics of the otoliths from Montgomery Landing

Species assignment was possible for many of the otoliths from two formations at the locality. However in many cases, it was possible only to assign the otolith to a family. Further identifications will be made when additional Recent and fossil comparative material is obtained.

The vast majority of otoliths from the locality are sagittae (the otoliths located in the sacculus of the fish). There are a few lapilli

*by Gary Stringer, Monroe, Louisiana

(represented mainly by ariids) and no asterisci represented in the samples examined from Montgomery Landing. This is not unexpected since the sagittae are the largest of the three otoliths in the majority of marine fish. Stinton (1975) in his study of Eocene otoliths in England reports that one lapillus was found for every one thousand sagittae. Stringer (1977) reports similar results in his study of Upper Eocene otoliths from Caldwell Parish, Louisiana.

Systematic Paleontology

Preliminary identifications suggest the presence of at least 40 species of teleosts. Fitch (1980, personal communication) also notes that as many as 45 species of teleosts may be represented by otoliths in the Eocene strata at Montgomery Landing. Table 30 summarizes the initial identifications of the otoliths from the Montgomery Landing locality. When generic designation was not possible, otoliths were assigned to a family. In most cases, the classification utilized in this report is based upon _A List of Common and Scientific Names of Fishes from the United States and Canada_, Fourth Edition, 1980 published by the American Fisheries Society.

Although numbers of otoliths are not reported in Table 30, it should be noted that the most abundant otolith is _Bregmaceros_ sp.. Approximately 5000 specimens of _Bregmaceros_ sp. were identified from the 17 samples in Section 5 (all samples collected in the Yazoo Clay). Other samples are equally as prolific in the minute sagittae of _Bregmaceros_ sp.. This is not unexpected, since Stringer (1979) reports that _Bregmaceros_ is one of the most abundant otoliths in the Yazoo Clay in Caldwell Parish, Louisiana.

Generalized illustrations of many of the families of fishes represented at Montgomery Landing based on otoliths are shown in Figure 15.

Significance of Otoliths

Often in the study of marine vertebrate faunas, only the skeletal components are analyzed. These skeletal components include teeth, scales, vertebrae, spines, and various other bones. Often the small, seemingly insignificant otoliths are ignored when reconstructing ancient environments. The use of otoliths may prove to be more advantageous in understanding the ichthyological fauna of an ancient environment than many of the skeletal components. If only skeletal components are utilized in the reconstructing of the ichthyological fauna present at the Montgomery Landing locality during the Upper Eocene, the fauna would be greatly distorted and underestimated. Since otoliths have a characteristic pattern found on the inner face, identifications are possible as to genus and species, or at least family. Thus, a large majority of the otoliths from Montgomery Landing can be related and compared to extant families in the Gulf of Mexico. The vast majority of fish scales, spines, vertebrae, and bones can not be related to any extant species with any certainty.

Another advantage in the use of otoliths in interpreting paleoenvironments is that otoliths provide a more accurate representation of abundance. Teeth are extremely abundant in many fish and sharks and are shed periodically. Upon the death of fish, rays, and sharks, an untold number of teeth, scales, spines, vertebrae, and bones may become part of the thanatocoenosis or death assemblage. Their abundance is misleading and is often misinterpreted in research. An individual fish has only two sagittae, one in each of the labyrinths. Otoliths are not shed periodically and are not replaced. Therefore, every two sagittae found in a sample represent the presence of at least one teleost.

Otoliths are concentrated in samples by two major processes. One process takes place upon the death and decay of the fish, as the otoliths are released from the neocranium. After the release of the otoliths, they usually lie on the bottom. In most depositional environments, current action has little effect on the otoliths. Schafer (1972) states that otoliths are not transported over great distances because of their compact shape and size. The author has also observed otoliths placed in stream tables under controlled corditions. The otoliths usually traveled a short distance and then settled on the bottom in a stable position.

Another manner in which otoliths may have been derived in the Montgomery Landing locality is as excreta. Fitch and Brownell (1968) have shown that thousands of otoliths may be found in the stomachs of marine mammals, such as whales. Otoliths have also been reported in shark coprolites (Hantzschel, El-Baz, and Amstrutz, 1968). The sagittae can survive the action of digestive juices and only be slightly eroded. The presence of whales (Basilosaurus cetoides), numerous species of sharks, and various species of fish are well documented at Montgomery Landing and may have played a major role in the deposition of otoliths.

Relationship to extant fauna

The vast majority of the otoliths from Montgomery Landing can be related to extant families presently living in the northwestern Gulf of Mexico (Hoese and Moore, 1977). Similar to the present teleost fauna of the northwestern Gulf of Mexico, the otoliths seem to have tropical and temperate components. The otoliths represent teleosts that are mainly inshore fishes (found mainly in waters less than 200 meters). Many of the genera indicate water depths much shallower in certain parts of the section. A brief discussion of the more abundant otoliths at Montgomery Landing may aid in the determination of the paleoenvironment.

The most abundant otolith, Bregmacerous sp., represents a cod-like fish found mainly in tropical and subtropical marine waters. A single species of Bregmaceros is believed to occur presently in the northwestern Gulf of Mexico. This species is widespread and is common on the middle shelf in the present Gulf (Hoese and Moore, 1977). Little is known of the specific life habits of the extant Bregamaceros.

The congrids (Family Congridae) are also well represented in the sediments at the Montgomery Landing locality with at least six species. Congrids are among the most common of fishes presently in the northwestern Gulf of Mexico (Hoese and Moore, 1977). Congrids prefer tropical and subtropical seas with the juveniles being found mainly in shallow, coastal waters.

Another family, the Ophidiidae, is highly characteristic of the samples from Montgomery Landing. The ophidiids represent the second most abundant otoliths found at the locality by this study and by Fitch (1980: personal communication). The ophidiids or cusk-eels are common in the present Gulf of Mexico. Most of the present ophidiids are nocturnal and burrow into the bottom sediments or hide in crevices during the daylight hours.

Sagittae of the Family Sciaenidae are most abundant in the Moodys Branch and the lower samples of the Yazoo Clay. The sciaenids are related to the extant drums and croakers. The sciaenids are among the most important species in the biomass of the present northwestern Gulf of Mexico. Most species prefer shallow waters with muddy bottoms and feed on benthonic organisms.

The teleost fauna, based on otoliths, at Montgomery Landing displays many similarities to the present ichthyoloical fauna of the northwestern Gulf of Mexico. As more precise information is obtained on the otoliths, a more complete and detailed paleoecology may be constructed for the Montgomery Landing locality based on otoliths.

General trends based on otoliths at Montgomery Landing

Several general trends based upon otoliths can be ascertained from the samples collected at the various sections at the Montgomery Landing locality. More detailed trends will be possible with further identifications and further analysis.

Within Section 1, the following general trends can be determined. No otolith material was found in Samples 1 through 5. These samples are in the upper part of the Cockfield Formation. Due to the depositional conditions, otoliths were not really expected. However, otoliths were found in Sample 6, which is 40 cm below the unconformity between the Cockfield Formation and overlying Moodys Branch. Three otoliths were found Jefitchia claybornensis (a sciaenid), Bregmaceros sp., and a juvenile perciform. These otoliths represent marine teleosts. Their occurence in the Cockfield, which is probably deltaic, was probably related to the abundant bioturbation. Numerous burrows just below the contact were filled with blue-green, sandy marl typical of the sediments of the overlying Moodys Branch. The otoliths probably came from the sediments that filled the burrows.

Approximately 75 otoliths were found in Sample 7 of Section 1, which represents the base of the Moodys Branch. Samples 7 through 10 were collected in the Moodys Branch, and all of the samples have fairly abundant otoliths. In these samples (7 through 10), there is a wide diversity of teleost species. However, with Sample 11, there is a large reduction in species diversity and abundance. Sample 11 was collected from the first resistant ledge of the Yazoo Clay. It is not known whether the reduction in abundance and diversity is related to depositional environment or to sample preparation or to other factors. A similar reduction in abundance and diversity of otoliths was also noted in many of the other resistant ledges. Sample 12 was also collected in the Yazoo Clay approximately 30 cm above the first resistant ledge. The abundance of otoliths increases, but diversity remains low.

In Section 1, the dominant species starting with Sample 7 (Moodys Branch) through Sample 12 (Yazoo Clay) is *Bregmaceros* sp.. Although it is abundant throughout the section, its relative abundance seems to increase in the Yazoo Clay.

General trends can also be ascertained within the Yazoo Clay as seen in Section 5. Section 5 consists of 19 samples all of which are from the Yazoo Clay. The most recognizable trend is the presence of *Bregmaceros* and its increase in abundance upward in the Yazoo Clay. The abundance of *Bregmaceros* increases dramstically in Sample 17 where it represents 99% of the total otoliths (approximately 1880 *Bregmaceros* otoliths out of 1900 total otoliths). Extant *Bregmaceros* are common in the middle shelf of the northwestern Gulf of Mexico (Hoese and Moore, 1977). Their abundance in the Yazoo Clay is probably indicative of a similar environment. As in the other sections, there is a reduction in abundance and diversity of otoliths in the resistant ledges (Samples 1, 11, and 18).

It should be noted that as a general trend, reductions in abundance and diversity of otoliths do occur in the indurated ledges or layers. As previously noted, this trend was found in Sections 1 and 5. This trend can also be found in Section 4 as well as other sections. Section 4, Sample 13, which consisted of a soft blue clay, contained approximately 150 sagittae of *Bregmaceros* sp. The next sample, Sample 14, which is a resistant ledge, contained only 4 sagittae of *Bregmaceros* sp. Samples 22 and 23 of Section 4 were also collected from ledges and display similar reductions in diversity and abundance.

Table 30

Systematic paleontology of the otoliths represented at the Montgomery Landing locality

- CLASS OSTEICHTHYES (bony fishes)
  - Order Elopiformes
    - Family Albulidae
      - *Albula* sp.
  - Order Anguilliformes
    - Family Anguillidae
      - c.f. *Anguilla* sp.
    - Family unknown
      - eel
    - Family Congridae
      - *Ariosoma* sp.
      - *Conger* sp.
      - "*Conger*" *dissimilis*
      - several congrids
  - Order Siluriformes
    - Family Ariidae
      - c.f. *Arius* sp.
      - *Clabornichthys* sp.
  - Order Lophiiformes
    - Family Ogcocephalidae
      - *Ogcocephalus* sp.
  - Order Gadiformes
    - Family Bregmacerotidae
      - *Bregmaceros* sp.
    - Family Ophidiidae
      - *Brotula* c.f. *barbata*
      - *Lepophidium* sp.
      - c.f. *Ophidion* sp.
      - *Preophidion* *stintoni*
    - Family Carapidae
      - *Carapus* sp.
  - Order Atheriniformes
    - Family Exocoetidae
      - c.f. *Hemiramphus* sp.
  - Order Beryciformes
    - Family Holocentridae
      - *Myripristis* *creola*
    - Family unknown
      - beryciforms
  - Order Zeiformes
    - Family Oreosomatidae
      - oreosomatid
  - Order Perciformes
    - Family Percichthyidae
      - c.f. *Allomorone* sp.
    - Family Apogonidae
      - c.f. *Apogon* sp.
      - c.f. *Epigonus* sp.

(Systematic paleontology continued)

  - Family Sparidae
    - sparid
  - Family Sciaenidae
    - *Corvina* sp.
    - *Ekokenia* sp.
    - *Jefitchia claybornensis*
    - *Sciaena* c.f. *umbra*
    - several sciaenids
  - Family Cepolidae
    - *Cepola* sp.
  - Family Pempheridae
    - pempherid
  - Family Dactyloscopidae
    - dactyloscopid
  - Family Eleotridae
    - eleotrids
  - Family Scombridae
    - scombrid
  - Family Triglidae
    - c.f. Peristedion sp.
    - triglids
- Order Pleuronectiformes
  - Family Bothidae
    - c.f. *Citharichthys* sp.
    - several bothids

Plate 46

Figure 46-1

Corvina intermedia

inner face right sagitta

X 20

Figure 46-2

Jefitchia claybornensis

inner face left sagitta

X 20

Plate 46

Plate 47

Figure 47-1

Brazosiella sp.

inner face left sagitta

X 30

Figure 47-2

Allomorone sp.

inner face right sagitta

X 30

Figure 47-3

Preophidion *stintoni*

inner face right sagitta

X 30

Figure 47-3

"*Conger*" *dissimilis*

inner face right sagitta

X 30

Plate 47

Plate 48

Figure 48-1

Bregmaceros troelli

inner face right sagitta

X 60

Figure 48-2

Eosolea sp.

inner face left sagitta

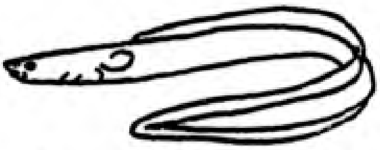
X 60

Plate 48

Fig. 18 Generalized illustrations of families of fishes at Montgomery Landing based on otoliths.

Albulidae

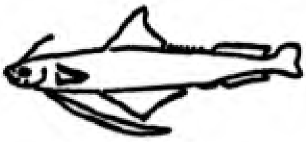
Anguillidae



Congridae

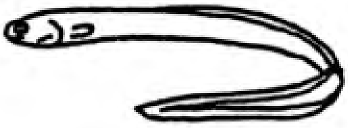
Ariidae

Ogcocephalidae

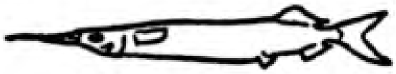


Bregmacerotidae

Ophidiidae

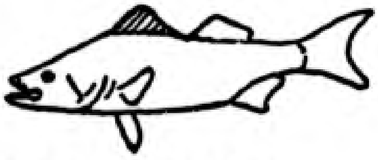


Carapidae



Exocoetidae

Holocentridae

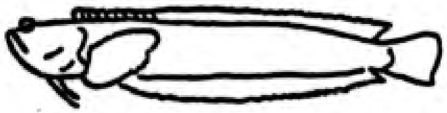


Percichthyidae

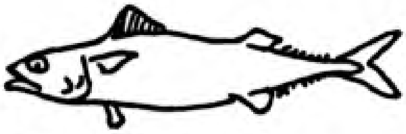
Apogonidae

Sparidae

Sciaenidae

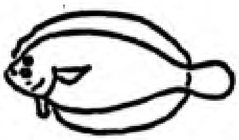


Dactyloscopidae



Scombridae

Triglidae



Bothidae

M. MAMMALIA (ARCHAEOCETI)*

History of Whales Found at Montgomery Landing

The first recorded discovery of Archaeocete remains at Montgomery Landing was made by Dr. Mathew A. Dunn on 14 September 1893. Dr. Dunn, a local physician, found three lumbar vertebrae of Zygorhiza kochii, presumably in the Moody's Branch Formation. This material is housed at the U.S. National Museum (Kellogg, 1936; Mr. O. C. Harrison, pers. com.) and is the only Archaeocete find from Montgomery Landing reported in the literature.

Other finds have been made by local amateur fossil hunters over the years. Mr. Tim Poston of Monroe, Louisiana, found two lumbar vertebrae of Basilosaurus in the uppermost Moody's Branch roughly midway between sections 1 and 3 (see locality map, Figure 4M-1) in 1967. Mr. Poston also discovered a fragmentary skull of Zygorhiza kochii in June 1977 (date probable but not certain) from the lower Moody's Branch (several meters south of section 2). The material was loaned to the LSU Museum of Geoscience for study in conjunction with this project. The Breard family of Monroe, Louisiana, has found Archaeocete remains at Montgomery Landing on several occasions. I have been allowed to see, but not to study, this material. Most of the Breard's material was found in the Yazoo Clay during the summers of 1979 and 1980. It is probable that S.Q. Breard, Jr. was present at the time of discovery of the Poston Zygorhiza. Two teeth and fragments of a mandible of Basilosaurus were found weathering on the surface approximately 35 meters south of section 1 on 13 December 1979 by Robert Guidry, William Chauvin, and Winston Lancaster while engaged in the fourth excavation at the Basilosaurus site. The material appeared to have washed out and fallen downslope, but probably came from the Moody's Branch. Informally designated as the Whale C (WC, LSUMG V2), this could be part of the same individual found by the Breard's at other times.

Due to the relative abundance of Archaeocete fossils at Montgomery Landing and the fact that it is a well known fossil locality, it is likely that important material exists in private collections whose owners have not been reached by our inquiries or who have not contacted us. The LSU Museum of Geoscience is in possession of numerous Basilosaurus lumbar vertebrae and other bones that reportedly were found at Montgomery Landing, but no exact stratigraphic data exists on them.

HISTORY OF Basilosaurus

The type specimen of Basilosaurus cetoides was collected by Judge H. Bry in 1832. It came from an exposure of the Jackson Group on a hill near the Ouachita River in Caldwell Parish, Louisiana. This material consists of a poorly preserved upper lumbar or lower thoracic vertebra

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*by Winston Lancaster, LSU

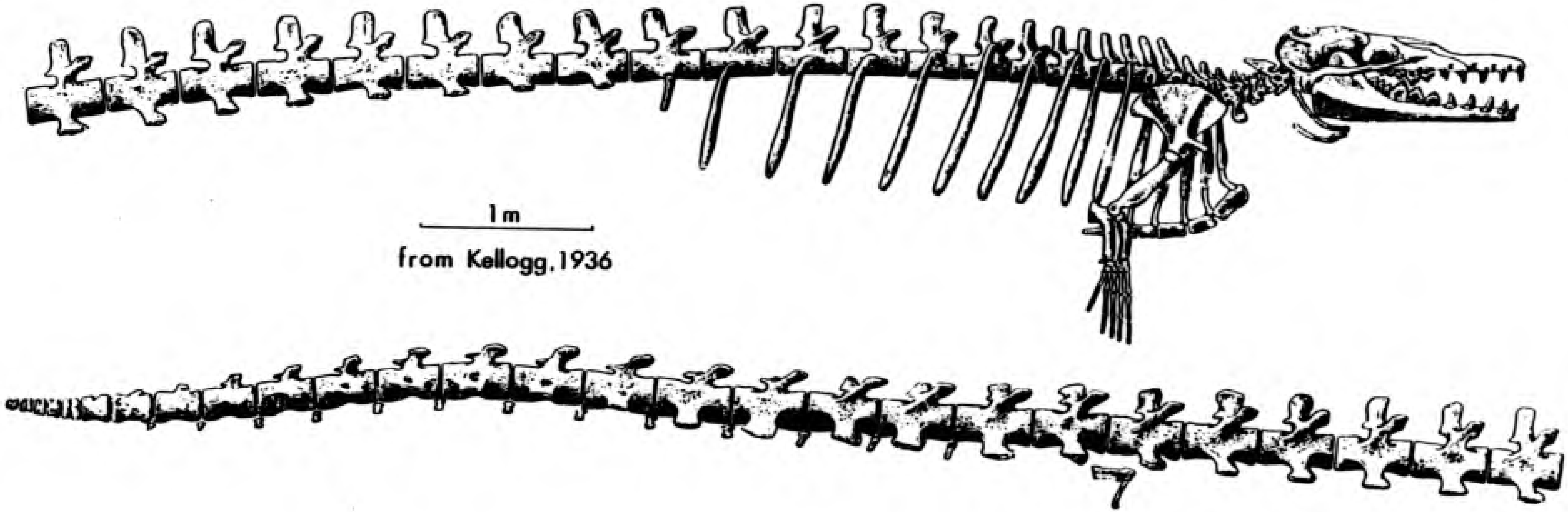
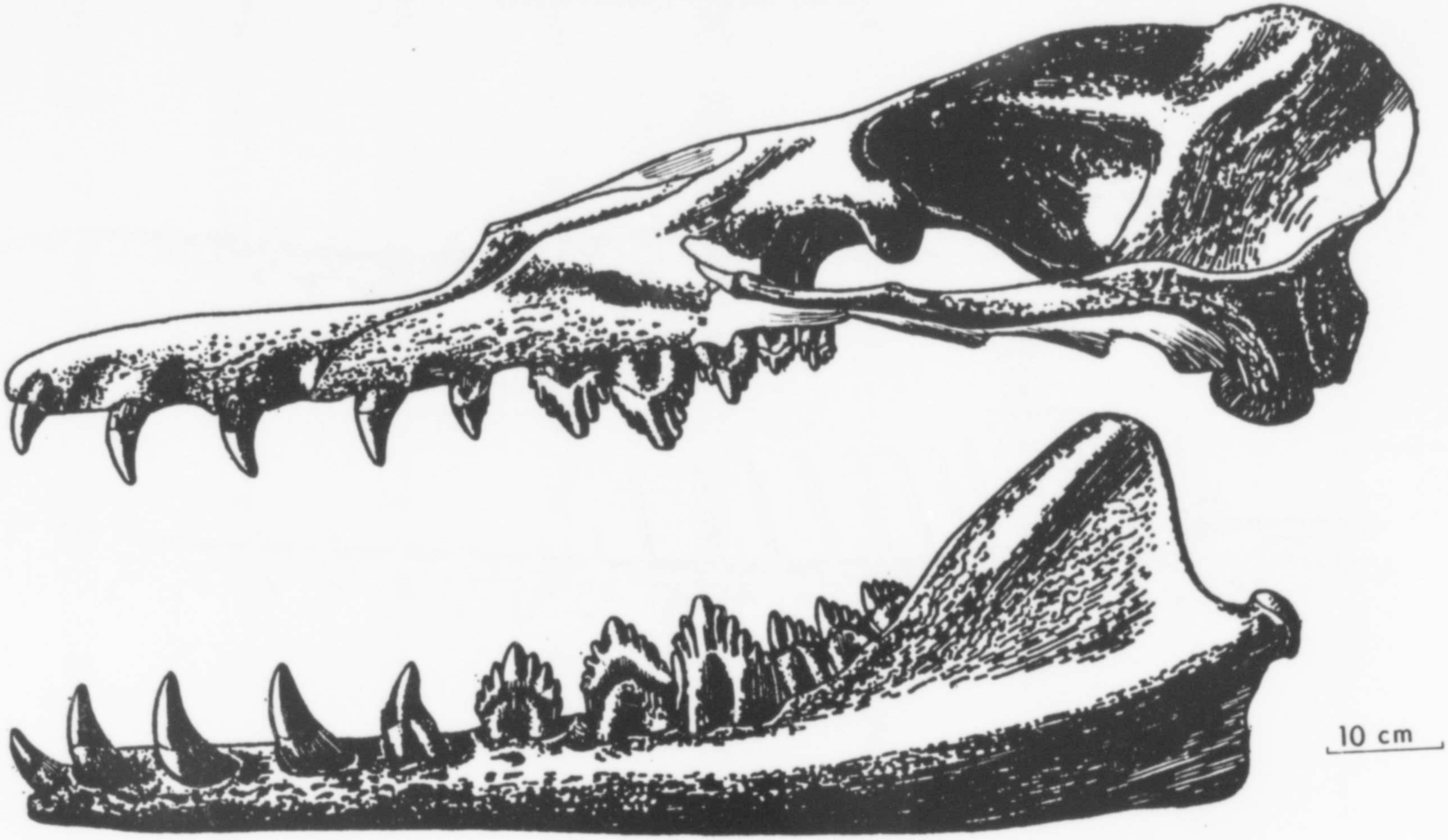


FIGURE 19

Basilosaurus cetoides (Owen)
from Kellogg, 1936



Skull of <u>Basilosaurus</u>   from, Kellogg. 1936

Fig. 20

(Academy of Natural Sciences of Philadelphia 12944A) (Kellogg, 1936). Given the name Basilosaurus by Richard Harlan in 1834, the vertebra was originally believed to be reptilian. Harlan did not apply a specific epithet.

The mammalian nature of Basilosaurus was recognized by Richard Owen from material shown to him by Harlan (some mandibular material and other bone fragments collected in Clarke County, Alabama). Owen, in 1839, sought to substitute the name Zeuglodon cetoides which he felt was more appropriate considering the animal's taxonomic affinities. Numerous other names have been applied to Basilosaurus. The name Hydrarchos was proposed by Albert Koch, who traveled throuqh the U.S. and Europe exhibiting a skeleton composed of parts of several individuals, as the "great sea-serpent of Alabama." Parts of numerous other individuals of Basilosaurus have been found, mostly in Alabama, but also in Arkansas, Louisiana, Mississippi, and southern England. The only mounted skeleton in existence (displayed at the Smithsonian Institution) is composed of parts of three individuals. The skull of this was collected by Charles Schuchert in November, 1894, from Choctaw County, Alabama.

SYSTEMATIC PALEONTOLOGY
(from Barnes and Mitchell, 1979)

Order CETACEA Brisson 1762
Suborder ARCHAEOCETI Flower 1883
Family BASILOSAURIDAE Cope 1868
Subfamily BASILOSAURINAE Cope 1868 (new rank)
Genus BASILOSAURUS Harlan 1834

Generic Synonomy

Basilosaurus Harlan, 1834
Zygodon Owen, 1839
Zeuglodon Owen, 1839
Hydrargos Koch, 1845
Hydrarchos Koch, 1845
Zyglodon Hammerschmidt, 1848
Hydrarchus Muller, 1849
Zugodon Scudder, 1882
Alabamornis Abel, 1906

BASILOSAURUS CETOIDES (Owen), after Kellogg, 1936

Zeuglodon cetoides Owen, 1839
Zeuglodon harlani DeKay, 1842
Hydrargos sillimanii Koch, 1845
Hydrarchos sillimani Wyman, 1845

Zeuglodon ceti Wyman, 1845
Hydrarchos harlani Koch, 1845
Basilosaurus (Harl.) cetoides (Owen) Geinity and Reichenbach, 1847
Basilosaurus cetoides (Owen) Gibbes, 1847
Basilosaurus harlani Hammerschmidt, 1848
Zeuglodon macrospondylus Muller, 1849
Alabamornis gigantea Abel, 1906

Referred Material

Basilosaurus Site

The referred material excavated at the primary *Basilosaurus* site (LSU MG V1) consists of the following: the skull (including two auditory auditory bullae, one stapes, one malleus, and two incuses), two dentaries, two thyrohyals, two partial stylohyals, cervical vertebrae two through seven, thoracic vertebrae one through nine, and eleven, two scapulae, two humeri, one (left) ulna, one partial radius, ten phalanges, two metacarpals, four partial carpals, two mesosternal elements, the xiphisternum, ten complete ribs, and eighteen partial ribs. A detailed description of *Basilosaurus* anatomy was made by Kellogg (1936).

Whale C

The referred material of Whale C (LSU MG V2) consists of the lower left fourth premolar, the lower left first molar, and one fragment of the lingual side of the left dentary.

The Whale C find (LSU MG V2) is the second known *Basilosaurus* found at this site. It is unlikely that this is part of the *Basilosaurus* site whale, because these portions are intact on it.

The Whale C find consists of two teeth, and one bone fragment collected by Robert Guidry, William Chauvin, and the author on 13 December 1979. The teeth were found weathering out of the surface of the Moody's Branch Formation approximately 35 m north of section 1 (see fig. 18).

WCDP2 is a fourth lower left premolar. This tooth shows excessive wear on the anterior edge. The accessory denticles are completely worn smooth (except the fourth) with no separating enamel remaining. The anterior cingulum has been worn smooth. Heavy wear is also present on the primary denticle, but not as great as the anterior accessory denticles. Wear is evident on the posterior edge, but the denticles are well defined, and distinct from one another. The third posterior denticle has been broken off, probably after death. The fourth posterior denticle and cingulum show no wear, both being virtually intact. Much wear is present on the posterior lingual side of the tooth. This wear has laterally flattened the first and second accessory denticles, and removed the enamel which formerly covered this part of the tooth. Wear in this area has also removed part of the posterior cingulum ridge, just anterior of the cingulum cusp. Laterally, both roots are straight sided. The gap between the roots narrows proximally. The posterior root (viewed from the posterior) bulges below the crown, and tapers proximally. The anterior root does not taper, but bends slightly towards the lingual side. The posterior root appears to be broken, but is still longer than the anterior root. The lingual side of the anterior root appears to be complete.

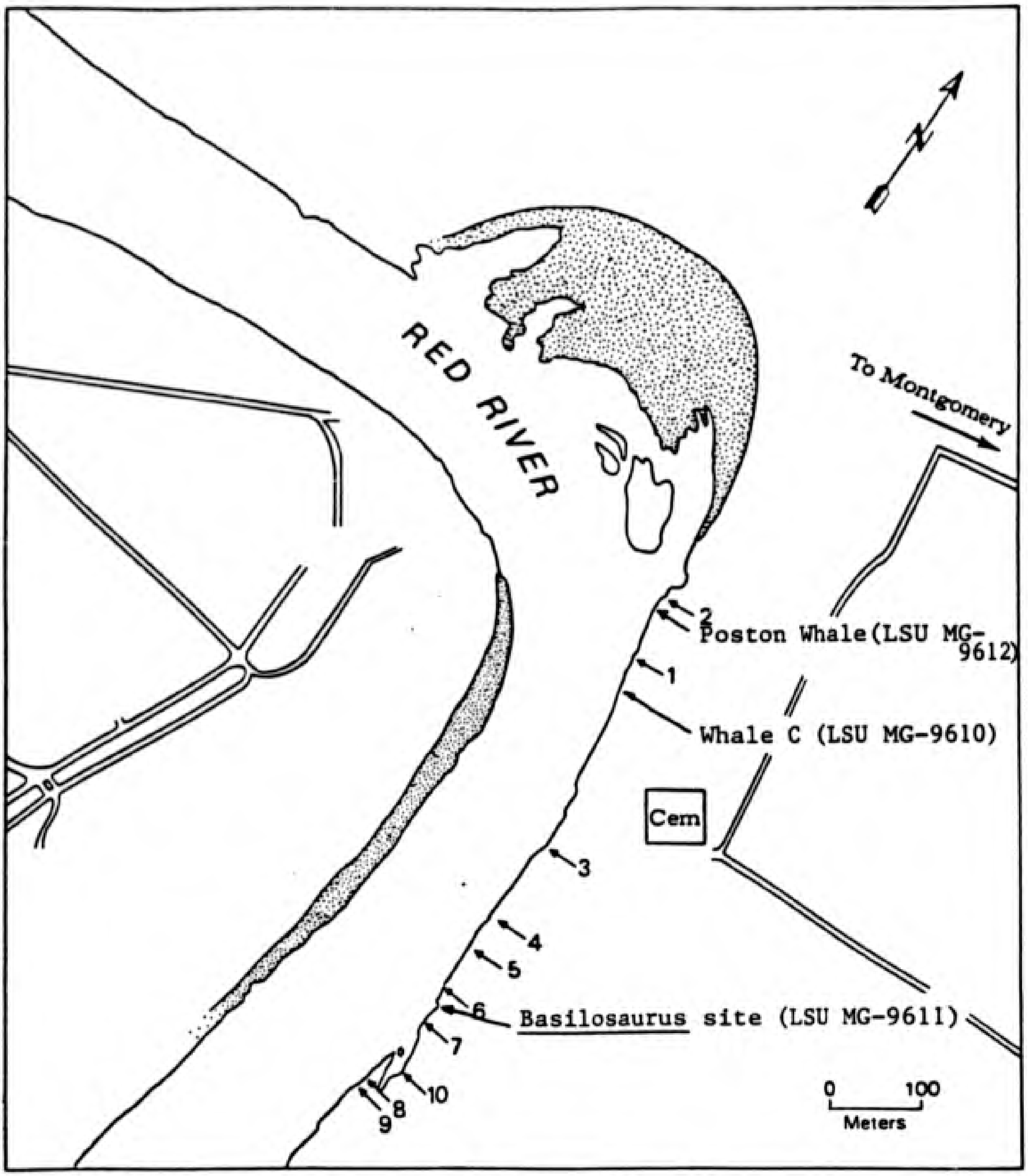


Figure 21 Locality map with whale sites.

