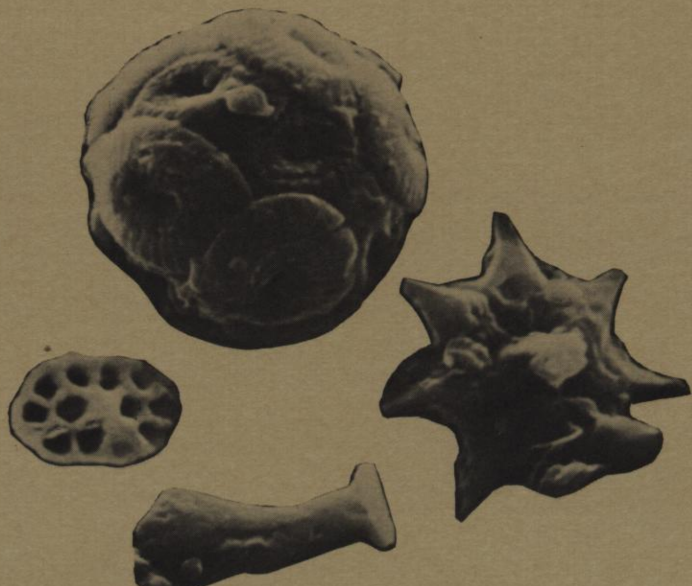
PALEOGENE CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY: MISSISSIPPI, ALABAMA AND TENNESSEE

William G. Siesser



BULLETIN 125

MISSISSIPPI DEPARTMENT OF NATURAL RESOURCES

BUREAU OF GEOLOGY

ALVIN R. BICKER, JR.
Bureau Director

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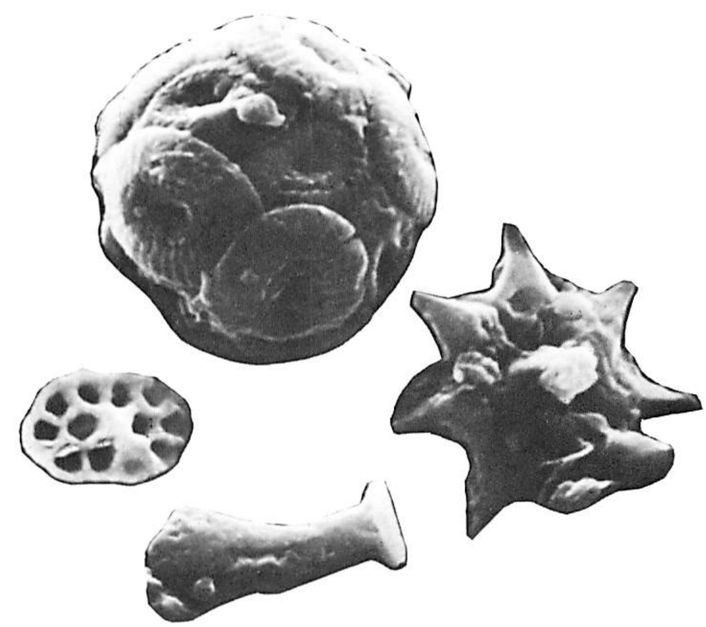

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Suggested cataloging data by the Bureau of Geology

Siesser, William G.

Paleogene calcareous nannoplankton biostratigraphy: Mississippi, Alabama, and Tennessee.

(Mississippi. Bureau of Geology. Bulletin, 125)

1. Plankton, Fossil. 2. Micropaleontology - Tertiary. 3. Micropaleontology - Mississippi. 4. Micropaleontology - Alabama. 5. Micropaleontology - Tennessee. I. Title. II. Series.

QE 129.A2 no.125 557.62
[QE 719] 562.0976

COVER: Calcareous nannoplankton from the lower Yazoo Formation at Riverside Park in Jackson, Mississippi (sample M4b; MGS locality 2). Clockwise, starting with the specimen at top, the species are: (1) *Coccolithus pelagicus*, (2) *Discoaster saipanensis*, (3) *Bramletteius serraculoides*, and (4) *Holodiscolithus macroporus*. Scale is approximately 1 cm = 2 µm.

LETTER OF TRANSMITTAL

Mississippi Department of Natural Resources
Bureau of Geology

Mr. Jolly McCarty, Chairman, and
Members of the Commission
Department of Natural Resources

Commissioners:

The Bureau of Geology is pleased to transmit to you Bulletin 125, entitled "Paleogene Calcareous Nannoplankton Biostratigraphy: Mississippi, Alabama, and Tennessee", by William G. Siesser.

This bulletin reports on the fossil calcareous nannoplankton found in various Paleogene formations of Mississippi, Alabama, and Tennessee. Modern calcareous nannoplankton are minute, flagellate algae that are covered with calcareous plates during at least one stage in their life cycles. These algae live in the surface waters of oceans around the world. Their calcareous plates occur in the sea-floor sediments of most marine environments, with the exception of the deepest ocean regions where calcium carbonate goes into solution. Fossil calcareous nannoplankton are of great value to chronostratigraphy because of their world-wide distribution. In this work, these minute fossils are identified and illustrated from Paleogene formations in Mississippi. These formations are then assigned to the previously defined NP zones of Martini (1971), an internationally recognized zonation that divides the Paleogene into 25 biostratigraphic units (NP1-NP25). This zonation allows stratigraphic units and associated geologic events in Mississippi to be correlated with other units and events of equivalent age on a world-wide basis. Such correlations are of great importance to Mississippi's geologic industries who utilize this type of data in their exploration of the State's mineral resources.

The author of this publication, Dr. Siesser, is Chairman of the Department of Geology at Vanderbilt University in Nashville, Tennessee. Dr. Siesser's paper was recommended to me for publication by David T. Dockery, III and Michael B. E. Bograd, who reviewed the abstract for submission as a paper to be given at the Gulf Coast Association of Geological Societies' 1983 convention in Jackson, Mississippi. The lithostratigraphic nomenclature in this work is not entirely the same as that used by this Bureau.

Respectfully submitted,

Alvin R. Bicker, Jr.
Director and State Geologist

ARB,Jr:ds

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PALEOGENE CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY: MISSISSIPPI, ALABAMA AND TENNESSEE

by

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ABSTRACT

Distribution and abundance of calcareous nannoplankton in the Paleogene formations of Mississippi (MS), Alabama (AL) and Tennessee (TN) are reported in this study. These data have been used to assign each of the following nannoplankton-bearing formations and members to Martini's (1971) internationally recognized calcareous nannoplankton zones.

Formations and Members	Zones
Paynes Hammock Formation (MS)	NP 24
Chickasawhay Limestone (AL)	NP 24
Bucatunna Formation (AL)	NP 22
Byram Formation (MS)	NP 22
Glendon Limestone (MS)	NP 22
(AL)	NP 22
Marianna Limestone (MS)	NP 21, 22
(AL)	NP 21
Mint Spring Formation (MS)	NP 22
Forest Hill Formation (MS)	NP 21
Red Bluff Formation (AL)	NP 21
Bumpnose Limestone (AL)	NP 21
Crystal River Formation (AL)	NP 19/20
Yazoo Formation	
Shubuta Clay Member (MS)	NP 19/20, NP 20, 21
(AL)	NP 19/20, NP 20, 21
Pachuta Marl Member (MS)	NP 19/20
(AL)	NP 19/20
Cocoa Sand Member (AL)	NP 17, 18, 19
North Twistwood Creek Clay Member (AL)	NP 17
Moodys Branch Formation (MS)	NP 17
(AL)	NP 17
Gosport Sand (AL)	NP 17
Cook Mountain Formation	
Potterchitto Member (MS)	NP 16
Lisbon Formation	
'Upper' (AL)	NP 16, 17
'Middle' (AL)	NP 16
'Lower' (AL)	NP 15
Tallahatta Formation (AL)	NP 14, 15
Hatchetigbee Formation	
Bashi Marl Member (AL)	NP 9, 10
Tuscahoma Sand	
Bells Landing Marl Member (AL)	NP 9
Nanafalia Formation	
Ostrea thirsae beds (AL)	NP 7, 8
Salt Mountain Limestone (AL)	NP 7
Naheola Formation	
Coal Bluff Marl Member (AL)	NP 5
Porters Creek Formation (AL)	NP 3/4
Matthews Landing Marl Member (AL)	NP 3/4
Clayton Formation (TN)	NP 2, NP 3/4
McBryde Limestone Member (AL)	NP 3/4, NP 4
Pine Barren Member (AL)	NP 1, 2

INTRODUCTION

Geologists began investigating the fossiliferous lower Tertiary rocks of the eastern Gulf Coastal Plain early in the 19th Century (e.g., Conrad, 1832; Lea, 1833; Lyell, 1846). Superb fossil-bearing formations eventually made this region the classic area for study of Paleogene stratigraphy in America; stratotypes for most of the Paleogene Groups/Stages used in eastern North America are now located in the eastern Gulf Coastal Plain.

A voluminous literature exists on the paleontology and stratigraphy of the eastern Gulf Coastal Plain (see Toulmin, 1977, for a review). Most of these studies deal with macrofossils, but a substantial number describe microfossils (in particular foraminifers and ostracodes). Considerably less attention has been devoted to the calcareous nannoplankton fossils in these rocks. Although there have been a number of excellent studies of the calcareous nannoplankton in isolated Paleogene samples/sections, no systematic study of all Paleogene formations within the region has previously been published. Furthermore, many of the earlier calcareous nannoplankton papers emphasized taxonomy rather than biostratigraphy. The relatively few papers that were concerned with biostratigraphy investigated only isolated sections and in most cases applied zonations not widely used today.

The main purposes of this paper are 1) to describe the distribution and relative abundance of calcareous nannoplankton in all the Paleogene formations of Mississippi, Alabama, and Tennessee, in this study the area referred to as the 'eastern Gulf Coastal Plain', and 2) to assign each formation to the standard calcareous nannoplankton zonation of Martini (1971). Accurate stratigraphic placement for each formation over this large geographic area will show the degree of diachronism of the formations. The zonal assignments will allow interregional correlation of each formation using these widely recognized calcareous nannoplankton zones, and will, moreover, complement recently renewed biostratigraphic studies of the Gulf Coast Paleogene using planktic foraminifers (Mancini, 1979; Oliver and Mancini, 1980; Mancini and Oliver, 1981). Finally, the zonal assignments will establish a refined stratigraphic framework for dating geologic events occurring during the Paleogene of the eastern Gulf Coastal Plain.

In this study, I investigated a series of outcrop sections within the Paleogene outcrop belt (Fig. 1) extending from the Chattahoochee River westward across Alabama and Mississippi to the Mississippi River and northward into southwestern Tennessee. Collection localities which contain calcareous nannoplankton are shown on Fig. 2; details concerning samples collected at each locality are given in Appendix I. Surface outcrops are emphasized in this study, supplemented by only a few subsurface boreholes. I hope that this reconnaissance survey will provide a reference for further research on the calcareous nannoplankton in the Paleogene formations of the eastern Gulf Coastal Plain.

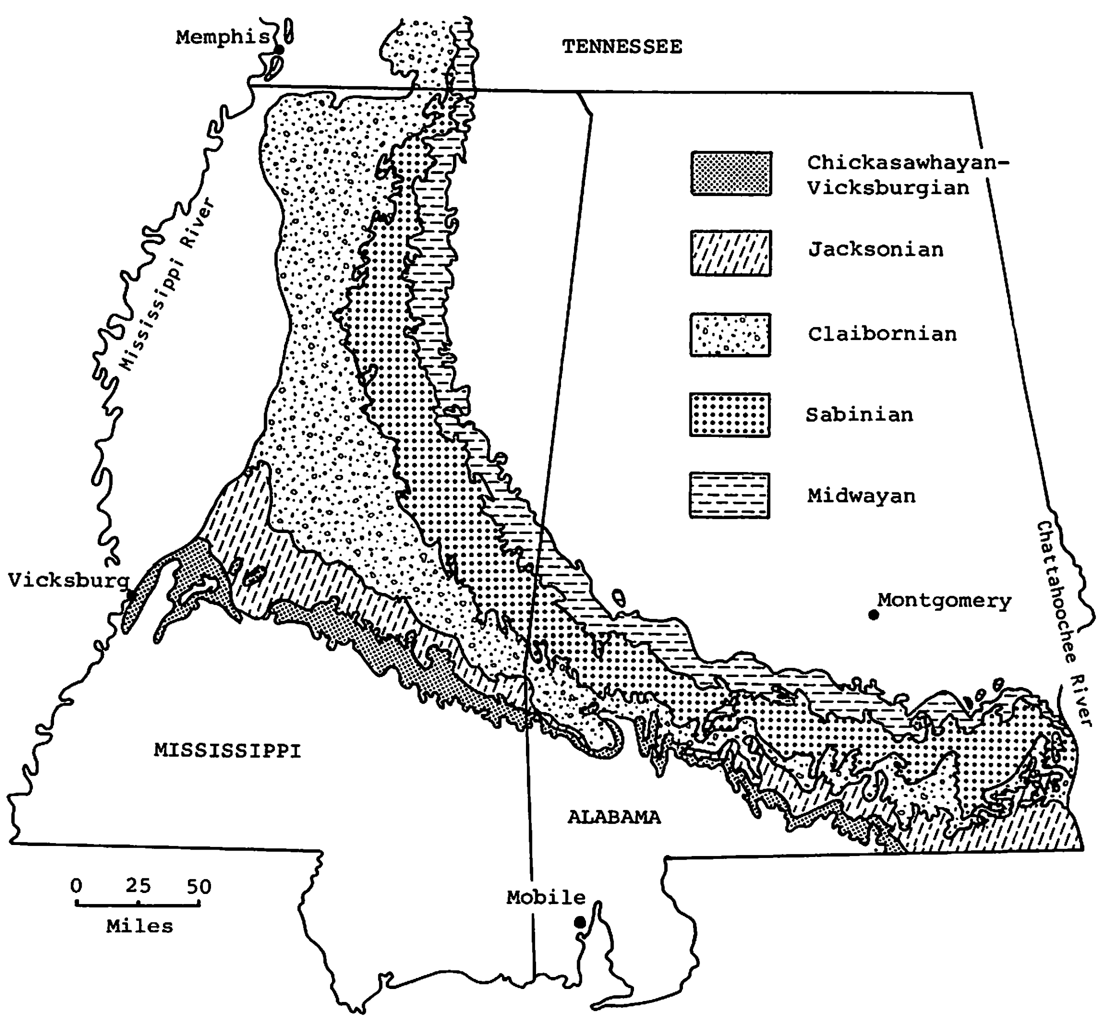


Figure 1. Generalized geologic map showing distribution of the Midwayan, Sabinian, Claibornian, Jacksonian, Vicksburgian, and Chickasawhayan Stages in Alabama, Mississippi, and Tennessee (modified from AAPG Geological Highway Maps, Southeastern and Mid-Atlantic Regions).

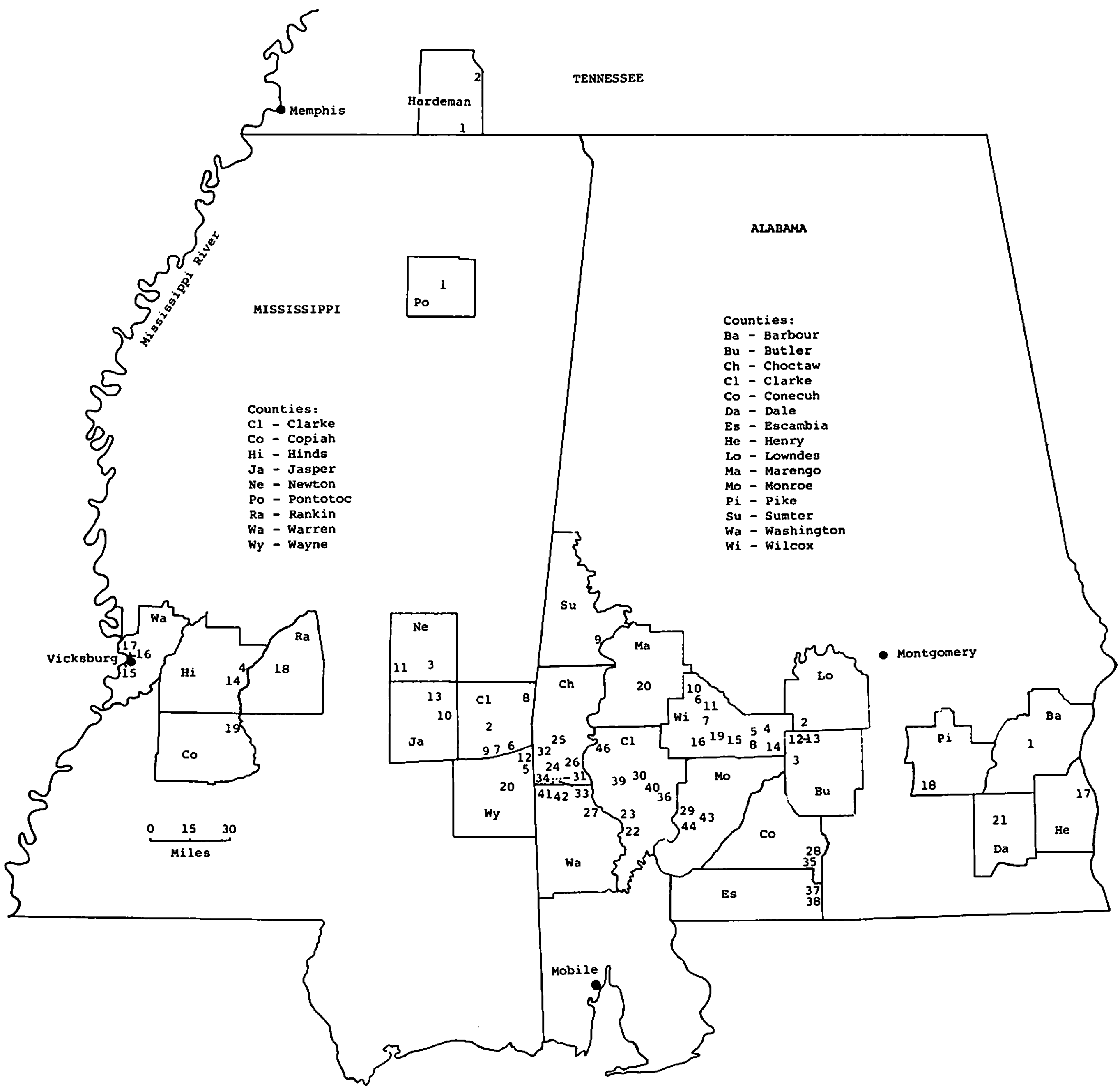


Figure 2. Collection localities of samples containing calcareous nannoplankton fossils.

CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY

One of the major goals of stratigraphy is to classify the Earth's strata lithostratigraphically and chronostratigraphically. Chronostratigraphy is the systematic arrangement of strata into named chronostratigraphic units which correspond to specific geochronologic units. The establishment of well-defined chronostratigraphic units provides a reference framework for recording and correlating events in the history of the earth. Chronostratigraphic classification and correlation are therefore important stratigraphic objectives, and biostratigraphy is the means by which these objectives are realized.

Biostratigraphers use various types of biozones (almost universally referred to simply as 'zones') as a means for subdividing and correlating sequences of strata. Ideally, one would like to use only zones that are of short duration and which can be recognized and correlated on a worldwide basis. Zones based on planktic organisms satisfy these requirements particularly well, since many taxa underwent rapid evolution and, as floating organisms, had a generally widespread distribution.

Two zonations based on calcareous nannoplankton fossils are in common use today: that of Martini (1971) and of Bukry (1973a; 1975). The main difference between these two zonations is that Martini's (1971) zonation uses more fossil data taken from onshore outcrops of nearshore sediments than does Bukry's zonation, which relies more heavily on data from open-ocean sediments. I have selected Martini's (1971) zonation for use in this study, since it is readily applicable to other rocks deposited in nearshore marine environments, e.g., Gulf Coast Paleogene formations.

Martini's (1971) Paleogene zones draw heavily on zones established by earlier workers; Bramlette and Sullivan (1961), Bramlette and Wilcoxon (1967) and, in particular, Hay et al. (1967). Another zonation which has been utilized in the Paleogene of the eastern Gulf Coastal Plain was proposed by Gartner (1971). Gartner (1971) modified and expanded the zonation of Hay et al. (1967) by adding several additional zones in the Paleocene and middle and upper Eocene. All these zonations are similar in that they utilize 'interval zones' whose boundaries are essentially synchronous biohorizons represented by a unique biostratigraphic event such as the evolutionary first appearance or extinction of a particular species. Interval zones are easiest to identify in continuous cores of oceanic sediment such as those obtained by the Deep Sea Drilling Project. One can trace the gradually changing composition of nannoplankton assemblages down the length of a core, marking the first appearances and disappearances of species to within a fraction of an inch. The question still arises as to the reason for the absence of a particular species: is the absence because of extinction, or is it because of some environmental preference (the species never lived in those environmental conditions) or diagenetic (lived there but was destroyed during or after deposition)? Problems concerning reasons for presence and absence are magnified when one attempts to define interval zones in discontinuous onshore outcrops such as those dealt with in this study. Surface exposures are also more likely to have been affected by diagenesis which dissolved solution-susceptible species and/or deposited calcite overgrowths on more resistant species. It becomes necessary, when working in such an area, to rely partially on 'secondary markers', i.e., fossils which are not those specifically designated as defining zonal boundaries, but which are known to have first or last appearances closely approximating the position of the zonal boundary. In this way an outcrop/rock unit can be fitted 'loosely' into a recognized zonal scheme, even if the zonal assignment is not as 'tight' as one might prefer. *Discoaster nodifer* is an example of a useful secondary marker species. Although this species makes its first appearance in uppermost NP 15 (Martini, 1971; Müller, 1978; Beckmann et al., 1981), its first appearance may be used to approximate the NP 15-NP 16 boundary where the defining species (*Rhabdolithus gladius*) is missing.

Other biostratigraphers have chosen to deal with the problems of limited exposures and impoverished assemblages differently; some erect essentially ad hoc zonations based on events within the assemblage in the particular section(s) they are working on. Although this procedure may allow fairly precise subdivision in a local area, it often cannot be applied outside the region where it was developed. Many of the ornate and diverse nannoplankton species inhabiting inner-shelf environments could readily be incorporated into provincial zonation schemes. But many of these inner-shelf species are rare in open-ocean sediments and are unreliable as time-synchronous markers for interregional correlations, even in nearshore sediments. Moreover, use of provincial zonations causes communication problems. It seems more desirable, stratigraphically, to state that a given section falls approximately within the NP 9 calcareous nannoplankton zone, which most calcareous nannoplankton biostratigraphers the world over will immediately recognize as latest late Paleocene, than to use a provincial zonal name which is unfamiliar both in name and stratigraphic position to stratigraphers working outside the province. In this study, I assign all outcrops of each formation to one or a combination of Martini's zones, relying on the designated (primary) zonal marker species of Martini (1971) where possible, but utilizing secondary marker species where necessary. Stratigraphic ranges of the secondary markers are taken from the literature. Ranges that were originally tied to Bukry's (1973a, 1975) zonation have been correlated to Martini's zonation using the cross-correlation chart of Okada and Bukry (1980).

Figure 3 shows calcareous nannoplankton biostratigraphic zonations which have previously been applied to formations in the eastern Gulf Coastal Plain, together with the standard calcareous nannoplankton zonation of Martini (1971) and the two most commonly used planktic foraminifer zonations: Blow (1969)/Berggren and van Couvering (1974), and Bolli (1957a,b,c; 1966)/Stainforth et al. (1975).

Calcareous nannoplankton fossils found in eastern Gulf Coastal Plain formations and members are listed in Table I. Bibliographical references for most of these species are found in Loeblich and Tappan (1966, 1968, 1969, 1970a, 1970b, 1971, 1973); species not included in the Loeblich and Tappan series are listed under 'References Cited', and are identified by an asterisk.

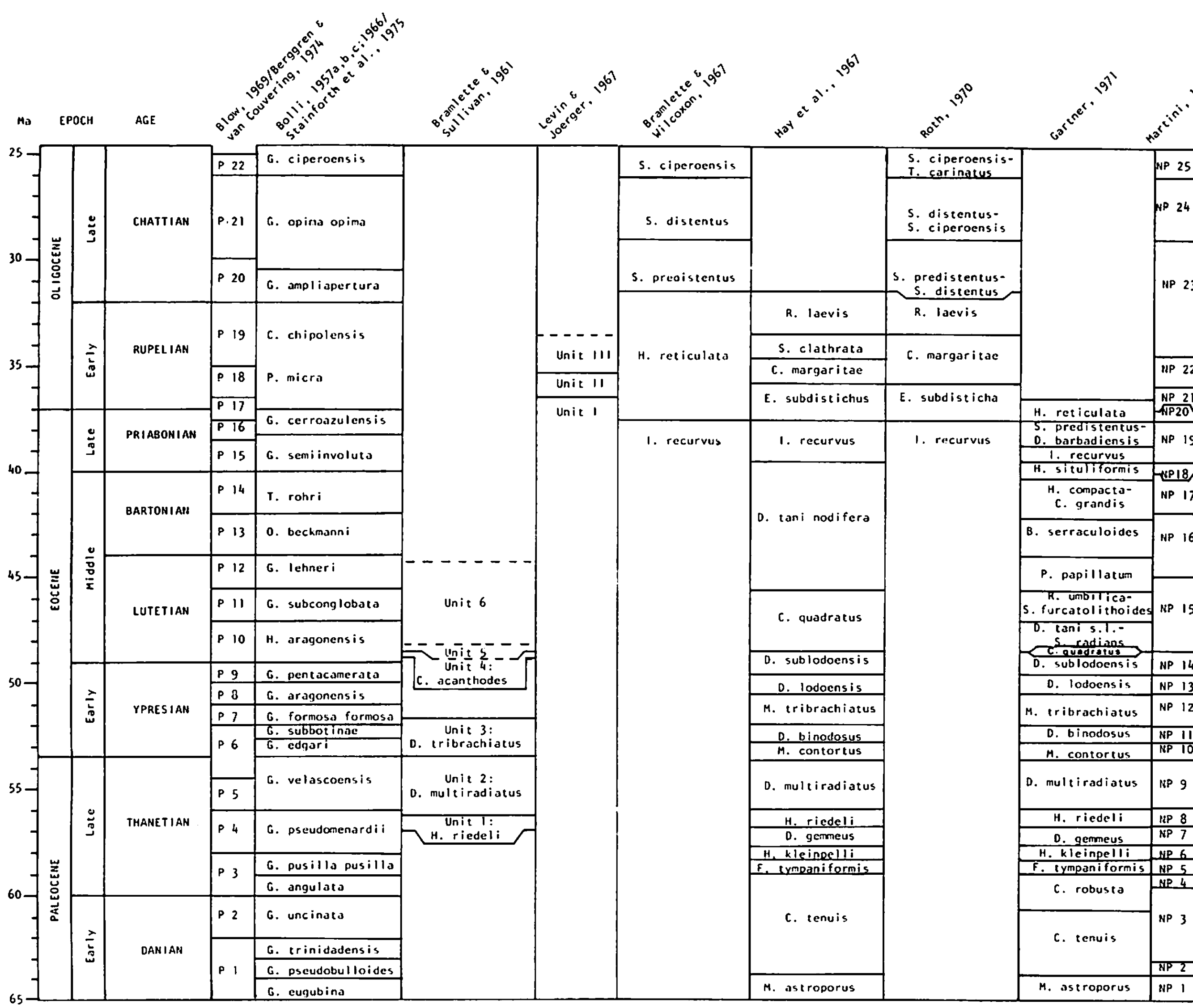


Figure 3. Calcareous nannoplankton biostratigraphic zonations previously applied to Paleogene formations in the eastern Gulf Coastal Plain. Epochs, ages, time scale and foraminiferal zonations adapted from Vail et al. (1977).

