**U.S. Department of the Interior
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Dinocyst Biostratigraphy of Tertiary Sediments from Five Cores from Screven and Burke Counties, Georgia

By Lucy E. Edwards

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GEOLOGY AND PALEONTOLOGY OF FIVE CORES FROM
SCREVEN AND BURKE COUNTIES, EASTERN GEORGIA

Edited by Lucy E. Edwards

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ABSTRACT

Dinoflagellate cysts and acritarchs from five cores in Burke and Screven Counties in Georgia reveal a complex pattern of deposition and erosion. Paleocene sediments in the Ellenton Formation include two separate assemblages. The older one is of early Paleocene age (Danian, Midwayan) and contains *Carpatella cornuta* Grigorovich; the younger assemblage contains *Phelodinium* sp. of Edwards (1989, U.S. Geological Survey Professional Paper 1489-C) and is of late Paleocene age (Selandian and Thanetian, Midwayan and Sabinian). *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980, Geological Society of America Field Trip Guidebooks, v. 2, p. 424–427) and *Isabelidinium viborgense* sensu Kurita and McIntyre (1995, Palynology, v. 19, p. 119–136) may be found just below and in the lower part of the upper assemblage.

The Snapp Formation is present in varying thicknesses in four of the five cores. Rare dinocysts are present but are not age diagnostic. The Fourmile Branch Formation is early Eocene and is recognized only in the Thompson Oak core where the Snapp Formation is absent and in the Girard core. Early Eocene dinocysts are conspicuously missing from the Millhaven, Millers Pond, and McBean cores.

Lower middle Eocene sediments of the Congaree Formation containing *Pentadinium favatum* Edwards are present in all cores. The highest occurrence of *Turbiosphaera* cf. *T. galatea* and the lowest occurrence of *Glaphyrocysta* cf. *G. vicina* may mark an important level near the calcareous nannofossil Zone NP 14/NP 15 boundary. Sediments containing both *P. favatum* Edwards and *Pentadinium goniferum* Edwards are found only in the Millhaven core, where they are assigned to calcareous nannofossil Zone NP 15 and to the Warley Hill Formation.

Upper middle Eocene sediments are present in the Santee Limestone in all cores. The lowest occurrences of *Cordosphaeridium cantharellus* (Brosius) Gocht, *Cyclopsella vieta* Drugg & Loeblich, and *Dapsilidinium*

pseudocolligerum (Stover) Bujak et al. are found in the Santee Limestone, and *Hystrichosphaeropsis* Deflandre n. sp. A, *Pentadinium* Gerlach n. sp. D, and *Pentadinium polypodium* Edwards are apparently restricted to the Santee Limestone. Specimens of species of the genus *Wetzeliiella* are present in a few Santee samples but are not common.

Dinocyst recovery is variable in sediments of the Barnwell unit. In the Millhaven core, *Batiacasphaera baculata* Drugg, *Batiacasphaera compta* Drugg, and *Cordosphaeridium funiculatum* Morgenroth indicate a late Eocene age.

Core-to-core correlations based on the dinocyst assemblages show striking variations in units and thicknesses. The oldest Paleocene sediments are thickest in the updip direction. Of the five cores studied, none contains all three of the Fourmile Branch, Congaree, and Warley Hill Formations. Erosion by a paleo-Savannah River may have allowed selective infilling during later transgressions and selective preservation of the stratigraphic units.

INTRODUCTION

The Savannah River Site (SRS) in Aiken, Barnwell, and Allendale Counties, S.C., has manufactured, disposed of, and stored a variety of hazardous materials since the early 1950's. The U.S. Geological Survey, in cooperation with the U.S. Department of Energy and the Georgia Geological Survey of the Georgia Department of Natural Resources, is conducting a study of the subsurface geology, hydrology, and water quality in the vicinity of the SRS. The goal of the study is to understand the actual and possible future ground-water flow in the aquifers of the area. This paper focuses on the Tertiary dinocyst biostratigraphy in Burke and Screven Counties in Georgia, directly across the Savannah River from the SRS (fig. 1).

Dinoflagellates are microscopic algae with a complex life cycle that may include an encysted stage. Chemically resistant dinoflagellate cysts (dinocysts) are abundant and well-preserved fossils in many of the Tertiary sediments in

Figure 1. Index map showing the Savannah River Site and locations of stratigraphic test holes in the study area.

Burke and Screven Counties in Georgia. These rapidly evolving and distinctive fossils produce a detailed biostratigraphic framework for the area. Two distinctive, chemically resistant microfossils of uncertain origin (acritarchs) are also included in this study.

PREVIOUS WORK

Relatively little has been published on the dinoflagellate biostratigraphy of the southeastern United States. Early taxonomic works by Drugg and Loeblich (1967) and Drugg (1970) laid the foundation for later studies. Much of the biostratigraphic information used for correlation with classic Alabama localities is contained in Edwards (1977), and key species were named and documented in Edwards (1982). A preliminary report on the biostratigraphy of the Chattahoochee area in Alabama and Georgia was given in Edwards (1980). Prowell, Christopher, and others (1985) and Prowell, Edwards, and Frederiksen (1985) used dinocysts to help correlate units in the subsurface of Georgia and South Carolina and to help document the ages of stratigraphic units. Firth (1987) documented the dinocyst stratigraphy across the Cretaceous/Tertiary boundary in western Georgia.

More recently, brief papers by Edwards (1992) and Lucas-Clark (1992) have focused on the dinocysts of the

SRS and surrounding areas. Clarke and others (1994, 1996) and Leeth and others (1996) described the geologic and hydrologic data from three of the cores that are used in the present study. Recent papers by Kurita and McIntyre (1995) on the Paleocene of Manitoba, Canada, and by Edwards (1996) on the Eocene of Virginia and Maryland, U.S., show many forms similar to those encountered here.

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MATERIAL AND METHODS

This study is based on the dinocysts from five cores in east-central Georgia (fig. 1). They are discussed in order from most basinward (downdip) to most inshore (updip):

- The Millhaven test hole (33X048) was drilled by the U.S. Geological Survey in 1991–92 in northern Screven County at lat 32°53'25" N., long 81°35'43" W. Surface elevation is 110 ft above sea level.
- The Girard test hole (32Y020) was drilled by the U.S. Geological Survey in 1992 in southern Burke County at the lookout tower on Griffins Landing Road. The test hole is located 2 miles north of the town of Girard at lat 33°03'54" N., long 81°43'13" W. Surface elevation is 250 ft above sea level.
- The Thompson Oak test hole (GGs-3794, TR92–6, Burke 12) was drilled by the Georgia Geologic Survey in 1993 in northeastern Burke County. The test hole is located 21 miles south of Augusta just above the flood plain of the Savannah River at lat 33°10'42" N., long 81°47'10" W. Surface elevation is 240 ft above sea level.
- The Millers Pond test hole (GGs-3758, Burke 2) was drilled by the Georgia Geologic Survey in 1991 in northern Burke County. The test hole is located 2 miles west of the Savannah River and 16 miles south of Augusta, at lat 33°13'48" N., long 81°52'44" W. Surface elevation is 245 ft above sea level.
- The McBean test hole (GGs-3757, Burke 5) was drilled by the Georgia Geologic Survey in 1991 in northern Burke County. The test hole is located on the north shoulder of Collins Road, 1.1 miles east of

the intersection of GA 56 and Collins Road at lat 33°13'38" N., long 81°55'50" W. Surface elevation is 297 ft above sea level.

Core samples were selected on the basis of favorable lithology and providing biostratigraphic coverage. Samples were assigned U.S. Geological Survey paleobotanical numbers by locality and letter designations by depth. Table 1 provides a convenient summary of these. The depth range includes the thickness of the sample as well as the uncertainty of the core recovery; sample depths recorded only to the nearest foot have a least 1 ft of uncertainty in recovery.

Samples were cleaned and scraped and treated with hydrochloric and hydrofluoric acids. The samples were oxidized using nitric acid, stained with Bismark brown, sieved at 20 micrometers, and mounted in glycerin jelly for light-microscope observation. All slides are stored at the U.S. Geological Survey, Reston, Va.

Coordinates for dinoflagellate specimens are given for Olympus Vanox microscope 201526 at the U.S. Geological Survey, Reston, Va. On this microscope, the coordinates for the center point of a standard 25.4×76.2-millimeter slide are 27.5 and 112.7 for the vertical and horizontal axes. The vertical coordinates increase as the stage is moved up, and the horizontal coordinates increase as the slide is moved from left to right. Slide numbers and microscope coordinates of photographed specimens are listed in table 2.

Taxonomy follows Williams and others (1998). Full taxonomic citations for all forms in the text and figures are found in "Taxonomic Notes." In contrast to Williams and others (1998), however, I do not recognize the genus *Tityrosphaeridium* Sarjeant as separate and distinct from the genus *Cordosphaeridium* Eisenack, because both appear to possess cingular processes. Except for the distinctive species that are listed separately, the highly variable plexus that contains members of the genera *Adnatosphaeridium*, *Areoligera*, and *Glaphyrocysta* was considered to be a single taxonomic entity (miscellaneous areoligeraceae, pl. 4, figs. 13, 14).

