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Biostratigraphy and Physical Stratigraphy of the USGS-Cannon Park Core (CHN-800), Charleston County, South Carolina

By Laurel M. Bybell, Kevin J. Conlon, Lucy E. Edwards, Norman O. Frederiksen, Gregory S. Gohn, and Jean M. Self-Trail

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BIOSTRATIGRAPHY AND PHYSICAL STRATIGRAPHY OF THE USGS-CANNON PARK CORE (CHN-800), CHARLESTON COUNTY, SOUTH CAROLINA

By Laurel M. Bybell[1], Kevin J. Conlon[2], Lucy E. Edwards[1], Norman O. Frederiksen[1], Gregory S. Gohn[1], and Jean M. Self-Trail[1]

ABSTRACT

The Cannon Park corehole was drilled within the city limits of Charleston, S.C., to a depth of 1,012 ft below land surface. Based on microfossil studies, sediments in this core are Late Cretaceous (Campanian and Maastrichtian), Paleocene, Eocene, and Oligocene in age. From oldest to youngest, the marine sedimentary units that were encountered and their ages are the (1) Donoho Creek Formation of late Campanian age - calcareous nannofossil Zone CC 21 and Subzones CC 22b and CC 22c; (2) Peedee Formation of late Maastrichtian age - Subzones CC 25b, CC 26a, CC 26b; (3) Rhems Formation of early and late Paleocene age - calcareous nannofossil Zones NP 1, NP 4; (4) Lower Bridge Member of the Williamsburg Formation of late Paleocene age - Zone NP 5; (5) Chicora Member of the Williamsburg Formation of late Paleocene age - Zone NP 8; (6) Cross Member of the Santee Limestone of middle Eocene age - Zones NP 16, NP 17; (7) Harleyville Formation of late Eocene age - Zones NP 18, NP 19/20; (8) Ashley Formation of late Oligocene age - Zone NP 24; and (9) Wando Formation, which had no apparent microfossils in the Cannon Park core, but is of Pleistocene age elsewhere in the Charleston area. Where possible, comparison is made between the age of sediments in the Cannon Park core and in other cores in South Carolina.

INTRODUCTION

PURPOSE AND SCOPE

In November and December of 1994, the Cannon Park corehole (CHN-800) was drilled in Cannon Park in the city of Charleston, S.C. (fig. 1). The site is located in the Charleston 7.5' quadrangle at lat 32°46'55"N., long 79°56'41"W. Ground elevation at the site is 4 ft above sea level. The corehole, which was cored continuously to a total depth of 1,012 ft below land surface, recovered Upper Cretaceous, Paleocene, Eocene, and Oligocene sediments that were dated using microfossils (calcareous nannofossils, dinocysts, and pollen). The Cannon Park core currently (July 1998) is stored at the College of Charleston in Charleston, S.C.

In this report, we provide stratigraphic, lithologic, and paleontologic data and analyses for the Cretaceous and Paleogene portions of the Cannon Park core. Calcareous nannofossils were studied from the Cretaceous and Paleogene units, whereas dinoflagellates and pollen were studied only from the Paleogene units. Laurel M. Bybell provided

[1] U.S. Geological Survey, Reston, VA 20192
[2] U.S. Geological Survey, Sullivans Island, SC 29482

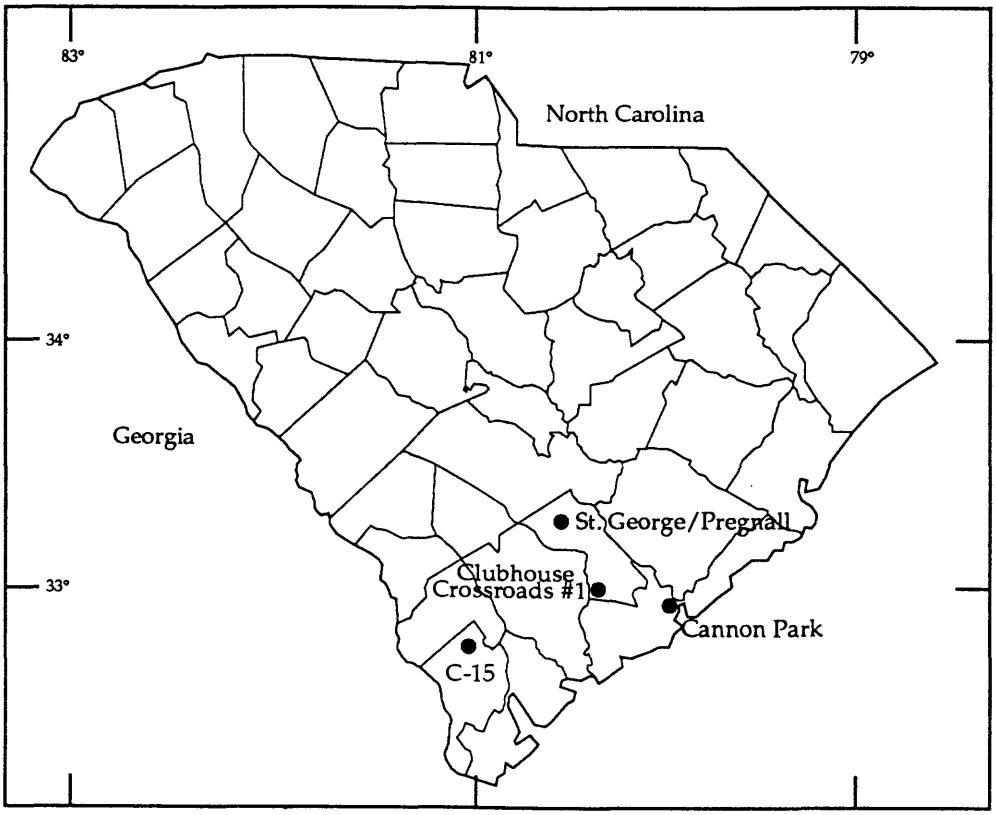

Figure 1. Map of South Carolina showing location of coreholes discussed in text.

Cenozoic calcareous nannofossil data and is the compiler for this paper; Kevin J. Conlon provided the lithologic data for the Cenozoic portion of the core; Lucy E. Edwards studied the Cenozoic dinocysts; Norman O. Frederiksen studied the Cenozoic pollen; Gregory S. Gohn provided lithologic data for the Cretaceous portion of the core; and Jean M. Self-Trail studied the Cretaceous calcareous nannofossils.