Table 1

CALCAREOUS NANNOPLANKTON IN EASTERN GULF COAST PALEOGENE FORMATIONS

Chiphragmalithus acanthodes Bramlette & Sullivan 1961

Zygodiscus adamas Bramlette & Sullivan 1961

Micrantholithus aequalis Sullivan 1964

Chiasmolithus altus Bukry & Percival 1971

Micrantholithus altus Bybell & Bukry 1972

Micrantholithus angulosus Stradner & Papp 1961

Orthozygus aureus (Stradner) Bramlette & Wilcoxon 1967

Discoaster barbadiensis Tan Sin Hok 1927

Pemma basquense basquense (Martini) Bybell & Gartner 1972*

Chiasmolithus bidens (Bramlette & Sullivan) Hay & Mohler 1967

Braarudosphaera bigelowii (Gran & Braarud) Deflandre 1947

Zygrhablithus bijugatus (Deflandre) Deflandre 1959

Discoaster binodosus Martini 1958

Dictyococcites bisectus (Hay, Mohler & Wade) Bukry & Percival 1971

Prinsius bisulcus (Stradner) Hay & Mohler 1967
Helicosphaera bramlettei Müller 1970
Ericsonia cava (Hay and Mohler) Perch-Nielsen 1969
Sphenolithus ciperoensis Bramlette & Wilcoxon 1967
Helicosphaera compacta Bramlette & Wilcoxon 1967
Heliorthus concinnus (Martini) Hay & Mohler 1967
Chiasmolithus consuetus (Bramlette & Sullivan) Hay & Mohler 1967
Pemma basquense crassum (Bouche) Bybell & Gartner 1972*
Coccolithus crassus Bramlette & Sullivan 1961
Blackites creber (Deflandre) Sherwood 1974*
Micrantholithus crenulatus Bramlette & Sullivan 1961
Reticulofenestra daviesi (Haq) Haq 1971
Discoaster deflandrei Bramlette & Riedel 1954
Thoracosphaera deflandrei Kamptner 1956
Discoaster delicatus Bramlette & Sullivan 1961
Cruciplacolithus delus (Bramlette & Sullivan) Perch-Nielsen 1971
Reticulofenestra dictyoda (Deflandre & Fert) Stradner *in* Stradner & Edwards 1968
Braarudosphaera discula Bramlette & Riedel 1954
Sphenolithus distentus (Martini) Bramlette & Wilcoxon 1967
Ellipsolithus distichus (Bramlette & Sullivan) Sullivan 1964
Discoaster distinctus Martini 1958
Neococcolithes dubius (Deflandre) Black 1967
Discoaster elegans Bramlette & Sullivan 1961
Clathrolithus ellipticus Deflandre *in* Deflandre & Fert 1954
Toweius eminens (Bramlette & Sullivan) Perch-Nielsen 1971
Micrantholithus entaster Bramlette & Sullivan 1961
Coccolithus eopelagicus (Bramlette & Riedel) Bramlette & Sullivan *in* Bramlette & Wilcoxon, 1967
Helicosphaera euphratis Haq 1966
Discolithus exilis Bramlette & Sullivan 1961
Discoaster falcatus Bramlette & Sullivan 1961
Koczyia fimbriatus (Bramlette & Sullivan) Perch-Nielsen 1971
Cyclicargolithus floridanus (Roth & Hay) Bukry 1971
Goniolithus fluckigeri Deflandre 1957
Cyclococcolithus formosus Kamptner 1963
Scapholithus fossilis Deflandre *in* Deflandre & Fert 1954
Marthasteroides furcatus (Deflandre) Deflandre 1959
Corannulus germanicus Stradner 1962
Discoaster germanicus Martini 1958
Rhabdosphaera gladius Locker 1967
Chiasmolithus grandis (Bramlette & Riedel) Gartner 1970
Thoracosphaera heimi (Lohmann) Kamptner 1920
Discoaster helianthus Bramlette & Sullivan 1961
Reticulofenestra hillae Bukry & Percival 1971
Micrantholithus inaequalis Martini 1961
Rhabdosphaera inflata Bramlette & Sullivan 1961
Helicosphaera intermedia Martini 1965
Markalius inversus (Deflandre) Bramlette & Martini 1964
Fasciculithus involutus Bramlette & Sullivan 1961
Fasciculithus janii Perch-Nielsen 1971
Peritrachelina joidesa Bukry & Bramlette 1968
Neochiastozygus junctus (Bramlette & Sullivan) Perch-Nielsen 1971
Cyclolithella kariana Bukry 1971
Cyclococcolithus kingi Roth 1970
Heliolithus kleinpelli Sullivan 1964
Discoasteroides kuepperi (Stradner) Bramlette & Sullivan 1961
Syracosphaera labrosa Bukry & Bramlette 1969
Pedinocyclus larvalis (Bukry & Bramlette) Loeblich & Tappan 1973
Discoaster lenticularis Bramlette & Sullivan 1961
Discoaster levini Hay *in* Hay et al. 1967
Pentaster lisbonensis Bybell & Gartner 1972*
Discoaster lodoensis Bramlette & Riedel 1961
Helicosphaera lophota Bramlette & Sullivan 1961
Cyclococcolithus luminis Sullivan 1965
Ellipsolithus macellus (Bramlette & Sullivan) Sullivan 1964
Holodiscolithus macroporus (Deflandre) Roth 1970
Prinsius martinii (Perch-Nielsen) Haq 1971
Discoaster mediosus Bramlette & Sullivan 1961
Discoasteroides megastypus Bramlette & Sullivan 1961
Clathrolithus minutus Bramlette & Sullivan 1961
Lanternithus minutus Stradner 1962
Discoaster mirus Deflandre 1954
Lophodolithus mochlophorus Deflandre *in* Deflandre & Fert 1954
Discoaster mohleri Bukry & Percival 1971
Sphenolithus moriformis (Brönnimann & Stradner) Bramlette & Wilcoxon 1967
Pontosphaera multipora (Kamptner) Roth 1970
Russellia multiplus (Perch-Nielsen) Wind & Wise *in* Wise & Wind 1977*

Discoaster multiradiatus Bramlette & Riedel 1954
Lophodolithus nascens Bramlette & Sullivan 1961
Discoaster nodifer (Bramlette and Riedel) Bukry 1973
Chiasmolithus oamaruensis (Deflandre) Hay, Mohler & Wade 1966
Transversopontis obliquipons (Deflandre) Hay, Mohler & Wade 1966
Thoracosphaera operculata Bramlette & Martini 1964
Lithostromation operosum (Deflandre) Bybell 1975*
Pemma papillatum Martini 1959
Pontosphaera pectinata (Bramlette & Sullivan) Sherwood 1974*
Coccolithus pelagicus (Wallich) Schiller 1930
Lithostromation perdurum Deflandre 1942
Rhabdosphaera perlonga (Deflandre) Bramlette & Sullivan 1961
Discoaster perpolitus Martini 1961
Micrantholithus pinguis Bramlette & Sullivan 1961
Pontosphaera plana (Bramlette & Sullivan) Haq 1971
Zygodiscus plectopons Bramlette & Sullivan 1961
Sphenolithus predistentus Bramlette & Wilcoxon 1967
Micrantholithus procerus Bukry & Bramlette 1969
Neococcolithes protenus (Bramlette & Sullivan) Hay & Mohler 1967
Transversopontis pulcher (Deflandre) Hay, Mohler & Wade 1966
Daktylethra punctulata Gartner *in* Gartner & Bukry 1969
Sphenolithus pseudoradians Bramlette & Wilcoxon 1967
Sphenolithus radians Deflandre 1952
Isthmolithus recurvus Deflandre *in* Deflandre & Fert 1954
Helicosphaera recta Haq 1966
Helicosphaera reticulata Bramlette & Wilcoxon 1967
Reticulofenestra reticulata (Gartner & Smith) Roth & Thierstein 1972*
Heliolithus riedeli Bramlette & Sullivan 1961
Cycloccolithina robusta (Bramlette & Sullivan) Gartner 1967
Braarudosphaera rosa Levin & Joerger 1967
Pemma rotundum Klumpp 1953
Discoaster saipanensis Bramlette & Riedel 1954
Thoracosphaera saxea Stradner 1961
Discolithina segmenta Bukry & Percival 1971
Helicosphaera seminulum Bramlette & Sullivan 1961
Bramletteius serraculoides Gartner 1969
Pemma serratum (Chang) Bybell & Gartner 1972*
Zygodiscus sigmoides Bramlette & Sullivan 1961
Lithostromation simplex (Klumpp) Bybell 1975*
Hayella situliformis Gartner 1969
Pemma snavelyi Bukry & Bramlette 1969
Holodiscolithus solidus (Deflandre) Roth 1970
Chiasmolithus solitus (Bramlette & Sullivan) Locker 1968
Biantholithus sparsus Bramlette & Martini 1964
Blackites spinosus (Deflandre & Fert) Hay & Towe 1962
Cruciplacolithus staurion (Bramlette & Sullivan) Gartner 1971
Sphenolithus stellatus Gartner 1971
Discoaster strictus Stradner 1961
Ericsonia subdisticha (Roth & Hay) Roth *in* Baumann & Roth 1969
Discoaster sublodoensis Bramlette & Sullivan 1961
Ericsonia subpertusa Hay & Mohler 1967
Discoaster tani Bramlette & Riedel 1954
Blackites tenuis (Bramlette & Sullivan) Bybell 1975*
Cruciplacolithus tenuis (Stradner) Hay & Mohler *in* Hay, Roth, Schmidt & Boudreaux 1967
Chiasmolithus titus Gartner 1970
Braarudosphaera turbinea Stradner 1963
Reticulofenestra umbilica (Levin) Martini & Ritzkowski 1968
Pontosphaera versa (Bramlette & Sullivan) Sherwood 1974*
Micrantholithus vesper Deflandre *in* Deflandre & Fert 1954
Rhabdosphaera vitrea (Deflandre) Bramlette & Sullivan 1961
Koczyia wechesensis (Bukry & Percival) Sherwood 1974*
Helicosphaera wilcoxonii Gartner 1971
Transversopontis zigzag Roth & Hay *in* Hay et al. 1967

Taxonomic Notes

A survey of the literature shows that species concepts differ considerably with regard to species within the *Thoracosphaera* group. Several recent attempts have been made to clarify the taxonomy of this group (e.g., Fütterer, 1977; Jafar, 1979) but a consensus is not yet apparent. I use the following concepts for the four species of *Thoracosphaera* occurring in these Paleogene samples:

a) *T. operculata* -- small body; imperforate wall elements and a distinctive circular rim around the body which is bright between crossed nicols (Fig. 7J,j).

b) *T. saxea* -- large body; crenulated and sutured, imperforate wall elements (e.g., Fig. 8J,j).

c) *T. deflandrei* -- distinguishable from *T. saxea* by having distinctly smaller wall elements (e.g., Fig. 12f). This may be the species listed as *Thoracosphaera* sp. 4 by Jafar (1979).

d) *T. heimi* -- body and wall elements about the same size as those of *T. saxea,* but perforate wall elements (e.g., Fig. 7G,g).

Cyclicargolithus floridanus is an abundant, ubiquitous component of middle Eocene to Oligocene assemblages. *C. floridanus,* as used here, includes species described in the literature as *Coccolithus marismontium* Black, *C. pseudogammation* Bouche and *Cyclococcolithus neogammation* Bramlette and Wilcoxon. *Dictyococcites hesslandii* may be a separate species, although Haq and Lohman (1976) note that there appears to be a continuous gradation from *D. hesslandii* to the species used here as *C. floridanus* (e.g., Fig. 25g). I have been unable to separate the two species consistently using the light microscope; any *D. hesslandii* specimens are therefore included with *C. floridanus* on the range charts.

Perch-Nielsen (1979) named a new species, *Markalius apertus,* which differs from *M. inversus* in lacking the radial elements which cover the center of specimens. Under crossed nicols, *M. apertus* therefore has a bright circle of elements surrounding a dark center. *M. apertus* (Fig. 7A,a) occurs with *M. inversus* (Fig. 7b) in the Paleogene of the eastern Gulf Coastal Plain. I was, however, unaware of the erection of this species when I made the identifications for this study. *M. apertus* is therefore included with *M. inversus* in Tables 2-14.

Two species of *Cruciplacolithus* occur in the lower Paleocene: *C. primus* and *C. tenuis*. *C. primus* (Fig. 8H,h) is distinguished by being smaller and having a relatively larger central opening and relatively more slender cross bars compared with *C. tenuis* (Perch-Nielson, 1977). I have been unable to distinguish between the two species consistently in these rocks; most specimens, however, resemble *C. tenuis* (e.g., Fig. 8K,k), and therefore all *Cruciplacolithus* species are included as *C. tenuis* s.*l*. on Tables 2-4.

Pontosphaera multipora is a name widely used in the literature, but specimens illustrated under this species epithet vary markedly in their number of rings of perforations, size and arrangement of perforations and wall structure. I use *P. multipora* s.*l*. in this study for pontosphaerids with a moderately heavy rim surrounding either three concentric rings of perforations, or two concentric rings enclosing a number of randomly arranged perforations (e.g., Fig. 28R,r).

Micrantholithus aff. *M. procerus* (Fig. 7K) is a tall form which has slightly crenulate margins when seen in plan view. Its height and shape in side view are similar to *M. procerus,* except the marginal indentations are not as pronounced. The occurrence of *M. procerus* has not been documented earlier than the Eocene, whereas *M.* aff. *M. procerus* occurs in the lower Paleocene Clayton Formation.

Koczyia aff. *K. fimbriatus* (Fig. 20K,k) differs from *K. fimbriatus* in having slightly larger circular openings, poorly defined slits, and a less flaring rim. This species occurs in the middle Eocene.

Coccolithus sp. A (Figs. 7S,s; 12R,r) is circular, has 36-47 elements in its distal shield and ranges from about 6 to 8 µm in diameter. Morphology and extinction pattern of this species resemble *Ericsonia cava,* with which it is always associated, but *Coccolithus* sp. A differs by being circular, rather than elliptical. *Coccolithus* sp. A may be the same species referred to as *C. orbiculatus* by Reimers (1976). *Coccolithus* sp. A occurs frequently in the Paleocene.

Neochiastrozygus sp. A (Figs. 7Q; 8L,*l*) is a small (5 µm in long dimension) early Paleocene neochiastozygid with bars that form tight 'v's where they cross.

Micrantholithus sp. A (Fig. 34O,o) has a shape generally similar to *M. aequalis,* except the ray segments are somewhat wider. *M. aequalis* is known only from the Paleocene-early Eocene, whereas *Micrantholithus* sp. A occurs sporadically throughout the late Eocene and early Oligocene.

'Polycladolithus' sp. A (Fig. 17W,X) is probably a form related to *Polycladolithus*? sp. reported by Bramlette and Sullivan (1961). The structural openings of *'Polycladolithus'* sp. A have apparently been closed by calcite overgrowths. I found *'Polycladolithus'* sp. A only in the middle Eocene Tallahatta Formation. Bramlette and Sullivan (1961) also reported this form only from the middle Eocene and the species may eventually prove to be a useful biostratigraphic marker, whatever its true taxonomic affinities may be.

Tables 2 to 15 show the distribution, abundance and preservation of calcareous nannoplankton fossils in the Paleogene formations of the eastern Gulf Coastal Plain. Abundance and preservation are indicated as follows: A = Abundant; more than 10 specimens of a single species per field of view at a magnification of 800X. C = Common; 1 to 10 specimens per field. F = Few; one specimen per 2 - 10 fields. R = Rare; one specimen per 11 -100 fields. V = Very Rare; one specimen per 101 - 1000 fields. G = Good preservation; overgrowth or dissolution effects rare. M = Moderate; a moderate amount of calcite overgrowth on specimens and dissolution of the more soluble species. P = Poor; overgrowth common and numerous species removed.

In this paper I have departed from the common practice of illustrating one specimen of each species in order to demonstrate species concepts. Instead, I have prepared one figure for each formation, in order to illustrate the most characteristic and/or stratigraphically important species in that particular formation. I hope that this approach will provide the nonspecialist, interested only in, say, the Tallahatta Formation, with easy access to the typical Tallahatta calcareous nannoplankton assemblage.

STRATIGRAPHY

Figure 4 is a correlation chart of Paleogene lithostratigraphic units in the eastern Gulf Coastal Plain. The extent, stratigraphic relationships, general lithology, and biostratigraphy of each formation are summarized in the following sections.

Clayton Formation
Lithostratigraphy

This formation was named by Langdon (1891)for exposures near the town of Clayton, Alabama. At the type locality the Clayton consists of 150 feet of massive glauconitic, fossiliferous limestone, underlain by calcareous sand and overlain by calcareous clay (Murray, 1961; Toulmin, 1977).

The Clayton is not subdivided in eastern Alabama, but in central and western Alabama it is subdivided into two members: the lower Pine Barren Member and the upper McBryde Limestone Member. The Pine Barren is about 140 feet thick and consists mostly of gray arenaceous, calcareous silt alternating with irregular beds of gray arenaceous limestone. The uppermost bed of this member contains abundant mollusc fossils and has been called *'Turritella* rock' (Toulmin, 1977) (Fig. 5). The Pine Barren thins to 55 feet in western Wilcox County. The McBryde Limestone Member (*'Nautilus* rock') consists of gray to white marl and clayey chalk (Fig. 6). It ranges from about 40 feet thick in central Alabama to about 20 feet thick in western Wilcox County (Toulmin, 1977). The Pine Barren and McBryde Members are not recognized west of Wilcox County in Alabama, or in Mississippi or Tennessee.

Lowe (1933) described the undivided Clayton in Mississippi as consisting of a basal marl or limestone (20 to 25 feet thick) overlain by greenish-yellow, glauconitic and micaceous sands and marls. Parks (1975) divided the Clayton Formation in western Tennessee, where it has an average thickness of about 80 feet, into the following five informal members: (1) a lower gray or greenish-gray limestone and glauconitic sand member, (2) a middle fossiliferous, gray to greenish-gray sand and clay member, (3) a gray or pale orange, micaceous sand facies, (4) a gray, white or pale orange sand and clay facies, and (5) an upper glauconitic sand member. The lower three beds pinch out progressively to the north.

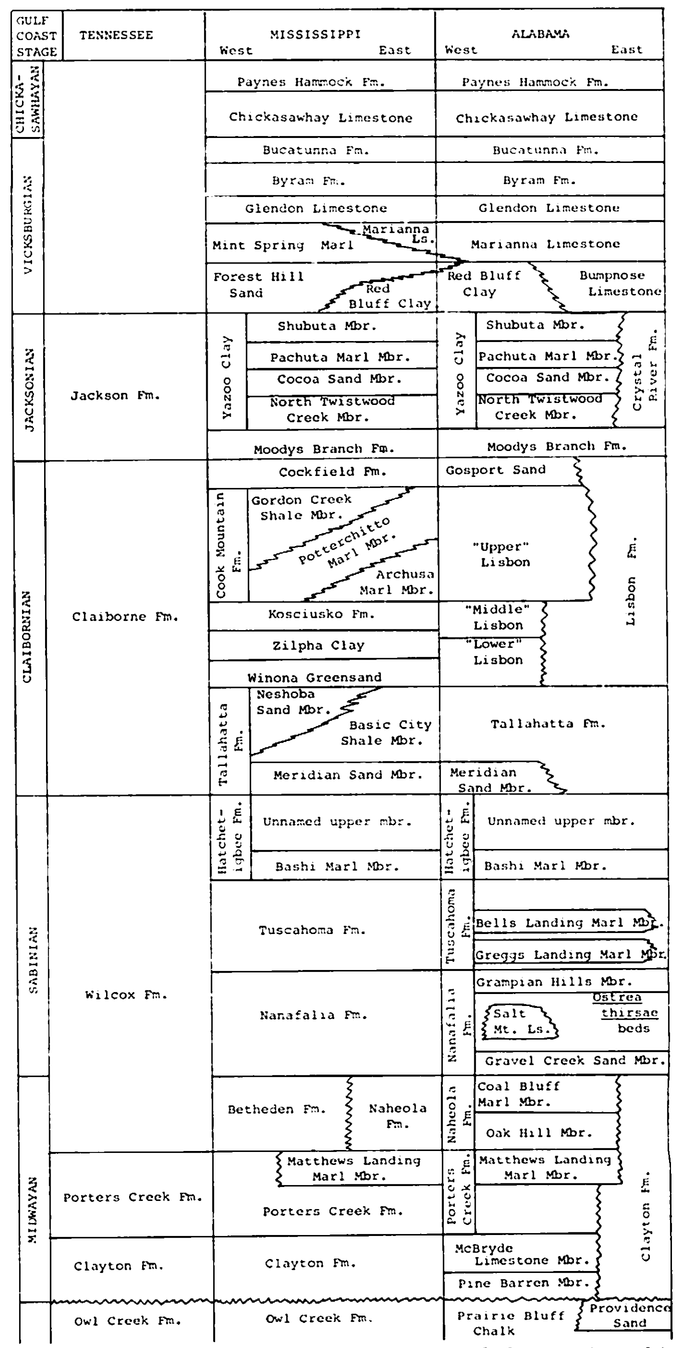


Figure 4. Correlation chart of Paleogene lithostratigraphic units in the eastern Gulf Coastal Plain, largely following Copeland (1968) and Toulmin (1977).

Figure 5. Pine Barren Mbr. (**Turritella** rock) of Clayton Fm., Wilcox Co., AL.

Figure 6. McBryde Mbr. of Clayton Fm. exposed in ditch (white outcrops), overlain by Porters Creek Fm., Butler Co., AL.

The Clayton lies disconformably on the Upper Cretaceous (Gulfian) Series throughout much of the eastern Gulf Coastal Plain. The physical break is accentuated in places by a basal conglomerate or a phosphatic bed. In other places, however, there is little physical evidence of erosion or nondeposition. Moreover, the Clayton is lithologically very similar to the underlying Upper Cretaceous in some parts of Alabama, and there the Cretaceous-Tertiary boundary can be discerned only by the marked faunal change across the boundary (Cushing et al., 1964; Worsley, 1974; Toulmin, 1977). In this region the boundary is marked in the field by the abrupt extinction of the characteristic Cretaceous bivalves *Exogyra costata* and *Gryphaea* spp., and the sudden appearance of *Venericardia* spp. in the Paleocene.

In northeastern Mississippi and western Tennessee the Clayton rests with marked disconformity on the Upper Cretaceous Owl Creek Formation or on the McNairy Sand farther north in Tennessee after the Owl Creek pinches out. But where the lower part of the Clayton is sand in Tennessee, the Cretaceous-Tertiary contact is difficult to determine on the basis of lithologic characteristics alone (Parks, 1975).

Biostratigraphy

All previously published reports on calcareous nannoplankton from the Clayton Formation have been based on relatively few samples or sections studied, e.g., Bramlette and Sullivan (1961); Bramlette and Martini (1964); Hay and Mohler (1967); Hay et al. (1967); Gartner (1970); Martini (1971); Ellis and Lohman (1973); Worsley (1974); and Thierstein (1981). Partial lists of species were sometimes included. Reimers (1976) made a more detailed study of the Clayton Formation in Alabama by systematically collecting at five sections. Reimers (1976) reported 13 Paleocene species from the Clayton, together with several possibly new species that have not yet been formally published. Bybell (1980) examined calcareous nannoplankton in several Paleogene formations in Georgia and eastern Alabama, and provided a list of selected fossils found in these formations (10 species are listed for the Clayton).

Hay et al. (1967) and Hay and Mohler (1967) included the Pine Barren Member in their *Markalius astroporous* and *Cruciplacolithus tenuis* Zones (Fig. 3). The overlying McBryde Member was assigned to the *Fasciculithus tympaniformis* Zone (although they noted that the McBryde lacked the nominal species). Martini (1971) suggested that the basal few feet of the Pine Barren Member belonged to his NP 1 Zone, and at least part of the McBryde Member was assignable to NP 4. He suggested a restudy of strata assigned to the *C. tenuis* Zone of Hay et al. (1967) in view of his (Martini's) proposed intervening NP 2 and NP 3 Zones.

Reimers (1976) used Gartner's (1971) zonation and concluded that both the Pine Barren and the McBryde sections are assignable to Gartner's (1971) *C.*

tenuis Zone (Fig. 3). Bybell (1980) assigned the Clayton Formation to Martini's (1971) Zone NP 3, and Gibson et al. (1982) recognized NP 1, NP 2 and NP 3 in Alabama and western Georgia.

Mancini (1981a,b) has made the most recent study of the eastern Gulf Coastal Plain Paleogene rocks using planktic foraminifers. He found the P1 Zone of the Blow (1969)/Berggren and van Couvering (1974) zonation in the Clayton. The P1 Zone corresponds to the NP 1 to mid-NP 3 interval of Martini (1971) (see Fig. 3).

TABLE 2a

CLAYTON FORMATION

LOCALITY	A1	A2a	A2b	A2c	A2d	A3a	A3b	A3c	A3d	A3e	A3f	A4a	A4b	A4c	A5a	A5b	A6	A7a	A7b	A8	A9a	A9b
ABUNDANCE	V	R	F	F	R	R	C	C	C	F	R	F	F	R	F	F	A	F	A	R	R	F
PRESERVATION	P	P	P	P	P	P	G	G	M	M	P	P	P	P	P	P	G	M	G	P	P	M
Z. adamas																	R		R			
B. bigelowii		R	F				V	R	R												F	F
P. bisulcus									R													
E. cava	V			R	R		F	C	C	F		R	R	V	F	F	C	F	C	V		
H. concinnus															R		R	R	R			
C. consuetus				R			F	F	R						R			F	C	V		
C. crassus						F	R	F	F	V										R		
T. deflandrei		R	F	R	R										F	R	F	F	F		F	F
B. discula																						
M. cf. M. entaster																			V			
T. heimi			R												R		F	R	R		R	R
M. inaequalis																						
M. inversus								R	F								C	F	C		R	R
E. macellus																						
P. martinii																						
R. multiplus							R	R														
T. operculata		R				R	C	F	F	R	V	R	F	V	R		C	F	C	F		R
C. pelagicus			R					R	R						R		R	R	F			
M. pinguis			R																			F
M. aff. M. procerus																						R
N. protenus				R	R			F	R		V											
T. saxea							F	F	F	R	R	R	R	R			C	C	C			
Z. sigmoides							R	R	R	R		F				R	C	R	F			R
Z. simplex								R								R	F		R			
B. sparsus																	R		R			
C. cf. C. staurion									V				R									
E. subpertusa							R	R														
C. tenuis s.l.			F	R	R		R		R			R	V				C	R	R	R		R
B. turbinea							V	R														
Biscutum sp.																	F		R			
Coccolithus sp. A				R	R											F	C	C	F			
Pontosphaera sp.																						
Toweius sp.													V									
Cretaceous spp.		R	F	F	R			R				V									F	F

Tables 2a and 2b show the distribution and relative abundance of calcareous nannoplankton in the samples I collected during this study; Fig. 7 shows some of the most abundant and/or stratigraphically important species in the formation. A hiatus representing at least NP 1 exists throughout most of the study area; NP 2 rocks usually rest disconformably on Maastrichtian rocks. Only at the Locality A2 section (south of Braggs, AL), and in the Locality A11 core (Fig. 2) does NP 1 exist, suggesting that the hiatus is less than the duration of NP 1 at these two localities. Extensive reworking of Cretaceous nannoplankton at both the Locality A2 section and in the Locality A11 core creates a real problem in accurately identifying the Cretaceous-Tertiary boundary. Martini's (1971) definition of the lower boundary of NP 1 is "...the last occurrence of *Arkangelskiella cymbiformis* Vekshina and other Cretaceous species..." Because I frequently found these Cretaceous species reworked into what was clearly the NP 2 Zone, Martini's definition could not be used. Instead, I place the Cretaceous-Tertiary boundary at the level where *Thoracosphaera* spp. first becomes a significant component in the assemblage. Numerous workers (e.g., Perch-Nielsen, 1977; Haq et al., 1977; Haq and Aubry, 1981) have recognized that this genus not only survived the terminal Cretaceous extinctions, but increased dramatically in numbers ('floods', often along with *Braarudosphaera*) in all latitudes just after the boundary extinction event. *Thoracosphaera* and *Braarudosphaera* are present, but very rare in the Maastrichtian Prairie Bluff Chalk underlying the Clayton Formation at Locality A2. Just above a slightly phosphatized limestone ledge, generally taken by field workers as the Cretaceous-Tertiary boundary in this section, *T. operculata* and *T. deflandrei* increase markedly in abundance, as does *Braarudosphaera bigelowii*. The change in the nannoplankton assemblage is even more apparent in the Locality A11 core, which has generally better preservation than the Locality A2 section. In this core, *T. deflandrei* becomes markedly more abundant in sample A11a (Table 2b), which I take to be lowermost Tertiary in this core (see Appendix 1 for stratigraphic details concerning the core).

TABLE 2b

CLAYTON FORMATION

LOCALITY	A10a	A10b	A10c	A11a	A11b	A11c	A11d	A11e	A11f	A11g	A11h	A11i	A12a	A12b	A13a	A13b	A13c	M1	T1a	T1b	T1c	T1d	T1e	T1f	T2a	T2b	T2c	T2d
ABUNDANCE	R	F	F	F	A	F	C	C	C	C	A	F	F	F	F	F	F	R	F	F	F	F	F	F	R	F	F	R
PRESERVATION	P	M	M	P	M	M	M	M	M	M	M	M	M	M	M	M	M	P	M	M	M	M	M	M	P	M	M	P
Z. adamas							R		R	R	R													R				
B. bigelowii				R			F	R	R	F	F								C	F	F	F	R		F	F	F	
P. bisulcus																												
E. cava									C	F	C	F	F	F	F	F	F					R	R	F			R	
H. concinnus														F	R													
C. consuetus															R	F		R					R	R				
C. crassus																								R				
T. deflandrei		F	F	F	F	F	C	F	C	F	F	F	F	F	F	F	F										R	
B. discula								R																				
M. cf. M. entaster										R																		
T. heimi					R		R	R	R	R	R			R		R												
M. inaequalis																											R	V
M. inversus		R		R	F		F	F	C	R	R													R				R
E. macellus													R	R														
P. martinii											R																	
R. multiplus																												
T. operculata	R			R	R	R	C	C	C	C					F	R												
C. pelagicus											R			R		R	R					R		R				
M. pinguis																												
M. aff. M. procerus							R												F	R	R	R				F	F	
N. protenus										R			R			R	R	R										
T. saxea	R		R						R			R							R		F	F	R	F	F	F	F	R
Z. sigmoides	R	R	R		R		R		R	F	C				R	R											V	R
Z. simplex							F	F	F	R	F	R			R								R	R				
B. sparsus																												
C. cf. C. staurion																												
E. subpertusa																												
C. tenuis s.l.					R	R	R		C	F	C	R			R	R			R	R	R		R	R		R	R	
B. turbinea							R																					
Biscutum sp.							R																					
Coccolithus sp. A										R		R		R														
Pontosphaera sp.										R																		
Neochiastozygus sp. A													R	R														
Cretaceous spp.	R	F	R	F	C	F	F	C	F		R							R										

The base of Zone NP 2 is defined by Martini (1971) as the first occurrence of *Cruciplacolithus tenuis*. It should be noted that Thierstein and Okada (1979) believed *C. tenuis* extends to the base of the Danian, and that its absence in Zone NP 1 is caused by diagenetic removal in most sections. However, the detailed study of the Danian by Perch-Nielsen (1979) seems to confirm the first appearance of *C. tenuis* at the base of NP 2.