LITHOSTRATIGRAPHIC FRAMEWORK

Details of the lithostratigraphy are given by Falls and Prowell (this volume, chap. A). They recognize seven Tertiary units, and their terminology and correlations are followed here. However, the individual components of their "Fourmile Branch/Congaree/Warley Hill unit" are discussed separately. The Ellenton Formation is the lowest Tertiary unit and consists of calcareous and noncalcareous sand and clay that is locally glauconitic. It is overlain by the Snapp Formation, a distinctive unlithified sand and overlying white kaolin. The Fourmile Branch Formation is recognized only in the Girard and Thompson Oak cores, where it consists of layers of clay and poorly sorted sand. The Congaree Formation consists of interbedded sand, marl, and limestone in

down dip cores and sand with or without sandy carbonate in more updip cores. The Warley Hill Formation is found only in the Millhaven core and is primarily a carbonate sand. The Santee Limestone is predominantly a carbonate that includes beds of calcareous sand and clay. The Barnwell unit is a mixed lithologic package of sandy limestone, marl, clay, and sand. The Ellenton and Snapp Formations are Paleocene; the Fourmile Branch Formation, Congaree Formation, Warley Hill Formation, Santee Limestone, and Barnwell unit are Eocene (Edwards and others, this volume, chap. B).

DINOCYSTS FROM THE MILLHAVEN CORE

Thirty-three samples were examined for dinocysts in the Tertiary sediments in the Millhaven core, and all but six contained dinocysts. The occurrences of dinocyst taxa in this core are shown in figure 2.

ELLENTON FORMATION (642–570 ft)

Dinocysts in the Paleocene Ellenton Formation in the Millhaven core were studied from eight samples from 639.5–571 ft depth (table 1). The lowest sample (R4664 GC, at 639.5 ft) contains *Areoligera volata* Drugg, *Carpateella cornuta* Grigorovich (pl. 1, fig. 10), *Spinidinium densispinatum* Stanley, *Spinidinium pulchrum* (Benson) Lentin & Williams, and *Tenua* sp. cf. *T. formosa* of Kurita and McIntyre (1995). *Carpateella cornuta* Grigorovich has not been reported from sediments younger than early Paleocene (Danian). Ellenton samples below 635.4 ft have been assigned to calcareous nannofossil Zone NP 4 (Bybell, this volume, chap. F). The early-late Paleocene boundary is within Zone NP 4 (Berggren and others, 1995); the presence of *C. cornuta* Grigorovich indicates that these sediments are from the early Paleocene part of the zone.

The next higher sample (R4664 CH, at 632–632.2 ft) is dominated by small peridiniaceans such as *Senegalinium microgranulatum* (Stanley) Stover & Evitt and contains other forms such as *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant and *Hafniasphaera septata* (Cookson & Eisenack) Hansen, *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980), and *Deflandrea* cf. *D. diebelii* of Drugg (1967). The remaining Ellenton samples contain similar assemblages that include *Damassadinium californicum* (Drugg) Fensome et al. (pl. 2, fig. 3), *Phelodinium* sp. of Edwards (1989) (lowest occurrence in R4664 GD, at 620.8 ft), and *Deflandrea delineata* Cookson & Eisenack (lowest occurrence in R4664 A, at 589 ft, pl. 5, 5.5). *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant and *Fibradinium annetorpense* Morgenroth are present in the highest sample (R4664 D, at 571 ft). Most of the Ellenton has been

Table 1. Samples studied by core with U.S. Geological Survey paleobotanical numbers (R numbers), depth below surface, and geologic unit.

[Fourmile, Fourmile Branch Formation; T/F, discussed in text and figures]

R number	Depth (ft)	Unit	Notes	R number	Depth (ft)	Unit	Notes
Millhaven core				Girard core—Continued			
R4664 AV -----	105	Barnwell	Barren.	R4705 E -----	362–362.3	Congaree	T/F
R4664 AU -----	118	Barnwell	1 dinocyst.	R4705 CF -----	415	Fourmile	T/F
R4664 AT -----	195	Barnwell	1 dinocyst.	R4705 AE -----	415.2–415.5	Fourmile	T/F
R4664 AS -----	205	Barnwell	T/F	R4705 D -----	484.1–484.3	Ellenton	T/F
R4664 AR -----	210	Barnwell	T/F	R4705 C -----	514–514.3	Ellenton	T/F
R4664 AQ -----	216.5	Barnwell	T/F	R4705 AD -----	517.9–518.1	Ellenton	T/F
R4664 AP -----	227.5	Barnwell	T/F	R4705 B -----	521–521.2	Ellenton	T/F
R4664 AO -----	237.5	Santee	Barren.	R4705 A -----	532.5–532.7	Ellenton	T/F
R4664 AN -----	242.5	Santee	Barren.	Thompson Oak core			
R4664 AL -----	260	Santee	Barren.	R4836 R -----	138	Santee	T/F
R4664 AI -----	293	Santee	T/F	R4836 Q -----	154	Santee	T/F
R4664 AG -----	313.5	Santee	T/F	R4836 P -----	164	Santee	T/F
R4664 AC -----	346	Santee	T/F	R4836 O -----	172	Santee	T/F
R4664 Y -----	375	Santee	T/F	R4836 N -----	174	Santee	T/F
R4664 X -----	396	Santee	Barren.	R4836 M -----	181.5	Santee	T/F
R4664 V -----	413	Warley Hill	T/F	R4836 L -----	183	Congaree	T/F
R4664 R -----	442	Warley Hill	T/F	R4836 K -----	192	Congaree	T/F
R4664 O -----	466	Congaree	T/F	R4836 J -----	194	Congaree	T/F
R4664 N -----	473.5	Congaree	T/F	R4836 I -----	210	Congaree	T/F
R4664 L -----	483.5	Congaree	T/F	R4836 H -----	231.5	Congaree	T/F
R4664 K -----	490	Congaree	T/F	R4836 G -----	245	Congaree	T/F
R4664 J -----	495.5	Congaree	T/F	R4836 F -----	255	Fourmile	T/F
R4664 I -----	498.5	Congaree	T/F	R4836 E -----	269	Fourmile	T/F
R4664 F -----	527	Snapp	Barren.	R4836 D -----	281	Ellenton	T/F
R4664 E -----	564–565	Snapp	T/F	R4836 C -----	302	Ellenton	T/F
R4664 D -----	571	Ellenton	T/F	Millers Pond core			
R4664 C -----	577	Ellenton	T/F	R4581 Y -----	72–77	Barnwell	Barren.
R4664 B -----	581	Ellenton	T/F	R4581 X -----	82–83	Santee	Barren.
R4664 A -----	589	Ellenton	T/F	R4581 W -----	120	Santee	T/F
R4664 GE -----	599.5	Ellenton	T/F	R4581 V -----	124	Santee	T/F
R4664 GD -----	620.8	Ellenton	T/F	R4581 U -----	148	Santee	T/F
R4664 CH -----	632–632.2	Ellenton	T/F	R4581 T -----	155	Santee	T/F
R4664 GC -----	639.5	Ellenton	T/F	R4581 S -----	165	Congaree	T/F
Girard core				R4581 R -----	237–242	Ellenton	T/F
R4705 L -----	64.1–64.3	Barnwell	Barren.	R4581 Q -----	252–257	Ellenton	T/F
R4705 K -----	103.6–103.8	Barnwell	Barren.	McBean core			
R4705 J -----	146.6–146.8	Barnwell	T/F	R4663 G -----	181	Santee	T/F
R4705 I -----	211.1–211.3	Barnwell	T/F	R4663 F -----	210	Congaree	T/F
R4705 H -----	257.8–258	Santee	T/F	R4663 E -----	243	Snapp	No dinocysts.
R4705 G -----	321.4–321.6	Santee	T/F	R4663 D -----	264	Snapp	T/F
R4705 F -----	322.3–322.5	Santee	T/F	R4663 C -----	276	Ellenton	T/F
R4705 AF -----	327.3–327.5	Congaree	T/F	R4663 B -----	294	Ellenton	T/F

Table 2. Slide numbers and microscope coordinates of photographed specimens.

[The slide designations show the sample number (table 1) followed by the slide number in parentheses. Coordinates are given for Olympus Vanox microscope 201526 at the U.S. Geological Survey, Reston, Va.]

