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 *Glaphycysta* 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) Goeth, *Cyclospiella vieta* Drugg & Loeblich, and *Dapsilidinium pseudocolligerum* (Stover) Bujak et al. are found in the Santee Limestone, and *Hystrichosphaeropsis* Dellandre n. sp. *A. Pentadinium Gerlach n. sp. D*, and *Pentadinium polydatum* Edwards are apparently restricted to the Santee Limestone. Specimens of species of the genus *Wetzeliella* 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 bacalata* Drugg, *Batiacasphaera comptu* 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...
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.

ACKNOWLEDGMENTS

I thank U.S. Geological Survey colleagues Joan S. Baum, Laurel M. Bybelle, John S. Clarke, W. Fred Falls, R. Farley Fleming, Norman O. Frederiksen, Thomas G. Gibson, Gregory S. Gohn, and David C. Prowell, as well as Raymond A. Christopher (Clemson University), Paul F. Huddlestun (Georgia Geologic Survey, Atlanta), Joyce Lucas-Clark (Fremont, Calif.), and Robert Van Pelt (Bechtel Savannah River) for the generous sharing of data and ideas concerning the biostratigraphy and lithostratigraphy of the coastal plain. Paul Huddlestun provided the samples from the Thompson Oak and McBean cores.

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 110 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 2 miles north of the town of Girard at lat 33°03'54" N., long 81°43'13" W. Surface elevation is 110 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 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 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
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 the intersection of GA 56 and Collins Road at lat 33°13'38" N., long 81°55'30" W. Surface elevation is 297 ft above sea level.

Core samples were collected on the basis of favorable lithology and providing bioclastic 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 Girvan and Sarjeant as separate and distinct from the genus Cordosphaeridium Carpineti and Sarjeant. Tityrosphaeridium was considered to be a single taxonomic entity (miscellaneous areoligeraceae, pl. 4, figs. 13, 14).

Dinocysts in the Paleocene Ellenton Formation in the Millhaven 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 voluta Drugg, Carpatella cornuta Grigorovich (pl. 1, fig. 10), Spinidinium denso- spinatum Stanley, Spinidinium pulchrum (Benson) Lentin & Williams, and Tenus sp. cf. T. formosa of Kurita and McInerney (1995). Carpatella 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 Senegalinum 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 Danusaidinium californicum (Drugg) Fensome et al. (pl. 2, fig. 3), Phelodium sp. of Edwards (1989) (low occurrence in R4664 GD, at 620.8 ft), and Deflandrea delinata Cookson & Eisenack (lowest occurrence in R4664 A, at 589 ft, pl. 5, 5.5). Palaeoperidinium pyrophorum (Ehrenberg) Sarjeant and Fribaldinium annenopense Morganroth are present in the highest sample (R4664 D, at 571 ft). Most of the Ellenton has been

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

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<td>T/F</td>
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<td>T/F</td>
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<td>R4663 B</td>
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<td>Ellenton T/F</td>
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### 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.]

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<tr>
<th>Figure</th>
<th>Slide</th>
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| Plate 2 | R4663 B (4) | 34.5x93.8 |
|         | R4664 A (3) | 22.1x71.8 |
|         | R4664 AS (1) | 30.9x86.7 |
|         | R4664 O (3) | 19.4x103.8 |
|         | R4664 AQ (2) | 37.5x80.7 |
|         | R4705 E (2) | 21.1x75.0 |
|         | R4664 A (3) | 19.4x97.7 |
|         | R4664 AR (1) | 37.2x84.5 |
|         | R4664 O (3) | 34.3x76.4 |
|         | R4664 K (1) | 30.4x75.6 |
|         | R4664 AC (3) | 26.5x94.4 |
|         | R4705 I (3) | 30.4x89.0 |

| Plate 3 | R4836 F (2) | 30.0x76.0 |
|         | R4836 R (3) | 22.6x79.6 |
|         | R4663 G (3) | 33.2x94.2 |
|         | R4663 G (3) | 21.9x77.1 |
|         | R4664 AC (3) | 34.7x84.7 |
|         | R4836 R (3) | 17.8x75.3 |
|         | R4705 AD (2) | 26.9x101.6 |
|         | R4836 E (3) | 19.2x89.6 |
|         | R4705 I (3) | 28.9x86.7 |
|         | R4836 N (4) | 35.0x107.8 |
|         | R4664 O (3) | 34.8x85.1 |
|         | R4664 N (2) | 30.8x86.6 |
|         | R4664 AC (3) | 35.7x71.7 |
|         | R4664 AR (1) | 26.4x94.9 |
|         | R4836 P (1) | 24.1x108.0 |

