The Eocene Tallahatta Formation of Alabama and Georgia: Its Lithostratigraphy, Biostratigraphy, and Bearing on the Age of The Claibornian Stage

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By Laurel M. Bybell and Thomas G. Gibson

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The Eocene Tallahatta Formation of Alabama and Georgia: Its Lithostratigraphy, Biostratigraphy, and Bearing on the Age of the Claibornian Stage

By Laurel M. Bybell *and* Thomas G. Gibson

Abstract

Biostratigraphic determination of the Eocene age of the Tallahatta Formation has been difficult because few calcareous fossils are found in the formation. In western Alabama and eastern Mississippi, the Tallahatta consists of noncalcareous sand overlain by siliceous clay, silt, and quartz sand. In eastern Alabama and western Georgia, it consists predominantly of heavily leached, noncalcareous, coarse clastic deposits that were laid down in fluvial to shallow-marine environments.

As part of this study, five continuous coreholes were drilled from western Alabama to western Georgia downdip (south) of the outcrop belt of the Tallahatta Formation. In addition, several of the farthest downdip outcrop sections were examined. These downdip deposits of inner neritic sand and clay contain calcareous nannofossils and limited numbers of planktonic foraminifers. The occurrence of these biostratigraphically useful groups, particularly in the continuous subsurface sections, made possible the reliable dating of the entire Tallahatta Formation.

Fossiliferous sand at the base of the Tallahatta unconformably overlies carbonaceous clay and silt of the Hatchetigbee Formation. These lowest Tallahatta strata, considered to be the downdip equivalent of the outcropping Meridian Sand Member of the Tallahatta, contain calcareous nannofossils diagnostic of Zone NP12 of Martini (1971); overlying these strata are beds placed in Zone NP13. The upper Tallahatta beds are assigned to Zone NP14; no positive evidence for strata belonging to Zone NP15 was found. At many places, erosion surfaces separate the sediments belonging to each of the three calcareous nannofossil zones. On the basis of foraminiferal assemblages in the cored sections, the strata belonging to Zone NP12 and the lower part of Zone NP13 are judged as probably representing very shallow marine deposition; sediments in the upper part of Zone NP13 and in Zone NP14 probably were deposited in somewhat deeper water inner shelf environments.

Zones NP12 and NP13 normally are considered to be of early Eocene age, whereas Zone NP14 normally is considered to straddle the early-middle Eocene boundary or to be entirely of middle Eocene age. Thus, most of the Tallahatta Formation, including those strata considered to represent the downdip equivalent of the basal Meridian Sand Member, is of early Eocene age. As the Tallahatta is the lowest formation of the Claiborne Group, the base of the Claibornian Stage is placed within the early Eocene. The Sabinian-Claibornian Stage boundary in Alabama and Georgia does not correspond to the early-middle Eocene boundary.

INTRODUCTION

Purpose and Scope

The Tallahatta Formation, the basal unit of the Claiborne Group, crops out over a wide area from Mississippi to Georgia in the eastern Gulf Coastal Plain. In Mississippi and western Alabama, siliceous strata of the Tallahatta form prominent, steep outcrops. In eastern Alabama and western Georgia, coarse sand and gravel typical of the lower part of the Tallahatta in this area rest in conspicuous channels, which are cut into various Paleocene and Eocene units. Biostratigraphic information on the age of the Tallahatta has been very limited because most of the previously examined outcrops either lack calcareous fossils (mainly because of leaching) or contain sparse or difficult-to-remove specimens.

To biostratigraphically date the entire formation, the most marine sections at the southern (downdip) extent of the Tallahatta outcrop belt were examined along the Chattahoochee and Pea Rivers and at Little Stave Creek. In addition, five coreholes (fig. 1) were drilled in Alabama and Georgia at, or just south of, the outcrop belt. These downdip coreholes penetrated thicker, less weathered sections representing slightly deeper water sediments. Calcareous microfossils, including calcareous nannofossils and foraminifers, were present in significant numbers in portions of the cores. By combining calcareous nannofossil data from all the corehole and outcrop samples, the age of the entire Tallahatta Formation was determined for the first time. Diagnostic planktonic foraminifers were not present in most samples; benthonic foraminifers were more common, but they consisted mainly of relatively long-ranging

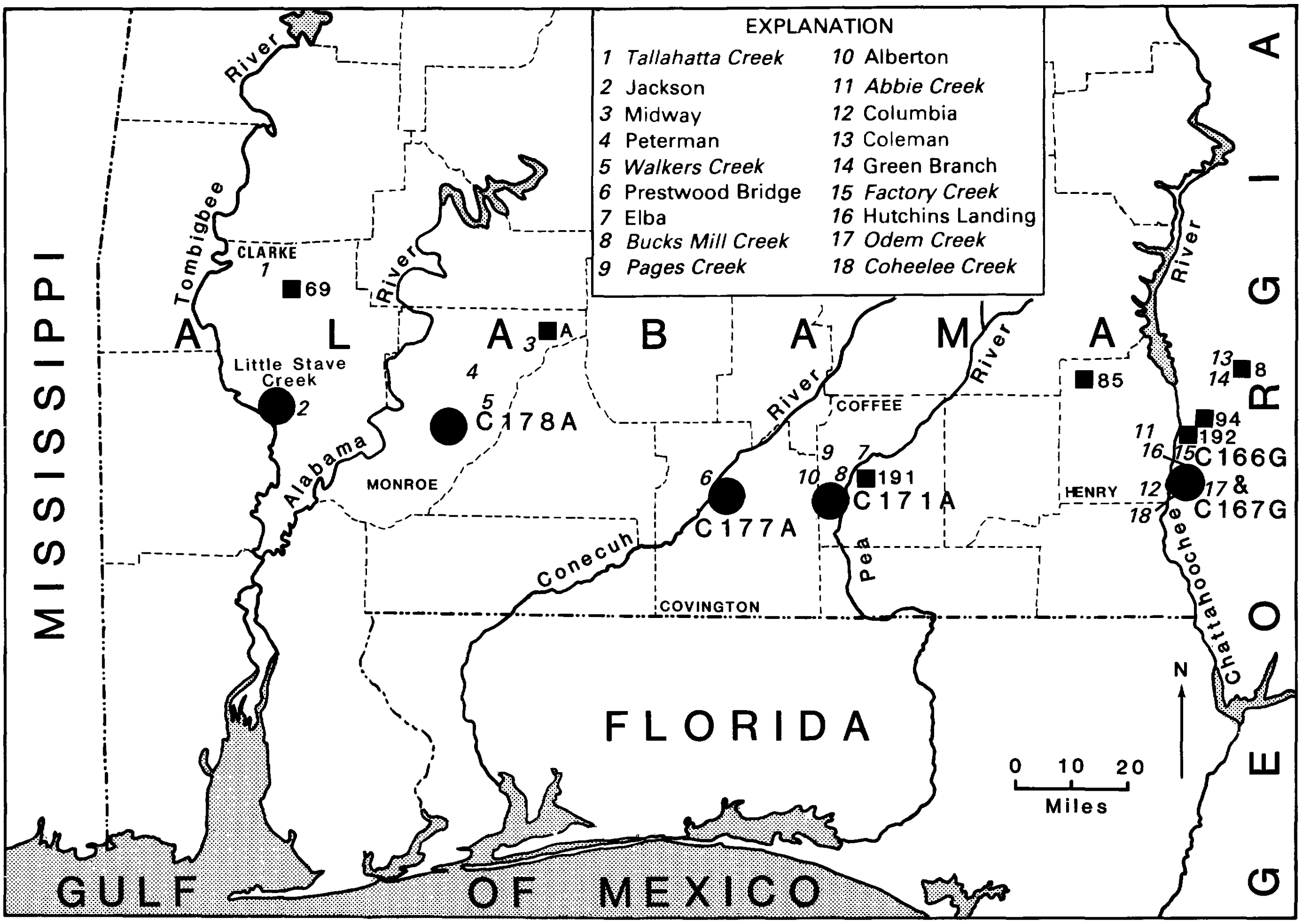

Figure 1. Localities in Alabama and western Georgia discussed in text. Large round dots are thick fossiliferous sections in downdip locations; small squares are reference sections in more updip areas.

species. These benthonic foraminiferal assemblages are useful, however, in paleoenvironmental interpretations.

Acknowledgments

We wish to thank Betsy Funk and Harry Dowsett for making all the foraminiferal and calcareous nannofossil preparations and drafting all the illustrations. We also wish to thank Harry for doing all the scanning electron microscope work. We thank David Govoni, who contributed many helpful suggestions throughout the preparation of the manuscript. We are grateful to James A. Miller and Joseph E. Hazel for their reviews of this paper.

LITHOSTRATIGRAPHY

The Tallahatta Formation in its type area in eastern Mississippi and western Alabama is dominated by siliceous claystone and siltstone (Toulmin, 1977), although several different lithologies were recognized by Smith and others (1894). The siliceous sediments contain significant amounts of cristobalite, as well as clinoptilolite and montmorillonite (Reynolds, 1966). In the earlier literature (for example, Smith and others, 1894), these siliceous sediments were called buhrstones because of their hardness and resistance to erosion, although little of the material was actually used for millstones (Thomas, 1942).

In western Alabama and Mississippi, the Meridian Sand Member of the Tallahatta Formation is commonly found beneath the buhrstone and above the carbonaceous and laminated clay and silt of the Hatchetigbee Formation (fig. 2). The thickness of the Meridian Sand Member is variable and reaches a maximum of 225 feet (Childress, 1973). The unit consists in

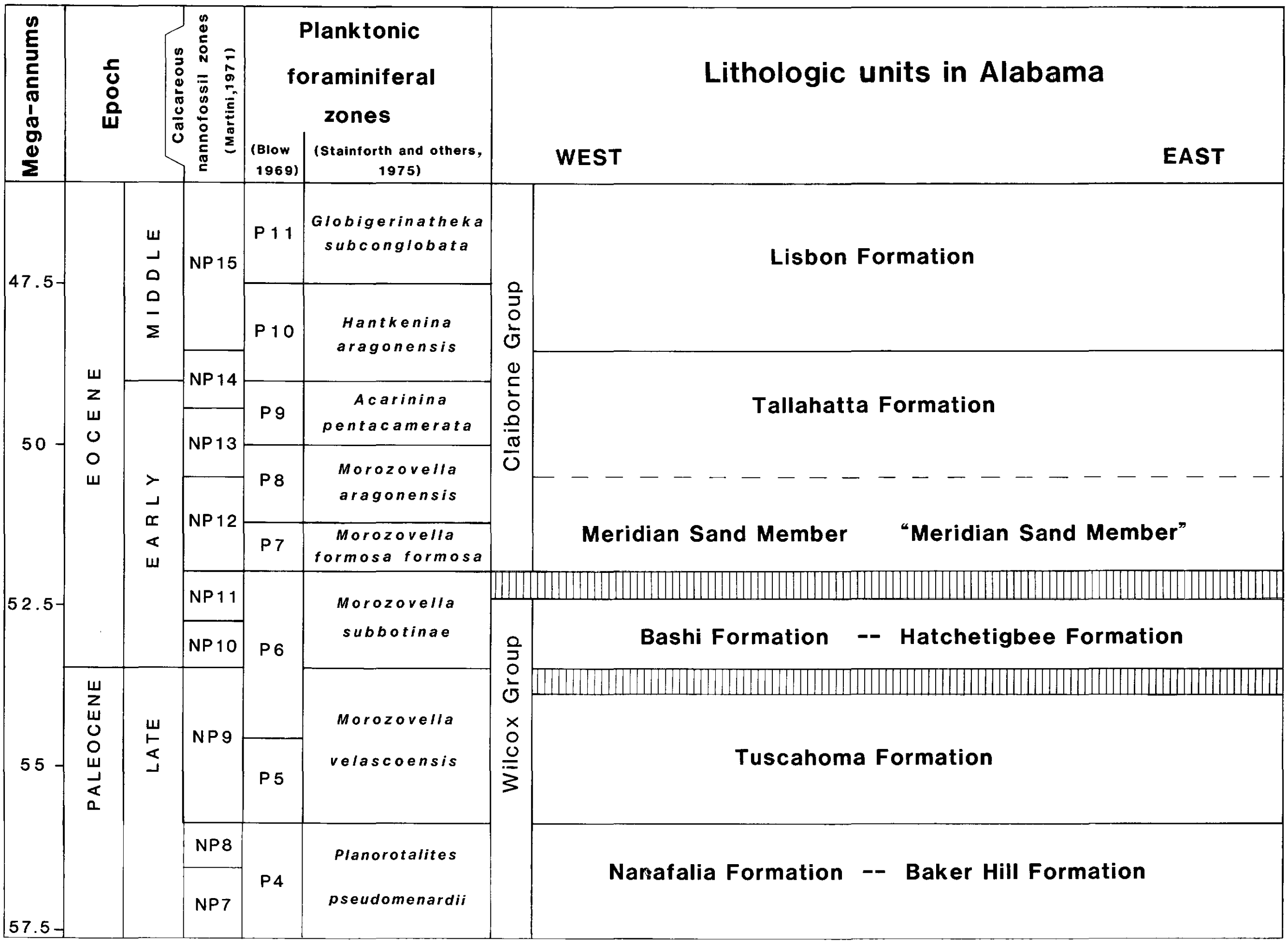

Figure 2. Age placements for the Tallahatta and other formations of late Paleocene to middle Eocene age in Alabama and Georgia (zones and radiometric time scale from Vail and Hardenbol, 1979).