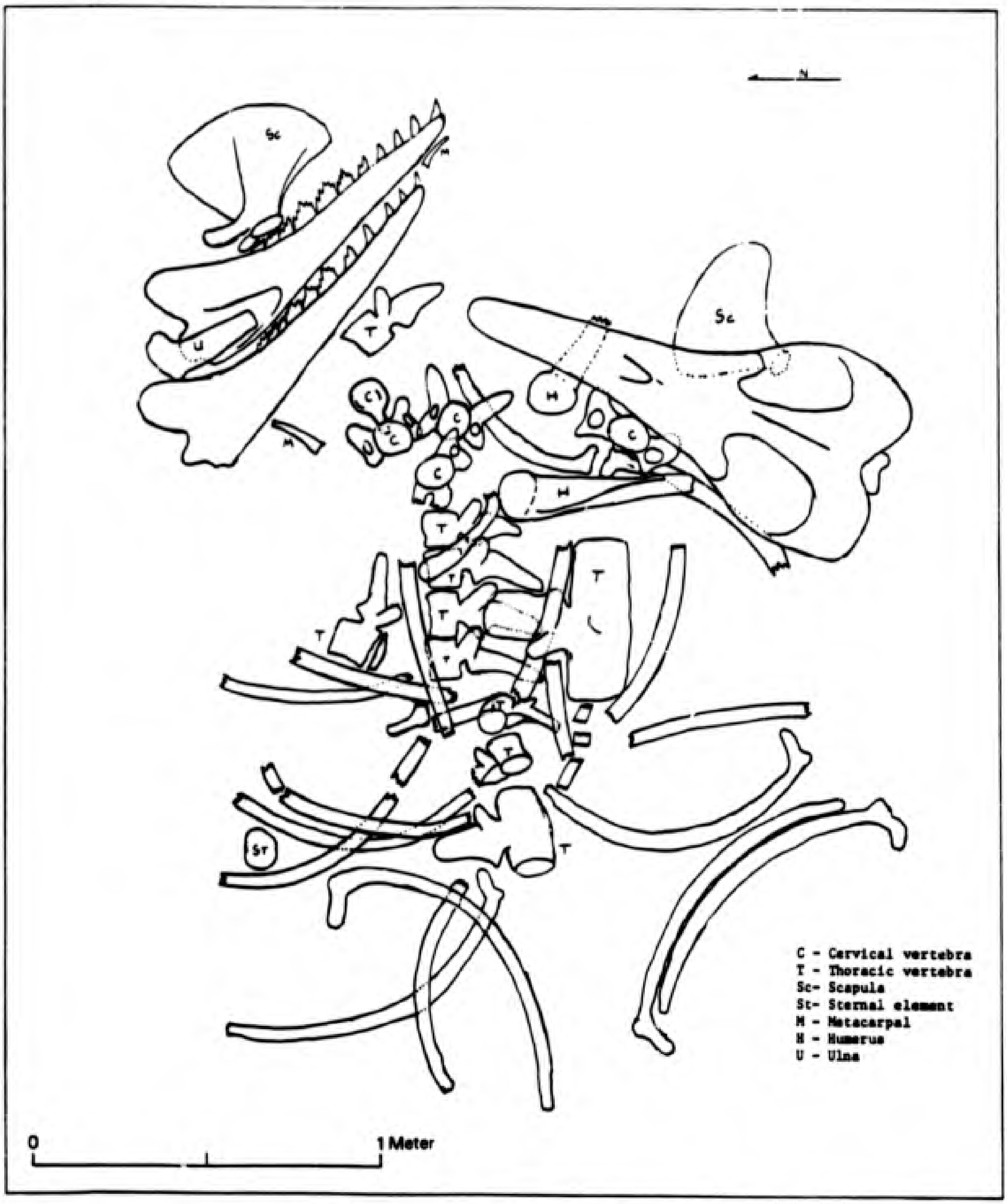


Figure 22 **BONE ASSEMBLAGE**

Fossil cetacean teeth of many types carry ornamentation. This consists of ridges on the enamel of the tooth, usually stronger toward the proximal margin of the enamel. Ornamentation tends to be more pronounced on the lingual side of the tooth, but more intricate or wavy on the labial side (R. E. Fordyce, pers. com.). This does not appear to hold true on WCDP2. Providing that the orientation with WCD (a dentary fragment discussed below) is correct, the most pronounced ornamentation is labial. This may possibly be due to the wear on the lingual side, but this is purely speculation. The ornamentation on the lingual side does appear more extensive, but less pronounced. This again may be a phenomenon of wear.

WCDM1 (Fig. 26) is a first lower left molar. It is in line with WCDP2, and both fit into the alveoli of WCD3. It is heavily worn, and little remains of the original form. The extent of the wear is such that all of the enamel, and the first two denticles of the anterior portion of the tooth have been removed. Based on diagrams by Kellogg (1936), this tooth should have five denticles decreasing in size posteriorly. Only three remain. A small patch of enamel remains on the labial side of the anterior root. Heavy wear is evident on the lingual side of the third denticle. Lateral flattening is evident on the lingual side of the fourth denticle, as seen in WCDP2. The fourth and fifth denticles as well as the cingulum are virtually intact. The former extent of the enamel can be seen as a darkening over the crown of the tooth. The roots are large and expand just below the crown and taper proximally from a lateral view. The anterior root is bifurcate, and there is a bony septum separating the two portions of the root in the respective alveolus of WCD3. From an anterior perspective the root expands proximally above the bifurcation. Both the anterior and posterior roots are broken above their natural termination.

WCD3 is a partial left dentary with alveoli for WCDP2, WCDM1, and an alveolus for the anterior root of the second molar. Only the labial side is present, and the ventral margin is also missing.

Both teeth (Fig. 26) show heavy wear on their anterior cutting surfaces. This wear is believed to be caused by tooth-food wear, as it is unlikely that *Basilosaurus* chewed its food. Teeth of this type are probably used for grasping and tearing food items into pieces small enough to swallow.

The WC teeth were compared to USNM 4674 and identified as *Basilosaurus cetoides*. The teeth, while smaller, are of very similar proportion and appearance to 4674. Heavy wear that is present on the WC teeth could account for the smaller crown height. The proportions and size progression closely match the $P_{\bar{4}}$ and $M_{\bar{1}}$ of 4674.

Due to the circumstances under which this specimen was found, no data exists concerning its associated fauna.

Subfamily DORUDONTINAE (Miller 1923)
Genus ZYGORHIZA True 1908

ZYGORHIZA KOCHII (Reichenbach 1847) from Kellogg, 1936

Basilosaurus kochii Reichenbach, 1847
Zeuglodon hydrarchus Carus, 1849
Zeuglodon brachyspondylus Muller, 1849
Zeuglodon trachyspondylus Koch, 1851
Zeuglodon brachyspondylus minor Muller, 1851
Z(ygorhiza) brachyspondylus minor True, 1908
Zeuglodon brachyspondylum Abel, 1913
Zygorhiza minor Kellogg, 1928

Subfamily DORUDONTINAE
ZYGORHIZA KOCHII (Reichenbach 1847)

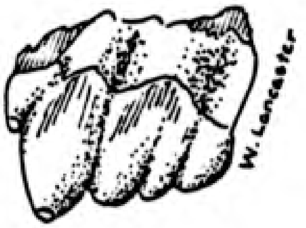
Type specimen: A partial cranium, No. 15324a-b of the Institute of Geology and Paleontology, and the Museum of the University of Berlin. Collected from the Ocala Limestone in Clark County, Alabama by Dr. Albert C. Koch in March, 1845. Comparative material: USNM 11962, a partial skull collected by Remington Kellogg, and Norman H. Boss in Choctaw County, Alabama in October, 1929.

Referred Material

The referred material consists of three teeth; the first upper right molar, the third upper right premolars and the second upper left premolar with a fragment of the maxilla.

Poston Whale

The material of *Zygorhiza* collected by Timothy Poston (LSU MG V3) from what we believe to be the Moody's Branch Formation (see Fig. 18), is highly fragmentary and consists mostly of unidentifiable pieces of bone. There are, however, three complete teeth and one broken tooth represented. These teeth were compared to USNM 11962, which is the best preserved and most complete *Zygorhiza* specimen in the United States National Museum. DM1 (Fig. 23) is a first upper right molar 24mm in length. It shows little wear but has slight breakage anterior to the primary denticle which could have removed the anterior most accessory denticle. DM1 is virtually identical to the right M^1 of 11962. Both anterior accessory denticles are intact. Both teeth have a well developed posterior cingulum and protocone remnant. The two teeth are similar in size.



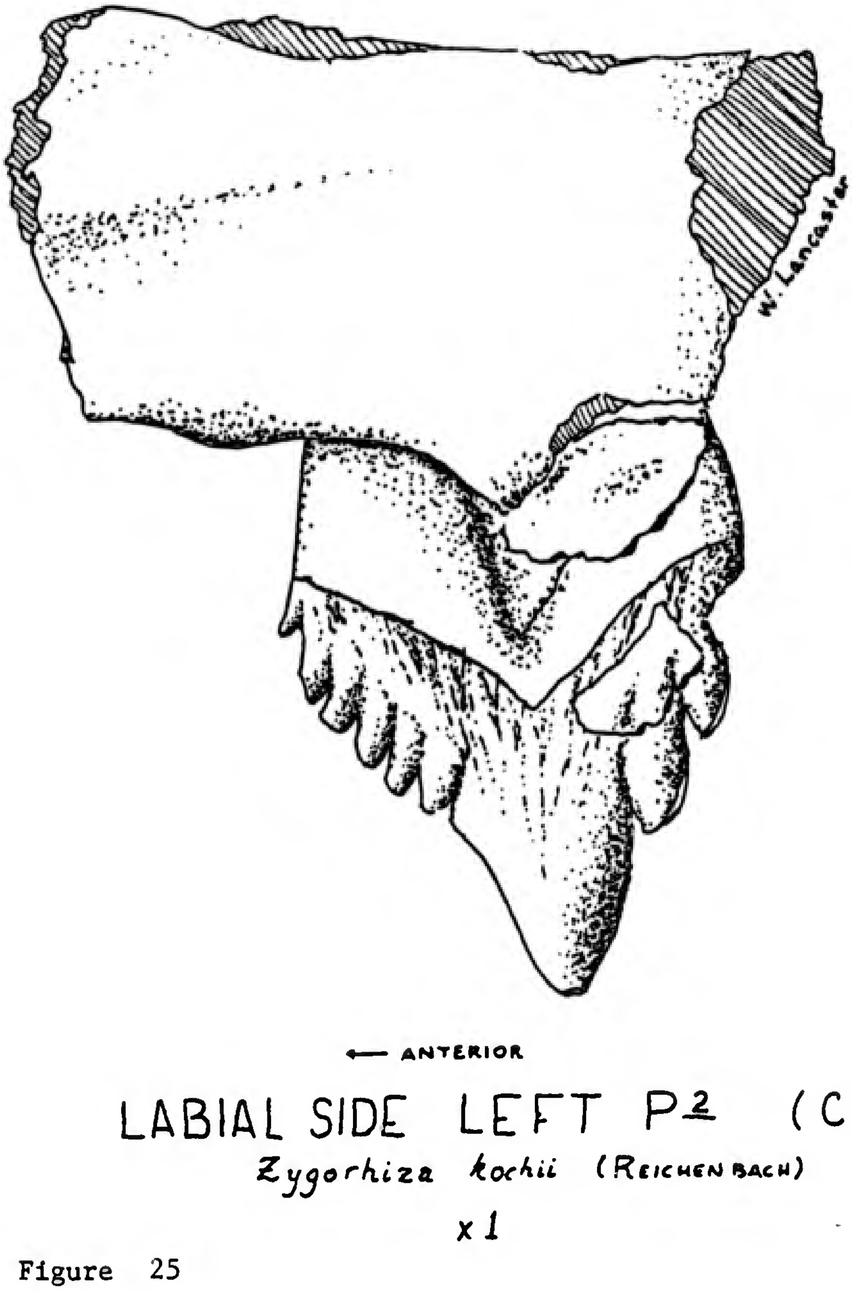
← ANTERIOR

LINGUAL SIDE RIGHT M^1 (DM1)
Zygorhiza kochii (Reichenbach)
x1

Figure 23

LINGUAL SIDE · LEFT P$^{\underline{3}}$ - (DP2)
Zygorhiza kochii (REICHENBACH)
x1

Figure 24



LABIAL SIDE LEFT $P^{\underline{2}}$ (C2)

Zygorhiza kochii (REICHENBACH)

x 1

Figure 25

DP2 (Fig. 24) is a third upper left premolar. Heavy wear is present on the posterior accessory denticles. Anterior denticles show little wear. The primary denticle is broken. This tooth is 5 mm in length. The characteristic roots are intact. It is similar to the right P^3 of 11962. The protocone remnant and posterior cingulum are both well developed, more so than on the P^2. The size of the two teeth is similar.

C2 (Fig.29) consists of a partial left maxilla with the second premolar remaining in the alveoli. This tooth shows a similar wear pattern to DP2. It compares well to the left P^2 of 11962. Both teeth show a moderately developed protocone remnant, similar arrangement of denticles, and similar size.

DP2 and C2 when observed together exhibit a size and proportion progression similar to that seen in the P^2 and P^3 of 11962.

DP3 is the posterior half of the second upper right premolar. Typical wear patterns are seen as compared to other teeth.

Taphonomy

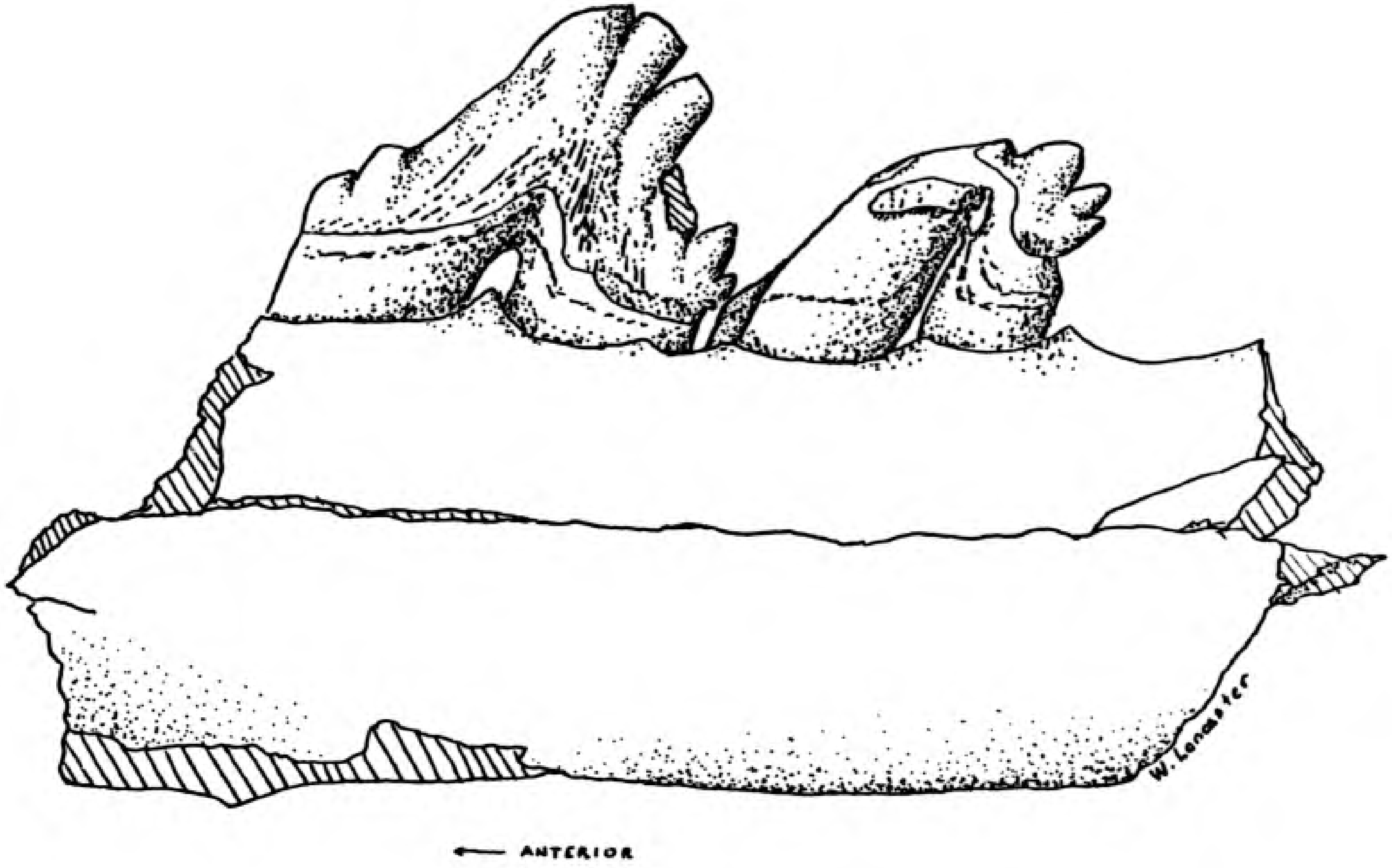
Some of the teeth of this specimen of *Zygorhiza* show a heavy encrustation of bottom dwelling invertebrates. The bryozoan *Lichenopora* cf. *L. boletiformis* and a pelecypod of the genus *Ostrea* are found on C2. This indicates that the carcass of this animal probably was exposed on the sea floor prior to complete burial. The water was probably shallow. Since the entire assemblage of bones was not seen by anyone other tnan Poston, little else can be offered in terms of taphonomy.

Associated fauna

Lichenopora and *Ostrea* are directly attached to the bones. Other invertebrates found in close association include the coral *Flabellum*, and the pelecypods *Nucula spheniopsis*, *Caestocoubula wailesiana*, and *Caryocorbula densata*. The habits and ecology of these species are discussed in the associated fauna portion of the report.

Taphonomy of the Montgomery Landing Basilosaurus

The study of taphonomy must take into account each physical feature of a fossil assemblage and attempt to explain how all organisms interacted with each other and their environment to produce the assemblage. To understand organisms by studying them as fossils, we must first understand the means through which a living organism becomes a fossil. We can then identify which characteristics of the fossil are truly characteristics of the living animal. This study will attempt to



PARTIAL LEFT DENTARY WITH $P_{\overline{4}}$ & $M_{\overline{1}}$
Basilosaurus cetoides (OWEN)
x1

Figure 26

explain the condition of the V1 Basilosaurus skeleton, the accumulation of other vertebrate remains, and the origin of the dense concentration of small pelecypod shells found within the assemblage (henceforth referred to as the shelly layer). These conclusions will be related to existing knowledge of marine paleoecology to further the understanding of how this primitive marine mammal functioned in its environment.

The positions of the major bones of the LSUMG V1 site are diagrammed in Figure 19. The majority of the bones are in a rough line with anterior to the east. The assemblage is oriented such that the anterior end is toward the cutbank, and the posterior end towards the river. In this orientation, any bones riverward were removed by erosion, or by fossil collectors.

Individual bones showing the most anomalous position are the fifth and eleventh thoracic vertebrae. The fifth has been displaced approximately one meter east of its life position. The eleventh thoracic is positioned immediately to the south of thoracics one through four, and it is oriented such that anterior is facing west rather than east. The tenth thoracic was not found. The significance of the displacement of the eleventh thoracic is uncertain, but it is evidence of the degree of decomposition of the carcass prior to complete burial.

A primary goal of taphonomy is the determination of how the animal under study died. An understanding of this can illuminate the role of the particular animal in its environment. Animals in the wild seldom live long lives, and this individual of Basilosaurus was no exception. The lack of complete fusion of the vertebral and humeral epiphyses could indicate that growth had not yet ceased (see discussion of thoracic vertebrae). The dentition is, however, fully developed, and therefore the animal was not a juvenile at the time of death. Observation of the condition of some of the bones can aid in our understanding of the mode of death of this individual, and its physical condition at the time.

Spiral breakage of some of the ribs indicates that breakage occurred prior to fossilization (either pre- or post-mortem). The left humerus was crushed on its anterolateral side along the deltoid crest. The area of breakage is sharply defined, and appears to have been made by a single strong crushing force, rather than by the slow compression of sediment compaction which is seen on the medial side of the right mandible. Additionally, some of the metacarpals show evidence of prefossilization breakage. Prefossilization breakage in this case is best explained by the predatory or scavenging activities of other large marine vertebrates such as sharks or other whales.

The teeth of this specimen show severe in-life breakage. Six of the 42 permanent teeth show breakage, and subsequent wear. In some of the teeth the pulp cavity was exposed. Carious lesions and hyperostosis of the alveolar bone indicate that this animal suffered from severe dental infections which were probably associated with much pain. Its food gathering capabilities impaired, it would become weakened, and subject to attacks by predators.

The completeness of this assemblage attests to the fact that it did not undergo extensive decomposition on the surface of the sea. Accounts of the whaling industry of the late 19th century report that it was impossible to determine if a given whale would sink or float immediately after death. It was further noticed that 'lean' species tend to sink more often than "fat" species (Scammon, 1874). If a whale (or any other mammal) sinks at the time of death, it will rise to the surface after the peritoneal cavity becomes bloated with the gases of decomposition (Schafer, 1972). As decomposition progresses, the skull and mandibles are usually the first parts lost. This is especially true for the Archaeoceti who have a relatively long neck and unfused cervical vertebrae. The appendages are attacked by scavengers, and the bones freed. Vertebrae and ribs would drop off separately, or in groups. In _Basilosaurus_ the abdomen would probably be quickly separated from the remainder of the body due to the poor post-thoracic vertebral articulation. The post-thoracic vertebrae, being attached only by soft tissues, would easily break apart. This (and the durable nature of the bone) accounts for single lumbar vertebrae being among the commonest remains of _Basilosaurus_ found by amateur fossil hunters. This is also the taphonomic condition of the type specimen of _Basilosaurus_ as well as other specimens (Kellogg, 1936). In LSUMG VI, the tenth, and the twelfth through fifteenth thoracics and all of the post-thoracic vertebrae are not present. However, ribs articulating to some of the missing thoracic vertebrae are present indicating that these vertebrae were probably here, but were previously removed. It is impossible to speculate if any of the post-thoracic skeleton was ever present at this site.

The portion of this skeleton recovered was, however, still well articulated when it reached the sea floor. The skull, mandibles, auditory bullae, and periotics (which had already achieved some decoupling from the skull (Kellogg, 1936) were still attached. Many of the elements of the manus were also still attached. As the carcass lay on the sea floor decomposing, it attracted scavengers and other marine organisms. A variety of encrusting invertebrates used the hard surface of the bone for an attachment surface. The presence of the bryozoans indicates that sedimentation was slow, and the water clear. The repositioning of most of the bones is probably the result of scavenger action and water motion. After decomposition had progressed, shifting of the skull occurred, and the auditory bullae fell out. The mandibles fell into their fossilization position, and the cervical vertebrae were scattered. This shifting could have been caused by storm-waves, or other bottom disturbances. Such disruption of the sediments could have also caused the mass die-off of the pelecypods _Alveinus_ and _Nucula_ to form the shelly layer. In terrestrial assemblages, scavenger activity was found to be a major cause of scattering of bones (Coe, 1980). Water motion of sufficient velocity to significantly transport the bones did not occur, as bones of all sizes were present in the assemblage. Prolonged currents of even a moderate velocity would probably have tended to sweep away small objects such as piscine teeth, otoliths, and the whale's otic ossicles. This did not occur. Large, single-event water movements could have caused some shifting of the bones. Long period storm-generated waves have been shown to transport bottom sediments (silts and clays) on the continental shelf off Washington state in waters 75 m deep. This was found to occur an average of 52 days per year (Richard Sternberg, 1981, pers. com.).

It is unlikely that the teeth and otoliths were transported into the assemblage. The deposition of large particles (in the form of vertebrate teeth) has long been noted around obstructions in fluvial environments (D. R. Womochel, 1981, pers. com.). This is reasonable in a fluvial system with a concentrated water flow over a relatively narrow area. It is, however, less plausible in a marine environment where water movement is not as restricted, and sediment load less concentrated. A single obstruction on a broad sea floor has a significantly smaller impact on the nature of the sea floor sediments than would an obstruction of similar size in a stream. In that the otoliths were not found associated with the skulls of the fish that bore them, they (and some of the shark teeth) are probably the remains of the whale's stomach contents. Schafer (1972) notes that otoliths are the last part of the fish carcass to be freed and transported independently. Schafer (1972:61) states, "It is therefore rare for certain areas to be subsequently enriched by preferential transport of otoliths; if concentrations exist, one must conclude that they are due to a concentration of fish carcasses or at least of skulls." The only fish bones present are highly fragmentary, and rarely even identifiable anatomically, much less taxonomically. There are far more otoliths around the assemblage than can be accounted for by the comparatively scarce fish bones. If Schafer (1972) is correct in his statement concerning subsequent enrichment, the only remaining explanation as to the origin of the otoliths is as stomach contents of the whale. As of yet, there are no known criteria for determining if an otolith has passed through the digestive tract of another animal. When these criteria are established, a more direct determination can be made.

Water movement could not only be responsible for the scattering of some bones, but also for the origin of the shelly layer. The shelly layer is a concentration of small pelecypod valves. The layer is usually one to five cm thick and forms a discrete level 10-20 cm above the basal level of the bones. Alveinus minutus is by far the major constituent followed by Nucula spheniopsis and Caestocorbula wailesiana. Fragments of Pinna and numerous microfossils are also present. Careful examination of the layer reveals that most of the valves are oriented horizontally. Sediment compaction has caused severe breakage, and in some cases determination of whether the shell is concave-up or concave-down is impossible (especially for the smaller shells). For large shells, concave-up is the preferred orientation in approximately 75% of the cases. Small shells are more likely to be non-horizontal due to proximity with larger objects, but are also more often concave-up when determination is possible.

This agrees with the findings of Emery (1968) who found a tendency for empty pelecypod valves to orient concave-up on the continental shelf off Chesapeake Bay. He attributed this phenomenon partly to human activities (dredging and trawling), but mostly to the location of the center of gravity in empty valves, and to the burrowing and scavenging activities of benthonic organisms. The concave-up position of pelecypod valves is considered to be indicative of a continental shelf environment with only minor bottom currents. The shelly layer at the V1 site originated as a mass die-off of the infaunal pelecypods following a major disturbance in the bottom sediments. Armstrong (1965) demonstrated that severely disoriented infaunal pelecypods are often unable to right themselves, and will die. Gernant (1970) investigated the origin of thicker shelly layers (composed of larger shells) in the Miocene Choptank Formation of Maryland and Virginia. He explained their death and accumulation to soft sediment disturbance by passing long period, tropical storm waves.

As decomposition of the carcass progressed, sediments slowly accreted. That the rate of sedimentation was slow is borne out by the encrustation of filter feeding invertebrates. Notable among these are specimens of Ostrea sp. in excess of 5 cm in diameter attached below the supraoccipital process, and numerous smaller oysters on many bones. Encrusting bryozoans found on many of the bones, and plates of lepidomorph barnacles in the surrounding sediments attest to the low level of suspended sediments in the water.

Trophic relationships

If, as it appears, the otoliths and some of the shark teeth found in the assemblage are the remains of the animal's stomach contents, an analysis of the animal's diet and indirectly its feeding habits and methods can be made based on our knowledge of the prey species.

The otoliths and teeth in the assemblage represent fishes broadly divergent in habitat and form. This indicates that Basilosaurus was an opportunistic predator not specialized toward the exploitation of a single resource. Such a conclusion is not surprising given that the most significant difference between Basilosaurus and the most abundant contemporary cetacean, Zygorhiza, is size. While Basilosaurus is a highly derived form in terms of its post-cranial morphology, its feeding apparatus is generalized, and it differs little from that of other Archaeoceti.

Utilizing the closest modern analogue approach of paleoecological interpretation, Basilosaurus preyed on shallow water bottom-dwelling forms (Ginglymostoma, Dasyatis, and Pristis) as well as pelagic fishes (Galeocerdo, Trichiurides, and Bregmaceros). It must be remembered, however, that sharks and fish have many teeth, but teleost fishes have only two sagittae. Therefore, numerous teeth can represent only one individual while numerous otoliths represent half as many individuals. Had Basilosaurus fed on sharks with any regularity, the amount of teeth found would probably have been far greater. If Basilosaurus preyed upon sharks, it was probably infrequent, simple due to their size. While the premolars and molars of the Archaeoceti form a better masticatory apparatus than that possessed by modern Odontoceti, it seems unlikely that archaeocetes chewed their food to any great extent. The fact that the Odontoceti did not retain a complex masticatory apparatus indicates that it is neither necessary nor advantageous for pelagic predators. As with most predators, prey items were probably just torn into pieces small enough to swallow. A shark, while it would represent a greater mass of food than a single small fish, would also take more energy to subdue and eat. Conversely, a small form that concentrates itself into compact units (schools) would be more easily and safely exploited. *Bregmaceros* would have been such a form. A large school of *Bregamaceros* in open water would represent a concentration of easily ingested food. The open water habitat of *Bregmaceros* would give a large animal like *Basilosaurus* room to operate. The size of *Basilosaurus* would have been restrictive in an extremely shallow water situation.

The incisiform nature of the first premolar of *Basilosaurus* indicates that its dentition was developing towards homodonty. A look at piscivorous animals of many taxa illustrates that this is the most effective tool for catching fish. Having freed the teeth from the function of chewing, the only remaining function is in seizing and immobilizing prey. A series of interlocking peg-like teeth is more effective for this than a complex battery of grinding teeth. Simple teeth are also less prone to breakage than complexly intermeshing teeth. The reduction of the serrated premolars and molars to homodont pegs would make the utilization of prey too large to swallow whole difficult, if not impossible. Thus, as with all specialization, the value of the increase in efficiency provided by the specialization must be weighed against the loss in options.

If *Bregmaceros* and other small to medium sized, pelagic, schooling fish were the principal prey of *Basilosaurus*, they were probably grasped by the anterior teeth as the whale swept its snout through the school while snapping its jaws. The fish caught could then be thrown to the back of the mouth by the tongue as the mouth opened for the next bite. Any large individuals could be cut with the posterior teeth. These posterior teeth form an efficient cutting apparatus. The serrated premolars interlock with each other with the lower dentitions fitting lingual to the upper. Embrasure depressions are present on the palatine process of the maxilla (medial to the tooth row) between P^1 and P^2, and P^2, and P^3 to accomodate P^2 and P^3, respectively. This would allow tight closing of the jaw, and more complete shearing action between the juxtaposed tooth rows. Interlocking is also seen in the anterior teeth. The lower incisors and canines fit into embrasure depressions on the lateral side of the snout between the upper incisors, canine and P^1 (in line with as opposed to medial to the teeth). This interlocking would form an effective mechanism for seizing and retaining fast moving prey. The greatest disadvantage of tightly intermeshing teeth is that occlusion must be perfect. This was not the case with *Basilosaurus*, and the result is a high rate of tooth breakage. V1 had broken I^1, I^3, and M^1 on the right side, and C^1, I1, I3, and M1 on the left side. In several of the teeth, the pulp cavity was exposed, and severe decay of the tooth had occured. Such a structural problem, if common in *Basilosaurus*, could have been a distinct competitive disadvantage. In modern Odontoceti this problem is reduced by polydonty, making teeth low and broad rather than long and thin, and (as in *Physeter*) elimination of the upper dentition.