| Plate 4 | R4664 AI (4) | 33.3x76.5 |
|         | R4664 AI (4) | 21.4x74.8 |
|         | R4836 K (3) | 28.4x97.0 |
|         | R4664 AC (3) | 31.4x103.8 |
|         | R4664 AC (3) | 24.3x72.3 |
|         | R4705 I (3) | 24.0x75.3 |
|         | R4705 AD (2) | 33.7x76.4 |
|         | R4705 G (3) | 24.9x90.4 |
|         | R4664 AR (1) | 35.7x104.9 |
|         | R4705 AD (2) | 33.6x76.3 |
|         | R4664 K (1) | 30.3x78.0 |
|         | R4664 K (1) | 31.9x87.1 |
|         | R4581 R (4) | 36.1x91.1 |

| Plate 5 | R4581 R (1) | 23.2x74.8 |
|         | R4665 C (4) | 21.1x91.5 |
|         | R4581 R (1) | 26.0x73.0 |
|         | R4836 D (3) | 22.4x75.2 |
|         | R4664 A (3) | 23.5x92.3 |
|         | R4705 AD (2) | 27.2x95.5 |
|         | R4705 CF (1) | 32.6x72.4 |
|         | R4705 B (3) | 30.5x107.9 |
|         | R4664 AS (1) | 24.6x78.8 |
|         | R4836 D (3) | 18.2x74.6 |
|         | R4664 AQ (2) | 37.4x98.2 |
|         | R4705 E (2) | 17.9x80.4 |
|         | R4664 A (3) | 23.7x82.8 |
|         | R4664 C (4) | 33.4x95.2 |
|         | R4664 AQ (2) | 32.3x86.3 |
|         | R4664 O (3) | 26.0x95.7 |
|         | R4664 V (4) | 18.9x91.0 |
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=comparis with; ?=questionably identified; 1=single specimen.
Figure 2. Continued.
assigned to the early late Paleocene calcareous nanofossil 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 palaeontologically. 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 *Trirhaphaerda* cf. *T. pelata* (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 *Hofstaedteria goodmani* 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 nanofossils 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 *Glaphycysta* cf. *G.? vicina* (pl. 2, figs. 10–12) and appears to be correlative with the lowest part of the Lisbon Formation in Alabama (Edwards, unpublished data). This level could be assigned to either calcareous nanofossil 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 (pl. 4, 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 Parker’s Ferry and Harleyville Formations (lower part of the Cooper Group, upper Eocene) in South Carolina (Edwards, 1977; unpublished data). Three samples above 205 ft are barren. Santee sediments above 308 ft in the Millhaven core have been assigned to late middle Eocene calcareous nanofossil Zone NP 17 (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), Tena-aculeum nigrum (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 assemblage. It contains early Paleocene (Danian, Midwayan) dinocysts, including D. truncata and Deflandrea n. sp. aff. D. truncata Stover.

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), Spiniferites mantelli (Williams & Downie) Costa & Davey & Williams is tentatively identified. A nearby repeat sample (R4705 CF, at 415 ft) recovered a single specimen of Dracodinium 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 fassatus Edwards, Corrudinium sp. I of Edwards (1984), Phthanoperidinium echinatum Eaton, Pseudohombodinium lisbonense Wrenn (pl. 6, fig. 6), Samlandia chlamydophora Eisenack, Wetzeliella aciculata 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. fassatus 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 Cystothecliferidium cantharellus (Brossius) Gocht. The sample at 257.8–258 ft (R4705 H) contains a well-preserved, diverse dinocyst assemblage that includes Pentadinium polyspum Edwards, Samlandia chlamydophora Eisenack, and Eocladopyxis 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), Characteclidium variabilis (Bujak) Lentin & Vozhennikova, and Corrudinium incompressum (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.
DINOCYST BIOSTRATIGRAPHY OF TERTIARY SEDIMENTS FROM FIVE CORES, GEORGIA

Heteraulacacysta sp.
Enneadocysta spp.
Pentadinium n. sp. D
Hystrichostrogylon membraniphorum
cf. Nematosphaeropsis sp.
Wetzeliella spp. (misc.)
Charlesdowniea variabilis (sensu amplo)
Corrudinium incompositum
Distatodinium ellipticum
Homotryblium plectilum
Hystrichokolpoma cinctum
Hystrichosphaeropsis n. sp. A
Palaeocystodinium golzowense
Rhombodinium perforatum
Pentadinium polypodum

200
100
500
300
500
300
100

BARNWELL UNIT (part)
SANTTEE LS.
CONGAREE FORMATION
FOURMILE BRANCH FM.
SNAPP FM.
ELLENTON FM.