outcrop of pale-colored, fine- to coarse-grained sand, which commonly contains quartz granules and clay clasts and is generally crossbedded. Thomas (1942) and Murray (1955) placed the Meridian Sand Member in the Wilcox Group. However, more recent studies in Mississippi (Priddy, 1961; Lusk, 1963; Childress, 1973; and Gilliland, 1980) and in Alabama (MacNeil, 1946; Toulmin, 1977) have considered the Meridian to be the basal member of the Tallahatta Formation and thus the lowest unit of the Claiborne Group. The Tallahatta has not been so intensively studied in eastern Alabama and western Georgia, but MacNeil (1946) considered the sand and gravel beds at the base of the Tallahatta Formation in this area to be a Meridian equivalent. MacNeil's view is supported by the lithostratigraphic and biostratigraphic data of the current study.

The lithofacies observed in the Tallahatta are discussed in this paper from updip (north) to downdip (south) and from east (eastern Alabama-western Georgia) to west (western Alabama-Mississippi). Significant lithofacies changes are present in the updip-downdip (north-south) transects through the Tallahatta Formation. These facies changes are best seen in eastern Alabama along the deeply incised valleys of the Chattahoochee River and other nearby river systems. In updip areas in eastern Alabama, the Tallahatta commonly fills undulating channels cut into the top of the Hatchetigbee Formation. In western Georgia, these channels may be incised into the Hatchetigbee, Tuscahoma, or Baker Hill Formations as the intervening units pinch out. This channelized surface can range in relief from 5 to 20 feet within an individual outcrop. Good updip exposures of this contact can be seen in Henry County, Ala. (locality 85, fig. 1 and table 1). The basal Tallahatta deposits occurring immediately above this unconformity range from gravelly coarse

Table 1. Locality information for outcrops and coreholes discussed in the text

Location	Description
Loc. 8--In Randolph County, Ga., a stream cut 500 feet north Georgia Highway 266, 1.6 miles west of Coleman (Coleman, Ga., 7½-min quadrangle); exposes lower beds of Tallahatta Formation and contact with underlying Hatchetigbee Formation.	
Loc. 69--In Clarke County, Ala., along Alabama Highway 69, on hill slope above Tallahatta Creek, secs. 19 and 20, T. 11 N., R. 1 E (Marvin and Woods Bluff, Ala., 7½-min quadrangles); exposes Tallahatta Formation and underlying Hatchetigbee and overlying Lisbon Formations.	
Loc. 85--In Henry County, Ala., a roadcut on north side of County Highway 57, 320 feet east of Abbie Creek, NE1/4 sec. 21, T. 6 N., R. 28 E. (Haleburg, Ala., 7½-min quadrangle); exposes lower beds of Tallahatta Formation and contact with underlying Hatchetigbee Formations.	
Loc. 94--In Early County, Ga., along north bank of Factory Creek, 1.1 miles east of juncture with Chattahoochee River (Columbia NE, Ga.-Ala., 7-min quadrangle); exposes lower beds of Tallahatta Formation.	
Loc. 191--In Coffee County, Ala., along east and west banks of Pea River, 0.3 mile below mouth of Bucks Mill Creek, SW1/4 sec. 21, T. 4 N., R. 20 E. (Ino, Ala., 7½-min quadrangle); exposes lower beds of Tallahatta Formation and contact with underlying Hatchetigbee Formation.	
Loc. 192--In Early County, Ga., along left (east) bank of Chattahoochee River, 0.2 mile south of Hutchins Landing (Columbia NE, Ga.-Ala., 7½-min quadrangle); exposes lower beds of Tallahatta Formation and contact with underlying Bashi Formation.	
Loc. A--In Monroe County, along Alabama Highway 47, about 2 miles west of Midway, secs. 29 and 30, T. 9 N., R. 10 E. (Skinnerton, Ala., 7½-min quadrangle); exposes Tallahatta Formation and underlying Hatchetigbee and overlying Lisbon Formations.	
Little Stave Creek--In Clarke County, Ala., north of Jackson, small stream to west of U.S. Highway 43, secs. 19 and 20, T. 7 N., R. 2 E. (Jackson, Ala., 7½-min quadrangle); exposes upper part of Tallahatta Formation and overlying Lisbon and higher formations.	
Corehole C166G--In Early County, Ga., 1.7 miles northeast of Columbia, Ala., on north bank of Coheelee Creek, 160 feet west of covered bridge (Columbia, Ga.-Ala., 7½-min quadrangle); elevation at top of hole 115'; penetrated lower part of Lisbon and upper part of Tallahatta Formations.	
Corehole C167G--In Early County, Ga., on east bank of Chattahoochee River at boat launching ramp at mouth of Odem Creek (Columbia, Ga.-Ala., 7½-min quadrangle); elevation at top of hole 107'; penetrated lower part of Tallahatta and upper part of Bashi Formations.	
Corehole C171A--In Coffee County, Ala., on south bank of Pages Creek, 0.1 mile west of Alberton, NE1/4 sec. 34, T. 4 N., R. 19 E. (Opp East, Ala., 7½-min quadrangle); elevation at top of hole 155'; penetrated lower part of Tallahatta and Bashi and Hatchetigbee Formations.	
Corehole C177A--In Covington County, Ala., on east bank of Conecuh River, 225 feet south of Prestwood Bridge, SW1/4 sec. 14, T. 4 N., R. 15 E. (River Falls, Ala., 7½-min quadrangle); elevation at top of hole 155'; penetrated lowest part of Lisbon Formation and most of Tallahatta Formation.	
Corehole C178A--In Monroe County, Ala., on north bank of Walkers Creek, 2.2 miles south of Peterman, SW1/4 sec. 22, T. 7 N., R. 8 E. (Monroeville, Ala., 7½-min quadrangle); elevation at top of hole 180'; penetrated Tallahatta, Hatchetigbee, and Bashi Formations.	

sand, commonly containing clay clasts as large as 6 inches in diameter, to alternating coarse sand and clay layers ½ to 2 inches in thickness. The clay beds in these alternating sequences, such as those examined at Green's Branch in Randolph County, Ga. (Gibson, 1980b) (locality 8, fig. 1 and table 1), contain only pollen and spores; the absence of dinoflagellates suggests deposition in freshwater. At some updip localities in eastern Alabama, thick basal Tallahatta sand units contain massive bedding to large-scale crossbedding and occasionally contain *Ophiomorpha*; these characteristics suggest brackish to shallow-marine depositional environments. The basal Tallahatta beds in eastern Alabama are considered the lateral equivalents of the Meridian Sand Member in western Alabama.

Above these basal beds, the outcropping updip Tallahatta in eastern Alabama is composed largely of medium-grained sand and commonly reaches a thickness of 30 to 40 feet or more. The thick sand beds are heavily weathered because of their high permeability and their location high up on topographic divides. Several clay beds occur widely in the lower part of this interval. In eastern Alabama, a clay bed about 5 feet thick is overlain by several thinner clays that are approximately 6 inches thick and by medium- to coarse-grained, gravelly sand.

Downdip in eastern Alabama and western-most Georgia, the basal Tallahatta gravel and sand units become finer grained and are composed mainly of fine- to medium-grained sand containing some siliceous clayey sand intervals that range from 5 to 10 feet thick. These sediments are seen in outcrops in the western part of Early County, Ga., both along the Chattahoochee River (locality 192, fig. 1 and table 1) and Factory Creek (locality 94, fig. 1 and table 1), as well as along the Pea River in Coffee County, Ala. (locality 191, fig. 1 and table 1), and in the most downdip sections in coreholes C166G, C167G, and C171A (figs. 1 and 3, table 1), located a short distance south of the outcrop area. The sand contains sparse to abundant glauconite and scattered to abundant molluscan shells and occasionally is bound by a calcareous matrix. The lowest part of the section, presumed to be the Meridian Sand Member equivalent, is a clayey or silty, shelly sand typical of an inner neritic environment of deposition. This unit, which is sometimes partially indurated to form a calcareous sandstone and shows moldic porosity, serves locally as an artesian aquifer, confined below by the clay and silt of the Hatchetigbee Formation and above by clayey beds higher in the Tallahatta. These downdip sections of clayey, silty, fine sand are interpreted as a shallow-marine, inner neritic sequence on the basis of the foraminiferal and calcareous nannofossil assemblages that they contain. The Tallahatta Formation is about 100 feet thick in eastern Alabama and western Georgia, as determined from the coreholes. Toulmin and LaMoreaux (1963) estimated the Tallahatta to be about 60 feet thick along the Chattahoochee River, but slumping of the thick sand sequences along the river banks impedes accurate measuring of the thickness of the formation in outcrop.

Westward across Alabama, the Tallahatta Formation increases in thickness, and fossiliferous