Martini (1971) defined the NP 2 - NP 3 boundary as the level of the first occurrence of *Chiasmolithus danicus*. However, Gartner (1977) stated that *C. danicus* is restricted to northern Europe and is not present in Gulf Coast Paleocene rocks. Nor have I found *C.danicus* s.s. in this study; specimens reported as *C. danicus* in the region (Hay and Mohler, 1967) appear to fit better the definition of *C. consuetus*. Stratigraphically, *C. consuetus* first appears either just before (Gartner, 1977) or just after (Perch-Nielsen, 1979) the first appearance of *C. danicus*. In the eastern Gulf Coastal Plain, I suggest the first appearance of *C. consuetus* be used as the closest approximation of the NP 2 - NP 3 boundary; it is so used in this study.

A more difficult problem is defining the top of NP 3 in these rocks. The NP 3 - NP 4 boundary is defined by the first appearance of *Ellipsolithus macellus*. *E. macellus* Is a solution-prone species (Perch-Nielsen, 1977) and it is difficult to say whether its general absence is because it has not yet evolved, or simply because of diagenetic removal. Samples above NP 2, but below NP 5, are therefore placed in an NP 3/4 combined zone, except where *E. macellus* is present.

The NP 1 Zone is about 9 feet thick at Locality A2 and about 2 feet thick at Locality A11, based on the first occurrence of *C. tenuis* above the influx of *Thoracosphaera* spp. NP 1 is also present in a 3-feet thick section at Locality 10, where NP 2 is missing. The NP 2 Zone is recognized by the presence of *C.*

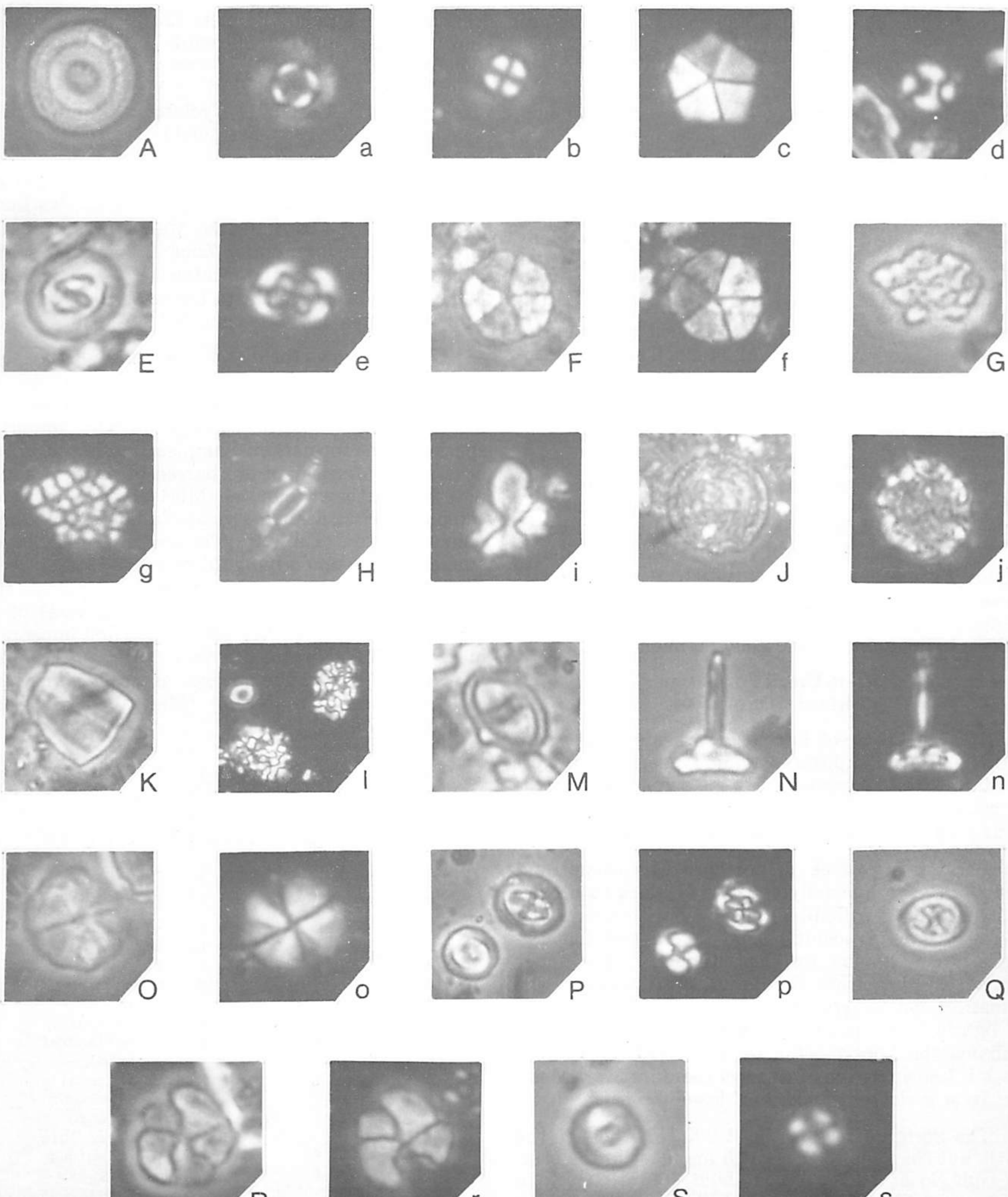


Figure 7. Calcareous nannoplankton in the Clayton Fm. Phase-contrast illumination indicated by upper-case letters; cross polarized by lower case. Sample numbers are in parentheses. A,a, **Markalius apertus** (A11b); b, **Markalius inversus** (A7b); c, **Braarudosphaera bigelowii** (T1a); d, **Prinsius bisulcus** (A3d); E,e, **Chiasmolithus consuetus** (A7b); F,f, **Braarudosphaera discula** (A11e); G,g, **Thoracosphaera heimi** (A6); H, **Ellipsolithus macellus** (A12a); i, **Russellia multiplus** (A3c); J,j, **Thoracosphaera operculata** (A3b); K, **Micrantholithus aff. M. procerus** (T2c); l, **Thoracosphaera saxea** (A7a); M, **Zygodiscus sigmoides** (A6); N,n, **Zygodiscus simplex** (A11f); O,o, **Biantholithus sparsus** (A7b); P,p, **Cruciplacolithus tenuis** (upper) and **Ericsonia cava** (lower) (A6); Q, **Neochiastozygus** sp. A(A12a); R,r, **Braarudosphaera turbinea** (A3c); S,s, **Coccolithus** sp. A(A7a). Approximate magnifications: 1000X, except G,g,i (1600X) and l,P,p (700X).

tenuis and the absence of *Chiasmolithus consuetus*. This zone is present in Alabama at Localities A2, A3, A6, A9 and A11. At Localities T1 and T2 in Tennessee, the NP 2 Zone is about 1½ feet thick and disconformably overlies rocks of late Maastrichtian age. All the NP 1 and NP 2 samples from Alabama are from the Pine Barren Member; NP 2 in Tennessee occurs in Parks' (1975) informal member number 1.

Combined Zone NP 3/4 is recognized by the presence of *C. consuetus* and/or *Heliorthus concinnus* (first appearance in NP 3 or NP 4) (Martini, 1971; Perch-Nielsen, 1979) and the absence of *Fasciculithus* spp. (first appearance in NP 5) (Martini, 1971; Huang and Chi, 1979). Zone NP 3/4 is present at Localities A2, A3, A7, A8, and A12 in Alabama. This zone is also present at Locality M1 in Mississippi and Locality T1 in Tennessee.

The Locality A12 core contains the only *Ellipsolithus macellus* I found during this study. This core is assigned to NP 4 based on the presence of *E. macellus* and the absence of *Fasciculithus* spp. Alabama NP 3/4 samples are all from the McBryde Member, except the Locality A11-A13 cores which are considered Clayton Formation undifferentiated. Mississippi NP 3/4 samples are also in the Clayton Formation undifferentiated, and in Tennessee Zone 3/4 occurs in Parks' (1975) informal member number 1.

Porters Creek Formation
Lithostratigraphy

The Porters Creek Formation was defined by Safford (1864) from exposures along Porters Creek west of Middleton, Tennessee. At the type locality the formation is a black to dark gray, laminated, micaceous clay with subordinate beds of sand.

The Porters Creek in northern Mississippi and western Alabama usually consists of black to brown, massive, montmorillonitic silty clay with conchoidal fracture. Thin glauconitic sand layers and flat ferruginous concretions are characteristic of the upper part of the formation (Toulmin, 1977). Locally the formation may be arenaceous, calcareous, micaceous or lignitic. In eastern Mississippi and western Alabama the uppermost 5 to 20 feet of the Porters Creek is known as the Matthews Landing Marl Member. It is a richly glauconitic, fossiliferous marl.

The Porters Creek is about 200 feet thick in the north, but thickens to the south and east in the eastern Gulf Coastal Plain. It is about 400 feet thick in Sumter and Choctaw counties in Alabama, but thins to about 130 feet and becomes increasingly calcareous in eastern Wilcox County (Toulmin, 1977) (Fig. 6).

Biostratigraphy

The only previously published studies listing calcareous nannoplankton in the Porters Creek Formation have been those by Ellis and Lohman (1973), who described one species, Reimers (1976), who listed 12 known species and one possibly new species, and Bybell (1980), who listed 11 species. Reimers (1976) assigned the Matthews Landing Marl of the Porters Creek to Gartner's (1971) *Cyclococcolithina robusta* Zone, and Bybell (1980) assigned the Porters Creek in Georgia and eastern Alabama to NP 4. Gibson et al. (1982) concluded that the lower part of the Porters Creek is in NP 3 and the upper part (Matthews Landing Marl) in NP 4 in Alabama. Mancini (1981 a,b) reported planktic foraminifer Zone P 2 in the Porters Creek and P 3 in the Matthews Landing Marl Member. P 2 is equivalent to the upper part of NP 3, and P 3 includes both NP 4 and NP 5 (Fig. 3).

Table 3 shows the distribution and relative abundance of calcareous nannoplankton in samples collected during this study; Fig. 8 illustrates some of the most abundant and/or stratigraphically important species in the formation. Samples I collected in Tennessee and Mississippi are barren of nannoplankton, but the Matthews Landing Marl and one lower calcareous layer in Alabama yielded a fair assemblage of nannoplankton (Table 3). The overall assemblage is similar to the underlying McBryde Member of the Clayton Formation. I assign these Porters Creek samples to Martini's Zone NP 3/4, on the basis of the presence of *Chiasmolithus consuetus* (first appearance in NP 3) and *Heliorthus concinnus* (first appearance in NP 3 or NP 4) and the absence of *Fasciculithus* spp. (first appearance in NP 5) (Martini, 1971; Perch-Nielsen, 1979).

TABLE 3

PORTERS CREEK FORMATION

A2e	A2f	A2g	A3g	A3h	A3i	A14	A15	LOCALITY
R	F	F	F	F	F	F	C	ABUNDANCE
P	M	P	P	M	M	M	G	PRESERVATION
						R	F	M. aequalis
R			R	C	C	C	C	B. bigelowii
	R	R	F	F	R	R	F	E. cava
R	R						R	H. concinnus
	R							C. consuetus
		R					R	C. crassus
	R			R			R	T. deflandrei
	R							T. heimi
R				R		R	R	M. inaequalis
							F	M. inversus
							R	C. robusta
			F		R			T. operculata
				R			R	C. pelagicus
	R			R				M. pinguis
							R	Z. plectopons
R	R			R	R	R		N. protenus
R	R	R		R		R	R	T. saxea
			V	R				Z. sigmoides
				·			R	E. subpertusa
R				R			F	C. tenuis s.l.
	R							Coccolithus sp. A
R	R							Neochiastozygus sp. A

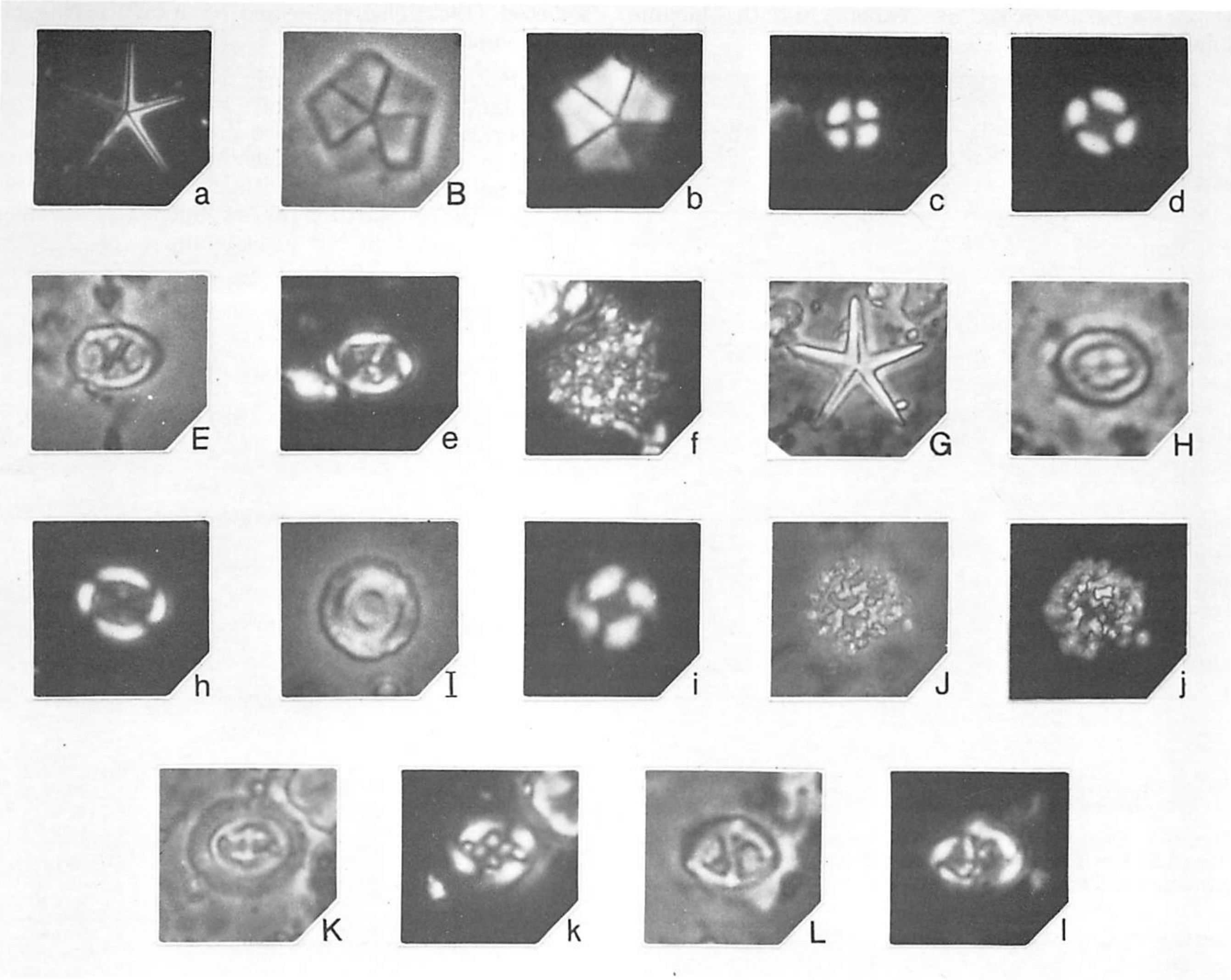


Figure 8. Calcareous nannoplankton in the Porters Creek Fm. Designations as in Figure 7. a, **Micrantholithus aequalis** (A15); B,b, **Braarudosphaera bigelowii** (A15); c, **Ericsonia cava** (A3h); d, **Coccolithus crassus** (A15); E,e, **Heliorthus concinnus** (A15); f, **Thoracosphaera deflandrei** (A2f); G, **Micrantholithus inaequalis** (A14); H,h, **Cruciplacolithus primus** (A15); I,i, **Cycloccolithina robusta** (A15); J,j, **Thoracosphaera saxea** (A14); K,k, **Cruciplacolithus tenuis** (A15); L,l, **Neochiastozygus** sp. A (A2f). Approximate magnifications: 1000X, except E,e,L,l (1200X).

Naheola Formation and Betheden Formation
Lithostratigraphy

Smith (1886) named the Naheola Formation based on exposures at Naheola Landing on the Tombigbee River in Alabama (Fisher, 1961). At its type section, the Naheola consists of unfossiliferous sand and silty clay overlying the fossiliferous Matthews Landing Marl (Toulmin, 1977).

The Naheola is divided into two members in Alabama: the Oak Hill Member and the overlying Coal Bluff Marl Member (Fig. 9). The Oak Hill consists of about 80 feet of thinly bedded, carbonaceous, micaceous silt and fine sand at its type section. Palynomorphs and plant debris are the only common fossils. The Coal Bluff Marl is 22 feet thick at its type section, and consists of calcareous, glauconitic sand (Murray, 1961; Toulmin, 1977). The Coal Bluff contains fairly abundant macrofossils, with an assemblage similar to that of the Matthews Landing Marl (Toulmin, 1977).

The Naheola thins both to the east and west away from western Alabama, where it is thickest, eventually pinching out in eastern Alabama. In Mississippi the Naheola becomes much sandier, eventually grading into a non-marine facies called the Betheden Formation (Murray, 1961).

The Betheden Formation was named by Mellen (1939) for exposures near Betheden, Mississippi. This formation is about 25 feet thick and consists mostly of quartzose sands. It is the stratigraphic equivalent of the Naheola Formation; some workers have discarded the name Betheden and use Naheola in both Alabama and Mississippi.

Figure 9. Coal Bluff Mbr. of Naheola Fm., overlain by Nanafalia Fm. End of hammer handle on contact. Nanafalia Landing on Tombigbee River, AL.

Figure 10. **Ostrea thirsae** beds, Nanafalia Fm., Wilcox Co., AL.

Biostratigraphy

Reimers (1976) reported that the Naheola sections he sampled, including the Coal Bluff Marl Member, were barren of nannoplankton. Mancini (1981a,b) indicated planktic foraminiferal Zone P 3 is present in the Coal Bluff Marl. P 3 correlates with NP 4 and NP 5. Gibson et al. (1982) also suggested NP 5 for the Naheola in Alabama.

I found only rare, poorly preserved calcareous nannoplankton in Coal Bluff samples I collected. However, R.W. Pierce (Amoco Production Co.) kindly allowed me to examine samples he had collected from other Coal Bluff Marl localities in Alabama, where *Fasciculithus involutus* is present but not *H. kleinpelli*. This suggests an NP 5 assignment for these localities.

TABLE 4

SALT MOUNTAIN LIMESTONE		NANAFALIA FORMATION								
A22a	A22b	A16	A17	A18	A19a	A19b	A19c	A19d	A20	LOCALITY
F	F	F	R	F	R	R	C	R	F	ABUNDANCE
P	P	P	M	M	P	P	M	P	G	PRESERVATION
R									R	Z. adamas
							C			M. aequalis
	R					R			R	C. bidens
							F			B. bigelowii
R							R			P. bisulcus
F	F	R	F	R	R	R	F	F	C	E. cava
		R								H. concinnus
R	R	R	R				F			C. consuetus
						R	R			C. crassus
R							R		R	T. deflandrei
		R	R	R					R	E. distichus
R									R	T. eminens
							V			M. entaster
R										T. heimi
									R	M. inaequalis
							R		R	M. inversus
R	R	R		F			F		R	F. involutus
							R			F. janii
									R	N. junctus
		R		R			R		R	H. kleinpelli
		R								P. martinii
				R			R			D. mediosus
			R	R			R		R	D. megastypus
	R		R	R			R			D. mohleri
		R		R			R			T. operculata
R	R	R								C. pelagicus
R	R						R			Z. plectopons
									R	H. riedeli
R				R			R			C. robusta
		R	R	R			R		F	T. saxea
R				R						E. subpertusa
				R						C. tenuis s.l.
				R						Coccolithus sp. A
									R	Pontosphaera sp.
R										Toweius sp.

Nanafalia Formation and Salt Mountain Limestone Lithostratigraphy

The Nanafalia Formation was named by Smith (1883) for exposures at Nanafalia Landing on the Tombigbee River in Alabama (Fig. 9). The Nanafalia is up to 230 feet thick and can be divided into three lithostratigraphic units in Alabama. These are, from oldest to youngest; the Gravel Creek Sand Member, the *'Ostrea thirsae'* beds (informal unit) and the Grampian Hills Member. The Gravel Creek Member is a non-marine sand which thickens progressively northward (up to about 80 feet) until it makes up the entire Nanafalia Formation; the overlying *O. thirsae* beds and the Grampian Hills Member pinch out to the north (updip) in Alabama (Cushing et al., 1964; Toulmin, 1977). The *O. thirsae* beds are mostly glauconitic, calcareous, clayey sands containing abundant oysters dominated by *Odontogryphaea thirsae* (Fig. 10). These beds thin from a maximum thickness of 60 feet in western Alabama to about 20 feet at the Alabama-Georgia border (Toulmin, 1977). The Grampian Hills Member consists of greenish-gray, coarse-grained, glauconitic sandstone interbedded with claystone. This member is thickest in central Alabama (up to 110 feet thick) but thins both to the east (to about 30 feet) and west (to 15-20 feet) in Alabama (Toulmin, 1977). The distinctive *O. thirsae* is present, although not common, in this member.

The Nanafalia overlies the Clayton Formation with marked disconformity in eastern Alabama, and is probably also disconformable where it rests on the Naheola elsewhere in Alabama (Toulmin, 1977).

The Salt Mountain Limestone was named by Langdon (1891) for exposures of hard, coral-bearing, recrystallized limestone at Salt Mountain, near Jackson, Alabama (Fig. 11). The exposures are about 90 feet thick (Fisher, 1961), but the lateral extent is very limited. Toulmin (1940) considered the Salt Mountain to be an offshore facies correlative to the *O. thirsae* beds of the Nanafalia.

Figure 11. Salt Mountain Limestone. Near Jackson, Clarke Co., AL.

Biostratigraphy

Bramlette and Sullivan (1961) recorded 10 species and Bybell (1980) recorded 21 species of calcareous nannoplankton within the Nanafalia Formation. Hay and Mohler (1967) and Hay et al. (1967) assigned the Nanafalia to the *Heliolithus riedeli* Zone, based on the presence of the nominal species as recorded by Bramlette and Sullivan (1961). Bybell (1980) and Gibson et al. (1982) judged the Nanafalia to range from Zones NP 7 to NP 9 in Alabama and Georgia. Mancini (1981a,b) found planktic foraminiferal Zone P 3 (=NP 4 and NP 5) in the lower Nanafalia and P 4 (=NP 6 to NP 8) in the upper Nanafalia.

Wind (1974) described 22 species of calcareous nannoplankton from the Salt Mountain Limestone. He concluded that the Salt Mountain could be assigned to the *Discoaster gemmeus* [=*D. mohleri*] Zone of Hay et al. (1967), which is equivalent to NP 7.

Calcareous nannoplankton from Nanafalia sections I investigated (Localities A16-A20) are listed in Table 4 and illustrated in Fig. 12. Samples from Henry County in eastern Alabama (Fig. 2) can only be assigned to the NP 7 to NP 9 interval based on *D. mohleri* (range NP 7 - NP 9). Farther west, in Pike and Wilcox counties, I assign the *O. thirsae* beds to NP 7, on the basis of the co-occurrence of *Heliolithus kleinpelli* (range NP 6 - NP 7) and *Discoaster mohleri*. The Nanafalia in Marengo County to the northwest is NP 8, on the basis of the presence of *H. riedeli* (first appearance in NP 8) and the absence of *D. multiradiatus* (first appearance in NP 9) (Martini, 1971).

Calcareous nannoplankton from the Salt Mountain Limestone are listed in Table 4, and illustrated in Fig. 13. I assign these samples to Zone NP 7, on the basis of the presence of *Discoaster mohleri* and *Toweius eminens* (both first appeared in NP 7) (Martini, 1971; Huang and Chi, 1979) and the lack of *Heliolithus riedeli*.

Tuscahoma Sand

Lithostratigraphy

This formation was named by Smith et al. (1894) for exposures at Tuscahoma Landing on the Tombigbee River, Alabama. The Tuscahoma is about 350 feet thick in the area of the type locality and consists mostly of interbedded layers of carbonaceous silt and fine sand (Cushing et al., 1964; Toulmin, 1977). Two richly fossiliferous beds within the lower part of the Tuscahoma have been given member status. Toulmin (1977) described the lower unit, the Greggs Landing Marl Member as a 6-feet-thick calcareous, glauconitic, silty sand or clayey silt containing lignite and small spheroidal concretions. The upper 9-feet-thick member, the Bells Landing Marl, is a very fine-grained, glauconitic sand, containing large (5 to 6 feet thick) pillow-shaped concretions.

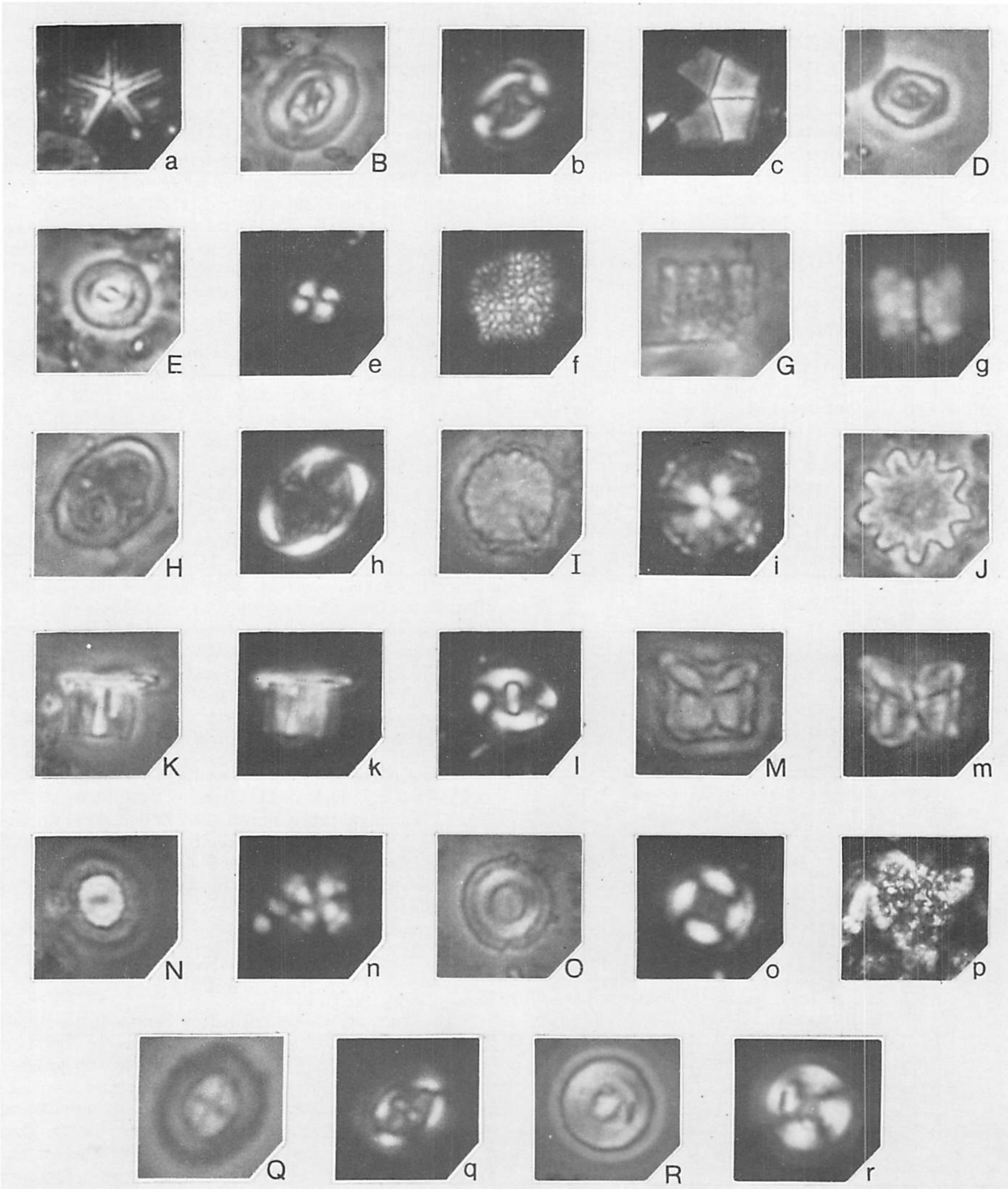


Figure 12. Calcareous nannoplankton in the Nanafalia Formation. Designations as in Figure 7. a, **Micrantholithus aequalis** (A19c); B,b, **Chiasmolithus bidens** (A20); c, **Braarudosphaera bigelowii** (A19c); D, **Chiasmolithus consuetus** (A19c); E,e, **Ericsonia cava** (A17); f, **Thoracosphaera deflandrei** (A20); G,g, **Fasciculithus involutus** (A19c); H,h, **Neochiastozygus junctus** (A20); I,i, **Heliolithus kleinpelli** (A20); J, **Discoaster mediosus** (A19c); K,k, **Discoasteroides megastypus** (A18); l, **Zygodiscus plectopons** (A19c); M,m,N,n, **Heliolithus riedeli** (A20); O,o, **Cycloccolithina robusta** (A18); p, **Thoracosphaera saxea** (A20); Q,q, **Cruciplacolithus tenuis** (A18); R,r, **Coccolithus** sp. A (A18). Approximate magnifications: 1000X, except G,g,H,h,I,i,Q,q (1200X).