CHAPTER 5. PALEOECOLOGY

A. AGE OF THE BEDS AT MONTGOMERY LANDING

Cockfield Formation.

As these beds are non-marine, they do not contain any calcareous nannoplankton nor planktonic foraminifera and therefore there is no direct evidence for the age of these beds. Their constant position underlying the Moodys Branch Formation (Fisk, 1938) and overlying the middle Eocene Cook Mountain Formation is the only argument for assigning them a late middle Eocene age.

Moodys Branch Formation

Paleontological evidence for the age assignment of this formation is based on nannofossils and planktonic foraminifera.

Nannofossils. The Moodys Branch Formation at Montgomery Landing lies entirely within the *Discoaster tani nodifer* zone of Hays (1967), which is placed at the base of the upper Eocene.

Planktonic foraminifera. The formation lies entirely within the *Globigerapsis involuta* zone, which is classically considered as earliest late Eocene.

Yazoo Clay.

Only the lower, Tullos, member of the Yazoo Formation is present.

Nannofossils.

The lower part of the Tullos member still lies within the *Discoaster nodifer* zone. A short distance below the second ledge the first specimens of *Isthmolithus recurvus* have been found. As the *Isthmolithus recurvus* zone ranges to the top of the Eocene, no further subdivision is possible. The lowest occurrence of the zone has been found in Alabama in the Cocoa sand (Fig. 27)

Planktonic foraminifera.

The lower part of the Tullos member at Montgomery Landing belongs to the *Globigerapsis semiinvoluta* zone. Above ledge three, the beds belong to the *Globorotalia cerroazulensis* zone (Priabonian stage of the International zonation), and a few species of a *Hantkenina* have been found, which can be assigned to *Cribrohantkenina inflata*, which would place the uppermost part of the Tullos member here in the *Cribrohantkinina inflata* zone of Blow, (1969). No evidence for the presence of latest Eocene was encountered. This is in agreement with the position of the Tullos member, which is overlain in other places in Louisiana by the Verde member. The Danville Landing beds, which according to Fisk (1938) form the highest Eocene in Louisiana, carry a fauna which strongly resembles that of the Tullos member. According to the present faunal evidence, the Tullos member would correlate with the North Twistwood clay member of the Yazoo in Alabama. The part between ledges two and three would likely be the equivalent of the Cocoa sand in Alabama (Fig. 27). The Verde member and the Danville Landing beds could be equivalent to the Shubuta clay, uppermost Eocene of Alabama.

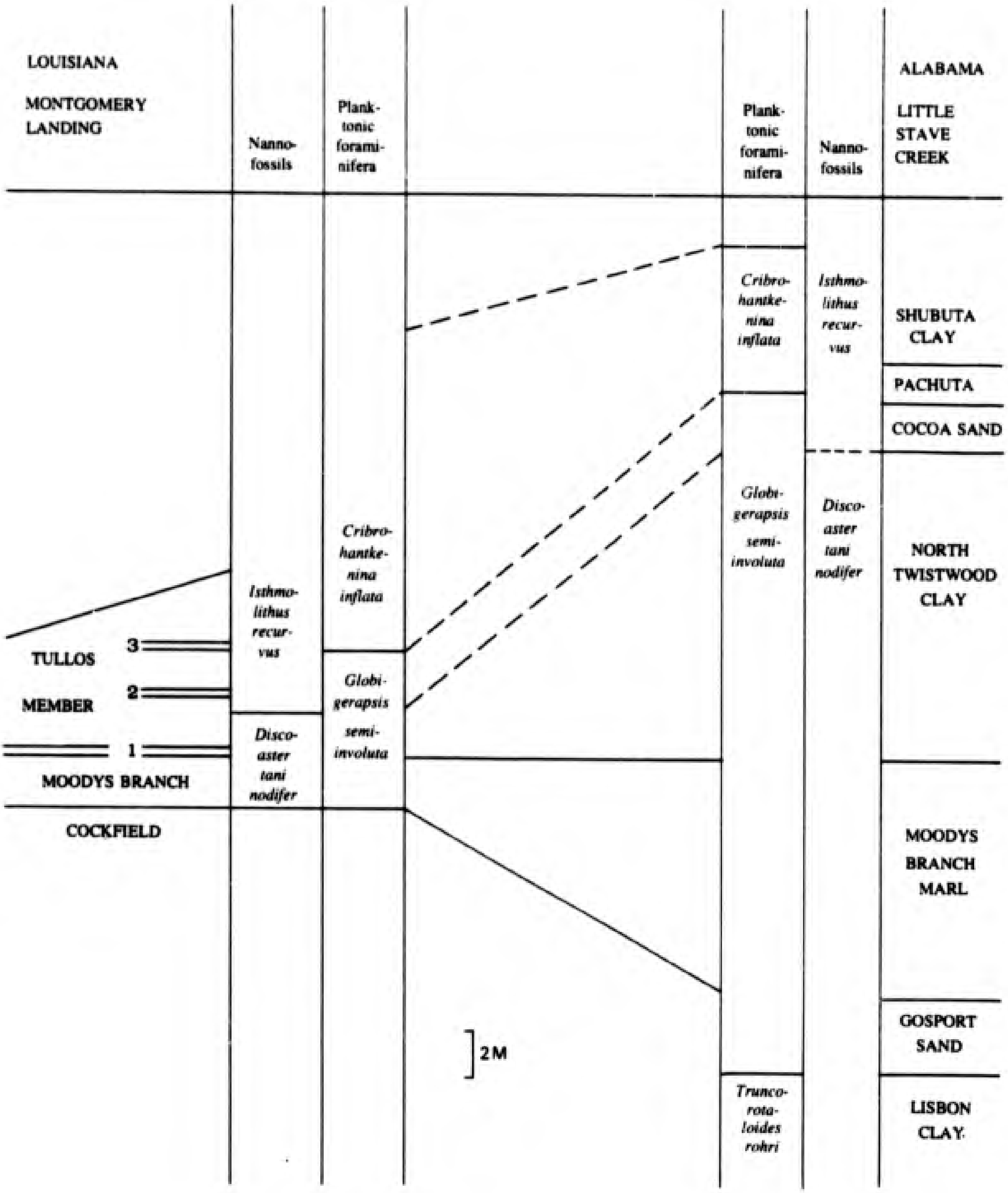


FIG. 27 Correlation of the Montgomery Landing section with the Eocene sequence in Alabama.

B. SELECTED ANIMAL LIFE MODES AND ECOLOGY

MICROFAUNA

Ostracodes

The predominant species in the upper Eocene have no direct living descendants and therefore no direct comparison with modern conditions is possible. Some of the representatives of the extant genera appear to have migrated to deeper water environments in the Neogene, which makes comparison even more hazardous. Most extant genera are confined to shallow water. Many of them carry eye-tubercles, which species living in deep water environment lose subsequently. No such reduction or loss has been observed in any of the species under consideration here. Two species only occur in the burrows into the Cockfield: *Opimocythere mississippiensis* and *Cushmanidea gosportensis*. Some others are restricted to the burrows and the basal Moodys Branch Formation: *Cocoaia grigsbyi*, *Cyamocytheridea watervallyensis*, *Ouachtia caldwellensis*, *Tropidocythere carinata*, *Hermani hysonensis* and *Clithrocytheridea garretti*. Most of these forms, including the species from the basal Moodys Branch (*Haplocytheridea montgomeryensis* and *Cytheretta jacksonensis*), are forms that have been found in the marine middle Eocene Gosport sand. Most species found in the Moodys Branch marl and the Tullos member have lived till at least the end of the Eocene, occur in many different environments in the upper Eocene, and are therefore unsuitable for direct environmental interpretation; however, their relative abundance changes drastically within the short time span in which the beds at Montgomery Landing were deposited. Interpretation remains uncertain because of the many variables that control their horizontal and vertical distribution: shape of the shelf (open or protected bay environment, and protective barriers), distance from shore, salinity, water depth, temperature, food supply, sediment influx, and consequent nature of the substrate. The dominance of the genus *Haplocytheridea* in the Moodys Branch and of *Haplocytheridea* and *Buntonia* in most of the Yazoo clay is an indication of nearshore environment. These appear to have been opportunistic species, that were capable of rapid expansion. Infaunal species, such as *Cytherella*, favour the muddy environment of the Yazoo, but are sparse in the

TABLE 31 Ostracode factor-analysis - biofacies

YAZOO C	Fauna 1 (occ. 4)	very low diversity
YAZOO LEDGE 3	Fauna 3 (or 6)	high diversity
YAZOO B	Fauna 1	low diversity
YAZOO LEDGE 2	Fauna 6	high diversity
	Fauna 1	
YAZOO A	Fauna 2	low diversity
	Fauna 4 (sec. 4)	
YAZOO LEDGE 1	Fauna 4 (sec. 1, 2), or 6 (sec. 4)	high diversity
MOODYS BRANCH	Fauna 5	very high diversity

calcareous ledges, where they are replaced by the related form *Cytherelloidea*, which prefers a warm, clear water and calcareous milieu, similar to some species of *Loxoconcha*. In the ledge fauna, we also observe a reduction in the number of *Haplocytheridea* and an increase in numbers in such species as *Echinocythereis jacksonensis* and *Brachycythere russelli*, whose descendants show a tendency to migrate towards deeper water. We recognize four different faunas:

1. *Haplocytheridea* fauna, Moodys Branch, with reasonable diversity, but strong predominance of the species *Haplocytheridea montgomeryensis*. Biofacies 5 of Kilmartin (1981)
2. *Haplocytheridea-Buntonia* fauna (this is mostly biofacies 1 of Kilmartin, but includes parts of biofacies 4
3. *Cytherella* fauna (mostly biofacies 2 of Kilmartin)
4. Ledge fauna: (mostly biofacies 6 of Kilmartin, but including parts of 4 and 3)

If we eliminate the ledge fauna from our consideration, as the presence of this fauna is clearly related to sedimentation rates only, we see the following in verticial succession:

Haplocytheridea fauna (Moodys Branch) - *Haplocytheridea/Buntonia* fauna- *Cytherella* fauna - back to *Haplocytheridea/Buntonia* fauna - again *Cytherella fauna* (only in the southern part of the section) and back to *Haplocytheridea/Buntonia* fauna. As we have reason to assume that the *Cytherella* fauna represents slightly deeper water conditions we have here a regularly fluctuating water depth, with the greatest depth occurring between ledges 1 and 2 and just below ledge 3 (Plate 3-1). These fluctuations can only have been very minor, possibly of the order of a few tens of meters. Greatest depth was certainly less than 100 m and probably not beyond 50 m. Subsidence must have been very slow and depth of deposition was probably more controlled by sediment influx than by increase and decrease of subsidence or eustatic fluctations of sea level.

Foraminiferida

Until full statistical analyses have been made, no detailed account of minor changes in distribution of the fauna can be given. However, in view of the results of the analysis of the ostracodes, it appears that a general statement can be significant.

The foraminiferal fauna of the Tullos member of the Yazoo formation at Montgomery Landing turns out to be very similar to the fauna at Danville Landing, that is, found in a much higher stratigraphic position. The succession in Louisiana is according to Fisk (1938):

Danville Landing beds: sands and clays with concretions, marine fauna.
Verde member: lignitic non-marine clays and silty sands with lentils of marine clay and sand.
Tullos member: marine clay.
Moodys Branch: glauconitic marl.
Cockfield: non-marine lignitic clays.

The Danville Landing beds indicate a late Jacksonian marine invasion and the marine lentils in the non-marine Verde member show that the site of deposition was never far from the shoreline. These marine lentils generally yield only a fauna of agglutinated benthic foraminifera, which indicates that marine conditions were only marginal. The almost identical faunas of the Tullos member and Danville Landing beds show that environmental conditions must have been identical, considering their disparity in age. Therefore, the foraminiferal fauna, just as the ostracodes, shows that depositional conditions never strayed very far from marginal marine, and probably the ultimate depth never reached beyond inner shelf.

Macrofauna

Nektonic

Vertebrates are the main preserved swimmers at Montgomery Landing. Arthropods such as shrimp must have been common swimmers but the only fossil shrimp remains at Montgomery Landing are the burrows Ophiomorpha. Some soft-bodied types like jellyfish or sea slugs may have been present, but are not preserved. Fossil remains represent a great size range of vertebrates, from 10 cm long bony fish up to the 15 m long Basilosaurus. Both predatory carnivores and possible scavengers are present. Prey of large forms such as Basilosaurus and Carcharodon would have been mainly confined to vertebrates, but smaller forms fed on plankton or, like the ray Myliobatis, preyed upon the invertebrate epifauna. The crabs and oysters were among forms which were likely prey to swimming vertebrates. Micro-organisms also were preyed upon. Thousands of foraminifera and valves of ostracodes have been found in fish excrement.

The high motility of the nektonic vertebrates makes their role in the ecosystem difficult to assess. Many living marine vertebrates change feeding area and prefered depth seasonally or even daily. We have no examples of breakage of invertebrate shells directly attributable to vertebrate predation, but it seems likely that they played a role in the formation of shell hash. Heavy vertebrate predation in the modern environment can be both spotty and sporadic. Absence or diminished numbers of epifaunal mollusks in some section samples could have been caused by vertebrate predation. Vertebrate predators and scavengers can increase turbidity in the course of food search on a muddy bottom, making soft-bottom dwelling more difficult for suspension-feeding invertebrates. The variety and abundance of vertebrates at Montgomery Landing suggests that some may occassionally have had this effect.

Motile epibenthic

Gastropods and arthropods (crabs) are the main bottom crawling types found at Montgomery Landing. The crabs have left definite evidence of their predation on gastropods in the columellas stripped of shell which are common at Montgomery Landing. The same animals would have also been scavengers and detritus feeders as the opportunity arose. The dominant gastropod predator was probably Athleta petrosa (C. R. Givens, pers. comm.) Its large size and fragility prevented its being adequately represented in the section samples. Gastropods also included scavengers, herbivorous grazers, and detritus feeders (Chapter 4-I). Concrete evidence of gastropod predation includes small holes bored in bivalve shells. Activities of the motile epifauna were probably also significant at times in generating turbidity.

Sessile epifauna

The Montgomery Landing sessile epifauna is composed of suspension feeders. The main forms at Montgomery Landing are coelenterates (horn corals), bryozoa, and bivalve mollusks. The solitary corals and large bryozoa are the tallest suspension feeders preserved at Montgomery Landing and those draining particles from the lowest position of the water column include the encrusting bryozoa and the shallow burrowing small bivalves.

Problems for the sessile epifauna include turbidity and sinking into soft sediments. Competition for solid settling places for larvae must have been high. The encrustation on the *Basilosaurus* bones is an example of opportunistic utilization of any hard surface by the sessile epifauna. The lack of good larval settling places may have been a limiting factor to coral distribution in the Yazoo clay. One individual suspension feeder's response to life on a soft bottom is shown in Figure 5-B-1. The oyster has a sharply raised vertical rim which is the result of its holding its mantle vertically to keep out irritating particles.

Infauna

The preserved infauna at Montgomery Landing is dominated by bivalve mollusks. Both suspension feeders, for example, *Alveinus minutus*, and deposit feeders, for example, *Nucula spheniopsis*, are common. The suspension feeders extend siphons above the sediment surface but are still very low level suspension feeders. Activities of deposit feeding infauna can adversely affect suspension feeders by creating turbidity.

This is partially responsible for the negative correlation of some suspension and deposit feeding bivalves (p. 373 this study). Soft bodied deposit feeders such as annelids could have been present in small numbers at Montgomery Landing, but large numbers of them should have produced more bioturbation than is visible here. Conversely, large numbers of suspension feeders prevent the addition of food to the sediments where deposit feeders can get it, by catching it first there by automatically limiting the number of deposit feeders.

A problem for the infaunal types is exposure or disorientation by currents or storm-generated waves. If they cannot rebury or reorient themselves, they die. Bedding planes in the Yazoo Formation are defined by layers of small bivalves and/or fragments of the large infaunal suspension feeder *Pinna*. Boucot (1981) described the effect of a storm on Sanibel Island (Florida) as follows:

> Bivalves unable to make use of the foot, like Pinctada, Pteria, Pinna, and the mytilids, are caught by the waves, and continue floating in the water from high tide to low tide and from low tide back to high tide they knock against each other so that their shells grit audibly, they smash each other and expose the animals thus bared to inevitable death, usually by suffocation in the sand. These dead or dying pinnas, which constitute such a high percentage of the beach deposits, finally come to rest below high-water mark, and the odor of putrefaction is soon perceivable at a great distance.

The Pinna hash in the Yazoo need not have formed in such dramatic circumstances, because the shells are very fragile. Currents sufficient to expose buried Pinnas would have sufficed.

Microfauna/Macrofauna Relationships

Big fleas have little fleas
Upon their backs to bite'm,
Little fleas have lesser fleas
And so ad infinitum.
And the big fleas in turn
Have bigger fleas to go on
While these again have bigger still
And bigger still and so on.

This little doggerel, which generally is applied to the business and political communities, applies also basically to any living biological community and especially to the food chain of planktonic and benthonic organisms living in a shallow marine environment such as was the area around Montgomery in late Eocene times. Among the smallest organisms floating in the seawater were many species of algae, of which the nannofossils mentioned in that particular section form an important part. As these organisms lived largely by photosynthesizing complex organic molecules out of carbon dioxide and water, they formed the basis of the food chain. They were ingested by Protozoa, although the food intake of these was not necessarily restricted to marine algae. Planktonic foraminifera are known to have ingested such highly evolved creatures as copepods (Crustacea). The algae, planktonic foraminifera, and ostracodes are the basis of the food chain for the wide range of larger nektonic organisms, mostly vertebrates such as fish and crustaceans that also prey upon each other and on benthonic life.

In the benthos the algae and plants form the basic link of the food chain. Some of the smaller animals and protozoa derive their food from plant debris, but others graze on living plants or suck plant juices. Some ostracodes have specially developed mouthparts that enable them to do this. Here also the general rule is that the larger creatures prey on the smaller ones, and the small benthonic foraminifera and ostracodes form a basic link in the chain. Larger benthonic foraminifera (Nummulites) are found only in the Moodys Branch marl. Normally these occur mainly in limestone, and preferably reef limestones, on or near coral reefs, and in clear agitated water. In the Yazoo clay the environment was too muddy for them to exist.

The benthic epifauna and infauna, whether they are detritus, suspension or deposit feeders live on the remains of plant life and the smaller animals of the shallow marine community. Some carnivores prey directly on the microfauna, like the gastropods known to bore ostracode shells that belong to species that live either upon the surface of the sediment, or in interstitial spaces within the upper layers of the bottom sediment. Small gastropods in turn are pursued by more active animals such as crustaceans, who also prey upon other sessile organisms such as corals and, of course, upon many soft bodied creatures, which must have lived there, but of which no fossil record remains because they had no hard parts to fossilize. Essentially this is also true for many examples of plant life, which form the basis of the food chain, but are rarely preserved and therefore leave no fossil record. Some of the smaller organisms, such as ostracodes, apart from ingesting minute particles of food carried in the water, similar to foraminifera, are also scavengers and participate with the larger crustaceans, such as crabs, in the removal of decaying dead bodies from the environment.

Fig. 49-1 Oyster on weathered surface at "Oyster Point."

Fig. 49-2 Bivalve internal cast being removed from surface of "Oyster Point."

PLATE 49

C. OSTRACODA DISTRIBUTION AT MONTGOMERY LANDING

The Ostracoda from fifty-six samples were examined in this study and resulted in the recovery of 33,931 specimens. Forty-six species from 29 genera have been identified and are listed in Table 32. Of these, twenty-three species and ten genera have not previously been reported from Montgomery Landing. One species is previously undescribed and is considered new. Table 33 summarizes the results of this and previous studies of the Ostracoda from the Montgomery Landing outcrop.

The number of valves of each species recovered in this study is listed in Table 32. The absolute (number of specimens), normalized absolute (number of specimens per gram), and proportional abundances of each species for each sample are listed in the tables of Appendix I.

Haplocytheridea montgomeryensis is the most abundant species at Montgomery Landing. Nearly one-third (30.6%) of the valves belong to this species. Buntonia shubutaensis is the second most abundant species, as 18.2% of the valves belong to this species. Together these two species represent nearly one-half (48.6%) of the specimens recovered at Montgomery Landing. No other species represents more than 6% of the total fauna. The stratigrapnic distribution of the species is shown in Tables 34 to 39. The relative abundances of the species have been divided into three arbitrary classes: (1) 0.1 -5%, (2) 5.1 -15%, and (3) greater than 15%.

A sample from an Ophiomorpha burrow was collected 1.9 meters below the Cockfield - Moodys Branch contact at Section One. Because only 145 specimens were recovered the species occurrence data are reported in checklist form on the distribution graphs. A list of the species recovered and their relative abundance is given in Figure 28. The following species in this study were found only in the burrow sample:

Cushmanidea gosportensis (Blake)
Opimocythere mississippiensis (Meyer)

The fauna of the Ophiomorpha burrow has important stratigraphical significance. As previously discussed, Stenzel (1940) believed a paralic facies was developed in the upper Claibornian sediments at Montgomery Landing, and named this the Creola Member. Stenzel placed great importance on the foraminiferal fauna of a glauconite bed approximately 8 to 9 feet below the Moody's Branch - Cockfield contact, stating that it "clearly is older than Moody's marl."

Sections one and two of this study started at 1.9 and 4.0 meters below the contact, respectively. No evidence of a glauconite bed was found in either section. The burrow sample, though, was collected very near the stratigraphic level of Stenzel's glauconite bed. The ostracode fauna of this burrow is quite different from either of the basal Moodys Branch samples studied (Fig. 28). Although the abundance of the "Clithrocytheridea" - type species suggest affinities to the Claibornian Gosport Sand of Alabama, this is due to ecological, and not

TABLE 32

IDENTIFIED MATERIAL

SPECIES	VALVES
Acanthocythereis florienensis	1044
Acanthocythereis howei	710
Acanthocythereis molts	554
Actinocythereis gibsonensis	557
Actinocythereis purii	149
Alatacythere ivanti	9
Argilloecia subovata	64
Brachycythere russeli	286
Brachycythere watervalleyensis	953
Buntonia morsei	256
Buntonia shubutaensis	6172
Buntonia smithi	257
Clithrocytheridea garretti	8
Cocoaia grigsbyi	19
Cushmanidea gosportensis	1
Cyamocytheridea chambersi	2
Cyamocytheridea watervalleyensis	8
Cytherella insculptilla	93
Cytherella spp.	1915
Cytherelloidea montgomeryensis	1431
ytheretta jacksonensis	1097
Cytheromorpha cf. C. asperata	1
Cytheromorpha calva	201
Cytheropteron montgomeryensis	1338
Cytherura aff. C. ultra	1
Echinocythereis jacksonensis	987
Eucythere lowei	29
Haplocytheridea montgomeryensis	10393
Hermanites dohmi	732
Hermanites hysonensis	3
Loxoconcha cocoaensis	130
Loxoconcha concentrica	1967
Loxoconcha creolensis	32
Loxoconcha jacksonensis	9
Loxoconcha watervalleyensis	149
Loxoconcha sp.	1
Occultocythereis broussardi	101
Occultocythereis sp.	2
Opimocythere mississippiensis	1
Ouachitaia caldwellensis	17
Paracypris franquesi	218
Paracypris licina	105
Trachyleberis? grigsbyi	57
Trachyleberis? montgomeryensis	1551
Triangulocypris gibsonensis	284
Tropidocythere carinata	5
Xestoleberis sarsi	32
TOTAL	33931

TABLE 33

RESULTS OF MONTGOMERY LANDING OSTRACODA STUDIES

SPECIES	Howe and Chambers, 1935	Howe, in Fisk, 1938	Howe and Howe, 1975a	Present Study
Acanthocythereis florienensis	X	X	X	X
Acanthocythereis howei				X
Actinocythereis gibsonensis		X	X	X
Actinocythereis purii				X
Alatacythere ivani		X?		X
Argilloecia subovata				X
Brachycythere russeli				X
Brachycythere watervalleyensis	X	X	X	X
Buntonia morsei				X
Buntonia shubutaensis	X	X	X	X
Buntonia smithi				X
Clithrocytheridea garretti	X			X
Cocoaia grigsbyi	X		X?	X
Cushmanidea gosportensis				X
Cyamocytheridea chambersi				X
Cyamocytheridea watervalleyensis				X
Cytherella insculptilla				X
Cytherella spp.	X			X
Cytherelloidea montgomeryensis	X	X		X
Cytheretta jacksonensis	X	X	X	X
Cytheromorpha cf. C. asperata				X
Cytheromorpha calva				X
Cytheropteron montgomeryensis	X	X	X	X
Cytherura aff. C. ultra				X
Echinocythereis jacksonensis	X	X	X	X
Eucythere lowei				X
Haplocytheridea montgomeryensis	X	X	X	X
Hermanites dohmi	X		X	X
Hermanites hysonensis	X			X
Loxoconcha cocoaensis				X
Loxoconcha concentrica				X

TABLE 33 (continued)

SPECIES	Howe and Chambers, 1935	Howe, in Fisk, 1938	Howe and Howe, 1975a	Present Study
Loxoconcha creolensis	X			X
Loxoconcha jacksonensis	X	X		X
Loxoconcha watervalleyensis				X
Loxoconcha sp.				X
Monoceratina alexanderi	X			
Occultocythereis broussardi	X			X
Occultocythereis sp.				X
Opimocythere mississippiensis				X
Ouachitaia caldwellensis	X		X?	X
Paracypris franquesi	X	X		X
Paracypris licina				X
Trachyleberis? grigsbyi	X			X
Trachyleberis? montgomeryensis	X	X	X	X
Triangulocypris gibsonensis	X	X	X	X
Tropidocythere carinata				X
Xestoleberis sarsi				X

stratigraphical similarities. The total ostracode fauna of the burrow resembles much more a Jacksonian, or Moodys Branch fauna, than a Claibornian, or Gosport Sand fauna.

It is suggested here that Stenzel's glauconite bed was actually an *Ophiomorpha* burrow, which commonly forms fairly long horizontal branches. It this is true, then the Creola Member, or marginal marine to deltaic facies of the upper Cockfield, does not exist at Montgomery Landing. The Creola Member has been reported from other localities (Treadwell, 1954). If this member does indeed occur elsewhere, then one is faced with the situation where the Creola Member exists, but not at its type locality.

In order to circumvent this source of nomenclatural confusion, it is proposed that the stratigraphical term Creola Member be abandoned. It is still recognized, however, that a paralic facies may occur in upper Claibornian sediments at other localities.

As can be seen from the graphs, many species are common throughout the entire marine section exposed at Montgomery Landing. Some species, however, are restricted. The following species at Montgomery Landing are restricted to the Moody's Branch Formation:

Clithrocytheridea garretti (Howe and Chambers)
Cocoaia grigsbyi (Howe and Chambers)
Cushmanidea gosportensis (Blake)
Cyamocytheridea chambersi (Stephenson)
Cyamocytheridea watervalleyensis (Stephenson)
Cytherura aff. *C. ultra*
Hermanites hysonensis (Howe and Chambers)
Occultocythereis sp.
Opimocythere mississippiensis (Meyer)
Ouachitaia caldwellensis (Howe and Chambers)
Tropidocythere carinata Huff.

The following species at Montgomery Landing are restricted to the Yazoo Clay Formation:

Buntonia morsei (Howe and Pyeatt)
Cytheromorpha cf. *C. asperata*
Loxoconcha sp.
Trachyleberis? *grigsbyi* (Howe and Chambers)

Note that all of the restricted species are relatively rare, or uncommon species. All of the abundant species are found in the Moodys Branch and continue throughout the Yazoo Clay.

Several species that occur throughout the marine section are abundant only at restricted stratigraphic levels. *Cytherella* spp., represented by 1915 valves, is the fourth most abundant form at Montgomery Landing. One-half (49.7%) of the valves, however, were recovered from an approximately one meter thick interval Yazoo Clay.

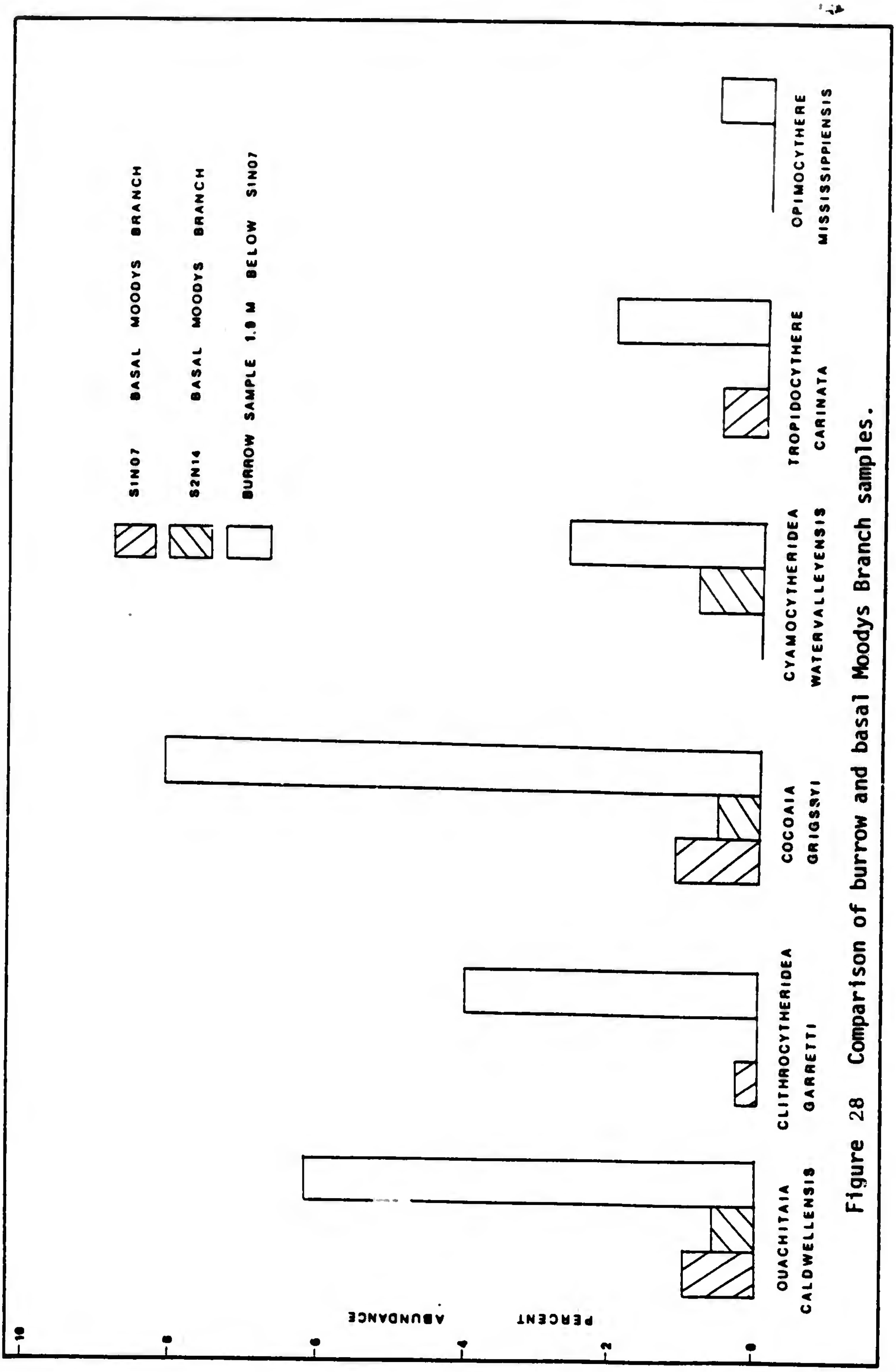


Figure 28 Comparison of burrow and basal Moodys Branch samples.