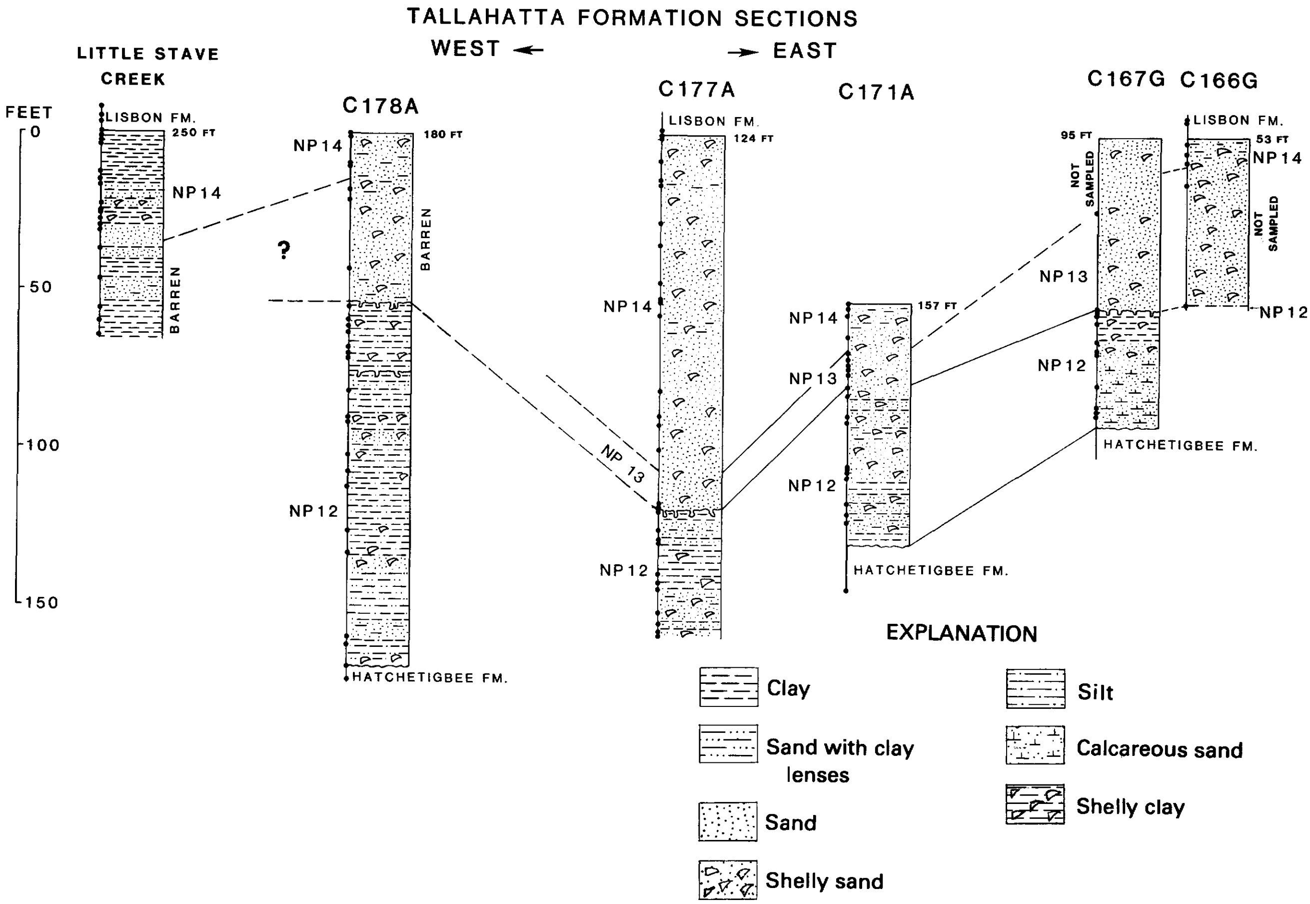

Figure 3. Lithographic sections from five coreholes and from the outcrop section at Little Stave Creek showing facies changes across Alabama. Solid lines between sections indicate close biostratigraphic control; dashed lines indicate less control and suggested zonal boundaries.

clayey sand becomes a more significant component of the formation. Sections in coreholes C177A and C178A and at the classic outcrop section at Little Stave Creek represent the most downdip Tallahatta sediments from which data were obtained in central and western Alabama (fig. 3). Clayey fine sand and silty clay are important components of the section, along with intervals of highly glauconitic sand. The strata in coreholes C177A and C178A generally contain foraminiferal assemblages indicative of shallow-marine, inner neritic depositional environments. The basal part of the formation is sandier in places and is considered to be the downdip, more marine equivalent of the updip Meridian Sand Member. As no biostratigraphic control on the unfossiliferous Meridian Sand Member is available, this correlation is based on (1) the stratigraphic position of the sandier strata on the underlying Hatchetigbee Formation (corehole C178A, fig. 3) and (2) the presence both updip and downdip of a substantial unconformity separating the sandier strata from both underlying and overlying clay-rich beds. In contrast to the commonly carbonaceous, very fine grained sand, silt, and clay of the Hatchetigbee Formation, the lower Tallahatta sand in the coreholes is similar to the sand in the remainder of the Tallahatta Formation and in the overlying Lisbon Formation of the Claiborne Group in that it is coarser grained and more calcareous. These basal Tallahatta sandy beds thus mark the beginning of a genetically related sedimentary package characteristic of the entire Claiborne Group in Alabama and western Georgia.

Murray (1955, p. 685) stated that

> the events most prominently impressed on the Coastal Plain Tertiary section are the major transgressions and regressions of the sea over the edge of the continent. It is logical that stages defined in the Coastal Plain should be geared to those cycles. Midway and Sabine stages are considered to include rocks deposited during the first two major Tertiary events of this nature in the Coastal Plain Province.

An important part of the determination of these broad depositional cycles (and thus the stages) has been the recognition of the significance of the unconformities preserved in a section. A striking contact is seen at the base of the downdip Meridian equivalent. Here, medium-grained sand rests upon the carbonaceous clay found at the top of the Hatchetigbee Formation. In Mississippi outcrops, a prominent unconformity also is developed at the base of the Meridian (Lowe, 1933; Gilliland, 1980). A prominent erosional surface in updip exposures in eastern Alabama and western Georgia is present between the Hatchetigbee and the basal Meridian Sand Member of the Tallahatta (Gibson, 1980b).

In the more complete cores used in this study, detectable disconformities sometimes separate sediments that represent each of the three calcareous nannofossil zones (Martini, 1971) in the Tallahatta Formation. The disconformity that exists in the cores between strata placed in calcareous nannofossil Zone NP12 and those placed in Zone NP13 (see the section Biostratigraphy for a detailed discussion of the floral zones) probably represents the disconformity found between the Meridian Sand Member and the remainder of the Tallahatta in updip areas. Therefore, the sand unit found above the clay of the Hatchetigbee Formation in Alabama, both updip and downdip, is placed in the Tallahatta Formation on lithologic grounds, stratigraphic position, and contact relations. This sand is thus considered to be the basal unit of the Claiborne Group.

We are using Claiborne Group and Claibornian Stage in the sense of Toulmin (1977); in Alabama this includes the Tallahatta Formation with its basal Meridian Sand Member, the Lisbon Formation, and the Gosport Sand. The Wilcox Group and Sabinian Stage of Murray (1955) in Louisiana included the Carizzo Sand at the top. Murray and other authors, including Toulmin (1977), considered the Meridian Sand Member in Alabama and Mississippi to be equivalent to the Carrizzo, but no evidence has been presented to date to establish this correlation.

Updip (northern) sections in western Alabama, given in Jones (1967) (locality 69, fig. 1 and table 1) and Scott (1972) (locality A, fig. 1 and table 1), expose a variable thickness of from several feet to several tens of feet of massive to crossbedded sand, commonly gravelly at the base, which is generally referred to as the Meridian Sand Member. The best developed and thickest sections of the Meridian are found in eastern Mississippi, where the sand may be as thick as 225 feet and consists of massive to highly crossbedded, lignitic to nonlignitic sand (Thomas, 1942).

Claystone and siltstone with large amounts of cristobalite dominate the middle part of the Tallahatta in central and western Alabama, as seen both in the coreholes downdip (fig. 3) and in updip outcrops (Toulmin, 1977). These siliceous beds continue into Mississippi where they are called the Basic City Shale Member of the Tallahatta (Toulmin, 1977). Sand, which is commonly glauconitic, is prominent in the downdip part of the upper Tallahatta both at Little Stave Creek (Bandy, 1949; Toulmin, 1962) and in corehole

C178A (fig. 3), although clayey intervals also are common. The dominance of sand in the upper part of the formation continues to the west, where the Neshoba Sand Member is the highest part of the Tallahatta in Mississippi (Toulmin, 1977).

BIOSTRATIGRAPHY

The previous scarcity of information on the age of the Tallahatta probably resulted from limited sampling and the sparseness of microfossils in many outcrops. The Tallahatta Formation customarily has been placed in the lower part of the middle Eocene, mainly on the basis of its molluscan assemblage (Toulmin, 1977). Bandy (1949, p. 7), studying the Foraminifera from Little Stave Creek, placed the Tallahatta in the middle Eocene. This placement was not based on foraminifers because, as he stated, "the hitherto unreported fauna from the Tallahatta cannot be compared with others, inasmuch as little foraminiferal work has been published upon the Lower Claiborne." Our examination of his species lists did not reveal any diagnostic species of planktonic foraminfers. In a study of calcareous nannofossils from California, Bramlette and Sullivan (1961) established several local biostratigraphic units for the Paleocene and Eocene. They considered at least part of the Tallahatta to be possibly assignable to their lowest middle Eocene Biostratigraphic Unit 4. However, they listed neither species nor localities for their Tallahatta samples. On the basis of their California samples, Bramlette and Sullivan (1961) reported that Biostratigraphic Unit 4 contained the FAD's (first appearance datum) of *Discoaster sublodoensis* (pl. 1, figs. 4 and 5), *Lophodolithus mochlophorus* (pl. 2, fig. 6), *Blackites tenuis, Chiphragmalithus acanthodes*, and *Pemma basquense*; we would place this unit within Zone NP14 of Martini (1971). Hay and others (1967) considered at least part of the Tallahatta to belong in their *Discoaster lodoensis* Zone (which is equivalent to Martini's Zone NP13), but they included Biostratigraphic Unit 4 of Bramlette and Sullivan in their overlying *Discoaster sublodoensis* Zone (equivalent to Martini's Zone NP14). Hay and Mohler (1967, p. 1523) stated that "according to Bramlette and Sullivan (1961), samples from the Tallahatta Formation have a meager nannofossil assemblage that is similar to their Unit 4, which would be indicative of the *Discoaster lodoensis* Zone or higher." Hay and Mohler (1967) stated that they collected a sample from the Tallahatta Formation just below the Point "A" Dam, Covington County, Ala., but they gave no species list or age determination. In the current study, a sample from this locality also was collected and examined. In summary, the Tallahatta has been considered in past studies to belong in zones equivalent to Zones NP13 or NP14.

In the current study, microfossils are sparse or absent in most updip sections, but both calcareous nannofossils and foraminifers are more abundant in the further downdip sediments exposed along the river sections and in the five coreholes examined for this study. Planktonic foraminifers are present in low percentages (commonly from 2-7 percent) in many samples and generally lack diagnostic species for correlation and dating. Calcareous nannofossils, however, are generally more abundant and diverse and much more useful in dating the Tallahatta.

We examined 100 corehole and 58 outcrop samples for calcareous nannofossils from the freshest, most calcareous, and most marine intervals; of these, 49 samples were barren. Of the remaining 109 samples, many contained a diverse calcareous nannofossil assemblage, and we were able to place the Tallahatta Formation within calcareous nannofossil Zones NP12 to NP14 of Martini (1971) (figs. 4-8). Bybell (1975) examined the Tallahatta at Little Stave Creek, Ala., with a light microscope and placed the upper part of this formation in the *Reticulofenestra umbilica-Sphenolithus furcatolithoides* Zone of Gartner (1971), which Gartner equated with the planktonic foraminiferal Zone P11 of Blow (1969). Bybell 1975) also reported the occurrence of the calcareous nannofossil species *Reticulofenestra umbilica* from the Tallahatta at Little Stave Creek. The FAD of this species marks the base of the upper middle Eocene *Reticulofenestra umbilica* Zone of Bukry (1973, 1978). The species also has been used to approximate the base of Martini's Zone NP16 when *Rhabdosphaera gladius* is sparse or absent. Reexamination in the current study of these Tallahatta sediments from Little Stave Creek with the scanning electron microscope revealed that, instead of *R. umbilica*, the species actually present is *Reticulofenestra dictyoda* (pl. 2, figs. 1 and 2), a form that is similar to *R. umbilica* but which occurs in much older sediments. *Dictyococcites bisectus* and *Lanternithus minutus*,two species with their FAD's also in Zone NP16, were reported by Bybell (1975) from one Tallahatta sample. These occurrences could not be confirmed in the current study, and the presence in this sample is attributed to contamination.

