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POST-OLIGOCENE STRATIGRAPHY AND MAPPING CONSIDERATIONS

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INTRODUCTION

Background

The nature, distribution, and relationships between the post-Oligocene (Neogene) sediments currently named and mapped as Catahoula, Hattiesburg, Pascagoula, and Citronelle formations in the southern portions of Mississippi have challenged the authors as well as other stratigraphers, geologic mappers, and sedimentologists for a number of years (Moore, 1965; May, 1980; Adamczak, 1986; Albertson and others, 1986; Gerald, 1986; Day, 1987). Generally, the challenges and difficulties have resulted from several related factors which include: 1) limited outcrops, 2) deep weathering and alteration, 3) lack of subsurface data including cores and geophysical logs, 4) poorly defined stratigraphic boundaries, 5) apparent absence of fossils, and 6) an inadequate depositional model for these sediments.

These challenges assume practical significance in understanding the occurrence and movement of ground water and the siting of solid waste landfills in these materials. They are also important issues facing the state in its efforts to revise the state geologic map. Many of these issues were addressed at the MISGEOMAP Conference held in Jackson in 1989 (Bograd and Dockery, 1990; Bowen, 1990; Cameron, 1990; May, 1990; Otvos, 1990; Patrick, 1990; and Saucier, 1990). Specifically, we believe that the Neogene formations identified on the state geologic map cannot be mapped in the field using the current criteria for their recognition. The following views and recommendations are offered in the hope of stimulating interest and discussion pertaining to the Neogene of Mississippi.

Purpose

The purposes of this paper are: 1) to address the adequacy of current post-Oligocene (Neogene) stratigraphic terminology for southern Mississippi, 2) to describe the problems associated with current usage, 3) to present a hypothesis and model which more closely describe the nature and distribution of these sediments and which conform to the rules of the North American Stratigraphic Code (AAPG, 1983), and 4) to recommend methods for testing this hypothesis.

CURRENT STRATIGRAPHIC USAGE

The post-Oligocene (Neogene) of Mississippi as currently defined by the Mississippi Office of Geology (Dockery, 1981) utilizes updip and downdip members or formations to help explain complex stratigraphic terminology (Figure 1). They define updip as to the north, northeast and east and downdip to the south, southwest and west. Usually (but not always), the overlying and presumably younger units are given formation status (i.e., Hattiesburg, Pascagoula, Graham Ferry, and Citronelle formations). The downdip units occasionally have formation status (i.e., Paynes Hammock, Biloxi, Pamlico, and Gulfport) but also use lithologic or even paleontologic modifiers such as the Chickasawhay Limestone, Tatum or *Heterostegina* Limestone, and the *Amphistegina* Zone. Dockery (1981) considered the Chickasawhay Limestone, Paynes Hammock, Tatum or *Heterostegina* Limestone, and the *Heterostegina* Reef to be age equivalent to the Catahoula Formation, the *Amphistegina* Zone to be age equivalent to the Hattiesburg Formation, and the Pamlico, Biloxi, and Gulfport formations to be age equivalent to the loess deposits in western Mississippi. Saucier and Snead (1989) mapped those deposits shown on the 1969 state map as Citronelle as the Upland Complex.

THE PROBLEM

The reason that the mapping of the post-Oligocene deposits of Mississippi has been so difficult and controversial stems from the failure to recognize that the Citronelle, Catahoula, Hattiesburg and Pascagoula formations are all part of the same massive non-marine offlapping regressive complex with multiple source areas (Figure 2). The views of Amadeus Grabau made over 70 years ago are applicable here:

"Thus it is brought about that each successive formation of the retreated series extends shoreward to a less extent than the preceding one. As each formation or bed passes shoreward into a coarse clastic it is evident that the shore ends of all the formations deposited during the retreat will 'together' constitute a stratum of sandstone or conglomerate. The sand ends of all the beds will be exposed at or just above sea level and constitute a continuous sand formation, which, however, is not the same age at any two points along a line transversing the direction of the shore." (Grabau, 1960 (1924))

The fact that minor transgressive events which occurred during the post-Oligocene did not reach inland far enough to deposit mappable deposits has added to the difficulty in geologic interpretation. Attempts to map time-equivalent sediments across the ends of the non-time equivalent regressive deposits without understanding their interrelationship has resulted in additional dilemma. The post-Oligocene regressive complex has superpositional fining upward beds of clay, sands and gravels. The correlation problems arise when similar materials of different ages are mapped as a time equivalent formation (Figure 3). For example, if it were not for diagnostic fossils, the outcropping limestones of the Glendon and Chickasawhay formations (Oligocene) in Wayne County, Mississippi, could easily be mistaken for the same unit. Note the widespread unconformities that are not shown on the latest geologic maps and stratigraphic sections.

Similarly, Cretaceous age Tuscaloosa gravel deposits in southern Tishomingo County are only distinguishable into two different age deposits by subtle differences in mineralogy and size (Russell, 1987). The mapping of similar non-marine materials in south Mississippi as time equivalent formations has resulted in units being mapped as formations that do not meet the geologic requirements for mapping, that is, having a top and bottom, and a type section. If no one can identify the formational contacts in a core or on the outcrop, it is probable that the laws of stratigraphic nomenclature have been violated. Li and Meylan (1994) suggested that the Catahoula and Hattiesburg formations are not mappable; however, they did map the Citronelle. If they had recognized the subsurface sand and gravel deposits in the area mapped, they would, most likely, have had to map the Citronelle differently (Brown, 1944; May, 1980; Gerald, 1986; Patrick and Zhao, 1989; Sturdivant and Patrick, 1990).

A CONCEPTUAL MODEL

Concurrent with demonstrating the need to re-study and re-map the sediments presently shown on the state geologic map as Catahoula, Hattiesburg, Pascagoula, and Citronelle, it is appropriate to suggest a conceptual model that would be used to guide any revised mapping. The proposed conceptual model for the post-Oligocene sediments is not a new or radical model but simply an extension of the concept used in mapping the pre-Oligocene sediments in Mississippi.

The pre-Oligocene sediment mapping was based on the premise that dip-oriented subsurface beds could be projected to and mapped on the surface. The mapping of post-Oligocene sediments for a variety of reasons did not follow the same logic. Dip-oriented, non-marine clastics were mapped as one formation in the subsurface and a different formation at the geochemically altered outcrop. Massive subsurface Miocene sand and gravel units, some hundreds of feet thick, were not recognized at the surface (Brown, 1944; Gerald, 1986; May, 1980; Patrick and Zhao, 1989; Sturdivant and Patrick, 1990). Unlike the mapping of the pre-Oligocene beds, multiple clay and sand zones of different time periods were mapped on the surface as time equivalent.

To correct the errors made in the past, the basic concepts used in mapping the pre-Oligocene beds must be applied. The basic assumptions are as follows:

1) The post-Oligocene sediments are comprised primarily of non-marine, time-equivalent, dip-oriented, fining upward alluvial beds.

2) The outcropping sediments have downdip portions which are often different in color, induration, and mineralogy than the equivalent surface sediments. At least three zones are mappable in the subsurface.

3) The differences in the outcrops are caused by differences in weathering and geochemical alterations and rework-

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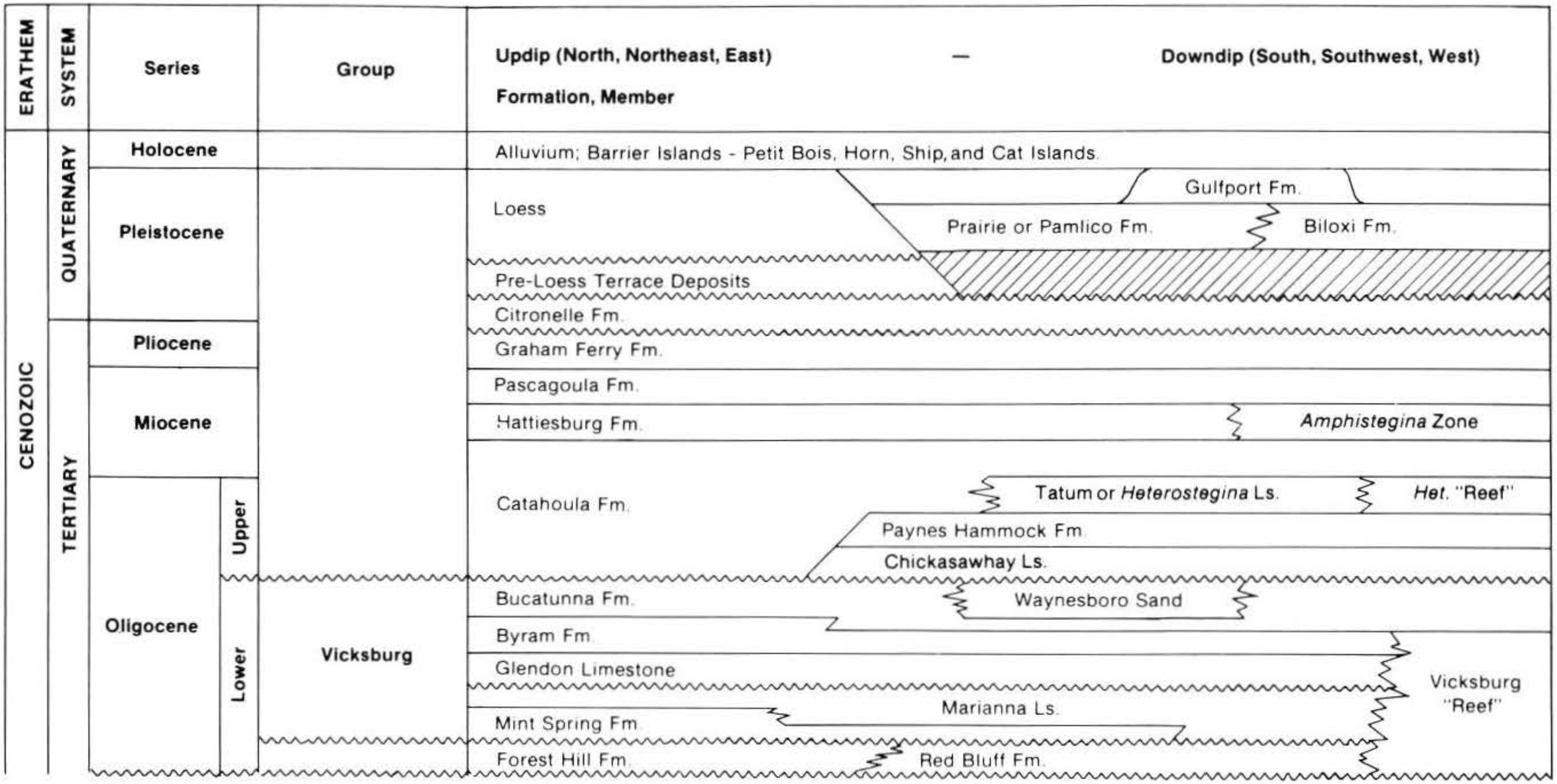

Figure 1. Post-Oligocene geology of Mississippi (Dockery, 1981).