Figure	Slide	Coordinates	Figure	Slide	Coordinates
Plate 1			Plate 4		
1 -----	R4664 K (1)	31.1×83.0	1 -----	R4664 AI (4)	33.3×76.5
2 -----	R4664 O (3)	20.2×93.2	2 -----	R4664 AI (4)	21.4×74.8
3 -----	R4705 E (2)	33.5×74.5	3 -----	R4836 K (3)	28.4×97.0
4 -----	R4705 D (2)	18.7×80.3	4 -----	R4664 AC (3)	31.4×103.8
5 -----	R4581 Q (4)	22.6×81.2	5 -----	R4664 AC (3)	24.3×72.3
6 -----	R4664 R (4)	27.6×98.4	6 -----	R4705 I (3)	24.0×75.3
7 -----	R4664 AS (1)	30.7×86.0	7 -----	R4705 AD (2)	33.7×76.4
8, 9 -----	R4664 AS (1)	30.2×81.4	8 -----	R4705 G (3)	24.9×90.4
10 -----	R4664 GC (1)	20.4×97.0	9 -----	R4664 AR (1)	35.7×104.9
11 -----	R4664 AS (1)	33.7×78.6	10, 11 -----	R4705 AD (2)	33.6×76.3
12, 13 -----	R4664 K (1)	28.2×79.1	12 -----	R4664 K (1)	30.3×78.0
14 -----	R4664 AC (3)	29.8×81.4	13 -----	R4664 K (1)	31.9×87.1
15 -----	R4705 I (3)	35.6×90.6	14 -----	R4581 R (4)	36.1×91.1
16 -----	R4664 O (3)	34.3×89.4	Plate 5		
17 -----	R4664 AC (3)	27.3×103.4	1 -----	R4581 R (1)	23.2×74.6
18 -----	R4705 I (3)	26.9×94.4	2 -----	R4663 C (4)	21.1×93.5
Plate 2			3 -----	R4581 R (1)	26.0×73.0
1, 2 -----	R4663 B (4)	34.5×93.8	4 -----	R4836 D (3)	22.4×75.2
3 -----	R4664 A (3)	22.1×71.8	5 -----	R4664 A (3)	23.5×92.3
4 -----	R4664 AS (1)	30.9×86.7	6 -----	R4705 AD (2)	27.2×95.5
5 -----	R4664 O (3)	19.4×103.8	7 -----	R4705 CF (1)	32.6×72.4
6 -----	R4664 AQ (2)	37.5×80.7	8 -----	R4705 B (3)	30.5×107.9
7 -----	R4705 E (2)	21.1×75.0	9 -----	R4664 AS (1)	24.6×78.8
8 -----	R4664 A (3)	19.4×97.7	10 -----	R4836 D (3)	18.2×74.6
9 -----	R4664 AR (1)	37.2×84.5	11 -----	R4664 AQ (2)	37.4×98.2
10–12 -----	R4664 O (3)	34.3×76.4	12 -----	R4705 E (2)	17.9×80.4
13 -----	R4705 E (2)	30.4×75.6	13 -----	R4664 A (3)	23.7×82.8
14 -----	R4836 K (3)	26.0×71.1	14 -----	R4663 C (4)	33.4×95.2
15 -----	R4705 G (3)	30.4×89.0	15 -----	R4664 AQ (2)	32.3×86.3
Plate 3			16, 17 -----	R4664 O (3)	26.0×95.7
1 -----	R4836 F (2)	30.0×76.0	18 -----	R4664 V (4)	18.9×81.0
2, 3 -----	R4836 R (3)	22.6×79.6	Plate 6		
4 -----	R4663 G (3)	33.2×94.2	1 -----	R4705 E (2)	29.8×95.6
5 -----	R4663 G (3)	21.9×77.1	2 -----	R4664 AG (4)	34.6×69.6
6 -----	R4664 AC (3)	34.7×84.7	3 -----	R4705 I (3)	23.0×91.7
7–9 -----	R4836 R (3)	17.8×75.3	4 -----	R4664 V (4)	18.3×78.9
10 -----	R4705 AD (2)	26.9×101.6	5 -----	R4581 R (1)	28.8×104.8
11 -----	R4836 E (3)	19.2×89.6	6, 10 -----	R4836 C (3)	32.4×80.8
12 -----	R4705 I (3)	28.9×86.7	7 -----	R4664 K (1)	35.1×91.8
13 -----	R4836 N (4)	35.0×107.8	8 -----	R4705 B (3)	28.9×94.8
14 -----	R4664 O (3)	34.8×85.1	9 -----	R4664 AQ (2)	22.0×74.4
15 -----	R4664 N (2)	30.8×86.6	11 -----	R4664 L (1)	26.9×83.5
16 -----	R4664 AC (3)	35.7×71.7	12 -----	R4581 V (4)	18.3×79.0
17 -----	R4664 AR (1)	36.5×101.9	13 -----	R4664 D (4)	35.3×92.6
18 -----	R4664 AR (1)	26.4×94.9	14 -----	R4664 E (4)	18.9×72.1
19–21 -----	R4836 P (1)	24.1×108.0	15 -----	R4663 C (4)	31.4×91.4
			16 -----	R4581 R (1)	22.7×73.5
			17 -----	R4664 AS (1)	25.3×86.8
			18 -----	R4664 D (4)	29.0×81.0

Figure 2. Range and occurrence chart of dinocysts and acritarchs in the Millhaven core. Lithostratigraphy from Falls and Prowell (this volume, chap. A). R=reworked; cf=compares with; ?=questionably identified; 1=single specimen.

Figure 2. Continued.

assigned to the early late Paleocene calcareous nannofossil Zone NP 5, but the uppermost part of the Ellenton (above 578 ft) has been placed in the middle late Paleocene Zone NP 8 (Bybell, this volume, chap. F).

SNAPP FORMATION (570–504 ft)

A single sample in the Snapp Formation (R4664 E, at 564–565 ft) produced rare, small peridiniacean dinocysts (pl. 6, fig. 14), as well as miscellaneous areoligeracean forms and *Cordosphaeridium* Eisenack sp. This Snapp Formation sample remains undated paleontologically. In this sample, the Snapp is at least marginally marine, unless all specimens are reworked. A higher sample (R4664 F, at 527 ft) did not contain dinocysts.

FOURMILE BRANCH FORMATION (NOT PRESENT)

The Fourmile Branch Formation is not present in the Millhaven core. Sediments containing marine middle Eocene dinocysts directly overlie the Snapp Formation.

CONGAREE FORMATION (504–462 ft)

The dinocyst assemblages in six samples in the Congaree Formation from 498.5–466 ft were studied. All contain *Pentadinium favatum* Edwards (pl. 3, fig. 15). The lower five samples (R4664 I, J, K, L, and N) contain *Turbiosphaera* cf. *T. galatea* (pl. 4, fig. 12), which is reported from the upper part of the Tallahatta Formation in Alabama (Edwards, 1977) and unit E3 of Prowell, Christopher, and others (1985). The absence of *Hafniasphaera goodmanii* Edwards suggests that these samples are of middle Eocene age, rather than early Eocene age, and that lower Eocene sediments are not present in this core. The calcareous nannofossils in these lower samples are assigned to Zone NP 14 (Bybell, this volume, chap. F).

The assemblage at 466 ft (R4664 O) contains the lowest occurrence *Glaphyrocysta* cf. *G. ? vicina* (pl. 2, figs. 10–12) and appears to be correlative with the lowest part of the Lisbon Formation in Alabama (Edwards, unpub. data). This level could be assigned to either calcareous nannofossil Zone NP 14 or NP 15 (Bybell, this volume, chap. F).

WARLEY HILL FORMATION (462–401 ft)

Both *Pentadinium favatum* Edwards and *Pentadinium goniferum* Edwards are present in the samples of the Warley Hill Formation at 442 and 413 ft (R4664 R and V). These species overlap in a thin interval within the lower, but not lowest, part of the Lisbon Formation in Alabama, which has been dated as NP 15 or NP 16 (Wrenn, 1996). It is assigned

to NP 15 in the Millhaven core. The dinocyst assemblages in these samples correspond to those reported in part of the unit E4 of Prowell, Christopher, and others (1985).

SANTEE LIMESTONE (401–228 ft)

Eight samples were examined for dinocysts within the Santee Limestone; four of these are barren. One sample (R4664 Y, at 375 ft) contained only two specimens, both of *Pentadinium goniferum* Edwards. The three remaining samples (R4664 AC, at 346 ft; R4664 AG, at 313.5 ft; and R4664 AI, at 293 ft) produced well-preserved, diverse dinocysts that include *Cordosphaeridium cantharellus* (Brosius) Gocht (pl. 1, fig. 14), *Distatodinium ellipticum* (Cookson) Eaton, *P. goniferum* Edwards (pl. 3, fig. 16), *Pentadinium polypodium* Edwards (pl. 4, fig. 2), *Rhombodinium draco* Gocht (pl. 6, fig. 2), *Samlandia chlamydophora* Eisenack sensu Stover and Hardenbol (1993) (pl. 4, fig. 4), and *Areosphaeridium diktyoplokum* (Klumpp) Eaton. This assemblage is typical of the late middle Eocene and suggests correlation with the upper part of the Lisbon Formation or the Gosport Sand in Alabama. Three samples higher in the Santee (R4664 AL, at 260 ft; R4664 AN, at 242.5 ft; and R4664 AO, at 237.5 ft), as well as one near its base (R4664 X, at 396 ft), are barren. Santee sediments above 368 ft in the Millhaven core have been assigned to late middle Eocene calcareous nannofossil Zone NP 17 (Bybell, this volume, chap. F).

BARNWELL UNIT (228–0 ft)

Seven samples from the Barnwell unit were examined for dinocysts; four were productive, and three are barren or contain only a single specimen.

Samples from the Barnwell unit are above the highest appearance of *P. goniferum* Edwards and are most likely of late Eocene age. The basal Barnwell sample (R4664 AP, at 227.5 ft) contains the lowest occurrence of *Charlesdowniea variabilis* (Bujak) Lentin & Vozzhennikova and *Batiacasphaera baculata* Drugg (pl. 1, fig. 7). Higher samples (R4664 AR, at 210 ft, and R4664 AS, at 205 ft) contain *B. baculata* Drugg or *Batiacasphaera compta* Drugg (pl. 1, figs. 8–9) or both, which suggest correlation with the upper Eocene Yazoo Clay in Alabama, and *Cordosphaeridium funiculatum* Morgenroth (pl. 1, fig. 11), which is found in the Gosport Sand and Moodys Branch Formation (upper middle Eocene) in Alabama and the Parkers Ferry and Harleyville Formations (lower part of the Cooper Group, upper Eocene) in South Carolina (Edwards, 1977; unpub. data). Three samples above 205 ft are barren or nearly so (R4664 AT, AU, AV, at 195, 118 and 105 ft, respectively). Barnwell sediments in the Millhaven core have been assigned to calcareous nannofossil Zones NP 17 and 19/20–21(?) (Bybell, this volume, chap. F).

DINOCYSTS FROM THE GIRARD CORE

Sixteen samples were taken for dinocysts in the Tertiary sediments from the Girard core and all but two contained dinocysts. The occurrences of dinocyst taxa in this core are shown in figure 3.