Discoaster sublodoensis (pl. 1, figs. 4 and 5), the FAD of which defines the base of Zone NP14, was common in the upper Tallahatta samples

Little Stave Creek

Formation	Tallahatta														Lisbon		
Series	lower Eocene										middle Eocene						
Calcareous Nannofossil Zones (Martini,1971)	NP 14														NP 15 ?		
Species / Sample elevation	0-27'	34'	35'	37'	39'	40'	42'	48'	50'	52'	61'	62'	63'	65'	68'	70'	73'
Blackites creber	BARREN				●		●		●	●	●	●	●	●	●	●	
Blackites scabrosus/spinosus		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Blackites tenuis					●		●		●	●	●		●	●	●	●	●
Braarudosphaera bigelowi								●	●	●	●	●			●	●	●
Campylosphaera dela			●	●	●			●	●		●		●	●	●	●	
Cepekiella lumina		●		●					●		●	●	●	●		●	●
Chiasmolithus bidens/solitus		●	●	●	●		●	●	●		●	●		●	●	●	●
Chiasmolithus grandis		●	●		●		●	●	●			●			●	●	●
Chiasmolithus titus			●	●	●			●	●	●	●	●	●	●	●	●	●
Chiphragmalithus acanthodes		●	●				●										
Coccolithus crassipons																●	
Coccolithus eopelagicus				●	●		●	●				●	●			●	●
Coccolithus pelagicus		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Cruciplacolithus staurion												●	●		●		●
Cyclococcolithus formosis		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●
Cyclococcolithus protoannulus							●								●	●	●
Discoaster barbadiensis			●		●		●	●	●	●		●	●	●	●	●	●
Discoaster elegans		●	●	●	●					●	●	●	●	●			●
Discoaster lodoensis		●															
Discoaster mirus			●	●	●		●	●	●	●	●	●	●	●			
Discoaster sublodoensis		●	●	●	●		●	●	●	●	●	●	●	●			
Discolithina fimbriata			●	●	●			●									
Discolithina multipora				●	●		●			●	●	●	●	●	●	●	
Discolithina pectinata			●	●	●			●	●		●	●		●			
Discolithina wechesensis				●	●				●	●	●		●		●	●	●
Ellipsolithus lajollaensis		●	●				●			●		●					
Goniolithus fluckigeri							●										
Helicosphaera lophota		●	●	●		●		●			●	●	●	●	●	●	●
Helicosphaera seminulum		●	●	●	●	●		●	●	●	●	●	●	●		●	●
Lanternithus minutus																	●
Lithostromation operosum								●									
Lithostromation simplex								●									●
Lophodolithus mochlophorous					●								●			●	●
Markalius inversus		●	●				●	●	●	●	●	●	●	●	●	●	●
Micrantholithus vesper									●		●						
Neochiastozygus dubius			●				●					●					●
Pemma basquense						●		●	●	●		●		●		●	●
Pemma basquense crassum																	●
Pemma rotundum								●	●	●		●			●		●
Reticulofenestra coenura			●	●				●		●		●	●	●	●	●	●
Reticulofenestra dictyoda			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Rhabdosphaera inflata				●	●		●	●	●	●							
Sphenolithus moriformis		●	●	●	●		●	●	●	●	●	●	●		●	●	●
Sphenolithus radians		●	●	●			●	●	●		●	●	●	●		●	
Thoracosphaera spp.		●		●	●		●	●	●	●		●	●	●	●	●	
Transversopontis pulcher		●		●	●	●	●		●		●	●	●		●		
Transversopontis pulcheroides		●	●	●	●		●	●	●	●	●	●	●	●	●	●	●
Tribrachiatus inversus															●	●	
Zygrhablithus bijugatus		●	●		●	●	●	●	●	●	●		●	●	●	●	●
PRESERVATION		G	G	G	G	G	F	G	G	F	G	F	F	F	P	F	G
ABUNDANCE		C	C	A	A	C	C	A	A	C	A	C	C		A	C	A

Figure 4. Occurrence of calcareous nannofossils at Little Stave Creek, Clarke County, Ala. Samples are listed by number of feet above the base of the Tallahatta exposed above the Jackson fault and can be related to columnar charts of Bandy (1949) or Toulmin (1962). Preservation: G, good; F, fair; P, poor. Abundance: A, abundant (10-100 specimens per field of view at X 600); C, common (1-10 specimens per field of view at X 600); F, frequent (1 specimen per 1-10 fields of view at X 600); R, rare (1 specimen per 10-100 fields of view at X 600).

Formation	Bashi		Tallahatta																													
Series	lower Eocene																															
Calcareous Nannofossil Zones (Martini, 1971)	NP 10		NP 12																				?						NP 14			
Species / Sample Depth	189'4"	185'	178'	176'6"	175'	169'	166'	163'	148'6"	142'6"	141'6"	128'	123'	118'	113'6"	107'6"	106'	98'	87'6"	86'	84'	79'	77'	74'6"	70'6"	59'	37'	34'	26'6"	26'	17'6"	16'
		BARREN			BARREN	BARREN	BARREN	BARREN		BARREN					BARREN	BARREN	BARREN		BARREN				BARREN									
Blackites creber																														●		
Blackites scabrosus/spinosus																													●	●		●
Braarudosphaera bigelowi																																●
Campylosphaera dela			●	●					●			●	●									●							●	●		●
Cepekiella lumina																													●	●		
Chiasmolithus bidens/solitus													●									●							●	●	●	●
Chiasmolithus grandis																													●	●		●
Chiasmolithus titus																													●	●		
Chiphragmalithus acanthodes																													●	●		
Chiphragmalithus calathus			●																													
Cocccolithus eopelagicus			●																			●							●		●	●
Coccolithus pelagicus			●	●					●			●	●								●	●							●	●	●	●
Cruciplacolithus spp.																														●		
Cyclococcolithus formosus												●	●	●																		
Discoaster elegans			●	●									●																●	●	●	●
Discoaster limbatus			●																													
Discoaster lodoensis			●	●					●			●	●									●							●			
Discoaster mirus												●	●									●							●	●		●
Discoaster sublodoensis																													●	●	●	●
Discoasteroides kuepperi			●	●					●		●	●	●	●							●	●							●	●		●
Discolithina fimbriata																													●	●		
Discolithina multipora																														●	●	●
Discolithina pectinata												●																		●		
Discolithina wechesensis																														●	●	●
Ellipsolithus lajollaensis																														●		
Ellipsolithus macellus			●																													
Helicosphaera lophota																						●							●	●		●
Helicosphaera seminulum											●	●	●									●							●	●		●
Lithostromation simplex																															●	
Lophodolithus mochophorous																														●		
Lophodolithus nascens			●																													
Markalius inversus																													●	●		●
Micrantholithus vesper																																
Neochiastozygus sp. aff protenus			●	●																												
Reticulofenestra coerna																													●	●	●	●
Reticulofenestra dictyoda																													●	●	●	●
Rhabdosphaera inflata																															●	●
Rhabdosphaera truncata			●																													
Sphenolithus moriformis									●				●																●	●	●	●
Sphenolithus radians			●	●					●													●								●		●
Thoracosphaera spp.	●		●	●								●		●				●				●									●	●
Toweius occulatus			●									●	●																			
Transversopontis pulcher			●	●					●													●										●
Transversopontis pulcheroides			●	●								●	●																●	●	●	●
Transversopontis cf. T. zigzag																														●		
Tribrachiatus contortus	●																															
Tribrachiatus orthostylus			●	●					●		●	●	●							●	●	●										
Zygrhablithus bijugatus																													●	●	●	●
PRESERVATION	P		G	F					P		F	F	F	F				P		F	P	F							F	G	F	P
ABUNDANCE	R		C	F					F		F	F	F	F				R		R	F	F							C	C	C	C

Figure 5. Occurrence of calcareous nannofossils in corehole C178A in Monroe County, Ala. Samples are listed by number of feet below ground level. See figure 4 for an explanation of abundance and preservation symbols.

Corehole C177A

Formation	Tallahatta																													Lisbon
Series	lower Eocene																	middle Eocene												
Calcareous Nannofossil Zones (Martini, 1971)	NP 12											NP 13		NP 14																NP 15
Species / Sample Depth	185'9"	184'6"	182'6"	179'	172'	170'	167'	157'	156'	153'6"	146'6"	146'	145'6"	136'	126'	123'6"	115'6"	91'6"	87'	86'	80'6"	75'	63'	56'	44'	42'6"	36'6"	28'6"	28'2"	27'
Blackites creber	BARREN			BARREN				BARREN	BARREN	BARREN					●		●									BARREN		BARREN	BARREN	●
Blackites scabrosus/spinosus														●	●		●			●		●								
Braarudosphaera bigelowi																														●
Campylosphaera dela					●	●					●		●	●	●		●			●										●
Cepekiella lumina																								●			●			●
Chiasmolithus bidens/solitus			●								●	●	●	●	●	●	●					●		●			●			●
Chiasmolithus gigas																														●
Chiasmolithus grandis														●	●							●		●						
Chiasmolithus titus														●	●		●										●			●
Coccolithus eopelagicus													●	●			●	●				●		●						●
Coccolithus pelagicus		●			●	●	●				●	●	●	●	●	●	●	●		●	●	●	●	●	●		●			●
Cruciplacolithus sp.																	●										●			
Cyclococcolithus formosus						●	●				●		●	●	●		●	●		●	●	●		●			●			●
Cyclococcolithus protoannulus																														●
Discoaster barbadiensis												●					●													●
Discoaster elegans											●			●	●		●	●		●	●	●		●			●			
Discoaster lodoensis					●	●	●				●	●	●		●															
Discoaster mirus													●	●	●		●	●				●					●			●
Discoaster sublodoensis														●	●		●	●		●	●	●					●			
Discoasteroides kuepperi					●						●	●	●				●													
Discolithina fimbriata																	●													
Discolithina multipora														●	●			●												●
Discolithina pectinata																	●													
Discolithina wechesensis																											●			●
Helicosphaera lophota											●	●		●	●	●	●	●									●			●
Helicosphaera seminulum		●									●			●	●	●	●					●		●			●			●
Lithostromation operosum														●																●
Lithostromation simplex															●												●			●
Lophodolithus mochlophorous																											●			
Lophodolithus nascens																								●						
Markalius inversus														●	●		●			●		●					●			
Micrantholithus vesper																														●
Neochiastozygus dubius														●																●
Pemma basquense																														●
Pemma basquense crassum																														●
Pemma rotundum																														●
Pemma serratum																														●
Pemma spp.															●												●			
Reticulofenestra coenura											●			●	●					●	●						●			●
Reticulofenestra dictyoda											●				●		●	●		●				●			●			●
Rhabdosphaera inflata																				●	●	●					●			
Sphenolithus moriformis														●	●		●			●		●					●			●
Sphenolithus radians					●						●	●		●			●													●
Thoracosphaera spp.			●		●	●	●				●	●			●	●					●	●	●	●			●			
Toweius occulatus			●		●	●	●				●	●			●	●					●	●	●	●			●			
Transversopontis pulcher		●			●						●									●		●		●						
Transversopontis pulcheroides						●					●	●		●	●		●	●		●	●	●		●			●			●
Transversopontis cf. T. zigzag																						●					●			
Tribrachiatus orthostylus					●	●	●				●																			
Zygrhablithus bijugatus					●		●							●			●			●							●			●
PRESERVATION		P	F		F	P	P				P	P	P	G	F	F	G	P	P	P	P	F	P	P	P		F			F
ABUNDANCE		F	F		F	F	F				F	F	F	C	C	F	C	F	F	C	C	C	F	F	F		F			A

Figure 6. Occurrence of calcareous nannofossils in corehole C177A in Covington County, Ala. Samples are listed by number below ground level. See figure 4 for an explanation of abundance and preservation symbols.