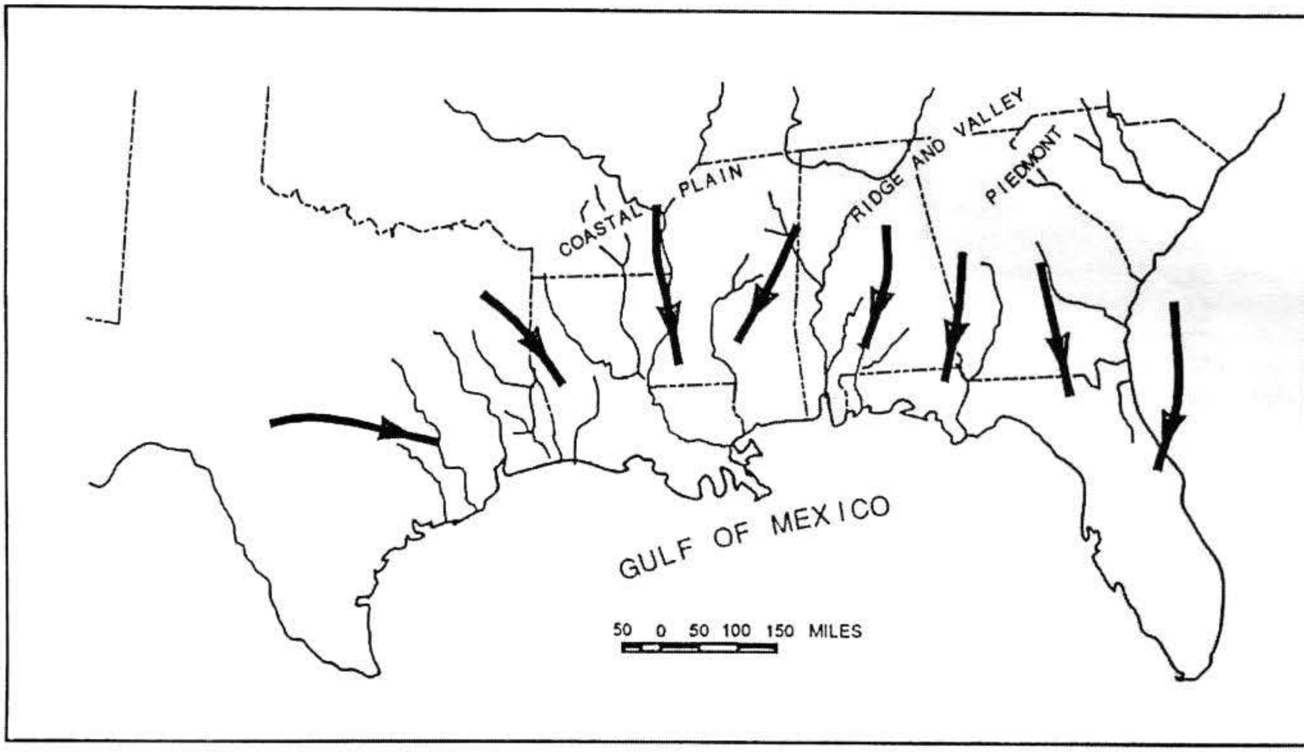

Figure 2. Source areas for Miocene sediments (after Isphording, 1977).

ing of underlying formational materials.

4) The basal Miocene does not maintain a uniform stratigraphic position, but rests on progressively older formations updip.

5) The outcrop patterns of the post-Oligocene clastics follow closely the outcropping patterns of the pre-Oligocene sediments.

The conceptual model in Figure 4 illustrates the conditions as they occur over a large portion of Mississippi where superpositioned alluvial cycles approach the surface. It can be seen how lithologically similar cycles of deposition could be incorrectly mapped across time lines. The oxidized basal portion of Cycle C fits the lithologic description of material commonly mapped as Citronelle. The finer upper portions of Cycle C could fit the characteristics of the Hattiesburg Formation. The indurated portions of Cycle B are characteristic of the Catahoula. In current usage, the lower portion of Cycle C would commonly be described as Miocene in the subsurface and Citronelle at the outcrop.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1) There is no general agreement on the terminology and criteria for recognition of post-Oligocene units in Mississippi.

2) The terminology and criteria used for the 1969 state map do not conform to current and accepted standards of stratigraphic nomenclature and, in many cases, do not fully describe the lithology and stratigraphic relationships between the units.

3) It is premature at this time to apply distant formation names to units of presumably similar age in Mississippi.

4) The development of acceptable terminology and criteria for small-scale mapping may be different than those used for preparation of large-scale maps of small areas.

5) Subsurface data relative to post-Oligocene units consist mainly of water wells, some of which have geophysical well logs. Only a limited number of petroleum test wells were logged near the surface. The quality of the data is not consistent.

6) In order to establish acceptable terminology and criteria for mapping at any scale, consideration must be given to the concept of offlapping depositional wedges and to subsurface data.

Recommendations

1) Until further studies have been completed, the entire non-marine regressive system (less the Citronelle) could be referred to as the Post-Oligocene Regressive Complex. This includes materials represented as the Upland Complex of Saucier and Snead (1989). Or, we could refer to the entire

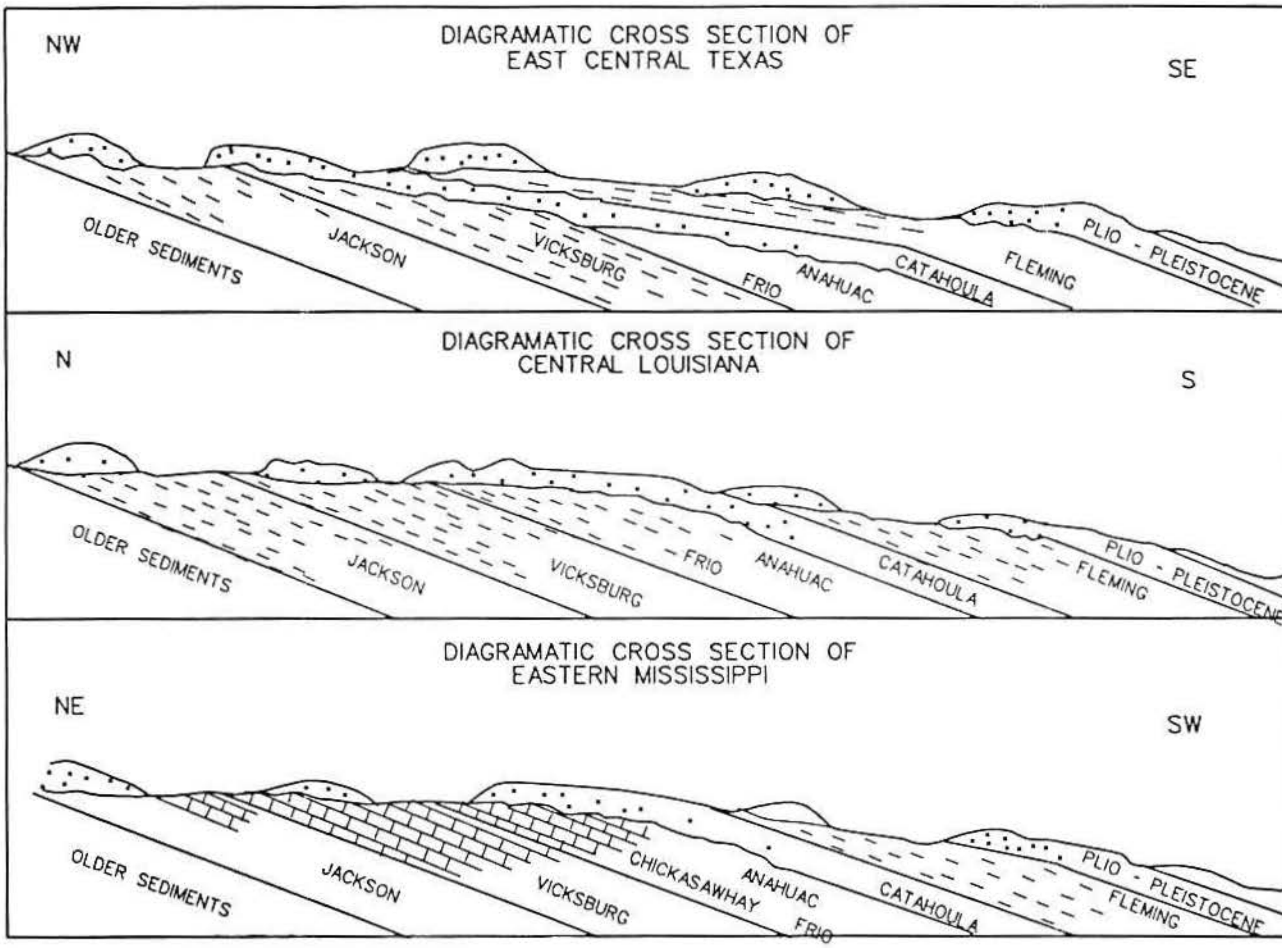

Figure 3. Cross sections showing several major unconformities (Lafayette Geological Society, 1968).

system as the Neogene, Pleistocene, or Holocene Complex with locally mappable time-equivalent members or facies.

2) Enhanced understanding of the stratigraphic relations between members of the Post-Oligocene Regressive Complex would be accomplished by an in-depth surface and subsurface study of this complex in a selected region. The study area should be along a downdip traverse in a region having reasonable surface exposures and sufficient numbers of geophysically logged water wells for subsurface information. Additionally, several continuously cored borings should be constructed through the total depth of the complex at selected locations. Shallow core borings should be drilled in the updip and exposed portion of the traverse. An important objective of these studies would be to obtain detailed lithologic and stratigraphic information of the updip ends of the system and, by tracing these exposed units into the subsurface, to determine their vertical and lateral continuity down dip.

3) Paleomagnetic and palynology studies should be attempted on the cores to help place them in proper stratigraphic sequence.

4) The rounding of quartz grains as an indicator of multiple reworking should be looked at in conjunction with silicified wood types incorporated from underlying units.

5) These proposed studies, as well as others dealing with Miocene and younger materials, should include the examination of the agronomic soils developed upon them since the maturity of the soils is an indication of the relative age of the deposits (Autin and others, 1991).