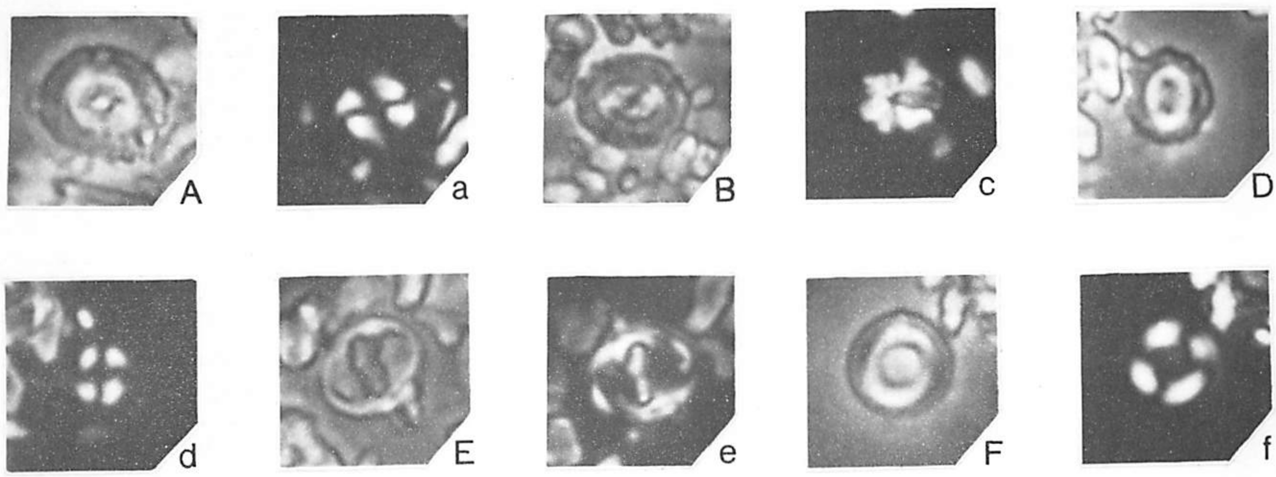


Figure 13. Calcareous nannoplankton in Salt Mountain Limestone. Designations as in Figure 7. A,a, **Ericsonia cava** (A22b); B, **Chiasmolithus consuetus** (A22a); c, **Fasciculithus involutus** (A22a); D,d, **Coccolithus pelagicus** (A22b); E,e, **Zygodiscus plectopons** (A22a); F,f, **Cycloccolithina robusta** (A22a). Approximate magnifications: 1000X.

The two members are separated by a 25-30 feet clay interval. Both the Greggs Landing and Bells Landing Marls contain a diversified fauna dominated by *Ostrea, Venericardia* and *Turritella* (Toulmin, 1977); specimens in the Bells Landing are particularly large. At least one other glauconitic, fossiliferous zone is present in the formation (Copeland, 1968).

The Tuscahoma extends from Georgia across Alabama into Mississippi, but the Greggs and Bells Landing members are distinguishable only in western Alabama.

Biostratigraphy

The only previously published report on calcareous nannoplankton in the Tuscahoma Sand is that of Bybell (1980), who recorded 15 species from this unit in Georgia and eastern Alabama. She noted that these species are typical of NP 9. Gibson et al. (1982) also assigned the Nanafalia to NP 9 in Alabama. Oliver and Mancini (1980), Mancini and Oliver (1981) and Mancini (1981a,b) have recently described several sections with assemblages of planktic foraminifers which are assignable to planktic foraminifer Zones P 5 and P 6 (Mancini, 1981b).

The Tuscahoma is barren of calcareous nannoplankton everywhere I sampled it, but R.W. Pierce kindly allowed me to study a nannoplankton-bearing sample he collected from the Bells Landing Marl in Alabama (Locality A45). Species present are recorded in Table 5. The co-occurrence of *Fasciculithus involutus, Discoaster mohleri* (last appearance in NP 9) and *D. multiradiatus* (first appearance in NP 9) indicates a zonal assignment to NP 9 (Martini, 1971). *D. perpolitus* is also present, and although the range of this species is not well documented in the literature, Martini (1971) also reported it only from Zone NP 9.

TABLE 5

TUSCAHOMA FORMATION	HATCHETIGBEE FORMATION				
A45	A21a	A21b	A46a	A46b	LOCALITY
F	R	F	C	R	ABUNDANCE
G	P	P	M	P	PRESERVATION
F			R		M. aequalis
			R		C. bidens
			C		B. bigelowii
	V				Z. bijugatus
R	R	F	F	R	E. cava
				R	C. consuetus
			R	R	C. crassus
		R			D. delicatus
			F		D. elegans
R				R	T. eminens
		R			C. eopelagicus
R					D. helianthus
			R		M. inaequalis
F			F		F. involutus
			R		D. lenticularis
			R		D. mediosus
			F		D. megastypus
R			R		D. mohleri
R		R	F		D. multiradiatus
			R		T. obliquipons
R		R	R		C. pelagicus
R					D. perpolitus
		R	R		P. plana
R		R	F		Z. plectopons
			R		T. pulcher
		R	R		T. saxea
		R			Pontosphaera sp.

Hatchetigbee Formation

Lithostratigraphy

Smith (1886) named this formation (originally called a 'series') from exposures at Hatchetigbee Bluff on the Tombigbee River, Alabama. The bulk of the Hatchetigbee is lithologically similar to the Tuscahoma, consisting of laminated, carbonaceous, silty clay, silt, and beds of fine-grained sand, some of which are cross bedded (Cushing et al., 1964; Toulmin, 1977).

The Hatchetigbee extends from western Georgia across Alabama into southeastern Mississippi. In western Alabama the formation is about 250 feet thick, thinning to about 70 feet at the type section and to 35 feet in eastern Alabama (Toulmin, 1977).

The Bashi Marl Member is distinguished as a separate unit at the base of the Hatchetigbee (Fig. 14). The Bashi Marl is 6 to 35 feet thick and consists of glauconitic, calcareous sand containing large concretions and abundant macro- and microfossils (Toulmin, 1977).

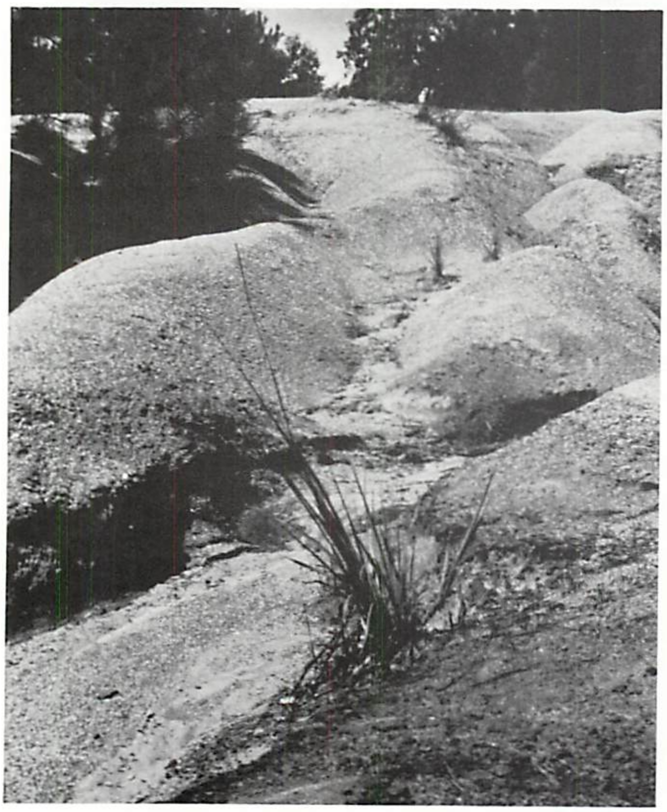


Figure 14. Hatchetigbee Fm. with the Bashi Mbr. exposed in lower part of ravines. Behind the Red Hot Truck Stop on east side of Interstate 20 at Meridian, MS. (MGS locality 19).

Biostratigraphy

Bramlette and Sullivan (1961) listed 14 species and Bybell (1980) listed 22 species of calcareous nannoplankton in the Hatchetigbee. Other workers have not provided lists of species, but have assigned the Hatchetigbee to a zone. Hay and Mohler (1967) and Hay et al. (1967) assigned the Hatchetigbee to the *Discoaster multiradiatus* Zone and Martini (1971) correlated the Hatchetigbee to NP 9, based on the assignment of Hay et al. (1967). Bybell (1980) and Gibson et al. (1982) assigned the Hatchetigbee in Georgia and Alabama to NP 10. Mancini (1981a,b) assigned the Bashi to planktic foraminifer Zone P 6 (= NP 9 (in part), NP 10 and NP 11).

Calcareous nannoplankton I found in the Hatchetigbee (Bashi Marl Member) during this study are listed in Table 5 and shown in Fig. 15. I assign the Bashi Marl, at the localities where I sampled it, to Zone NP 9 based on the co-occurrence of *D. multiradiatus* (first appearance in NP 9) and *D. mohleri* (range NP 7 - NP 9) (Martini, 1971). R.W. Pierce (pers. communic.) has, however, identified both the NP 9 and NP 10 Zones in Bashi sections at other Alabama localities.

Tallahatta Formation

Lithostratigraphy

This formation name was first used in print by Dall (1898) for exposures around the Tallahatta Hills in western Alabama. At the type locality the Tallahatta consists of about 120 feet of very fine-grained, hard, siliceous 'claystone', commonly called 'buhrstone' in the region, together with some beds of glauconitic sand and sandstone (Copeland, 1968; Toulmin, 1977). Some of the calcareous sands at the top of the formation are very fossiliferous (Copeland, 1968) (Fig. 16). The formation thins to the east in Alabama, where the siliceous claystone becomes less prominent, and clayey sand, sandy clay and limestone dominate. The buhrstone continues westward from Alabama into Mississippi, where it is known as the Basic City Shale Member. The upper part of the Tallahatta in Mississippi is distinguished as a separate member, the Neshoba Sand Member, which is a fine-grained, micaceous, marine sand, lacking fossils (Toulmin, 1977). The Tallahatta is up to 200 feet thick in Mississippi (Cushing et al., 1964).

A lower unit, the Meridian Sand Member, is best developed in Mississippi where it averages 100 feet thick. This member consists of beds of clayey sand and sandy clay, overlain by cross bedded, coarser sands (Cushing et al., 1964; Toulmin, 1977). The Meridian wedges out in central Alabama, where the Tallahatta rests disconformably on the Hatchetigbee (Copeland, 1968; Toulmin, 1977).

Biostratigraphy

Bybell (1975) provided the only previously published list of calcareous nannoplankton from the Tallahatta. Bybell's study was restricted to the Little Stave Creek section in western Alabama. Bybell (1975) listed some 37 different species in this section, and assigned the Tallahatta to the *Reticulofenestra umbilica - Sphenolithus furcatolithoides* Zone of Gartner (1971), which falls within the NP 15 Zone of Martini (1971). Gibson and Bybell (1981) later reported finding Zone NP 13 in the Tallahatta in Georgia. Hay et al. (1967) had previously assigned this formation to their *Discoaster lodoensis* Zone (Fig. 3)

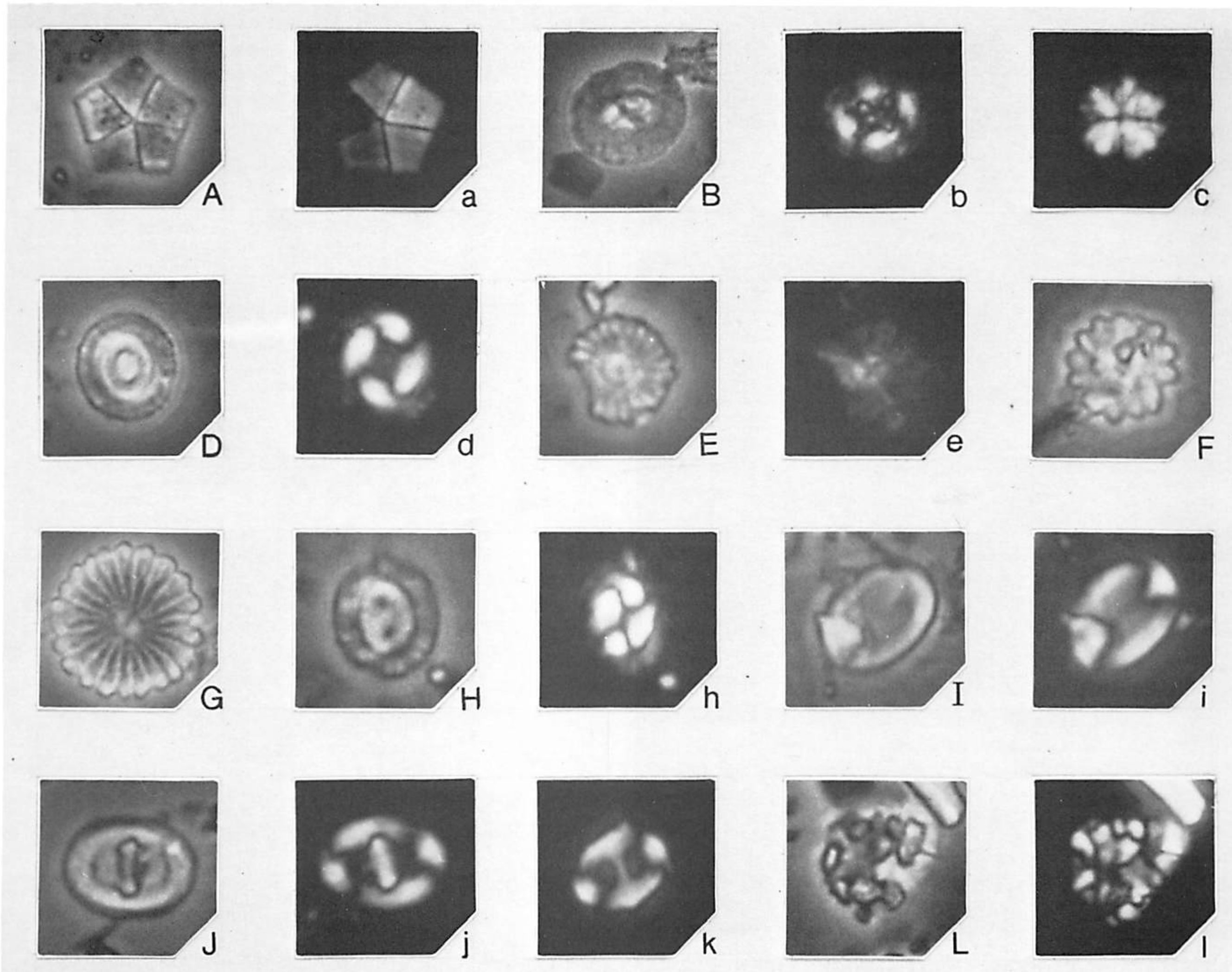


Figure 15. Calcareous nannoplankton in the Hatchetigbee Fm. Designations as in Figure 7. A,a, **Braarudosphaera bigelowii** (A46a); B,b, **Chiasmolithus consuetus** (A46b); c, **Fasciculithus involutus** (A46a); D,d, **Coccolithus crassus** (A46a); E,e, **Discoasteroides megastypus** (A46a); F, **Discoaster mohleri** (A46a); G, **Discoaster multiradiatus** (A46a); H,h, **Coccolithus pelagicus** (A21b); I,i, **Pontosphaera plana** (A46a); J,j, **Zygodiscus plectopons** (A46a); k, **Transversopontis pulcher** (A46a); L,l, **Thoracosphaera saxea** (A46a). Approximate magnifications: 1000X.

Calcareous nannoplankton found in samples I collected during this study are listed in Table 6 and shown in Fig. 17. These assemblages indicate a zonal assignment of NP 14 for at least the middle part of the Tallahatta Formation at Little Stave Creek (Locality A23), based on the presence of *D. lodoensis, D. germanicus, Lophodolithus nascens* (all last appear in NP 14) and *D. sublodoensis* (first appears in NP 14), together with *Rhabdosphaera inflata* and *Lophodolithus mochlophorus*; *R. inflata* is restricted to NP 14, and *L. mochlophorus* is also essentially restricted to NP 14 (Martini, 1971, Bukry, 1973b; Müller, 1978; Beckmann et al., 1981).

The NP 14 - NP 15 boundary in Martini's zonation is marked by the first appearance of *Chiphragmolithus alatus* (=*Nannotetrina fulgens*). This species is not present in the Little Stave Creek section, but the extinction of *R. inflata* may be used to mark the equivalent boundary (Bukry, 1973a; Okada and Bukry, 1980). Absence of *R. inflata* and the other NP 14 species in the upper part of the Tallahatta suggests the formation passes into NP 15 at Little Stave Creek. The same assemblage, suggesting NP 15, occurs in Tallahatta samples I collected to the north, in Choctaw County.

This formation is apparently markedly diachronous. Gibson and Bybell (1981) and Gibson et al. (1982) reported the Tallahatta to range from NP 12 to NP 15 in Alabama and Georgia, and R.W. Pierce (pers. communic.) has also found nannoplankton indicating that the Tallahatta is as old as NP 12 at some Alabama localities.

Figure 16. Tallahatta Fm. Note glauconite-filled burrows. Choctaw Co., AL.

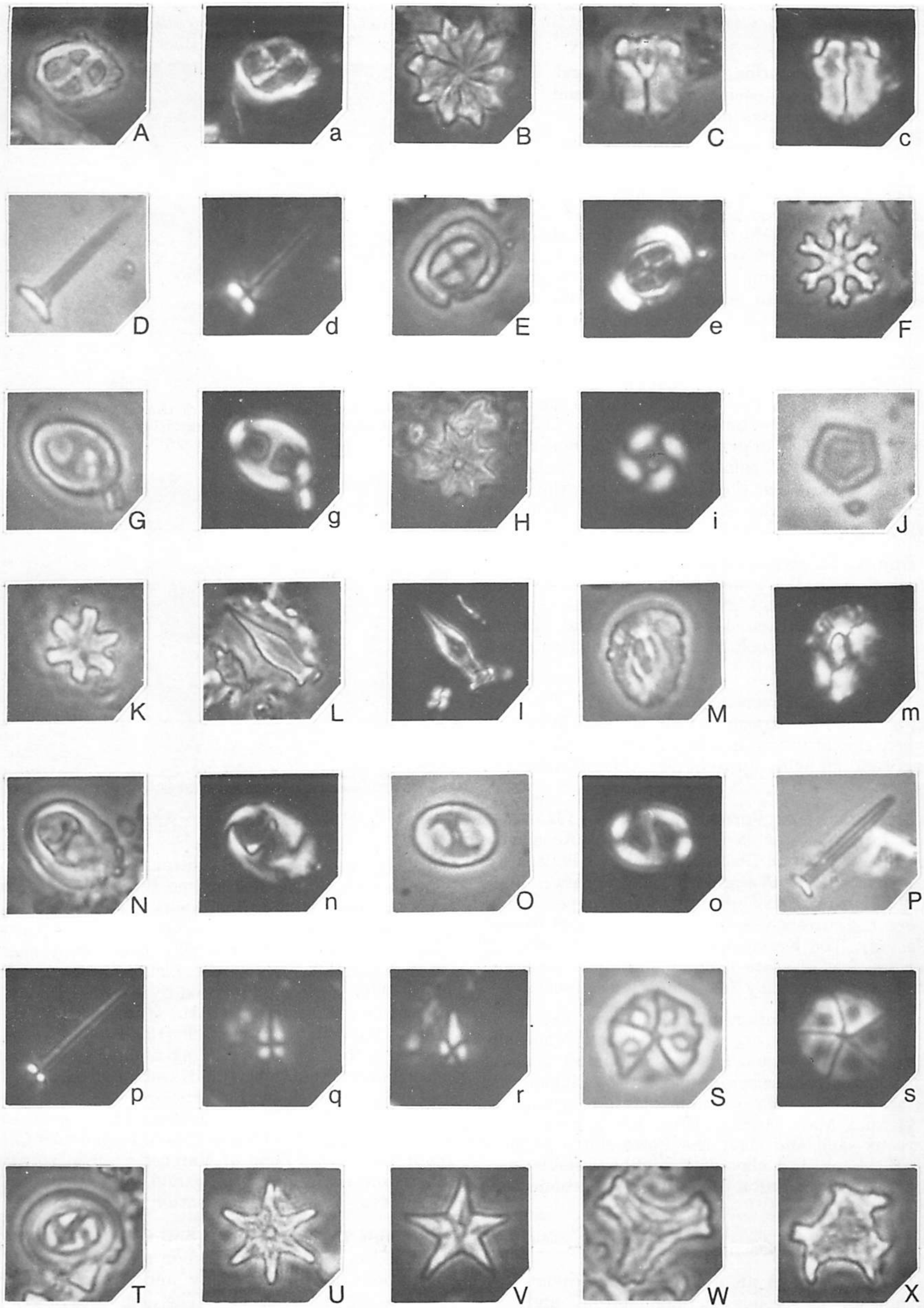
It is obvious that a major early Eocene hiatus exists between the Hatchetigbee and Tallahatta Formations, although some of the apparently 'missing' time may be represented by the upper nonmarine member of the Hatchetigbee.

TABLE 6

TALLAHATTA FORMATION

A23a	A23b	A24a	A24b	A25	LOCALITY
C	F	C	F	C	ABUNDANCE
G	M	M	M	M	PRESERVATION
		V			C. acanthodes
		R			M. angulosus
R		F		F	D. barbadiensis
				R	B. bigelowii
F		F		F	Z. bijugatus
		R			D. binodoensis
R		R		C	R. dictyoda
		V			H. concinnus
		R			P. basquense crassum
		V		R	B. creber
R		R		R	D. deflandrei
		R		R	C. delus
R					D. distinctus
R		R			N. dubius
				R	D. elegans
R		R	R	R	C. eopelagicus
R					H. cf. euphratis
F	V				D. falcatus
V					G. fluckigeri
C	F	C	C	F	C. floridanus
F	F	F	F	F	C. formosus
		R		R	D. exilis
R					D. germanicus
		R		R	C. grandis
		R			M. inaequalis
R					R. inflata
V		R			M. inversus
R		R		R	C. kingi
R		R		V	D. kuepperi
		R			P. larvalis
V					D. lenticularis
V					D. lodoensis
		V			H. lophota
	V				C. minutus
R					L. mochlophorus
R					P. multipora s.l.
R					L. nascens
				R	D. nodifer
	R	F		F	T. obliquipons
F	R	F	F	F	C. pelagicus
				R	B. perlonga
R					P. plana
		R		R	T. pulcher
		V		R	S. radians
R		F			H. seminulum
R	R				B. serraculoides
				R	P. serratum
		R		V	L. simplex
F		R	R	F	C. solitus
R					B. spinosus
R					D. strictus
F		R			D. sublodoensis
R		R		F	B. tenuis
		R	R	R	R. umbilica
		R		R	Polycladolithus sp.
R		R		R	Pontosphaera sp.
R					Micrantholithus sp. A

Figure 17. Calcareous nannoplankton in the Tallahatta Fm. Designations as in Figure 7. A,a, **Chiphragmalithus acanthodes** (A24a); B, **Discoaster barbadiensis** (A25); C,c, **Zygrhablithus bijugatus** (A24a); D,d, **Blackites creber** (A25); E,e, **Cruciplacolithus delus** (A25); F, **Discoaster distinctus** (A23a); G,g, **Discolithus exilis** (A25); H, **Discoaster falcatus** (A23a); i, **Cyclococcolithus formosus** (A23a); J, **Goniolithus fluckigeri** (A23a); K, **Discoaster germanicus** (A23a); L,l, **Rhabdosphaera inflata** (A23a); M,m, **Helicosphaera lophota** (A24a); N,n, **Lophodolithus nascens** (A23a); O,o, **Transversopontis obliquipons** (A25); P,p, **Rhabdosphaera perlonga** (A25); q,r, **Sphenolithus radians** (q: 0°; r: 45°) (A25); S,s, **Pemma serratum** (A25); T, **Chiasmolithus solitus** (A23a); U, **Discoaster strictus** (A23a); V, **Discoaster sublodoensis** (A23a); W,X, '**Polycladolithus**' sp. A (A24a). Approximate magnifications: 1000X, except J,q,r,W,X (1200X).


A a B C c
D d E e F
G g H i J
K L l M m
N n O o P
p q r S s
T U V W X

Lisbon Formation, Winona Greensand, Zilpha Clay, Kosciusko Formation and Cook Mountain Formation

Lithostratigraphy

The Lisbon Formation was named by Aldrich (1886) for exposures at Lisbon Bluff on the Alabama River, Alabama. This formation consists of about 150 feet of glauconitic, calcareous, fossiliferous sand and sandy clay in Alabama (Toulmin, 1977), where the Lisbon is divided into 'lower', 'middle', and 'upper' units. The 'lower' Lisbon is a coarse-grained, glauconitic, highly fossiliferous sand disconformably overlying the Tallahatta Formation (Toulmin, 1977). The 'middle' Lisbon is mostly carbonaceous sand and carbonaceous silty clay. The 'upper' Lisbon is the thickest (75 feet) of the three units making up the Lisbon in Alabama. It consists of glauconitic, calcareous, clayey sand, sandy clay and calcareous sand, all containing fossils. Eastward, near the Georgia border, the upper Lisbon makes up the entire formation (Toulmin, 1977).

Units in Mississippi which are assumed to be age equivalent with the lower Lisbon are the Winona Greensand and Zilpha Clay; equivalent with the middle Lisbon is the Kosciusko Formation; and with the upper Lisbon is the Cook Mountain Formation (Toulmin, 1977) (Fig. 4).

The Winona Greensand (Lowe, 1919; Thomas, 1942) is named for exposures near Winona, Mississippi, where the formation is a highly glauconitic, fossiliferous sand and clay up to 50 feet thick (Cushing et al., 1964).

The Kosciusko Formation (Cooke, 1925) was named for exposures in the vicinity of Kosciusko, Mississippi. The U.S. Geological Survey has used the name Sparta Sand (Vaughan, 1895; Spooner, 1926) from Texas to Mississippi, but in this paper I have followed the current usage of the Mississippi Bureau of Geology. The Kosciusko/Sparta Sand consists of about 300 feet of cross bedded quartzose sand and subordinate sandy clay (Cushing et al., 1964).

The Cook Mountain Formation was named by Kennedy (1892) for exposures at Cook Mountain, Houston County, Texas. The Cook Mountain is about 100 feet thick in Mississippi and can be divided into three members, which are from oldest to youngest: the Archusa Marl Member (Fig. 18), a glauconitic, calcareous sand and clay; the Potterchitto Member (Fig. 19), sand and clay with highly variable composition; and the Gordon Creek Shale, a carbonaceous clay (Toulmin, 1977).

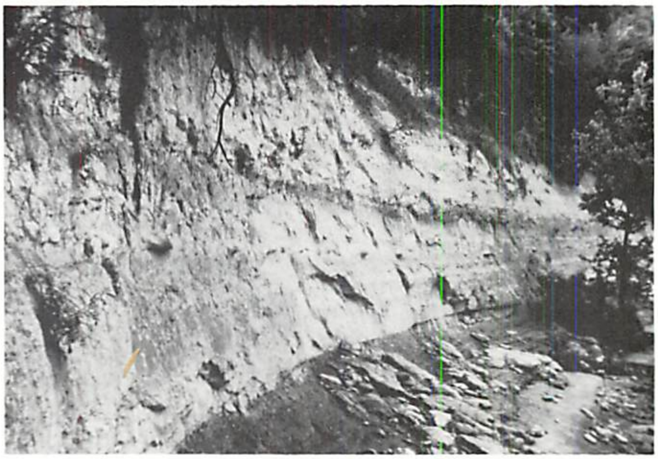


Figure 18. Archusa Marl Mbr. of the Cook Mountain Fm. Dobys Bluff on the Chickasawhay River south of Quitman, Clarke Co., MS. (MGS locality 26).

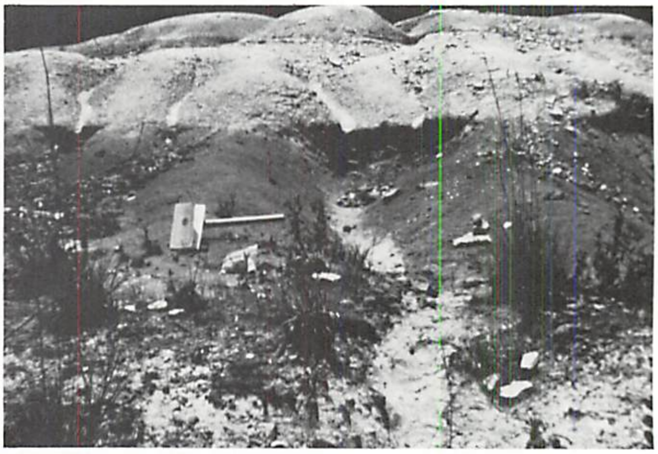


Figure 19. Potterchitto Mbr. of Cook Mountain Fm., Newton Co., MS. (Locality M3, MGS locality 65).