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 goodmani* Edwards (pl. 3, fig. 1), primitive forms of *Pentadinium favatum* Edwards, *Wetzeliella articulata* Eisenack. The lowest of these contains *Homorothyrium 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 goodmani* Edwards. Five samples from 231.5–183.5 ft all contain dinofloras that are roughly comparable 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 *Turbinosphaera 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 *Glaphycysta cf. G.? victina* (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., *Heteroaulacacysta porsa* Bujak, and *Hystrichosphaerina membraniphora* Ageleopoulos (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* (Broosi) 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, *Spins-
Dinocyst Biostratigraphy of Tertiary Sediments from Five Cores, Georgia

**Dinocysts**
- *Coruttia* has not been reported from sediments younger than early Paleocene. This sample contains early Paleocene pollen (Frederiksen, this volume, chap. H).

**Ellenton Formation**
- 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.

**Snapp Formation** (232–165 ft)
- 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.

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

**Congaree Formation** (165–156 ft)

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**Figure 4** Range and occurrence chart of dinocysts and acritarchs in the Thompson Oak core. Lithostratigraphy from Falls and Prowell (this volume, chap. A). *A* = questionably identified.

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**SNAPP FORMATION (232–165 ft)**
- 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.

**FOURMILE BRANCH FORMATION** (NOT PRESENT)
- The Fourmile Branch Formation is not present in the Millers Pond core. There is no evidence of early Eocene marine deposition in this core.

**CONGAREE FORMATION** (165–156 ft)
forms of *Pentadinium favatum* Edwards, *Turbiosphaera* cf. *T. galatea*, and *Wetzeliella 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 *Tur biosphaera* 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 *Tur biosphaera* 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* n. sp. D, *Samlandia chlamydophora* Eisenack, *Hystrichostrogylon coninckii* Heilmann-Clausen, *Cordosphaeridium cantharellus* (Brosius) Gocht, and *Dapsilidinium pseudocolligerum* (Stover) Bujak et al. This assemblage could represent the interval of overlap of the ranges of *P. goniferum* Edwards and *P. favatum* Edwards, or it could represent a lag deposit at the base of the overlying unit. Because *P. goniferum* Edwards and *Turbiosphaera* cf. *T. galatea* are each represented by one poorly preserved specimen, and because *Turbiosphaera* cf. *T. galatea* and *P. favatum* Edwards do not overlap in other cores, the interpretation of this sample as a lag deposit appears more likely.

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 assemblage could represent the interval of overlap of the ranges of *P. favatum* Edwards and *Tur biosphaera* 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 *Tur biosphaera* 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.
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, Midwayan) 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 *Eoeadophysis* Morganroth 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 pusilula* van den 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 *Tenus* sp. cf. *T. formosa* of Kurita and McIntrye (1995). This assemblage is assigned to calcareous nanofossil Zone NP 4 in the Millhaven core. The younger assemblage contains *Phleodus* sp. of Edwards (1988) (pl. 5, fig. 10) and is assigned to calcareous nanofossil Zones NP 5 and NP 8 in the Millhaven core (Bybell, this volume, chap. F). Both assemblages contain *Damassadinum californicum* (Drugg) Fensome et al., *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant. and *Deflandrea* cf. *D. diebela* 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 nanofossil Zone NP 8 (Bybell, this volume, chap. F) although the dinocyst assemblage is not noticeably different from assemblages in the samples below it.