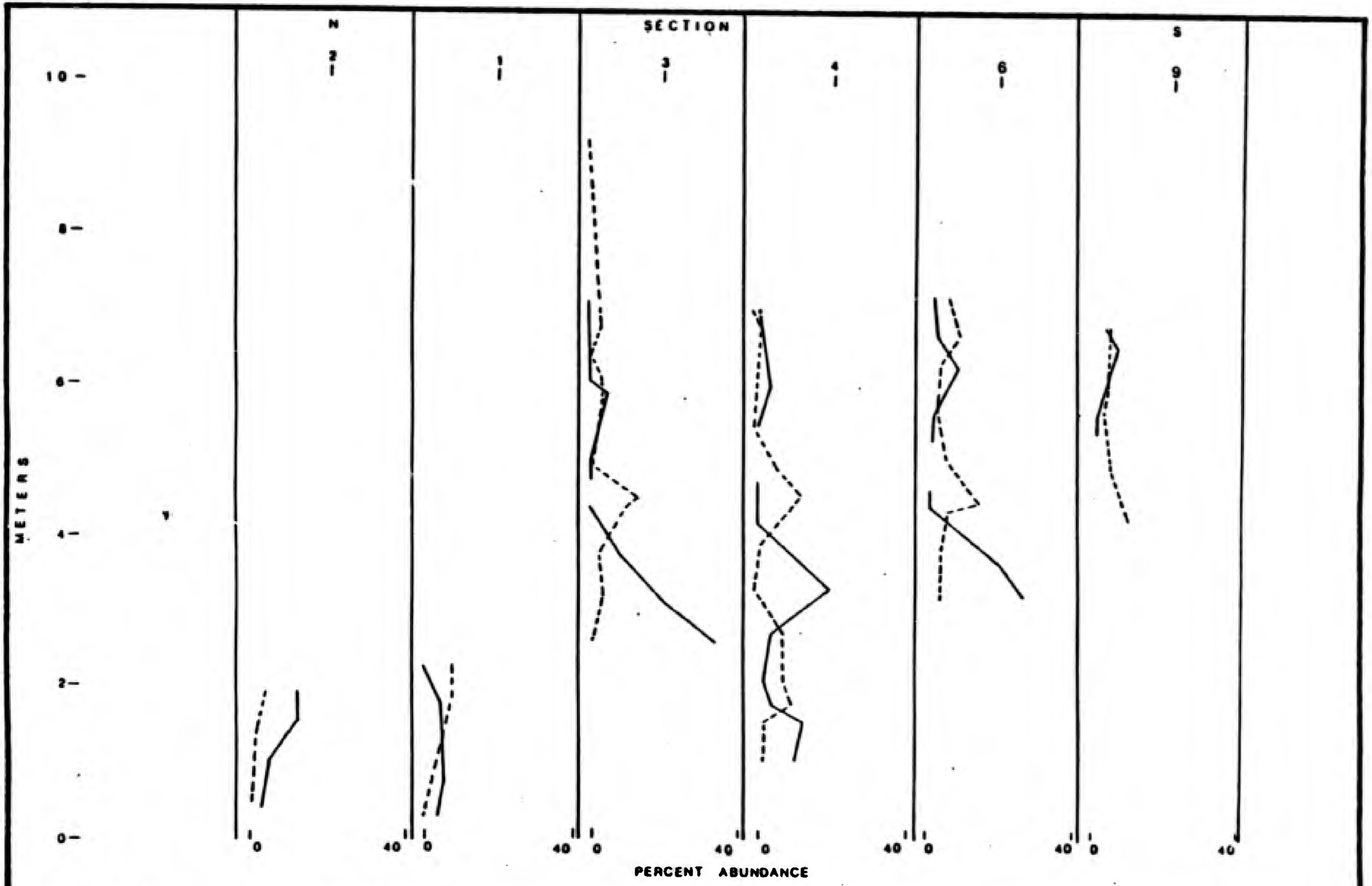


Figure 29 SPECIES. —— CYTHERELLA SPP ---- CYTHERELLOIDEA MONTGOMERYENSIS

Cytherelloidea montgomeryensis is represented by 1431 valves and is the seventh most abundant species at Montgomery Landing. One-third (33.7%) of its valves were recovered from limestone ledge samples.

A mutually exclusive relationship appears to exist between *Cytherella* spp. and *Cytherelloidea montgomeryensis*. These species are never abundant at the same time, and when one becomes vey abundant the other becomes very rare (Figure 29).

Several of the rarer species also reach their peak abundance levels in restricted stratigraphic intervals. *Buntonia morsei* is very rare to absent except in the upper one-third of the section represented by the Yazoo Clay above the uppermost limestone ledge, where it becomes as high as 6.5% relative abundance.

Trachyleberis? grigsbyi is either absent or extremely rare (less than .5%) throughout the entire section except for a half-meter interval of Yazoo Clay midway between the middle and uppermost limestone ledges.

Loxoconcha cocoaensis and *Loxoconcha watervalleyensis* are absent throughout most of the section at Montgomery Landing. In the upper-most limestone ledge, however, they become as high as 8.9% and 7.2% relative abundance, respectively.

As shown by the figures in Tables 34-39 however the majority of species at Montgomery Landing are present throughout the entire marine portion of the section and exhibit diverse abundance patterns. That is, their distribution is quite complex and shows no easily recognizable trends. Because of these complex distribution patterns, it was decided that factor analysis, a multivariate statistical technique, would be used to identify significant trends within this large data base.

Distribution of Ostracoda

Tables 34-39 graphically show the vertical distribution of the species at each stratigraphic section. Tables 34 - 39 list the absolute abundance (the number of specimens recovered), the normalized absolute (the number of specimens recovered per gram), and the relative (proportional) abundance of each species in each sample. These tables are grouped by category and stratigraphic section.

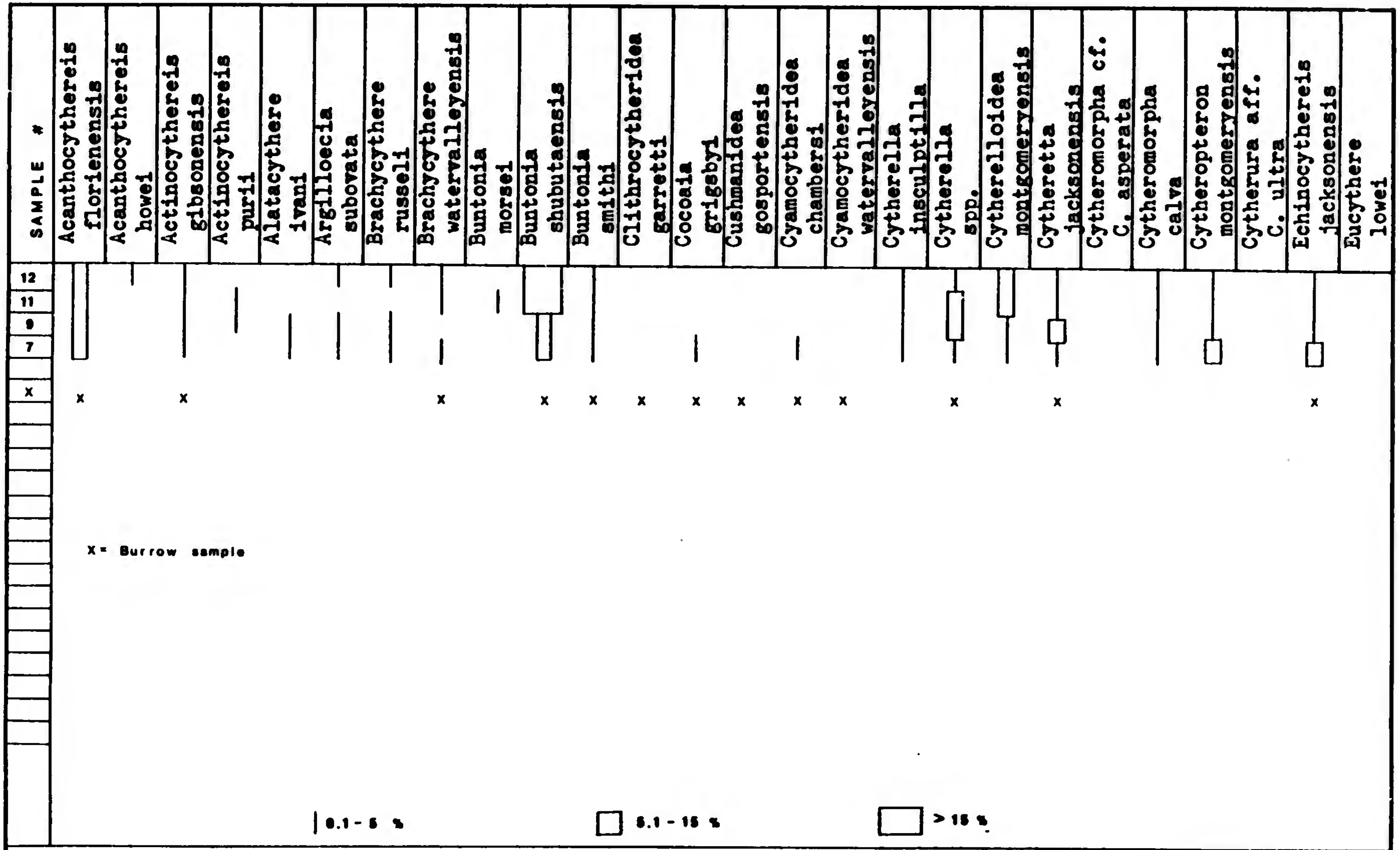


Table . 34 Section One Species Distribution.

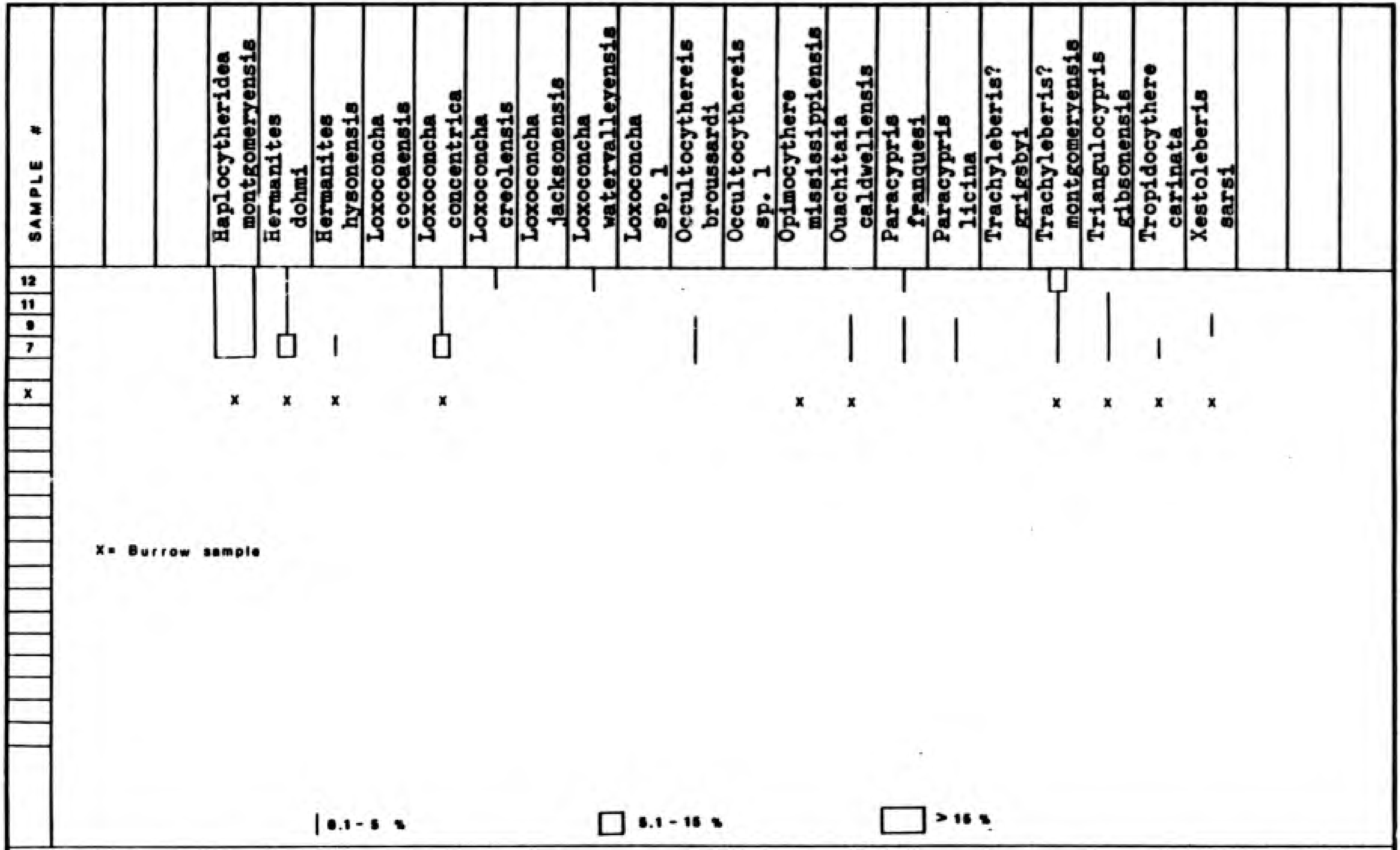


Table 34 (Continued).

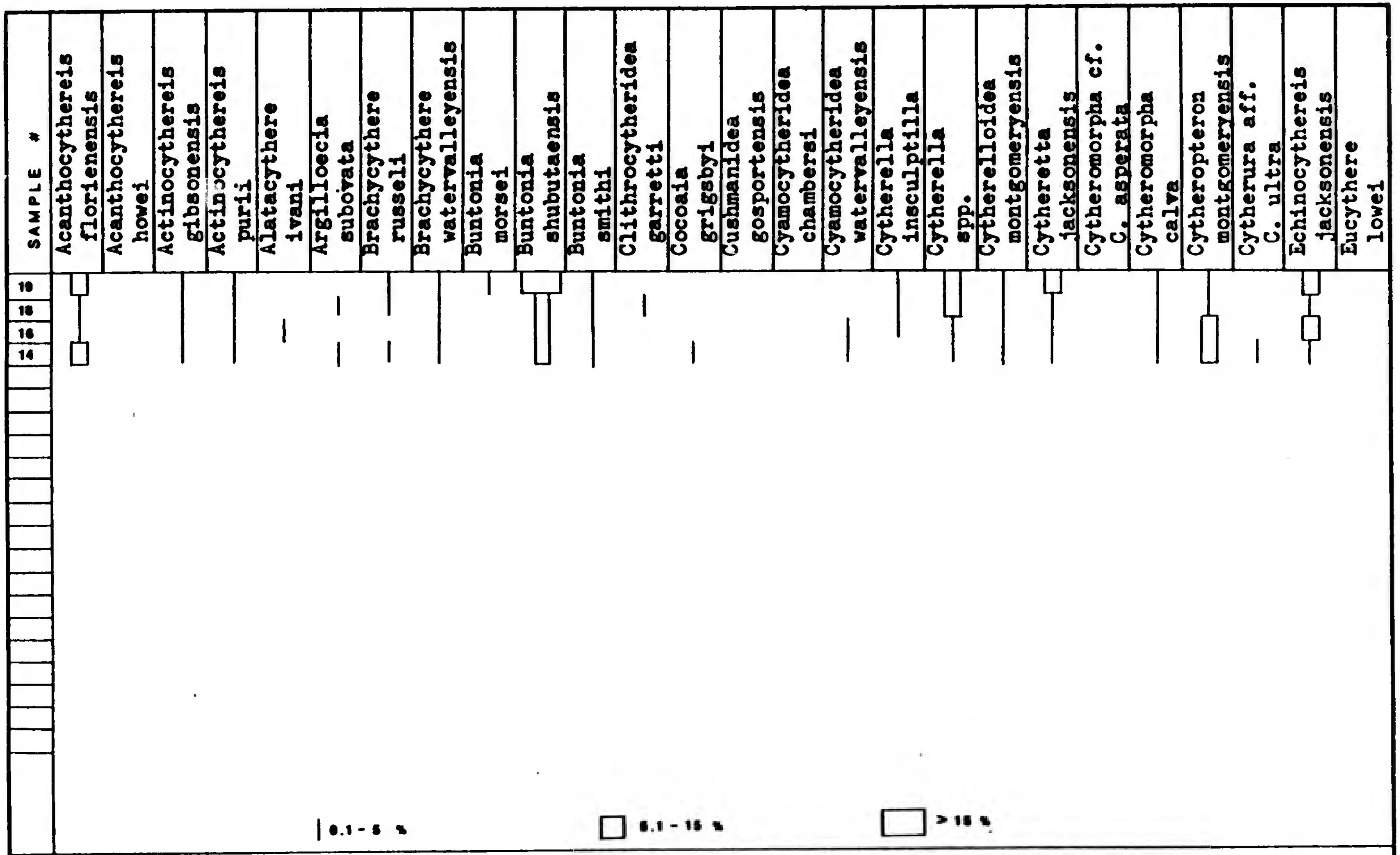


Table 35 Section Two Species Distribution.

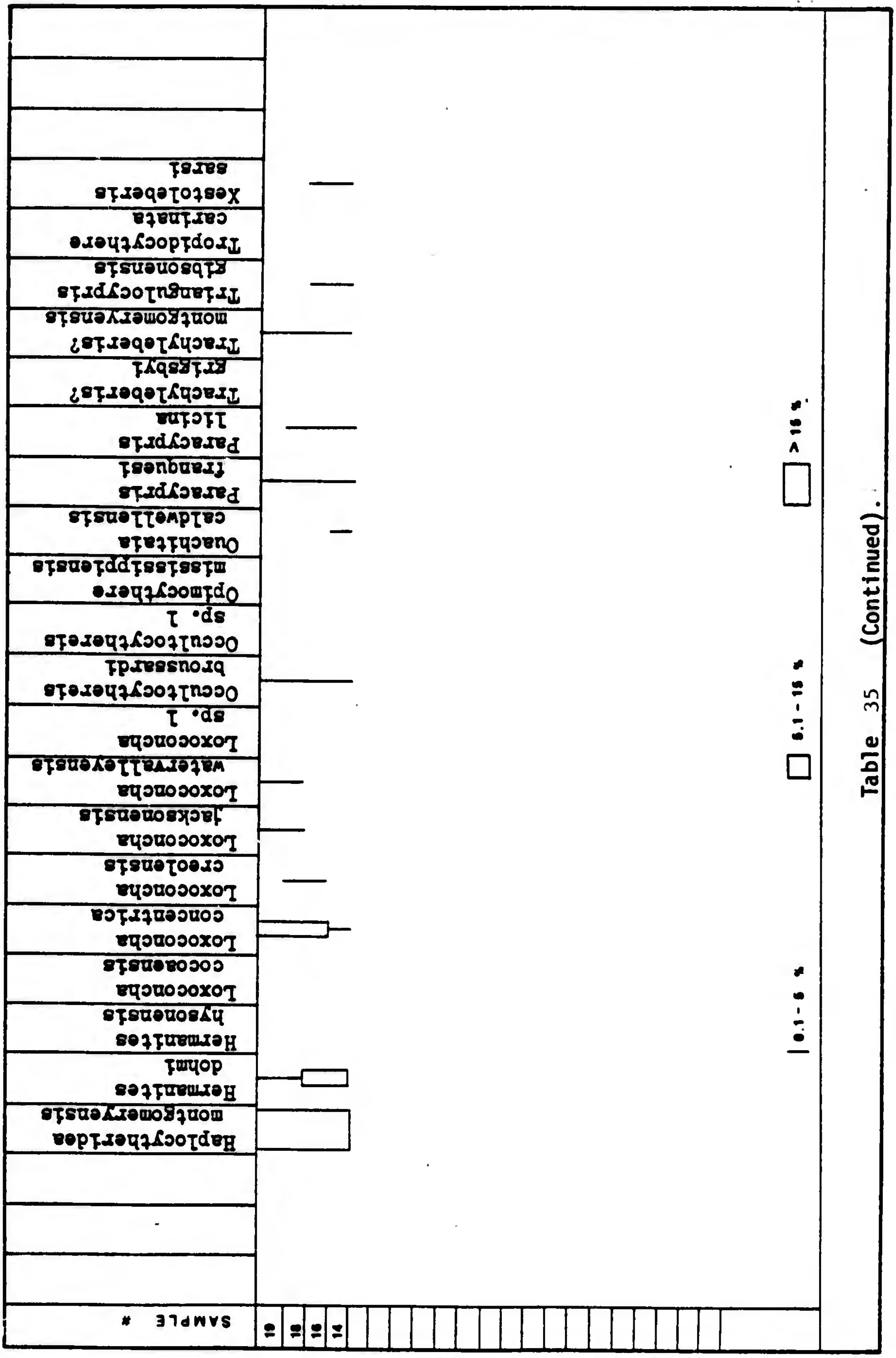


Table 35 (Continued).

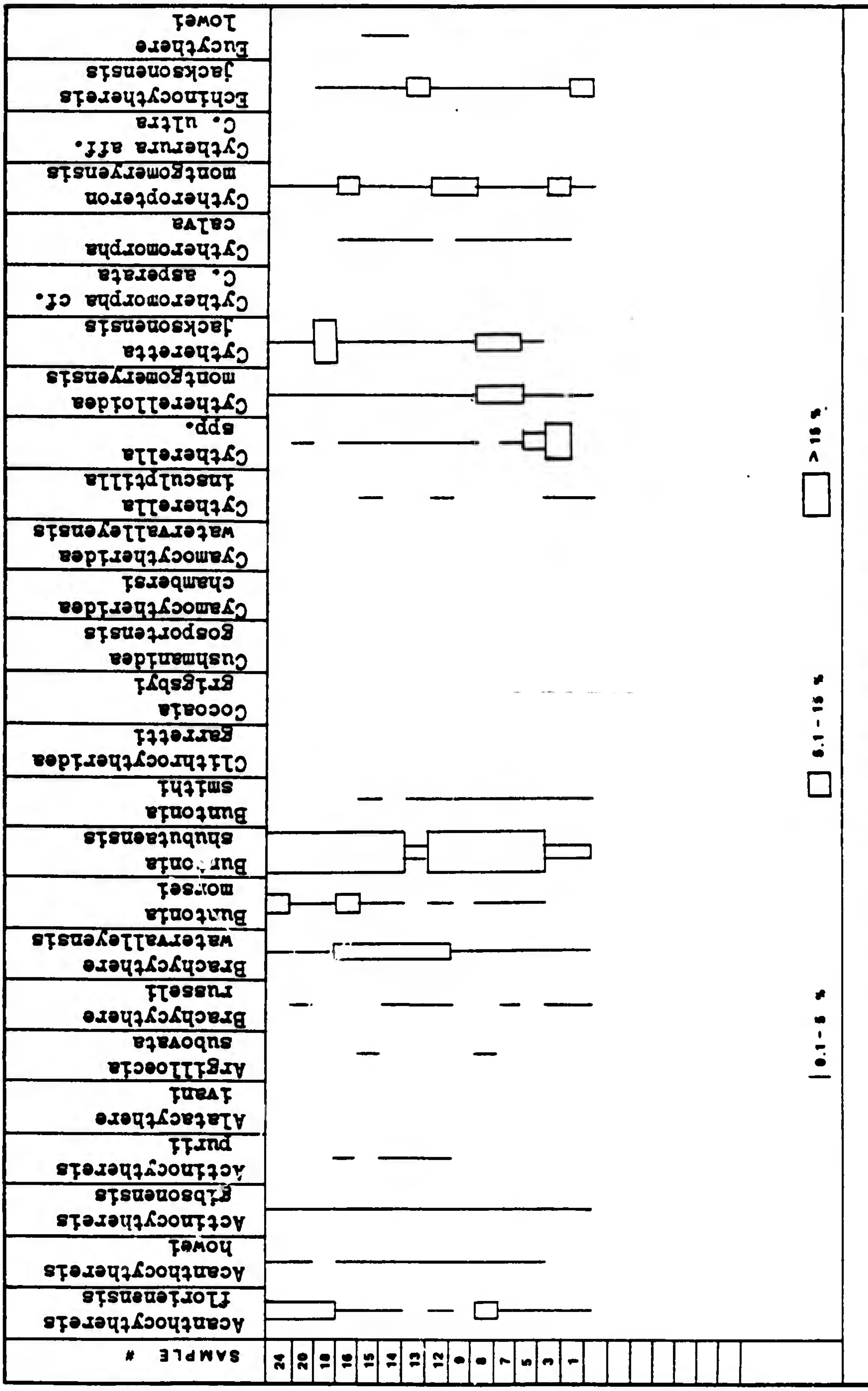


Table 36 Section Three Species Distribution.

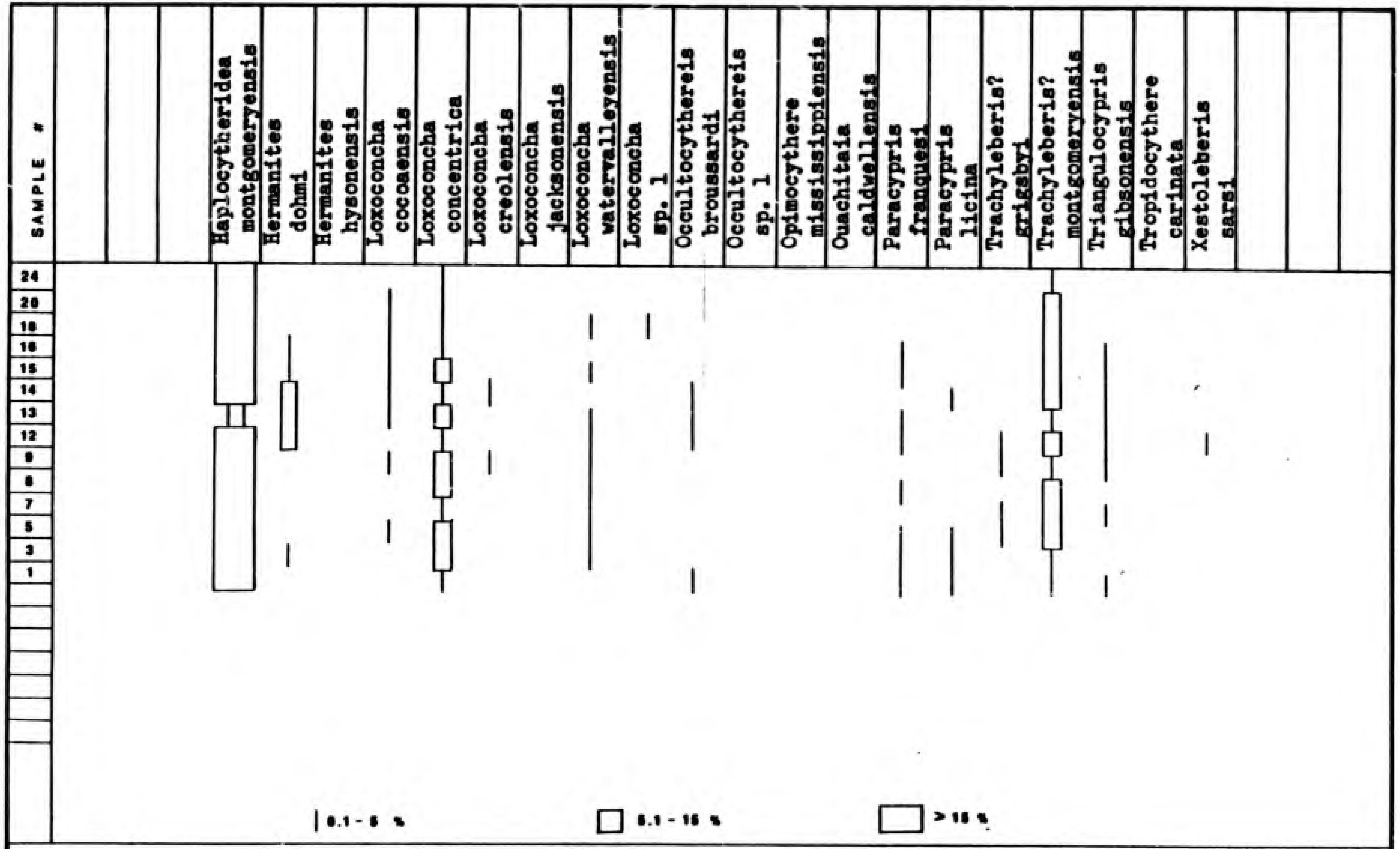


Table 36 · (Continued).

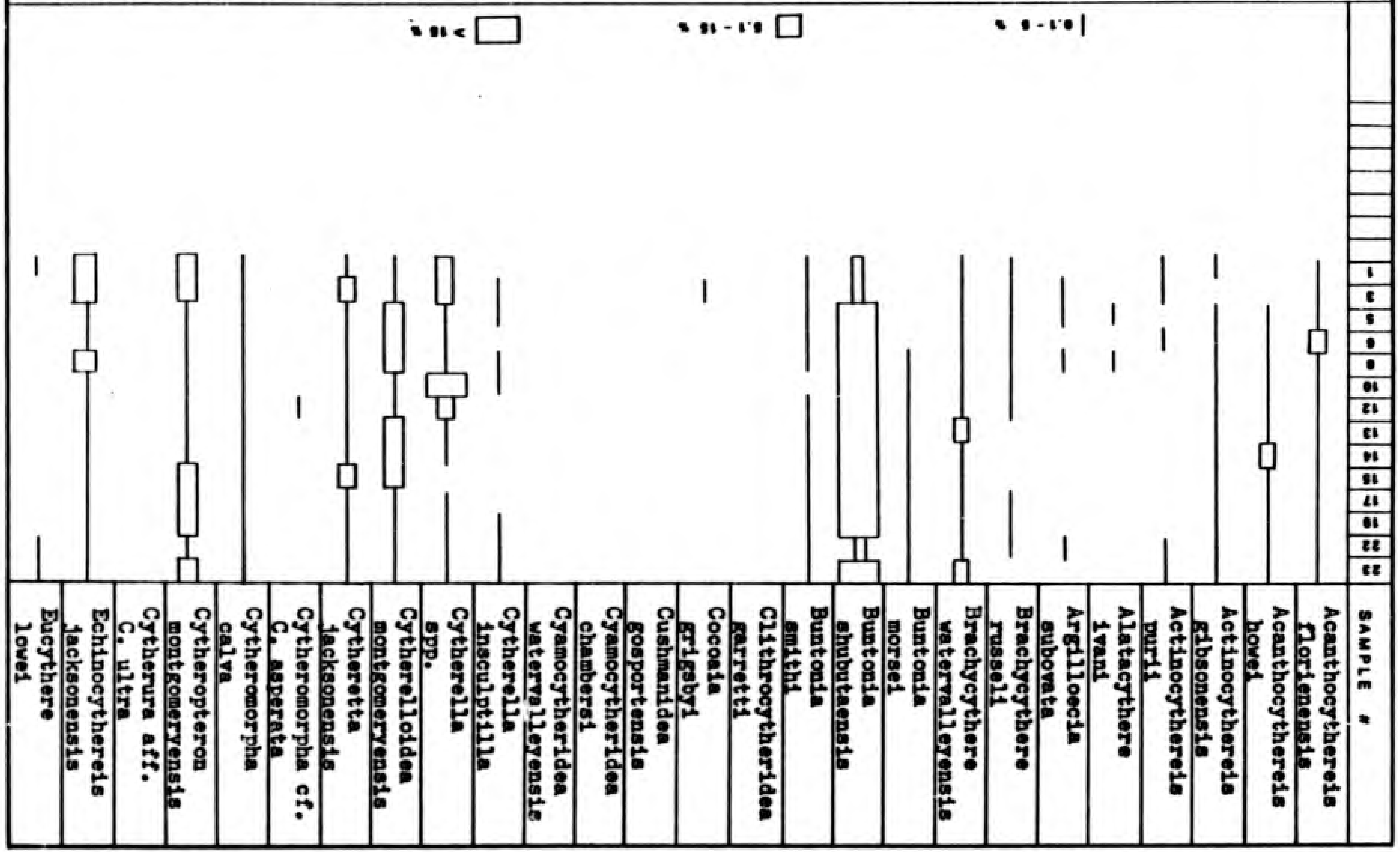


Table 37 Section Four Species Distribution.