Biostratigraphy

The Lisbon has an abundant and diverse assemblage of calcareous nannoplankton, and, accordingly, has received the attention of several previous investigators. Gartner and Bukry (1969), Bukry and Bramlette (1969), Boudreaux (1974) and Gartner (1970) noted several species occuring in the Lisbon, and Bybell and Gartner (1972) listed many species from the middle unit of the Lisbon at Little Stave Creek. This work was followed by a detailed study of the Lisbon Formation at the Little Stave Creek section (Bybell, 1975). Bybell (1975) listed some 64 species in the Lisbon, including a remarkably diverse assemblage of pentaliths and assigned the Lisbon at Little Stave Creek to the *Reticulofenestra umbilica - Sphenolithus furcatolithoides* Zone, the *Pemma papillatum* Zone and the *Helicosphaera compacta - Chiasmolithus grandis* Zone of Gartner's (1971) zonation. These zones correlate with the mid-NP 15 to upper NP 17 interval in Martini's zonation (Fig. 3).

Table 7 shows the distribution of calcareous nannoplankton found in the Lisbon and Cook Mountain formations during this study, and Figs. 20 and 21 illustrate important species. The diagnostic species of

TABLE 7

LISBON FORMATION							COOK MOUNTAIN FORMATION		
A23c	A23d	A23e	A24c	A24d	A24e	A26	M2	M3	LOCALITY
F	F	A	A	F	C	C	R	C	ABUNDANCE
P	M	G	G	M	G	G	M	G	PRESERVATION
	R	F							M. altus
		R				R		R	M. angulosus
	R	R	R					R	D. barbadiensis
	R	F						F	P. basquense basquense
R	R	R	R	R		V		R	B. bigelowii
	R	F	F	F	F	F		F	Z. bijugatus
		F						R	D. binodosus
	F	F	C	C	C	F	R	R	R. dictyoda
	R	F						R	P. basquense crassum
						F			B. creber
					R			R	D. deflandrei
		R							C. delus
			R						B. discula
			R		F	R		R	D. distinctus
	R	V			R			R	N. dubius
		R	R		F			R	D. elegans
	R		R		R			R	C. eopelagicus
					R		R		K. aff. K. fimbriatus
F	F	R	R	F		R	R	R	C. floridanus
	R	R	C	F	C	F	R	R	C. formosus
		R			R				C. germanicus
			R						R. gladius
					R				C. grandis
	R								M. inaequalis
		V							M. inversus
		R	R		R				D. kuepperi
		R				R			P. lisbonensis
			V						H. lophota
		R						R	L. minutus
		F			R				D. mirus
		R	R	R	R			R	S. moriformis
			R			R		F	P. multipora s.l.
		R	R					R	D. nodifer
		R			R				S. labrosa
	R		R			R	R	C	T. obliquipons
		V							T. operculata
	R	R							L. operosum
		R	R						P. papillatum
R	R	R	R		C	R	R	R	C. pelagicus
		V							L. perdurum
	R							R	M. procerus
			F	R	F				T. pulcher
		R						F	D. punctulata
	R								S. radians
		R						R	R. reticulata
			F	F				R	P. rotundum
	V	R			R			R	D. saipanensis
						R			T. saxea
								R	H. seminulum
		R						R	B. serraculoides
	C	F	R		R	F	R	R	P. serratum
		R			R				L. simplex
			V						H. solidus
R		R	F		F	R			C. solitus
		R	R		R			R	S. spinosus
					R				C. staurion
			F						D. sublodoensis
	R	F			C				B. tenuis
			F		F	F		C	R. umbilica
				R	F				K. wechesensis
								R	P. snavelyi
			R						Micrantholithus sp. A

Zone NP 15, *Rhabdosphaera gladius,* occurs only near the bottom of the Lisbon section in Choctaw County (Locality A24). *Discoaster saipanensis* is also absent in the lower part of the section. The absence of *R. gladius* (restricted to NP 15) and the co-occurrence of *D. saipanensis* (first appearance in NP 16) and *Chiasmolithus solitus* and *Neococcolithes dubius* (all last appear in NP 16) (Martini, 1971; Beckmann et al., 1981) higher in the Choctaw County section indicate that the Lisbon passes into Zone NP 16 here. Siesser, Pierce and Govean (in prep.) also recognize the approximate position of the NP 15 - NP 16 boundary within the Lisbon at Little Stave Creek (Locality A23), based on the first appearance of *Discoaster nodifer*. They assign the uppermost 11 feet of the Lisbon at that locality to NP 17, on the basis of the last occurrence of *Chiasmolithus solitus* in this continuous section.

Calcareous nannoplankton have not previously been reported in the correlative equivalents of the Lisbon in Mississippi (Fig. 4). I found the Winona, Zilpha and Kosciusko formations to be barren, or contain only very rare, poorly preserved nannoplankton. The Archusa Marl Member (M2, Table 7) of the Cook Mountain Formation contains only rare middle Eocene specimens which I could not assign to a specific zone. The Potterchitto Member (M3, Table 7), however, contains a diverse, well-preserved assemblage indicative of Zone NP 16, based on the presence of *Discoaster saipanensis* and *Neococcolithes dubius*.

Gosport Sand
Lithostratigraphy

This formation was named by Smith (1907) for exposures at Gosport Landing on the Alabama River. The Gosport Sand consists of up to 30 feet of glauconitic, quartzose, calcareous sand, extremely rich in fossils and containing intertongues of carbonaceous shale (Copeland, 1968) (Figs. 22 and 23). The Gosport overlies the Lisbon disconformably.

This formation occurs only from the Alabama River west to the Mississippi border. Near the Mississippi state line the marine facies pinches out in a nonmarine section of cross bedded sand and carbonaceous clay known as the Cockfield Formation in Mississippi (Toulmin, 1977).

Vaughan (1895) named the Cockfield for exposures at Cockfield Ferry on the Red River, Winn Parish, Louisiana. This formation consists of about 250 feet of fine to medium quartzose sand and carbonaceous clay.

Biostratigraphy

Bybell (1975) has published the only previous report on calcareous nannoplankton in the Gosport Formation, again restricted to the Little Stave Creek section. She found 21 different species in the Gosport at this section and assigned it to Gartner's (1971) *H. compacta - C. grandis* Zone, which is equivalent to most of Martini's (1971) Zone NP 17 and uppermost Zone NP 16 (Fig. 3).

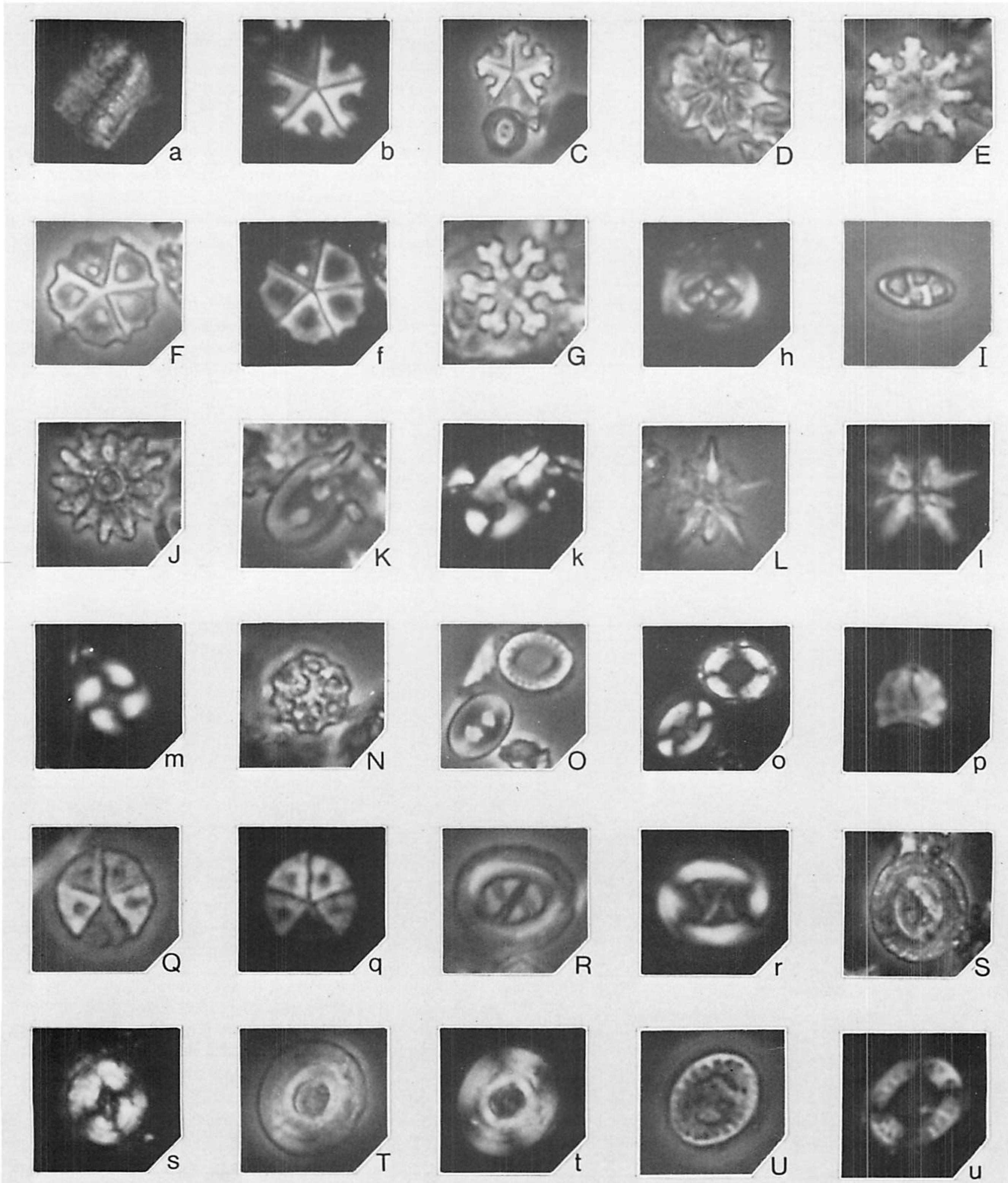


Figure 20. Calcareous nannoplankton in the Lisbon Fm. Designations as in Figure 7. a, **Micrantholithus altus** (A23e); b, **Micrantholithus angulosus** (A23e); C, **M. angulosus** and **Coccolithus pelagicus** (A26); D, **Discoaster barbadiensis** (A24c); E, **Discoaster binodosus** (A23e); F,f, **Pemma basquense basquense** (A23e); G, **Discoaster deflandrei** (A24e); h, **Cruciplacolithus delus** (A23e); I, **Neococcolithes dubius** (A24e); J, **Discoaster elegans** (A24e); K,k, **Koczyia** aff. **K. fimbriatus** (A24e); L,l, **Pentaster lisbonensis** (A23e); m, **Cyclococcolithus formosus** (A24c); N, **Lithostromation operosum** (A23e); O,o, **Transversopontis** cf. **T. pulcher** (lower) and **Koczyia wechesensis** (upper) (A24e); p, **Daktylethra punctulata** (A23e); Q,q, **Pemma rotundum** (A24d); R,r, **Chiasmolithus solitus** (A24c); S,s, **Cruciplacolithus staurion** (A24e); T,t, **Reticulofenestra umbilica** (A26); U,u, **Koczyia wechesensis** (A24d). Approximate magnifications: 1000X, except p,R,r (1200X) and C,O,o (700X).

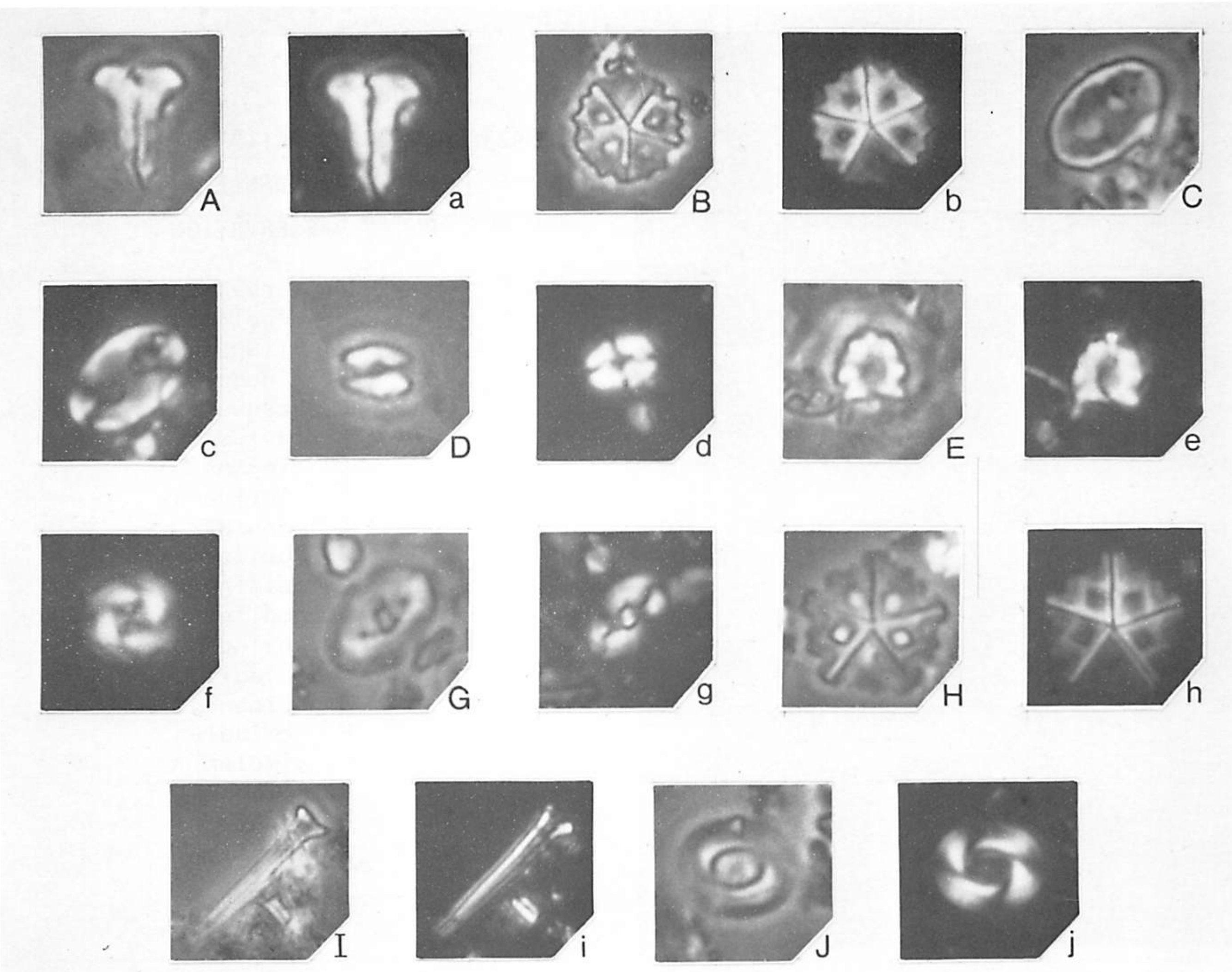


Figure 21. Calcareous nannoplankton in the Cook Mountain Fm. Designations as in Figure 7. A,a, **Zygrhablithus bijugatus** (M3); B,b, **Pemma basquense crassum** (M3); C,c, **Koczyia aff. K. fimbriatus** (M2); D,d, **Lanternithus minutus** (M3); E,e, **Daktylethra punctulata** (M3); f, **Reticulofenestra reticulata** (M3); G,g, **Helicosphaera seminulum** (M3); H,h, **Pemma snavelyi** (M3); I,i, **Blackites spinosus** (M3); J,j, **Reticulofenestra umbilica** (M3). Approximate magnifications: 1000X.

Figure 22. Abundantly fossiliferous layer of middle Gosport Sand, Little Stave Creek, Clarke Co., AL.

Table 8 and Fig. 24 list and illustrate calcareous nannoplankton I found in the Gosport during this study; samples from the Cockfield were barren of nannoplankton. I assign the Gosport to Zone NP 17 on the basis of the presence of *Discoaster saipanensis* and the absence of *Chiasmolithus solitus* and *Neococcolithes dubius*. Rare specimens of *Helicosphaera seminulum* are present in the Gosport at Little Stave Creek. Haq (1973) reported this species as ranging only up to Zone NP 16. These specimens are therefore either reworked, or the stratigraphic range of *H. seminulum* should be extended.

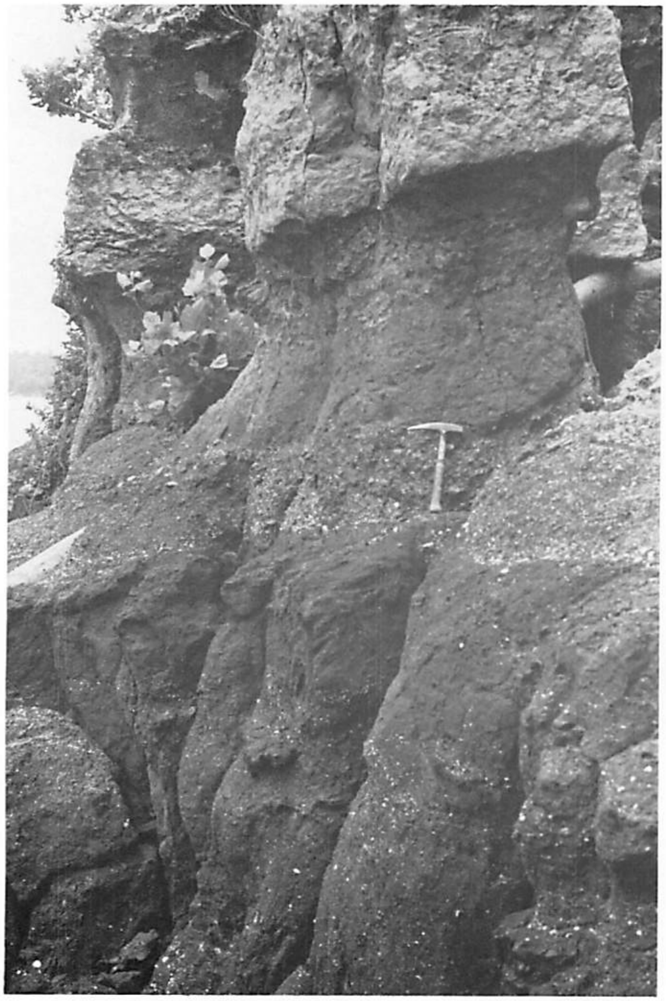


Figure 23. Gosport Sand underlying Moodys Branch Fm. End of hammer handle at base of shell bed marks the contact between the two formations. St. Stephens Bluff on the Tombigbee River, Washington Co., AL.

TABLE 8

GOSPORT SAND

A23f	A27	LOCALITY
F	R	ABUNDANCE
G	P	PRESERVATION
R		D. barbadiensis
F		B. bigelowii
R		Z. bijugatus
R		D. binodosus
R		P. basquense crassum
R		R. daviesi
R		D. elegans
F	R	C. floridanus
R		L. minutus
R		S. moriformis
R		P. multipora s.l.
R		D. nodifer
R		T. obliquipons
R		C. pelagicus
R		D. saipanensis
R		H. seminulum
V		L. simplex
R	R	B. spinosus
R		B. tenuis
R	R	R. umbilica

Moodys Branch Formation
Lithostratigraphy

Meyer (1885) named this formation for exposures near Jackson, Mississippi. The Moodys Branch consists of up to 48 feet of glauconitic, calcareous clayey sand with minor limestones, and extends eastward into and across Alabama with much the same lithology (Copeland, 1968; Toulmin, 1977). The upper part of the Moodys Branch is generally less glauconitic and more calcareous and clayey than the lower part. The Moodys Branch disconformably overlies the Gosport (Fig. 23) and Cockfield formations (Copeland, 1968; Moore, 1975).

Biostratigraphy

No previous reports on calcareous nannoplankton from the Moodys Branch Formation have been published. Calcareous nannoplankton I found in this formation are listed in Table 9 and illustrated in Fig. 25. All samples collected from the Moodys Branch lack *Chiasmolithus solitus* and *C. oamaruensis*, suggesting a zonal assignment to NP 17 (Martini, 1971). This assignment was confirmed by investigation of 35 closely spaced samples collected from the Moodys Branch, Yazoo, Red Bluff and Marianna formations at Little Stave Creek (Locality A23) by R.W. Pierce, Amoco Production Company. Amoco kindly allowed me to study these samples; distribution and abundance of species and other information on this section will be presented elsewhere (Siesser, Pierce and Govean, in prep.). Results indicate that the Moodys Branch at Little Stave Creek is in Zone NP 17, based on the presence of *Helicosphaera compacta* and *Discoaster tani* (both first appear in NP 17) and the absence of *Chiasmolithus solitus* (last appearance in NP 16) and *C. oamaruensis* (first appearance in NP 18) (Martini, 1971; Bukry, 1973b; Haq, 1973).

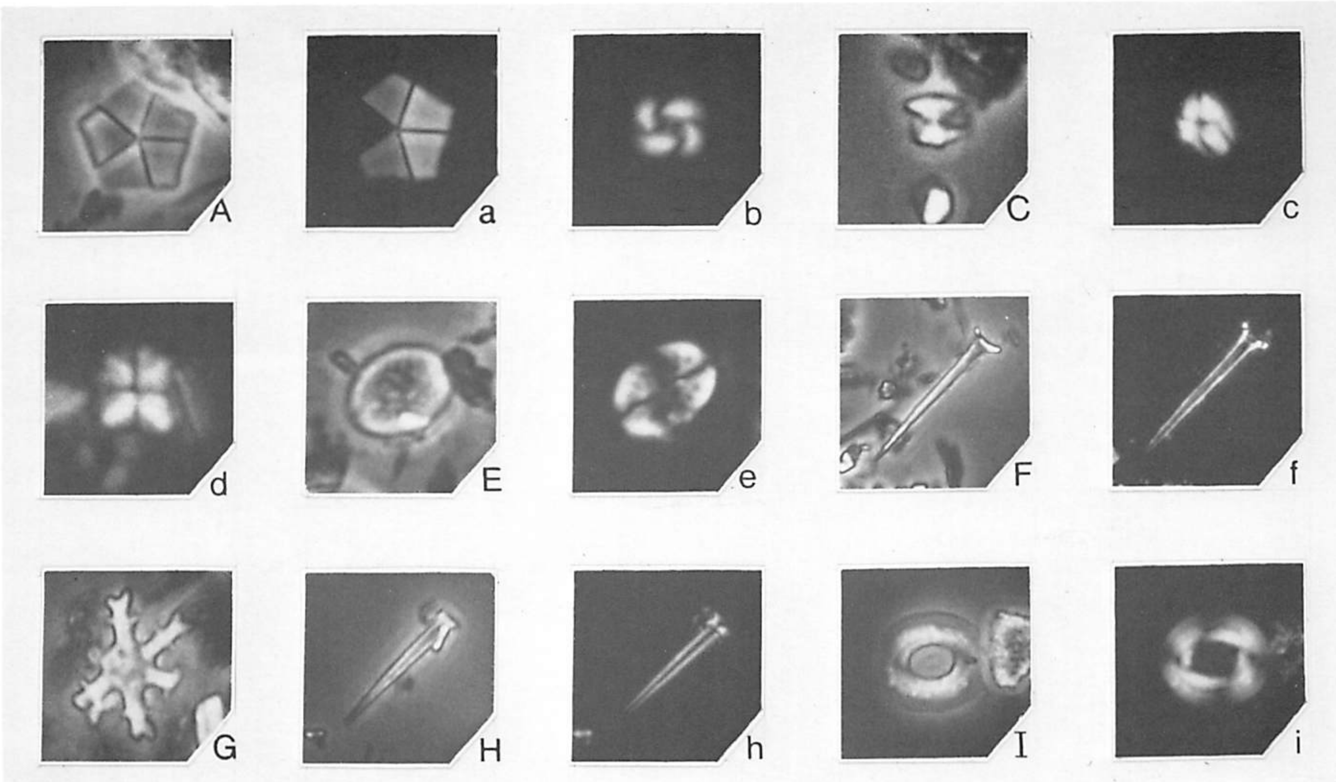


Figure 24. Calcareous nannoplankton in the Gosport Sand. Designations as in Figure 7. A,a, **Braarudosphaera bigelowii** (A23f); b, **Reticulofenestra daviesi** (A23f); C,c, **Lanternithus minutus** (A23f); d, **Sphenolithus moriformis** (A23f); E,e, **Pontosphaera multipora** s.l. (A23f); F,f, **Blackites spinosus** (A23f); G, **Discoaster nodifer** (A23f); H,h, **Blackites tenuis** (A23f); I,i, **Reticulofenestra umbilica** (A23f). Approximate magnifications: 1000X, except I,i (800X).

TABLE 9

MOODYS BRANCH FORMATION

A23g	A23h	A27b	A28	A29a	A29b	A29c	A30	A31	A32	M4a	LOCALITY
C	C	A	F	C	C	C	C	F	C	C	ABUNDANCE
P	M	M	P	M	M	M	M	P	G	M	PRESERVATION
R		F			R	R			R	R	D. barbadiensis
R		R						R	F	F	B. bigelowii
R		C		C	C	C	R	F	C	F	Z. bijugatus
R		R		F	F	C	R	F	R	F	D. bisectus
				R							H. bramlettei
		R		V	R	R			R	R	R. dictyoda
		R									P. basquense crassum
						R					T. deflandrei
		R							F		D. elegans
R		R	R	R	R	R	R	R	R	R	C. eopelagicus
V		R		V			V		V		H. euphratis
F	C	C	F	C	C	C	C	F	C	R	C. floridanus
F		F		F	F	F	C	R	F	R	C. formosus
									R		C. germanicus
			R	R	R	R					T. heimi
		R			R				V	R	M. inversus
V		R		R	R	F		R	R	R	C. kingi
										R	D. levini
		R			R		R		R		C. luminis
					F	F			F	R	L. minutus
R		F		F	F	R		R	R		S. moriformis
		R		R	R	R	R	R	R		P. multipora s.l.
						R					S. labrosa
		R			R	R	R	R	F	R	T. obliquipons
		V									P. papillatum
R		F	R	F	F	F	R	R	F	F	C. pelagicus
									R		H. reticulata
R				F	C	R	R		V	R	R. reticulata
R		F		R	R	F	R		C	R	D. saipanensis
										V	T. saxea
									R	V	L. simplex
									V		H. cf. H. situliformis
R		R		R	F	F			R	R	B. spinosus
R		R		R	R	R			F	R	D. tani
		R			F	R				R	B. tenuis
					R		R		R	R	R. umbilica
					R	R					P. versa

Yazoo Formation and Crystal River Formation
Lithostratigraphy

The Yazoo Formation was named by Lowe (1915) for exposures on the Yazoo River near Yazoo City, Mississippi. At its type locality, the Yazoo consists of about 450 feet of greenish, massive, calcareous clay (Toulmin, 1977). The formation thins eastward, to about 100 feet in southeastern Alabama, and eventually grades into the Crystal River Formation (Ocala Group) in eastern Alabama (Huddlestun and Toulmin, 1965). The Yazoo is divisible into four members. From oldest to youngest these are: the North Twistwood Creek Clay Member, chiefly a micaceous, calcareous sandy clay (Fig. 26); the Cocoa Sand Member, a massive calcareous sand; the Pachuta Marl Member, a glauconitic, clayey, very fossiliferous limestone and chalky marl (Fig. 27); and the Shubuta Member, a mostly massive, calcareous clay, containing small calcareous nodules (Toulmin, 1977) (Fig. 27). The Yazoo conformably overlies the Moodys Branch (Moore, 1975; Toulmin, 1977).