REFERENCES CITED

Adamczak, D.L., 1986, The petrology of the Hattiesburg lutite (Miocene), northern Forrest County, Mississippi: unpublished M.S. thesis, University of Southern Mississippi, Hattiesburg, 56 p.

Albertson, P.E., D.W. Harrelson, and S.L. Lee, 1986, An

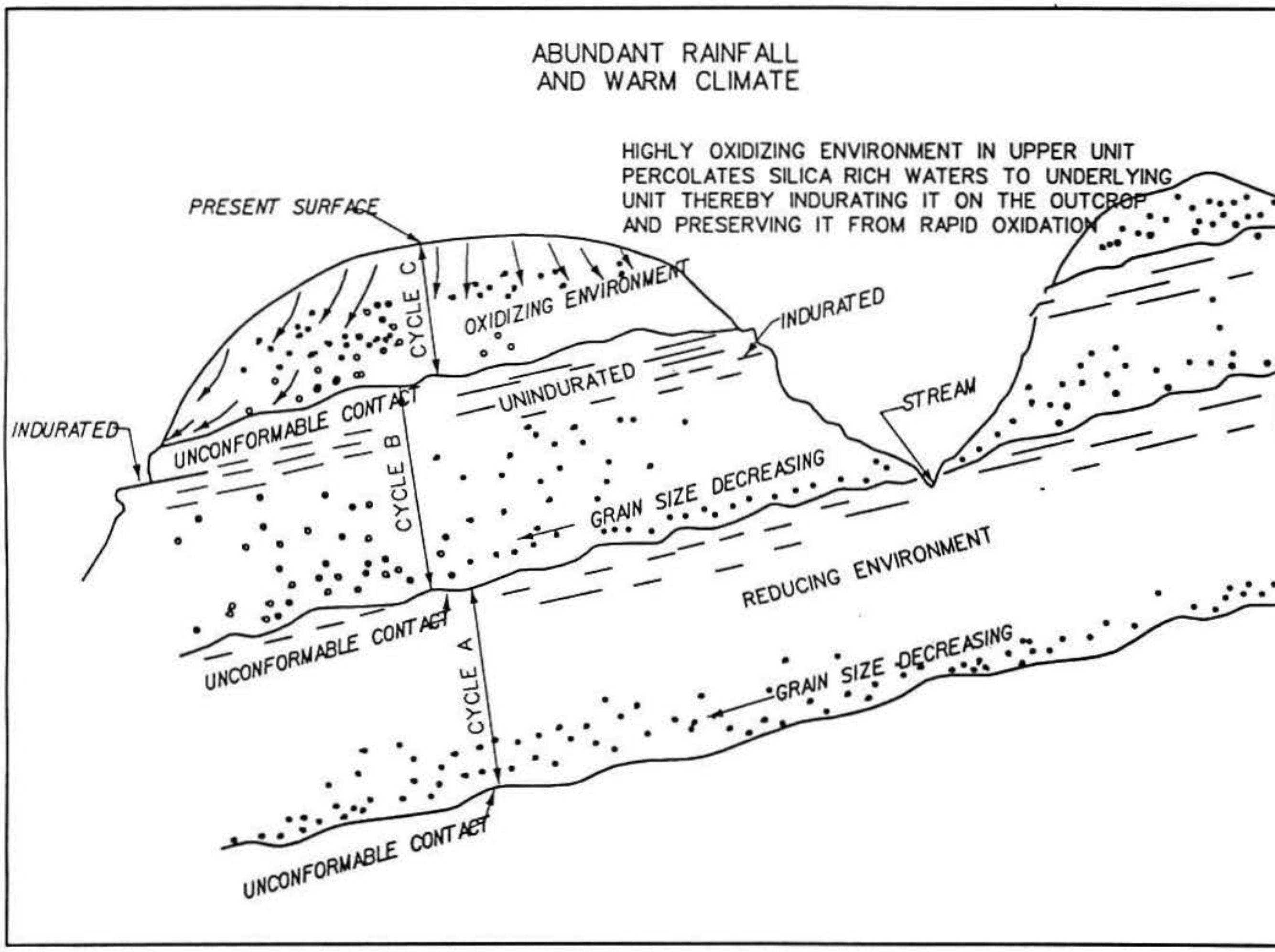

Figure 4. Schematic showing different portions of fining-upward alluvial cycles exposed at the surface. The basal portion of Cycle C is characteristic of material usually called "Citronelle" and the upper part of Cycle B probably would be mapped as Miocene Catahoula or Hattiesburg (May, 1976).

evaluation of the subsurface Catahoula Formation in Natchitoches Parish, Louisiana: Gulf Coast Association of Geological Societies, Transactions, v. 36, p. 371-378.

American Association of Petroleum Geologists (AAPG), 1983, North American stratigraphic code: American Association of Petroleum Geologists Bulletin, v. 67, n. 5, p. 841-875.

Autin, W.J., S.F. Burns, B.J. Miller, R.T. Saucier, and J.I. Snead, 1991, Quaternary geology of the Lower Mississippi Valley *in* R.B. Morrison, ed., Quaternary nonglacial geology; Conterminous U.S.: Geological Society of America, The Geology of North America, v. K-2, Boulder, CO, p. 547-582.

Bograd, M.B.E., and D.T. Dockery III, eds., 1990, Geologic mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, 48 p.

Bowen, R.L., 1990, Geologic mapping in the Hattiesburg district, Mississippi, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 29.

Brown, G.F., 1944, Geology and ground-water resources of the Camp Shelby area: Mississippi State Geological Survey, Bulletin 58, 72 p.

Cameron, C.P., 1990, Stratigraphy and depositional environments of Catahoula Sandstones and associated facies in south-central Mississippi, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 27-28.

Day, L.A., 1987, Stratigraphy and depositional environments of the Catahoula Sandstones and associated facies in southeast Mississippi: unpublished M.S. thesis, University of Southern Mississippi, Hattiesburg.

Dockery, D.T., 1981, Stratigraphic column of Mississippi:

Mississippi Bureau of Geology, one sheet.
Gerald, W.C., 1986, The distribution and correlation of shallow aquifers in southeastern Mississippi: unpublished M.S. thesis, University of Southern Mississippi, Hattiesburg, 80 p.
Grabau, A.W., 1960, Principles of stratigraphy: Dover Pub. Inc., New York, v. 2, p. 734, reprint of 1924 edition.
Isphording, W.C., 1977, Petrology and stratigraphy of the Alabama Miocene: Gulf Coast Association of Geological Societies, Transactions, v. 27, p. 304-313.
Lafayette Geological Society, 1968, Tertiary of central Louisiana: Lafayette Geological Society field trip guide book, p. 16-51.
Li, Z., and M.A. Meylan, 1994, Lithostratigraphy and petrology of Neogene and Pleistocene sedimentary rocks, south-central Mississippi: Gulf Coast Association of Geological Societies, Transactions, v. 44, p. 383-392.
May, J.H., 1976, General geology and mineral resources of the Mendenhall West Quadrangle: Mississippi Geological, Economic and Topographical Survey, Map GQ 82-NW, 1:24,000 and 53 p. booklet.
May, J.H., 1980, Interpretation of post-Oligocene deposition cycles in the Mendenhall West Quadrangle, Mississippi: unpublished M.S. thesis, University of Southern Mississippi, Hattiesburg, 118 p.
May, J.H., 1990, Key concepts to aid in mapping non-marine sediments in Mississippi, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 25.
Moore, W.H., 1965, Hinds County geology and mineral resources: Mississippi Geological, Economic and Topographical Survey, Bulletin 105, 244 p.
Otvos, E.G., 1990, Geological mapping projects, coastal Mississippi; past results and suggestions for the future, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 41-42.
Patrick, D.M., 1990, Geologic mapping issues in southern Mississippi, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 31-32.
Patrick, D.M., and S. Zhao, 1989, Ground-water extraction trends in Forrest and Lamar counties, Mississippi: Proceedings, Mississippi Water Resources Conference, Mississippi Water Resources Research Institute, Starkville, MS, p. 85-89.
Patrick, D.M., R. Sturdivant, Jr., and S. Zhao, 1989, Groundwater models for the Hattiesburg and Laurel, Mississippi regions: Technical Completion Report, Project G1571-04, Water Resources Research Institute, Mississippi State University, Mississippi State, Mississippi, 92 p.
Russell, E.E., 1987, Gravel aggregate in Mississippi - its origin and distribution: Mississippi Geology, v. 7, no. 3, p. 1-7.
Saucier, R.T., 1990, Progress and problems in the synthesis of the Quaternary of Mississippi, *in* M.B.E. Bograd and D.T. Dockery III, eds., Geologic Mapping in Mississippi: Proceedings of the 1989 MISGEOMAP Conference: Mississippi Bureau of Geology, Circular 3, p. 35-40.
Saucier, R.T., and J.I. Snead, 1989, Quaternary geology of the Lower Mississippi Valley (map): Geological Society of America, DNAG Project, Boulder, CO, one sheet.
Sturdivant, R., Jr., and D.M. Patrick, 1990, Ground-water models of the Miocene aquifer system in Jones County, Mississippi: Proceedings, Mississippi Water Resources Conference, Mississippi Water Resources Research Institute, Starkville, MS, p. 136-146.

REPLY TO MIOCENE DISMAY

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STRATIGRAPHY

The previous discussion of May et al. (this issue) can be summarized in two general statements: (1) The Miocene formations of southern Mississippi lack distinguishing lithologies, fossils, and mappable boundaries and are in need of reassessment, and (2) The Citronelle Formation in Mississippi is a "waste basket" unit comprised of the updip graveliferous facies of multiple Miocene and younger formations and should be reassessed.

These statements have merits, but we agree that merging the present stratigraphy into a single undifferentiated post-Oligocene mapping unit is not the answer. Such a unit would render the southern part of the state geologic map useless. The Surface Geology Division of the Mississippi Office of Geology is conducting a statewide investigation of the Miocene in search of mappable divisions. Hopefully these divisions can be tied to currently used formational names. The U.S. Geological Survey and Mississippi Office of Land and Water Resources recognize Catahoula and Hattiesburg aquifers, each having a lower sandy interval and an upper shale-dominated interval (Strom and Oakley, 1995). These formations are important in ground-water models and regulations. The Pliocene Graham Ferry Formation of coastal Mississippi seems to be a mappable sand. Such findings are encouraging in the search for a well-defined Miocene stratigraphy. Continuing in the steps of our professional predecessors, we hope to make order out of a bewildering sedimentary sequence.