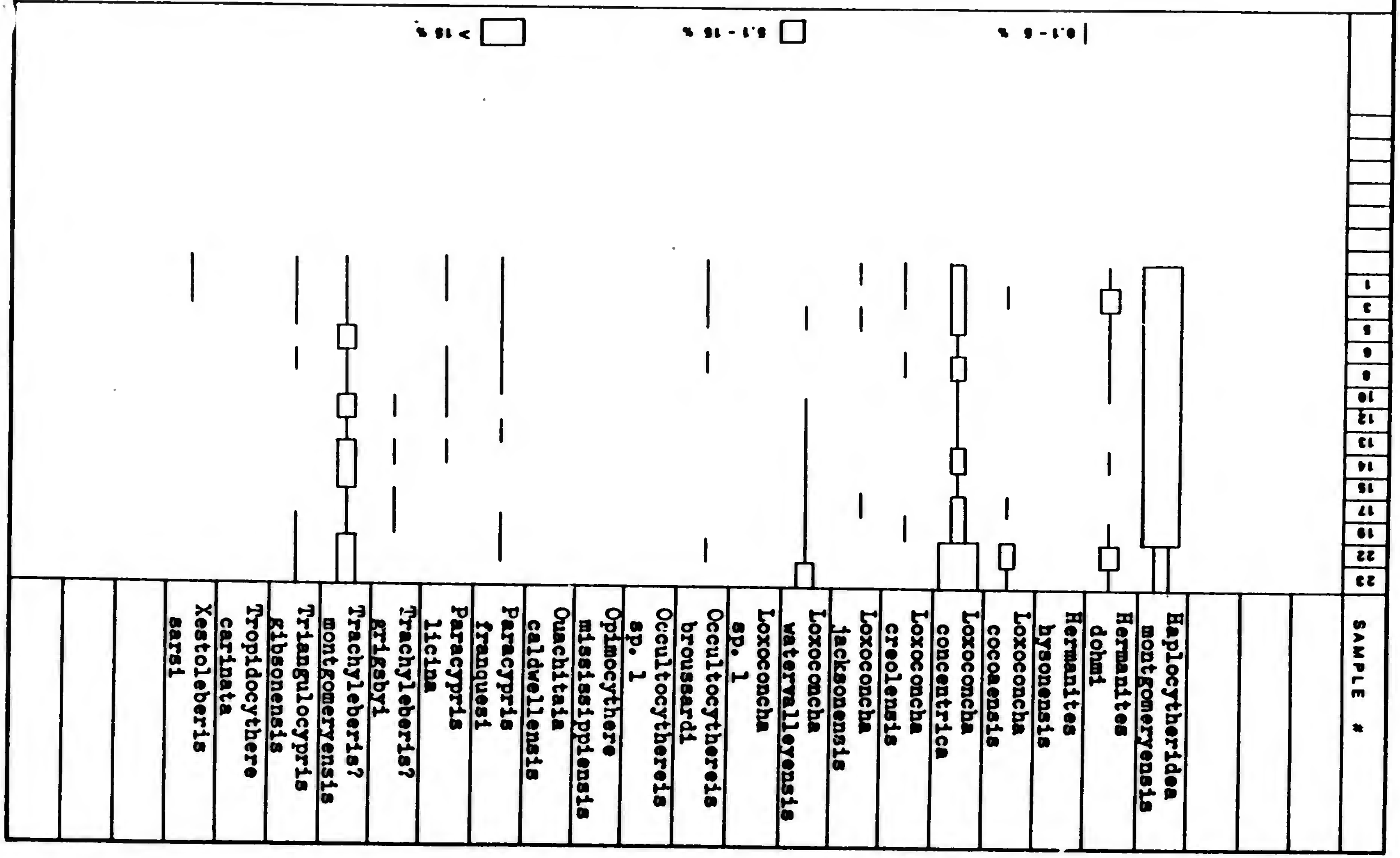


Table 37 (Continued).

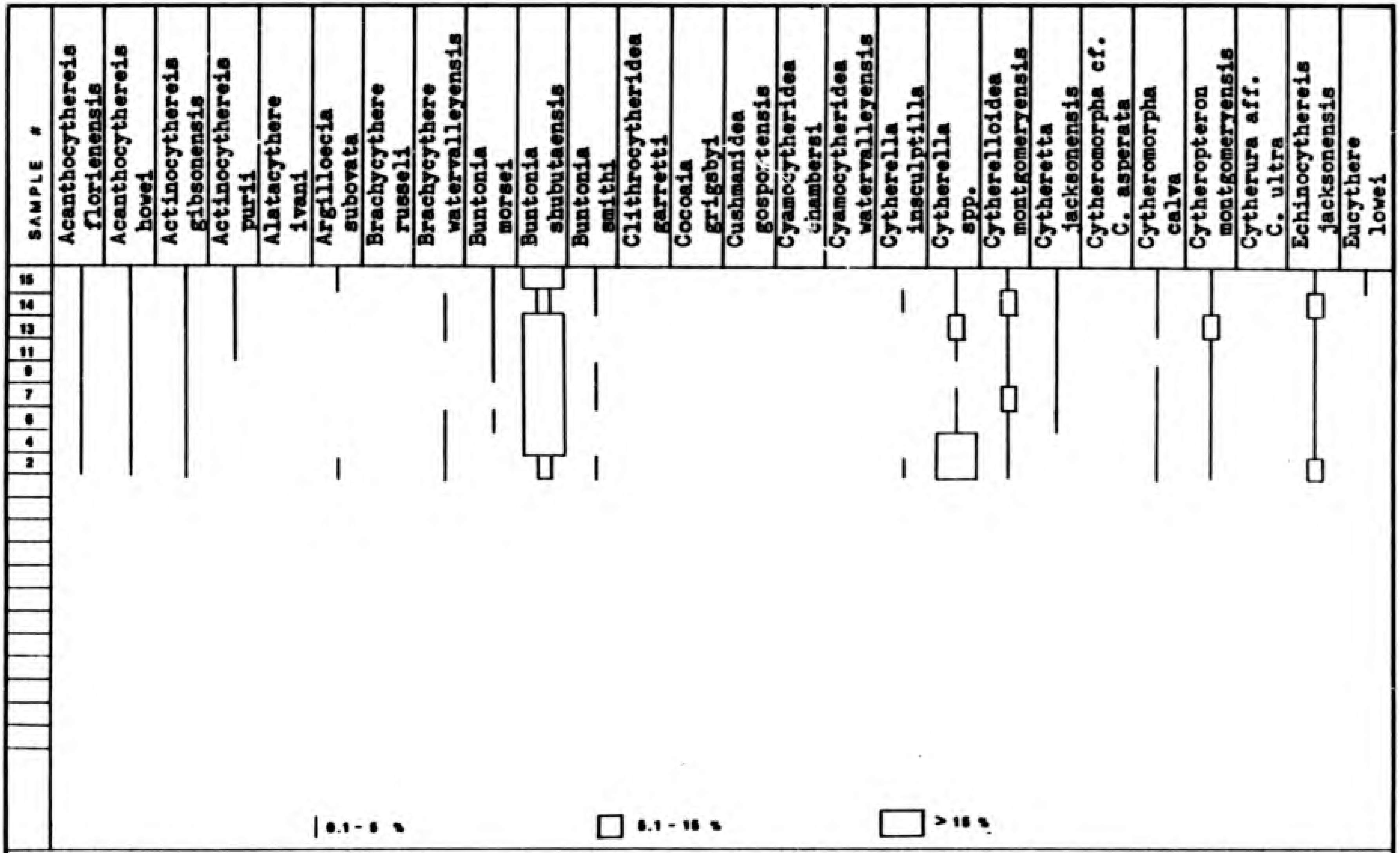


Table 38 Section Six Species Distribution.

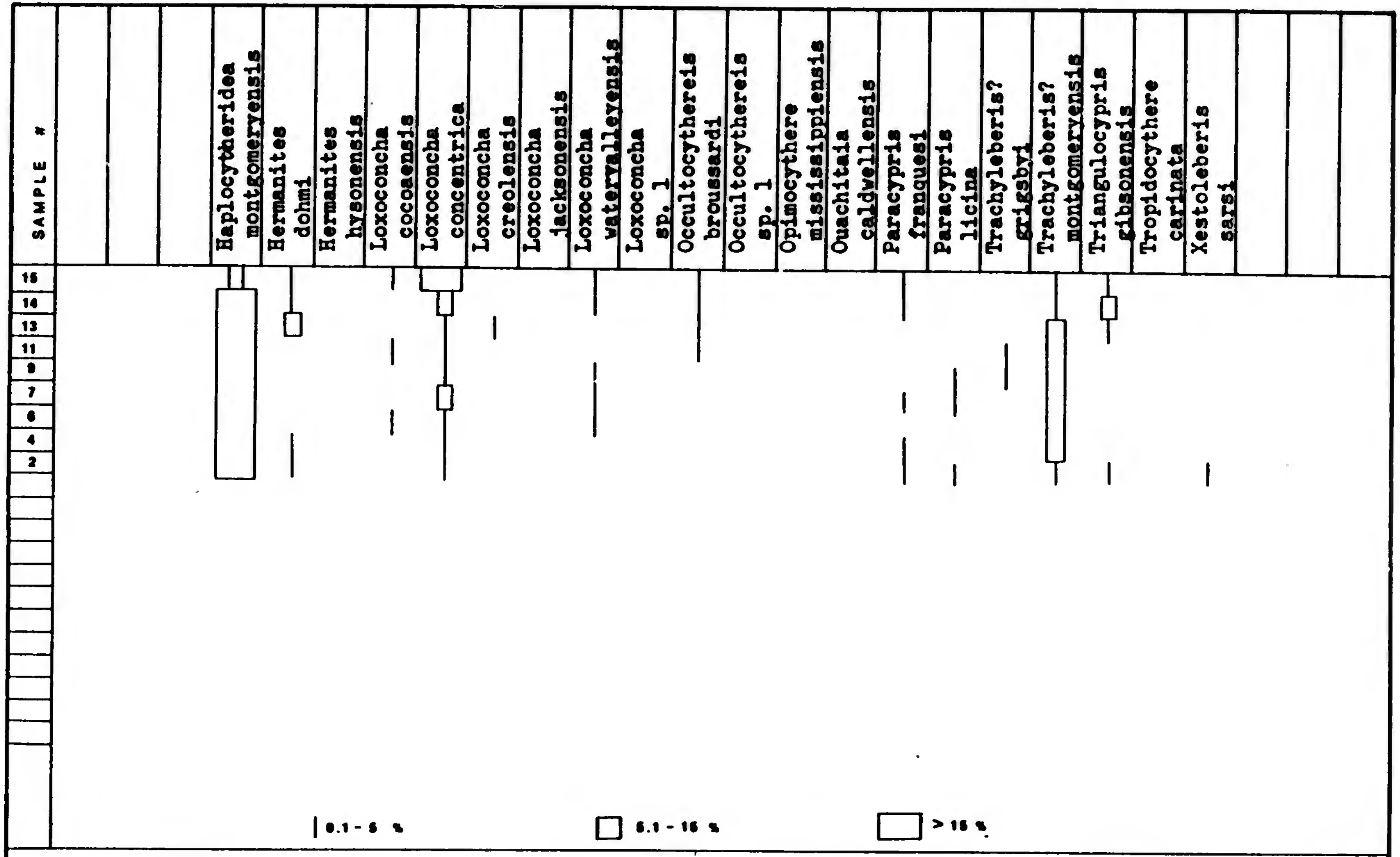


Table 38 (Continued).

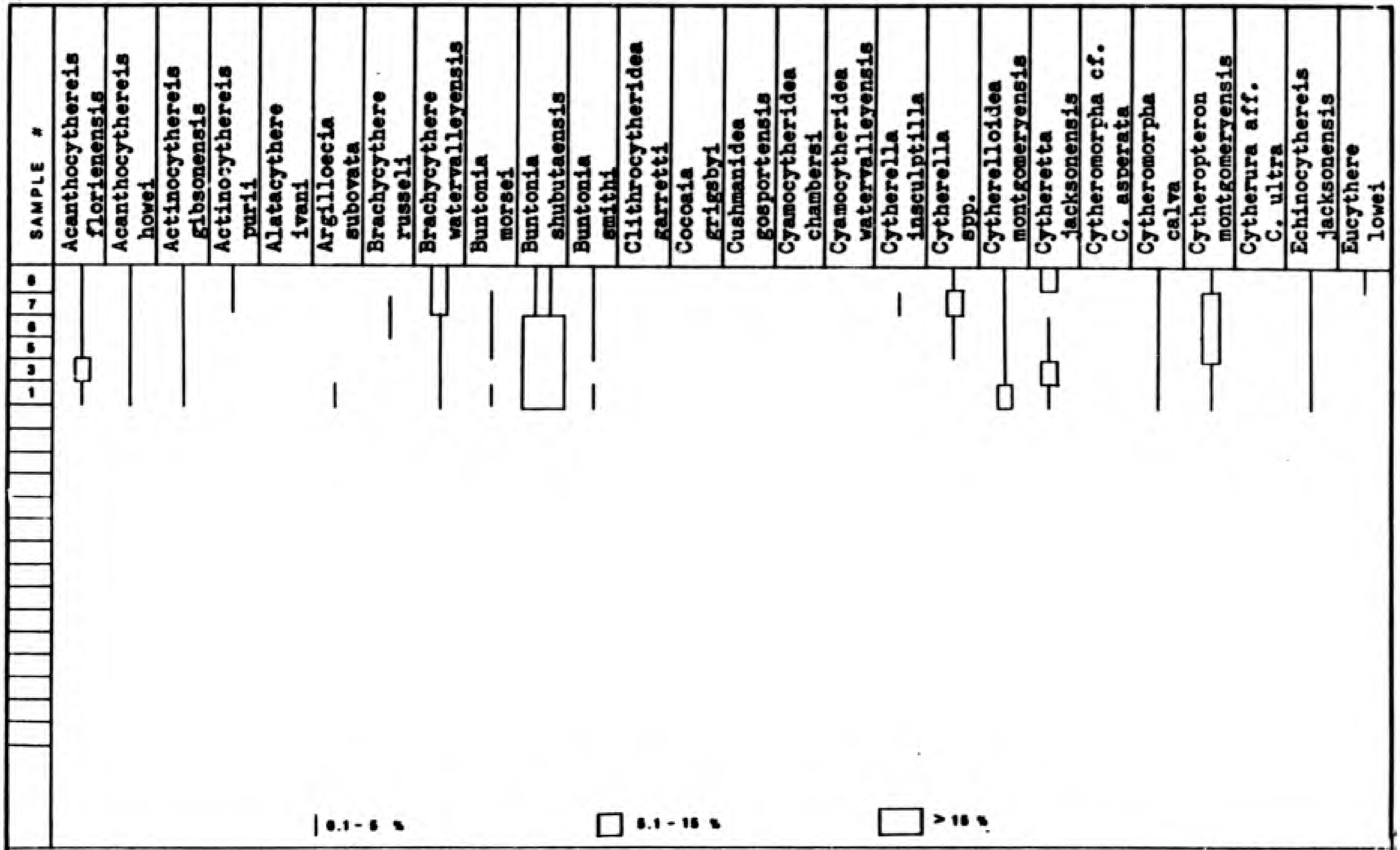


Table 39 Section Nine Species Distribution.

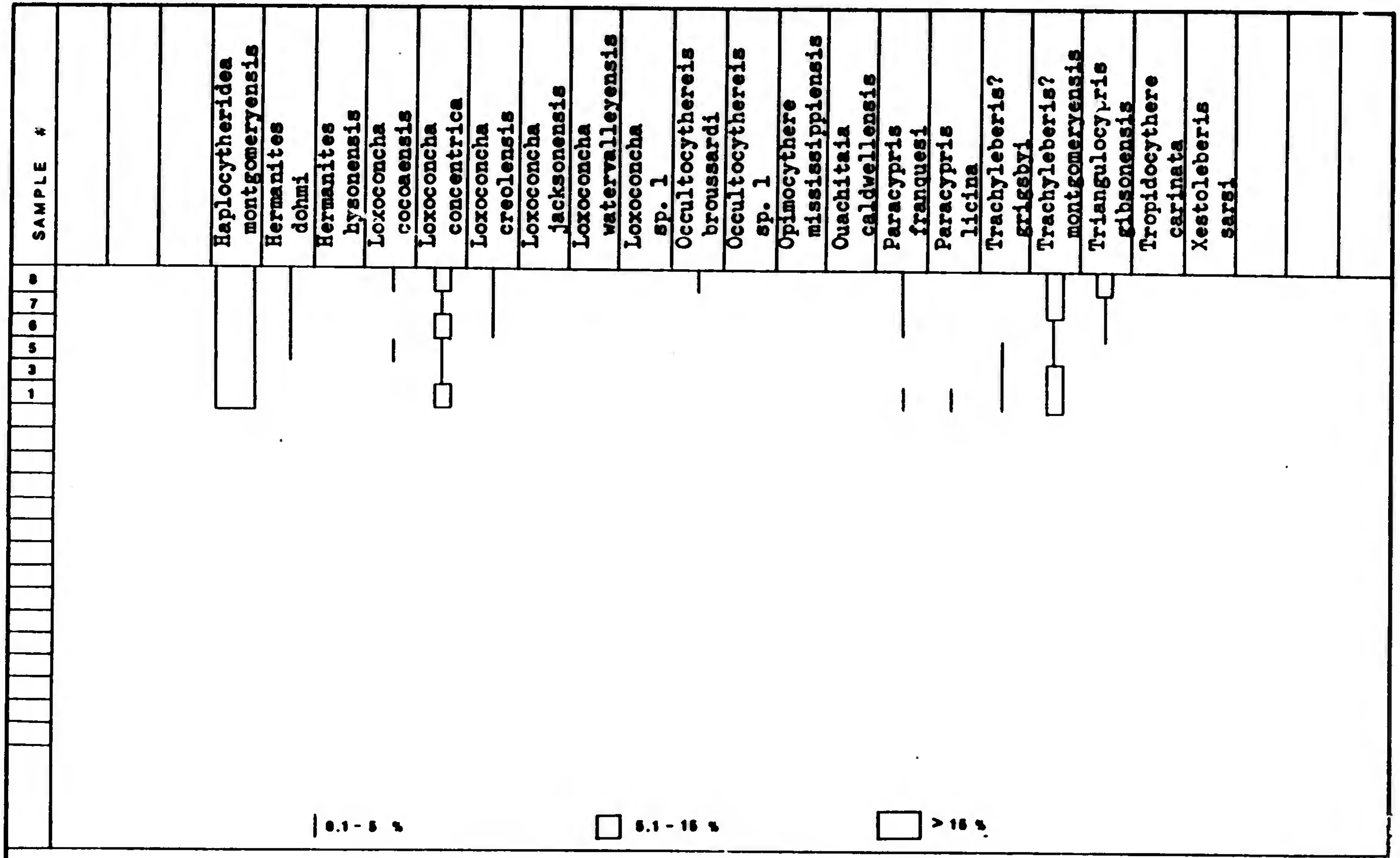


Table 39 (Continued).

Results of the Factor Analysis of Ostracode Species Occurences

Factor Analysis Execution

The factor analyses for this study were run on an IBM 3033 computer. The Q-Mode factor analysis was performed by the CABFAC program (Klovan and Imbrie, 1971; Klovan and Miesch, 1975).

Data Treatment

The option of factoring raw or transformed data has been discussed. During the initial computer runs it became apparent that factoring the raw data resulted in a much "cleaner" factor model with higher communalities and a low number of factors. Factoring the transformed data resulted in a factor model with a greater number of factors and lower communalities. This agrees with the results reported by Imbrie and Kipp (1971).

An examination of the percent abundance data values reveals that the Montgomery Landing ostracode communities are dominated by only few species (most notably Haplocytheridea montgomeryensis and Buntonia shubutaensis), and that the other species occur in low percentages. The cause behind the relationship of data treatment and factor results in a situation such as this may be readily seen in the following example of a two component system.

The relationship between ostracodes and foraminfera from a nearshore sediment will be used as an example. Suppose the foraminifera range from 80% - 90% abundance in these samples and the ostracodes from 0 - 5%. The data are plotted in Figure 27.

Notice that all of the data vectors are constrained to fall within a restricted area (the outline box), which allows for little variance, or spread, between the vectors.

Transforming the data through the percent-range transformation allows both variables to vary between zero and one. The transformed data are also plotted in Figure 30.

The data vectors are no longer constrained and have much larger area within which to fall. This introduces more variance into the model, and is analogous to the statistical noise generated in the percent-range transformation in the Montgomery Landing factor model.

The criteria used for retaining species in the factor model will be discussed in the following section. Briefly, however, use of raw data allowed only six species to be retained in the model, while use of the transformed data allowed the retention of nineteen species. The inclusion of more variables leads to the inclusion of more variance, or noise, in the model. A third source of noise in the transformed data model comes from the fact that the percent-range transformation tends to magnify counting errors (Imbrie and Kipp, 1971).

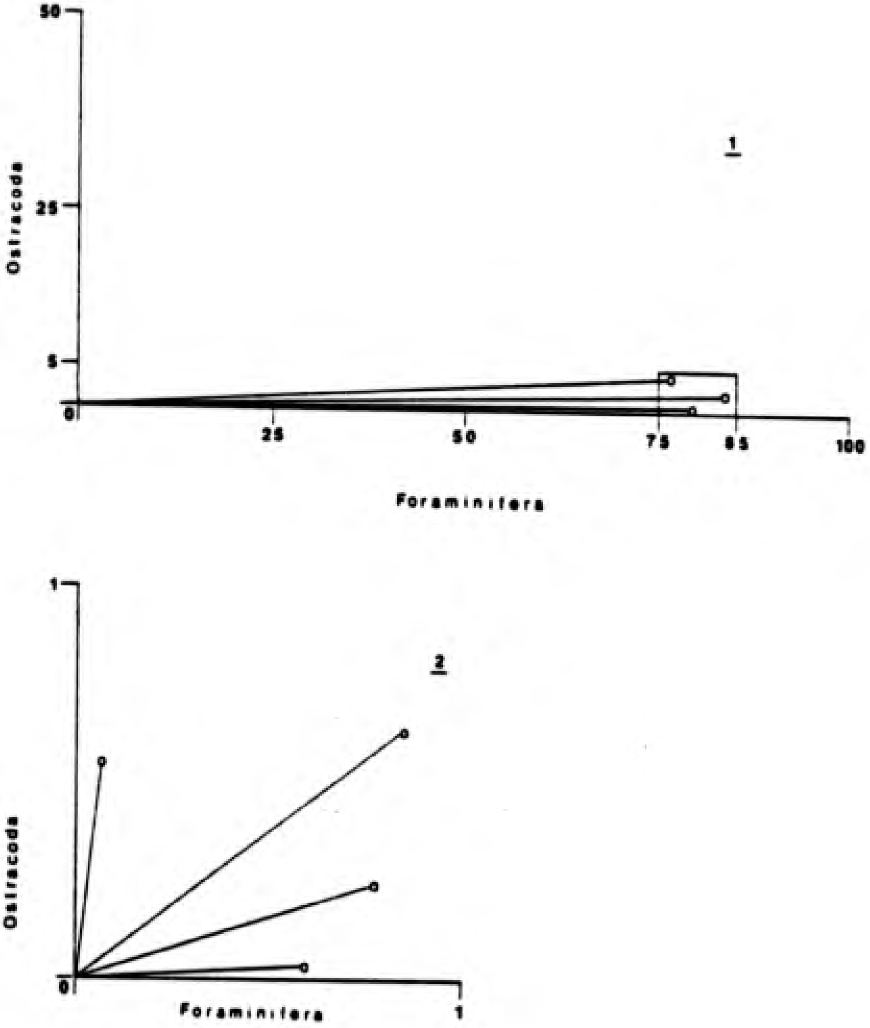


Figure 30 The amount of variance in the factor model was dependent on whether (1) the raw data, or (2) the percent range transformed data, was factored.

The main objective of this project was to conduct a stratigraphic and paleoecologic analysis of the ostracodes at Montgomery Landing and to formulate statistical models for each. Therefore, it was decided to include both data treatment models in the analysis. The "cleaner" raw data factor model was used to formulate a stratigraphic model that could possibly be used in local correlations. This treatment resulted in more pronouced "spikes" on the loading logs which would facilitate correlation. Also, this model includes only the more widespread abundant species which would have a higher probability of being found in any particular sample.

Because the raw data factor model included only six species, it was found to be an insufficient base upon which to make paleoecological conclusions. As previously stated, little is known about the paleoecology of many Montgomery Landing species. Therefore, species assemblages are relied upon heavily for paleoecological interpretations. Thus, the transformed data factor model was used for paleoecological analyses.

By factoring the transformed data, the lead of Imbrie and Kipp (1971) is followed. They, who believed the paleoecological importance of a species is not related to its average abundance. There is no reason to suspect that a species, especially one that occurs consistently, albeit in low percentages, can not be a good paleoecological indicator. In fact, just the opposite may be true. By looking at only the abundant species, the paleoecologist is ignoring much potentially useful data.

This theory was challenged by Schafer and Cole (1976) and Poag (1980), who addressed the question of how much resolution is lost by considering only the abundant species. They concluded "in quantitatively establishing species associations that reflect biotopes, or for paleoecological interpretations, changes in the proportions of the more ubiquitous and abundant species should yield about the same degree of resolution as is obtained using total species data" (Schafer and Cole, 1976). However, these authors were all working with modern benthonic foraminifera about which ecological characteristics are either already understood or in many cases readily measureable.

The theory of Schafer and Cole (1976) is being partially fol-lowed in the Montgomery Landing project. The number of species in the paleoecological model was reduced from 49 to 19. However, this worker believes a further reduction in the number of species would create an insufficient base upon which to make paleoecological conclusions, and therefore chose to conduct this phase of the investigation with the percent-range transformation factor model.

The Biostratigraphic Factor Model

The biostratigraphic model was formulated by factoring the raw untransformed percent abundance data. The twenty-nine species to be included in the initial analysis were selected through the procedure described on p. 338 of this study. These species are listed in Table 40. Due to the set-up of the computer program, the maximum statistical

TABLE 40

SPECIES INCLUDED IN ORIGINAL FACTOR ANALYSIS

Acanthocythereis florienensis
Acanthocythereis howei
Actinocythereis gibsonensis
Actinocythereis purii
Brachycythere russeli
Brachycythere watervalleyensis
Buntonia morsei
Buntonia shubutaensis
Buntonia smithi
Cocoaia grigsbyi
Cytherella insculptilla
Cytherella spp.
Cytherelloidea montgomeryensis
Cytheretta jacksonensis
Cytheromorpha calva
Cytheropteron montgomeryensis
Echinocythereis jacksonensis
Haplocytheridea montgomeryensis
Hermanites dohmi
Loxoconcha cocoaensis
Loxoconcha concentrica
Loxoconcha watervalleyensis
Occultocythereis broussardi
Ouachitaia caldwellensis
Paracypris franquesi
Paracypris licina
Trachyleberis? grigsbyi
Trachyleberis? montgomeryensis
Triangulocypris gibsonensis

information is extracted when the data matrix is composed of constant row-sums. Therefore, it was necessary to define a thirtieth variable (called "others"), which equals the difference between 100% and the row-sum of the sample. Thus, a data matrix of 30 species and 52 samples with constant row-sums (100%) was created.

As has been discussed, these are too many variables to be optimally included in the analysis. Therefore, the first computer run was used to discard those variables not being adequately explained by the factor model. Their distribution patterns are thus regarded as statistical noise and not correlative to any biofacies defined by the analysis. The coefficients of determination (r2) were used to delineate the important variables in the analysis. The factor model was examined and the number of factors to be retained in the model chosen. It was decided that all variables with r^2 values greater than .50 for the m-factor model would be retained. In other words, these species had greater than 50% of their original variance accounted for by the factor model.

The factor analysis results are compiled in Kilmartin (1981). This clearly is a four factor solution. There is a large drop in eigen values (hence the amount of variance explained) between the fourth and fifth factors. Also, the fourth factor contains many high factor loadings while the fifth factor contains none. Note that over 95% of the original variance is accounted for in these four factors.

For the four factor model only six species have r^2 values greater then .50. It is these species that will be considered in subsequent analyses. They are:

	r^2
Brachycythere russelli	.8181
Buntonia shubutaensis	.8705
Cytherella spp	.9796
Echinocythereis jacksonensis	.5110
Haplocytheridea montgomeryensis	.9054
Loxoconcha concentrica	.8336

As explained previously, a seventh variable ("others") was created to fulfill the requirement of constant row-sums. These seven variables form the basis of the factor analysis investigation of raw, untransformed data, or the stratigraphic model. The Q-mode factor analysis was the re-run using only these seven variables.

The principal factor loadings, eigen values and variance values are combined in tables that are kept on open file. The results, especially the varimax factor matrix, clearly indicates a four factor solution. From the composition score matrix the following results are obtained:

a. Factor 1 is the Haplocytheridea montgomeryensis factor;
b. Factor 2 is a combination of Echinocythereis jacksonensis, Loxoconcha concentrica, and the "others" variable;
c. Factor 3 is a combination of Cytherella sp. and Brachycythere russelli;
d. Factor 4 is the Buntonia shubutaensis factor.

It thus appears that factor analysis may be a promising biostratigraphic tool. Complex relationships in large faunal assemblages may be simplified and pictured in several loadings-logs that can be correlated in the same manner as electric logs.

The local usefulness of this method is now documented at Montgomery Landing. If the limestone ledges were absent, or obscure, because of slump or erosion, a precise lithostratgraphic subdivision would not be possible. The factor model, though, would still have produced the same correlations on the same scale (centimeters).

Factor stratigraphy should be a powerful tool in areas consisting of only small, isolated outcrops. Correlation may be possible on a scale equal to that of continuous, well-exposed areas. The potential use of factor stratigraphy in subsurface correlation is quite obvious.

The local versus regional potential of factor stratigraphy is not known. As the model defines biofacies, it apparently would not be useful over a large distance in an up- or down-dip direction as facies change rapidly in these directions. However, this model could be useful over large horizontal distances along strike where facies are more consistent. The Jacksonian sediments of the Gulf Coast, which out-crop in a band from Florida to Texas, are offered as excellent future "testing ground" for this hypothesis.

When the varimax loadings of the four factors are plotted together with the abundance values of their respective species, an interesting trend develops. Because only a few species are included in the analysis a one-to-one relationship develops between the percent abundance values and the factor loadings. For example, since Factor 1 is composed almost entirely of Haplocytheridea montgomeryensis the varimax loadings produce a pattern nearly identical to the species abundance values. The same is true for Factor 2 and Loxoconcha concentrica, Factor 3 and Cytherella spp., and Factor 4 and Buntonia shubutaensis. Echinocythereis jacksonensis, which is an important constituent of several factors, does not exhibit this trend.