Corehole C171A																					
Formation	Bashi	Tallahatta																			
Series	lower Eocene																				
Calcareous Nannofossil Zones (Martini, 1971)	NP 10 or 11	NP 12											NP 13					NP 14			
Species / Sample Depth	109'3"	87'6"	85'	81'6"	73'6"	71'6"	70'6"	70'	56'	54'	47'6"	45'	41'	39'	37'6"	35'9"	34'6"	29'	22'	19'6"	18'2"
Blackites creber		BARREN	BARREN										●	●	●						BARREN
Blackites scabrosus/spinosus																		●			
Braarudosphaera bigelowi	●									●											
Campylosphaera dela	●												●	●	●	●	●				
Cepekiella lumina														●				●			
Chiasmolithus bidens/solitus					●	●					●	●	●	●		●	●	●	●	●	
Chiasmolithus expansus														●							
Chiasmolithus grandis																		●		●	
Coccolithus eopelagicus	●													●				●			
Coccolithus pelagicus	●				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Cyclococcolithus formosis												●		●		●		●	●	●	
Discoaster barbadiensis														●				●			
Discoaster diastypus	●																				
Discoaster elegans	●										●										
Discoaster limbatus	●																				
Discoaster lodoensis						●	●	●	●		●	●	●	●	●	●	●	●	●	●	
Discoaster mirus													●	●		●	●				
Discoaster sublodoensis																		●			
Discoasteroides kuepperi	●											●		●			●				
Discolithina fimbriata																		●			
Discolitnina multipora																		●			
Ellipsolithus bolli	●																				
Ellipsolithus macellus	●																				
Helicosphaera lophota													●	●			●	●		●	
Helicosphaera seminulum								●				●	●	●	●	●	●	●			
Lophodolithus nascens	●											●									
Markalius inversus	●								●			●						●		●	
Neochiastozygus dubius														●	●			●			
Neochiastozygus aff protenus	●																				
Sphenolithus moriformis	●				●		●						●				●				
Sphenolithus radians	●			●	●	●						●	●	●	●			●			
Thoracosphaera spp.	●			●	●	●			●		●	●	●	●	●	●	●	●		●	
Toweius craticulus	●																				
Transversopontis pulcher	●											●									
Transversopontis pulcheroides											●	●	●	●	●		●				
Tribrachiatus orthostylus	●					●		●	●		●	●									
Zygodiscus sigmoides	●																				
Zygrhablithus bijugatus	●											●									
PRESERVATION	F			P	P	P	P	P	F	P	F	P	P	F	F	P	P	P	P	P	
ABUNDANCE	F			F	F	F	F	F	F	F	F	C	C	C	C	C	F	C	F	F	

Figure 7. Occurrence of calcareous nannofossils in corehole C171A in Coffee County, Ala. Samples are listed by number of feet below ground level. See figure 4 for an explanation of abundance and preservation symbols.

Corehole	C166G						
Formation	Tallahatta					Lisbon	
Series	lower Eocene		middle Eocene				
Calcareous Nannofossil Zones (Martini, 1971)	NP12	?	NP 14			?	
Species \ Sample Depth	116'	78'	71'	68'	65'	58'	57'
Blackites creber		BARREN	●				
Blackites scabrosus/spinosus			●	●		●	
Campylosphaera dela							
Chiasmolithus bidens/solitus	●					●	
Chiasmolithus grandis			●				●
Chiasmolithus titus					●		●
Coccolithus eopelagicus			●			●	
Coccolithus occulatus							
Coccolithus pelagicus	●		●	●	●	●	●
Cruciplacolithus staurion						●	
Cyclococcolithus formorus	●		●	●	●	●	●
Discoaster barbadiensis					●	●	
Discoaster elegans	●		●	●			
Discoaster lodoensis	●						
Discoaster mirus	●		●	●			
Discoaster sublodoensis			●	●	●		
Discoasteroides kuepperi	●						
Discolithina multipora			●				
Helicosphaera lophota			●		●		
Helicosphaera seminulum			●		●		
Markalius inversus						●	
Reticulofenestra coenura							
Rhabdosphaera inflata			●	●	●		
Sphenolithus radians	●		●		●		
Thoracosphaera spp.	●		●		●		●
Transversopontis pulcher							
Transversopontis pulcheroides			●	●	●		●
Zygrhablithus bijugatus			●	●		●	●
PRESERVATION	F		F	P	F	P	P
ABUNDANCE	C		C	C	C	C	A

Corehole	C167G											
Formation	Tallahatta											
Series	lower Eocene											
Calcareous Nannofossil Zones (Martini, 1971)	?				NP 12						NP 13	
Species \ Sample Depth	105'6"	104'6"	103'	96'	86'	85'2"	82'	76'	73'	71'6"	71'	41'6"
Blackites creber	BARREN											
Blackites scabrosus/spinosus												●
Campylosphaera dela							●				●	●
Chiasmolithus bidens/solitus												●
Chiasmolithus grandis												
Chiasmolithus titus												
Coccolithus eopelagicus											●	
Coccolithus occulatus						●	●					
Coccolithus pelagicus						●	●	●	●	●	●	●
Cruciplacolithus staurion												
Cyclococcolithus formorus						●	●	●	●			
Discoaster barbadiensis												
Discoaster elegans												
Discoaster lodoensis							●		●		●	●
Discoaster mirus												
Discoaster sublodoensis												
Discoasteroides kuepperi												
Discolithina multipora												
Helicosphaera lophota											●	
Helicosphaera seminulum									●		●	
Markalius inversus						●						●
Reticulofenestra coenura												●
Rhabdosphaera inflata												
Sphenolithus radians						●				●	●	
Thoracosphaera spp.							●				●	●
Transversopontis pulcher						●	●					
Transversopontis pulcheroides									●	●	●	●
Zygrhablithus bijugatus											●	●
PRESERVATION						F	F	P	P	P	F	P
ABUNDANCE						F	C	F	F	F	C	C

Figure 8. Occurrence of calcareous nannofossils in corehole C166G and C167G in Early County, Ga. Samples are listed by number of feet below ground level. See figure 4 for an explanation of abundance and preservation symbols.

throughout the study area (figs. 4-8). Neither *Nannotetrina fulgens* (the FAD of which marks the base of Zone NP15) nor any other member of the genus *Nannotetrina* was observed in any Tallahatta samples. The FAD of the genus *Nannotetrina* was proposed by Perch-Nielsen (1977) to indicate the base of Zone NP15 in the absence of *N. fulgens* or when poor preservation made individual species of this genus indistinguishable. In the absence of *Nannotetrina*, the upper 31 feet of fossiliferous Tallahatta sediments exposed at Little Stave Creek would normally be placed within Zone NP14 (figs. 3 and 4); the lower exposed 33 feet are barren of calcareous nannofossils. An additional 100 feet of subsurface Tallahatta, which were projected by Bandy (1949, p. 9) to occur in this area, were not sampled.

Despite the absence of species of *Nannotetrina*, the uppermost Tallahatta at Little Stave Creek could still be in Zone NP15. The genus *Nannotetrina* has been not reported to date anywhere in the eastern Gulf Coastal Plain, and its absence may be due to environmental rather than evolutionary factors. Because of this possibility, the ranges of the taxa *Chiasmolithus gigas* and *Rhabdosphaera inflata* (pl. 1, fig. 6) were examined in an attempt to more accurately date the uppermost Tallahatta. Because the LAD (last appearance datum) of *R. inflata* has been reported at the top of Zone NP14 (Romein, 1979) and the FAD of *C. gigas* has been reported at the base of Zone NP15 (Müller, 1979; Perch-Nielsen, 1977; Romein, 1979), these species could be used as possible alternative markers in place of *Nannotetrina*. However, Müller (1979) reported the LAD of *R. inflata* below the NP14-NP15 boundary, and Okada and Thierstein (1979) and Proto Decima and others (1975) reported the FAD of *C. gigas* above this boundary. At Little Stave Creek, which contains the best preserved calcareous nannofossils in the study area, the LAD of *R. inflata* occurs several feet below the top of the Tallahatta (fig. 4). The uppermost Tallahatta in corehole C177A is barren of calcareous nannofossils (fig. 6). *C. gigas* is present in the basal Lisbon Formation in this core; however, the Tallahatta and Lisbon are separated by an unconformity here. *C. gigas* was not found in the poorly preserved basal Lisbon at Little Stave Creek. Because of these inconsistencies both in the published species ranges of *R. inflata* and *C. gigas* and in this study, one can state only that the uppermost 13 feet of Tallahatta at Little Stave Creek above the LAD of *R. inflata* may be in Zone NP15. Careful examination of upper Tallahatta and basal Lisbon from additional localities in the Gulf Coastal Plain may document the presence of *Nannotetrina* and (or) more accurately define the ranges of *R. inflata* and *C. gigas* and, thus, permit more precise placement of the NP14-NP15 boundary. Zone NP14 age sediments also were present in the upper Tallahatta from four coreholes across Alabama and into Georgia: C178A, C177A, C171A, and C166G (figs. 5-8).

Figure 9 is a composite range chart for Zones NP12 to NP14 based on all the Tallahatta sections in the study area. As seen in this figure, *R. inflata, Chiphragmalithus acanthodes*, and *Ellipsolithus lajollaensis* (pl. 2, fig. 8) occur only in the middle of Zone NP14 and are absent from the lowermost and uppermost part of this zone. Several other species also have their FAD's and LAD's within Zone NP14, and these species can be used to finely subdivide this zone. This information can then be used to interpret an individual section or corehole. For example, in corehole C178A (figs. 3 and 5), the basal NP14 age sediments are presumed missing because the lowest fossiliferous NP14 sediments encountered in the section contain *R. inflata, C. acanthodes*, and *Discolithina wechesensis*. Corehole C177A (figs. 3 and 6), in contrast, contains first the FAD of *D. sublodoensis*, followed by the FAD of *R. inflata* and then *D. wechesensis*, and most, if not all, of basal NP14 appears to be represented in this core. At Little Stave Creek, at least 5 feet of uppermost Tallahatta sediments lack *R. inflata* (figs. 3 and 4). This uppermost Tallahatta may be missing in coreholes C177A and C178A on the basis of the presence of *R. inflata* in each uppermost fossiliferous sample. The Tallahatta sample examined from just below the Point "A" Dam (locality given in Copeland, 1966), which is assumed to be essentially equivalent to the one Tallahatta sample listed in Hay and Mohler (1967), is placed in lower Zone NP14 on the basis of the presence of *D. sublodoensis*, the absence of *R. inflata*, and the presence of *Lophodolithus mochlophorus* and *L. nascens* (fig. 9).

At Little Stave Creek, approximately 27 feet of nonfossiliferous Tallahatta sediments are exposed below the Zone NP14 material (figs. 3 and 4). About 30 miles to the east at corehole C178A, about 50 feet of nonfossiliferous sediments are also below the Zone NP14 material (figs. 3 and 5). However, farther to the east in the most downdip coreholes (C177A, C171A, and C167G), sediments directly underlying Zone NP14 material do contain calcareous nannofossils. They were placed in Zone NP13 (figs. 3, 6, and 8), on the basis of the absence of *Tribrachiatus orthostylus* (pl. 1, fig. 2) (LAD

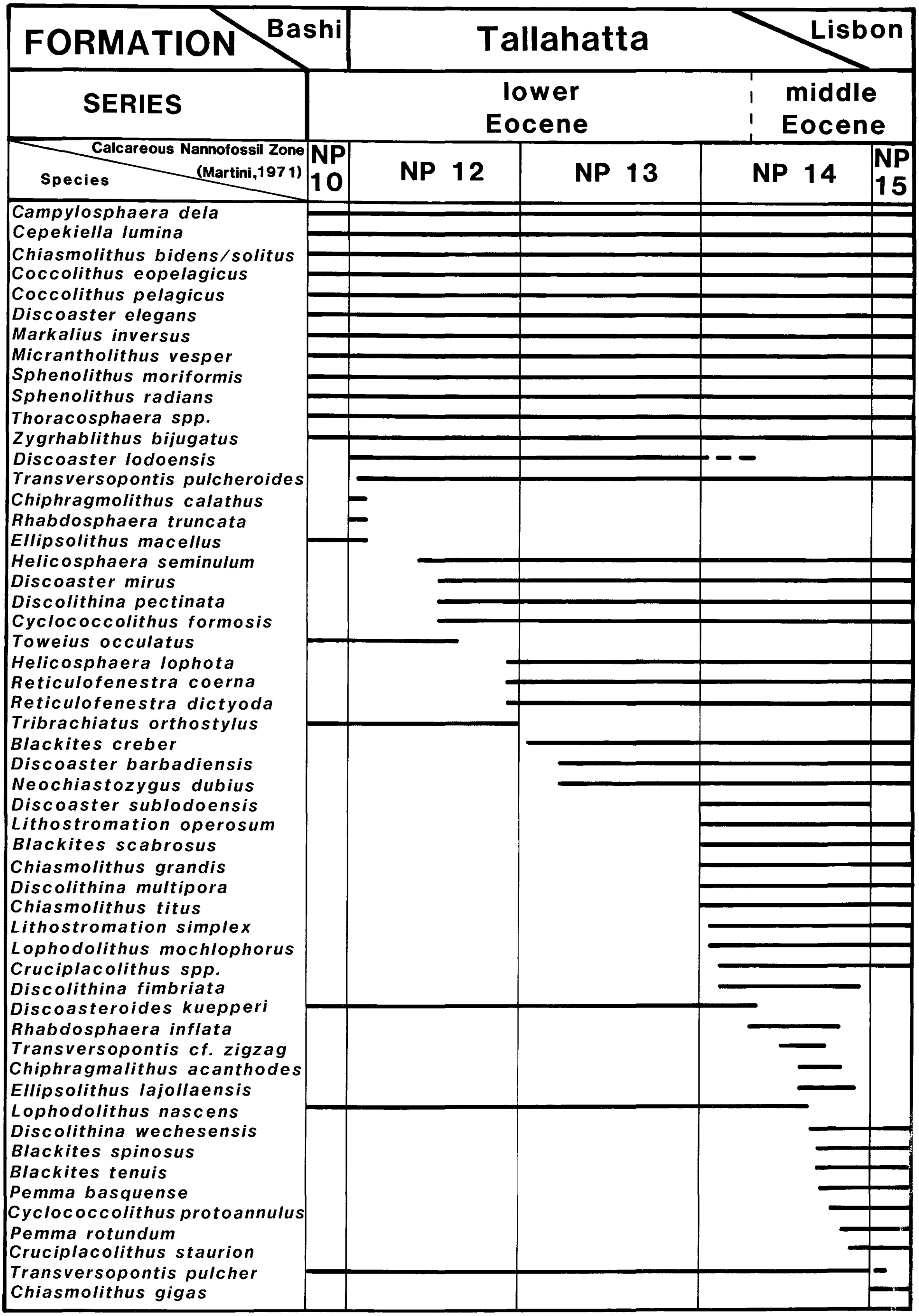

Figure 9. Composite range chart for calcareous nannofossils of the Tallahatta Formation. The chart data were derived from all the localities examined. Small portions of the underlying Bashi and overlying Lisbon Formations are included to indicate which species continue below and above the Tallahatta.