The Miocene sands and clays of the state most likely reflect the world-wide rise and fall of sea level as demonstrated by Vail and Hardenbol (1979). After careful study, they may prove to be mappable sequence-related sedimentary packages much like that of the Cretaceous and Paleogene of northern and central Mississippi. While the Miocene lacks widespread transgressive marine units at the surface, such units are present in the subsurface and allow for relative age determinations (Dockery, 1987a).

Upland Complex of Saucier and Sneed (1989) and Autin et al. (1991) includes both the Citronelle of southern Mississippi and the pre-loess gravels bordering the Mississippi River alluvial plain. I prefer to retain the pre-loess gravels as an informal unit. It is distinguished from the classical Citronelle of southern Mississippi in: (1) its general lower elevation, (2) loess cover, (3) distribution, and (4) the common occurrence of large ice-rafted sandstone and chert clasts, some of which show little rounding due to transport. The latter character almost certainly equates this unit, at least in part, with periods of Pleistocene glaciation. Therefore, it is an unlikely candidate for a coarse-grained updip Miocene facies.

The classical Citronelle has a distribution on (as outliers) and south of the Jackson Prairie of central Mississippi. Some of the northern outliers are fluvial sands lacking gravel and may be older than the Citronelle of the main outcrop belt. Such sands are the likely source of rare silicified palm specimens found in central Mississippi (Dockery, 1987b). The bulk of the Citronelle outcrop is south of the Catahoula outcrop belt and thus is not an updip facies of that unit. Most of it overlies Hattiesburg and younger units (not known for an abundance of gravel) and could well be a genetically related package of graveliferous sands overlying a regional unconformity. As such, it is worthy of a formal name.

Gravels are rare in Mississippi's coastal plain section, but are a distinguishing characteristic (though not always present) of weathered, high-level sands mapped as Citronelle. Russell (1987) reported on the gravel resources of the state, which with some modification here can be broken down into relatively few units: (1) Tuscaloosa (Cretaceous), (2) Tennessee River Terrace, (3) Tombigbee River, (4) Mississippi River alluvium, (5) loess belt, and (6) southern Mississippi = Citronelle. Except for the Tuscaloosa gravels, the other deposits are restricted to a Late Pliocene-Recent age. While reports of gravel in subsurface Miocene units need to be followed up, gravels are not characteristic of this interval. According to Russell (1987), gravels in the Citronelle are thickest in southwestern Mississippi and thin toward the east. This suggests a common ancestral Mississippi River source in the Late Pliocene or Pleistocene (the age shown in Figure 1 of May et al.).

This brings us to what may be an important misconception in the multiple-age model for Citronelle gravel. This model assumes that gravels have always characterized updip fluvial facies in the Cenozoic. Not so; gravel can only be present in updip facies when a source for gravel is available. As shown by repetitive marine incursions, the lower Mississippi River Basin was an area of subsidence through much of the Late Cretaceous and Cenozoic. It was not until renewed uplift of the Nashville Dome in the Pliocene (Reesman and Stearns, 1989; Self, 1993) that the ancestral Tennessee River breached chert-bearing carbonates of Mississippian age, including the Fort Payne Chert, and sent a flood of gravel southward. This was the major source for Citronelle gravels as shown by their microtexture and many fossils (Smith and Meylan, 1983).

ENGINEERING PROPERTIES OF MISSISSIPPI GRAVELS

The province of the state's gravels is reflected in their physical characteristics. Figure 1 is a plot of soundness and abrasion for Mississippi gravels as compiled in a data base by Charles Canoy, Mississippi Department of Transportation, for tests run from 1985 to the present. Soundness is a gravel's resistance to fracturing by ice wedging. It is measured by boiling the gravel in a solution of magnesium sulfate and then sieving to check for breakage. Abrasion is a gravel's hardness and wear resistance. It is measured by tumbling the gravel with crushing balls and then sieving to check for breakage. Acceptable limits set by the Department of Transportation for gravel to be mixed in concrete is 15 or less for soundness and 40 or less (45 or less for asphalt) for abrasion.

Cretaceous and Tombigbee River gravels (17 measured) from Clay, Itawamba, Lowndes, and Monroe counties of Highway District 1 fall within $x=8$ and, with 3 exceptions, below the line $y=0.5x+15$. Loess Belt gravels (16 measured) from Carroll, DeSoto, Holmes, Panola, Tallahatchie, Warren, Yalobusha, and Yazoo counties of Highway Districts 2 and 3 fall within $x=8$ and between the lines $y=0.5x+15$ and $y=0.5x+19$. Citronelle gravels (53 measured) lie above the line $y=0.5x+13$ but are scattered beyond $x=8$ and above $y=0.5x+19$. Three Citronelle gravels, two in Harrison County and one in Pearl River County, are not included in Figure 1 as they scattered beyond the chart parameters.

The Cretaceous-Tombigbee gravels of Figure 1 can be distinguished by their excellent soundness and abrasion parameters being generally within $x=8$ and $y=0.5x+15$. Loess Belt gravels have excellent soundness within $x=8$ but with abrasion and soundness between $y=0.5x+15$ and $y=0.5x+19$. Citronelle gravels vary greatly in soundness and abrasion. Only two Citronelle gravels plot with the majority of the Cretaceous-Tombigbee gravels as defined above, while many plot with those of the Loess Belt. Twenty-three Citronelle gravels (or 43%), counting the three that plotted off the scale, are beyond $x=8$ and above $y=0.5x+19$. In an ordered sequence, the Cretaceous-Tombigbee gravels have the best mean soundness and abrasion, followed by the Loess Belt gravels, and with the Citronelle gravels last.

Mississippi's native peoples were the first to conduct engineering tests for soundness on the state's gravels. Preforms from various gravels were often heat-treated to improve their workability in the napping of projectile points and tools. According to tests by Sam McGahey, Chief Archaeologist for the Mississippi Department of Archives and History (personal communication), using aboriginal techniques, Cretaceous gravels from Tishomingo County could be heat-treated to the point that tan gravel became some shade of red throughout without significant breakage of preforms. Loess Belt gravels from St. Catherines Creek near Natchez and Sand Creek in Claiborne County could be heat-treated only to the point that the outer millimeter of the preform was reddened. Further heating resulted in significant breakage of preforms. Collins (1984) reported similar results for Citronelle gravels. Heat-treated artifacts of the Loess Belt and Citronelle can be identified by reddened tips and bases, while those originating from northeastern Mississippi are a reddish shade throughout.

Poor scores for soundness and abrasion among Citronelle gravels reflect on the length of time these gravels have been subjected to weathering and leaching of silica. Tuscaloosa gravels of Cretaceous age were buried beneath the laminated clays and sands of the McShan Formation, which served as an aquitard. Present exposures of Tuscaloosa gravels and their redeposition along the Tombigbee River date to the Pleistocene. Loess Belt gravels are also of Pleistocene age as indicated by ice-rafted clasts and their petrified wood floras of extant hardwoods (Blackwell and Dukes, 1981). Citronelle gravels are older than those of the Loess Belt and probably date to the Pliocene. They are not covered by younger formations and have been exposed to weathering since that time. This long period of time may have also included weathering under subtropical climate regimes as indicated by some southern Mississippi friable gravels.

CONCLUSIONS

In conclusion, work on differentiating the Miocene into mappable units is under way, and the Citronelle, by whatever name, is still a good mapping unit.

REFERENCES CITED

Autin, W.J., S.F. Burns, B.J. Miller, R.T. Saucier, and J.I. Snead, 1991, Quaternary geology of the Lower Mississippi Valley, Chapter 18, *in* Quaternary Nonglacial Geology: Conterminous U.S.: Geological Society of America, The Geology of North America, v. K-2, p. 547-582.

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

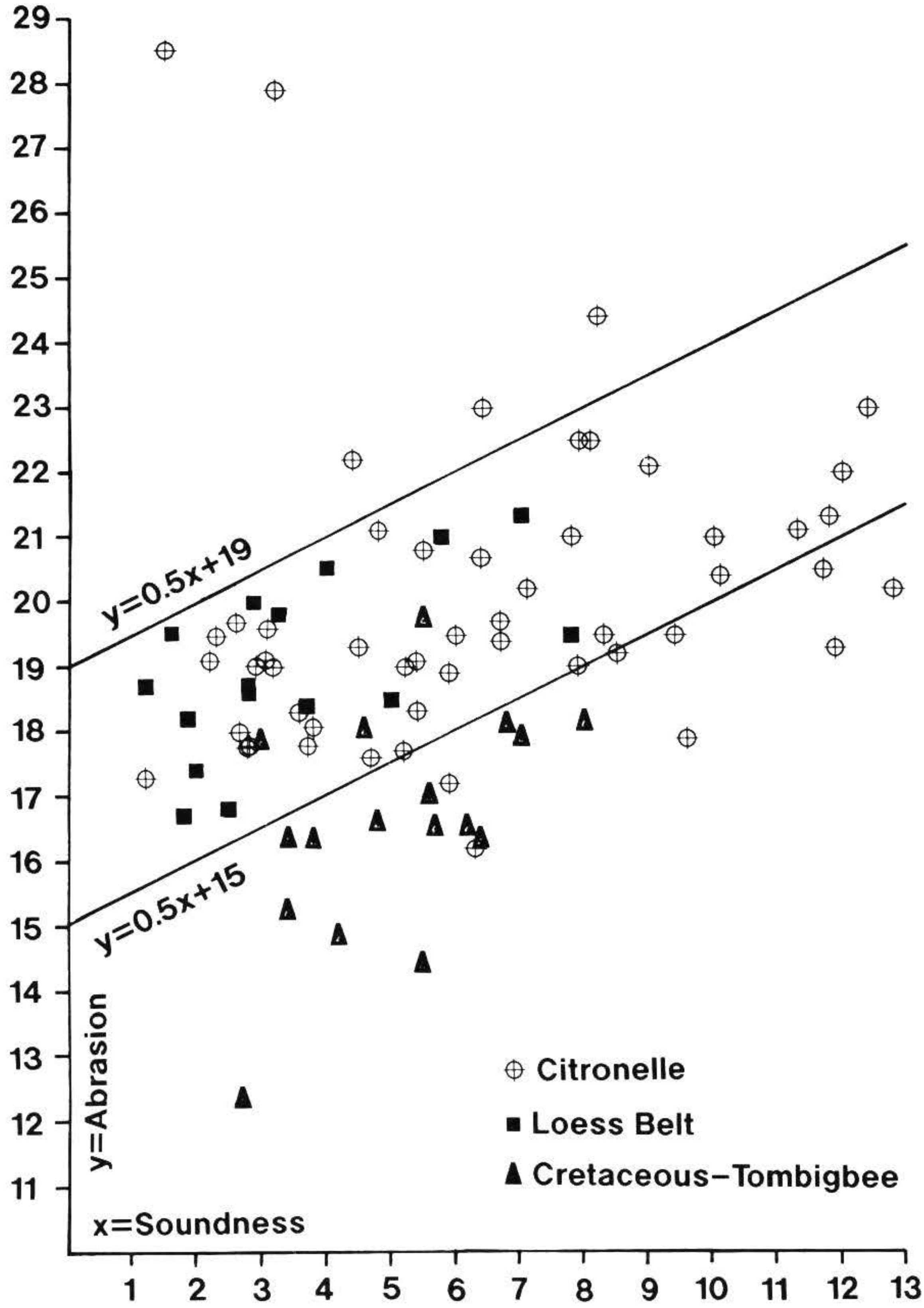
Collins, W.J., 1984, Observations on thermal treatment of Citronelle gravels from Louisiana and Mississippi: an archaeological assessment: Mississippi Archaeology, v. 19, no. 2, p. 7-13.