Other recent paleontologic and lithologic studies of cores from the southeastern U.S. include: Edwards and others (1997) and Self-Trail and Gohn (1996) in Dorchester County, S.C.; Self-Trail and Bybell (1997) in Jasper County, S.C.; and Clarke and others (1996) and a new volume that includes papers by Bukry, Bybell, Edwards, Edwards and others, Falls and Prowell, Frederiksen, Frederiksen and others, Gibson, and Gohn (in press) in Screven and Burke Counties, Ga. Earlier publications by Hattner and Wise (1980), Hattner and others (1980), Habib and Miller (1989), and Moshkovitz and Habib (1993) also provided micropaleontological data for South Carolina and Georgia sediments.

AKNOWLEDGMENTS

We thank Bruce G. Campbell of the U.S. Geological Survey Water Resources Division District Office in Columbia, S.C., for organizing the drilling of and developing the funding for the Cannon Park corehole. The corehole was drilled by the U.S. Geological Survey's (USGS) Eastern Region Geologic Mapping Team drill crew for the South Carolina District of the USGS Water Resources Division as part of a cooperative project with the Charleston Commissioners of Public Works. USGS drillers at the Cannon Park site were Eugene F. Cobbs, Eugene F. Cobbs III, and Donald G. Queen. We thank Nancy J. Durika and Thomas P. Sheehan for processing the palynological samples and Amanda J. Chapman for processing the calcareous nannofossil samples. We thank Michael P. Katuna of the College of Charleston and Lucy McCartan of the U.S. Geological Survey for their thoughtful reviews of this paper.

UNIT CONVERSIONS

U.S. customary units are used throughout this report, except for descriptions of grain size, pore size, and measurements used in processing methods, which are given in metric units. To convert millimeters to inches, multiply the value in millimeters by 0.03937. To convert micrometers to inches, multiply the value in micrometers by 0.00003937. To convert feet to meters, multiply the value in feet by 0.3048.

METHODS

LITHOLOGY

Generalized lithologic descriptions of the core were made at the site during drilling operations. These descriptions were augmented by additional lithologic information gathered during a second examination of the core in the laboratory. General lithologic descriptions of the core, including semi-quantitative visual estimates of grain size, particle abundances, colors, and related information, are given in appendixes 8 and 9.

In some cases, depths for stratigraphic contacts picked from the geophysical logs may vary by one to three feet from depths picked in the core for the same contacts. These variations result from inherent uncertainties in choosing precisely the positions of contacts on the logs and from small errors in assigned core depths caused by unrecovered intervals. Log depths are used in the stratigraphic discussions in this report. Core depths appear in appendixes 8 and 9.

PALEONTOLOGY

CALCAREOUS NANNOFOSSILS

Thirty-two Cretaceous and sixty Cenozoic calcareous nannofossil samples were examined from the Cannon Park core at approximately 1- to 10-foot intervals. A small amount of sediment was extracted from the central portion of a core segment (freshly broken where possible). The samples were dried in a convection oven to remove residual water, and the dry sediment was placed in vials for long-term storage in the calcareous nannofossil laboratory at the U.S. Geological Survey in Reston, Va. Semi-consolidated or consolidated samples were ground with a mortar and pestle. A small portion of each

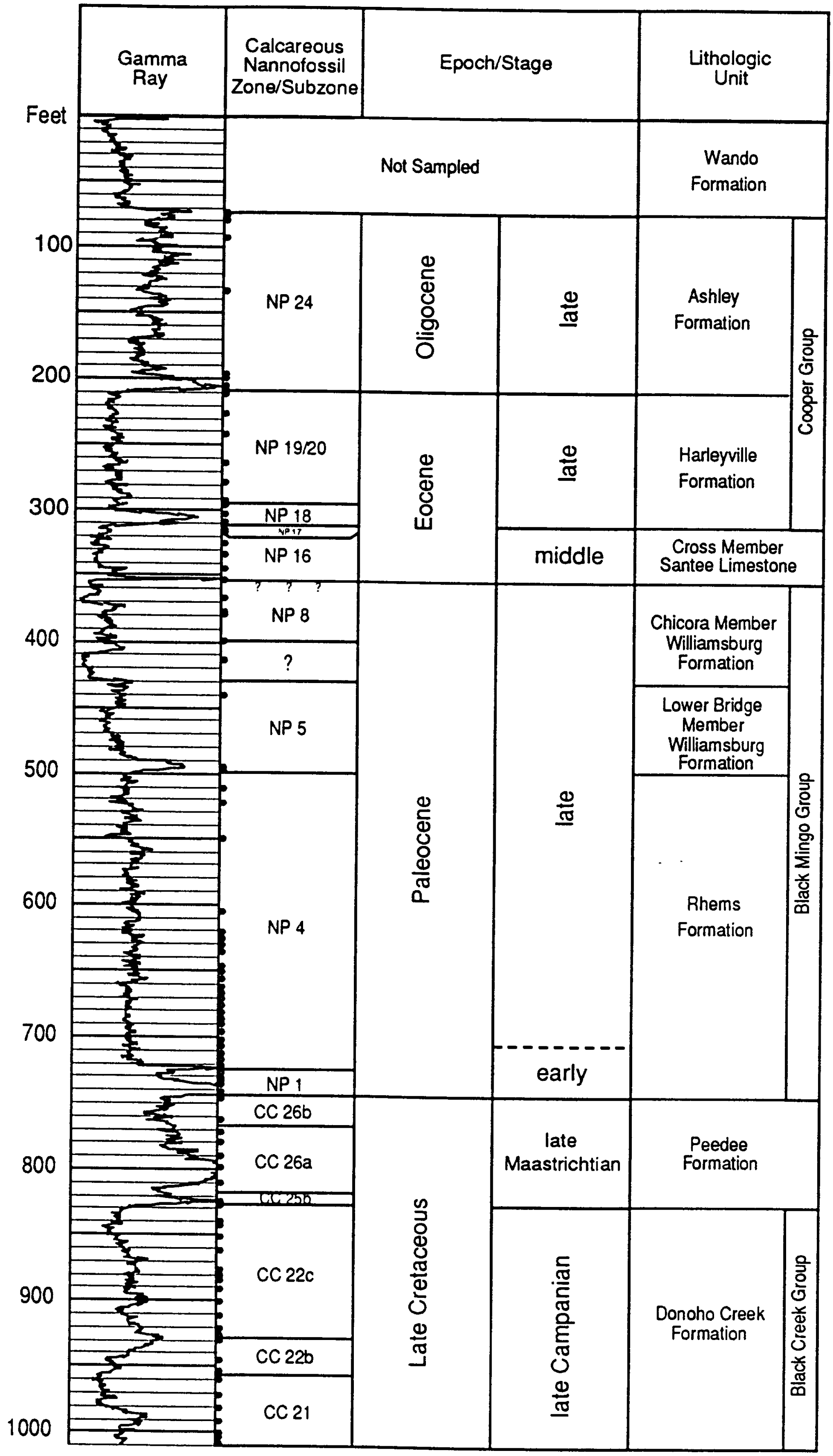

Figure 2. Stratigraphic column and gamma-ray log for Cannon Park corehole. Solid circles indicate position of microfossil samples.