The Snee 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 Snee 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 Snee 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 *Hafniaephaea goodmani* Edwards and primitive forms of *Pentadinium favatum* Edwards, *Homotryblium abbreviatum* Eaton is also present. Sediments in the Fourmile Branch in the Girard core contain *Dracodinium varielongitudum* Williams & Downie) Costa & Downie and *Homotryblium teusiuspinatum* 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 correlate 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 bifformoides* (Eisenack) Eaton (pl. 1, figs. 1–3), *Diphyes colligerum* (Deflandre & Cookson) Cookson, *Eoeadophysis* Morganroth n. sp. A, *Glyphtrocynta* cf. *G. ? vicina*, *Phlanoperidinium echinatum* Eaton (pl. 5, figs. 16, 17), *Pentadinium favatum* Edwards, *Samlandia chlamydophora* Eisenack (pl. 4, fig. 3), *Turbiosphaera* cf. *T. galatea*, *Wetzeliella articulata* Eisenack (pl. 6, figs. 7, 11), and many areoligeracean forms. The highest occurrence of *Turbiosphaera* cf. *T. galatea* and the lowest occurrence of *Glyphtrocynta* 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 nanofossils 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 correlate with the upper part of the Lisbon Formation and the Gosporn Sand in Alabama are present in the Santce 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 (pl. 3, figs. 7–9) are found in the Santee Limestone. 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.
Figure 7. Correlation diagram by dinocyst assemblages for the five Georgia cores. Datum is the base of the Santee Limestone.
DINOCYST BIOSTRATIGRAPHY OF TERTIARY SEDIMENTS FROM FIVE CORES, GEORGIA

BAITACASPHAERA COMPTA DRUGG 1970
Plate 1, figures 8, 9
CEREBROCYSTA BARONENSSIS BUJAK 1980
Plate 1, figure 12, 13
CORDOSPHAERIDUM-CANTHARELLUS (BRUNIES 1960) 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).

CORDOSPHAERIDUM PUNCULATUM MORGENROTH 1966
Plate 1, figure 11

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 Cerebrocyta baronensis Bujak 1980.

CRIBROPERIDINIUM GIUSEPEI (MORGENROTH 1966) HELENES 1984
Plate 1, figure 17
CRIBROPERIDINIUM TYNITABULATUM (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 PSEUDELLIGERUM (STOVER 1977) BUJAK ET AL. 1980
Plate 1, figure 18
DISOPTERYGIUM CLADOIDES SENSU MORGENROTH 1966
Plate 2, figure 4

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

DIPHYES COLLIGERUM (DEFLANDRE & COOKSON 1955) COOKSON 1965

DIPHYES FICUSIMODES ISLAM 1983
Plate 2, figure 5

DISTATODINIUM ELLPTICUM (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.

EOCLADOPYXES MORGENROTH 1966 N. SP. A
Plate 2, figure 7
Remarks.—The processes resemble those of Polysphaeridium zoharyi (Rossignol 1962) Bujak et al. 1980, but the separation of the individual paraphyses requires placement in the genus Eocladopyx Morgenroth 1966.

FIBRADINIUM ANNETORPENSE MORGENROTH 1968
Plate 2, figure 8

FIBROCYSTA STOVER & EVITT 1978 SPP.
Remarks.—Various species of the genus are included.

Plate 2, figures 10–15
Remarks.—This form is highly variable in the degree of development of the marginal flanges. It resembles Membranealthidium 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 Membranealthidium 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.

HAFNIA SPHAERA 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.

HAFNIA SPHAERA SEPTATA (COOKSON & MORGENROTH 1967) HANSEN 1977
Plate 3, figure 10

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).
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HETERAULACACYSTA POROSA BUJAK 1980
Plate 3, figures 2, 3

HETERAULACACYSTA PESTIFLOSA JAN DU CHÊNE & ADEHIAN 1985
Plate 3, figure 4

HETERAULACACYSTA DRUOG & 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 TENUESPINOSUM DAVEY & WILLIAMS 1966

HYSTRICHOKOLPOMA CINCTUM KLUMPP 1953

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 CONINCKI HEILMANN-CLAUSEN 1985

HYSTRICHOSTROGYLON MEMBRANIPHORUM ACELOPOULOUS 1964
Plate 3, figure 13

LINGULODINIUM MACRAEIOPHORUM (DEFLANDRE & COOKSON 1955) WALL 1967

MELITASPHAERIDUM ASTERIUM (EATON 1976) BUJAK ET AL. 1980

MELITASPHAERIDUM PSEUDORECURVATUM (MORGENROTH 1966) BUJAK ET AL. 1980
Plate 3, figures 10, 11.

Millioudodinium sp. I OF EDWARDS (1984)
Plate 3, figure 4

Millioudodinium sp. I. Edwards, 1984, pl. 2, fig. 2. Cribroperidinium sp. II. Damassa and others, 1990, fig. 4C. Cribroperidinium sp. II. Furth, 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) DRUOG 1970

NEMATOSPHAEROPSIS DEFLANDRE & COOKSON 1955 SPP.
Remarks.—Various species of the genus are included.