Dockery, D.T., III, 1987a, Stratigraphy of the Sapphire #1 State of Mississippi well - offshore, Harrison County, Mississippi (abstract): Journal of the Mississippi Academy of Sciences, v. 32, supplement, p. 31.

Dockery, D.T., III, 1987b, Petrified palm "wood" from Thompson Creek, Yazoo County, Mississippi: Mississippi Geology, v. 8, no. 2, p. 10-11.

Reesman, A.L., and R. Stearns, 1989, The Nashville Dome - an isostatically induced erosional structure - and the Cumberland Plateau Dome - an isostatically suppressed extension of the Jessamine Dome: Southeastern Geology, v. 30, no. 3, p. 147-174.

Russell, E.E., 1987, Gravel aggregate in Mississippi - its origin and distribution: Mississippi Geology, v. 7, no. 3, p. 1-7.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Citronelle
Loess Belt
Cretaceous–Tombigbee
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Figure 1.

Saucier, R.T., and J.I. Snead, 1989, Quaternary geology of the lower Mississippi Valley (map): Geological Society of America, DNAG Project, Boulder, CO, one sheet.

Self, R.P., 1993, Late Tertiary to early Quaternary sedimentation in the Gulf Coastal Plain and lower Mississippi Valley: Southeastern Geology, v. 33, no. 2, p. 99-110.

Smith, M.L., and M.A. Meylan, 1983, Red Bluff, Marion County, Mississippi: a Citronelle braided stream deposit: Gulf Coast Association of Geological Societies, Transactions, v. 33, p. 419-432.

Strom, E.W., and W.T. Oakley, 1995, Hydrogeology and analysis of ground-water withdrawal in the Mendenhall-D'Lo area, Simpson County, Mississippi: U.S. Geological Survey, Water-Resources Investigations Report 95-4013, 18 p.

Vail, P.R., and J. Hardenbol, 1979, Sea-level changes during the Tertiary: Oceanus, v. 22, p. 71-79.

1994 Open-File Reports Available From The Mississippi Mineral Resources Institute

The following open-file reports, for the year 1994, are presently available. To purchase these reports, please send the publication number, publication title, and prepayment in the form of a check or money order made payable to the University of Mississippi. A list of older reports is available upon request. All orders and/or correspondence should be addressed to The Mississippi Mineral Resources Institute, 220 Old Chemistry Building, University, Mississippi 38677.

94-1 **Formation Hydrofracturing in the Paleozoic Aquifer, Corinth Municipal Water Well Project, Corinth, Mississippi**; The Mississippi Mineral Resources Institute; April, 1994; 184 pgs., $10.00.

94-2F **Field Verification of Remote-Sensed Lineaments Via Radon Detection**; Desmond Fletcher; August, 1994; 80 pgs., $7.00.

94-3F **Radon Detection as a Method for Ground-Truthing Lineaments by Remote Sensing**; Sridhar Katragadda, Robert R. Tarver, and Douglas L. Lockhart; August, 1994; 73 pgs., $7.00.

94-4F **Remote Sensing Interpretation of the Vicksburg Area, Warren County, Mississippi**; Charles T. Swann, James M. McKeown, II, and Alphonse C. Van Besien; July, 1994; 35 pgs., $3.00.

94-5F **Role of Lignite Char During Reburning of Nitrogen Oxides**; Wei-Yin Chen and Long Ma; August, 1994; 29 pgs., $3.00.

94-6F **Design and Development of a Prototype Acoustic, Self-Cleaning Filter System**; J. Robert Woolsey; July, 1994; 34 pgs., $3.00.

MARINE MACRO-INVERTEBRATE PALEOENVIRONMENTAL INTERPRETATION OF THE HARVEY SITE (COOK MOUNTAIN, EOCENE) IN NORTH-CENTRAL LOUISIANA

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ABSTRACT

The Harvey site, two and one half miles west of Quitman, Louisiana, contains one of the best preserved Cook Mountain marine assemblages found in northern Louisiana. Ninety-six species of marine invertebrates and four species of vertebrates have been documented. Excellent preservation and high diversity lend themselves well to a paleoenvironmental interpretation. Three different assemblages can be recognized at this site. The fauna at the base of the exposed cut is characterized by the oyster *Cubitostrea sellaeformis*. *Nucula mauricensis*, a detritivor, and *Venericardia rotunda*, a filter feeder, are also common. This fauna has a low diversity (10 species) and is dominated by *Cubitostrea* (21%). Common articulated valves of these three bivalves and the excellent preservation suggest that this is a life assemblage. We interpret this fauna to represent a shallow inner shelf community with fluctuating salinity and oxygen levels. The middle of the cut bank is characterized by a pair of shell lenses composed of disarticulated bivalves and severely worn gastropods. The diversity of this fauna is somewhat higher (29 species), but the dominance remains high (29%). *Caestocorbula*, *Eburneopecten*, and *Nucula mauricensis* were the most common in this assemblage. The high concentration of shell material and lack of articulated specimens suggest that these two shell lenses represent storm deposits. The fauna above the storm deposits is much more diverse (57 species) and has a lower dominance (7%). The corals, *Flabellum* and *Endopachys*, and the gastropods, *Coronia margaritosa* and *Neverita limula*, were the most common species. This shift to greater diversity dominated by suspension feeders and predators suggests a deeper, more stable environment. Again, articulated shells, fine clay sediments, and extremely good preservation suggest that this assemblage is a biocoenosis. This fauna represents a shallow middle shelf, normal marine, tropical community.

INTRODUCTION

The exceptional preservation and faunal diversity of the Harvey outcrop presents a rare opportunity for paleoecologic reconstruction of Eocene marine invertebrate communities in north-central Louisiana. Eocene outcrops containing macro-fauna assemblages are scarce in this area. Eocene subsurface deposits serve as oil, gas, and water reservoirs, but most available paleoecologic research is from adjacent regions and largely based on Foraminifera.

The Harvey site, in the Eocene Cook Mountain Formation of the Claiborne Group, is located southwest of Quitman, Louisiana, on Louisiana Highway 155, 2.6 miles from the junction with United States Highway 167. The outcrop occurs in a borrow pit northwest of the bridge across Choctaw Creek at the SE 1/4, NE 1/4, Sec. 27, T16N, R4W, in Jackson Parish, on property owned by J.P. Harvey of Jonesboro. The outcrop consists of coarse-sandy clays with concretions of ironstone grading into sandy clays capped by a bentonite bed. The bentonite cap preserves a high pH region, preventing acid leaching common throughout north-central Louisiana (McCurdy et al., 1991). Three samples from the site were strontium dated forty-five million years old by Tim Dennison of Mobil Laboratories.

The Claiborne Group is composed of a transgressive sequence including the Cane River, Sparta, Cook Mountain, and Cockfield (Rainwater, 1982). Cockfield fluvial deposits are also present in the area. The Cook Mountain Formation was deposited during the latter part of the Claiborne stage of the Tejas sequence. It shows a transgression with influence from the Mississippi and possibly a Ouachita source (McCarley, 1981). The Laramide and Mexican Cordilleran orogens contributed large amounts of sediment to the Gulf throughout the Eocene (Frazier and Schwimmer, 1987). The tropical climate at the lower latitude and the shallowness of the Gulf resulted in heavy carbonate deposition contemporaneous with the terrestrial influx. Carbonate clays and marls are common.

Multiple point sources, frequent transgressive/regressive cycles, shifting river systems, and changing depocenters (Rainwater, 1982) make the Gulf of Mexico a stratigraphically challenging area.

Modern analogous invertebrate communities of the gulf coast have been studied by Parker (1959) and others. Foraminifera of the Cook Mountain Formation were documented by Howe (1939). Dockery (1980) documented the Eocene macromarine invertebrate fauna of Louisiana and Mississippi. The Stone City Formation (middle Eocene, Texas) was interpreted as a shallow marine community (Stanton et al., 1981). The faunal communities represented at the Harvey site range from

TABLE 1

TAXA	QA	QB	QC	QD	QE	QF
Solariella tricostata				1	1	
Tiburnus eboreus						3
Turritella detexata		3		2	8	28
Mesalia claibornensis						
Ectinochilus texanum						
Neverita limula		2				
Euspira newcomensis						
Galeodia planotecta						
Ficopsis	2				4	2
Distorsio					3	12
Pseudoliva vetusta carinata		1				1
Monoptygma						
Clavilithes kennedyanus						3
Levifusus mortoniopsis carexus		5			7	10
Falsifusus bastropensis	3				1	
Latirus moorei				1	6	6
Athleta sp.						13
Athleta petrosus				14	3	20
Lapparia sp.						2
Caricella sp.		1				4
Agaronia sp.					3	8
Ancilla staminea punctulifera		3		2		2
Marginella (Dentimargo) constrictoides		2		1	2	5
Conomitra fusoides						1
Bonollitia sp.						