Figure 3. Cretaceous calcareous nannofossil occurrences in the Cannon Park core. The following symbols are used in the body of the figure: X, present; C, specimens from downhole contamination; R, reworked specimens; ?, questionable occurrence. Abundances: A, abundant or greater than 10 specimens per field of view (FOV) at X1,250; C, common or 1 to 9 specimens per FOV at X1,250; F, frequent or 1 specimen per 1 to 10 FOV at X1,250. Preservation: G, good; M, moderate; P, poor.

Late Cretaceous																																
Campanian																							Maastrichtian									Age
Donoho Creek Formation																							Peedee Formation									Formation
CC 21							CC 22b			CC 22c													CC 25b		CC 26a					CC 26b		Zones (Perch-Nielsen, 1985)
1010.4	1003.7	1001.0	990.7	980.2	970.8	960.4	953.0	946.0	930.3	926.3	919.5	911.0	900.3	891.1	882.0	880.4	877.0	861.3	851.0	842.1	840.3	828.3	825.2	823.2	810.2	798.7	790.1	780.4	770.7	760.9	745.2	Depth (ft) / Species
.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	*Acuturris scotus*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	X	X	.	X	X	X	*Ahmuellerella octoradiata*
X	X	X	.	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X	.	X	*Ahmuellerella regularis*
.	X	.	.	X	.	X	X	X	X	.	.	.	.	.	.	.	X	X	X	.	.	X	X	X	X	X	X	X	X	X	X	*Arkhangelskiella cymbiformis*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X	.	.	X	X	X	.	X	*Arkhangelskiella specillata*
X	.	X	X	X	X	.	X	.	X	X	X	.	X	X	X	X	X	X	X	.	X	X	.	.	.	.	.	.	.	.	.	*Aspidolithus parcus constrictus*
.	.	.	X	.	.	.	X	X	.	.	.	X	X	.	.	.	X	X	X	.	X	X	.	.	.	.	.	.	.	.	.	*Aspidolithus parcus expensus*
X	.	X	X	X	X	X	X	.	X	X	X	X	X	.	X	X	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Aspidolithus parcus parcus*
.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Axopodorhabdus albianus*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	*Biscutum constans*
.	.	X	.	.	.	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	X	X	X	X	.	.	.	.	.	*Biscutum notaculum*
X	X	.	.	.	X	.	.	.	X	X	X	X	.	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	*Biscutum zulloi*
.	.	.	X	.	X	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	.	*Biscutum* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X	X	X	X	.	X	.	.	.	*Braarudosphaera bigelowii*
X	X	X	X	X	X	X	X	X	.	X	.	X	X	X	X	.	.	X	X	X	.	X	X	.	X	X	X	.	X	.	X	*Broinsonia dentata*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	*Broinsonia enormis*
X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	X	.	.	*Calculites obscurus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	*Centosphaera barbata*
X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	.	*Ceratolithoides aculeus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	*Ceratolithoides arcuatus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	*Ceratolithoides kamptneri*
X	X	X	X	X	X	X	X	X	.	X	.	X	.	X	X	X	X	X	.	X	X	X	X	.	X	.	.	X	.	.	.	*Chiastozygus amphipons*
X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Chiastozygus litterarius*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	X	X	.	.	.	*Chiastozygus propagulis*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	X	.	.	.	.	*Chiastozygus* spp.
.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	*Corollithion? completum*
.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Corollithion exiguum*
X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	.	.	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Corollithion signum*
X	X	.	X	.	.	.	.	X	.	X	.	X	X	X	X	.	X	X	.	X	X	X	.	.	.	X	X	X	.	.	.	*Cretarhabdus conicus*
.	X	.	.	X	X	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	*Cretarhabdus multicavus*
.	.	.	X	.	.	.	X	X	.	.	X	.	.	X	X	X	.	X	.	.	.	X	.	X	.	X	X	X	X	X	X	*Cretarhabdus schizobrachiatus*
.	.	.	.	.	.	.	.	.	.	X	X	.	.	X	.	.	X	.	.	X	.	.	.	X	.	X	.	.	.	.	.	*Cretarhabdus* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	*Cribrocorona gallica*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Cribrosphaerella ehrenbergii*
X	X	.	.	.	X	.	.	.	X	.	X	X	.	.	.	X	X	X	.	X	.	X	.	.	X	X	.	X	X	.	X	*Cribrosphaerella* sp. filled
X	.	X	X	X	X	.	X	.	.	.	.	X	.	.	.	X	.	X	X	.	.	.	X	X	X	X	X	X	X	X	.	*Cyclagelosphaera margerelii*
.	X	.	X	.	.	.	X	X	X	X	X	X	.	X	X	.	X	X	X	X	X	X	.	.	.	.	.	X	.	.	.	*Cylindralithus crassus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	*Cylindralithus duplex*
X	X	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Cylindralithus nudus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	X	.	.	*Cylindralithus serratus*
X	X	X	X	X	X	X	X	.	X	X	.	.	.	X	X	X	X	X	.	X	.	.	.	X	X	X	X	X	X	X	X	*Discorhabdulus ignotus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	*Discorhabdulus* spp.
.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	*Eiffellithus eximius*
X	X	.	.	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Eiffellithus gorkae*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	*Eiffellithus parallelus*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Eiffellithus turriseiffelii*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	*Eiffellithus* spp.
X	.	.	.	.	X	.	.	.	.	X	.	X	X	X	X	X	X	X	X	X	.	X	.	X	X	.	X	X	X	.	X	*Gartnerago diversum*
X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	.	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X	*Gartnerago obliquum*
.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	*Gephyrorhabdus coronadventis*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	X	.	.	.	.	.	*Glaukolithus compactus*
X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	X	.	.	.	X	X	.	*Glaukolithus diplogrammus*
.	X	X	x	X	X	X	X	X	.	X	.	.	X	X	.	X	.	X	X	X	.	.	X	X	.	X	X	.	X	X	.	*Glaukolithus minimus*
.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	*Goniolithus fluckigeri*
.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Hexalithus gardetae*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	*Kamptnerius magnificus*
X	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	X	X	.	X	.	X	.	X	.	.	.	.	.	.	X	*Kamptnerius punctatus*
.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Lithastrinus grillii*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Lithraphidites carniolensis*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	*Lithraphidites grossopectinatus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	*Lithraphidites kennethii*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	*Lithraphidites praequadratus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	*Lithraphidites quadratus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	X	.	.	X	X	.	.	X	X	.	X	X	*Loxolithus armillus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	*Lucianorhabdus arcuatus*
.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	X	.	.	.	.	.	*Lucianorhabdus cayeuxii*
.	.	.	.	.	X	X	X	X	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Lucianorhabdus maleformis*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	*Lucianorhabdus* spp.
X	.	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	*Manivitella pemmatoidea*
.	.	.	X	X	X	X	.	.	.	.	.	.	.	.	X	.	.	.	X	X	.	X	X	X	X	X	X	.	X	.	.	*Markalius inversus*