The implication behind these relationships is clear. To develop a dependable stratigraphic tool based upon the Montgomery Landing ostracode fauna one needs only to work with the percent abundance data of four species. A factor analysis of these data is not necessary and will not increase the useful information.

This relationship exists because of the dominance of only a few species. As there are no other studies reporting the percent abundance values of these species at any other Gulf Coast Tertiary localities it is not known if this relationship exists elsewhere. Therefore, it must be emphasized that this stratigraphic model is at present applicable only to the Montgomery Landing outcrop.

In conclusion, then, the biostratigraphic factor analysis model has factored the raw percent abundance data of Montgomery Landing ostracode species and computed a four-factor mode. This model employs six species found to be statistically the most significant in the analysis and accounts for over 99% of the original variance of these species.

The varimax factor loadings of the raw, untransformed data are excellent correlative measures. Plots of the varimax loadings and percent abundance values for the species, however, reveal four species whose abundance proportions alone produce excellent correlative measures. These are Haplocytheridea montgomreyensis, Buntonia shubutaensis, Cytherella spp., and Loxoconcha concentrica.

An advantage to correlation based on proportions data alone is that the worker need not have access to a computer to perform correlations. Also, since this is a stratigraphical model only, the rarer species do not need to be counted, and the identification of 300 specimens per sample is not so critical. The four species in the model are common species and should be abundant even in small samples. The relatively rare Brachycythere russelli may not be found in small samples, so is not a good species upon which to base correlations.

It is not known whether these same abundance patterns occur in other Moodys Branch and lower Yazoo Clay beds. A quantitative systematic study of other localities would establish the regional usefulness of these patterns as opposed to their proven local value at Montgomery Landing.

The Paleoecological Factor Model

The paleoecological factor model was formulated by factoring the percent-range transformed data. As previously discussed, this has the effect of making abundant and rare species equally important in the analysis.

The twenty-nine species to be included in the initial analysis were the same as those used in the stratigraphic model. Again, a thirtieth variable ("others") was created to satisfy the requirement of constant row sums.

The transformed-data paleoecological factor analysis results in a six factor model. This is indicated by the relatively sharp drop-off in eigenvalues and amount of variance accounted for between the sixth and seventh factors. By using r^2 minimum value of .05, nineteen species have a significant amount of their variance accounted for by the factor model. These species are listed in Table 41.

The paleoecological factor model is not as "clean" as the stratigraphic model. This is the result of the statistical noise generated by the data transformation. Six factors are retained in the model, but they account for less variance than the four factors of the raw data model. Also, the seventh factor has high loadings for S3N09 (.4509), S3N15 (.4110), and S4N23 (.6439), although this alone does not warrant inclusion of the seventh factor in the model.

TABLE 41

SPECIES INCLUDED IN FACTOR ANALYSIS: PALEOECOLOGICAL MODEL

Acanthocythereis florienensis
Acanthocythereis howei
Actinocythereis gibsonensis
Actinocythereis purii
Brachycythere russeli
Brachycythere watervalleyensis
Buntonia shubutaensis
Buntonia smith
Cytherella spp.
Cytherelloidea montgomeryensis
Cytheropteron montgomeryensis
Echinocythereis jacksonensis
Haplocytheridea montgomeryensis
Hermanites dohmi
Loxoconcha concentrica
Occultocythereis broussardi
Paracypris franquesi
Triangulocypris gibsonensis
Trachyleberis? montgomeryensis

The twenty variables (nineteen species + "others") were then used as the new data for the paleoecological factor model. Again a six factor solution is indicated.

In review, the factor analysis has created new variables (the factors) through the linear combination of samples with similar ostracode compositions. Assuming similar faunas are indicative of similar environments, each factor then represents a biofacies. As the factor analysis operates on proportional data. similar assemblages (in a presence / absence sense) with significantly different specific proportions will be placed in separate biofacies. The factor analysis has delineated six biofacies that account for 29.6% of the original data's variance.

The communalities, or proportions of variance accounted for in each sample by the factor model, range from a low of .7790 (S4N23) to a high of .9700 (S3N14), with a mean value of .8958. These values are quite good, although not as high as the raw data factor model. Again, this is due to the statistical noise generated by the percent-range transformation.

Table 42 lists the composition of the six biofacies as revealed by examination of the composition scores matrix. Note that several of the assemblages sum to greater than 100%. This is a result of the negative composition scores of some variables. While a negative composition score may at first appear dubious, one must realize that the factors are representing idealized, theoretical samples. That is, a negative score indicates a variable is not a component of that biofacies, and to approximate that end-member, this variable would have to be subtracted from the sample. Miesch (1976) discussed the meaning and interpretation of negative composition scores. It is believed that for the purpose of this investigation they are perfectly acceptable.

The next step was the assignment of samples to biofacies. As prevously discussed, this was accomplished through investigation of the varimax matrix. High loadings indicate a sample to be a component of a factor. The six biofacies and their constituent samples are listed in Table 43.

Note that most samples fall into one category only. Several samples, however, have high loadings for more than one factor, or they have no high loadings for a factor, but several equally low loadings on more than one factor. These must be characterized as "transitional" samples, exhibiting the characteristics of more than one biofacies.

Figure 31 shows the stratigraphic distribution of the biofacies. There is good correlation between sections. By combining the stratigraphic occurrence of biofacies with their constituent species it becomes apparent that the factor analysis has segregated the two fossil-bearing formations at Montgomery Landing based solely on ostracode-distribution data. All eight Moodys Branch samples have been included in the same factor (Biofacies 5), that includes no Yazoo Clay samples. Similarly, no Moodys Branch samples are included in any other factor. Therefore, Factor 5 represents Moodys Branch, or "greensand" biofacies.

TABLE 42

BIOFACIES ASSEMBLAGES AND COMPOSITION SCORES

SPECIES	%
BIOFACIES 1	
Haplocytheridea montgomeryensis	66
Buntonia shubutaensis	22
Cytheropteron montgomeryensis	7
Acanthocythereis howei	6
BIOFACIES 2	
Cytherella spp.	65
Buntonia shubutaensis	14
Echinocythereis jacksonensis	14
Actinocythereis gibsonensis	12
Digmocythere russeli	10
BIOFACIES 3	
Brachycythere watervalleyensis	40
Hermanites dohmi	36
Trachyleberis? montgomeryensis	34
Triangulocypris gibsonensis	25
Echinocythereis jacksonensis	16
Actinocythereis purii	14
Acanthocythereis howei	10
Occultocythereis broussardi	7
Cytheropteron montgomeryensis	6
BIOFACIES 4	
Buntonia shubutaensis	45
Acanthocythereis florienensis	24

TABLE 42 cont.

SPECIES	%
BIOFACIES 5	
Haplocytheridea montgomeryensis	39
Cytheropteron montgomeryensis	9
Hermanites dohmi	7
Echinocythereis jacksonensis	6
Acanthocythereis florienensis	5
BIOFACIES 6	
Loxoconcha concentrica	84
Cytherelloidea montgomeryensis	56
Buntonia shubutaensis	17
Buntonia smithi	14
Paracypris franquesi	5
Acanthocythereis howei	4

TABLE 43

ASSIGNMENT OF SAMPLES TO BIOFACIES

BIOFACIES

1	2	3	4	5	6
S3N05	S3N01	S3N12	S1N11	S1N07	S3N08
S3N07	S3N03	S3N13	S1N12	S1N09	S4N05
S3N09	S4N08	S3N14	S2N19	S2N14	S6N07
S3N15	S4N10	S3N15	S3N18	S2N16	S6N15
S3N16	S6N02	S3N16	S3N20	S2N18	S9N01
S3N24	S6N04	S4N22	S3N24	S4N01	
S4N12		S4N23	S4N06	S4N03	
S4N13				S4N33	
S4N14					
S4N15					
S4N17					
S4N19					
S6N06					
S6N09					
S6N11					
S6N13					
S9N01					
S9N03					
S9N05					
S9N06					
S9N07					

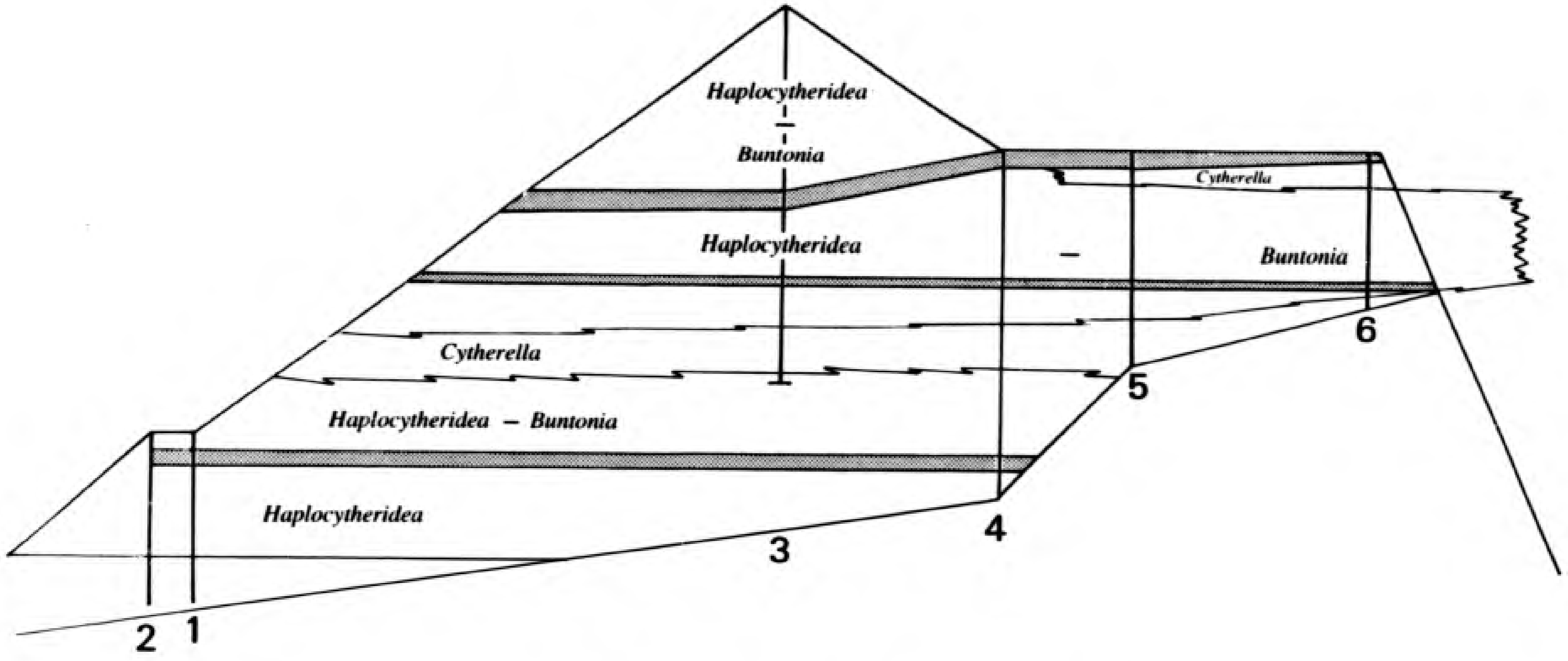


FIG. 31. Distribution of ostracode biofacies at Montgomery Landing.

As previously discussed, the contact between the Moodys Branch and Yazoo Clay is gradational. At Montgomery Landing there has been confusion as to the placement of the contact. Some workers place it at the bottom of the first ledge, while others place it at the top of the ledge. The results of this factor analysis suggest the lower ledge should be placed within the Yazoo Clay and the Moodys Branch should be restricted to the sediments below the ledge.

The Relationship Between Biofacies and Paleobathymetry

1. Biofacies 5: The greensand facies.

As discussed, biofacies 5 is related to the greensand facies. Every Moodys Branch sample is included in this biofacies and every Yazoo Clay sample is excluded. The Moodys Branch Formation at Montgomery Landing was deposited in water depths of 30 - 60 feet. Therefore, biofacies 5 represents an inner neritic, open - marine, shallow water assemblage.

The very near shore, high energy environment of the Moodys Branch has not been preserved at Montgomery. The Ophiomorpha burrows, however, are remnants of this environment as they formed in waters probably less than 20 feet deep. The sediment filling these burrows, then, has also been deposited in the near shore environment. A burrow sample from Section 1 taken 1.9 meters below the Moodys Branch-Cockfield was examined for ostracodes. No statistical tests were conducted as only 145 specimens were recovered, but it seems quite apparent that this assemblage is different from samples S1N07 or S2N14, which are basal Moodys Branch samples taken immediately above the contact.

The burrow sample contains higher proportions of the species Ouachitaia caldwellensis, Clithrocytheridea garreti, Cocoaia grigsbyi, Cyamocytheridea watervalleyensis, Tropidocythere carinata, and Opimocythere mississippiensis than the basal Moodys Branch samples (Figure 25). This is due to the reworking of the basal samples by wave turbulance and bioturbation which mixed near shore and off-shore deposits. Therefore, the burrow samples are better representatives of the near shore environment than the basal samples above the contact, which are more indicative of the inner neritic environment.

As only one burrow sample was collected it was not included in the factor analysis. It is suggested, however, that if sufficient samples had been collected another factor composed only of burrow samples representing the near shore environment would have been created by the analysis.

The seven species listed above do not occur in the muddy facies of the Yazoo Clay of Louisiana and central Mississippi. Huff (1970) reports these species as being common to abundant in the Cocoa Sand of southeast Mississippi, which is a sandier facies of the Yazoo Clay stratigraphically equivalent to the Verda member of Louisiana. Krutak (1961) reports these species as occurring in the Cocoa Sand of Alabama.

Therefore, it appears that substrate type is the major ecological factor controlling the distribution of these species as they occur only in the sandier substrate environments.

The Moodys Branch sediment was deposited on a shallow marine shelf characterized by very slow sedimentation rates (Fisher, 1970). The water was probably very clear. The abundant coral fauna of the Moodys Branch seem to substantiate this observation. It is possible that water turbidity may also have been an important ecological variable, although this is probably related to the type of sediment being deposited, and therefore to the substrate type.

2. Biofacies 4: The *Buntonia* facies.

This facies represents both the basal and uppermost sequences of Yazoo Clay exposed at Montgomery. The dominant species in this biofacies is *Buntonia shubutaensis*. As discussed, this species and *Haplocytheridea montgomeryensis* are the most abundant species at Montgomery Landing, commonly comprising greater than 50% of the ostracode community. In this biofacies *B. shubutaensis* is more abundant than *H. montgomeryensis*. Although it is common throughout the section, *B. shubutaensis* has pronounced peaks in its abundance curve in this zone.

Acanthocythereis florienensis is the other dominant member of this biofacies. It is also a member of the greensand biofacies (biofacies 5), and in terms of proportional data is the second most abundant species in the burrow sample. This species apparently preferred the near shore and inner neritic environment, although the exact identification of the ecological variables controlling its distribution are unknown.

Because of its position in the basal Yazoo Clay sequence and the importance of *Acanthocythereis florienensis* in the assemblage, this biofacies is correlated, with reservation, to the outer part of the inner neritic zone or the inner part of the middle neritic zone. Huff (1970) reports *A. florienensis* as being common to abundant in all facies of the Moodys Branch and Yazoo Clay of Mississippi, and Howe and Howe (1975a) state that it is one of the most abundant ostracode species in Jacksonian sediments in the central Gulf Coast. Therefore, its potential use as a paleoecological indicator is uncertain.

The stratigraphically highest section of Yazoo Clay (the top of Section 3) also is placed in this biofacies. If this biofacies may indeed be used as a bathymetric indicator it indicates the Yazoo Clay sequence at Montgomery may not, as previously believed, represent a purely transgressional sequence. The presence of this biofacies at the top of the outcrop may either represent shallowing of waters at this time or the return of the unidentified ecological variables that were present during early Yazoo Clay deposition.

It is suggested that the proximity of the area to the Fayette delta system may be a factor. As discussed, during deposition of the Verda member the Montgomery area was marginal to the delta system. Possibly, the early effects of the delta's progradation to the east are being seen in the upper Yazoo Clay at Montgomery. Fisk (1938), however, states tht the regression at the end of Tullos deposition was very rapid, so it is not known if the effects could be seen this low stratigraphically in the section.

It is also possible that most Yazoo Clay sediments were de-posited at approximately the same water depths. If this was the case the biofacies would reflect a set of ecological and sedimentotological conditions not necessarily directly related to water depth (for example, nutrient distribution, energy level, and water turbidity). The upper Yazoo Clay at Montgomery would then indicate a return to the same environmental conditions present during early Yazoo Clay deposition.

The distribution of Cytheretta jacksonensis supports the hypothesis that even the upper Yazoo Clay deposits at Montgomery were not deposited in very deep water. This large, heavily calcified species occurs, although usually in low percentages, throughout the entire sequence. It reaches its highest proportional value, however, in sample S3N18 (18%), which is near the top of the outcrop.

Morkhoven (1962) states that Cytheretta is primarily an epineritic, near shore genus, although he (1972) reports it is ranging from 0 - 400 feet in recent sediments of the northwest Gulf of Mexico. Cytheretta is also part of Curtis' (1960) nearshore (inner neritic) assemblage from the Mississippi delta region. Benson and Coleman (1963) state that Cytheretta ranges from 20 to 63 feet in the eastern Gulf of Mexico, although it is most common at depths of less than 35 feet. Therfore, this genus is generally indicative of shallower waters, and it is doubtful that sediments containing abundant specimens of Cytheretta were deposited much deeper than the inner part of the middle neritic zone.

3. Biofacies 2: The Cytherella facies.

Cytherella spp. are rare throughout the section except for the one meter thick interval in the lower Yazoo Clay, where they become as great as 30% in relative abundance. This is very distinctive and an easily correlatable facies, yet its ecological interpretation is difficult.

Cytherella is reported as occurring at all depths of marine waters by Morkhoven (1962). As its morphology suggests, it generally is an infaunal genus burrowing in the upper substrate layers, so would prefer mudddy sediments. As previously discussed, however, the substrate primarily was muddy throughout the Yazoo Clay deposition, so substrate type alone would not explain Cytherella's abundance in this section only.

It is suggested here that substrate stability may have been an ecological factor. The muds in this section may have been more unstable, or soupier, which would have facilitated burrowing and promoted an infaunal assemblage. The substrate instability may have been related to a possible increased sedimentation rate at this time.

Brachycythere russelli, a robust, alate form, is also statistically abundant in this facies only. Benson (1959) suggests this morphology would help keep epibenthic forms upright on very soft bottoms, although this would not explain the absence of other alate forms present elsewhere (*Cytheropteron montgomeryensis*, *Brachycy-there watervalleyensis*) from this biofacies. *Buntonia shubutaensis* and *Echinocythereis jacksonensis*, which are also epibenthic species, are common in this and other zones, so if the substrate was indeed more unstable it apparently did not greatly affect the epibenthic community.

4. Biofacies 1: The *Haplocytheridea* facies.

Biofacies 1 accounts for the greatest amount of Yazoo Clay sediment (Fig. 31) and is dominated by the species *Haplocytheridea montgomeryensis*, which in the idealized end-member accounts for two-thirds (66%) of the ostracode population.

The paleoecological significance of *H. montgomeryensis* is difficult to determine. Many recent forms placed in *Haplocytheridea* are not congeneric with *H. montgomeryensis*, which is the type species of the genus. That was recognized by Morkhoven (1962); presently this genus is being revised by Dr. J. E. Hazel (Bold, 1980, personal communication). Morkhoven (1962) stated this genus is found in brackish to epineritic waters.

The other members of this assemblage offer little help in the paleoecological analysis of this biofacies. The genera *Buntonia* and *Cytheropteron* occur in all depths of marine waters (Morkhoven, 1962). They have been reported at depth ranges of 70 -12000 feet (*Cytheropteron*) and 150 - 800 feet (*Buntonia*) in recent sediments of the northwest Gulf of Mexico (Morkhoven, 1972). Both genera are part of Curtis' (1960) offshore (middle and outer neritic) biofacies. Little is known of the paleoecological significance of *Acanthocythereis*.

As will be seen in the diversity study, this biofacies is characterized as a low diversity zone and is dominated by *Haplocytheridea montgomeryensis*. The ecological interpretation of the diversity patterns is difficult. Possibly this was an unstable environment in which *H. montgomeryensis* has some type of adaptational advantage. Alternatively, it could have been a stable environment that was particularly conducive to this species.

H. montgomeryensis is common to abundant in all Jackson sediments of Mississippi (Huff, 1970). It is abundant throughout the Gulf Coast in upper Claibornian and all Jacksonian sediments (Howe, H.J. and Howe, R.C. 1975), and apparently was one of the most successful upper Eocene species. With such a wide lateral and vertical range it undoubtedly was exposed and adapted to many environments, so its potential use as an ecological indicator is doubtful.

The ostracode assemblage of this biofacies, however, does indicate an open marine environment with depostiion probably occurring within the inner part of the middle neritic zone. The statistical absence of any burrowing (infaunal) species indicates that although muddy, the substrate may have been fairly firm or stable.

5. Biofacies 3 and 6: The carbonate facies.

Biofacies 3 and 6 will be considered together as they apparently represent approximately the same facies. These biofacies occur only in the limestone ledges. As discussed, these ledges represent periods of decreased terrigenous influx that allowed calcareous environments to be established. As evidence by the high carapace/valve ratio, this must have been a very low energy environment.
Biofacies 3 is restricted to the upper ledge at Montgomery, but biofacies 6 occurs wihtin all 3 ledges at different stratigraphic levels. For this reason, it is believed their separation (that is their differences), may only be more of a statistical, and not ecological nature. Also, since both factors are restricted to the ledges, it was felt they could best be analyzed by considering them together as a calcareous facies.

These two biofacies are similar to the greensand biofacies (and unlike the other Yazoo Clay biofacies) in that they are identifiable by sedimentological as well as faunal criteria. Therefore, one may make ostracode paleoecological conclusions based upon ob-served sedimentological conditions, rather than make sedimentological conclusions form inferred ostracode paleoecology.

As discussed, this was a quiet water, carbonate mud-rich environment. Although present in all samples, Haplocytheridea montgomeryensis is less abundant in this environment and is not included in the faunal assemblage by the factor analysis. Neither Swain (1947) nor Puri (1957) described this species from the stratigraphically equivalent carbonate rocks of Florida. Apparently H. montgomeryensis, which is very abundant in terrigenous muds, was not as adaptable to the carbonate enivronment.

Loxoconcha concentrica, Cytherelloidea montgomeryensis, Trachyleberis? montgomeryensis, Triangulocypris gibsonensis, Hermanites dohmi, and Brachycythere watervalleyensis are all abundant and characteristic of the calcareous facies. They are also reported as common to abundant, however, at most levels of the Yazoo Clay in Mississippi (Huff, 1970). That study, though, was on a more general scale than the present one and it is not known how the species distribution responded to sedimentological changes within each member. None of these genera or species have previously been reported as being restricted to or particulary indicative of carbonate environments.

The ostracode genera of the carbonate facies are indicative of an open marine environment. The assemblage is similar to Curtis' (1960) offshore (middle and outer neritic) biofacies. There is nothing about either carbonate biofacies, however, to indicate it was deposited in deeper waters than the other Yazoo Clay biofacies. As previously discussed, this suggests that either the deltas has decreased output at this time due to continental climatic changes, the delta depocenters temporarily shifted to the west, eastern delta lobes were abandoned, or currents prevented deposition in this area. Frederiksen (1980b) states that the continental climate of the middle to late Eocene in the Gulf Coast was more or less uniform, so a climatic change probably was not responsible for the decreased output.

Regardless of the actual cause, biofacies 3 and 6, which are restricted to the limestone ledges, are indicative of a time of decreased terrigenous influx which allowed the formation of low energy, calcareous environments. The development of this environment appears to be related solely to the sedimentary conditions and not to water depth. The carbonate biofacies, like the other Yazoo Clay biofacies, formed in open marine waters probably in the inner portions of the middle neritic zone.

Summary of Paleoecology Factor Model

In conclusion, the transformed-data paleoecological factor model has recognized six ostracode biofacies occuring at Montgomery Landing. The biofacies have been related to both observed and hypothesized sedimentological conditions in an attempt to reconstruct the paleoenvironments.

All Moodys Branch samples have been statistically grouped into a cluster designated the "greensand" biofacies. This is a shallow water assemblage that probably lived at depths of 30 - 60 feet. A sample recovered from an Ophiomorpha burrow is unlike either basal Moodys Branch samples and is believed to represent the shallow water, near shore environment that was preserved in the overlying sediments due to wave agitation and bioturbation.

The Yazoo Clay samples have been grouped into five biofacies (factors). All biofacies are somewhat similar to modern assemblages reported by Benson (1959) and Curtis (1960) that indicate deposition in the outer inner neritic to middle neritic zone. Based on ostracode data, no Yazoo Clay biofacies seems to represent markedly deeper water deposition than any other. This indicates that distance from shore (Fisk, 1938) or changing sedimentological conditions, and not abosolute water depth, was a major factor controlling biofacies distribution.

A constant increase in water depth or a continuous transgression is not indicated by the vertical distribution of the biofacies.

Rather, it appears the transgression was fairly rapid and the Montgomery areea quickly reached the middle neritic (100 - 300 feet) zone After this time sedimentation rates, sedimentation patterns, and substrate type controlled ostracodal distribution.

It has been hypothesized that the early effects of an eastward progradation of a Fayette delta system lobe may be evident in the upper Yazoo Clay deposits of Montgomery Landing. It most likely is too low stratigraphically in the section to be evidence of the major progradation of the system that marks Verda deposition, but could represent a temporary advance of one of the system's eastern-most delta lobes. Investigation of stratigraphically higher Tullos member samples from the Grant Parish area could confirm or refute this hypothesis.

Faunal Diversity

Diversity measurements: background

The past decade has seen a great increase in the use of faunal diversity in paleoecological studies. Controversies still exist, however, as to the practical interpretation of diversity measures and to the indentification and effects of environmental variables on species diversity. Beerbower and Jordan (1969) warned of the difficulties in biologic interpretation of fossil diversity patterns because of weaknesses in niche theory, the uncertain relationship between numerical abundance and biological activity, and because of the role of diagenesis in modifying species occurence and abundance in the geological record.

Poole (1974) stated that species diversity is controlled by four major factors:

1) the evolutionary history of an area,
2) patterns of interactions among the species of the community,
3) fluctuations of the physical variables in the environment, and
4) the spatial heterogeneity of the environment.

One can conclude from this list that both biological (1, 2) and physical (3, 4) variables control patterns of species diversity. Poole warned, though, that these are all interacting factors, that no one factor alone accounts for observed distribution patterns, and the effects of any one factor cannot be isolated. Poole concluded that "it is possible to generalize about diversity, but a community is probably too complex to understand well enough to explain or predict diversity with any precision."

Slobodkin and Sanders (1969) investigated the relationship between species diversity and the physical environment. They characterized low diversity environments as "severe" and "unpredictable," that is, the ecological parameters vary greatly about their mean. High diversity environments are less "severe" and more "predictable," or stable. Therefore, they concluded that species found in low diversity environments must have broad tolerance limits to withstand the severity and large variation in the ecologic variables of such an environment.

Sanders (1969), in developing his stability-time hypothesis, referred to a low diversity environment as a physically controlled community, where "physical conditions fluctuate widely and are not rigidly predictable." Sanders designated a high diversity environment a biologically accomodated community, where physical conditions are constant and uniform over long periods of time.

Basically, Sanders' stability-time hypothesis states that where physiological stress increases due to either fluctuating physical conditions or increasingly unfavorable physical conditions, the community will change to a low diversity (physically controlled) community. Sanders related this to possible increased competition and predation in physically controlled environments. In other words, in a stable environment, biologic variables should through time become more important than physical variables (Gibson and Buzas, 1973). This theory has been criticized by Buzas (1972) who claims the stability-diversity relationship is not borne out by most geological observations.

The unifying theme through these and other (Margalef, 1969; Deevey, 1969; Bretsky and Lorenz, 1970) diversity studies, however, is the positive relationship between species diversity and environmental stability and predictability. Grassle (1972) stated that "the diversity of species in unpredictable environments is lower because of the large population sizes necessary for maintenance of the high genetic variability necessary for survival."

Goodman (1975) was critical of the entire diversity-stability theory. He stated "the expectations of the diversity -stability hypothesis are borne out neither by experiments, by observation, nor by models; its theoretical formulations have no necessary connection with secure scientific law, and its preconceptions are inconsistent with an evolutionary perspective." Goodman concluded "clearly, the belief that more diverse communities are more stable is without support."

Osman and Whitlatch (1978) warned of the dangers involved in drawing cause and effect conclusions from environmental variables and diversity. They stated that diversity changes can be a result of probabilistic disturbance in naturally patchy environments, and that "diversity patterns can exist regardless of any assumptions concerning the importance of competition, predation, species packing, niche characteristics, species ability to adapt, etc., and, in this sense they do not justify the existence of these processes or any local or global differences in them." They concluded that faunal diversity does not necessarily imply anything about an environment.

The use of diversity analysis in micropaleontological investigations has been given great impetus by the work of T. G. Gibson and M. A. Buzas (199, 1973). In their work on foraminiferal diversity patterns in the western North Atlantic, they found general patterns of increased diversity with depth (Gibson and Buzas, 1973). Although the diversity patterns generally followed the stability-time hypothesis, Gibson and Buzas concluded that in its present form this theory did not adequately explain their observations, and suggested that a more concrete definition of stability is needed in order to evaluate hypotheses on species diversity. They recommended the collection and study of long-term data on organismal and environmental variables in order to study the effects of the variability and magnitude of these variables on faunal diversity.

Sen Gupta and Kilborne (1974) studied the diversity of the benthic foraminiferal fauna of the Georgia continental shelf. They found foraminiferal species diversity to increase with depth on the inner shelf, then reach a "plateau" on the middle and outer shelves. Again, the time-stability hypothesis generally explained the diversity patterns found in their study.

Hazel (1975) measured the patterns of ostracode diversity in the Cape Hatteras, North Carolina area using depth, sediment, and temperature data as the environmental variables. He also found a general, but irregular pattern of increased diversity with depth, but did not find strong correlations between diversity and any of the measured variables.

Hazel believed that other unmeasured factors must have been important. He suggested one such factor could be the stability of the substrate, which is related to depth, but admitted the diffuculties in quantifying this variable. This problem was brought out by Buzas (1972), who stated that we can now quantitiatively define species diversity, but not the variables by which it is explained. Hazel pessimistically concluded "until the factors that control diversity in different environmental situations are better understood, it seems doubtful if diversity will be an effective tool in the determination of paleoenvironment."

Krutak and Rickles (1979) studied the ostracode diversity of two modern coral reefs in the western Gulf of Mexico and attempted to relate the diversity patterns to several quantitative environmental variables (depth, salinity, pH, temperature, Eh, and dissolved oxygen). They found that the diversity patterns observed did not reflect the observed environmental differences.

In conclusion, then, it has been shown that the relationship between environment and faunal diversity is poorly understood. Neither general hypotheses (the stability-time hypothesis) nor quantitatively measured specific environmental variables (the work of Krutak and Rickles, 1979) can adequately explain the diversity found in Recent faunal assemblages. To predict changes in environmental variables (which must be inferred to begin with!) in the fossil record, seems a hopeless task. One must agree with Poole (1974) that at present, species abundance relationships are "answers to which questions have not yet been found."

It is possible, though, to use species diversity in a stratigraphical analysis such as the present study. The diversity indices should be used as general indicators of changing environments, however, and not as actual "barometers" measuring the change of any one or group of environmental variables. This view is shared by Sen Gupta and Kilbourne (1974), who stated that in using diversity measures to delineate general bathymetric distinctions, it is not necessary that the actual factors affecting diversity be precisely known.