Pleuroliria crenulosa						
Coronia margaritosa			1	1	7	32
Hesperiturris nodocarinatus						
Trypanotoma terebriformis cooperi					17	
Raphitoma sabinia						
Scobinella (Moniliopsis) hammettensis						5
Lyrosurcula dalli quadrivaricata						
Eopleurotoma gemmaria					1	4
Cochlespira sp.					2	2
Melanella sp.						3
Cirsotrema sp.						4
Penion sp.						1
Bullia sp.						8
Bullata semen	7					4
Conus sauridens		1				4
Retusa (Cylichnina) galba				3	20	8
Hastula houstonia						10
Hastula sabina						
Architectonica sp.		1		1	10	18
Chiton				1		1
Cadulus (Dischides) subcoarcuatus					4	22
Nucula (Nucula) mauricensis	9	14	1	38	29	17
Yoldia (Calorhadia) semen						2
Barbatia (Cucullaearca) ludoviciana				1	1	2
Anadara vaughani						
Limopsis aviculoides						3
Glycymeris trigonella		12	1	18	84	20
Eburneopecten sp.				86	1	1

Anomia lisbonensis						
Pilicatula filamentosa concentrica				1	5	7
Cubitostrea sellaeformis	2	74	8	21	18	48
Chama harrisi						
Venericardia (Venericor)				1		4
Venericardia (Rotundicardia) rotunda	5	7		15	11	15
Glyptoactis (Claibornicardia) trapaquara						2
Lirodiscus sp.						
Crassatella texalta	4		1	1	2	11
Bathytormus clarkensis						2
Pteropsella lapidosa						
Callista (Callista) perovata lisbone	1	1		37	1	4
Corbula sp.						
Caestocorbula fossata	4			24	13	15
Haliris (Haliris) mississippiensis						
Flabellum cuneiforme pachyphyllum				1	8	41
Platytrochus stokesi					1	
Paracythus bellus					1	
Endopachys lonsdalei				5	1	8
Discotrochus orbignianus		4			13	27
Dendrophyllia lisbonensis						
Astrangia sp.						
Balanophyllia sp.		1		2	10	18
Lunulites sp.	10	4	1	4	28	43
Holoporella granulosa				3	1	5
Dentalium minutistriatum		8		5	4	39
Annelida (tubes)		1			11	7
Euscalpellum eocenense				1		7

eurytropic organisms in an unstable, nearshore environment to middle shelf tropical marine communities with higher diversity, highly integrated food chains, and slower deposition. The environments were all soft-bottomed with relatively low turbulence which decreased with time as the depth and distance from shore increased.

METHODS AND MATERIALS

Horizontal bulk samples were collected, disaggregated, sieved, and counted. Forty pounds of substrate were removed from a four inch horizontal layer near each lithologic boundary. The outcrop sampled has five lithologically distinct layers capped by a bentonite layer (Figure 1). (Since sampling, the bentonite has been removed from the southern half of the outcrop, exposing more of the diverse fauna below.) These bulk samples were dried and a thirty pound sub-sample was taken from each bulk sample, except for the lag deposit sample which was ten pounds. Each sub-sample was boiled in Quaternary O solution until they disaggregated. The disaggregated sub-samples were sieved through USGS #10 and #14 sieves. All specimens in both sieves were counted.

To obtain a minimum number of species, bivalve valves were counted and divided by two. A valve was counted if more than one-half of the shell remained or if a majority of the cardinal processes and one-third of the shell remained. Whole gastropods and recognizable spires were counted. For scaphopods the total length of species pieces was divided by the average length of the species. Remains of bryozoan colonies were counted as an individual. Solitary corals were counted as one organism if more than one-half of the theca remained.

A type collection was established from surface samples and identified using Dockery (1980) and MacNeil and Dockery (1984). This collection was confirmed by David T. Dockery of the Mississippi Office of Geology.

RESULTS

In addition to species counts, various summary descriptors were calculated from the raw data. Density is the total number of organisms present in a given area in a specific time. Diversity is the number of species present in a sample. Dominance[1] is the percentage of the total density represented by the most common species. Dominance[2] is the percentage of the total density represented by the two most common species. Faunal variability is the least number of species needed to equal a certain percentage of the entire population.

Table 1 contains a species count for each sample and compares the density, diversity, dominance and faunal variability of each assemblage. Figure 2 illustrates the distribution of feeding types. Figure 4 plots the relationship of active suspension feeders (filter and impingement) to passive suspension feeders.

DISCUSSION

The communal trends displayed by the samples result from varying degrees of fresh water influence and increasing depth, which accompanied marine transgression. Dominance peaks in sample B and decreases in each subsequent sample. Both density and diversity increase steadily throughout the samples with the exception of sample C. Sample C is inferred to be a storm lag deposit because of the high imbrication and breakage of the specimens and a dominant presence of the heavier more robust forms found in sample B. All other samples are life assemblages as evidenced by the variation in organism sizes, articulated bivalves, fine-grained sediments, and more fragile species.

The trends of diversity and dominance (Figure 3), and the trophic structure evidenced at the site suggest an increasingly stable environment. In stable environments, the organisms are free to adapt to specialized niches and form highly integrated food chains versus the simple webs found in harsher, less predictable environments. Deepening water creates a more stable environment by reducing the effects of wave energy, removing organisms from the catastrophic influence of storms, and decreasing the fluctuations in salinity caused by evaporation and terrestrial drainage.

The fossil density increased with each sample. Density increases can be accounted for by an increase in the total trophic resources available and/or a decrease in the rate of sedimentation. The increase in tiny bryozoans and the appearance of the easily fouled solitary corals, such as *Flabellum*, support decreasing depositional rates but do not exclude increased resources.

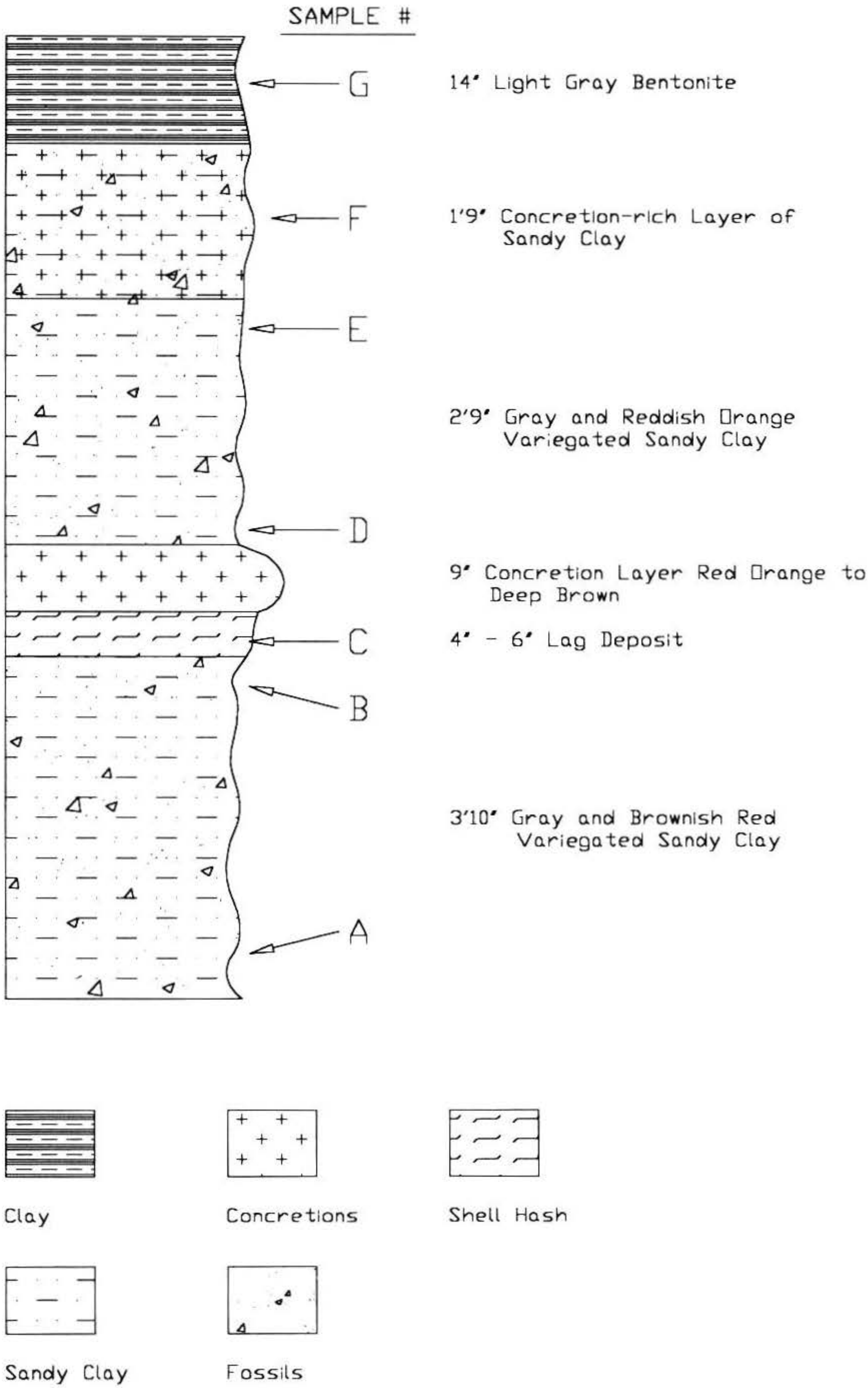
The Cook Mountain Formation at the Quitman site was a tropical marine ecosystem. Water temperature was fairly constant where not affected by river inlets. The primary factors influencing the communities were wave energy, rate and type of deposition, oxygen levels, and salinity.

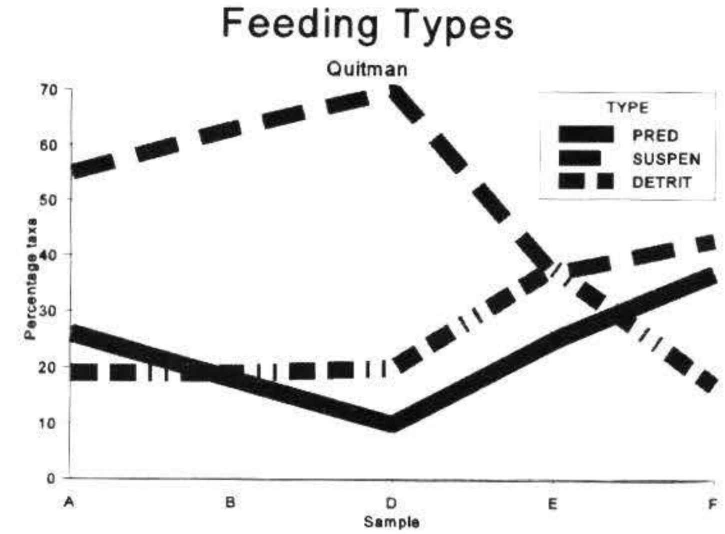
Echinoderms were prolific during this time (Levin, 1978). However, no echinoderm fossils were present in the bulk samples and were rare in the surface collection. Because echinoderms rely on osmotic pressure for many functions including respiration and movement the absence of echinoderm species suggests that the salinity was below normal or fluctuated in the area. The influx of fresh water from the Mississippi Embayment likely created fluctuating hyposaline conditions.

The sediments deposited at the site ranged from fine sand to clay. Vagrant infaunal detritivores such as *Nucula mauricensis*, which requires a soft substrate and water not too agitated for settling of fine organic particles (Elder and Hansen, 1981), are numerous throughout the samples. Few organisms in our samples required firm substrate and the few solid substrate dwelling organisms were likely restricted to an epizoan habitat.