marks the top of Zone NP12), the presence of *Helicosphaera lophota* (pl. 1, fig. 3) (FAD occurs at approximately the top of Zone NP12), and absence of *D. sublodoensis*. *T. orthostylus* has been reported above Zone NP12 elsewhere (Bukry, 1973; Perch-Nielsen, 1977), but this is assumed to be a result of reworking, on the basis of the observed resistance of this species to dissolution in the current study. Because of this possibility for reworking of *T. orthostylus*, Hazel and others (in press) have proposed substituting the FAD of *H. lophota* for the LAD of *T. orthostylus* to define the base of Zone NP13. In the Tallahatta Formation in Alabama, these two horizons are less than 1 foot apart (fig. 6).

The lowest Tallahatta clayey sand, considered to be the downdip equivalent of the Meridian Sand Member, is found in all five coreholes. These beds were placed in Zone NP12 on the basis of the presence of both *Discoaster lodoensis* (pl. 1, fig. 1) (FAD marks the base of Zone NP12) and *T. orthostylus* (LAD marks the base of Zone NP13). *H. lophota* was present only in the uppermost sample of Zone NP12.

As can be seen from the foregoing discussion, the Tallahatta Formation from western Alabama to western Georgia contains calcareous nannofossil Zones NP12, NP13, and NP14. Because the base of the middle Eocene is generally placed either at the base of Zone NP14 (Hardenbol and Berggren, 1978) or in the lower third of Zone NP14 (Haq, in press; Vail and Mitchum, 1979), most of the Tallahatta Formation must be considered to be early Eocene in age.

Forty species of calcareous nannofossils representing 35 FAD's and 14 LAD's occur within the Tallahatta (fig. 9), an interval of 4 to 5 m.y. (fig. 2). The first appearance in the eastern Gulf Coastal Plain within Zones NP12 to NP14 of a large number of new species supports the supposition that the early Eocene was a time when many new calcareous nannofossil species appeared worldwide (Haq, 1973, fig. 2). This apparently sudden and significant increase in calcareous nannofossil diversity could be associated with a global high temperature peak postulated by Haq and others (1977, p. 3871) and Haq (1981, p. 76) to have occurred at this time.

PALEOENVIRONMENTAL ANALYSIS

Several prominent erosional surfaces are present within the Tallahatta in most of the cores; these surfaces are characterized by a sharp lithologic change and by burrowing for as much as 3 feet downward from the hiatus. The erosional surfaces correspond in several places to calcareous nannofossil zonal boundaries. This correspondence suggests that the surfaces may represent missing sediments and that the strata contained within one calcareous nannofossil zone may represent a complete transgressive-regressive cycle, the top of which was truncated during the onset of the succeeding cycle.

Foraminiferal assemblages were used to determine any discernible environmental changes, particularly water depths, within these apparent cycles. Relative water depths, once determined from the foraminifers, could then be compared to global patterns of coastal onlap associated with sea-level fluctuations postulated by Vail and Mitchum (1979) (fig. 10). Relative water depth is

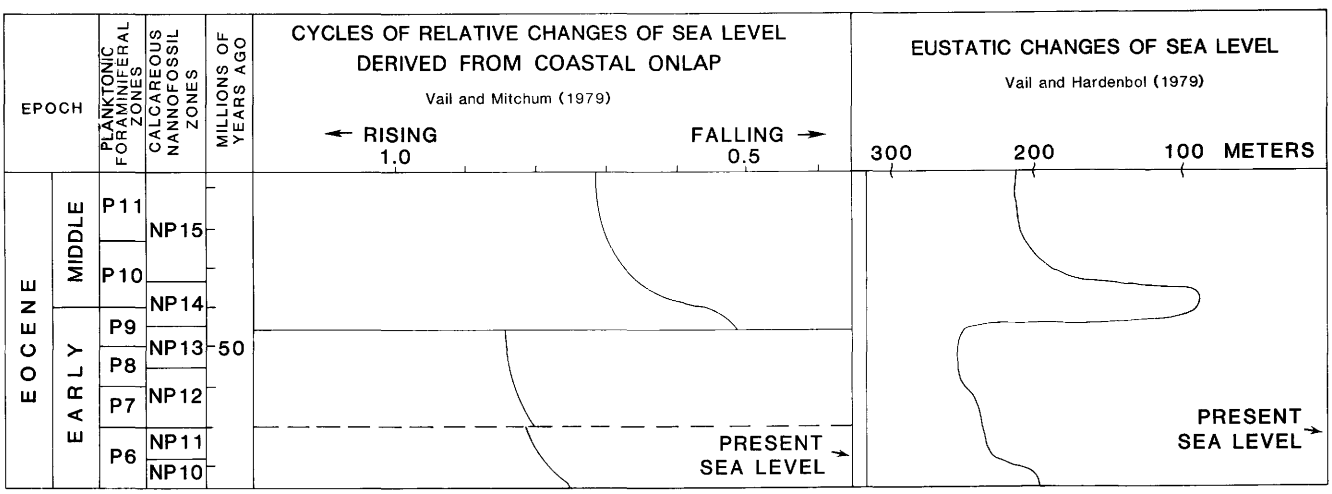

Figure 10. Coastal onlap curve from Vail and Mitchum (1979) and eustatic sea-level curve from Vail and Hardenbol (1979) for the early and middle Eocene.

derived from two parameters: (1) foraminiferal species diversity and (2) the percentage of planktonic specimens relative to the entire foraminiferal assemblage. The total species diversity is assumed to increase with increasing water depth (Gibson and Buzas, 1973), and the relative percentage of planktonic specimens also is assumed to increase with distance from shore or greater water depths (Grimsdale and van Morkhoven, 1955; Boltovskoy and Wright, 1976; Gibson, 1980a). A foraminiferal environmental index, *tau*, proposed by Gibson (1981), is the product of planktonic percentage times the total number of species in the sample. This index accentuates the difference between shallow and deeper marine waters by extending values over four orders of magnitude. Figure 11 is a plot using data from Parker (1954) on modern assemblages in the adjacent northeastern part of the Gulf of Mexico. Observe that the *tau* values increase gradually with increasing depth on this log-log plot with a steeper increase in the deepest samples. Although the *tau* values may vary from region to region because of differences in species diversity and (or) planktonic percentage, the *tau* value is thought to accurately reflect the depth similarities or differences, especially on an order of magnitude basis, within one depositional basin averaged over a relatively short period of time (a few millions of years). The plot of the *tau* value for corehole C171A and adjacent outcrops (fig. 12) shows a relatively low value in the lower Zone NP12 strata, with a considerable increase in value in upper NP12 strata. This change presumably indicates a deepening of the waters in this area as a result of either a eustatic sea-level rise or subsidence, or

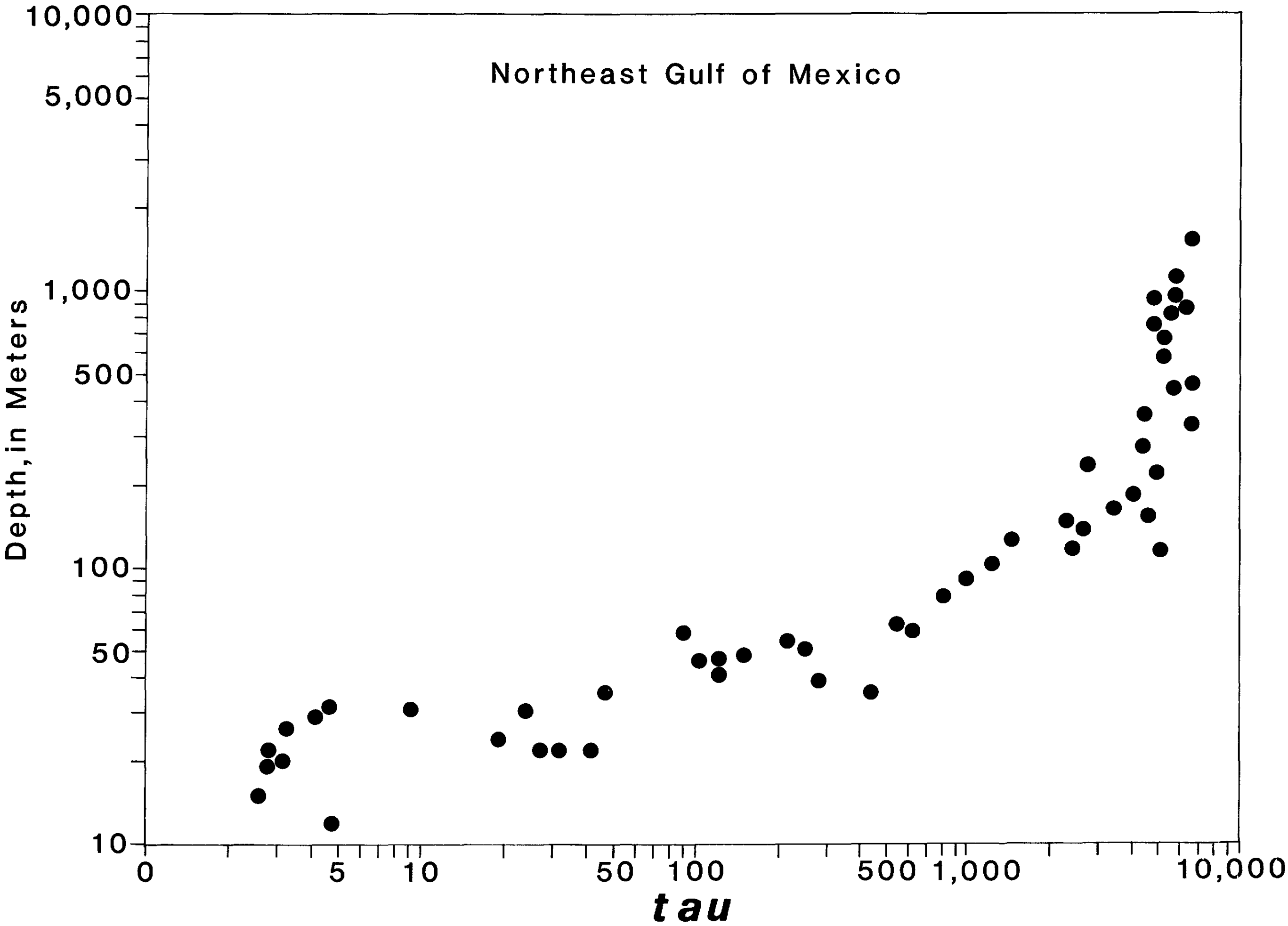

Figure 11. *Tau* values of modern foraminiferal assemblages from the northeastern Gulf of Mexico plotted versus sample depth on a log scale (date from Parker, 1954). *Tau* (Gibson, 1981) is the product of planktonic percentage times the total number of species in a sample.

both, during Zone NP12 time. A similar pattern in the rise in relative sea level was proposed by Vail and Hardenbol (1979) and Vail and Mitchum (1979) for this time interval. Compared to samples in the lower part of Zone NP12, those placed in Zone NP13 have relatively high *tau* values, and some from Zone NP14 have even higher. These values suggest that water depths during deposition of Zone NP14 age strata in this part of Alabama were as great or greater than those occurring during Zone NP13 and the upper part of Zone NP12. The coastal onlap curves of Vail and Mitchum (1979) and sea-level curves of Vail and Hardenbol (1979) (fig. 10) represented Zone NP13 as a time of higher sea-level stands than those of Zone NP12. The curves depicted Zone NP14 as a period of significant sea-level lowering, with depths lower than any observed for Zones NP12 or NP13. The *tau* values for the Tallahatta Formation in corehole C171A in central Alabama, however, indicate that, although sea level was considerably higher in Zone NP13 time than in Zone NP12 time, a large drop in sea level during Zone NP14 time did not occur. This apparent deviation from global patterns may have resulted from localized structural activity in central Alabama, but only a detailed analysis of the relation between sea-level stand and fossil zones during this time interval elsewhere in the Gulf Coastal Plain can resolve this problem.