.	X	X	.	X	.	X	X	X	X	X	X	X	X	.	X	.	X	X	.	.	X	X	X	X	X	X	X	X	X	X	X	*Micula concava*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Micula decussata*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	X	*Micula murus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	X	.	.	.	*Micula praemurus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	*Micula prinsii*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	*Micula* sp. cf. *M. prinsii*
.	.	X	.	.	.	X	X	X	.	X	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Microrhabdulus attenuatus*
X	X	X	X	X	X	.	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Microrhabdulus belgicus*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	*Microrhabdulus decoratus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	*Monomarginalis pleniporus*
.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	*Nannoconus* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	*Nephrolithus frequens*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	*Ottavianus terrazetus*
.	.	.	.	.	X	.	.	X	X	X	.	X	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	*Percivalia porosa*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Placozygus fibuliformis*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	.	.	.	.	X	*Placozygus sigmoides*
.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X	.	X	.	.	*Pontosphaera multicarinata*
X	.	.	.	X	X	X	.	.	.	X	X	.	X	X	X	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	*Prediscosphaera arkhangelskyi*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Prediscosphaera cretacea*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	X	X	X	.	*Prediscosphaera grandis*
.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	X	X	.	X	*Prediscosphaera intercisa*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	*Prediscosphaera majungae*
X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Prediscosphaera spinosa*
X	X	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	.	.	X	.	.	.	X	X	X	X	X	X	X	X	X	*Prediscosphaera stoveri*
.	X	X	X	X	X	.	.	.	X	.	.	X	.	X	X	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	*Quadrum gothicum*
X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	.	X	X	X	X	.	.	.	.	.	.	.	R	.	*Quadrum sissinghii*
.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Quadrum trifidum*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Reinhardtites anthophorus*
.	.	.	.	.	.	.	.	.	.	X	.	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	*Reinhardtites levis*
X	X	.	.	.	X	.	.	.	X	X	X	.	X	X	X	X	X	X	X	X	.	.	.	.	?	.	.	.	X	.	.	*Repagulum parvidentatum*
.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Retecapsa angustiforata*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	.	X	X	X	.	X	X	X	X	X	X	*Retemediaformis teneraretis*
.	.	X	.	X	.	X	.	X	.	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Rhagodiscus angustus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	X	X	X	X	.	X	X	X	.	X	*Rhagodiscus reniformis*
.	X	X	.	X	X	X	X	.	X	.	X	X	.	X	.	X	.	X	.	X	X	X	X	X	X	X	X	X	X	X	X	*Rhagodiscus splendens*
.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	.	*Rhombolithion rhombicum*
X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	*Rotelapillus crenulatus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	*Rotelapillus munitus*
X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Rucinolithus magnus*
.	.	.	.	X	X	.	X	X	X	X	X	X	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	*Rucinolithus* spp.
X	.	.	.	.	.	.	X	.	.	.	X	X	.	.	X	X	.	.	X	X	.	.	X	X	.	.	.	.	.	.	.	*Scapholithus fossilis*
.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	.	X	.	.	.	X	.	.	.	.	X	.	.	.	.	*Sollasites barringtonensis*
.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	X	.	.	.	X	.	.	.	*Sollasites lowei*
.	.	X	.	.	.	.	.	X	X	.	X	X	X	.	X	X	X	X	.	X	X	X	.	.	.	.	.	.	.	.	.	*Stovarius asymmetricus*
.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Stovarius biarcus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Stovarius coronatus*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Stradneria crenulata*
.	X	X	.	.	.	X	.	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Tetrapodorhabdus decorus*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	X	X	X	.	.	.	X	X	*Thoracosphaera* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	X	.	.	*Tortolithus* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.	*Tranolithus gabalus*
X	X	.	X	.	.	X	X	X	.	.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	*Tranolithus phacelosus*
X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	.	.	X	X	X	X	X	X	X	X	*Vekshinella aachena*
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	X	.	X	.	*Vekshinella parma*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Vekshinella stradneri*
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	*Watznaueria barnesae*
X	.	X	X	X	X	.	.	.	X	.	.	X	.	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X	X	X	X	*Watznaueria biporta*
X	X	X	X	X	X	X	X	.	X	X	.	.	X	X	.	X	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	*Watznaueria supracretacea*
X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	X	X	X	X	X	X	X	.	*Zeugrhabdotus acanthus*
X	X	.	.	X	.	.	.	X	X	X	X	X	.	X	X	X	X	X	.	X	X	X	X	X	.	X	X	X	X	X	.	*Zeugrhabdotus erectus*
.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	*Zeugrhabdotus obliqueclausus*
.	.	.	X	X	.	.	X	X	X	X	.	X	X	.	X	.	.	X	X	.	X	X	X	X	X	X	X	X	X	X	X	*Zeugrhabdotus pseudanthophor*
.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	X	.	*Zeugrhabdotus* spp.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	Tertiary contamination
A	F	A	A	A	A	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	Abundance
G	M	G	G	G	M	M	M	M	M	M	G	M	M	M	M	M	G	G	G	G	M	M	G	G	G	G	M	M	G	M	M	Preservation
1010.4	1003.7	1001.0	990.7	980.2	970.8	960.4	953.0	946.0	930.3	926.3	919.5	911.0	900.3	891.1	882.0	880.4	877.0	881.3	851.0	842.1	840.3	828.3	825.2	823.2	810.2	798.7	790.1	780.4	770.7	780.9	745.2	Depth (ft) Species
CC 21							CC 22			CC 22													CC 25		CC 26					CC 26		Zones (Perch-Nielsen, 1985)

Figure 3.