ELLENTON FORMATION (542–481 ft)

Dinocysts in the Paleocene Ellenton Formation in the Girard core were studied from five samples from 532.7 to 484.1 ft. As in the Millhaven core, both early Paleocene and late Paleocene assemblages were recorded.

The lowest sample (R4705 A, at 532.5–532.7 ft) contains a nondiagnostic dinoflora consisting of small peridiniacean cysts, *Spiniferites* Mantell spp., and a few specimens of the areoligeracean group. The next higher samples (R4705 B, at 521.0–521.2 and R4705 AD, at 517.9–518.1) contain early Paleocene (Danian, Midwayan) dinocysts, including *Carpatella cornuta* Grigorovich, *Tenua* sp. cf. *T. formosa* of Kurita and McIntyre (1995) (pl. 4, fig. 7), *Tectatodinium rugulatum* (Hansen) McMinn (pl. 4, figs. 10, 11) and *Deflandrea* n. sp. aff. *D. truncata* Stover (pl. 5, fig. 8). This assemblage is also dominated by small peridiniacean cysts. The sample R4705 C (at 514.0–514.3 ft) contains a rather sparse dinoflora that includes a fragment questionably identified as *C. cornuta* Grigorovich. The sample R4705 D (at 484.1–484.3 ft) contains a typical late Paleocene (Selandian, late Midwayan) dinoflora, which is also dominated by small peridiniacean cysts and contains *Damassadinium californicum* (Drugg) Fensome et al. and *Phelodinium* sp. of Edwards (1989).

SNAPP FORMATION (481–423 ft)

No samples were taken from the sand and clay of the Snapp Formation in the Girard core.

FOURMILE BRANCH FORMATION (423–390 ft)

Two samples were studied within the Fourmile Branch Formation. The age of these samples is Eocene. However, attempts to determine whether they are early or middle Eocene were inconclusive. In the lower sample (R4705 AE, at 415.2–415.5 ft), *Homotryblum tenuispinosum* Davey & Williams is tentatively identified. A nearby repeat sample (R4705 CF, at 415 ft) recovered a single specimen of *Draconidium varielongitudum* (Williams & Downie) Costa & Downie (pl. 5, fig. 7).

CONGAREE FORMATION (390–325 ft)

Two samples were studied within the Congaree Formation. The lower sample (R4705 E, at 362–362.3 ft) contains a variety of middle Eocene dinocysts that suggest correlation with the lower part of the Lisbon Formation in Alabama. Important species include *Pentadinium favatum* Edwards, *Corrudinium* sp. I of Edwards (1984), *Phthanoperridinium echinatum* Eaton, *Pseudorhombodinium lisbonense* Wrenn (pl. 6, fig. 1), *Samlandia chlamydophora* Eisenack, *Wetzeliiella articulata* Eisenack, *Glaphyrocysta* cf. *G. vicina* (pl. 2, fig. 13), and *Eocladopyxis* Morgenroth n. sp. A (pl. 2, fig. 7). The higher Congaree sample (R4705 AF, at 327.3–327.5 ft) contains a similar dinocyst assemblage.

WARLEY HILL FORMATION (NOT PRESENT)

No samples containing both *P. favatum* Edwards and *P. goniferum* Edwards were found. Sediments correlative with the Warley Hill in the Millhaven core apparently are not present in the Girard core.

SANTEE LIMESTONE (325–250 ft)

Three samples were examined from the Santee Limestone in the Girard core. The lowest Santee sample (R4705 F, at 322.3–322.5 ft) contains a very sparse and relatively nondiagnostic dinocyst assemblage. It does, however, contain the middle Eocene species *Pentadinium goniferum* Edwards. The sample a foot higher (R4705 G, at 321.4–321.6 ft) contains the lowest occurrence of *Cordosphaeridium cantharellus* (Brosius) Gocht. The sample at 257.8–258 ft (R4705 H) contains a well-preserved, diverse dinocyst assemblage that includes *Pentadinium polypodium* Edwards, *Samlandia chlamydophora* Eisenack sensu Stover and Hardenbol (1993), and *Enneadocysta* spp. These and other species present are characteristic of upper middle Eocene sediments correlative with the upper Lisbon Formation and the Gosport Sand (Edwards, 1977; unpub. data) and with unit E5 of Prowell, Christopher, and others (1985).

BARNWELL UNIT (250–0 ft)

Four samples from the Barnwell unit were studied from the Girard core. Sample R4705 I (at 211.1–211.3 ft) contains the species *Rhombodinium perforatum* (Jan du Chêne & Châteauneuf) Lentin & Williams (pl. 6, fig. 3), *Charlesdowniea variabilis* (Bujak) Lentin & Vozzhennikova, and *Corrudinium incompositum* (Drugg) Stover & Evitt (pl. 1, fig. 15). These species suggest a late middle or late Eocene age. The sample R4705 J (at 146.6–146.8 ft) contains a very sparse and nondiagnostic dinocyst

Figure 3. Range and occurrence chart of dinocysts and acritarchs in the Girard core. Lithostratigraphy from Falls and Prowell (this volume, chap. A). cf=compares with; ?=questionably identified.

Figure 3. Continued.

assemblage. Samples R4705 K and L (at 103.6–103.8 and 64.1–64.3 ft) are barren of dinocysts.

DINOCYSTS FROM THE THOMPSON OAK CORE

Sixteen samples were taken for dinocysts in the Tertiary sediments of the Thompson Oak core, and all contained dinocysts. The occurrences of dinocyst taxa in the Thompson Oak core are shown in figure 4.

ELLENTON FORMATION (324–274 ft)

Dinocysts in the Ellenton from the Thompson Oak core were studied from two samples. Both are Paleocene (Danian or Selandian, Midwayan). The lower sample (R4836 C, at 302 ft) is dominated by *Areoligera volata* Drugg and small peridiniaceans. Important species present include *Tectatodinium rugulatum* (Hansen) McMinn, *Damassadinium californicum* (Drugg) Fensome et al., *Tenua* sp. cf. *T. formosa* of Kurita and McIntyre (1995), and *Deflandrea* n. sp. aff. *D. truncata* Stover. The sample lacks *Carpatella cornuta* Grigorovich but contains other species recorded in the early Paleocene samples from the Millhaven, Girard, and Millers Pond cores. The upper sample (R4836 D, at 281 ft) is dominated by small peridiniaceans and contains *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980) (pl. 5, fig. 4) and *Phelodinium* sp. of Edwards (1989). It is of late Paleocene age (Selandian).

SNAPP FORMATION (NOT PRESENT)

The Snapp Formation is not present in the Thompson Oak core. Sediments containing marine Eocene dinocysts directly overlie marine Paleocene sediments.

FOURMILE BRANCH FORMATION (274–251 ft)

Two samples from 269 and 245 ft contain early Eocene dinocysts, including *Hafniasphaera goodmanii* Edwards (pl. 3, fig. 1), primitive forms of *Pentadinium favatum* Edwards, and *Wetzeliiella articulata* Eisenack. The lowest of these contains *Homotryblium abbreviatum* Eaton (pl. 3, fig. 11). These assemblages are likely to be of early Eocene age.

CONGAREE FORMATION (251–182 ft)

Six samples in the Congaree from the Thompson Oak core were studied for dinocysts. The lowest sample (R4836 G from 245 ft) contains the highest occurrence of *Hafniasphaera goodmanii* Edwards. Five samples from 231.5–183.5 ft all contain dinofloras that are roughly correlative

with the upper part of the Tallahatta Formation and the lower part of the Lisbon Formation in Alabama. Sample R4836 H (at 231.5 ft) is more likely correlative with the upper part of the Tallahatta because it contains *Turbiosphaera* cf. *T. galatea*. The three samples from 194–183 ft (R4836 J, K, and L) are more likely correlative with the lower part of the Lisbon because they contain *Glaphyrocysta* cf. *G. ? vicina* (pl. 2, fig. 14). Sample R4836 I (at 210 ft) does not contain sufficient diagnostic taxa.

WARLEY HILL FORMATION (NOT PRESENT)

The Warley Hill Formation is not present in the Thompson Oak core.

SANTEE LIMESTONE (182–130 ft)

Six samples of the Santee Limestone were studied from the Thompson Oak core. The five samples from 181.5–154 ft depth contain a distinctive dinocyst assemblage that includes *Pentadinium goniferum* Edwards, *Pentadinium* Gerlach n. sp. D (pl. 3, figs. 19–21), *Enneadocysta* Stover & Williams spp., *Heteraulacacysta porosa* Bujak, and *Hystrichostrogylon membraniphorum* Agelopoulos (pl. 3, fig. 13). These forms indicate an age in the later part of the middle Eocene and correlation with the upper part of the Lisbon Formation, the Gosport Sand, or the Moodys Branch Formation in the Gulf Coast. The highest Santee Limestone sample (R4836 R, at 138 ft) contains the lowest occurrence of *Cordosphaeridium cantharellus* (Brosius) Gocht.

BARNWELL UNIT (130–0 ft)

Sediments of the Barnwell unit in the Thompson Oak core were not sampled in this study.

DINOCYSTS FROM THE MILLERS POND CORE

Nine samples were taken in Tertiary sediments of the Millers Pond core; seven contained dinocysts, and the uppermost two samples are barren. The occurrences of dinocyst taxa in this core are shown in figure 5.