THE TALLAHATTA AND THE AGE OF THE CLAIBORNIAN STAGE

The Claiborne Group, as used in Alabama, consists (in ascending order) of the Tallahatta, Lisbon, and Gosport Formations (Toulmin, 1977). The Meridian Sand Member (as discussed in the

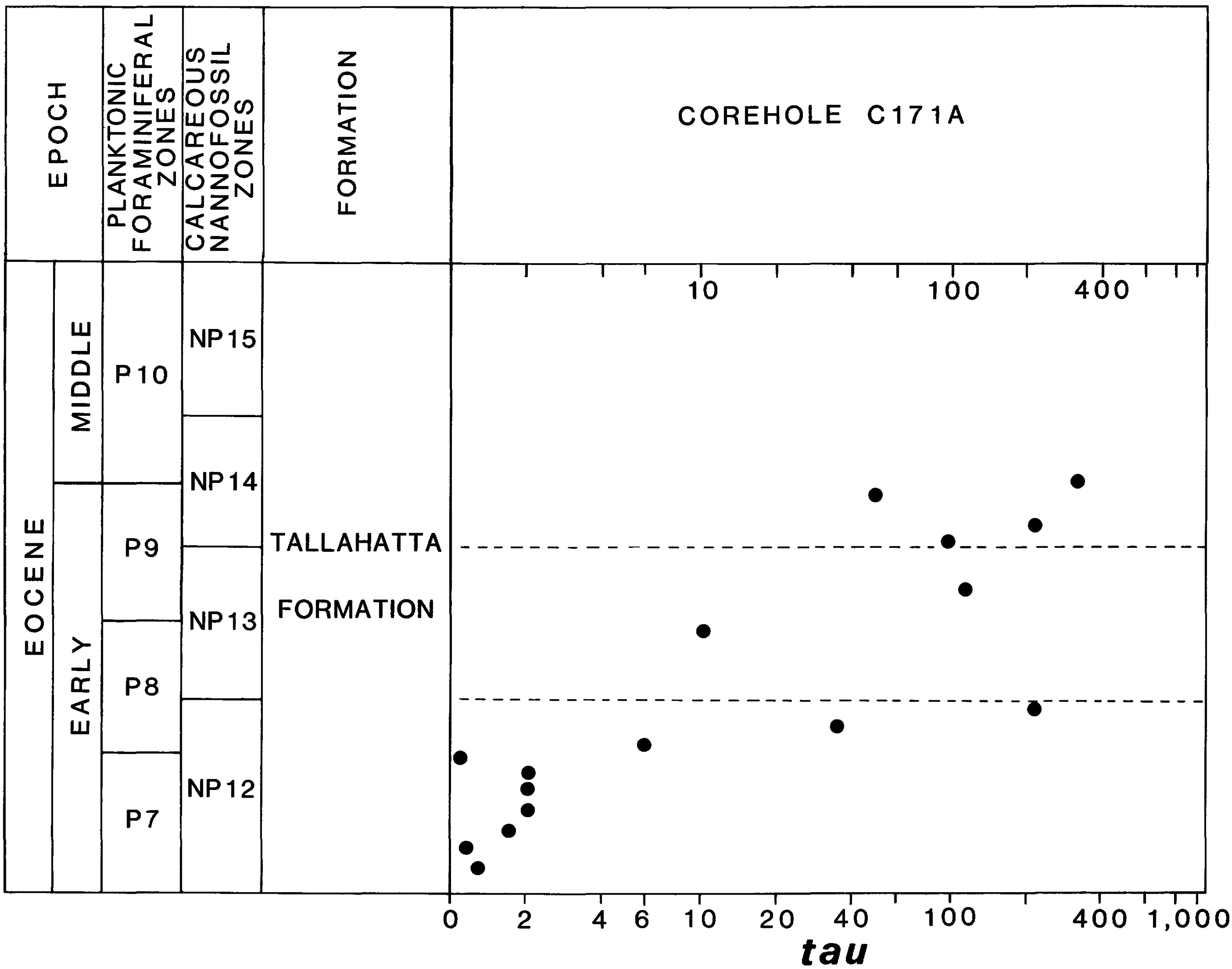

Figure 12. *Tau* values of foraminiferal assemblages from the Tallahatta Formation in corehole C171A, south of Elba, Ala. *Tau* (Gibson, 1981) is the product of planktonic percentage times the total number of species in a sample.

section Lithostratigraphy) forms the basal portion of the updip Tallahatta Formation in parts of western Alabama and Mississippi and has been recognized in easternmost Alabama (MacNeil, 1946). The limits of the Claiborne Group form the basis for the Claibornian Stage, so more accurate dating of the Tallahatta Formation by means of calcareous nannofossils has made possible a more accurate definition of the base of this stage. Zones NP12, NP13, and NP14 are recognized in the Tallahatta (see Lithostratigraphy). Zones NP12 and NP13 are exclusively early Eocene in age, and Zone NP14 probably straddles the early-middle Eocene boundary. Therefore, the Claibornian Stage represents a significant amount of early Eocene time, and the lower boundary of the Claibornian Stage (the base of the Tallahatta) does not correspond to the early-middle Eocene boundary. The Sabinian-Claibornian Stage boundary occurs at approximately 52 m.y., while the early-middle Eocene boundary is approximately 3 m.y. later (fig. 2). The underlying Bashi and Hatchetigbee Formations, the uppermost units of the Wilcox Group and the Sabinian Stage (Gibson, 1983), were placed in the lowermost Eocene Zone NP10 (Gibson and Bybell, 1981) (fig. 2). Recently, in central Alabama, an additional depositional cycle was recognized in these formations that may represent Zone NP11 (Bybell, unpub. data). The large unconformity of at least 2.6 m.y., which Gibson and Bybell (1981) previously believed to exist in the eastern Gulf Coastal Plain between the Sabinian and Claibornian Stages (or the Bashi-Hatchetigbee and Tallahatta Formations), was decreased through examination of additional material from more downdip localities (particularly from the coreholes) in the current study. This Sabinian-Claibornian separation now appears to be only about 1 m.y. in most localities examined (corehole C178A, outcrops along the Pea River, and along the Chattahoochee River) and perhaps less than 1 m.y. in central Alabama (C171A) where Zone NP12 age Tallahatta strata rest disconformably upon possible Zone NP11 age Bashi.

CONCLUSIONS

Detailed study of the lithologies, calcareous nannofossils, and planktonic and benthonic foraminifers of the Tallahatta Formation in the central Gulf Coastal Plain leads to the following conclusions:

1. The Meridian Sand Member is considered to be the basal member of the Tallahatta Formation on the basis of lithologic association, superposition, and boundary relations.
2. The Tallahatta in the study area is represented by calcareous nannofossil Zones NP12, NP13, and NP14, and most of the formation is thus early Eocene in age.
3. The Sabinian-Claibornian boundary in Alabama occurs approximately 3 m.y. before the lower-middle Eocene boundary.
4. It is now possible to more finely subdivide Zones NP12 to NP14 by using the detailed calcareous nannofossil composite range chart for the central Gulf Coastal Plain.
5. The lower Eocene in the Gulf Coastal Plain represented a time of significant increase in calcareous nannofossil diversity, possibly associated with a high global temperature peak at this time.
6. On the basis of the foraminiferal environmental index *tau*, during Zone NP12 time, relative sea level rose in the central Gulf Coastal Plain. Sea level was even higher in Zone NP13 time and continued to be high throughout Zone NP14 time. This contrasts with the coastal onlap curve of Vail and Mitchum (1979) that postulates a significant sea-level drop for Zone NP14.

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PLATES 1 AND 2

Contact photographs of the plates in this report are available, at cost, from the U.S. Geological Survey Library, Federal Center, Denver, CO 80225.

PLATE 1

Figure 1. *Discoaster lodoensis* Bramlette and Riedel (× 1,700). Corehole C171A 39′.

2. *Tribrachiatus orthostylus* Shamrai (× 3,900). Corehole C178A 178′.

3. *Helicosphaera lophota* (Bramlette and Sullivan) Locker (× 4,900). Little Stave Creek 37′.

4-5. *Discoaster sublodoensis* Bramlette and Sullivan.
- 4. Proximal view (× 3,700). Little Stave Creek 37′.
- 5. Distal view (× 5,700). Corehole C177A 136′.

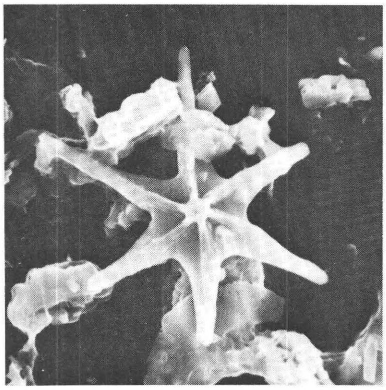
6. *Rhabdosphaera inflata* Bramlette and Sullivan (× 2,600). Little Stave Creek 39′.

7-8. *Transversopontis pulcheroides* (Sullivan) Baldi-Beke.
- 7. Distal view (× 7,800). Little Stave Creek 61′.
- 8. Proximal view (× 6,200). Little Stave Creek 34′.

9. *Helicosphaera seminulum* Bramlette and Sullivan (× 4,400). Little Stave Creek 39′.

10. *Cyclococcolithus formosus* Kamptner (× 5,300). Little Stave Creek 39′.

11-12. *Reticulofenestra coenura* (Reinhardt) Roth.
- 11. Distal view (× 10,000). Little Stave Creek 50′.
- 12. Proximal view (× 10,400). Little Stave Creek 61′.