Spatial and Temporal Ostracode Diversity Patterns at Montgomery Landing

The diversity of the ostracode fauna for each sample at Montgomery

Landing was measured by calculation of S, the number of species at each station, and H(S), the Shannon-Wiener information function. This is defined as:

$$H(S) = -\sum_{i=1}^{n} p_i \ln p_i \qquad (5)$$

where p_i is the proportion of the i^{th} species.

The information function is believed to give a better understanding of sample diversity than does S. As Gibson and Buzas (1973) and Gibson (1979) stated, two samples may be composed of similar species (A, B, C), yet their respective proportions may differ greatly (.3, .3, .4) versus (.1, .1, .8). If interpreted solely on S the two samples are equally diverse, yet when relative proportions are considered the former clearly is a more diverse sample. The information function is advantageous here because it is influenced both by the number of species and their proportions.

The information function is much less influenced by sample size than is the number of species found (Gibson and Buzas, 1973). The influence of sample size is not a factor in this study as all samples have over 300 specimens, which is generally regarded as the number needed to have a statistically significant sample (Shaw, 1964). Because species proportions are believed to be an important component of a measure of species diversity, the information function was chosen to be the primary tool used to investigate species diversity.

As shown by Gibson and Buzas (1973), extreme high and low species proportions contribute less to H(S) than do moderate proportions. This is due to the inverse relationship of pi and ln pi. As pi increases, ln pi decreases. Therefore, samples that are dominated by one or a few species (low diversity) will have a lower H(S) value than samples where many species occur in equal, relatively moderate proportions (high diversity). Low diversity samples should then be reflected by low H(S) values and high diversity samples should have high H(S) values.

The calculated H(S) values for the Montgomery Landing samples are listed in open file. Figure 28 illustrates the stratigraphic distribution of the H(S) values. Note that greater diversity occurs in the Moodys Branch Formation and in the calcareous ledges of the Yazoo Clay.

The Mann - Whitney - Wilcoxon test was used to test for significant differences of H(S) among the different lithologies. The results of these analyses indicate two major differences in the distribution of the diversity values. The Moodys Branch samples have a significantly higher diversity than the Yazoo Clay samples, and the limestone ledges of the Yazoo Clay are significantly more diverse than the argillaceous intervals.

Discussion

As previously mentioned, the distribution of ostracode species indicates the Montgomery Landing outcrop does not represent a transgressive sequence throughout. The Moodys Branch was deposited in shallower water than the overlying Yazoo Clay. Facies changes in the Yazoo Clay, however, seem to be in response to changing sedimentological conditions, and not changes in absolute water depth.

The Moodys Branch is a basal transgressive unit deposited in the inner neritic zone of a shallow detrital shelf, and the Yazoo Clay represents middle to outer neritic shelf deposits. The ostracode species diversity of the Moodys Branch has been shown to be significantly higher than that of the Yazoo Clay. Therefore, the general trend of increasing diversity with depth does not hold at this locality.

It appears that like the factor analysis biofacies distribution, sedimentological conditions may control the species diversity values. *Clithrocytheridea garretti*, *Cocoaia grigsbyi*, *Cyamocytheridea watervalleyensis*, *Cyamocytheridea chambersi*, *Ouachitaia caldwellensis*, *Tropidocythere carinata*, and *Opimocythere mississippiensis* occur in the Moodys Branch but not in the Yazoo Clay. *Xestoleberis sarsi* and *Occultocythereis broussardi* are much rarer in the Yazoo Clay than in the Moodys Branch. As has been discussed, these species have been reported from the younger deposits of the Cocoa Sand of eastern Mississippi (Huff, 1970) and western Alabama (Krutak, 1961). Therefore, at Montgomery, these must be ecologically, and not stratigraphically (phylogenetically) controlled occurrence patterns.

The Cocoa Sand is a quartzose, sandy deposit. Apparently, the above-mentioned species preferred sandy substrates, so were viable in the muddy sands of the Moodys Branch but not the muds of the Yazoo Clay. Unlike the Moodys Branch, the Cocoa Sand contains a well-developed planktic foraminifera fauna. Whether this indicates deeper water deposition, increased distance from shore, or both, it seems apparent that the Moodys Branch and the Cocoa Sand were not deposited under identical ecological conditions. Therefore, substrate type is most likely a very important factor controlling the species distribution, and therefore, the diversity values.

A voluminous amount of data has been published on the relationship between ostracode occurrence and substrate. A survey of the literature finds no general consensus as to the strength of this relationship. It is generally recognized, though, that since the benthic ostracodes live on or within the sediment, the nature of the substrate must have an effect on the ostracode community. This point is well illustrated by Pokorny (1979), who believed that the nature (size and shape) of the substrate has a pronounced effect on ostracode occurrence patterns. He explained how two environments with similar depths, temperatures, and salinities can support different ostracode communities solely because of substrate differences.

As the diversity decreases in the Yazoo Clay two species clearly begin to dominate the ostracode assemblage. These are *Haplocytheridea montgomeryensis* and *Buntonia shubutaensis*, which together commonly comprise greater than 50% of the ostracode population.

If the predictability-stability-diversity theory was being followed, one would expect the Yazoo Clay to be a more unpredictable environment, and H. montgomeryensis and B. shubutaensis to be successful because of their "generalist" life modes or broad ecological niches. The occurrence of H. montgomeryensis supports this hypothesis. This long-ranging species is found from the Claiborne (Howe, 1963) to nearly the top of the Jackson (Deboo, 1965), so has a long stratigraphical range. It has been found laterally from east Texas (Stephenson, 1946) to the Atlantic coastal plain (Swain, 1951). Although its proportional abundance at these localities is not known, this species could obviously exist in a variety of environments and would be expected to have an advantage in an unpredictable environment.

One might expect, however, the middle neritic environment of the Yazoo Clay to be a more stable and predictable environment than the shallow shelf sands and clays of the Moodys Branch. Therefore, it does not appear that environmental stability is the controlling factor of species diversity at Montgomery Landing. The extreme vagueness of the term stability, however, makes even the most general observations and conclusions speculative. Although there surely are many unknown interrelated factors, it appears substrate is one environmental factor controlling species diversity at Montgomery Landing.

The limestone ledges of the Yazoo Formation have a higher species diversity than the clay sequences. It was previously noted that these ledges are neomorphosed lime mudstones to wackestones that are indicative of a low-energy carbonate environment. X-ray diffraction data indicates a low input of terrigenous material at this time. The water was apparently very clear. Species of the genus Loxoconcha (L. concentrica, L. watervalleyensis, and L. cocoaensis) show a distinct preference for this environment. In the upper ledge L. concentrica becomes percentage-wise the most abundant species. The calcareous environment apparently was able to support a highly diverse fauna. It is difficult to determine, however, if it was the change in substrate size, substrate composition, energy level, or some other factor that caused this change. The carbonate provinces of the lower latitudes generally have a higher diversity than the terrigenous provinces of the higher latitudes (Gibson and Buzas, 1973; Krutak et al., 1979), but this general observation does not imply any causal relationships between substrate composition and species diversity.

The abundance of H. montgomeryensis and B. shubutaensis is reduced in the limestone ledges. Because the diagenesis of the ledges results in a relatively poorer preservation of the fossils, it is difficult to ascertain whether their numbers are actually declining. The measure of specimens per gram cannot be used as a comparative measure here because of the neomorphosed nature of the substrate. Also, because of decreased terrestrial input the ledges should represent more time than equivalent thicknesses of non-ledge material (Bold, 1980, personal communication). Therefore, it cannot be determined if the decreasing abundance is not merely an artifact created by the closure problem (forcing percentages to add to 100%) caused by the increased abundance of the Loxoconcha species. Also, because of the poorer preservation of fossils in the ledges, the diversity indices should be used only to show a relative, and not absolute, diversity increase.

The clay sequences of the Yazoo Clay show uniform diversity values. If the depth - diversity relationship was being followed this would be another indication that water depths did not change markedly during Yazoo Clay deposition. As it has already been shown that the depth - diversity relationship does not hold in the Moodys Branch -Yazoo Clay transition, however, this writer does not feel its use as a depth indicator in this case is justified. Rather, the faunal diversity patterns should only be used as indicators of changing ecological conditions that are most likely controlled by substrate composition, and not absolute water depth.

It is interesting to note that the highest diversity values occur in intervals characterized by very little terrigenous input and apparently very clear waters. This suggests some relationship between sedimentation rates, water turbidity, and ostracode species diversity, although it is recognized that this is probably the same relationship that is reflected in the substrate type.

An interesting aspect of the Shannon - Wiener information function is its possible use as a stratigraphic tool. The identification of paleoecological variables for this purpose is not necessary as it is the cumulative effect of these variables that is of interest. In this role the information index is actually measuring a physical parameter of the sediment and should be as useful as any other parameter such as quartz percentage.

One disadvantage discussed by Brower and Millendorf (1978) and McCammon (1970) with a quantitative measure such as the information function is the loss of possibly important qualitative data. Very abundant species are not necessarily stratigraphically useful (H. montgomeryensis is a good example), while an index species may occur in low percentages. There is no way to assign "weights" of stratigraphical importance to the species in computing the index. This same point may be considered an advantage, though, because the measure is considering the total ostracode community and not pre-determined "important" species. At Montgomery Landing this argument becomes irrelevant anyway as there are no ostracode species stratigraphically important in a presence / absence sense.

The Montgomery Landing outcrop is an ideal locality for testing the correlative usefulness of the information function. The limestone ledges provide excellent markers for lithologic stratigraphy against which the information function - derived stratigraphy may be checked.

Because of the interrelationship between facies and species diversity and because of the natural patchiness of any environment (Osman and Whitlatch, 1978), it must be cautioned that correlation with the aid of the information function should be used only in a restricted geographic sense. Further sampling along the strike of the Moodys Branch and Yazoo Formations would be helpful in determining the lateral range of correlative usefulness of the Shannon-Wiener information function.

D. STATISTICAL TREATMENT OF BIVALVE MOLLUSKA*

Average Bivalve Species Abundances

The average species abundances in each sedimentary unit were compared using Duncan's multiple Range Test reference at an alpha level of 0.05. This test allows the comparison of the average abundance of each species in each layer and determines which are significantly different for each species.

For thirteen species (Barbatia ludoviciana, Caestocorbula wailesiana, Caryocorbula densata, Bathytormus flexurus, Crassinella pygmaea, Glycymeris filosa, Liriodiscus pretriangulata, Limposis radiata, Kelliella boettgeri, Pleuromeris inflatior jacksonensis, Pleuromeris quadrata, Venericardia diversidentata, Spisula jacksonensis) the mean abundances are highest in the Moodys Branch Formation and are statistically higher than any zone (A, B, C, Fig. 11) of the Yazoo Formation.

Three species have mean abundances that are highest in zone B of the Yazoo Formation and are significantly higher than for every other sedimentary unit. These species are Alveinus minutus, Lucina subcurta, and Nucula spheniopsis. Alveinus minutus is a long ranging, ubiquitous species at Montgomery Landing, being among the most common species in both the Moodys Branch and the Yazoo Formation. It is important for determining environmental conditions since it is an opportunistic species. Levinton (1970) stated that opportunistic species are not limited by resources in the environment, and in environments of high physiological stress they can increase in number in a short period of time. The reasons for these sudden large increases are not entirely clear but are probably related to factors which improve planktonic larval survival such as a decrease in larval predation. The survival of the opportunitists, then, depends mainly on their ability to compete with species already established. Levinton (1970) states that dominance of opportunitists depends mainly on their ability to compete with species already established. Levinton also states that dominance of opportunists in a community indicates that the community is controlled by physical and not biotic factors. He also states that "most investigators agree that the degree of organization, diversity, and biotic stability of a community are directly proportional to the age and stability of the associated habitat, but inversely proportional to the degree of physiological stress (Levinton, 1970)."

Its high abundance in zone B and the restricted number of specimens of most other species suggest either an environment under stress where species that are more restricted in habitats cannot increase in population as rapidly, or one where many species are moving in, but where species with high population growth rates fill the environment first.

For Lucina curta there is a statistical similarity in species abundance between the Moodys Branch and zone B of the Yazoo Formation.

*by Thomas Klumpp of LSU

The analysis finds differences in abundances for this species between two zones to be neither significant nor non-significant, that is, indicating similarities. It is most common per sample in the Moodys Branch but there is no clear zone where this species is statistically significantly more common than in any other. There are also similarities indicated in the analysis between zone A and C in the Yazoo Formation. The differences between zones A and C are not statistically significant.

For Hilgardia multilineata there are similarities statistically between Yazoo zones B and C. This species also has no single zone where it is significaly more abundant than in any other. The Moodys Branch and Yazoo zone B do not differ significantly in average abundance and Yazoo zone C and A do not have a significant difference.

The final species, Verticordia (Verticordia) cossmanni is present in two distinct areas of Montgomery Landing. The sections within each area are not statistically significantly different from each other but the two areas do differ significantly. It is most common in the Moodys branch Formation and in zone A of the Yazoo. These two are not significantly different for mean abundance. Yazoo zone B and C differ from the Moodys and Yazoo A and do not differ significantly from each other and are much less in mean abundance for this species.

The fact that thirteen bivalve species in this study have significantly higher average abundances in the Moodys Branch than in the Yazoo Formation and that six species do not make the transition across the formation boundary are a reflection of the changing environment as the Jackson sea transgressed. Six of these species decline to zero in the Yazoo Formation and the other seven decline to very near zero.

The large decline of Barbatia (Cucullearca) ludoviciana, Caestocorbula wailesiana, Corbula (Caryocorbula) densata, Bathytormus flexurus, Kelliella boettgeri, Pleuromeris quadrata, and Venericardia (Rotundicardia) diversidentata suggests that their environmental requirements had at least some similarities. For each of these species, except Barbatia (Cucullearca) ludoviciana and Venericardia (Rotundicardia) diversidentata, which were not found in the Yazoo Formation, there is an increase in average abundance in zone B while in zones A and C they were rarer. The magnitude is small compared with their abundance in the Moodys Branch, but this does give indication that conditions in the Yazoo were subject to a certain amount of fluctuation. A possible interpretation is that with the transgression of the sea, the increasing depth of the water and the rate of sedimentation did not proceed at a uniform rate.

Like diversity, abundance data separates Montgomery Landing into two significant parts. The first is the Moodys Branch where most species are most abundant and the second is zone B of the Yazoo where three species have their greatest abundance. No species are most abundant in zone A and C of the Yazoo.

Diversity, Environmental Stability and Stress

Environmental theory states that species diversity increases with increasing depth on the shallow shelf. Stated in terms of stability, an environment that is stable has a higher diversity than one which is less stable like the nearshore.

Elder (1981) used species diversity and life modes (for bryozoans, gastropods, and corals as well as bivalves) in studying macrofossil assemblages in the Moodys Branch along strike in Louisiana and Mississippi. She identified six fossil assemblages (dominated by bivalves). Her *Spisula-Yoldia* assemblage was found in open bay sediments, the *Spisula-Glycymeris-Diplodonta* assemblage was found in nearshore wave-influenced sediments, the *Alveinus-Lucina-Spisula* assemblage was interpreted as an eastern middle shelf fauna, the *Alveinus-Corbula* assemblage was a western inner middle shelf fauna, the *Kelliella-Alveinus* assemblage was also an eastern inner middle shelf fauna, and her *Nucula-Hipponix*-solitary coral assemblage was interpreted as outer middle shelf. These assemblages represent increasing water depth and increasing distance from shore.

She divided the Moodys Branch at Montgomery Landing into two assemblages. The basal Moodys Branch is her *Alveinus-Corbula* assemblage, and the upper portion of the exposure she placed in the *Nucula-Hipponix*-solitary coral assemblage. *Alveinus* and the *Corbulas* were found by Thomas Klumpp to be the most common species throughout the Moodys Branch but abundance dropped off sharply as the lowermost calcareous layer of the Yazoo was approached. Three samples from the vicinity of this layer were examined for this study and, although specimens of *Nucula spheniopsis* were found where there had been none lower in the exposure, their abundance did not approach that reported by Elder. Even though her sample was several hundred grams larger than any single one used for this study, a significant increase in *Nucula spheniopsis* should have shown up. The Moodys Branch at Montgomery Landing is thin, averaging about a meter in thickness, so it is doubtful that two distinct bivalve assemblages are represented. Also it does not seem likely that the depositional environment was deeper than inner middle shelf due to the relatively short time interval represented by the Moodys Branch at Montgomery Landing. The fining upward of the sediments was influenced both by depth and by increasing distance from the rapidly retreating shoreline. The beginning of Yazoo deposition at Montgomery Landing is abrupt, followed by slow mud deposition with periodic fluctuation as the water became deeper and the shore farther away.

Using her fossil assemblages and grain size, Elder (1981) interpreted the Moodys Branch at Montgomery Landing as deeper water than exposures east ward in Mississippi. Sand and carbonate sediments are important in Mississippi, Alabama, and Florida whereas clay and silt are more important in Louisiana. She found that eastern exposures had high porportions of species like *Spisula*, *Glycymeris*, *Yoldia*, *Diplodonta*, and *Alveinus*, that indicate more nearshore and agitated environments. As the clay content increased moving west into Louisian, *Corbulas* and

Venericardia (Rotundicardia) diversidentata increase in abundance, probably because these bivalves prefer a more fine grained and less sandy substrate in a less agitated environment. With these assemblages, she was able to establish an onshore-offshore diversity gradient for the Moodys Branch. She found that the trends for diversity, equitability, and number of individuals are similar for mollusks in the Eocene and the Holocene. The number of individuals reaches a peak in the nearshore because of the abundance of opportunists, and equitability is correspondingly low. However, farther offshore where the abundance of the opportunists declines, equitability is higher. The trend for diversity closely follows equitability both in the Eocene and the Holocene. In contrast to increasing diversity and equitability offshore, a decrease in number of species was found the Eocene where the trend is for an increase in the Holocene. The reasons for this are unclear, but Elder (1981) believes that it could have been caused by any combination of lower density offshore, poor preservation, the nearshore actually being a mixture of several environments, fewer molluskan species offshore duing the Eocene, and many offshore species being too small to be classified as macrofossils.

Moodys Branch exposures in Mississippi had nearshore assemblages with lower diversity than exposures in Louisiana where deeper assemblages were found. According to Elder (1981) the higher diversity in the west is a result of the proportions of species being more equally distributed. She concluded that in eastern localities where opportunistic species like Alveinus minutus were more dominant, the environment was more physically controlled and unstable and not as suitable to other species. In the western localities where the proportion of opportunists decreased, the environment was more stable and other species such as Caestocorbula wailesiana, Corbula (Caryocorbula) densata, and Venericardia (Rotundicardia) diversidentata increased in abundance. Montgomery Landing was Elder's westernmost sampling locality.

The Yazoo at Montgomery Landing follows Elder's observed trend of decreasing number of species offshore but not that of increasing equitability. The value for evenness in the Moodys Branch is higher than zone A, significantly higher than zone B, and only slightly less than zone C. Since the number of species declined in the Yazoo, to increase evenness the diversity would have had to increase. The decline of diversity in the Yazoo suggests a more rigorous and unstable environment with increasing depth and distance from shore.

If an increase in water depth were the only factor controlling diversity, then an increase in diversity in the Yazoo is what diversity theory would have predicted. Substrate and influx of sediment are also important contributing factors. As has been pointed out, the Moodys Branch fines upward at Montgomery Landing and is coarser grained than the Yazoo Formation. It is probable that it had a higher organic content than the Yazoo, which would indicate a more stable food supply.

Sediment supply fluctuated during Yazoo deposition, but sedimentation was generally much slower than in the Moodys Branch. The limestone ledges at Montgomery Landing represent times of little terrigenous input and relatively quiet water, permitting a calcareous facies to develop. Fossil material is in the form of casts. Bivalves are almost exclusively Alveinus minutus. This species indicates that from the viewpoint of bivalves, the calcareous sediments represent a stressful environment, even though it was probably stable, and that only a species with an opportunistic life style could have exploited it successfuly.

Bivalve Paleocology and Environmental Stress

Several feeding modes are seen in invertebrate animals: suspension feeding, deposit feeding (both shallow burrowing and surface feeding), carnivorous feeding, and grazing. Suspension feeders feed on microorganisms and/or organic detritus suspended in the water, deposit feeders feed on the same kind of material in the sediment, carnivores feed on other animals, and grazers feed on plants and organic material in the sediment. Deposit feeding species are present, but suspension feeders dominate the Montgomery Landing bivalve fauna. Since most of the species are shallow burrowers and have short siphons, they fit at a low level in the trophic structure.

Bivalve diversity is relatively high in the Moodys Branch and populations of most species are larger than in the Yazoo. The supply of suspended food must have been plentiful and other environmental factors must have been equitable. Deposit feeding species (Nucula spheniopsis and Hilgardia multilineata) are also present in the Moodys Branch but are minor in importance compared to the suspension feeders. However in the Yazoo Formation the deposit feeders, especially Nucula spheniopsis, are among the most common species.

Because major centers of deposition, those associated with the Fayette Delta System, were to the west of Montgomery Landing, deposition in this area was relatively light. Sediments brought into the Gulf would have had a tendency to move west and southwest due to longshore drift. Sediment coming in form the east would have been negligible. The water in the eastern Gulf Coast was clear and warm resulting in extensive carbonate deposits. The carbonates found at Montgomery Landing are evidence that the site was subject to periods of clear, warm water with little or no terrigenous input.

Sedimentation at Montgomery Landing is a function of the amount of sediment that is being supplied and the distance from shore. Nearshore environments, the Moodys Branch, would receive more sediment and more organic matter. Since the water nearshore would have been more active, the sediment is coarser, more material was in suspension and suspension feeders were abundant. In more offshore environments, the Yazoo, the water was quieter and there was less suspended food. The sediment was finer grained, with increased amounts of organic matter reaching burial. The deposit feeders increased in numbers.

Conditions must have been favorable in terms of temperature, salinity and the food supply, for the variety of types of suspension feeding organisms to have been common in the Moodys Branch. There is a close correlation between currents, substrate, availability of food, sedimentation rate, and the types of animals that inhabit a given area. Suspension feeders that are above the substrate would receive food coming into the area first and could crowd out lower level suspension feeders like bivalves if they become numerous enough. However, sedentary upper level suspension feeders require a firm and stable substrate for attachment. Even though solitary corals and bryozoans are common, the bottom fauna is dominated by burrowing bivalves. The bottom in the Moodys Branch was certainly not soupy but it was also not entirely suitable for organisms that attach themselves to the bottom. The lack of byssally attached bivalve species that might have attached themselves to plants above the substrate suggests that plant growth was not abundant at this locality in the Moodys Branch.

The dominance of infaunal suspension feeding bivalves and the relative lack of deposit feeders in the Moodys Branch is environmentally significant. Suspension feeders need food particles suspended in the water. Water is drawn in through in the inhalant siphon, food particles and oxygen are removed, and waste products, including any inorganics that were drawn in, are expelled through the exhalant siphon. The water cannot be overly turbid and the sedimentation rate cannot be high or else the animals will become buried, their larvae could not become established but would be choked by the sediment, and their filtering apparatus would become fouled. With a large number of filterers in an area, the water would be quickly depleted of food and oxygen if it were not constantly replenished. This means that the Moodys Branch has weak currents flowing across the bottom. If the currents were strong and the water agitated, then there would probably have been larger populations of species like Glycymeris which prefer this type of environment. But these are not overly common in the Moodys Branch. Also there would be more evidence of winnowing and sorting.

A current, even a weak one, would result in some coarsening of the substrate. In keeping fine grained organic particles in suspension, which is a requirement for suspension feeders, the current would also prevent some of the fine grained terrigenous material from settling out. Current action in the Moodys Branch was not so strong as to cause much winnowing, but in conjunction with the Moodys Branch being a relatively nearshore deposit, it resulted in the Moodys Branch being coarser grained than the Yazoo. From the standpoint of suspension feeders, the important factor is how much organic material and oxygen is brought to them in a unit of time.

In the Yazoo, the population of the deposit feeder Nucula spheniopsis increased so that it is among the most common members of the fauna. For deposit feeders, the amount of organic matter suspended in the water is not of as much importance as is the amount that is deposited in the substrate. It is generally observed that as the substrate becomes finer grained, the proportion of deposit feeders increases. This is what is seen at Montgomery Landing. The Yazoo is richer in fine clastics than the Moodys Branch and the deposit feeders increase in population.

All of this points to generally lower current velocities in the Yazoo than in the Moodys Branch. Very weak currents not only would favor deposition of dispersed organic material, but would also favor deposition of fine grained terrigenous sediment. The fine grained material settling out and the resulting fine grained substrate would be unfavorable to most suspension feeders. The weaker currents would mean less suspended food in the water in a unit of time and the water itself would not be renewed as rapidly. With reduced organic matter, small populations and fewer species of suspension feeders could be supported.

The Yazoo Formation at Montgomery Landing records a series of small environmental changes that resulted in significant changes in faunal diversity and abundances between the zones. The substrate and rate of sedimentation are important environmental factors but the quantity distribution of organic matter in the water is also important. There is little appreciable difference in the quantity of sediment of very fine sand or finer grain size among the Yazoo zones. There was no consistent sedimentological observation to distinguish any portion of the Yazoo except for the calcareous sediment in the ledges.

Bivalve diversity and abundance changes provide evidence for some limiting factor or factors operating in the environment. From data on the average abundance per fossiliferous sample in Table 25 it is apparent that abundances in the Yazoo are related to two main considerations. The first is that some environments exclude some species and that some species can increase in population in response to environmental change much more rapidly than others. Species with a rapid population growth potential will naturally be more abundant in colonizing a changed region than those with a lower potential, although these can become more abundant over time in a stable and equitable environment. For an opportunistic species like *Alveinus minutus* the population growth can be explosive, while for others like *Nucula spheniopsis* and *Lucina (Callucina?) subcurta* it can be more modest but still cause larger populations than other species. The rate of growth will vary in different environments depending on conditions. This is what appears to be happening at Montgomery Landing.

The Moodys Branch had a higher number of species than the Yazoo, but some maintain much larger populations than others. Table 25 shows that going from the Moodys Branch through each zone of the Yazoo there is a pattern of population increase and decrease affecting most of the species. Moving from the Moodys Branch into zone A of the Yazoo, all but two species, *Verticordia (Verticordia) cossmanni*, an infaunal filter feeder, and *Nucula spheniopsis*, a deposit feeder, decrease in abundance per sample. Going from zone A to zone B, all but three of the rarer species in the Yazoo increase and moving into zone C every species except two decline in population.

In zones A and C the population growth of most species is held in check by some limiting factor or factors. Availability of organic material, both suspended in the water and being added to the substrate, and its distribution are important considerations. In zone B, populations increase over A and for three species, *Alveinus minutus*, terrigenous input and were times of stress for bivalves. They were probably stable; however, since their fauna persisted throughout their deposition. Fossils were exclusively in the form of casts of only one species, probably A. minutus. The clay zones had a finer substrate than the Moodys Branch and a higher proportion of deposit feeders. The substrate probably had a high organic content due to lower current velocities, allowing finer grained material to settle out. Species populations decline in zones A and C of the Yazoo in comparison to the Moodys Branch and Yazoo zone B indicating less equitable environments, most likely related to substrate and current conditions.

4. Zone B is dominated by A. minutus, an opportunistic species. Its high abundance relative to other species in this zone is the cause of the very low diversity found here. Dominance by an opportunistic species is usually one indication of an unstable and stressed environment. However because all other species but one increase in population, zone B is probably a more equitable environment than the rest of the Yazoo at Montgomery Landing. A. minutus dominates this zone so completely because, being an opportunist, it is able to increase very rapidly in population when conditions permit.

E. COMMUNITIES AND THE TROPHIC WEB

The roles within their community of the fossil animals of Montgomery Landing can be understood by their position in the energy cycle of the shallow marine environment. Plants are the primary producers and in this environment, exist mainly in the plankton, where they provide food for planktonic and nektonic animals. Individuals and fragments of both plants and animals from the plankton form a rain of suspension food falling upon the sea floor, where it is gathered by suspension feeders, or reaches the sea floor as detritus, or becomes incorporated into the sediment. Benthic animals, their wastes, and fragments contribute to the detritus as well and to the food buried in sediment which is consumed by deposit feeders. Predators and scavengers feed on all the other forms and themselves contribute to the organic rain and eventually to the detritus.

In 1972, Walker gave a variety of generalizations about trophic levels. He divided shallow benthic community members into high level suspension feeders, low level suspension feeders, sediment surface feeders eating detritus, and deposit feeders. Feeding competition is minimized and stability increased when the following conditions are met: (1) each community is dominated by one trophic group. (2) of the dominant species in a community each belongs to a different trophic group. (3) one species dominates each trophic group in a community (Walker, 1972). He recognized that animals may divide up the suspension feeding life mode more finely in environments where suspension food is common, instead of having only high level and low level suspension feeders (Walker, 1979, p. 89).

The environmental factors of major importance at Montgomery Landing include small depth changes, changes in the influx of clastics and suspension food availability, turbidity, competition for food, and soft substrate problems such as sinking. Salinity, on the other hand, must have varied little if at all. The material in burrows beneath the pre-Moodys Branch unconformity is our only sample of the more variable nearshore marine environment which was replaced by the Moodys Branch as the transgression progressed. The 2 m length of burrows indicates that animals had to dig deep to escape environmental fluctuations. No evidence of animals burrowing more than a few times their length is seen in the Moodys Branch or Yazoo.

The Moodys Branch environment had a steady supply of suspension food and fine sediment was winnowed out by currents. Epifaunal and infaunal suspension feeders partitioned the suspension feeding life style finely. The steady availability of food allowed numerically smaller and more specialized populations to survive. Minimizing interspecific competition could have been a major priority in animal evolutionary strategies. A wide variety of animals, classed as suspension feeders, including several very abundant species, can coexist it suspension feeding takes place at several levels.

In the Yazoo Formation suspension food was less constantly available, and in the period of formation of the limestone ledges, which represent times of little clastic input, suspension food may occasionally have been scarce. Tall suspension feeders require a steady particle rain. A food particle stays longer in detritus than in the water column and longer still in the sediment where deposit feeders can get it. In the less favorable and stable Yazoo environment, some suspension feeding types dropped out of the fauna and deposit feeders such as the bivalve Nucula increased in numbers. The common occurrence of the suspension feeder Alveinus in the Yazoo and its high numbers in the limestones can be explained in part by the fact that this is an opportunistic species, able to expand its population rapidly in favorable circumstances and, in part, by the fact that it is a very low level suspension feeder. Its short siphons draw from very low, close to the sea bottom, giving it some of the advantages of a deposit feeder. Clear water and lessened competition from other bivalves would make the limestone-forming conditions favorable to it. The fact that many of the Yazoo suspension feeders are very low level, their trophic category blurred into the detritus or sediment-surface-feeder category, explains in part why some of the same animals could thrive in the high suspension food situation of the Moodys Branch where they catch the leavings of taller suspension feeders. In the Yazoo where the taller types are sparser, they continue to thrive.

Elder (1981) recognized two distinct communities in the Moodys Branch Formation at Montgomery Landing: the Alveinus-Corbula assemblage and a deeper water Nucula-Hipponix-solitary coral assemblage. We did not find two distinct assemblages, but instead a single one extending up into the Tullos Member of the Yazoo. Alveinus and solitary corals are among the most common fossils throughout the Moodys Branch and the Yazoo Formations. In addition the deposit feeder Nucula, deposit-feeding gastropods, and the scaphopod Cadulus become important with sediment influxes in the Yazoo clay. Corbula occurs throughout, but in lesser numbers than Alveinus and it appears to maintain itself well in muddy environments.