OPERULODINIUM CENTROCARPUM (DEFLANDRE & COOKSON 1955) WALL 1967
Plate 3, figure 14

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

OPERULODINIUM WALL 1967 SPP.
Remarks.—Various species of the genus are included.

PENTADINIUM PAVATUM EDWARDS 1982
Plate 3, figure 15

PENTADINIUM GONIFERUM EDWARDS 1982
Plate 3, figure 16

PENTADINIUM LATINCINCTUM GERLACH 1961 SUBSP. LATINCINCTUM
Plate 3, figure 17

PENTADINIUM LATINCINCTUM GERLACH 1961 (VERM.)
Plate 3, figure 18

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

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

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

PENTADINIUM MEMBRANACEUM (EISENACK 1965)

PENTADINIUM POLYPODUM EDWARDS 1982
Plate 4, figure 1

PENTADINIUM POLYPODUM EDWARDS 1982
Plate 4, figure 2

PENTADINIUM GERLACH 1961 S. P. 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.

POLYSPHAERIDUM ZOHARYI (ROSSIGNOL 1962)

BUJAK ET AL. 1980
DINOCYST BIOSTRATIGRAPHY OF TERTIARY SEDIMENTS FROM FIVE CORES, GEORGIA

ROTTNESTIA BORUSSICA (EISENACK 1954)
COOKSON & EISENACK 1961

SAMLANDIA CHLAMYDOPHORA EISENACK 1954
Plate 4, figure 3

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

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.

TENUSA SP. CF. T. FORMOSA OF KURITA AND MCINTYRE (1995)
LENTIN & WILLIAMS 1977


Remarks.—Broad forms with two distinct antapical horns were seen.
Remarks.—The species name is used in the broad sense.

**Deflandrea delineata** Cookson & Eisenack 1965
Plate 5, figure 5


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 specimens 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.


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

**Dracodinium varieangulatum** (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.

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).

**Lejeunezysta artzneri** & Döhröfer 1978 spp.
Remarks.—Various species of the genus are included.

**Lentinia serrata** Bujak 1980
Plate 5, figure 11

**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 perrophorum** (Ehrenberg 1838) Sakjeant 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

**Phthiroperidinium comatum** (Morgenroth 1966) Eisenack & Kjellstrom 1972
Plate 5, figure 15
**Phthiroperidinium echinatum** Eaton 1976
Plate 5, figures 16, 17

**Pseudorhombodinium lisbonense** Wrenn 1996
Plate 6, figure 1
**Rhombodinium Draco** Gocht 1955
Plate 6, figure 2
DINOCYST BIOSTRATIGRAPHY OF TERTIARY SEDIMENTS FROM FIVE CORES, GEORGIA

RhomboDinizium perforatum (Jan du Chêne & Châteauneuf 1975) Lentín & Williams 1977
Plate 6, figure 3

SelenoPemphix nephiroides Beneck 1972
Plate 5, figure 18

SelenoPemphix Beneck 1972 SPP.

Remarks.—Various species of the genus were seen.

SeneGaLiniun Microgranulatum (Stanley 1965) Stover & Evitt 1978
Plate 6, figure 5

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

Spinidinizium densispinatum (Benson 1976) Lentín & Williams 1977
Plate 6, figures 6, 10

Spinidinizium Cookson & Eisenack 1962 SPP.
Plate 6, figure 9

Remarks.—Specimens from the Georgia cores assigned to Spinidinizium Cookson & Eisenack SPP. are miscellaneous forms that do not clearly fall into the endmember morphotypes of recognized species. The illustrated specimens, recovered from the upper Eocene Barnwell unit, is probably reworked.

Wetzeliiella articulata Eisenack 1938
Plate 6, figures 7, 11

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

Wetzeliiella Eisenack 1938 SPP.
Plate 6, figure 12

Remarks.—Specimens from the Georgia cores assigned to Wetzeliiella 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 Alberbisdinium Lentín & Williams 1985, Lentinita Boujak 1980, Senegalinitum Iain & Milippert 1973, and Spinidinizium Cookson & Eisenack 1962. The category includes poorly preserved specimens and specimens that do not fall into the endmember morphotypes of recognized species.

References Cited