Cannon Park core — Group	Black Mingo Group																												
Formation	Rhems Formation																												
Member																													
	Early										Late																		
Series	Paleocene																												
Calcareous Nannofossil Zones (Martini, 1971)	upper NP 1						NP 4																						
Species / Depth (ft)	743.2	741.2	736.0	733.0	731.0	726.0	723.3	720.7	713.7	710.0	705.0	699.6	695.1	690.0	684.7	679.7	675.0	670.0	665.0	660.0	655.0	650.0	645.0	635.0	630.0	625.0	620.0	521.0	510.0
Biscutum spp.	.	.	.	.	.	X	.	.	.	X	X	.	X	.	X	.	.	.	.	.	X	X	X	.	.	.	X	X	.
Blackites creber	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Blackites spinosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Blackites tenuis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Braarudosphaera bigelowii	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	.	.	.	X	.	X	X	X	.	X	X	X	X	.
Braarudosphaera discula	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Braarudosphaera stylifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bramletteius serraculoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Campylosphaera dela	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cepekiella lumina	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus bidens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1	.	.	.	.
Chiasmolithus consuetus s.l.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Chiasmolithus expansus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus grandis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus oameruensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus titus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coccolithus cribellum	.	.	.	.	.	.	.	.	X	X	X	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Coccolithus eopelagicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coccolithus pelagicus	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coronocyclus nitescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cribrocentrum reticulatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.
Cruciplacolithus asymmetricus	.	.	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus edwardsii	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus intermedius	X	X	X	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus primus	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X
Cruciplacolithus tenuis	.	.	.	.	.	.	X	X	X	.	X	X	X	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X
Cyclagelosphaera alta	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclagelosphaera prima	.	.	.	X	X	X	.	.	.	X	X	X	.	X	X	X	X	.	.	X	.	.	X	.	.	.	X	X	.
Cyclagelosphaera reinhardtii	.	.	X	X	X	X	.	.	.	.	.	.	.	.	X	.	X	.	X	X	.	X	.	X	.	X	X	.	X
Cyclococcolithus formosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclococcolithus protoannulus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclococcolithus robustus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Dictyococcites bisectus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyococcites scrippsae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster barbadiensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster mohleri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster saipanensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster tanii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster woodringii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ellipsolithus bollii	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X
Ellipsolithus macellus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ericsonia obruta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ericsonia subpertusa	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fasciculithus billii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fasciculithus involutus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fasciculithus janii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Goniolithus fluckigeri	.	.	.	.	X	X	.	X	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Hayella situliformis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera bramlettei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera carteri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera compacta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera euphratis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera intermedia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera lophota	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Helicosphaera recta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Cannon Park core — Group	Black Mingo Group								Cooper Group																						
Formation	Williamsburg Formation								Santee Limestone					Harleyville Formation									Ashley Formation								
Member	Lower Bridge			Chicora Mbr.					Cross Member																						
	Late								Middle					Late									Late								
Series	Paleocene								Eocene														Oligocene								
Calcareous Nannofossil Zones (Martini, 1971)	lower NP 5			contaminated	NP 8			contaminated	upper NP 16				NP 17	NP 18				NP 19/20					NP 24								
Species / Depth (ft)	497.7	492.0	439.0	412.2	399.0	378.1	378.0	367.4	353.0	345.0	331.7	326.0	315.0	311.8	308.6	302.3	295.3	291.0	279.0	262.0	226.0	210.5	207.0	205.0	199.3	197.0	132.0	92.0	80.5	75.5	74.6
Biscutum spp.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Blackites creber	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Blackites spinosus	.	.	.	.	.	.	.	.	.	X	X	X	.	.	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.
Blackites tenuis	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.
Braarudosphaera bigelowii	X	X	.	.	.	.	.	.	X	X	X	X	.	.	X	X	X	X	X	.	X	X	X	X	X	.	.	X	.	X	X
Braarudosphaera discula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.
Braarudosphaera stylifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bramletteius serraculoides	.	.	.	.	.	.	.	.	.	.	X	.	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Campylosphaera dela	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cepekiella lumina	.	.	.	.	.	.	.	.	X	X	X	X	.	X	.	X	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.
Chiasmolithus bidens	X	X	X	X	X	X	X	X	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus consuetus s.l.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus expansus	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus grandis	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus oameruensis	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus titus	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	.	.	.
Coccolithus cribellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coccolithus eopelagicus	.	.	.	.	.	.	.	.	X	.	X	X	X	X	X	X	X	X	.	X	.	X	X	.	.	.	X	X	X	X	X
Coccolithus pelagicus	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coronocyclus nitescens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	.	.	X	.	.
Cribrocentrum reticulatum	.	.	.	D	.	.	.	D	X	X	X	X	X	X	X	X	X	X	X	X	.	X	1	.	.	.	.	.	.	.	.
Cruciplacolithus asymmetricus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus edwardsii	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus intermedius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus primus	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cruciplacolithus tenuis	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclagelosphaera alta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclagelosphaera prima	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclagelosphaera reinhardtii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cyclococcolithus formosus	.	.	.	D	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1	1	.	.	.	.	.	.	.
Cyclococcolithus protoannulus	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	X	.	.	.	.
Cyclococcolithus robustus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyococcites bisectus	.	.	.	D	.	.	.	D	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	X	.	X	.	X
Dictyococcites scrippsae	.	.	.	.	.	.	.	.	X	X	X	.	X	X	X	X	.	X	.	X	.	X	.	X	.	X	.	.	.	.	.
Discoaster barbadiensis	.	.	.	.	1	.	.	D	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	1R
Discoaster mohleri	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Discoaster saipanensis	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.
Discoaster tanii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Discoaster woodringii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	X	X	X	X	X
Ellipsolithus bollii	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ellipsolithus macellus	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ericsonia obruta	.	.	.	D	.	.	.	.	X	.	X	.	X	.	.	X	.	.	.	X	.	X	.	.	X	.	X	X	X	.	X
Ericsonia subpertusa	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fasciculithus billii	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fasciculithus involutus	.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Fasciculithus janii	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Goniolithus fluckigeri	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	.	X
Hayella situliformis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Helicosphaera bramlettei	.	.	.	.	.	.	.	.	.	.	X	.	X	.	.	X	.	.	.	X	.	.	.	X	X	X	X	X	X	.	X
Helicosphaera carteri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	X	.	X
Helicosphaera compacta	.	.	.	D	.	.	.	D	X	X	X	X	X	.	X	X	X	X	X	X	.	X	X	X	.	.	.	.	.	.	.
Helicosphaera euphratis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	X	X	X	.	.
Helicosphaera intermedia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	X	.	.	X	X	X	.	X	X	X	X	X
Helicosphaera lophota	.	.	.	.	.	.	.	.	.	X	X	.	.	X	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.
Helicosphaera recta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	X	X	X

Figure 4. Cenozoic calcareous nannofossil occurrences in the Cannon Park core.
D, downhole contamination; R, specimens likely reworked.