The Crystal River Formation was established in publications by Moore (1955) and Puri (1957) based on exposures in Citrus County, Florida. The formation consists mostly of a white, chalky, very fossiliferous (often coquinoidal) limestone. The Crystal River is

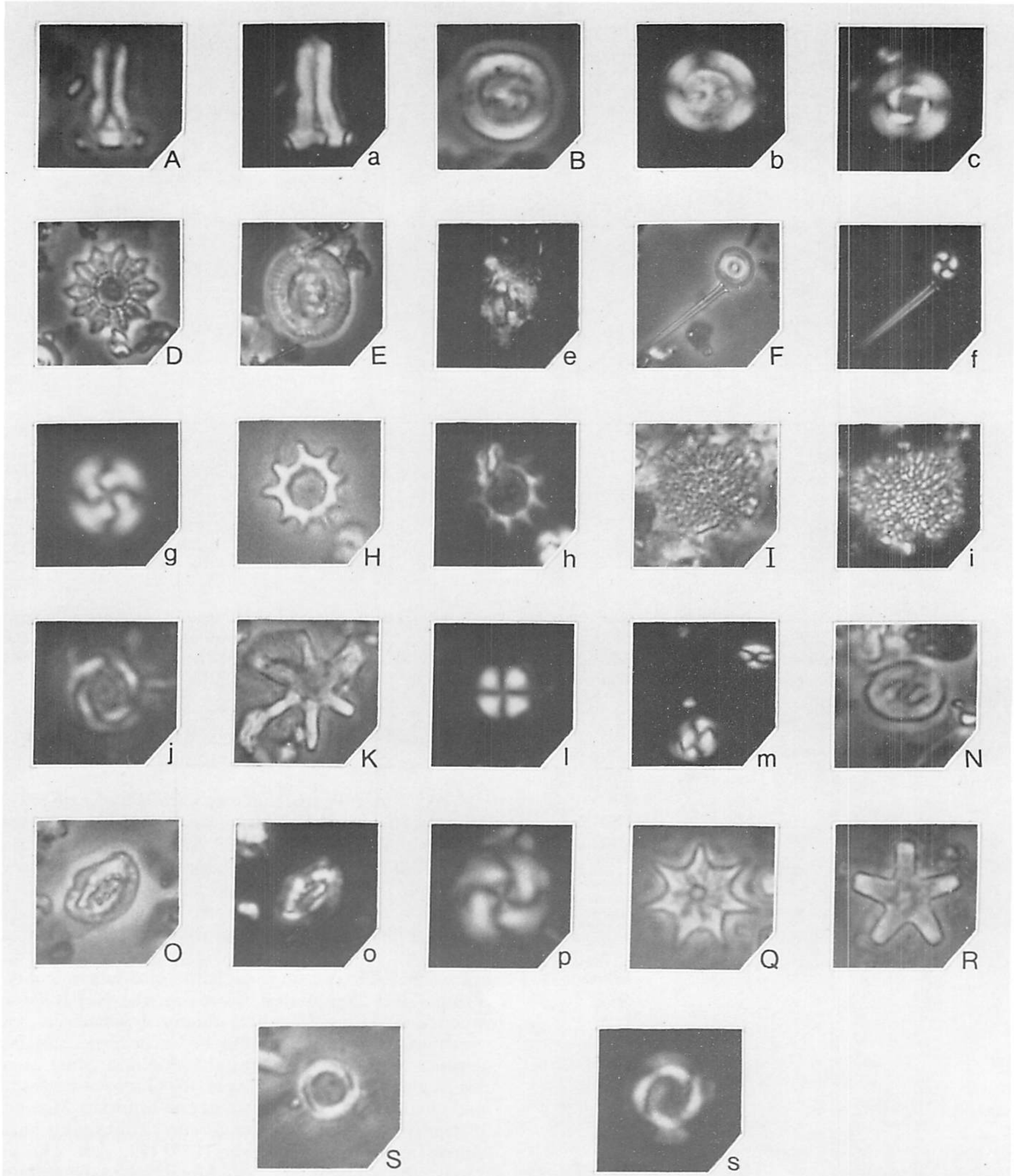


Figure 25. Calcareous nannoplankton in the Moodys Branch Fm. Designations as in Figure 7. A,a, **Zygrhablithus bijugatus** (A29c); B,b, **Dictyococcites bisectus** (A29c); c, **Reticulofenestra dictyoda** (M4a); D, **Discoaster elegans** (A32); E,e, **Coccolithus eopelagicus** (A27b); F,f, **Cyclococcolithus formosus** (upper) and **Blackites spinosus** (lower)(A29c); g, **Cyclicargolithus floridanus** (A27b); H,h, **Corannulus germanicus** (A32); I,i, **Thoracosphaera heimi** (A29b); j, **Cyclococcolithus kingi** (A29c); K, **Discoaster levini** (M4a); l, **Cyclococcolithus luminis** (A29b); m, **Lanternithus minutus** (upper) and **Coccolithus pelagicus** (lower) (A29b); N, **Transversopontis obliquipons** (A32); O,o, **Helicosphaera reticulata** (A32); p, **Reticulofenestra reticulata** (A29b); Q, **Discoaster saipanensis** (A32); R, **Discoaster tani** (A32); S,s, **Hayella** cf. **H. situliformis** (A32). Approximate magnifications: 1000X, except F,f,m (700X).

Figure 26. North Twistwood Creek Clay Mbr. of Yazoo Fm. Choctaw Co., AL.

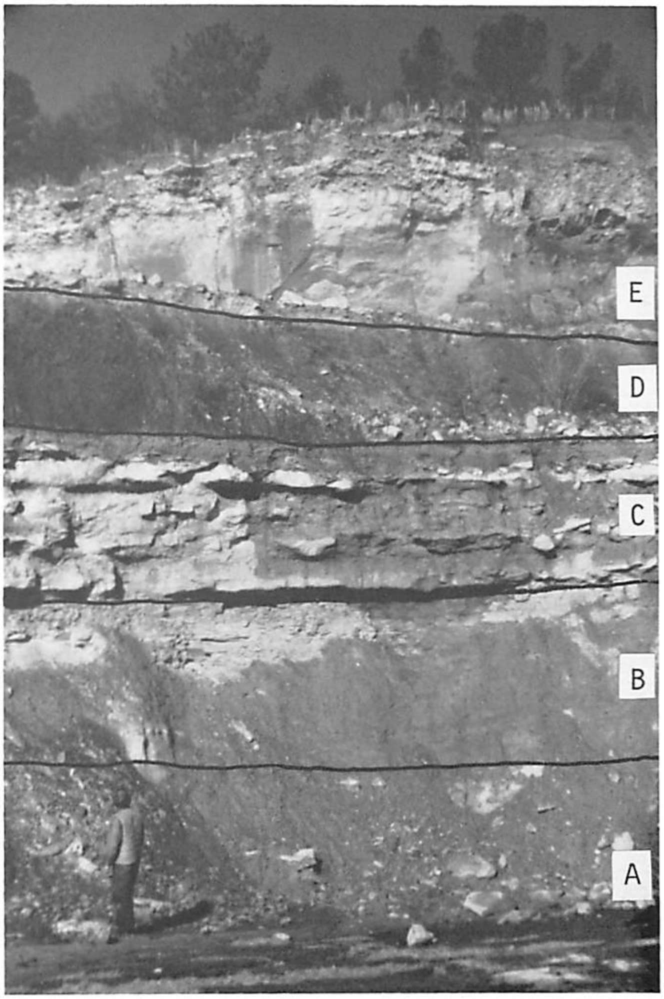


Figure 27. Pachuta Marl Mbr. of Yazoo Fm. (A); Shubuta Clay Mbr. of Yazoo Fm. (B); Red Bluff Fm., carbonate facies (Bumpnose Limestone equivalent) (C); Red Bluff Fm., shale facies (D); and Marianna Limestone (E). Ink lines mark approximate contacts. Quarry at St. Stephens, Washington Co., AL.

about 108 feet thick at the type locality, but the thickness varies considerably from place to place because the top of the formation was extensively eroded at the end of the Eocene and again in the Neogene (Toulmin, 1977). The name 'Ocala Limestone', sometimes used in Alabama for this formation, has been dropped (Toulmin, 1977).

Biostratigraphy

Abundant and diverse calcareous nannoplankton assemblages in the Yazoo Clay have understandably made this one of the most studied formations for calcareous nannoplankton in the eastern Gulf Coastal Plain. Levin (1965), Levin and Joerger (1967), Hay et al. (1967), Gartner and Smith (1967), Gartner (1969; 1970), Gartner and Bukry (1969), Bukry and Bramlette (1969), Bukry and Percival (1971) and Bybell (1982) all provided lists of calcareous nannoplankton and/or named new nannoplankton species from the Yazoo.

Levin and Joerger (1967) made the first zonal assignment of the Yazoo, based on sections at Little Stave Creek (Locality A23) and St. Stephens quarry (Locality A27) (Fig. 2). They assigned the Cocoa Sand, Pachuta Marl and Shubuta members to their 'Bio Unit I'. Hay et al. (1967) assigned these three members to their *Isthmolithus recurvus* Zone (Fig. 3). Bybell (1982) assigned the Pachuta Marl to NP 20 and NP 21. Waters and Mancini (1982) used planktic foraminifers to assign the Pachuta and Shubuta members and the Crystal River Formation to the *Globorotalia cerroazulensis* s.l. Zone of Stainforth et al. (1975). This zone corresponds to the upper part of Martini's (1971) NP 19, all of NP 20 and the lower part of NP 21.

The distribution of calcareous nannoplankton I found in this study is given in Table 10; important species are illustrated in Figs. 28 and 29. Calcareous

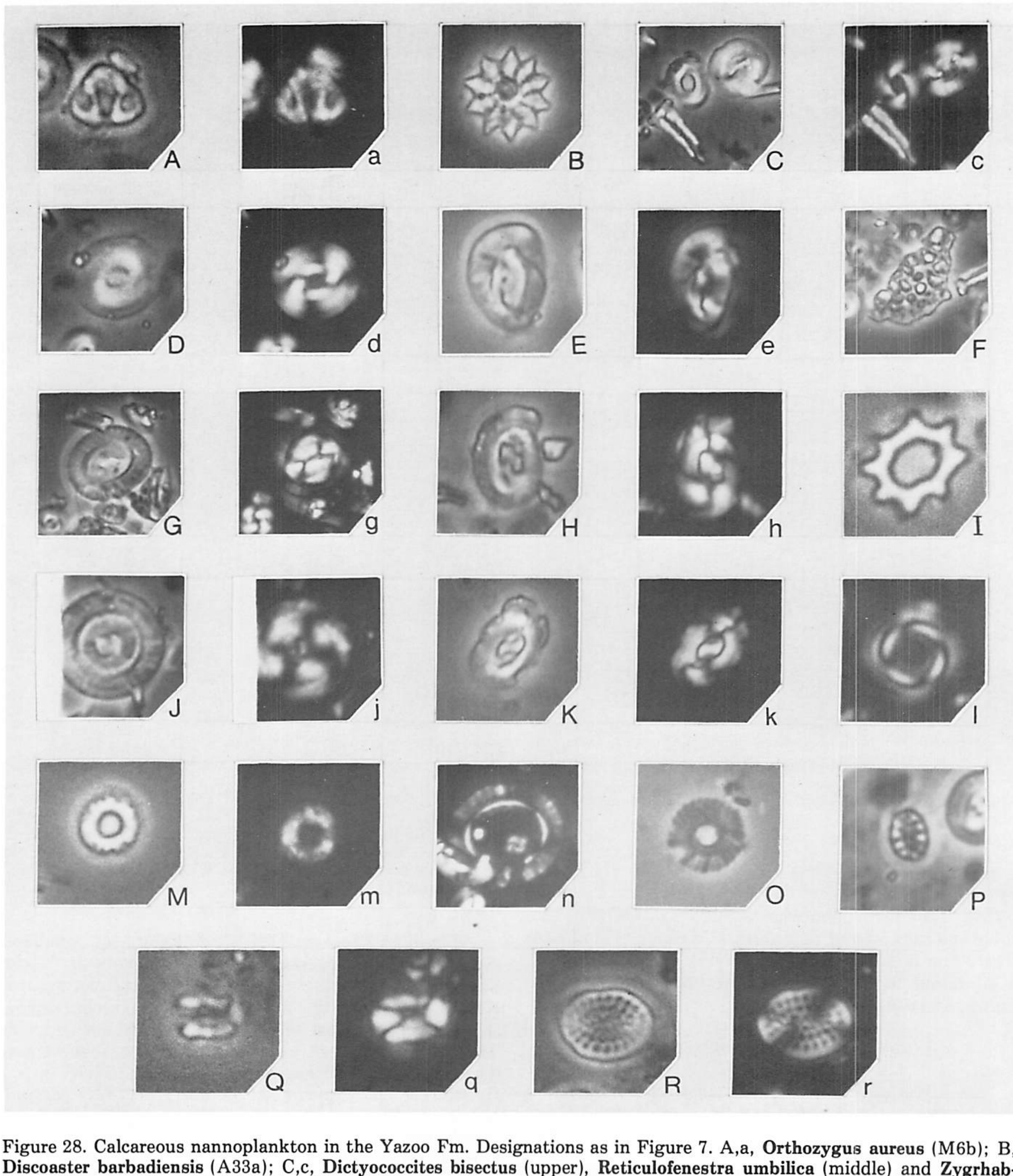


Figure 28. Calcareous nannoplankton in the Yazoo Fm. Designations as in Figure 7. A,a, **Orthozygus aureus** (M6b); B, **Discoaster barbadiensis** (A33a); C,c, **Dictyococcites bisectus** (upper), **Reticulofenestra umbilica** (middle) and **Zygrhablithus bijugatus** (lower) (M4b); D,d, **Reticulofenestra dictyoda** (M11); E,e, **Helicosphaera compacta** (A27d); F, **Clathrolithus ellipticus** (M4b); G,g, **Coccolithus eopelagicus** (middle) and **Cyclicargolithus floridanus** (lower left) (A41); H,h, **Helicosphaera euphratis** (A36a); I, **Corannulus germanicus** (M4b); J,j, **Cyclococcolithus formosus** (M6c); K,k, **Helicosphaera intermedia** (A27d); l, **Cyclococcolithus kingi** (A40); M,m, **Cyclolithella kariana** (A33b); n, **Syracosphaera labrosa** (M12); O, **Pedinocyclus larvalis** (A27d); P, **Holodiscolithus macroporus** (M4b); Q,q, **Lanternithus minutus** (A35); R,r, **Pontosphaera multipora** s.l. (M6d). Approximate magnifications: 1000X, except I, P (1600X), F,Q,q (1200X) and C,c (700X).

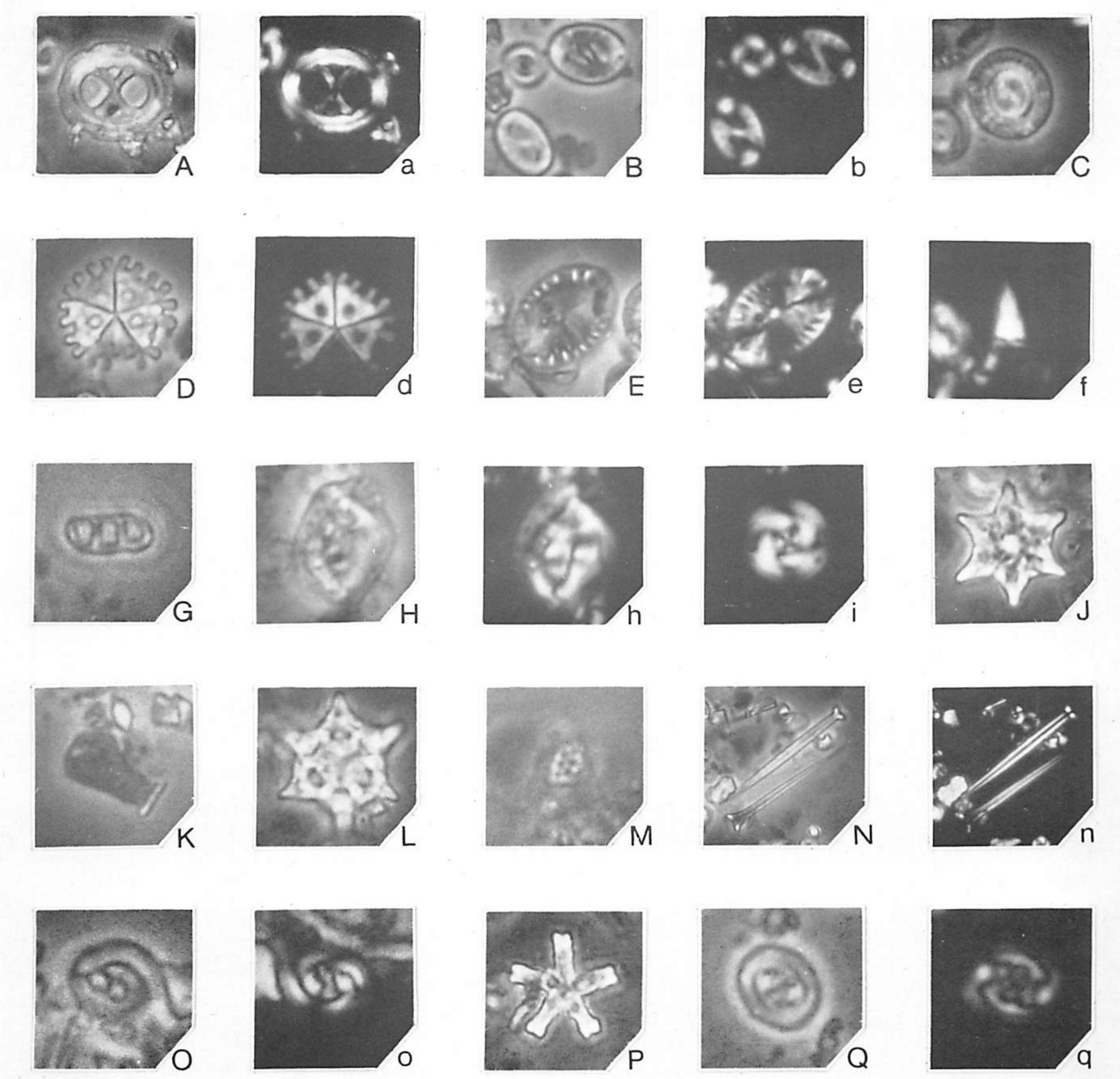


Figure 29. Calcareous nannoplankton in the Yazoo Fm. (Cont.). Designations as in Figure 7. A,a, **Chiasmolithus oamaruensis** (M4b); B,b, **Transversopontis obliquipons** (upper and lower)(A27d); C, **Coccolithus pelagicus** (A33a); D,d, **Pemma papillatum** (A40); E,e, **Pontosphaera pectinata** (M4b); f, **Sphenolithus predistentus** (M6b); G, **Isthmolithus recurvus** (M12); H,h, **Helicosphaera reticulata** (A40); i, **Reticulofenestra reticulata** (M4b); J, **Discoaster saipanensis** (A23l); K, **Bramletteius serraculoides** (M4b); L, **Lithostromation simplex** (A23l); M, **Holodiscolithus solidus** (M6b); N,n, **Blackites spinosus** (lower) and **Blackites tenuis** (upper)(A27d); O,o, **Ericsonia subdisticha** (M12); P, **Discoaster tani** (M6d); Q,q, **Chiasmolithus titus** (A40). Approximate magnifications: 1000X, except O,o (1600X), Q,q (1200X) and B,b,N,n (700X).

TABLE 10

YAZOO CLAY

"Lower Yazoo"		North Twistwood Creek Member						Cocoa Sand Member		Pachuta Marl Member																Shubuta Member						
M4b	M13	A23i	A33a	A33b	A34	A35	A36a	A23j	A36b	A23k	A27c	A36c	A36d	A39a	A39b	M6a	M6b	M6c	M6d	M6e	M7	M8	M9	M10	M11	A231	A27d	A40	A41	M6f	M12	LOCALITY
A	A	R	C	C	C	A	C	C	C	C	F	C	C	A	A	C	A	A	A	C	C	C	A	C	A	A	A	A	C	A	A	ABUNDANCE
G	M	P	M	M	M	G	M	M	M	M	P	P	M	M	P	P	G	G	M	M	M	M	G	P	G	G	G	G	G	M	G	PRESERVATION
																			R											V		C. altus
R																	R		R													O. aureus
F	F		C	R		F		F	R	R				F			F	F	R				R					R	F			D. barbadiensis
R			R		F				V									R	F								F	F	F	F	R	B. bigelowii
A	F		F	R	F	C			R	C		F		F			F	F	F				F		F	C	F		F	R		Z. bijugatus
			R																													D. binodosus
F			R	R	R	F	R	R	F	R	R	R	R	F	F	F	F	F		F	F			F	F	R	F	F	F	F	F	D. bisectus
R	F		R	R	R		R		R				R	F		F							F		F	F					F	R. dictyoda
R									R	R							F	F	C				R				C		R		F	H. compacta
																										V						B. creber
R																R													R	R	R	R. daviesi
R		R	R	V		R				R							R		R							R	F			R		D. deflandrei
								R																								T. deflandrei
					R			R																		F						D. elegans
	R					R	R					R	R	R				R				R	R			R		R	R			C. eopelagicus
R			R				F	R									R	R									F	R	R			H. euphratis
C	C	R	F	C	C	C	C	F	C	C	F	C	C	C	C	C	C	C	C	C	F	C	C	C	C	F	A	C	C	C	C	C. floridanus
C			C	F	F	F	R	F	C	F	R	R	C	C	F	F	C	A	A	C	F	F	F	F	F	F	R	C	F	C	F	C. formosus
R			V			R				R							R	R										V				C. germanicus
R			R																													M. inaequalis
	R		F	F				R		R	R			R					R							R	F					H. intermedia
			V				R	R																		V			R			M. inversus
																											R			R		P. joidesa
				V																												C. kariana
R			R	R		R			R		R		R	R			R	R	R		R				R			R				C. kingi
																	V	R	R				R				F	V			R	P. larvalis
R																																D. levini
			V																													C. luminis
F														R					R								R					H. macroporus
R								R		R																R						C. ellipticus
			R			F		R		R																R		R	R		V	L. minutus
R	R		R	R	R	R		R		R			R				R	R			R	R				R	F	R				S. moriformis
F	R			R	F	F		R	R	F				F			F	F	C							F	C	R	F		F	P. multipora s.l.
R					R	F				R																R		R	R			D. nodifer
R																	R											R		R	R	C. oamaruensis
R	R					R											R			R							R	F		R	F	S. labrosa
F				V	R	F	R	F	R	F	R			R				F	R	R		F					F	R				T. obliquipons
													R														R					T. cf. T.operculata
V					R																											L. operosum
R			V	R										R														R	R			P. papillatum
F																																P. pectinata
R			C	F	R		F	F	F	F	F						R									F	C	F			R	C. pelagicus
V																																L. perdurum
			R																													P. plana
																	V															S. predistentus
				V													R															M. procerus
V																																T. pulcher
										R				R				R	F								F	F		F	F	I. recurvus
R			R														R		R								F	F		F	R	H. reticulata
C	F		F	F	R	C	R	F	R		R		F	R		F		R				F	C			F						R. reticulata
C	F		R	R	R	F	R	R	R	R			R				F	F	R				R	F	R	C	V		R	V		D. saipanensis
F					R				R	R			R	R			R		R							F	F			R	R	T. saxea
R														R	R									R						R		D. segmenta
C									R								R	R	F	R			R					F		R	R	B. serraculoides
V			V	R																						R	R					L. simplex
F	F		R				F	R		R	R		R	R	F	R	R	F	R	R		R	R	R		R	C	F		R	F	B. spinosus
			R														R															H. solidus
																	R															S. stellatus
F									V	R				R	R		R	R	F	R			R		R	R	F	R		R	C	E. subdisticha
F			F	R	F	R		R		R				R			R	R	F							R	R	R			R	D. tani
	R		F			F			F					F			R				F		R		R	R	C	F			F	B. tenuis
R																		V	R									R				C. titus
C	F		F	R				R	F		R		R	F			F	F	F	F	F	F	C		F	F	F	C	F	F	F	R. umbilica
F																	R		R												R	P. versa
			V											R																		R. vitrea
																	R															H. wilcoxonii
																			R													Micrantholithus sp. A

nannoplankton in the North Twistwood Creek Clay Member of the Yazoo have never been reported separately before. As with the underlying Moodys Branch, this member contains *Discoaster tani* and *Helicosphaera compacta,* but lacks *Chiasmolithus oamaruensis* and is therefore assigned to NP 17. *C. oamaruensis* makes its first appearance (indicating Zone NP 18) in the lowermost part of the Cocoa Sand Member in the Amoco Little Stave Creek samples. The NP 17 - NP 18 boundary thus falls within the Cocoa Sand at Little Stave Creek, as does the NP 18 - NP 19 boundary, based on the first appearance of *Isthmolithus recurvus* near the top of the member (Siesser, Pierce and Govean, in prep.) In central Mississippi, the Yazoo is undifferentiated. Samply M4b represents the lower part of the Yazoo (Dockery, pers. communic.). This sample is very well preserved, and is assigned to Zone NP 18 on the basis of the presence of *Chiasmolithus oamaruensis* and the absence of *Isthmolithus recurvus* (first appearance at the base of NP 19) (Martini, 1971).

Isthmolithus recurvus occurs in the Pachuta Marl Member at numerous sample localities in Alabama and Mississippi (Table 10). *Sphenolithus pseudoradians* is extremely rare throughout the eastern Gulf Coastal Plain, and cannot be used to define the NP 19-NP 20 boundary as established by Martini

(1971). Therefore I assign the Pachuta Marl and the lower part of the Shubuta to undifferentiated NP 19/20. Some Shubuta samples may, however, be restricted to NP 20. *Peritrachelina joidesa* is rare, but present in the Shubuta Member at St. Stephens quarry and at Locality M6 in Mississippi. The range of this species is not well documented in the literature, but I found its first appearance in NP 20 in the Joides J-3 core from the Blake plateau (unpublished data). The co-occurrence of *P. joidesa* and *D. saipanensis* at Locality M6 suggests an assignment to Zone NP 20. The Shubuta Member passes into Zone NP 21 in the Amoco Little Stave Creek section, based on the continued presence of *Cyclococcolithus formosus* and the last occurrence of *Discoaster saipanensis* and *D. barbadiensis*. These last species are missing from the Shubuta in Mississippi at Locality M12, suggesting the locality may also be NP 21.

No previous workers have reported calcareous nannoplankton from the Crystal River Formation. Table 11 shows the distribution and abundance of calcareous nannoplankton found during this study; species are illustrated in Fig. 30. The co-occurrence of *I. recurvus* and *D. saipanensis* indicates Zone NP 19/20, but the absence of *Sphenolithus pseudoradians* again precludes separating these two zones.

Red Bluff Formation, Forest Hill Formation, and Bumpnose Limestone

Lithostratigraphy

Hilgard (1860) named the Red Bluff Formation from exposures at Red Bluff on the Chickasawhay River, near Shubuta, Mississippi. The formation extends from western Alabama into Mississippi, thickening to the west. In Alabama the Red Bluff consists of up to 60 feet of glauconitic, fossiliferous limestone, overlain by glauconitic, calcareous clay and silty clay and sand (Copeland, 1968) (Fig. 27). The Red Bluff disconformably overlies the Yazoo Clay (Murray, 1961) and grades into the Forest Hill Formation in Mississippi and into the Bumpnose Limestone in eastern Alabama (Huddleston and Toulmin, 1965).

The Forest Hill Formation (Cooke, 1918) is named for exposures near Forest Hill, Mississippi. This formation consists of carbonaceous, sandy silts and clays, with lenses of glauconitic, fossiliferous sands and clays (Murray, 1961). The Forest Hill Sand is a regressive sequence that is in part equivalent to and in part overlies the Red Bluff Clay.

'Bumpnose Limestone' was first used by Moore (1955) for exposures in northwestern Florida. This formation consists of hard, fossiliferous limestone overlying the Crystal River Formation with marked disconformity (Huddlestun and Toulmin, 1965; Toulmin, 1977).

TABLE 11

CRYSTAL RIVER FORMATION

A37	A43	A44	LOCALITY
C	F	A	ABUNDANCE
P	P	M	PRESERVATION
		R	B. bigelowii
R		F	D. bisectus
		R	Z. bijugatus
		F	H. compacta
		R	D. deflandrei
		R	C. eopelagicus
C	F	C	C. floridanus
F	F	C	C. formosus
		R	C. kingi
		R	P. larvalis
		R	S. moriformis
		R	S. labrosa
		F	T. obliquipons
		R	C. pelagicus
		R	I. recurvus
R			R. reticulata
R		R	D. saipanensis
		R	T. saxea
		R	D. segmenta
		R	B. serraculoides
		R	B. spinosus
		R	E. subdisticha
		R	D. tani
		R	C. titus
		R	B. tenuis
F	F	F	R. umbilica
		R	Thoracosphaera sp.