ELLENTON FORMATION (284–232 ft)

Dinocysts in the Ellenton Formation from the Millers Pond core were studied from two samples (R4581 Q, at 252–257 ft; R4581 R, at 237–242 ft). Both contain dinocyst assemblages of Paleocene age (Danian or Selandian, Midwayan). The lower sample contains *Areoligera volata* Drugg (pl. 1, fig. 5), *Carpatella cornuta* Grigorovich, *Spini-*

The upper sample in the Ellenton contains a distinctive assemblage including *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980) (pl. 5, fig. 3), *Deflandrea* cf. *D. diebelii* of Drugg (1967), *Senegalinium microgranulatum* (Stanley) Stover & Evitt (pl. 6, fig. 5), *Isabelidinium viborgense* sensu Kurita and McIntyre (1995), and *Damassadinium californicum* (Drugg) Fensome et al. The species in this upper sample were reported together in the Porters Creek Clay in Alabama (Edwards, 1980). However, the assemblage could perhaps range into slightly younger sediments, because the Naheola Formation was not included in the 1980 study. Kurita and McIntyre (1995) used the lowest occurrence of *I. viborgense* Heilmann-Clausen to mark the base of the Selandian (earliest late Paleocene) in Manitoba, Canada.

The interval from 232 to 165 ft in the core consisted of coarse sand and thoroughly oxidized kaolinitic clay and was not sampled for dinocysts.

The Fourmile Branch Formation is not present in the Millers Pond core. There is no evidence of early Eocene marine deposition in this core.

Directly above the oxidized clays of the Snapp Formation is a 9-ft-thick unit of silty sand. A sample just above the base (R4581 S, at 165 ft) contains a dinocyst assemblage that includes *Diphyes colligerum* (Deflandre & Cookson) Cookson, *Phthanoperidinium echinatum* Eaton, *Polysphaeridium zoharvi* (Rossignol) Bujak et al., somewhat primitive

Figure 5. Range and occurrence chart of dinocysts and acritarchs in the Millers Pond core. Lithostratigraphy from Falls and Prowell (this volume, chap. A). R=reworked; cf=compares with; ?=questionably identified.

forms of *Pentadinium favatum* Edwards, *Turbiosphaera* cf. *T. galatea*, and *Wetzeliiella articulata* Eisenack. This assemblage correlates with that recorded from the upper part of the Tallahatta Formation in Alabama, which is in the lower part of the middle Eocene.

WARLEY HILL FORMATION (NOT PRESENT)

The Warley Hill Formation is not present in the Millers Pond core.

SANTEE LIMESTONE (156–82 ft)

Five samples from the Santee Limestone were studied from the Millers Pond core. The lowest sample (R4581 T, at 155 ft) contains a diverse dinocyst assemblage including *Achilleodinium biformoides* (Eisenack) Eaton and *Pentadinium goniferum* Edwards, and single specimens of *Pentadinium favatum* Edwards and *Turbiosphaera* cf. *T. galatea*.

This assemblage could represent the interval of overlap of the ranges of *P. favatum* Edwards and *P. goniferum* Edwards, or it could represent a lag deposit at the base of the overlying unit. Because *P. favatum* Edwards and *Turbiosphaera* cf. *T. galatea* are each represented by one poorly preserved specimen, and because *Turbiosphaera* cf. *T. galatea* and *P. goniferum* Edwards do not overlap in other cores, the interpretation of this sample as a lag deposit appears more likely.

Three samples (R4581 U, V, W, at 148, 124, and 120 ft) contain diverse and abundant dinocyst assemblages including *Pentadinium goniferum* Edwards, *Pentadinium Gerlach* n. sp. D, *Samlandia chlamydophora* Eisenack, *Hystrichostrogylon coninckii* Heilmann-Clausen, *Cordosphaeridium cantharellus* (Brosius) Gocht, and *Dapsilidinium pseudocolligerum* (Stover) Bujak et al. This is a late middle Eocene assemblage, correlative with the upper part of the Lisbon Formation, Gosport Sand, or Moodys Branch Formation in Alabama. The uppermost

Figure 6. Range and occurrence chart of dinocysts and acritarchs in the McBean core. Lithostratigraphy from Falls and Prowell (this volume, chap. A). ?=questionably identified.

sample in the Santee Limestone (R4581 X, at 82–83 ft) is barren of dinocysts.

BARNWELL UNIT (82–0 ft)

Barnwell unit sediments were examined for dinocysts in a single sample at 72–77 ft in the Millers Pond core. The sample proved barren.

DINOCYSTS FROM THE MCBEAN CORE

Six samples were taken in Tertiary sediments of the McBean core; five contained dinocysts and one yielded only pollen. The occurrences of dinocyst taxa in this core are shown in figure 6.

ELLENTON FORMATION (305–272 ft)

Two samples from the Ellenton Formation in the McBean core yielded Paleocene (Danian or Selandian, Mid-

wayan) dinocyst assemblages. The lower sample (R4663 B, at 294 ft) includes *Damassadinium californicum* (Drugg) Fensome et al. (pl. 2, figs. 1–2), *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant, and *Tectatodinium rugulatum* (Hansen) McMinn. The upper sample (R4663 C, at 276 ft) includes *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980), *Deflandrea* cf. *D. diebelii* of Drugg (1967), *Hafniasphaera septata* (Cookson & Eisenack) Hansen, *Isabelidinium viborgense* sensu Kurita and McIntyre (1995) (pl. 5, fig. 2), and *P. pyrophorum* (Ehrenberg) Sarjeant. The lower sample is likely to be early Paleocene, as indicated by the presence of *T. rugulatum* (Hansen) McMinn. The upper sample is late Paleocene (Selandian, Midwayan) because of the presence of *I. viborgense* sensu Kurita and McIntyre (1995).

SNAPP FORMATION (272–222 ft)

A single fragmental specimen of the areoligeraceae group was recovered from the sample of the Snapp Forma-

tion at 264 ft (R4663 D) in the McBean core. A second sample (R4663 E, at 243 ft) yielded no dinocysts.

FOURMILE BRANCH FORMATION (NOT PRESENT)

The Fourmile Branch Formation is not recognized in the McBean core.

CONGAREE FORMATION (222–186 ft)

A single sample of the Congaree Formation in the McBean core (R4663 F, at 210 ft) contains the early middle Eocene species *Eocladopyxis* Morgenroth n. sp. A and *Pentadinium favatum* Edwards, and long-ranging species.

WARLEY HILL FORMATION (NOT PRESENT)

The Warley Hill Formation is not recognized in the McBean core.

SANTEE LIMESTONE (186–112 ft)

A single sample of the Santee Limestone in the McBean core (R4663 G, at 181 ft) yielded a diverse middle Eocene dinocyst assemblage. *Heteraulacacysta porosa* Bujak, *Heteraulacacysta pustulosa* Jan du Chêne & Adediran (pl. 3, fig. 5), *Pentadinium goniferum* Edwards, and *Samlandia chlamydophora* Eisenack are present. The assemblage resembles that in the Santee Limestone in the Thompson Oak core.

BARNWELL UNIT (112–0 ft)

Sediments of the Barnwell unit from the McBean core were not sampled in this study.

DISCUSSION

Paleocene sediments in the cores studied include two separate assemblages. The older one is early Paleocene (Danian, Midwayan) and contains *Carpatella cornuta* Grigorovich, *Spinidinium pulchrum* (Benson) Lentin & Williams (pl. 6, figs. 6, 10), *Tectatodinium rugulatum* (Hansen) McMinn, and *Tenua* sp. cf. *T. formosa* of Kurita and McIntyre (1995). This assemblage is assigned to calcareous nannofossil Zone NP 4 in the Millhaven core. The younger assemblage contains *Phelodinium* sp. of Edwards (1989) (pl. 5, fig. 10) and is assigned to calcareous nannofossil Zones NP 5 and NP 8 in the Millhaven core (Bybell, this volume, chap. F). Both assemblages contain *Damassadinium californicum* (Drugg) Fensome et al., *Palaeoperidinium*

pyrophorum (Ehrenberg) Sarjeant, and *Deflandrea* cf. *D. diebelii* of Drugg (1967) (pl. 5, fig. 6) and may be dominated by small peridiniaceans (pl. 6, figs. 13, 15, 16). *Andalusiella* sp. aff. *A. polymorpha* of Edwards (1980) and *Isabelidinium viborgense* sensu Kurita and McIntyre (1995) may be found just below, and in the lower part of, the upper assemblage. Kurita and McIntyre (1995) used the lowest occurrence of *I. viborgense* Heilmann-Clausen to approximate the early-late Paleocene (Danian-Selandian) boundary in Manitoba, Canada. In the Millhaven core, the uppermost Ellenton sample has been placed in calcareous nannofossil Zone NP 8 (Bybell, this volume, chap. F) although the dinocyst assemblage is not noticeably different from assemblages in the samples below it.

The Snapp Formation is present in varying thicknesses in four of the five cores. It is conspicuously absent in the Thompson Oak core, and an upper kaolinitic part is not present in the McBean core. Because the Snapp Formation is present in the most updip cores, it was probably also present in the Thompson Oak area originally but subsequently removed. Marginal marine or marine dinocysts are found in two samples of the lower part of the Snapp Formation in the Millhaven and McBean cores. However, the assemblages are not age diagnostic and could perhaps be reworked from the Ellenton.

Lower Eocene sediments are identified in the Fourmile Branch Formation in the Thompson Oak core on the basis of *Hafniasphaera goodmanii* Edwards and primitive forms of *Pentadinium favatum* Edwards. *Homotryblum abbreviatum* Eaton is also present. Sediments in the Fourmile Branch in the Girard core contain *Dracodinium varielongitutum* (Williams & Downie) Costa & Downie and *Homotryblum tenuispinosum* Davey & Williams and may be of early Eocene age. Early Eocene dinocysts are conspicuously missing from the Millhaven, Millers Pond, and McBean cores.