Depth (ft)	743.2	741.2	736.0	733.0	731.0	726.0	723.3	720.7	713.7	710.0	705.0	699.6	695.1	690.0	684.7	679.7	675.0	670.0	665.0	660.0	655.0	650.0	645.0	635.0	630.0	625.0	620.0	521.0	510.0	497.7	492.0	439.0	412.2	399.0	378.1	378.0	367.4	353.0	345.0	331.7	326.0	315.0	311.8	308.6	302.3	295.3	291.0	279.0	262.0	226.0	210.5	207.0	205.0	199.3	197.0	132.0	92.0	80.5	75.5	74.6
Helicosphaera reticulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	X	.	.	.	X	X	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.
Helicosphaera seminulum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	D	.	.	X	.	.	X	.	1	.	.	.	.	?	.	1	.	.	.	.	.	.	.	.
Helicosphaera seminulum/bramlettei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Heliolithus cantabriae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Heliolithus kleinpellii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Heliolithus riedelii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hornibrookina arca	.	.	?	.	?	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Isthmolithus recurvus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.
Lanternithus duocavus	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lanternithus minutus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.
Lithostromation operosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithostromation perdurum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lithostromation simplex	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Markalius apertus	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	.	X	X	X	X	X	.	.	.	X	X	.	X	X	.	X	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Markalius inversus	X	X	X	X	X	X	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	X	X	.	.	.	.	X	X	X	.	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.
Micrantholithus spp.	.	.	.	.	X	X	.	.	.	X	X	.	X	X	.	.	X	.	.	X	.	.	X	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.
Neochiastozygus concinnus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neochiastozygus sp. cf. *N. imbriei*	X	X	.	.	X	X	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neochiastozygus junctus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neococcolithes spp.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Neocrepidolithus spp.	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedinocyclus larvalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	X	.	.	.	X	.	X	X	.	X	X	.	.	?	?	?	?	?	?
Pemma basquense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pemma papillatum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	.	.	X	X	X	X	X	X	X	X	1	.	.	.	.	.	.	.	.
Placozygus sigmoides	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pontosphaera alta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	X	X	.	.	.
Pontosphaera multipora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	X	X	X	X	X	X	X	X	X	X	X	X
Pontosphaera punctosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.
Pontosphaera pygmaea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	X	.	.
Pontosphaera spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	X	.	X	X	X	.	.	X	.	.	X	.	.	.	.	.	X
Praeprinsius spp.	.	.	X	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudotriquetrorhabdulus inversus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	•	.	.	.	.	.	.	.
Reticulofenestra abisecta	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	X	X	X	X	X
Reticulofenestra daviesii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	D	.	.	.	X	X	X	X	X	X	X	.	X	.	X	X	X	X	X	X	X	X	X	X
Reticulofenestra floridana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	.	X	X	X	.	.
Reticulofenestra hillae	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	.	.	.	X	X	.	X	.	.	X	X	.	X	.	X	.	.	.	.
Reticulofenestra pseudolockeri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	X	X	.	.	.	X	.	.
Reticulofenestra umbilicus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	D	X	X	.	X	X	X	X	X	X	X	X	X	X	X	1	.	.	.	.	.	.	.	.
Reticulofenestra spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	D	.	.	.	.	D	.	D	.	.	.	.	.	.	.	D	.	.	.	.	X	.	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.
Rhabdosphaera vitrea	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	X	.	.
Scyphosphaera expansa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphenolithus ciperoensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X
Sphenolithus distentus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	X	X	X	X	X
Sphenolithus moriformis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	.	X	X	X	X	X	X	X	X	X	X
Sphenolithus obtusus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	X	.	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphenolithus predistentus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.
Sphenolithus primus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sphenolithus pseudoradians	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	X	.	.	X	.	.	.	X	.	.	.	.	.	X	.	.	.	.	X	.
Sphenolithus radians	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Thoracosphaera spp.	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	.	X	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toweius eminens var. *eminens*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toweius eminens var. *tovae*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Toweius pertusus	.	.	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Transversopontis pulcher	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Transversopontis pulcheroides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	X	X	X	.	X	.	.	X	X	X	X	.	.	.	.	.	.	.	.	.
Transversopontis zigzag	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	D	.	.	.	.	.	.	.	X	.	.	.	X	X	X	X	X	.	X	.	.	.	.	.	.	.	.	X
Zygodiscus herlyni	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Zygrhablithus bijugatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	D	.	.	.	.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cretaceous forms	X	X	X	X	X	X	X	X	X	.	.	X	X	X	X	X	X	X	X	X	X	.	.	.	X	.	X	X	X	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Abundance	C	C	A	A	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	A	C	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	F	C	A	C	C	C	C	C
Preservation	M	M	M	G	M	M	G	M	M	P	P	P	P	M	M	M	M	P	M	P	P	P	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	P	M	M	M	P	M	M	G	G	G	M	M	M	G	G	G	G	G	M	M	M	G	G
Calcareous Nannofossil Zones (Martini, 1971)	upper NP 1						NP 4																							lower NP 5			contaminated	NP 8			contaminated	upper NP 16				NP 17	NP 18				NP 19/20					NP 24								

Figure 4. Cont.

sample was placed in a beaker, stirred, and settled through 20 ml of water. An initial settling time of one minute was used to remove the coarse fraction, and a second settling time of 10 minutes was used to remove the fine fraction. Smear slides were prepared from the remaining suspended material. Cover slips were attached to the slides using Norland Optical Adhesive (NOA-65), a clear adhesive that bonds glass to glass and cures when exposed to ultraviolet radiation. Samples were examined with either a Zeiss Photomicroscope III or a Zeiss Axiophot 2.

PALYNOLOGY

Thirty-eight samples were examined for pollen content, and nineteen of these also were examined for dinocysts. All samples were treated with hydrochloric, hydrofluoric, and nitric acids. For some samples, organic material was separated by using a series of soap washes and swirling. Material was stained with Bismark brown, sieved at 10-200 µm, and mounted for light microscope observation using glycerin jelly. Many of the 38 samples from the Cannon Park core that were examined for pollen were screened at >10µm and <40µm to concentrate the angiosperm pollen.