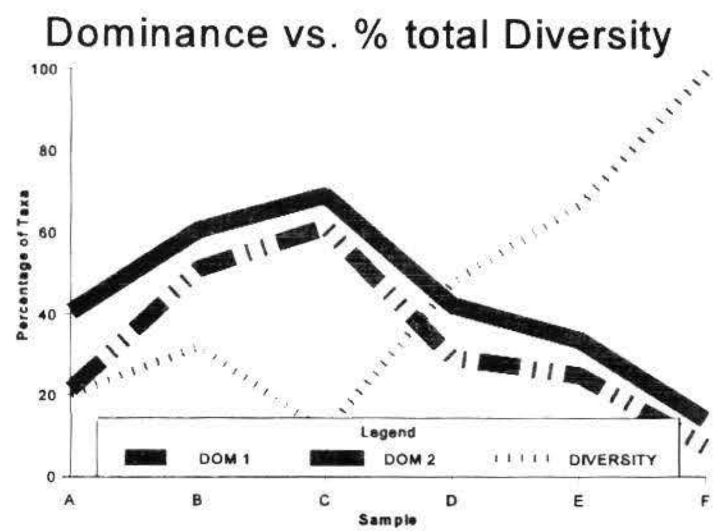
Sample A was deposited in a low energy, shallow marine

(Fig. 1)

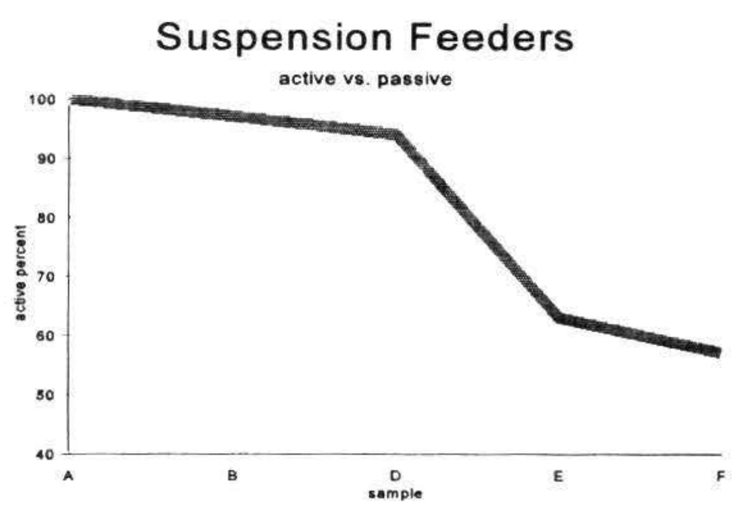

SAMPLE #
G
14' Light Gray Bentonite
F
1'9' Concretion-rich Layer of Sandy Clay
E
2'9' Gray and Reddish Orange Variegated Sandy Clay
D
9' Concretion Layer Red Orange to Deep Brown
C
4' - 6' Lag Deposit
B
3'10' Gray and Brownish Red Variegated Sandy Clay
A
Clay
Concretions
Shell Hash
Sandy Clay
Fossils



(Fig. 2)



(Fig. 3)



(Fig. 4)

TABLE 2

	A	B	C	D	E	F
Density	47	145	13	293	334	640
Diversity	10	19	6	29	37	57
Dominance [1]	21.3	51	61.5	29.4	25.1	7.5
Dominance [2]	40.4	60.7	69.2	42.3	33.8	14.2
Faunal Variability (80%)	6	6	3	7	14	29
Faunal Variability (90%)	7	9	5	10	19	31

environment of normal salinity. The presence of *Ficopsis* sp. in this sample indicates that the salinity was stable in this environment. *Ficopsis* sp. preys on sea urchins and other echinoderms which cannot tolerate salinity changes. This makes *Ficopsis* effectively a stenohaline organism which as a predatory species will only exist within the parameters of its prey. *Ficopsis* sp. is not present in samples B, C, or D, indicating that salinity was too unstable to support echinoderms in these environments. Assemblage A was dominated by the tiny, impingement feeding bryozoan, *Lunulites* sp. The second most populous species was *Nucula mauricensis*, a detritus feeder.

Sample B was a river-influenced, marginal marine environment. Sample B is dominated by the bivalve *Cubitostrea sellaeformis*, the index guide fossil for the Cook Mountain Formation. The dominance of 60.7% was the second highest in the sample column. High dominance of a single species results from high stress on a community. Fresh water influx into marine systems creates harsh and stressful conditions for marine organisms. *Cubitostrea sellaeformis* is a filter feeding oyster. Filter feeders chiefly consume phytoplankton, which require clear water for photosynthesis and vary in abundance, thus varying the stability of the environment (Scott, 1978).

Sample C is a storm lag deposit which indicates a diastem between time B and D. At time C the depth was not yet below storm wave base. A clast-supported coquina composed of broken robust shells of *Cubitostrea* comprise most of this sample. The lack of smaller species, smaller *Cubitostrea*, and the absence of articulated shells suggest that this sample records a large storm.

Sample D was deposited in an inner shelf environment with salinity variations from fluvial systems. The depth of water increases and the salinity fluctuations became less severe. Dominance decreases and diversity increases reflect more dependable and favorable conditions for marine organisms. Filter feeders continue to be the ascendant forms (67.9%) with *Eburneopecten* sp. the most abundant organism.

Sample E was deposited on an inner shelf environment farther from shore. Diversity and density increased. Predators are more diverse with fourteen species of predatory gastropods. The two most numerous are *Retusa galba* and *Architectonica*. The former is carnivorous on Opisthobranchia and Foraminifera, the latter on sea anemones and corals (Stanton et al., 1981).

Ficopsis feeds on urchins. The genera *Pseudoliva, Levifusus, Falsifusus*, and *Laterus* are carnivorous on bivalves, crustaceans, and polychaetes. High predator diversity (Figure 2) indicates multiple levels of predation reflecting increasingly specialized trophic structure.

The most plentiful organisms were vagrant detritovores, indicating abundant organics in the sediments. *Glycymeris trigonella* and *Nucula mauricensis* are the dominant species.

Solitary corals begin to appear as the water turbulence decreases. The ratio of suspension feeding organisms that actively filter food out of the water column compared to organisms which passively allow food to settle out of suspension alters appreciably (Figure 4) as the water turbulence decreases, suggesting greater depth. The occurrence of *Eburneopecten* decreases from the prior sample. As distance from shore increases, the density of *Eburneopecten* decreases (Elder and Hansen, 1981).

Sample F was deposited in a deep tropical marine inner

Cook Mountain Eocene

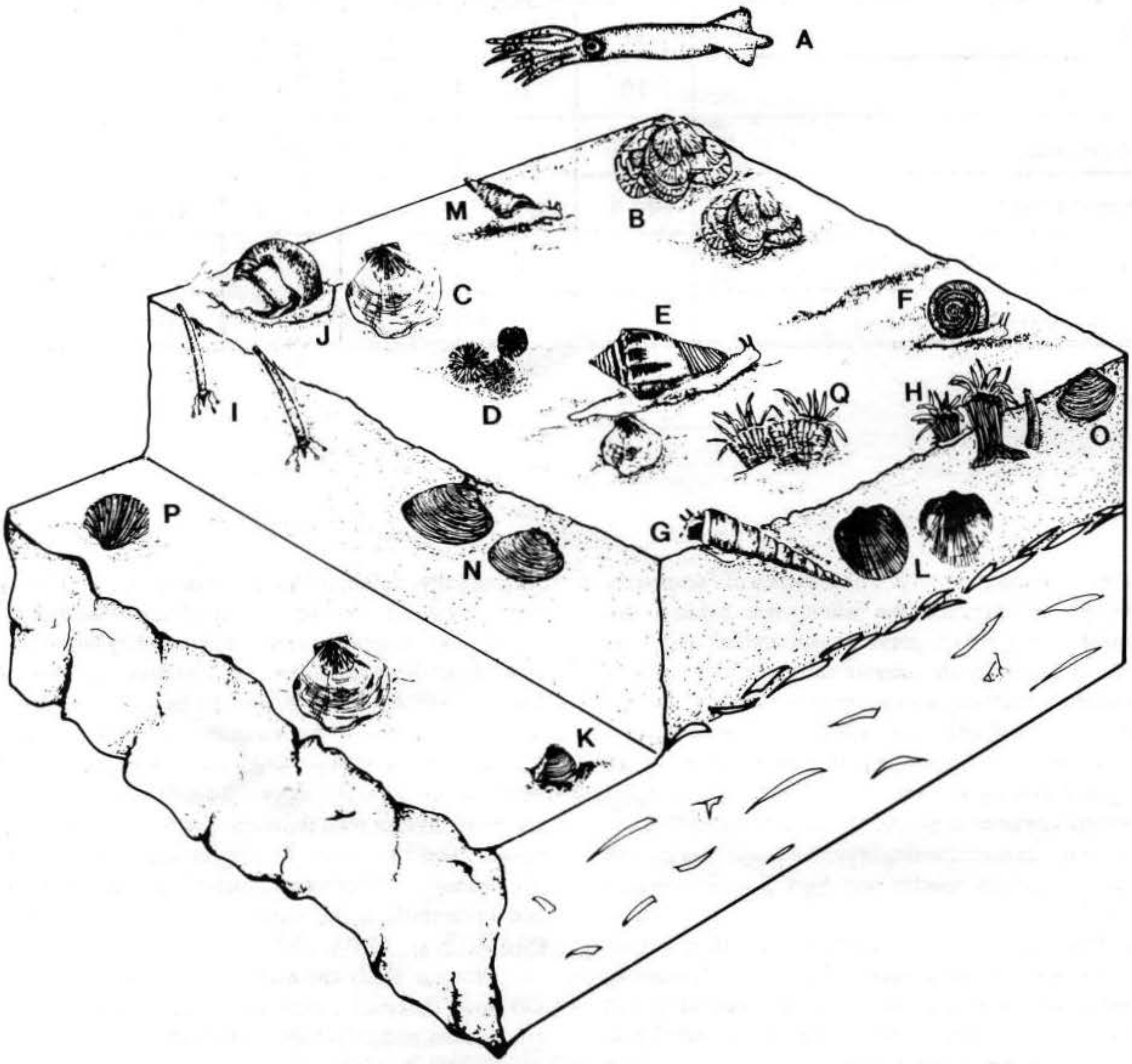


Figure 5. Paleoenvironmental reconstructions of the Harvey site during times of open marine conditions as indicated by samples E-F. The depicted biota includes the squid *Belosepia* (A); the oyster *Cubitostrea* (B); the clams *Eburneopecten* (C), *Corbula* (K), *Glycymeris* (L), *Callista* (N), *Nucula* (O), and *Venericardia* (P); the snails *Athleta* (E), *Architectonica* (F), *Turritella* (G), *Neverita* (J), and *Levifusus* (M); the scaphopod *Dentalium* (I); and the corals *Discotrochus* (D), *Balanophyllia* (H), and *Flabellum* (Q).

shelf environment. It has the highest diversity and lowest dominance of the samples. Deep water organisms such as *Cadulus* and *Limopsis* (Abbott, 1954) are present in the sample. Several species of solitary corals, including *Flabellum cuneiforme pachyphyllum* and *Discotrochus orbignianus*, are prevalent at this time.