Biostratigraphy

The Red Bluff Clay has been studied with almost the degree of attention given the Yazoo Clay. Levin and Joerger (1967), Bramlette and Wilcoxon (1967), Roth (1968; 1970), Gartner and Bukry (1969), Bukry and Percival (1971) and Bybell (1982) have all examined calcareous nannoplankton from the Red Bluff. Roth (1970) used the transmission electron microscope (TEM) in his study of the Red Bluff Clay and overlying Oligocene formations at St. Stephens quarry. A number of new species were erected by Roth (1970) on the basis of structural features seen with the TEM. I could not identify some of these species using the light microscope (LM) in the same formations at St. Stephens quarry or at other Oligocene sections in the area (compare Table 12, this paper, with Fig. 9 of

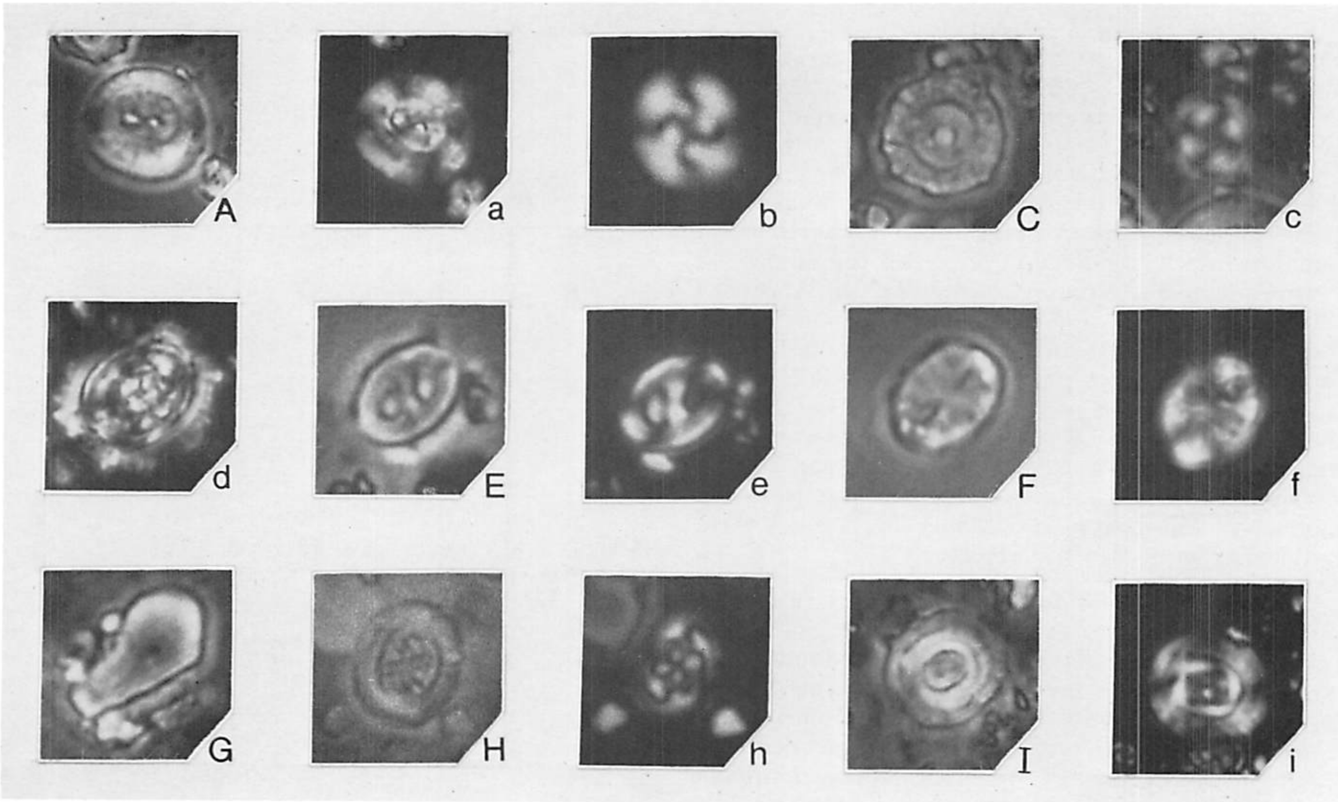


Figure 30. Calcareous nannoplankton in the Crystal River Fm. Designations as in Figure 7. A,a, **Dictyococcites bisectus** (A44); b, **Cyclicargolithus floridanus** (A37); C,c, **Cyclococcolithus formosus** (A44); d, **Syracosphaera labrosa** (A44); E,e, **Transversopontis obliquipons** (A44); F,f, **Discolithina segmenta** (A44); G, **Bramletteius serraculoides** (A44); H,h, **Chiasmolithus titus** (A44); I,i, **Reticulofenestra umbilica** (A37). Approximate magnifications: 1000X, except H,h (1200X) and A,a (800X).

Roth's (1970) paper; see also comments on biostratigraphy of the Marianna Limestone).

Levin and Joerger (1967) assigned the Red Bluff at Little Stave Creek and St. Stephens quarry to their Bio Unit II, as did Hay et al. (1967). Bramlette and Wilcoxon (1967) assigned the lowermost few feet of the Red Bluff to the *Isthmolithus recurvus* Zone, and the rest of the formation to the *Helicosphaera reticulata* Zone. Roth (1968; 1970) placed the Red Bluff in his *Ericsonia subdisticha* Zone, which he noted was correlatable with Levin and Joerger's (1967) Bio Unit II (Fig. 3). Bybell (1982) assigned the Red Bluff-Bumpnose to NP 21 at three localities in Alabama and one in Mississipi.

Table 12 shows the distribution of calcareous nannoplankton in the Forest Hill Sand, Red Bluff Clay and Bumpnose Limestone as determined in this study. Fig. 31 illustrates species from the Red Bluff.

The absence of *Discoaster saipanensis* as well as the secondary marker species *D. barbadiensis* and *Reticulofenestra reticulata*, and the persistence of *Cyclococcolithus formosus* (last appearance in NP 21) (Martini, 1971; Beckmann et al., 1981) indicate that the Red Bluff belongs to NP 21. Field relationships

TABLE 12

FOREST HILL SAND	BUMPNOSE LIMESTONE	RED BLUFF CLAY		
M5a	A38	A23m	A27e	LOCALITY
C	F	A	A	ABUNDANCE
M	P	G	M	PRESERVATION
C		R		B. bigelowii
C	R	C	C	Z. bijugatus
R		C	C	D. bisectus
		R		R. dictyoda
R		F		H. compacta
		R		R. daviesi
V		R		D. deflandrei
		R	R	T. deflandrei
C	F	A	C	C. floridanus
	R	R	R	C. formosus
F		C	F	H. intermedia
C		F		L. minutus
		R	F	S. moriformis
F		R	F	P. multipora s.l.
		R		D. nodifer
		R	R	S. labrosa
		F	F	T. obliquipons
	R	F	C	C. pelagicus
		R		R. perlonga
		R	F	P. plana
		R	F	H. reticulata
		R		B. rosa
R		C	C	B. spinosus
R		R	R	E. subdisticha
		R		D. tani
R		C	C	B. tenuis
R	R	C	F	R. umbilica
			R	M. vesper
		R	F	R. vitrea
			F	H. wilcoxonii
		F		Pontosphaera sp.
R		R		Micrantholithus sp. A

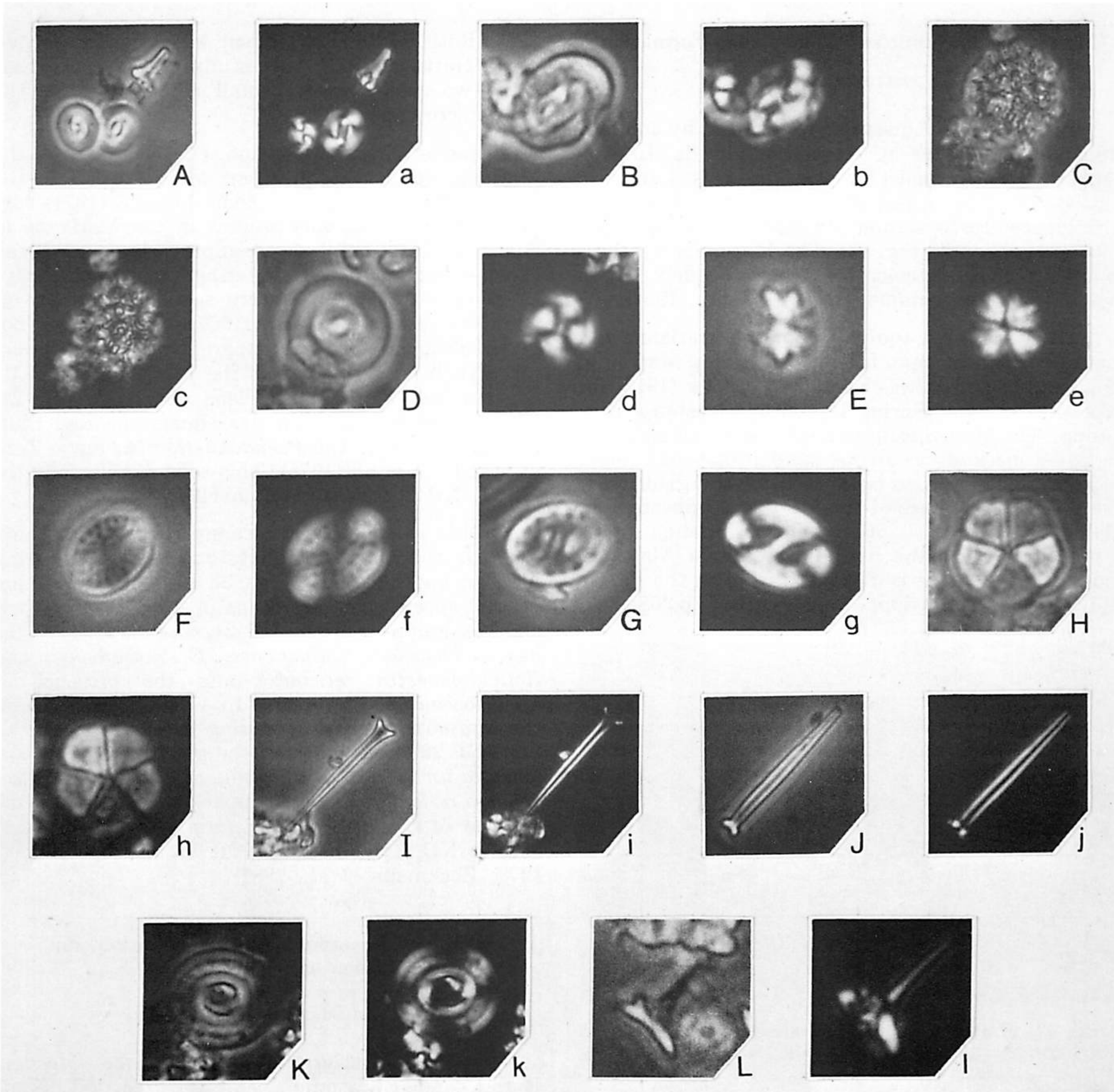


Figure 31. Calcareous nannoplankton in the Red Bluff Fm. Designations as in Figure 7. A,a, **Zygrhablithus bijugatus** (top), **Reticulofenestra dictyoda** (middle) and **Coccolithus pelagicus** (left)(A23m); B,b, **Helicosphaera compacta** (A23m); C,c, **Thoracosphaera deflandrei** (A23m); D,d, **Cyclococcolithus formosus** (A23m); E,e, **Sphenolithus moriformis** (A27e); F,f, **Pontosphaera multipora** s.l.(A27e); G,g, **Transversopontis obliquipons** (A23m); H,h, **Braarudosphaera rosa** (A23m); I,i, **Blackites spinosus** (A23m); J,j, **Blackites tenuis** (A23m); K,k, **Reticulofenestra umbilica** (A23m); L,l, **Rhabdosphaera vitrea** (A27e). Approximate magnifications: 1000X, except L,l (1200X) and A,a (700X).

(overlying the Crystal River Formation) and the presence of *C. formosus* also suggest NP 21 for the Bumpnose Limestone.

Sample M5a is from the upper part of the Forest Hill (Dockery, pers. communic.). This sample contains an assemblage similar to the Red Bluff, and is probably also NP 21. *C. formosus* is not present in this sample, but does occur in the Marianna Limestone overlying the Forest Hill at this locality.

Marianna Limestone and Mint Spring Formation

Lithostratigraphy

The Marianna Limestone was named by Johnson (1892) for exposures at Marianna, Florida. In Alabama and easternmost Mississippi this formation consists of 40 to 60 feet of chiefly chalky limestone, with glauconitic limestone and calcareous sand at the bottom of the unit (Fig. 27). The Marianna weathers to a white or cream-colored limestone, widely known in the region as 'chimney rock' (Murray, 1961).

The correlative equivalent of the Marianna farther west in Mississippi is the Mint Spring Marl (Fig. 32). This formation was named by Cooke (1918) for exposures at Mint Spring Bayou in Vicksburg, Mississippi. The Mint Spring consists mostly of glauconitic limestone and calcareous sand (Copeland, 1968). 'Mint Spring' has also been used for the glauconite-rich layers at the base of the Marianna Limestone in Alabama (Murray, 1961). The Marianna rests disconformably on the Red Bluff Clay in Alabama, and the Mint Spring is disconformable on the Forest Hill Sand in Mississippi (Murray, 1961, p.368).

Figure 32. Mint Spring Fm. Mississippi River bank at Vicksburg, Warren Co., MS. (Locality M15, MGS locality 107).

Biostratigraphy

Levin and Joerger (1967), Bramlette and Wilcoxon (1967), Bukry and Bramlette (1969), Roth (1968; 1970) and Bybell (1982) have described calcareous nannoplankton in the Marianna Limestone. Levin and Joerger (1967) and Hay et al. (1967) assigned the Marianna to Bio Unit III (Fig. 3). Roth (1968; 1970) assigned the lower 5 feet of the Marianna to the *Ericsonia subdisticha* Zone. *C. margaritae* in the Marianna Limestone and *Reticulofenestra laevis* in the overlying Glendon Limestone are important zonal markers in Roth's (1970) zonation of these formations at St. Stephens quarry. Both species were identified and described using the TEM (Hay et al., 1967; Roth, 1970). Subsequent workers (Roth et al., 1971; Gartner, 1971; this study) have found that these two species are too small to identify using the light microscope.

Bramlette and Wilcoxon (1967) assigned the Marianna (and the equivalent Mint Spring) to the *Sphenolithus predistentus* Zone. Martini (1971) suggested that NP 22 was present in the Marianna in Alabama. These studies were apparently based on calcareous nannoplankton in either the Little Stave Creek or St. Stephens quarry sections (locations of Bramlette and Wilcoxon's (1967) samples were not given, although some are apparently from Mississippi). Bybell (1982) assigned the Marianna at Little Stave Creek and St. Stephens quarry to NP 21. Waters and Mancini (1982) assigned the Red Bluff and Bumpnose to the *Pseudohastigerina micra* Zone of Stainforth et al. (1975). This zone correlates to the NP 21 - NP 22 Zones of Martini (1971).

Table 13 shows the calcareous nannoplankton I found in the Marianna Limestone and Mint Spring Marl during this study; Figs. 33 and 34 illustrate important species. The Marianna in Alabama and eastern Mississippi contains NP 21, as indicated by the lack of *Discoaster saipanensis*, *D. barbadiensis* and *Reticulofenestra reticulata* and the presence of *Cyclococcolithus formosus*. In western Mississippi, the Marianna and Mint Spring can be assigned to Zone NP 22 on the basis of the presence of *Reticulofenestra umbilica*, *Lanternithus minutus* and *Helicosphaera reticulata* (all last appear in NP 22) and the absence of *Cyclococcolithus formosus* (last appearance in NP 21) (Martini, 1971; Haq, 1973; Müller, 1978; Beckmann et al., 1981).

Glendon Limestone, Byram Formation, and Bucatunna Formation

Lithostratigraphy

The lithostratigraphic rank of the Glendon, Byram and Bucatunna has been debated. Some authors (e.g., MacNeil, 1944; Copeland, 1968) have favored using a single formation, the Byram, which would include three members. These members, in ascending order, would be the Glendon Limestone Member, an unnamed "marl" member, and the Bucatunna Clay Member. Other workers have preferred formational status for all three units, with the Byram Formation placed between the Glendon and Bucatunna. This approach seems to reflect the consensus today (e.g, Hazel et al., 1980; Dockery, 1980, 1982) and is the terminology followed in this paper.

The Glendon Limestone was named by Hopkins (1917) for exposures near Glendon in Clarke Co., Alabama. It is typically an irregularly indurated, coquinoidal and crystalline limestone. Well-developed

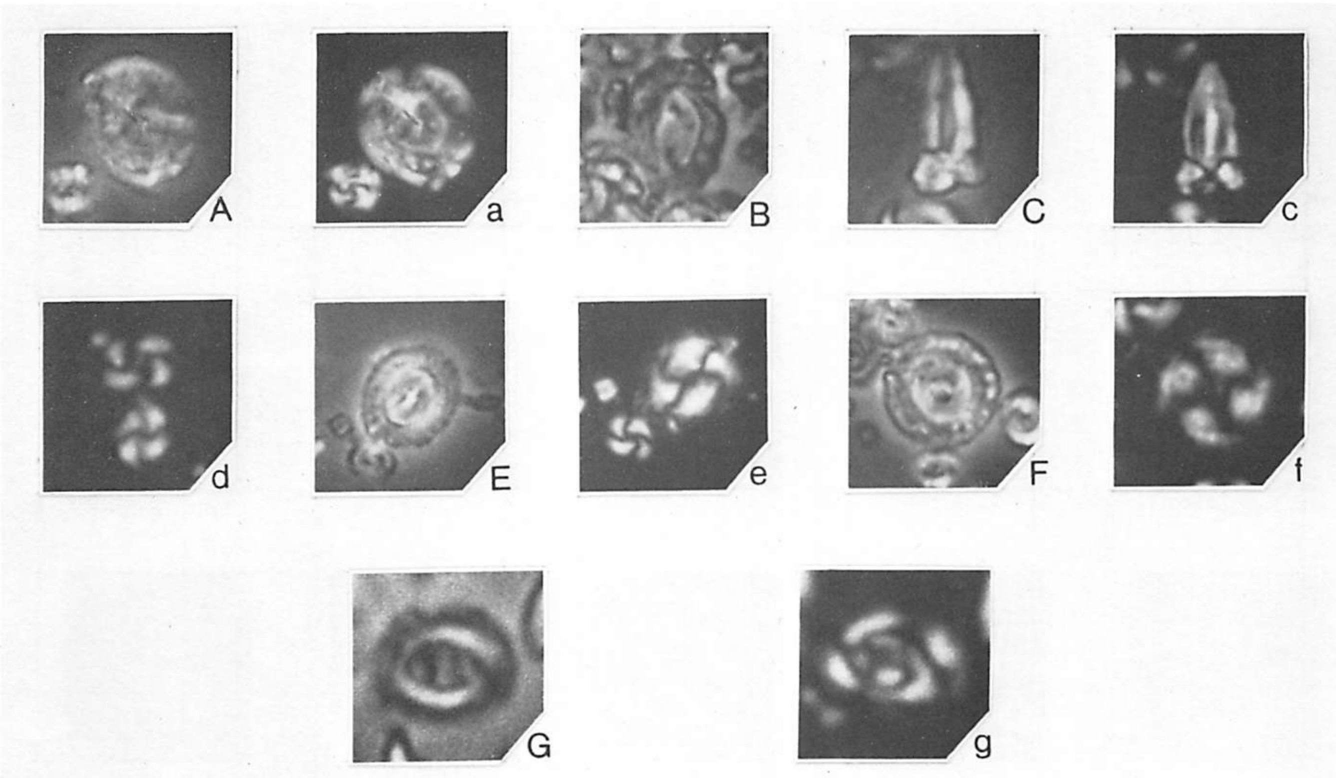


Figure 33. Calcareous nannoplankton in the Marianna Limestone. Designations as Fig. 7. A,a, **Dictyococcites bisectus** (A27f); B, **Helicosphaera compacta** (A27f); C,c, **Sphenolithus** cf. **S. distentus** (A27f); d, **Reticulofenestra daviesi** (upper) and **Cyclicargolithus floridanus** (lower)(A27f); E,e, **Coccolithus pelagicus** (upper) and **Cyclicargolithus floridanus** (lower)(A23n); F,f, **Cyclococcolithus formosus** (M5c); G,g, **Ericsonia subdisticha** (M5c). Approximate magnifications: 1000X, except G,g (1600X), C,c (1200X) and d (800X).

ledges interbedded with less-resistant zones are common (Fig. 35). The Glendon rests disconformably on the Marianna Limestone and is conformably overlain by the Byram Formation (Murray, 1961; Dockery, 1982).

The Bucatunna Formation was named by Blanpied (1934). The type locality is along Bucatunna Creek in Wayne County, Mississippi. The Bucatunna (Fig. 36) is typically a brown, bentonitic, carbonaceous clay (Copeland, 1968).

Biostratigraphy

Roth (1968; 1970) is the only other worker who has reported on calcareous nannoplankton from these formations. His study is based on the St. Stephens quarry section. Only one sample from the Byram contained calcareous nannoplankton suitable for zonation, and Roth (1970) assigned this sample to his *Reticulofenestra laevis* Zone (Fig. 3).

Table 14 lists the calcareous nannoplankton found in the Glendon Limestone, the Byram Formation and the Bucatunna Formation; species are shown in Fig. 37.

I found nannoplankton in the Bucatunna only at the St. Stephens quarry locality (A27) in Alabama. *Reticulofenestra hillae* is present in the Glendon and both *R. hillae* and *R. umbilica* are present in the Bucatunna. Both species last appear in Zone NP 22. The distinctive species *Lanternithus minutus* occurs throughout the three formations, and this species ranges only up to NP 22 (Martini, 1971; Beckmann et al., 1981). The presence of these species and the absence of *Cyclococcolithus formosus* indicates that all three formations are in Zone NP 22.

Chickasawhay Limestone

Lithostratigraphy

This formation was named for exposures along the Chickasawhay River, Wayne County, Mississippi (Blanpied, 1934). The Chickasawhay extends from Mississippi into Alabama and consists of up to 20 feet of soft, glauconitic marl and harder white limestone. A diagnostic and unusual fossil in the Chickasawhay is the large calcareous tube of the boring mollusc, *Kuphus incrassatus* (Copeland, 1968). The Chickasawhay disconformably overlies the Bucatunna Formation (Murray, 1961; Hazel et al., 1980) (Fig. 36).

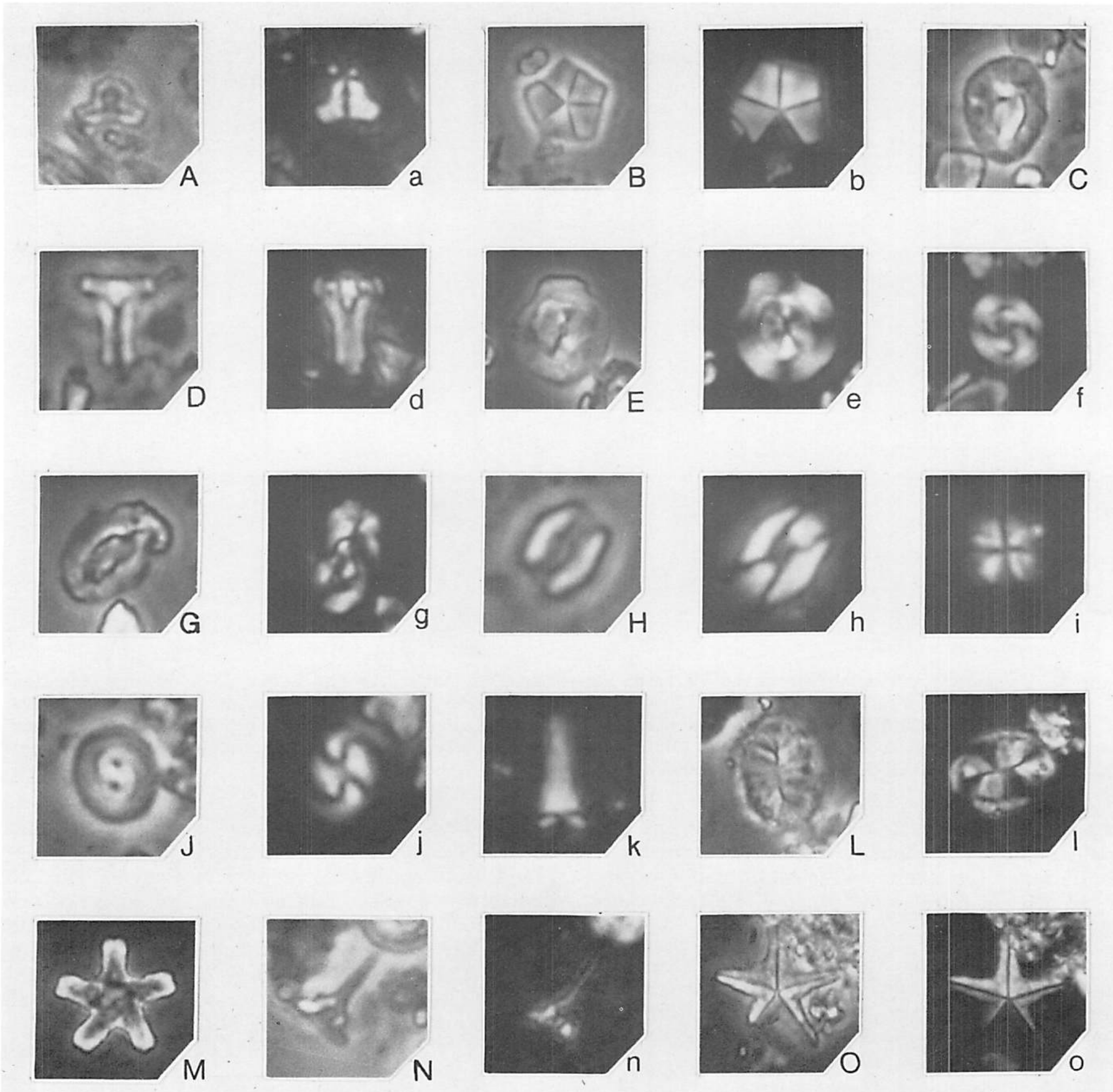


Figure 34. Calcareous nannoplankton in the Mint Spring Fm. Designations as in Figure 7. A,a, **Orthozygus aureus** (M16a); B,b, **Braarudosphaera bigelowii** (M16a); C, **Helicosphaera compacta** (M15a); D,d, **Zygrhablithus bijugatus** (M16a); E,e, **Dictyococcites bisectus** (M16a); f, **Cyclicargolithus floridanus** (M15a); G,g, **Helicosphaera intermedia** (M15a); H,h, **Lanternithus minutus** (M14); i, **Sphenolithus moriformis** (M16a); J,j, **Coccolithus pelagicus** (M15a); k, **Sphenolithus predistentus** (M16a); L,l, **Discolithina segmenta** (M15a); M, **Discoaster tani** (M15a); N,n, **Rhabdosphaera vitrea** (M16a); O,o, **Micrantholithus** sp. A (M16a). Approximate magnifications: 1000X, except H,h and k (1600X).

Biostratigraphy

Again, only Roth (1968; 1970) has previously reported on the calcareous nannoplankton from this formation. Roth (1968; 1970) listed calcareous nannoplankton from the section at St. Stephens quarry, and assigned the Chickasawhay to the *Sphenolithus distentus - Sphenolithus ciperoensis* Zone (Fig. 3).

The distribution and abundance of calcareous nannoplankton found in the Chickasawhay Limestone in this study are listed in Table 15; species are shown in Fig. 37. Nannoplankton assemblages are generally impoverished in this formation, but the co-occurrence of *S. distentus* (ranges from NP 23 to NP 24) and *S. ciperoensis* (first appearance in NP 24) (Martini, 1971; Beckmann et al., 1981) confirms an assignment to the

TABLE 13

MARIANNA LIMESTONE						MINT SPRING MARL			
A23n	A23o	A27f	M5b	M5c	M15b	M15a	M16a	M14	LOCALITY
C	C	A	C	A	C	C	C	F	ABUNDANCE
M	M	M	P	M	M	M	M	P	PRESERVATION
	V	V							C. altus
							F		O. aureus
					R	F	C		B. bigelowii
	F			F	R	R	F		Z. bijugatus
R	R	C		F	R	R	R		D. bisectus
		R							H. bramlettei
V									R. coenura
		R				F	R		H. compacta
		R		R			R		R. daviesi
	V								D. deflandrei
		V		R		R			T. deflandrei
R	R	R	R			R	R		C. eopelagicus
C	C	A	C	C	C	C	F	F	C. floridanus
R	R	R	F	F					C. formosus
							V		S. fossilis
	F	F				C	R		H. intermedia
							R		P. joidesa
R									C. luminis
			R				R	R	L. minutus
F		F		R		R	R		S. moriformis
				R				R	P. multipora s.l.
							V		D. nodifer
	V								C. oamaruensis
		V							S. labrosa
		F					R		P. pectinata
F	F	F			F	F	F		C. pelagicus
							R		S. predistentus
		V							S. pseudoradians
	F	F				F			H. reticulata
						R			D. segmenta
									H. solidus
	R	F	F				F		B. spinosus
	F	F	F	F	R	R	R		E. subdisticha
	R	R				R			D. tani
R	R	R		R	R	R	R		B. tenuis
V	F	F				R			R. umbilica
						R			M. vesper
		R	R	R			R		R. vitrea
		F							H. wilcoxonii
		V							S. cf. S. distentus
					R	R	R		Micrantholithus sp. A

TABLE 14

GLENDON LIMESTONE						BYRAM FORMATION		BUCATUNNA FORMATION	
A27g	M15c	M16b	M18a	M18b	M18c	M17	M19	A27h	LOCALITY
F	C	C	F	C	C	C	C	C	ABUNDANCE
M	M	G	M	M	M	G	M	M	PRESERVATION
		V					V		C. altus
R	R	R		F			F	R	B. bigelowii
	R	R		F		R	R	R	Z. bijugatus
R	R	V			R		R	R	D. bisectus
		R			R		R		R. daviesi
	R			R			R	R	D. deflandrei
	R	R	R		R	R		V	T. deflandrei
R	R	V		R	V				R. dictyoda
F	C	A	F	C	C	C	C	F	C. floridanus
R							R	R	R. hillae
	R	R		R			R	R	H. intermedia
				R					M. inversus
		R							C. kingi
R						R	R	R	C. luminis
	R	R		R		R	R		L. minutus
R	R	R		R	R		R	R	S. moriformis
	F	R		R	R	R	R	R	P. multipora s.l.
				R					D. nodifer
F	R	R		F	C		R	R	C. pelagicus
		R				R	R	R	S. predistentus
								R	T. saxea
								V	L. simplex
		V				V			H. solidus
		R		R		R	R		B. spinosus
		R			V	R	R		E. subdisticha
	R	R			R	R			B. tenuis
								R	R. umbilica
						R			R. vitrea
		F							T. zigzag
		V							Micrantholithus sp. A

TABLE 15

CHICKASAWHAY LIMESTONE			PAYNES HAMMOCK FORMATION			
A27i	A42a	A42b	M20a	M20b	M20c	LOCALITY
F	C	R	R	R	R	ABUNDANCE
M	M	M	P	P	P	PRESERVATION
	V					C. altus
R	F				S	B. bigelowii
	F	R				Z. bijugatus
R	R					D. bisectus
R						S. ciperoensis
	R					R. daviesi
	R					D. deflandrei
R	F	F	R			T. deflandrei
R				S	R	S. distentus
	V					C. eopelagicus
C	C	F	R	R	R	C. floridanus
	R					C. luminis
R	F					S. moriformis
R	F	R		S	R	C. pelagicus
	R					H. recta
R				R		T. saxea
					R	B. tenuis

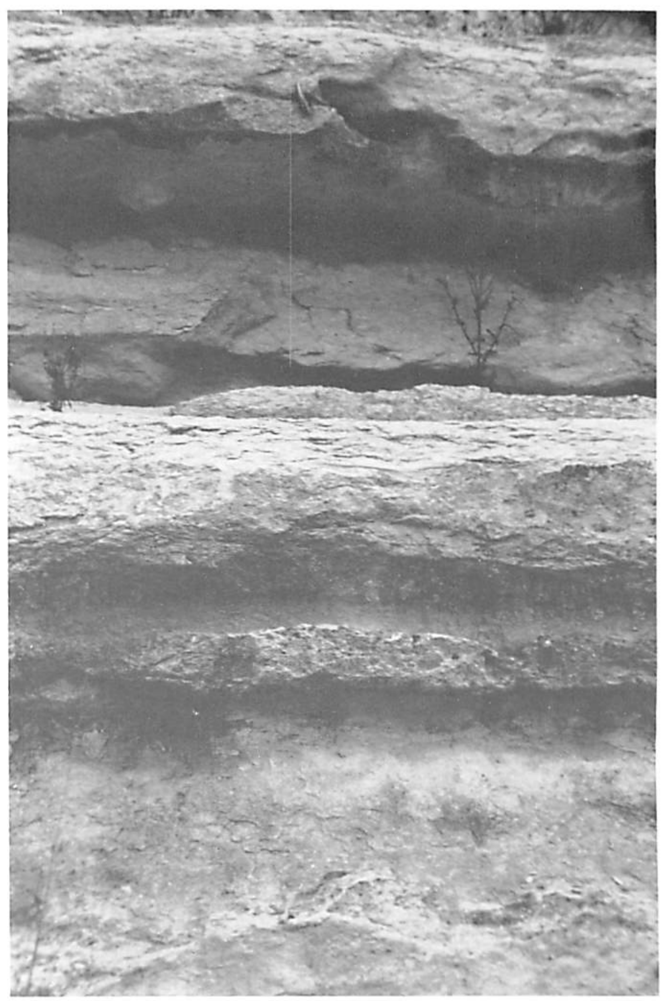


Figure 35. Glendon Limestone. Hammer in center of uppermost ledge for scale. Mississippi River bluff at Vicksburg, Warren Co., MS. (Locality M15, MGS locality 107).