RESULTS

GENERAL CORE STRATIGRAPHY

The Cretaceous and Cenozoic sections in the Cannon Park core consist entirely of marine sediments (fig. 2). The Upper Cretaceous section consists primarily of bioturbated, calcareous, silty and sandy clays and similar muddy fine sands that are assigned to the Donoho Creek Formation of the Black Creek Group and the overlying Peedee Formation. Similar bioturbated, calcareous, fine-grained marine deposits constitute the Paleocene section. Well-sorted shelly sands and sandy, shelly limestones are present near the top of the Paleocene section. The Paleocene sediments are assigned to the Rhems Formation and overlying Williamsburg Formation of the Black Mingo Group. The middle Eocene section consists of fine-grained limestone assigned to the Cross Member of the Santee Limestone. The upper Eocene section consists of calcareous clays and clayey fine-grained limestones assigned to the Harleyville Formation of the Cooper Group. The Oligocene section consists of micro-fossiliferous, phosphatic, clayey fine sand assigned to the Ashley Formation of the Cooper Group. A Pleistocene section consisting of shelly, muddy sands and silty clays is present at the top of the core and has been mapped at Charleston by Weems and Lemon (1993) as the Wando Formation. These surficial Pleistocene deposits are not considered further in this report.

PALEONTOLOGY

The calcareous nannofossil zonation used for the Cretaceous strata is based primarily on the zonation of Sissingh (1977) as modified by Perch-Nielsen (1985). The calcareous nannofossil zonation used for the Cenozoic strata is based primarily upon the zonation of Martini (1971) and secondarily on the zonation of Bukry (1973) and Okada and Bukry (1980). Calcareous nannofossil biostratigraphy is based on the highest and lowest occurrences of species; FAD indicates a first appearance datum, and LAD indicates a last appearance datum. Important Paleogene FAD's and LAD's are given in appendix 1. A list of Cretaceous calcareous nannofossil species that are considered in this report is given in appendix 2, and a list of Cenozoic species is given in appendix 3.

The calcareous nannofossil assemblages were sufficient in number of specimens, diversity of taxa, and preservational state in the Cannon Park samples to allow placement of samples within one specific zone or subzone. Calcareous nannofossil contamination is confined primarily to reworked specimens of Cretaceous species into Paleocene sediments, although there is sporadic reworking of older Cretaceous calcareous nannofossils into younger Cretaceous sediments (fig. 3). Cretaceous calcareous nannofossils and dinoflagellates are reworked up into various parts of the Rhems Formation (figs. 4-5). There is a small amount of downhole contamination caused by the coring operation. In particular, middle Eocene calcareous nannofossils were introduced into the coarser grained parts of the Rhems Formation and the Lower Bridge Member of the Williamsburg Formation. In addition, samples from the upper and lower parts of the upper Paleocene Chicora Member of the

Group	Black Mingo Group										
Formation	Rhems								Wmsburg		
Member									LB	Chicora	
Species / Depth (ft)	736	695	690	670	650	605	550	510	498	412	378
Kallosphaeridium brevibarbatum de Coninck 1969	.	.	.	.	.	.	.	.	.	.	X
Chiropteridium lobospinosum (Gocht 1956) Gocht 1960	.	.	.	.	.	.	.	.	.	C	.
Deflandrea spinulosa Alberti 1959	.	.	.	.	.	.	.	.	.	C	.
Deflandrea phosphoritica Eisenack 1938/*D.heterophlycta* Defl.&Cooks. 1955	.	.	.	.	.	.	.	.	.	C	.
Membranophoridium aspinatum Gerlach 1961	.	.	.	.	.	.	.	.	.	C	.
Pentadinium laticinctum Gerlach 1961 (verm.)	.	.	.	.	.	.	.	.	.	C	.
Wetzeliella Eisenack 1938 spp.	.	.	.	.	.	.	.	.	.	C	.
Turbiosphaera sp. aff. *T. magnifica* Eaton 1976 of Edwards (1989)	.	.	.	.	.	.	.	.	.	X	X
Amphorosphaeridium multispinosum (Davey & Williams 1966) Sarjeant 1981	.	.	.	.	.	.	.	.	X	.	.
Deflandrea delineata Cookson & Eisenack 1965	.	.	.	.	.	.	.	.	X	.	.
Fibradinium annetorpense Morgenroth 1968	.	.	.	.	.	.	.	X	X	.	.
Spinidinium Cookson & Eisenack 1962 spp.	.	.	.	.	.	.	X	.	X	.	.
Phelodinium sp. of Edwards (1989)	.	.	.	X	X	.	X	X	.	.	X
Tanyosphaeridium xanthiopyxides (Wetzel 1933) Stover & Evitt 1978	.	.	.	X	.	.	.	.	.	.	.
Lejeunecysta Artzner & Dorhofer 1978 sp.	.	.	X	.	X	.	X	.	.	.	.
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967	.	X	.	X	X	.	X	.	X	X	X
small peridiniacean forms	.	X	X	X	X	X	X	X	X	.	.
Palaeocystodinium Alberti 1967 sp.	.	X	X	X	X	.	X	X	.	.	.
Hafniaspha era Hansen 1977 sp.	.	X	X	X	X	.	X	.	.	.	.
?*Andalusiella rhombohedra* of Edwards and others (1984)	X	X	.	.	.	.	X	X	.	.	X
Cordosphaeridium Eisenack 1963 spp.	X	X	X	X	X	X	X	X	X	.	X
Damassadinium californicum (Drugg 1967) Fensome et al. 1993	X	X	X	X	X	X	.	.	X	.	X
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965	X	.	X	X	.	.	X	X	.	.	X
Palaeocystodinium golzowense Alberti 1961	X	X	X	X	.	.	X	X	.	.	.
Spiniferit es Mantell 1850 spp.	X	X	X	.	X	X	X	X	X	X	X
miscellaneous areoligeracean forms	X	X	X	X	X	X	X	X	X	X	X
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937	X	.	.	.	.	.	.	.	.	X	.
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977	X	X	X	.	X	X	X	X	X	.	.
Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967	X	X	.	.	.	.	.	.	X	.	.
Oligosphaeridium complex (White 1842) Davey & Williams 1966	X	X	.	X	X	.	.	.	.	.	.
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984	X	.	.	.	.	.	.	.	.	.	.
Cyclapophysis monmouthensis Benson 1976	X	.	.	.	.	.	.	.	.	.	.
Deflandrea cf. *D. diebelii* Alberti of Drugg (1967)	X	.	.	.	.	.	.	.	.	.	.
Deflandrea n. sp. aff. *D. truncata* Eisenack 1938	X	.	.	.	.	.	.	.	.	.	.
Exochosphaeridium Davey et al. 1966 sp.	X	.	.	.	.	.	.	.	.	.	.
Membranosphaera maastrichtica Samoilovitch 1961	X	.	.	.	.	.	.	.	.	.	.
Phelodinium Stover & Evitt 1978 spp.	X	.	.	.	.	.	.	.	.	.	.
Spinidinium densispinatum Stanley 1965	X	.	.	.	.	.	.	.	.	.	.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969	X	.	.	.	.	.	.	.	.	.	.
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960	X	.	.	.	.	.	.	.	.	.	.
Andalusiella sp. aff. *A. polymorpha* of Edwards (1980)	?	.	.	.	.	.	.	.	.	.	.
reworked Cretaceous specimens	.	.	.	.	.	.	R	R	.	.	.