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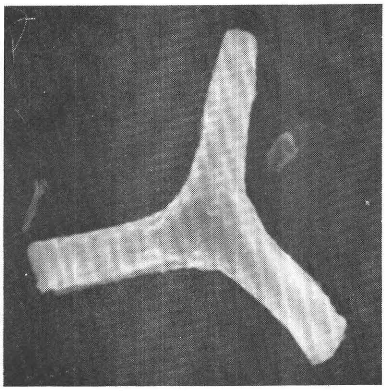

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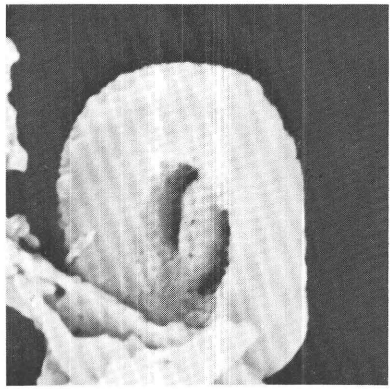

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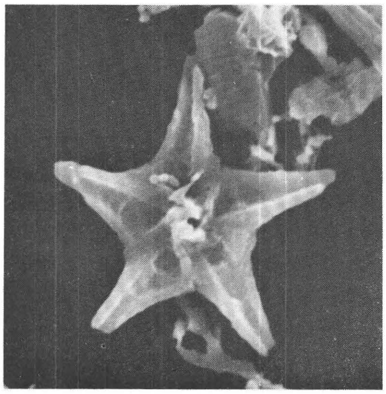

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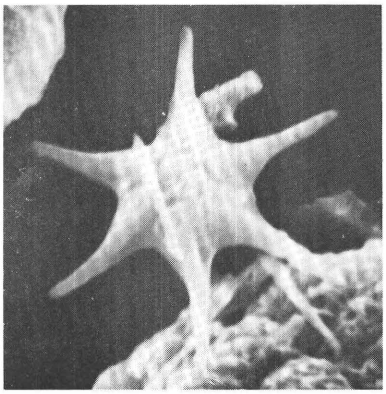

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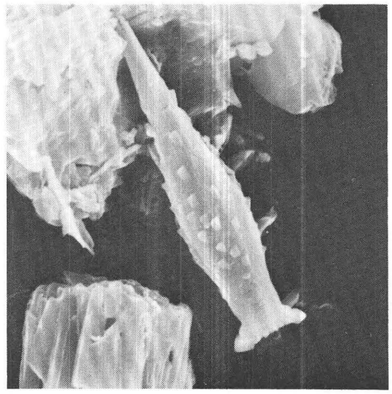

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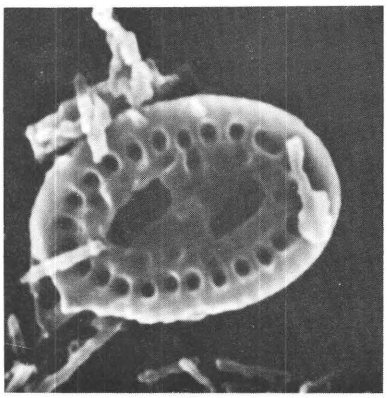

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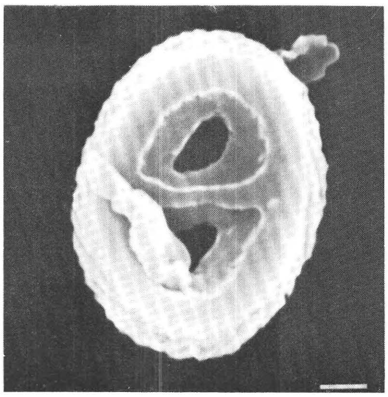

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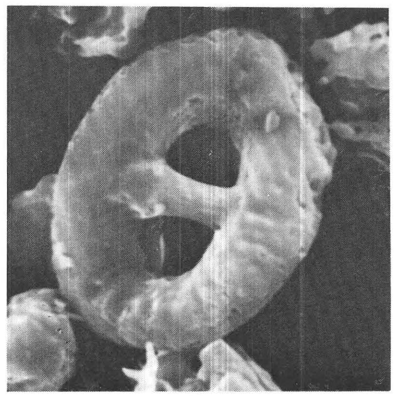

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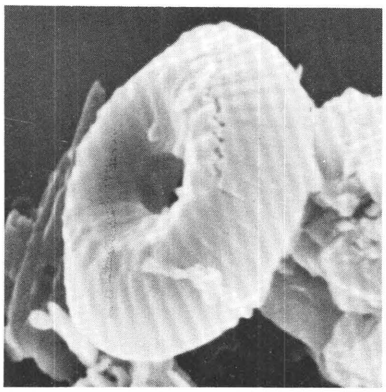

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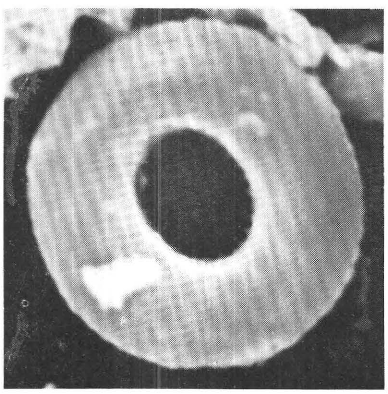

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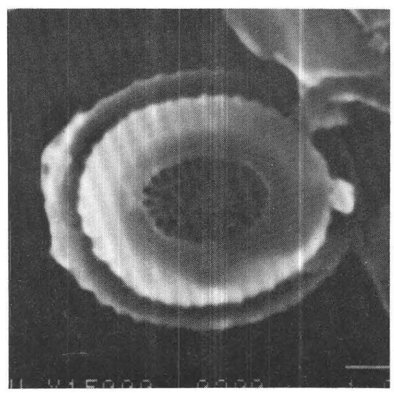

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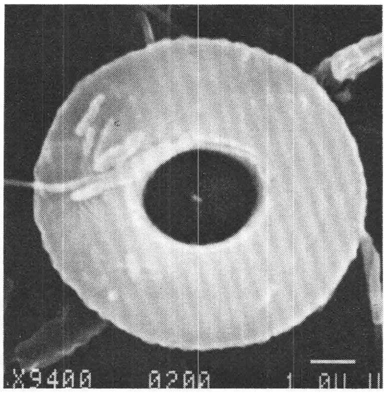
PLATE 2

Figure 1-2. *Reticulofenestra dictyoda* (Deflandre and Fert) Stradner and Edwards.
1. Distal view (× 5900). Little Stave Creek 61′.
2. Proximal view (× 5100). Little Stave Creek 39′.

3. *Blackites creber* (Deflandre) Stradner and Edwards (× 4800). Little Stave Creek 39′.
4. *Blackites scabrosus* (Deflandre) Roth (× 2600). Little Stave Creek 39′.
5. *Chiasmolithus titus* Gartner (× 5000). Corehole C177A 136′.
6. *Lophodolithus mochlophorus* Deflandre (× 3200). Little Stave Creek 37′.
7. *Transversopontis fimbriatus* (Bramlette and Sullivan) Locker 1968 (× 4100). Little Stave Creek 39′.
8. *Ellipsolithus lajollaensis* Bukry and Percival (× 5900). Little Stave Creek 42′.
9. *Blackites spinosus* (Deflandre and Fert) Hay and Towe (×2900). Little Stave Creek 39′.
10. *Discoaster elegans* Bramlette and Sullivan (× 2900). Little Stave Creek 37′.
11. *Campylosphaera dela* (Bramlette and Sullivan). Hay and Mohler (× 5300). Corehole C171A 39′.
12. *Zygrhablithus bijugatus* (Deflandre) Deflandre (× 5400). Little Stave Creek 61′.



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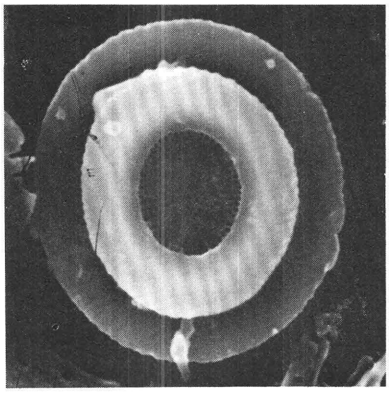
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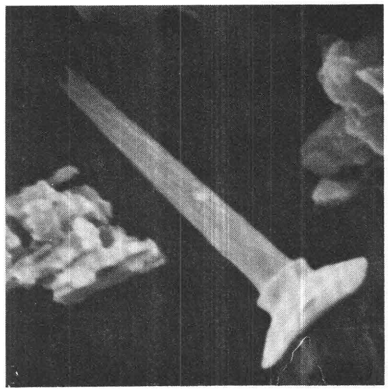
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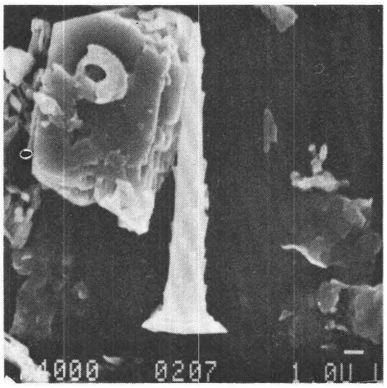

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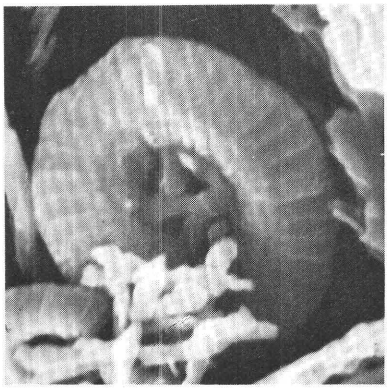
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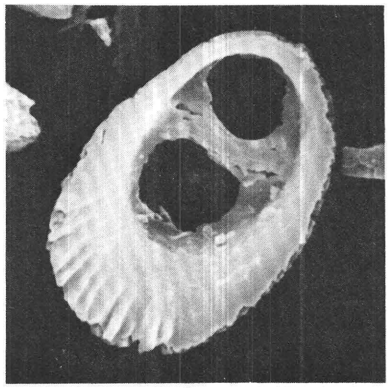
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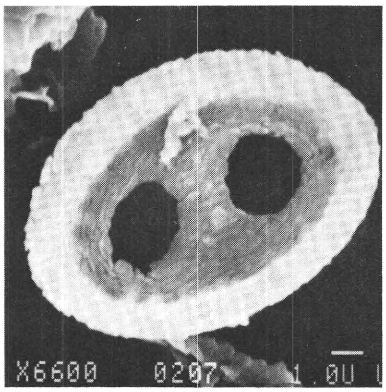

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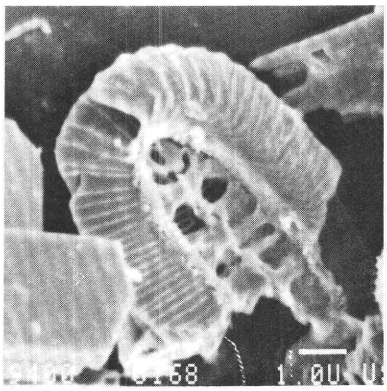

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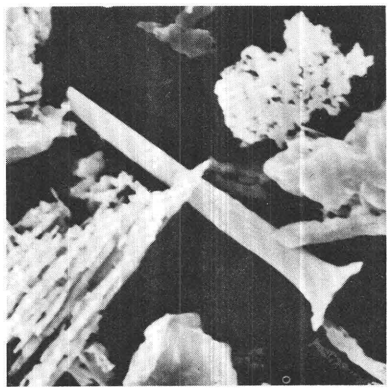
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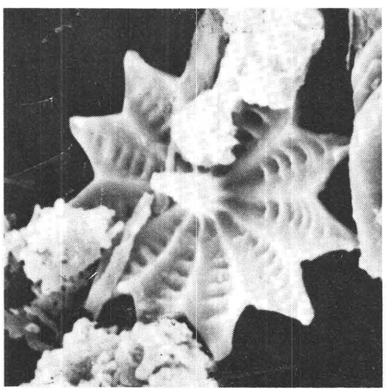
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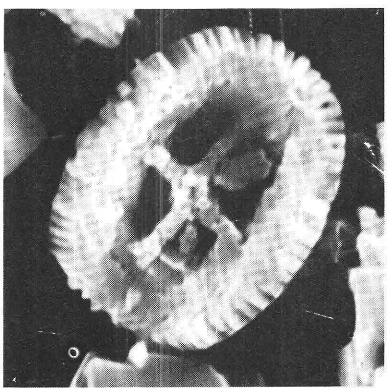
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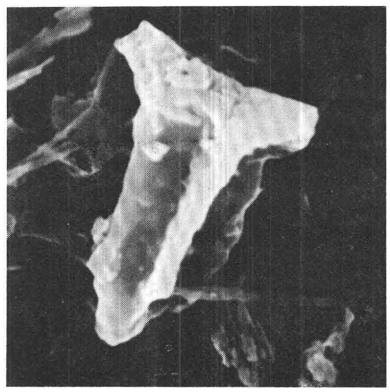
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