Middle Eocene Congaree sediments correlative with the uppermost part of the Tallahatta Formation and the lower part of the Lisbon Formation are present in all cores. Samples contain diverse dinocyst assemblages, which include *Achilleodinium biformoides* (Eisenack) Eaton (pl. 1, figs. 1–3), *Diphyes colligerum* (Deflandre & Cookson) Cookson, *Eocladopyxis* Morgenroth n. sp. A, *Glaphyrocysta* cf. *G.?* *vicina*, *Phthanoperidinium echinatum* Eaton (pl. 5, figs. 16, 17), *Pentadinium favatum* Edwards, *Samlandia chlamydophora* Eisenack (pl. 4, fig. 3), *Turbiosphaera* cf. *T. galatea*, *Wetzeliiella articulata* Eisenack (pl. 6, figs. 7, 11), and many areoligeracean forms. The highest occurrence of *Turbiosphaera* cf. *T. galatea* and the lowest occurrence of *Glaphyrocysta* cf. *G.?* *vicina* may mark an important level, correlative with the Tallahatta Formation-Lisbon Formation boundary in Alabama and the E3-E4 boundary (of Prowell, Christopher, and others, 1985) in Georgia. Calcareous nannofossils in the Millhaven core indicate that this boundary is near the NP 14/NP 15 boundary.

Sediments containing both *Pentadinium favatum* Edwards and *Pentadinium goniferum* Edwards are found only in the Millhaven core. It is here they are assigned to the Warley Hill Formation (Falls and Prowell, this volume, chap. A) and to calcareous nannofossil Zone NP 15 (Bybell, this volume, chap. F).

Middle Eocene sediments correlative with the upper part of the Lisbon Formation and the Gosport Sand in Alabama are present in the Santee Limestone in all cores. Assemblages vary from quite diverse to poorly preserved and nondiagnostic. *Pentadinium goniferum* Edwards is present in every sample. The lowest occurrences of *Cordosphaeridium cantharellus* (Brosius) Gocht, *Cyclopsiella vieta* Drugg & Loeblich, and *Dapsilidinium pseudocoligerum* (Stover) Bujak et al. (pl. 1, fig. 18) are found in the Santee Limestone. *Hystrichosphaeropsis* Deflandre n. sp. A (pl. 3, figs. 7–9), *Pentadinium* Gerlach n. sp. D, and *Pentadinium polypodium* Edwards are apparently restricted to the Santee Limestone. *Enneadocysta* spp., various species of *Heteraulacacysta*, and a wide variety of areoligeracean forms are present in the more diverse samples. Species of *Wetzeliella* (pl. 6, fig. 12) are present in a few samples but are not common.

In the Millhaven and Girard cores, the lowest samples in the Santee Limestone are barren or nearly so. In the Millhaven core, the sample at 346 ft contains the lowest occurrences of *Cordosphaeridium cantharellus* (Brosius) Gocht, *Pentadinium polypodium* Edwards, and *Samlandia chlamydophora* Eisenack sensu Stover and Hardenbol (1993). Here, the lowest occurrence of *Cordosphaeridium cantharellus* (Brosius) Gocht approximates the base of calcareous nannofossil Zone NP 17 (Bybell, this volume, chap. F). In the Girard core, the lowest occurrence of *Cordosphaeridium cantharellus* (Brosius) Gocht is just above the base of the Santee Limestone.

Dinocyst recovery is spotty in sediments of the Barnwell unit. In the Millhaven core, samples contain *Batiacasphaera baculata* Drugg, *Batiacasphaera compta* Drugg, and *Cordosphaeridium funiculatum* Morgenroth, which indicate a late Eocene age. In the Girard core, *Rhombodinium perforatum* (Jan du Chêne & Châteauneuf) Lentin & Williams is diagnostic. Both cores contain *Charlesdowniea variabilis* (Bujak) Lentin & Vozzhennikova (pl. 5, fig. 11). In the remaining cores, samples were not taken in Barnwell sediments, except one sample, which was barren (table 1).

Figure 7 shows core-to-core correlations suggested by the dinocyst assemblages. Lower Paleocene sediments are present in all cores, but these may be thicker in the updip cores (McBean, Millers Pond, and Thompson Oak) than in the most downdip core (Millhaven). The younger part of the Ellenton is thinnest in the updip cores.

The Snapp Formation is missing from the Thompson Oak core and truncated in the McBean core. The Fourmile Branch Formation is recognized only in the Girard and Thompson Oak cores. In the Thompson Oak core, the

absence of the Snapp corresponds with the presence of the Fourmile Branch and a thickened Congaree relative to other cores.

The Congaree Formation is middle Eocene. It contains two recognizable dinocyst assemblages, which are equivalent to those found in the upper part of the Tallahatta Formation and the lower part of the Lisbon Formation in Alabama. The Warley Hill Formation is recognized only in the most basinward core (Millhaven).

The Tertiary units in the Burke and Screven County cores studied here show a much more complex history than was anticipated. In these generally shallow marine sediments, local patterns of erosion and deposition are important. A paleo-Savannah River may have wholly or partially eroded units such as the Snapp Formation to allow selective infilling, or selective preservation of more widespread infilling, during later transgressions.

TAXONOMIC NOTES

The species present are listed in Williams and others (1998) and their taxonomic history is not repeated here. Brief synonymies are provided for dinocysts that are presented in open or informal nomenclature. Higher level taxonomy is taken from Fensome and others (1993). Taxa are presented alphabetically by order. For convenience, dates are provided with the authors' names for formal taxa; the works these represent are not included in the references here but may be found in Williams and others (1998). Table 2 provides the slide locations of all figured specimens.

Division DINOFLAGELLATA (Butschli 1885) Fensome et al. 1993

Subdivision DINOKARYOTA Fensome et al. 1993

Class DINOPHYCEAE Pascher 1914

Subclass PERIDINIPHYCIDAE Fensome et al. 1993

Order GONYAULACALES Taylor 1980

ACHILLEODINIUM BIFORMOIDES (EISENACK 1954) EATON 1976

Plate 1, figures 1–3

Remarks.—Both relatively smooth forms and those with striate processes are included.

AMPHOROSPHAERIDIUM? MULTISPINOSUM (DAVEY & WILLIAMS 1966) SARJEANT 1981

Plate 1, figure 4

AREOLIGERA VOLATA DRUGG 1967

Plate 1, figure 5

AREOSPHERIDIUM DIKTYOPOLOKUM (KLUMPP 1953) EATON 1971

Plate 1, figure 6

BATIACASPHAERA BACULATA DRUGG 1970

Plate 1, figure 7

Figure 7. Correlation diagram by dinocyst assemblages for the five Georgia cores. Datum is the base of the Santee Limestone.

BATIACASPHERA COMPTA DRUGG 1970

Plate 1, figures 8, 9

CARPATELLA CORNUTA GRIGOROVICH 1969

Plate 1, figure 10

CEREBROCYSTA BARTONENSIS BUJAK 1980

Plate 1, figures 12, 13

**CORDOSPHAERIDIUM CANTHARELLUS
(BROSIOUS 1963) GOCHT 1969**

Plate 1, figure 14

Remarks.—*Cordosphaeridium* Eisenack 1963 is considered here to be the senior taxonomic synonym of *Tityrosphaeridium* Sarjeant 1981. The holotype of *Cordosphaeridium inodes* (Klumpp 1953) Eisenack 1963 clearly shows cingular processes in the illustration by Sarjeant (1981, text-fig. 1).

CORDOSPHAERIDIUM FUNICULATUM MORGENROTH 1966

Plate 1, figure 11

CORDOSPHAERIDIUM EISENACK 1963 SPP.

Remarks.—The species *Cordosphaeridium fibrospinum* Davey & Williams 1966, *Cordosphaeridium gracile* (Eisenack 1954) Davey & Williams 1966, *Cordosphaeridium inodes* (Klumpp 1953) Eisenack 1963, and forms between these endmembers are not differentiated in this study.

**CORRUDINIUM INCOMPOSITUM
(DRUGG 1970) STOVER & EVITT 1978**

Plate 1, figure 15

CORRUDINIUM SP. I OF EDWARDS (1984)

Plate 1, figure 16

Corrudinium sp. I. Edwards, 1984, pl. 2, fig. 1.

Remarks.—Some forms are transitional to *Cerebrocysta bartonensis* Bujak 1980.

**CRIBROPERIDINIUM GIUSEPPEI
(MORGENROTH 1966) HELENES 1984**

Plate 1, figure 17

**CRIBROPERIDINIUM TENUITABULATUM
(GERLACH 1961) HELENES 1984****DAMASSADINIUM CALIFORNICUM
(DRUGG 1967) FENSOME ET AL. 1993**

Plate 2, figures 1–3

Remarks.—Both typical and elongate forms are included.

**DAPSILIDINIUM PSEUDOCOLLIGERUM
(STOVER 1977) BUJAK ET AL. 1980**

Plate 1, figure 18

DINOPTERYGIUM CLADOIDES SENSU MORGENROTH 1966

Plate 2, figure 4

Dinopterygium cladoides Deflandre. Morgenroth, 1966, pl. 2, fig. 11.

Heteraulacacysta sp. Damassa and others, 1990, fig. 5E, F.
Dinopterygium sp. Stover and Hardenbol, 1993, pl. 12, fig. 83.