Figure 36. Bucatunna Fm. overlain by Chickasawhay Limestone. Quarry at St. Stephens, Clarke Co., AL.

NP 24 Zone at the St. Stephens quarry (Locality A27) section.

I have not found NP 23 in the eastern Gulf Coastal Plain. The upper, non-fossiliferous facies of the Bucatunna may have been deposited during this interval, or NP 23 sediments may have been removed by erosion, evidence of which is seen in the disconformity separating the Bucatunna and Chickasawhay (Poag, 1975). A third possibility is that the lower part of the Chickasawhay may fall within NP 23. At Locality A42, the Chickasawhay Limestone lacks *S. distentus* and *S. ciperoensis* (which may be the result of diagenesis), but does contain *Helicosphaera recta*, a species reported by Martini (1971), Haq (1973) and Beckmann et al. (1981) as restricted to Zones NP 24 and NP 25. I have, however, seen specimens identical to *H. recta* in uppermost NP 22 (i.e., co-occurring with *Reticulofenestra umbilica*) in the Joides J-3 core, suggesting that *H. recta* occurs earlier than previously documented. If this is true, the Chickasawhay at Locality A42 may be NP 23.

Paynes Hammock Formation

Lithostratigraphy

MacNeil (1944) named this formation (originally called the Paynes Hammock Sand) for exposures near Paynes Hammock Landing on the Tombigbee River in Alabama. Prior to MacNeil's work, these rocks had been included in "the Upper Chickasawhay Member of the Catahoula Group" (Poag, 1975). The outcrop belt of the Paynes Hammock extends for approximately 100 miles from central Mississippi into southwestern Alabama, and consists mostly of clayey calcareous sands interbedded with clays and thin limestones; the formation is 12 feet thick at its type locality (Poag, 1975). The Paynes Hammock is locally disconformable over the Chickasawhay Limestone.

Biostratigraphy

There have been no previous reports on the calcareous nannoplankton from this formation. Most Paynes Hammock localities sampled during this study were barren of nannoplankton. Only locality M20 on the Chickasawhay River was found to contain an identifiable assemblage, although specimens are still rare and poorly preserved. Abundance and distribution of species found are listed in Table 15. The presence of rare *Sphenolithus distentus* (last occurrence at the top of NP 24) (Martini, 1971) indicates an age assignment not younger than NP 24. Since the Paynes Hammock overlies the Chickasawhay Limestone, which is assignable to NP 24 in Alabama, I assign the Paynes Hammock to NP 24 in this study. As discussed in a previous section, the Chickasawhay could, however, be NP 23 in part, and therefore part of the Paynes Hammock could also be NP 23.

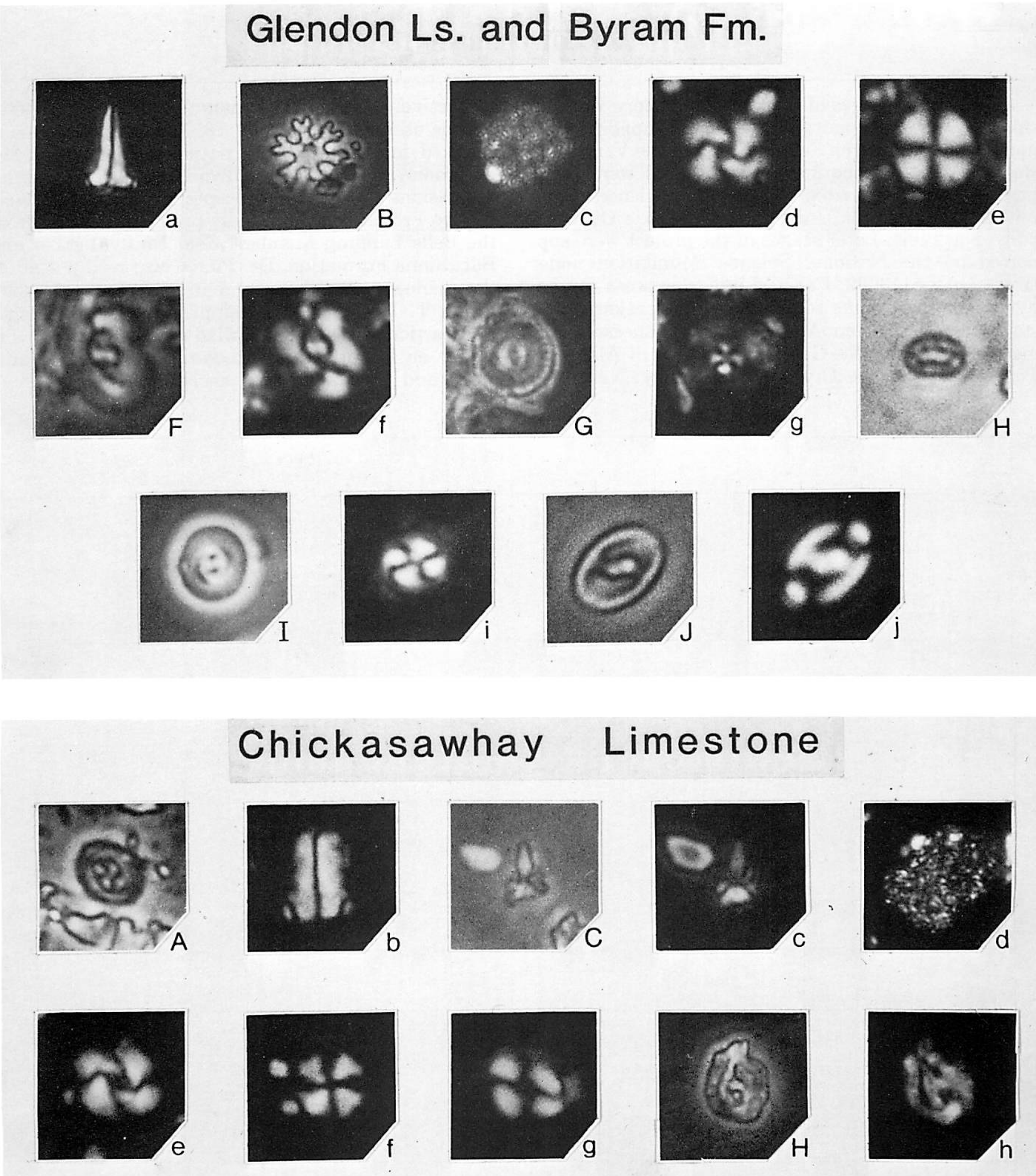


Figure 37. Calcareous nannoplankton in the Glendon Limestone, Byram Fm., and Chickasawhay Limestone. Designations as in Fig. 7. Glendon Ls. (c,e,F,f,G,g,I,i,J,j); Byram Fm. (a,B,d,H): a, **Zygrhablithus bijugatus** (M17); B, **Discoaster deflandrei** (M19); c, **Thoracosphaera deflandrei** (M16b); d, **Cyclicargolithus floridanus** (M17); e, **Cyclococcolithus luminis** (A27g); F,f, **Helicosphaera intermedia** (M16b); G,g, **Markalius inversus** (M18b); H, **Holodiscolithus solidus** (M17); I,i, **Coccolithus pelagicus** (M18c); J,j, **Transversopontis zigzag** (M16b). Chickasawhay Limestone: A, **Chiasmolithus altus** (A42a); b, **Zygrhablithus bijugatus** (A42a); C,c, **Sphenolithus ciperoensis** (A27i); d, **Thoracosphaera deflandrei** (A42b); e, **Cyclicargolithus floridanus** (A42a); f, **Cyclococcolithus luminis** (A42a); g, **Coccolithus pelagicus** (A42a); H,h, **Helicosphaera recta** (A42a). Approximate magnifications: 1000X, except Glendon e,J,j (1200X) and Byram H (1600X).

ACKNOWLEDGMENTS

The initial stages of field and laboratory work on this project were supported by a Direct Support Grant and Summer Research Fellowship from the Vanderbilt Research Council; equipment purchases were made possible by grants from the Natural Sciences Committee of Vanderbilt University and Dixie Oil Company, Nashville. Later stages of the project were supported by the National Science Foundation under Grant EAR-8113069. I should like to express my appreciation and thanks to all four organizations. Subsurface samples from Alabama and Tennessee were made available by the Geological Survey of Alabama, Tuscaloosa, and the Division of Geology, Nashville, respectively. David Kronman took the field photographs used as Figs. 9, 14, 18, 19. Peggy Wrenne is thanked for her long and patient assistance in the darkroom, and Frank R. Sullivan for many thoughtful discussions on species concepts. Robert W. Pierce, Amoco Production Co., kindly provided samples from the Bells Landing Member, Coal Bluff Member and Bucatunna Formation. Dr. Pierce also read a draft of the manuscript and made many helpful comments. David T. Dockery, Mississippi Bureau of Geology, was particularly helpful. I wish to thank him for his advice on localities and lithostratigraphy in Mississippi, and for his editorial assistance.

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APPENDIX I
Nannoplankton-Bearing Localities

Locality A1 - Railroad cut along C. of G. Railroad, about 250 yards north of intersection of railroad line and State Highway 30. Clayton, Barbour Co., AL. Stratotype of Clayton Fm. Only one nannofossiliferous sample obtained from section, about 18' above Cretaceous-Tertiary (K-T) contact.

Locality A2 - Roadcut on Highway 263, 4.6 miles south of intersection of State Highways 263 and 21, near Braggs, Lowndes Co., AL. Twenty-six closely spaced nannofossiliferous samples collected from just below the Prairie Bluff Fm. (Maastrichtian) - Pine Barren Mbr. of the Clayton Fm. contact to the top of roadcut. Assemblages are similar; two representative Pine Barren Mbr. samples are shown on Table 2a: A2a is from 2' above K-T boundary; A2b is 2' above A2a. Samples A2c and A2d are from the McBryde Mbr., along the same road about 11.5 miles south of the intersection. A2d is about 30' higher stratigraphically than A2c. Samples A2e - A2g are from the Porters Creek Fm., collected 12.3 miles south of the intersection. A2e is 2' above road level; A2f is 11' above A2e; A2g is 2' above A2f.

Locality A3 - Roadcut along County Highway 11, just south of intersection with Cedar Creek, near Monterey, Butler Co., AL. Samples collected from stream level to top of section. Pine Barren Mbr. of the Clayton Fm. (A3a); McBryde Mbr. of the Clayton Fm. (A3b-A3f); Porters Creek Fm. (A3g-A3i). A3a is at stream level; A3b is 60' above A3a; A3c is 15' above A3b; A3d is 12' above A3c; A3e is 13' above A3d; A3f is 10' above A3e; A3g is 12' above A3f; A3h is 8' above A3g; A3i is 11' above A3h.

Locality A4 - Stream bank under bridge, intersection of Pine Barren Creek and Highway 21, about 1 mile east of intersection of State Highways 21 and 28, Wilcox Co., AL. Pine Barren Mbr. of the Clayton Fm. Sample A4a is 2.5' above stream level; A4b is 3' above A4a; A4c is 2.5' above A4b.

Locality A5 - Roadcut at junction of State Highways 21 and 28, Wilcox Co., AL. Sample A5a at junction; sample A5b is on Highway 28, 3 miles west of junction. McBryde Mbr. of the Clayton Fm.

Locality A6 - Roadcut at entrance to Shell Creek Park, Wilcox Co., AL. Pine Barren Mbr. of the Clayton Fm.

Locality A7 - Stream bank at intersection of State Highway 28 and Rock Creek, Wilcox Co., AL. McBryde Mbr. of the Clayton Fm. Sample A7a is 1' above stream level; A7b is 3' above A7a.

Locality A8 - Roadcut on State Highway 21, about 1 mile north of Oak Hill, Wilcox Co., AL. Pine Barren Mbr. (*Turritella* rock) of the Clayton Fm.

Locality A9 - River bank of Tombigbee River, about 100 yards south of old Rooster Bridge, Sumter Co., AL. Pine Barren Mbr. of Clayton Fm. Sample A9a is 4.5' above K-T boundary; A9b is 1.5' above A9a.

Locality A10 - Railroad cut adjacent to State Highway 5 about 0.5 mile south of Gastonberg, Wilcox Co., AL. Pine Barren Mbr. of the Clayton Fm. Fifteen fossiliferous samples were collected; three representative samples are shown on Table 2b. Sample A10a is 19' above K-T boundary. Samples A10b and A10c are about 50 yards east of A10a. A10b is 20' above the K-T boundary and A10c is 20' above A10b.

Locality A11 - Core IC 128 from Millers Ferry. SE 1/4, SE 1/4, Sec. 18, T13N, R7E, Wilcox Co., AL. Clayton Fm. Sample A11a is from the lowermost Paleocene overlying Maastrichtian. Footages are depths below ground level: A11a - 104.5'; A11b - 104'; A11c - 103.3'; A11d - 100'; A11e - 96'; A11f - 88'; A11g - 85.6'; A11h - 75'; A11i - 38.6'.

Locality A12 - Core IC 187 from Fosters Farm, SW 1/4, NE 1/4, SE 1/4, Sec. 24, T11N, R13E, Butler Co., AL. Clayton Fm. Footages in depths below ground level: A12a - 95.5'; A12b - 69.5'.

Locality A13 - Core IC 188 from Fosters Farm, SE 1/4, NW 1/4, SE 1/4, Sec. 24, T11N, R13E, Butler Co., AL. Clayton Fm. Footages are depths below ground level: A13a - 85.3'; A13b - 65'; A13c - 30'.

Locality A14 - Roadcut on County Highway 7, 0.9 mi west of Butler-Wilcox County line, Wilcox Co., AL. Porters Creek Fm.

Locality A15 - Roadcut on State Highway 10, about 1 mile west of Rosebud, Wilcox Co., AL. Porters Creek Fm.

Locality A16 - Quarry, State Highway 41, 7.4 miles south of Camden, Wilcox Co., AL. Nanafalia Fm. (*Ostrea thirsae* beds).

Locality A17 - West bank of Chattahoochee River at boat ramp 0.3 mile north of highway bridge, Henry Co., AL. Nanafalia Fm.

Locality A18 - Roadcut on County Hghway 3, 0.8 mile north of Henderson, Pike Co., AL. Nanafalia Fm.

Locality A19 - Roadcut above Shoal Creek on Highway 265, 5.2 miles south of Camden, Wilcox Co., AL. Nanafalia Fm. (*Ostrea thirsae* beds). Sample A19a is 73' above stream level; A19b is 9' above A19a; A19c is 14' above A19b; A19d is 5' above A19c.

Locality A20 - Roadcut on County Highway 73 between Octagon and U.S. Highway 43, Marengo Co., AL. Nanafalia Fm.

Locality A21 - Railroad cut beneath trestle on U.S. Highway 231, 1 mile north of Ozark, Dale Co., AL. Bashi Marl Mbr. of the Hatchetigbee Fm. Sample A21a from base of section; A21b is 3' above A21a.

Locality A22 - Roadcut on County Highway 15, 5.5 miles southeast of Jackson, Clarke Co., AL. Salt Mountain Limestone. Sample A22a near middle of section; A22b is about 20' above A22a.

Locality A23 - Little Stave Creek, about 4 miles north of Jackson, Clarke Co., AL. Samples were collected as closely as possible to the localities sampled by Bandy (1949) at Little Stave Creek. Tallahatta Fm.: A23a (Bandy 8), A23b (Bandy 11); Lisbon Fm.: A23c (Bandy 12), A23d (Bandy 28), A23e (Bandy 32); Gosport Sand: A23f (Bandy 35); Moodys Branch Fm.: A23g (Bandy 41), A23h (Bandy 45); North Twistwood Creek Clay Mbr. of the Yazoo Fm.: A23i (Bandy 46); Cocoa Sand Mbr. of the Yazoo Fm.: A23j (Bandy 56); Pachuta Marl Mbr. of the Yazoo Fm.: A23k (Bandy 57); Shubuta Clay Mbr. of the Yazoo Fm.: A231 (Bandy 61); Red Bluff Fm.: A23m (Bandy 63); Marianna Limestone: A23n (Bandy 64-65), A23o (Bandy 67).

Locality A24 - Roadcut on State Highway 17, 0.3 mile south of intersection with Souwilpa Creek, Choctaw Co., AL. Tallahatta Fm. (A24a and A24b); Lisbon Fm. (A24c - A24e). A24a is just above road level; A24b is 5' above A24a; A24c is 1' above A24b; A24d is 3' above A24c; A24e is 2' above A24d.

Locality A25 - Roadcut on State Highway 17, 2.5 miles north of Toxey, Choctaw Co., AL. Tallahatta Fm.

Locality A26 - Roadcut on County Highway 31, 1.1 mile south of Barrytown, Choctaw Co., AL. Lisbon Fm.

Locality A27 - Lone Star Cement Quarry and river bank at St. Stephens Bluff on the Tombigbee River, 2.2 miles northeast of St. Stephens, Washington Co., AL. Gosport Fm.: A27a; Moodys Branch Fm.: A27b; Pachuta Marl Mbr. of the Yazoo Fm.: A27c; Shubuta Clay Mbr. of the Yazoo Fm.: A27d; Red Bluff Fm.: A27e; Marianna Limestone: A27f; Glendon Limestone: A27g; Bucatunna Fm.: A27h; Chickasawhay Limestone: A27i. Sample A27a is about 1' above water level; A27b is 2' above A27a; A27c is from floor of Pelham Hill Quarry; A27d is 6' above A27c; A27e is 10' above A27d; A27f ia 2' above floor of South Quarry; A27g is 63' above A27f; A27h is 13' above A27g; A27i is 21' above A27h.

Locality A28 - Stream bed, under Sepulga River Bridge on County Highway 43, about 5 miles northeast of Brooklyn, Conecuh Co., AL. Moodys Branch Fm.

Locality A29 - Claiborne Bluff, east bank of Alabama River, Claiborne, Monroe Co., AL. Moodys Branch Fm. A29a is 35' above road level; A29b is 5' above A29a; A29c is 3' above A29b.

Locality A30 - Roadcut on U.S. Highway 43, 2 miles north of Grove city limits, Clarke Co., AL. Moodys Branch Fm.

Locality A31 - Roadcut on U.S. Highway 84, 3.5 miles west of Silas, Choctaw Co., AL. Moodys Branch Fm.

Locality A32 - Roadcut on County Highway 14, 3.9 miles west of Gilbertown, Choctaw Co., AL. Moodys Branch Fm.

Locality A33 - Roadcuts on U.S. Highway 84, 4.0-4.2 miles west of Silas, Choctaw Co., AL. North Twistwood Creek Clay Mbr. of the Yazoo Fm. A33b is 0.2 mile west of A33a, and is about 15' higher stratigraphically.

Locality A34 - Roadcut on U.S. Highway 84, 1.1 mile east of Isney, Choctaw Co., AL. North Twistwood Creek Clay Mbr. of the Yazoo Fm.

Locality A35 - River bank under Sepulga River bridge at Brooklyn, Conecuh Co., AL. North Twistwood Creek Clay Mbr. of the Yazoo Fm.

Locality A36 - Roadcut on U.S. Highway 84, 10 miles west of Alabama River bridge, Clarke Co., AL. North Twistwood Creek Clay Mbr. of the Yazoo Fm. (A36a); Cocoa Sand Mbr. of the Yazoo Fm. (A36b); Pachuta Marl Mbr. of the Yazoo Fm. (A36c and A36d).

Locality A37 - West bank of Sepulga River about 2 miles north of Steamboat Point, near Brooklyn, Escambia Co., AL. Crystal River Fm.

Locality A38 - West bank of Sepulga River, about 2 miles south of Steamboat Point, Escambia Co., AL. Bumpnose Limestone.

Locality A39 - Roadcut on Highway 84, 4.4 miles west of intersection of U.S. Highway 84 and U.S. Highway 43, near Zimco, Clarke Co., AL. Pachuta Marl Mbr. of the Yazoo Fm. Sample A39a is at road level; A39b is about 2' above A39a.

Locality A40 - Roadcut on U.S. Highway 84, 1.1 mile west of railroad overpass at Whatley, Clarke Co., AL. Shubuta Clay Mbr. of the Yazoo Fm.

Locality A41 - Roadcut on U.S. Highway 84, 2.5 miles east of Isney, Choctaw Co., AL. Shubuta Clay Mbr. of the Yazoo Fm.

Locality A42 - Roadcut on State Highway 17, 1.8 miles north of Millry, Washington Co., AL. Chickasawhay Fm. Sample A42a is at road level; A42b is 3 1/2' above A42a.

Locality A43 - Streambed behind sewage plant, Monroeville, Monroe Co., AL. Crystal River Fm.

Locality A44 - Quarry of Claiborne Lime Plant, Perdue Hill, Monroe Co., AL. Crystal River Fm.

Locality A45 - Lower Peebles Landing on Alabama River, Clarke Co., AL. Bells Landing Marl Mbr. of the Tuscahoma Fm.

Locality A46 - Roadcut at hill slope on State Highway 69, 1.3 mile north of Campbell, 0.2 mile south of Bashi Creek, Clarke Co., AL. Hatchetigbee Fm. Sample A46a is 9' above road level; A46b is 7' above A46a.

Locality M1 - Railroad cut along ICG Railroad, 1.2 mile south of Pontotoc, Pontotoc Co., MS. Clayton Fm.

Locality M2 - Bank of Chickasawhay River at the south end of the U.S. Highway 45 bridge, about 1 mile south of Quitman, Clarke Co., MS. Archusa Marl Mbr. of the Cook Mountain Fm.

Locality M3 - Roadcut on Highway 15, 0.6 mile north of intersection of State Highway 15 and U.S. Highway 80, near Newton, Newton Co., MS. (MGS locality 65). Potterchitto Marl Mbr. of the Cook Mountain Fm.

Locality M4 - Ravine in Riverside Park, Jackson, Hinds Co., MS. (MGS locality 2). Sample M4a (Moodys Branch Fm.) is from about 15' above floor of ravine; M4b (lower Yazoo Fm.) is about 20' above M4a.

Locality M5 - Roadcut on U.S. Highway 84 about 1 mile east of intersection with Bucatunna Creek near Waynesboro, Wayne Co., MS. (MGS locality 88). Upper Forest Hill Fm. (M5a); Marianna Limestone (M5b and M5c). M5a is about 3' above road level; M5b is 9' above M5a; M5c is 8' above M5b.

Locality M6 - Gully, SE 1/4, NE 1/2, Sec. 29, T1N, R18E, Clarke Co., MS. Pachuta Marl Mbr. of the Yazoo Fm. (Samples M6a-M6e). Shubuta Clay Mbr. of the Yazoo Fm. (M6f). Sample M6a is from about 7' above bottom of gully; M6b is 4' above M6a; M6c is 3' above M6b; M6d is 1' above M6c; M6e ('*Zeuglodon* bed') is 5' above M6d; M6f is 3' above M6e.

Locality M7 - Stream bank about 100 yards north of intersection of Eucutta Street and old bridge over Chickasawhay River, in Shubuta, Clarke Co., MS. (MGS locality 57b). Pachuta Marl Mbr.

Locality M8 - Roadcut on north side of an unmarked county road from Horn to Bucatunna Creek, 0.5 mile east of Horn, SE 1/4, SE 1/4, SE 1/4, SW 1/4, NW 1/4, Sec. 14, T1N, R17E, Clarke Co., MS. Pachuta Marl Mbr. of the Yazoo Fm.

Locality M9 - Roadcut 0.1 mile past Mike Creek on south side of gravel road leading west from Highway 45 2.4 miles northwest of the Highway 45 - Eucutta Street intersection in Shubuta, NW 1/4, SE 1/4, SE 1/4, SE 1/4, Sec. 26, T1N, R15E, Clarke Co., MS. Pachuta Marl Mbr. of the Yazoo Fm.

Locality M10 - Roadcut on Highway 18, 1.5 miles east of intersection of State Highway 18 and County Highway 503, near Rose Hill, NE 1/4, NE 1/4, Sec. 11, T3N, R12E, Jasper Co., MS. Pachuta Marl Mbr. of the Yazoo Fm.

Locality M11 - Roadcut 2.7 miles east of Lake on U.S. Highway 80 between Lake and Lawrence, Newton Co., MS. Pachuta Marl Mbr. of the Yazoo Fm.

Locality M12 - Gully beside road (south fork) 200 yards west of first fork west of Frost Bridge Camp, north line of NE 1/4, NW 1/4, NE 1/4, NE 1/4, Sec. 32, T10N, R5W, Wayne

Co., MS. Shubuta Clay Mbr. of the Yazoo Fm. Sample taken 3' above contact with the Pachuta Marl Mbr. of the Yazoo Fm.

Locality M13 - Roadcut on County Highway 503, 5.4 miles south of Jasper Co. line, SE 1/4, SE 1/4, NE 1/4, NW 1/4, Sec. 34, T4N, R12E, Jasper Co., MS. Shubuta Clay Mbr. of the Yazoo Fm.

Locality M14 - Roadcut 0.2 mile northeast of Forest Hill School, Jackson, Hinds Co., MS. Mint Spring Fm.

Locality M15 - Bluff along east bank of Mississippi River, about 300 yards north of Mississippi River Bridge, Vicksburg, Warren Co., MS. (MGS locality 107). Mint Spring Fm. (M15a); Marianna Ls. (M15b); Glendon Ls. (M15c). M15a is about 5' above water level; M15b is 5'above M15a; M15c is 10' above M15b.

Locality M16 - Waterfall of Mint Spring Bayou, near north entrance to National Military Park, Vicksburg, Warren Co., MS. (MGS locality 108). Mint Spring Fm. (M16a); Glendon Ls. (M16b). M16a at base of waterfall; M16b is 21' above M16a.

Locality M17 - Roadcut on U.S. Highway 61, 1.7 miles north of National Military Park, Vicksburg, Warren Co., MS. Byram Fm.

Locality M18 - Marquette Cement Co. Quarry, Brandon, Rankin Co., MS. (MGS locality 98). Glendon Ls. M18a is from floor of south quarry; M18b is 2' above M18a; M18c is 1 1/2' above M18b.

Locality M19 - River bank, Pearl River at Old Byram, Hinds Co., MS. (MGS locality 102). Stratotype of Byram Fm.

Locality M20 - West bank of Chickasawhay River, 70 yards north of U.S. Highway 84 bridge, about 2 miles west of Waynesboro, Wayne Co., MS. Paynes Hammock Fm. M20a is 16' above water level; M20b is 4' above M20a; M20c is 2' above M20b.

Locality T1 - Core 1610 from Hardeman Co., TN. TN coordinates 245, 000N, 1, 125, 050E. Clayton Fm. Sample T1a is 270' - 260' below ground level; T1b is 260' - 250'; T1c is 250' - 240'; T1d is 240' - 230'; T1e is 230' - 220'; T1f is 220' - 210'.

Locality T2 - Core 1611 from Hardeman Co., TN. TN coordinates 343, 600N, 1, 164, 250 E. Clayton Fm. Sample T2a is from 220' - 210' below ground level; T2b is 210' - 200'; T2c is 200' - 190'; T2d is 190' - 180'.