Fourteen new species of gastropods are found at this sample. The food chain is more complex. For example, the gastropod, *Tiburnus eboreus*, eats benthic diatoms and filamentous algae; it is then preyed upon by *Clavilithes, Levifusus*, and *Latirus* (Stanton et al., 1981). The evidence of benthic photoautotrophs suggests that this environment was still within the photic zone. The increased specialization evidenced in the trophic structure is characteristic of a stable tropical shelf facies.

CONCLUSION

The patterns of diversity, dominance, faunal variability, and density illustrate a gradual increase in environmental stability culminating in a well-integrated tropical marine shelf environment, as reconstructed in Figure 5. The gradual increase in stability was the result of a marine transgression.

Early deposition occurred in a nearshore marine environment. The environment was later influenced by a fresh water source from the Mississippi Embayment. As the transgression continued, distance from the shore increased and the effects of fresh water were reduced.

All samples were deposited in a tropical physiographic zone and were low energy environments. Sample A was deposited in a nearshore marine environment. Sample B was deposited in a nearshore marginal marine environment. Sample C indicated a storm lag deposit. Sample D was deposited in an inner shelf environment with fresh water influence. Sample E was deposited in a shallow inner shelf environment. Sample F was deposited in a normal marine middle shelf environment.

ACKNOWLEDGMENTS

Credit and gratitude are due to David Dockery for verifying the type collection; J.P. Harvey for site access; and Diane Zumwalt for illustrations. Tim Dennison from Mobil Exploration and Production, Dallas, graciously age dated three samples from this locality.

WORKS CITED

Abbott, Tucker R., 1954, American Seashells: New York, D. Van Nostrand Company.

Dockery, David T., 1980, The invertebrate macropaleontology of the Clarke County, Mississippi, area: Mississippi Geological Survey, Bulletin 122, 387 p.

Elder, Susan R., and Thor A. Hansen, 1981, Macrofossil assemblages of the Moodys Branch Formation (upper Eocene), Louisiana and Mississippi: Mississippi Geology, v. 2, no. 1, p. 6-11.

Frazier, William, and David R. Schwimmer, 1987, Regional stratigraphy of North America: New York, Plenum Press, 719 p.

Howe, H.V., 1939, Louisiana Cook Mountain Eocene Foraminifera: Louisiana Geological Survey, Geology Bulletin 14, 122 p.

Levin, Harold L., 1978, The Earth through time: New York, Saunders College Publishing, p. 540-545.

MacNeil, F. Stearns, and David T. Dockery, 1984, Lower Oligocene Gastropoda, Scaphopoda, and Cephalopoda of the Vicksburg Group in Mississippi: Mississippi Geological Survey, Bulletin 124, 415 p.

McCarley, A.B., 1981, South-central Colorado rejected as provenance for lower Eocene sandstones, Texas coastal plain: Gulf Coast Association of Geological Societies, Transactions, v. 31, supplement, p. 456-457.

McCurdy, M., J. Moncrief, and G. Zumwalt, 1991, Diagenesis and preservation at the Harvey Site (Cook Mtn. Eocene): Proceedings of the Louisiana Academy of Sciences, v. 54, p. 68.

Parker, R.H., 1959, Macro-invertebrate assemblages of central Texas coastal bays and Laguna Madre: American Association of Petroleum Geologists Bulletin, v. 43, no. 9, p. 2100-2166.

Rainwater, E.H., 1982, Stratigraphy and its role in the future exploration for oil and gas in the Gulf Coast, *in* Samuel Ellison, Jr., ed., Biostratigraphy and Paleoecology of the Gulf Coast Cenozoic Foraminifera: Austin, University of Texas at Austin, p. 9-17.

Scott, Robert W., 1978, Approaches to trophic analysis of paleocommunities: Lethaia, v. 11, p. 1-14.

Stanton, Robert J., Eric N. Powell, and Penelope C. Nelson, 1981, The role of carnivorous gastropods in the trophic analysis of the fossil community: Malacologia, 20(2), p. 451-469.

MISSISSIPPI OFFICE OF GEOLOGY PUBLICATION SALES FOR FISCAL YEAR 1995

Margaret Allen and Michael B. E. Bograd
Mississippi Office of Geology

The Map Sales office of the Office of Geology had another busy year in Fiscal Year 1995, which ended June 30, 1995. The sales office is the means used by the Office of Geology to fulfill its mandate to distribute the publications resulting from its various research projects. The following is a tabulation and brief analysis of the maps and publications sold during the year. In addition to the geological reports published by the Office of Geology, Map Sales stocks all of the topographic maps available for the State of Mississippi. This public service is extensively utilized and greatly appreciated by the general public and by a great many of the clients of the Department of Environmental Quality.

FY 1995 Sales

Maps	15,510
Bulletins	669
Circulars	75
Cross Sections	31
Environmental Geology Series	4
Information Series	23
Open-File Reports	154
Reports of Investigations	6

The Maps and Charts series includes the topographic maps of the state published at a variety of scales by the U. S. Geological Survey and such Office of Geology publications as the state geologic map, economic minerals map, structural features map, stratigraphic column, chart of producing formations, and Mississippi Sound lease block maps. By number, most of the maps sold (14,065) were topographic maps at the 7.5 and 15 minute scales.

The Bulletin series is the flagship publication series of the Office of Geology. The first Bulletin was published in 1907, and manuscripts are in preparation for 131 and future numbers. All but 15 of the 103 Bulletins still in print had sales this year, ranging from one copy to 47 copies. Not surprisingly, the top seller was the most recently published Bulletin, B130, on the history and geology of coastal erosion at Belle Fontaine. Other titles with sales of 30 or more were (with abbreviated titles) B105, Hinds County geology, 32 copies; B113, water resources of Mississippi, 37 copies; B115, Rankin County geology, 37 copies; and B129, Coffee Sand gastropods, 30 copies.

The five titles in the Circular series sold a total of 75 copies. Of these, 42 were Circular 4, on the Frankstown vertebrate fossil locality. The four titles in the Cross Sections series sold 31 copies. The biggest seller was CS1, which extends north-south across the state from the Tennessee line to the Gulf of Mexico. The one remaining title in the Environmental Geology series sold four copies. Six copies of the two titles in the Report of Investigations series were sold. There are 11 titles still in print in the Information Series. These had even sales for a total of 23 copies.

A 19th title in the Open-File Report series became available late in the reporting period. The three biggest sellers all dealt with petroleum geology in coastal and offshore Mississippi. These were (again abbreviated) OF21, regional geologic framework of the Cretaceous, 37 copies; OF22, Jurassic geologic framework and petroleum geology, 41 copies; and OF23, regional geologic framework of the Miocene, 43 copies. The Open-File Report series contains results of specialized research projects that have distribution expected to be limited in time or numbers. Total sales for the series were 154 copies.

The figures presented here were compiled by Margaret Allen and analyzed by Michael B. E. Bograd. They represent only a partial report on the map and publication sales activities of the Office of Geology. A number of other items are maintained as well. Specific questions may be directed to the authors.

An up-to-date index of *Mississippi Geology* is available from the Office of Geology. Open-File Report 15, "Current Index to *Mississippi Geology*," compiled by Michael B. E. Bograd, is available for $2.00 ($2.50 by mail) from the Office of Geology, P. O. Box 20307, Jackson, MS 39289.

NEW PUBLICATION BY THE OFFICE OF GEOLOGY

A GEOLOGIC REPORT ON THE FEASIBILITY OF LARGE-QUANTITY BRINE DISPOSAL IN THE RICHTON DOME AREA

The Mississippi Office of Geology announces the publication of Open-File Report 20, "A Geologic Report on the Feasibility of Large-Quantity Brine Disposal in the Richton Dome Area," prepared by the staff of the Department of Environmental Quality.

Open-File Report 20 results from a cooperative project by several geologists and geohydrologists on the staff of the Department of Environmental Quality's Offices of Geology, Pollution Control, and Land and Water Resources. This report is the result of Mississippi's attempt to obtain a Strategic Petroleum Reserve crude oil storage facility. It has information on Wilcox Group stratigraphy and sand characteristics. Current industry practices of injection of large quantities of salt brine (>30,000 barrels per day per well) are documented, and demonstrate the ability of Wilcox sands to accept the large volumes of brine generated during the creation and operation of a salt dome cavern storage facility. Two stratigraphic cross sections of the Wilcox Group at the Richton Dome area, a reference map, and several well logs are included.

Open-File Report 20 may be purchased from the Office of Geology at Southport Center, 2380 Highway 80 West, Jackson, for $15.00 per copy. Mail orders will be accepted when accompanied by payment ($15.00, plus $5.00 postage and handling for each copy). Send mail orders (with check or money order) to:

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P. O. Box 20307
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NEW PUBLICATION AVAILABLE FROM THE OFFICE OF GEOLOGY

THE PETROLEUM GEOLOGY OF INDEPENDENCE FIELD (FRIO), WILKINSON AND AMITE COUNTIES, SOUTHWESTERN MISSISSIPPI

The Mississippi Office of Geology announces the availability of Open-File Report 40, "The Petroleum Geology of Independence Field (Frio), Wilkinson and Amite Counties, Southwestern Mississippi," by Stephen D. Champlin.

Open-File Report 40 is a study of the history, stratigraphy, structure, hydrocarbon trapping mechanisms, reservoir parameters, and gas production of Independence Field, which is centrally located in the shallow Frio gas trend of southwestern Mississippi. In addition to discussions of the listed topics the report includes three structure maps, a sand isopach map, a type log for the field, annual gas production data on individual wells in the field, and two structural cross sections. The report, with 36 pages and 2 plates in the back pocket, was completed as a research project by the Energy Section of the Mississippi Office of Geology.

Open-File Report 40 may be purchased from the Office of Geology at Southport Center, 2380 Highway 80 West, for $10.00 per copy. Mail orders will be accepted when accompanied by payment ($10.00 per copy, plus $3.00 postage and handling for the first copy and $1.00 for each additional copy). Send mail orders (with check or money order) to:

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