**DIPHYES COLLIGERUM (DEFLANDRE & COOKSON 1955)
COOKSON 1965****DIPHYES FICUSOIDES ISLAM 1983**

Plate 2, figure 5

DISTATODINIUM ELLIPTICUM (COOKSON 1965) EATON 1976

Plate 2, figure 9

ENNEADOCYSTA STOVER & WILLIAMS 1995 SPP.

Plate 2, figure 6

Remarks.—Various species of the genus are included.

EOCLADOPYXIS MORGENROTH 1966 N. SP. A

Plate 2, figure 7

Remarks.—The processes resemble those of *Poly-sphaeridium zoharyi* (Rossignol 1962) Bujak et al. 1980, but the separation of the individual paraplates requires placement in the genus *Eocladopyxis* Morgenroth 1966.

FIBRADINIUM ANNETORPENSE MORGENROTH 1968

Plate 2, figure 8

FIBROCYSTA STOVER & EVITT 1978 SPP.

Remarks.—Various species of the genus are included.

**GLAPHYROCYSTA CF. G.? VICINA
(EATON 1976) STOVER & EVITT 1978**

Plate 2, figures 10–15

Remarks.—This form is highly variable in the degree of development of the marginal flanges. It resembles *Membranophoridium aspinatum* Gerlach 1961 in overall appearance, but it is smaller, has less pronounced dorso-ventral compression, and has less prominent flanges. It resembles and may be transitional with *Membranophoridium bilobatum* Michoux 1985, which has narrower flanges and no development of pericoels other than along the margins. It is closest to *Glaphyrocysta? vicina* (Eaton 1976) Stover & Evitt 1978. However, the paracingulum may be more pronounced, and the details of the dorsal and ventral surfaces may warrant separation.

HAFNIASPHAERA GOODMANII EDWARDS 1982

Plate 3, figure 1

Remarks.—The illustrated specimen, like most specimens seen, is actually transitional with primitive forms of *Pentadinium favatum* Edwards.

**HAFNIASPHAERA SEPTATA
(COOKSON & EISENACK 1967) HANSEN 1977**

Plate 3, figure 10

HETERAULACACYSTA POROSA BUJAK 1980

Plate 3, figures 2, 3

**HETERAULACACYSTA PUSTULOSA JAN DU CHÊNE
& ADEDIRAN 1985**

Plate 3, figure 5

HETERAULACACYSTA DRUGG & LOEBLICH 1967 SPP.

Plate 3, figure 6

Remarks.—The species *Heteraulacacysta campanula* Drugg & Loeblich 1967 and *Heteraulacacysta? leptalea* Eaton 1976 and poorly preserved specimens of the genus that are unattributable to species are placed here.

HOMOTRYBLIUM ABBREVIATUM EATON 1976

Plate 3, figure 11

HOMOTRYBLIUM PLECTILUM DRUGG & LOEBLICH 1967

Plate 3, figure 12

HOMOTRYBLIUM TENUISPINOSUM DAVEY & WILLIAMS 1966**HYSTRICHOKOLPOMA CINCTUM KLUMPP 1953****HYSTRICHOKOLPOMA RIGAUDIAE DEFLANDRE
& COOKSON 1955****HYSTRICHOKOLPOMA DEFLANDRE 1935 SPP.**

Remarks.—Various species of the genus are included.

**HYSTRICHOSPHAERIDIUM TUBIFERUM
(EHRENBERG 1838) DEFLANDRE 1937****HYSTRICHOSPHAEROPSIS DEFLANDRE 1935 N. SP. A**

Plate 3, figures 7–9

Remarks.—This small, distinctive form has relatively high septa that are finely serrate distally.

**HYSTRICHOSTROGYLON CONINCKII
HEILMANN-CLAUSEN 1985****HYSTRICHOSTROGYLON MEMBRANIPHORUM
AGELOPOULOUS 1964**

Plate 3, figure 13

**LINGULODINIUM MACHAEROPHORUM
(DEFLANDRE & COOKSON 1955) WALL 1967****MELITASPHAERIDIUM ASTERIUM
(EATON 1976) BUJAK ET AL. 1980****MELITASPHAERIDIUM PSEUDORECURVATUM
(MORGENROTH 1966) BUJAK ET AL. 1980****MILLIOUDODINIUM SP. I OF EDWARDS (1984)**

Plate 3, figure 4

Millioudodinium sp. I. Edwards, 1984, pl. 2, fig. 2.
Cribroperidinium sp. 2. Damassa and others, 1990, fig. 4C.
Cribroperidinium sp. 2. Firth, 1996, pl. 5, figs. 7, 8.

Remarks.—The honeycomb pattern in the intraplate areas is distinctive. This form now correctly belongs in the

genus *Cribroperidinium* Neale & Sarjeant 1962, emend. Helenes 1984.

**MURATODINIUM FIMBRIATUM
(COOKSON & EISENACK 1967) DRUGG 1970****NEMATOSPHAEROPSIS DEFLANDRE & COOKSON 1955 SPP.**

Remarks.—Various species of the genus are included.

**OPERCULODINIUM CENTROCARPUM
(DEFLANDRE & COOKSON 1955) WALL 1967**

Plate 3, figure 14

Remarks.—The species name is used in the broad sense.

OPERCULODINIUM WALL 1967 SPP.

Remarks.—Various species of the genus are included.

PENTADINIUM FAVATUM EDWARDS 1982

Plate 3, figure 15

PENTADINIUM GONIFERUM EDWARDS 1982

Plate 3, figure 16

**PENTADINIUM LATICINCTUM GERLACH
1961 SUBSP. LATICINCTUM**

Plate 3, figure 17

PENTADINIUM LATICINCTUM GERLACH 1961 (VERM.)

Plate 3, figure 18

Pentadinium laticinctum subsp. *granulatum*. Edwards, 1982, pl. 4, figs. 10, 11.

Pentadinium laticinctum (vermicular) Gerlach. Edwards, 1984, pl. 2, fig. 4.

Remarks.—Specimens of *P. laticinctum* Gerlach 1961 with a vermicular surface are separated from *P. laticinctum* Gerlach 1961 subsp. *laticinctum*. The vermicular surface differs from the granular surface of *Pentadinium laticinctum* subsp. *granulatum* Gocht 1969.

**PENTADINIUM MEMBRANACEUM (EISENACK 1965)
STOVER & EVITT 1978**

Plate 4, figure 1

PENTADINIUM POLYPODUM EDWARDS 1982

Plate 4, figure 2

PENTADINIUM GERLACH 1961 N. SP. D

Plate 3, figures 19–21

Remarks.—In this undescribed form of *Pentadinium* Gerlach 1961, the periphragm in the paracingular region is separated from the endophragm only along the ventral side; the wall layers are appressed laterally and dorsally. The wall surface is smooth.

**POLYSPHAERIDIUM ZOHARYI (ROSSIGNOL 1962)
BUJAK ET AL. 1980**

**ROTTNESTIA BORUSSICA (EISENACK 1954)
COOKSON & EISENACK 1961****SAMLANDIA CHLAMYDOPHORA EISENACK 1954**

Plate 4, figure 3

**SAMLANDIA CHLAMYDOPHORA EISENACK SENSU STOVER
AND HARDENBOL (1993)**

Plate 4, figure 4

Samlandia chlamydophora Eisenack 1954. Stover and Hardenbol, 1993, pl. 8, fig. 54 a,b.

Remarks.—This form has considerably more differentiation into separate penetabular process complexes than does the type of *S. chlamydophora* Eisenack 1954.

**SPINIFERITES PSEUDOFURCATUS (KLUMPP 1953)
SARJEANT 1970**

Plate 4, figure 5

SPINIFERITES MANTELL 1850 SPP.

Remarks.—Various species of the genus are included.

**SYSTEMATOPHORA PLACACANTHA
(DEFLANDRE & COOKSON 1955) DAVEY ET AL. 1969**

Plate 4, figure 6

Remarks.—The species name is used in the broad sense. The process complexes are highly variable.

TECTATODINIUM PELLITUM WALL 1967

Plate 4, figure 8

Remarks.—The species name is used in the broad sense. The wall thickness is highly variable. Although some specimens are assignable to *Tectatodinium grande* Williams et al. 1993, they are clearly only endmembers in a spectrum.

TECTATODINIUM RUGULATUM (HANSEN 1977) MCMINN 1988

Plate 4, figures 10, 11

Remarks.—The species name is used in the broad sense. The wall is thicker than the wall in the type specimen.

TENUA SP. CF. T. FORMOSA OF KURITA AND MCINTYRE (1995)

Plate 4, figure 7

Tenua sp. cf. *T. formosa* (Mao & Norris 1988) Lentin & Williams 1993. Kurita and McIntyre, 1995, p. 134, pl. 2, fig. 15.

Remarks.—Like the specimens reported by Kurita and McIntyre (1995), the specimens in the Georgia cores lack well-defined paratabulation. This form was encountered in three cores in the lowest samples from the Ellenton Formation. In four of the five samples, *Carpatella cornuta* Grigorovich was also present.

**THALASSIPHORA PELAGICA (EISENACK 1954)
EISENACK & GOCHT 1960****TRIGONOPYXIDIA GINELLA (COOKSON & EISENACK 1960)
DOWNIE & SARJEANT 1965****TUBERCULODINIUM WALL 1967 N. SP. A**

Plate 4, figure 9

Remarks.—Only a few specimens of this form were encountered. It has a broad flange and faintly developed tubercles. The multiplate antapical archeopyle clearly indicates its affinity with *Tuberculodinium* Wall 1967.

TURBIOSPHERA CF. T. GALATEA EATON 1976

Plate 4, figure 12

?*Lanternosphaeridium lanosum* Morgenroth 1966. Drugg and Stover, 1975, pl. 5, fig. 2.