The sessile suspension feeding gastropod Hipponix appears in a Yazoo limestone but is not abundant. The lack of clastics and turbidity of the limestone-forming episodes is suitable for Alveinus, producing a sudden increase in numbers, which produces an appearance of lowered diversity in the bivalve statistical distribution studies (Section 5D). Alveinus' suspension feeding at a very low level, near the sea floor, allows it to thrive in the diverse suspension feeding community (Alveinus-solitary corals-bryozoa) of the Moodys Branch, remaining common in the more varied Yazoo environments, where the animals divide the resources across a greater span of trophic modes, with less emphasis on suspension feeding.

The Yazoo represents a more clastic environment with greater turbidity problems, less solid substrate and less reliable suspended food. Many suspension feeders decrease in numbers, and deposit feeders such as Nucula increase in numbers. Limestone ledges, which represent a quieter water environment with a decrease in clastic influx, and probably in suspended food, show a decrease in bivalve diversity, mainly because of the great abundance of Alveinus, and an increase in ostracode diversity. Quiet water is a more stable environment for ostracodes, allowing a greater diversity of forms to inhabit the region. Our conclusion in the limited area of Montgomery Landing is that whereas *Alveinus* can live under any circumstances in the Moodys Branch and Yazoo, the increase in *Nucula* is caused by the greater influx of clastic material and is not caused by greater depth of deposition.

Figure 32. Moodys Branch Ecological Grouping from Montgomery Landing.

a. *Sphyraena* (Chordata: Vertebrata: Osteichthyes)
b. *Odontaspis* (Chordata: Vertebrata: Chondrichthyes)
c. *Myliobatis* (Chordata: Vertebrata: Chondrichthyes)
d. *Calyptraphorus* (Mollusca: Gastropoda: Mesogastropoda)
e. *Euspira* (Mollusca: Gastropoda: Mesogastropoda)
f. *Flabellum cuneiforme* (Coelenterata: Anthozoa: Scleractinia)
g. *Conopeum* (Bryozoa: Gymnolaemata: Cheilostomata)
h. *Trochocyathus lunulitiformis* (Coelenterata: Anthozoa: Scleractinia)
i. *Athleta* (Mollusca: Gastropoda: Neogastropoda)
j. *Hilgardia multilineata* (Mollusca: Bivalvia)
k. *Nucula spheniopsis* (Mollusca: Bivalvia: Taxodonta)
l. *Corbula densata* (Mollusca: Bivalvia: Desmodonta)
m. *Alveinus minutus* (Mollusca: Bivalvia: Heterodonta)
n. *Venericardia diversidentata* (Mollusca: Bivalvia: Heterodonta)
o. *Lucina curta* (Mollusca: Vivalvia: Heterodonta)
p. *Glycymeris filosa* (Mollusca: Bivalvia: Taxodonta)

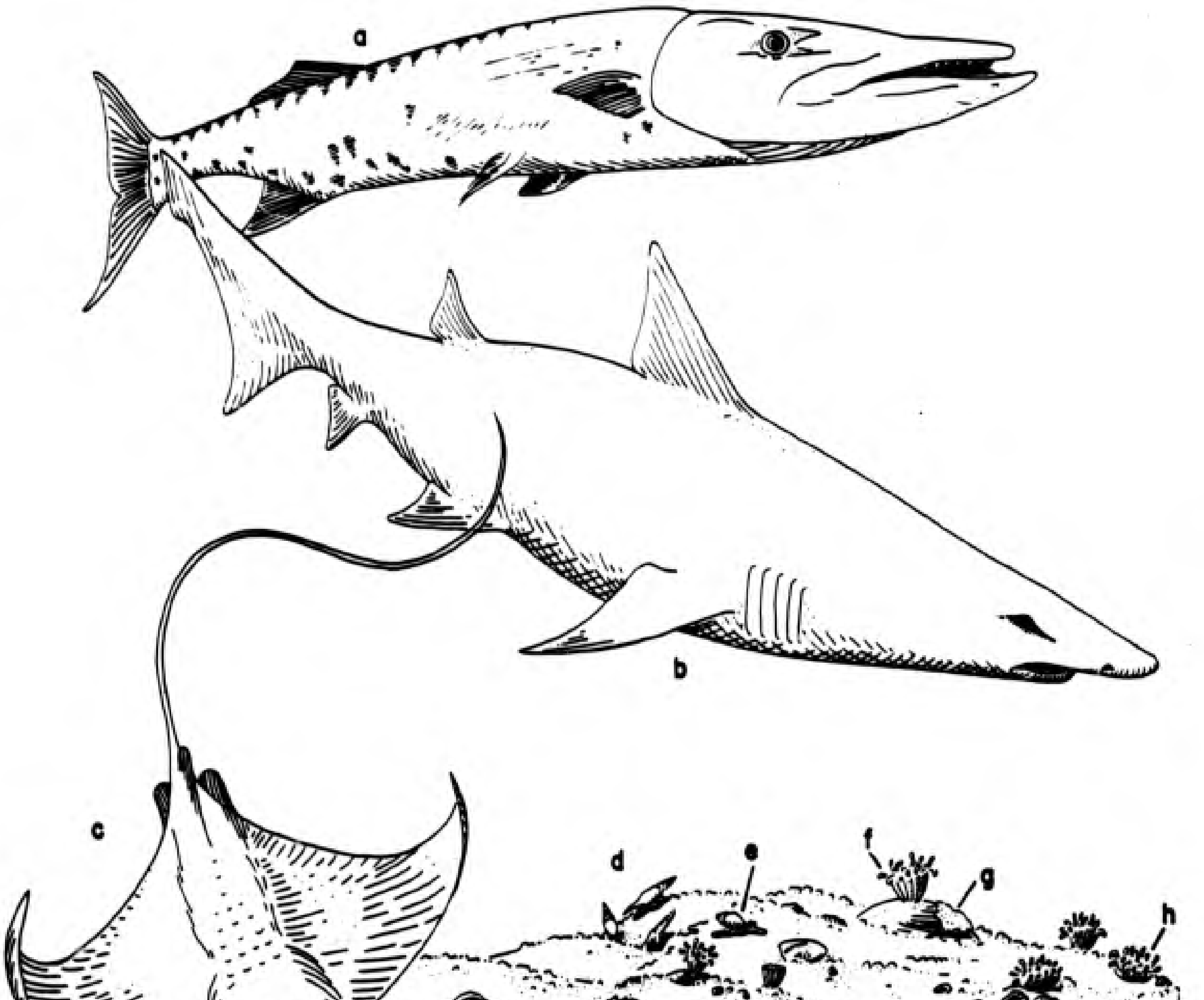


Figure 32

Figure 33. Moodys Branch Detail of Ecological Grouping

a. *Calyptraphorus* (Mollusca: Gastropoda: Mesogastropoda)
b. *Glycymeris filosa* (Mollusca: Bivalvia: Taxodonta)
c. *Flabellum cuneiforme* (Coelenterata: Anthozoa: Scleractinia)
d. *Corbula densata* (Mollusca: Bivalvia: Desmodonta)
e. *Athleta* (Mollusca: Gastropoda: Neogastropoda)
f. *Venericardia diversidentata* (Mollusca: Bivalvia: Heterodonta)
g. *Trochocyathus lunulitiformis* (Coelenterata: Anthozoa: Scleractinia)
h. *Trochopora bouei* (Bryozoa: Gymnolaemata: Cheilostomata)
i. *Conopeum* (Bryozoa: Gymnolaemata: Cheilostomata)
j. *Trochocyathus lunulitiformis* on *Schizorthosecos interstitia* (Bryozoa: Gymnolaemata: Cheilostomata)

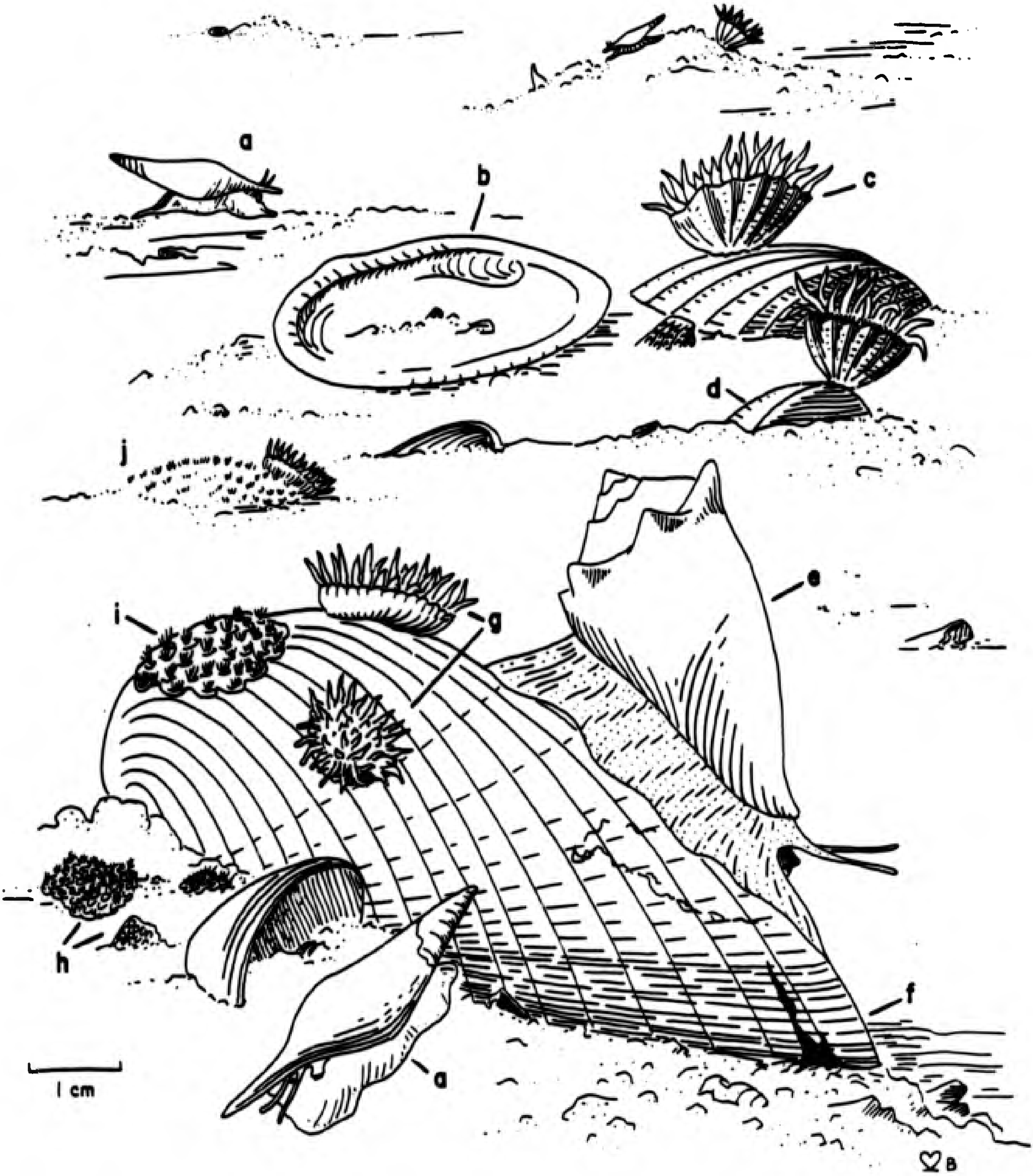


FIGURE 33

Figure 34. Yazoo Ecological Grouping From Montgomery Landing

a. Galeocerdo clarkensis (Chordata: Vertebrata: Chondrichthyes)
b. Trichiurus (Chordata: Vertebrata: Osteichthyes)
c. Turritella arenicola (Mollusca: Gastropoda: Mesogastropoda)
d. Ostrea (Mollusca: Bivalvia: Dysodonta)
e. Endopachys maclurii (Coelenterata: Anthozoa: Scleractinia)
f. Euspira jacksonensis (Mollusca: Gastropoda: Mesogastropoda)
g. Basilosaurus cetoides (Chordata: Vertebrata: Mammalia)
h. Euscalpellum latunculus (Arthropoda: Crustacea: Cirripedia)
i. Bregmaceros troelli (Chordata: Vertebrata: Osteichthyes)
j. Lichenopora (Bryozoa: Gymnolaemata: Cyclostomata)
k. Alveinus minutus (Mollusca: Bivalvia: Heterodonta)
l. Cadulus margarita (Mollusca: Scaphopoda)
m. Pinna (Mollusca: Bivalvia: Dysodonta)
n. Nucula spheniopsis (Mollusca: Bivalvia: Taxodonta)

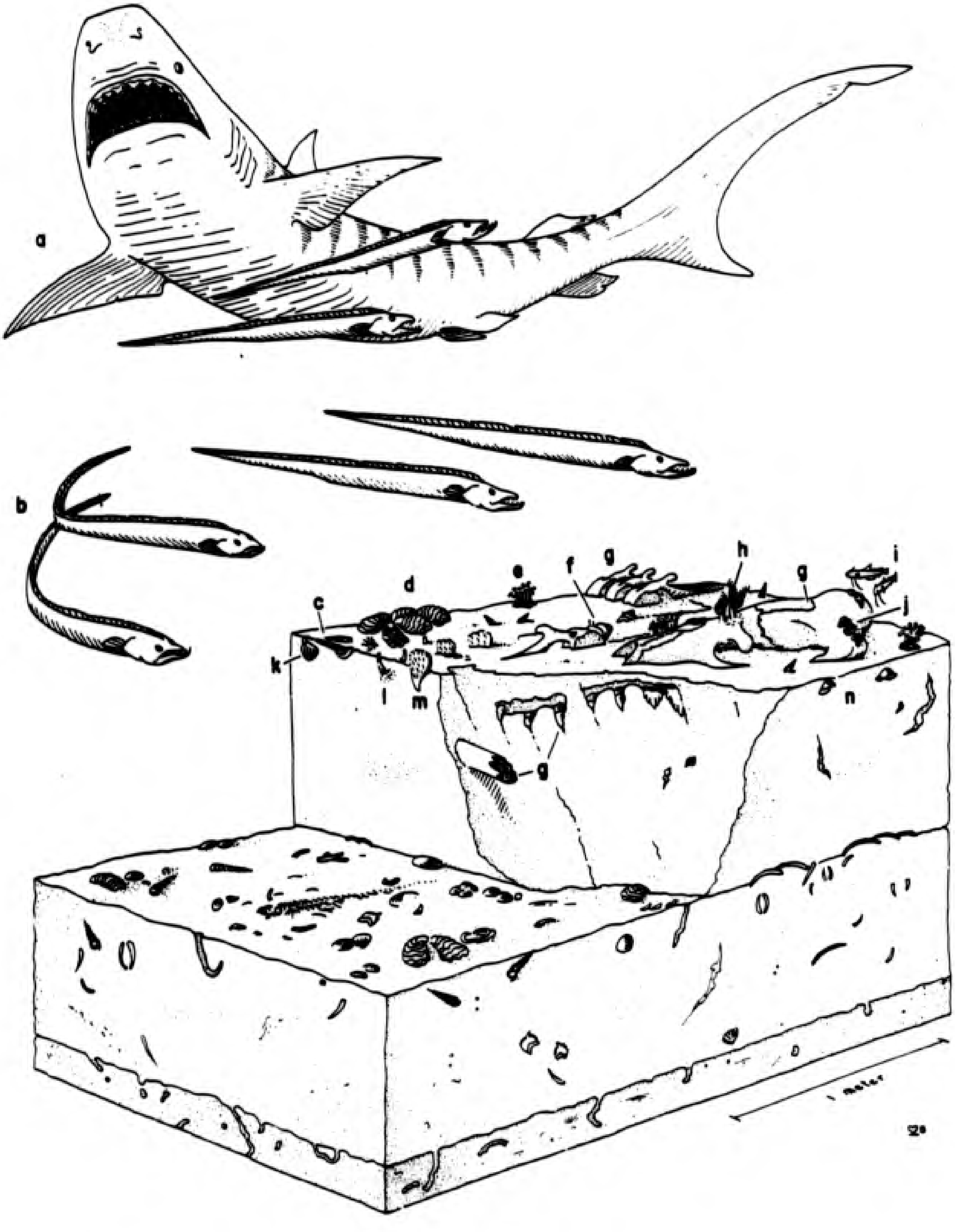


FIGURE 34

Figure 35. Yazoo Detail of Ecological Grouping

a. *Bregmaceros troelli* (Chordata: Vertebrata: Osteichthyes)
b. *Euscalpellum latunculus* (Arthropoda: Crustacea: Cirripedia)
c. *Basilosaurus cetoides* skull (Chordata: Vertebrata: Mammalia)
d. *Otionella* (Bryozoa: Gymnolaemata: Cheilostomata)
e. *Pinna* (Mollusca: Bivalvia: Dysodonta)
f. *Turritella* (Mollusca: Gastropoda: Mesogastropoda)
g. *Lichenopora* (Bryozoa: Gymnolaemata: Cyclostomata)
h. *Ostrea* (Mollusca: Gastropoda: Mesogastropoda)
i. *Lunulites bassleri* (Bryozoa: Gymnolaemata: Cheilostomata)
j. *Calappa* (Arthropoda: Crustacea: Malacostraca)
k. *Endopachys maclurii* (Coelenterata: Anthozoa: Scleractinia)

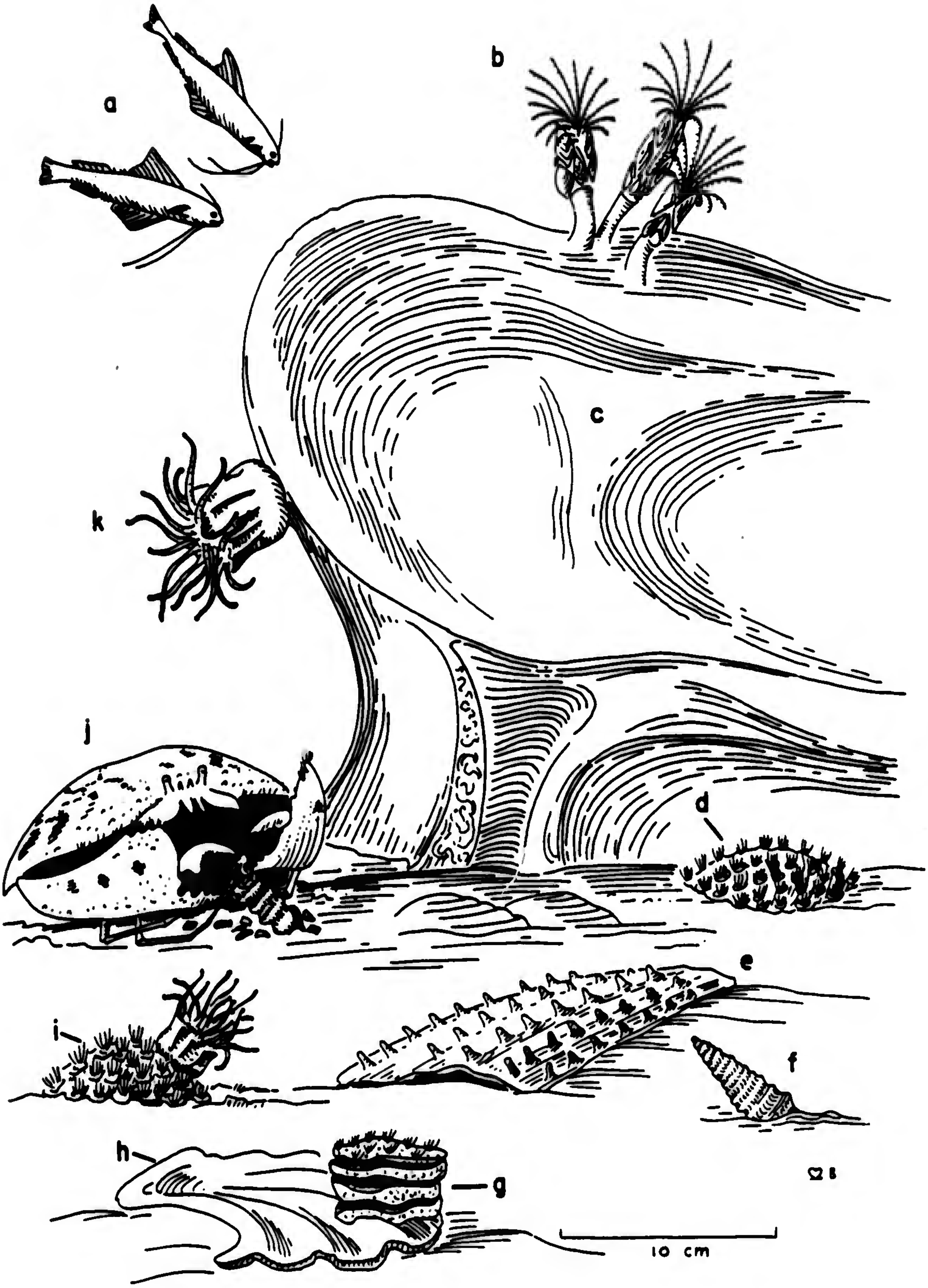


FIGURE 35

Chapter 6. IMPACT OF THE RED RIVER WATERWAY ON THE MONTGOMERY LANDING LOCALITY AND RECOMMENDATIONS

A. IMPACTS

It has always been clear that the Red River Waterway would produce major changes at the Montgomery Landing site. Over ten years ago, State Geologist Dr. Leo Huff made inquiries to determine how Corps activity would affect the site. Early concerns centered on the rise of water level and how much of the site would be covered. As plans for the immediate vicinity of the site were developed, it became clear that three other threats existed: erosion from wash created by river traffic, silting over of the site's lower parts in slack water areas, and vegetation and slumping cover. The last two are clearly of major importance now. The site exists only because the region is a cutbank, swept clean by the spring high water. The Red River Waterway Project as a whole will prevent the drastic water level changes common now. The present geometry of the site area, in which a channel has been cut by the Corps across the point bar opposite the fossil site, guarantees that the lower portions of the site will be covered by sediment (Plate 50). The old river channel at the foot of the cutbank is now slack water with most flow diverted through the channel. It is already silting in. The southern part of the site (sections 8 and 9; Plates 51, 52) no longer exists, having been covered with rock to prevent erosion by the river as diverted by the channel through the point bar. The areas of the site where erosion spurred by barge wash might have made a difference are either no longer existant or no longer open. Areas of the site beneath the new stable water table level or beneath thick sediment will also be inaccessible, as will the upper portions of the site as weathering blankets them and vegetation stabilizes the slope.

Under the old conditions at Montgomery Landing, the diagenetic carbonate ledges provided surfaces for visitors to the site to walk on, making the site accessible in all but the very highest water stands, even when only the steep cliff face was exposed (Plates 51-21). These hard ledges extend less than a foot into the cliff. Cover of the cliff face by weathered scree would prevent ledge development, so that even shoveling off the scree would not produce the old accessibility. Since the lower, gently sloping cliff face will be under water or sediment, there will soon be little or no fossil site to be seen by visitors. The faulting and dip of beds produce a situation in which the Moody's Branch highly fossiliferous beds are highest on the cliff to the north. It is at the north end of the outcrop where the Moody's Branch beds would be exposed for sampling at the constant higher water level, or could be kept exposed for viewing by visitors with the least effort. It is at least technically feasible to preserve a representative section by making a trench similar to the section trenches dug for this project, but wider, on the north end of the outcrop and one on the south end.

B. RECOMMENDATIONS

The presentation of recommendations is difficult because the future actions optimal for this site in our opinion are not possible because of circumstances beyond the control of either these investigators or the

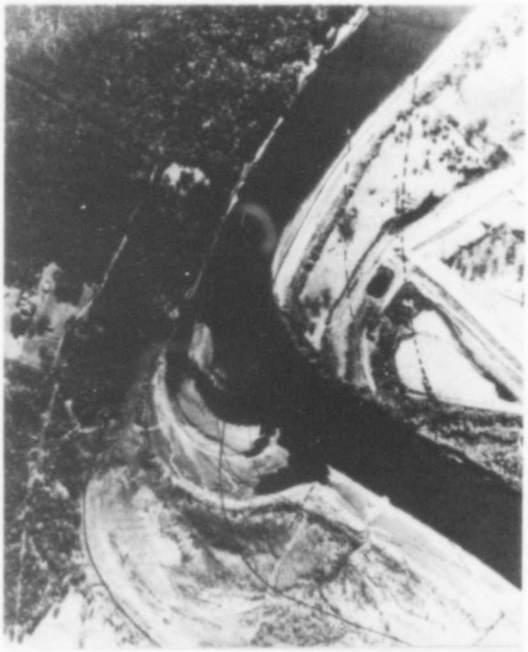


Figure 50-1 Aerial view of Montgomery Landing showing sand bars developing in slack water area at north of the outcrop.

Figure 50-2 View looking north along the Montgomery Landing outcrop towards the developing sand bars.

Figure 51-1. View south from Basilosaurus site to students working on section 10. A large chunk of driftwood lies on "Oyster Point" in the background.

Figure 51-2. Upper division geology students collect from the Yazoo during high water in the spring of 1977 on a Geology 3011 class field trip from LSU.

PLATE 51

Figure 52-1. Dr. and Mrs. C. R. Givens collect bivalve casts from the surface of "Oyster Point." View looking north.

Figure 52-2. Corps of Engineers representative Rader (l) and Dr. van den Bold(r) view revetment construction at Montgomery Landing. "Oyster Point" lies beneath the mound of earth. View looking south.

PLATE 52

Corps of Engineers. Our experience in attempting to obtain permission to carry out research on the land owned by the town of Montgomery and in attempting to interest citizens in the research have convinced us of several problems.

Some citizens' concern for the safety of the Creola Bluff Cemetery, located roughly one quarter mile inland from the cut bank which forms the Montgomery Landing fossil site, will prevent them from viewing positively any activity at the fossil site at all. Their often repeated concern about erosion which prevented the Cemetery Committee and the Town Council from approving research on their portion of the site is not a concern which reason can overcome. The shallow section trenches which we dug remove much less material than the river does each spring. An argument put forth by several townspeople was that digging any holes on the bluff would channel the river flow and speed erosion. Since the cut bank is deeply gullied naturally, one need not be a geologist or an engineer to see that any effect of digging by scientists or students would be extremely minor in comparison to the natural processes going on at the site. Even when a few rains had removed all trace of our sections, so that citizens could see that no harm at all resulted, they remained adamant. In part, this view stems from the feelings of people with beloved relatives in the cemetery. They are correct in believing that river erosion would have eventually threatened it, before Red River Waterway construction. They are also correct in the idea that scientific work at the fossil site attracts people to the area and may increase fishing and picnicking on the bank below the cemetery. The more people that come to visit, the higher the risk of vandalism to the cemetery becomes.

Townspeople of Montgomery are divided on many issues. If one person supports an idea, long-time opponents of that person will be on hand to oppose it. Even one prominent citizen opposing an activity, and threatening to sue, could stop anything. Despite kind and courteous help from several local citizens, we would not want to try to work any further with the citizenry.

We will present our recommendations in two parts, first, the impossible optimal situation in which citizens of Montgomery are proud of and interested in their fossil site and eager to have it be utilized for educational purposes, and second, some possible suggestions.

Suggestions For The Optimal Situation

Our research will continue on Montgomery Landing specimens and both fossils and samples will continue to be available for scientists to work with at LSU. Displays for the Museum of Geoscience as well as the one promised for the Corps of Engineers will be built. Most scientists who would have any interest in the site are aware that they should act within the next couple of years if they want to see good exposures. The symposium which we are planning to hold after the completion of this project will aid in notifying people of the opportunity now present to work at this site and to the fact that work at the site itself will gradually grow more and more difficult. Reports in newsletters and in scientific publications, which will be written after this project is complete, will have the effect of spreading the word.

Every effort should be made to have the site visited by laymen while it is readily available. The Corps and the Museum of Geoscience could distribute a handout for adults on the site, giving data on the site's ecology, paleontology, and geology, and a simplified version suitable for elementary level children. There is a newsletter which all elementary level and secondary level Louisiana teachers receive from the Louisiana Department of Education, and it could make known to teachers the availability of the handouts. The handout would have to distinguish between the rare finds of Montgomery Landing, like the whales, which should not be excavated by laymen, and the common invertebrates which even young children could collect and study without harming the site. It would have to make clear the styles of digging and fossil preservation methods that avoid damaging the appearance of the outcrop or wasting fossils.

Every effort should be made to have local citizens enjoy and understand the site. Few accepted our offers to watch our excavations. If local interest did develop, the site would make an excellent "living lab" for classes in science in local schools. By the time our work is completed, there will be plenty of data for teachers to work into lesson plans on biology, geology, or ecology. Students could see faults, dipping beds, and an unconformity in addition to all the fossils. One of the landowners (Ms. Harrison) requested, as part of the collecting agreement, fossils for a display at her historic home which she hopes to open to the public. This display or a visit by the portable display which we build for the Corps could help stir interest.

The rarity of outcrops in Louisiana and the fact that Montgomery Landing is the state's best and most diverse fossil locality would make efforts to keep parts of the site accessible worthwhile. The faults and other features of the central area of the cliff would not be of sufficient value to repay the effort of keeping them dug open. Perhaps the citizens could be persuaded to keep a three-meter wide trench up the cliff clean on both the north and south ends of the cliff so that most of the section could be seen and collected. Signs directing visitors to the area and telling its story could be erected. As the river silts in at the foot of the cliff, a flat area would be formed which would be a good place for a few picnic tables for visitors.

The visitors could be expected to patronize the restaurant, gas station, and grocery store of Montgomery, benefiting the economy of the town. We purchased food for our field crews in Montgomery and stayed at the nearest local motel. The town is losing population. The fossil site is the only feature of the immediate vicinity that has state-wide or national interest. If the citizenry could decide to make available data on the Creola Cemetery, which is old and is a very beautiful spot to visit among the pines, as well, Montgomery would merit a stop by many visitors. The fossil site was once a ferry landing area and the history of the town, cemetery, and ferry landing could be presented as well as data from the region's ancient history revealed at the fossil site.

Suggestions For The Actual Situation

Encouragement of visits to the site by any but the most responsible groups, which will stay away from the town-owned portion of the lands and be unobtrusive, would be an invitation to friction with some citizens of Montgomery. The boundaries of the town-owned portion of the locality are not visible from the river, and even if they were visible and were always respected, visitors would be resented by some.

If the condition of the site warrants at the time of the symposium planned as part of this project, a field trip will be led to the site. We will continue to share data with groups that approach us about site visits but cannot suggest much publicity on the site. Articles in scientific journals do not produce a risk of increasing visits drastically.

When the new Museum of Geoscience building in the proposed LSU Museum Complex is built, material from this project will be featured. A life-sized fiberglass replica of Basilosaurus as it appeared in life is currently being suggested as the focal point for the main two-story display hall. A large block of sediment which shows bivalves in place as they occured on the surface near section 9 (Plate 52) has been saved for display. Dioramas on the former appearance of the sea floor could bring to life the block diagrams from this report.

As the years pass, attitudes in Montgomery may change. The symposium and displays in the Museum of Geoscience might begin to spark citizen interest without arousing any conflicts. Many of the Montgomery citizens who oppose work at the site are very elderly. Perhaps in five or ten years citizens of the area will want to make the site accessible to scientists, students, and laymen and to develop their own local displays on it. Unfortunately, under the circumstances at the site right now, time and nature are working against this possibility, making the site less visually interesting year by year.

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