Remarks.—The Georgia form resembles *Turbiosphaera galatea* Eaton 1976, but the intratabular processes are not as well developed and may form a more or less continuous membrane that represents the postcingular and antapical areas. The endocyst may have a distinct apical boss. It is more elongate than *L. lanosum* Morgenroth sensu Drugg and Stover (1975).

MISCELLANEOUS AREOLIGERACEAN FORMS

Plate 4, figures 13, 14

Remarks.—This category is used for the highly variable plexus that contains members of the genera *Adnatosphaeridium*, *Areoligera*, and *Glaphyrocysta*, except for the distinctive species listed separately.

Order PERIDINIALES Haeckel 1894**ANDALUSIELLA POLYMORPHA (MALLOY 1972)
LENTIN & WILLIAMS 1977**

Remarks.—Broad forms with two distinct antapical horns were seen.

ANDALUSIELLA SP. AFF. A. POLYMORPHA OF EDWARDS (1980)

Plate 5, figures 3, 4

Andalusiella sp. aff. *A. polymorpha* (Malloy 1972) Lentin & Williams 1977. Edwards, 1980, p. 9, fig. 1.

Andalusiella australinum (Cookson 1965) Lentin & Williams 1977. Kurita and McIntyre (1995), pl. 1, fig. 12.

Remarks.—The two antapical horns are fused proximally. At one-third to one-half of the total length of the longer horn, they separate.

**?ANDALUSIELLA RHOMBOHEDRA OF
EDWARDS AND OTHERS (1984)**

Plate 5, figure 1

?*Andalusiella rhombohedra* (Benson) Stover & Evitt. Edwards and others, 1984, pl. 2, fig. 5.

Remarks.—This small, distinctive form could perhaps represent the endocyst only.

CHARLESDOWNIEA COLEOTHRYPTA (WILLIAMS & DOWNIE 1966) LENTIN & VOZZHENNIKOVA 1989**CHARLESDOWNIEA VARIABILIS (BUJAK 1980) LENTIN & VOZZHENNIKOVA 1989**

Plate 5, figure 11

Remarks.—The species name is used in the broad sense.

DEFLANDREA DELINEATA COOKSON & EISENACK 1965

Plate 5, figure 5

Deflandrea cf. *D. dartmooria* Cookson & Eisenack 1965. Edwards and others, 1984, pl. 1, fig. 7.

Deflandrea cf. *D. dartmooria* of Edwards and others (1984). Edwards, 1989, pl. 1, fig. 6.

Remarks.—This form lacks the broad shoulders characteristic of *Cerodinium dartmoorium* (Cookson & Eisenack 1965) Lentin & Williams 1987.

DEFLANDREA PHOSPHORITICA EISENACK 1938

Plate 5, figure 9

DEFLANDREA N. SP. AFF. D. TRUNCATA STOVER

Plate 5, figure 8

Remarks.—The specimen shown in plate 5, figure 8 is a rather large, circumcavate form with a granulate endocyst. This form is relatively rare in the Georgia cores studied, but it may be stratigraphically important.

DEFLANDREA CF. D. DIEBELII ALBERTI OF DRUGG (1967)

Plate 5, figure 6

Deflandrea cf. *D. diebelii* Alberti 1959. Drugg, 1967, p. 16–17, pl. 2, fig. 6.

Deflandrea sp. cf. *D. diebelii* sensu Drugg 1967. Edwards, 1980, pl. 9, fig. 4.

Cerodinium speciosum (Alberti 1959) Lentin & Williams 1987. Kurita and McIntyre, 1995, pl. 1, fig. 1.

Remarks.—The periphragm is almost smooth (lacking striations or spinules).

DRACODINIUM VARIELONGITUDUM (WILLIAMS & DOWNIE 1966) COSTA & DOWNIE 1979

Plate 5, figure 7

ISABELIDINIUM VIBORGENSE SENSU KURITA AND MCINTYRE (1995)

Plate 5, figure 2

Peridiniacean cyst sp. C. Edwards, 1980, pl. 9, fig. 11.

Peridiniacean cyst sp. C of Edwards (1980). Edwards, 1989, pl. 1, fig. 12.

Isabelidinium viborgense Heilmann-Clausen 1985. Kurita and McIntyre, 1995, p. 131, pl. 1, figs. 9, 10.

Remarks.—The specimens in the Georgia cores, like the ones described by Kurita and McIntyre (1995), lack the additional openings on the pericyst that are found in the type material of Heilmann-Clausen (1985).

LEJEUNECYSTA ARTZNER & DÖRHÖFER 1978 SPP.

Remarks.—Various species of the genus are included.

LENTINIA SERRATA BUJAK 1980

Plate 5, figure 12

PALAEOCYSTODINIUM GOLZOWENSE ALBERTI 1961**PALAEOCYSTODINIUM ALBERTI 1961 SPP.**

Remarks.—Specimens of the genus *Palaeocystodinium* Alberti in the Georgia cores were not assigned to species if the endocyst was clearly wider than the endocyst in specimens assigned to *Palaeocystodinium golzowense* Alberti.

PALAEOPERIDINIUM PYROPHORUM (EHRENBERG 1838) SARJEANT 1967

Plate 5, figure 13

PHELODINIUM SP. OF EDWARDS (1989)

Plate 5, figure 10

Phelodinium sp. Edwards, 1989, pl. 1, fig. 9.

Phelodinium magnificum sensu lato, Edwards, 1996, pl. 1, fig. 12.

Remarks.—*Phelodinium* sp. of Edwards (1989) has an elongated outline and straight sides on the epicyst; that is, the epicystal shape is neither convex nor concave in the terminology of Bujak and Davies (1983). This morphotype is restricted to the upper Paleocene in Virginia (Edwards, 1989, 1996) and the Georgia cores.

PHELODINIUM STOVER & EVITT 1978 SPP.

Plate 5, figure 14

Remarks.—Specimens from the Georgia cores assigned to *Phelodinium* Stover & Evitt spp. are of miscellaneous forms, probably several different species, that broadly are similar to *Phelodinium magnificum* (Stanley) Stover & Evitt sensu stricto.

PHTHANOPERIDINIUM COMATUM (MORGENROTH 1966) EISENACK & KJELLSTROM 1972

Plate 5, figure 15

PHTHANOPERIDINIUM ECHINATUM EATON 1976

Plate 5, figures 16, 17

PSEUDORHOMBODINIUM LISBONENSE WRENN 1996

Plate 6, figure 1

RHOMBODINIUM DRACO GOCHT 1955

Plate 6, figure 2

RHOMBODINIUM PERFORATUM (JAN DU CHÊNE & CHÂTEAUNEUF 1975) LENTIN & WILLIAMS 1977

Plate 6, figure 3

SELENOPEMPHIX NEPHROIDES BENEDEK 1972

Plate 5, figure 18

SELENOPEMPHIX BENEDEK 1972 SPP.

Plate 6, figure 4

Remarks.—Various species of the genus were seen.**SENEGALINIUM MICROGRANULATUM (STANLEY 1965) STOVER & EVITT 1978**

Plate 6, figure 5

Remarks.—This species name is used in the broad sense.**SPINIDIINIUM DENSISPINATUM STANLEY 1965**

Plate 6, figure 8

Remarks.—This species name is used in the broad sense.**SPINIDIINIUM PULCHRUM (BENSON 1976) LENTIN & WILLIAMS 1977**

Plate 6, figures 6, 10

SPINIDIINIUM COOKSON & EISENACK 1962 SPP.

Plate 6, figure 9

Remarks.—Specimens from the Georgia cores assigned to *Spinidinium* Cookson & Eisenack spp. are miscellaneous forms that do not clearly fall into the endmember morphotypes of recognized species. The illustrated specimen, recovered from the upper Eocene Barnwell unit, is probably reworked.**WETZELIELLA ARTICULATA EISENACK 1938**

Plate 6, figures 7, 11

Remarks.—The species name is used in the broad sense.**WETZELIELLA EISENACK 1938 SPP.**

Plate 6, figure 12

Remarks.—Specimens from the Georgia cores assigned to *Wetzelietta* Eisenack spp. are miscellaneous forms; many of the specimens are poorly preserved.**SMALL PERIDINIACEAN FORMS**

Plate 6, figures 13–16

Remarks.—The category “small peridiniacean forms” was used for specimens in the Georgia cores that belong to miscellaneous species of the Family Peridiniaceae Ehrenberg 1831. They belong to several genera including *Alterbidinium* Lentin & Williams 1985, *Lentinia* Bujak 1980, *Senegalinium* Jain & Millepied 1973, and *Spinidinium*

Cookson & Eisenack 1962. The category includes poorly preserved specimens and specimens that do not fall into the endmember morphotypes of recognized species.

ACRITARCHS**CYCLOPSIELLA VIETA DRUGG & LOEBLICH 1967**

Plate 6, figure 17

XENIKOON AUSTRALIS SENSU BENSON (1976)

Plate 6, figure 18

Xenikoon australis Cookson & Eisenack. Benson, 1976, p. 28, pl. 14, fig. 11.*Xenikoon australis* Cookson & Eisenack. Edwards and others, 1984, pl. 1, fig. 6.

Incertae sedis 1. Heilmann-Clausen, 1985, p. 26, text-fig. 11; pl. 15, figs. 7–10.

Xenikoon australis sensu Edwards and others, 1984. Edwards, 1989, pl. 1, fig. 4.*Remarks.*—As Heilmann-Clausen (1985) pointed out, this form lacks tabulation and an observable archeopyle.**REFERENCES CITED**

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