Figure 5. Paleocene Dinocysts from the Cannon Park core. Wmsburg, Williamsburg; LB, Lower Bridge Member; X, present; C, contaminant; R, reworked.

Williamsburg Formation contain a significant amount of downhole contamination of calcareous nannofossils from the overlying middle Eocene Santee Limestone (fig. 4). There also are conspicuous numbers of Oligocene and questionably Eocene dinoflagellates in the lower part of the Chicora Member. The upper and lower portions of the Chicora Member are much coarser grained than the underlying or overlying sediments, and thus much more prone to contamination during the coring process. Paleocene and questionably Eocene dinoflagellates are reworked into the upper Eocene Harleyville Formation, and there is a minor amount of reworking of late Eocene calcareous nannofossil specimens from the top of the Harleyville Formation into the lowest Ashley Formation sample (late Oligocene age).

Occurrences of dinocysts in the Cannon Park core are shown in figures 5 and 6. A list of dinocyst species that are considered in this report is given in appendix 4, and appendix 6 contains detailed information about dinocyst occurrences in the core. There is no widely accepted standard zonation for dinoflagellate cysts. However, there are lowest and highest occurrences that have proved to be useful in correlating dinocyst-bearing sediments, both on a local and an intercontinental basis, and where possible they are used for the Cannon Park sediments.

Occurrences of pollen and spores are shown in figure 7. A list of pollen species that are considered in this report is given in appendix 5, and appendix 7 contains information about pollen occurrences in the core. A pollen zonation has been proposed for the Paleocene of the eastern United States (Frederiksen, 1991, 1998), but no pollen zonation has been proposed for the Eocene of this region. However, higher resolution correlations can be obtained using lowest and highest occurrences of individual pollen taxa rather than zones, and that is the method used for pollen age determinations in this report.

DONOHO CREEK FORMATION
(upper part) Black Creek Group

1,012.0-826.6 ft
Late Campanian
Zone CC 21 and Subzones CC 22b and CC 22c

LITHOSTRATIGRAPHY

The Donoho Creek Formation consists of at least 185 ft of fine-grained marine sediments. The recovered Donoho Creek section extends from the base of the Cannon Park core at 1,012.0 ft to an unconformable contact with the Peedee Formation at 826.6 ft (figs. 2, 8). An additional unconformable contact is present within the Donoho Creek section at 954.1 ft. Regionally, the Donoho Creek Formation is known to consist of two, and locally three, subunits divided by unconformable contacts (Self-Trail and Gohn, 1996)(fig. 8).

The Donoho Creek section from 1,012.0 to 954.1 ft consists of bioturbated, calcareous, muddy, very fine to fine quartz sands and similar clayey quartz silts. The sand-silt fraction coarsens upward slightly within the interval from silt and very fine sand in the lower part to very fine and fine sand (with about 5 to 10 percent medium sand) in the upper part. Small to trace amounts of silt- and sand-sized mica and glauconite are present throughout this interval, as are sparse, sand-sized molluscan fragments. Microfossils are moderately common. The entire interval is bioturbated, and clay-lined burrows are discernible throughout the section. Small, irregular secondary nodules, in which calcite replaces the clay matrix, are irregularly spaced throughout the section.

At the contact at 954.1 ft, calcite-cemented, slightly muddy, very fine to medium quartz sand is overlain by calcareous, muddy, very fine to fine sand that contains phosphate sand and granules, cemented intraclasts, and common shell fragments in its basal 6 inches. The contact is sharp and 1 to 2 inches of relief are seen in the core. This upper part of the Donoho Creek interval also consists of calcareous, bioturbated, muddy, very fine to fine sands. Small to trace amounts of glauconite, mica, and sand-sized shell fragments again are present, as are small, secondary, calcite nodules. Unlined, sand-filled burrows are present above about 905 ft. The section from 878 to 865 ft consists primarily of bioturbated, calcareous, silty clay. Thin (tenths of an inch thick), inclined (less than 20 degrees), silt laminae are spaced every 4 to 6 inches in the upper part of this clay interval.

CALCAREOUS NANNOFOSSILS

The Donoho Creek Formation of the Black Creek Group is represented by 23 samples containing a flora indicative of calcareous nannofossil Zone CC 21 and Subzones CC 22b and

Group				Cooper Group				
Formation	Santee Fm			Harleyville Fm.				
Member	Cross Mbr.							
Species / Depth (ft)	353	332	315	302	295	262	242	211
Pentadinium membranaceum (Eisenack 1965) Stover & Evitt 1978	.	.	.	.	.	.	.	X
Cordosphaeridium funiculatum Morgenroth 1966	.	.	.	.	.	X	X	X
Glaphyrocysta cf. *G.? vicina* (Eaton 1976) Stover & Evitt 1978	.	.	.	.	.	X	.	.
Hystrichostrogylon coninckii Heilmen-Clausen 1985	.	.	.	.	.	X	.	.
Wetzeliella Eisenack 1938 spp.	.	.	.	.	X	.	X	X
Pentadinium laticinctum Gerlach 1961 (verm.)	.	.	.	.	X	X	.	.
Pentadinium laticinctum Gerlach 1961 subsp.*laticinctum*	.	.	.	X	X	X	X	X
Batiacasphaera baculata Drugg 1970	.	.	.	X	X	X	X	X
Batiacasphaera compta Drugg 1970	.	.	.	X	X	X	X	X
Deflandrea phosphoritica Eisenack 1938/*D.heterophlycta* Defl. & Cooks. 1955	.	.	.	X	X	X	X	X
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al. 1980	.	.	.	X	X	.	X	.
Polysphaeridium zoharyi (Rossignol 1962) Bujak et al. 1980	.	.	.	X	.	.	X	.
Charlesdownia variabilis (Bujak 1980) Lentin & Vozzennikova 1989	.	.	.	X	.	X	.	.
Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978	.	.	.	X	.	X	.	.
Fibrocysta Stover & Evitt 1978 sp.	.	.	.	X	.	X	.	.
Hystrichokolpoma cinctum Klumpp 1953	.	.	.	X	.	X	.	.
Melitasphaeridium pseudorecurvatum (Morgenroth 1966) Bujak et al. 1980	.	.	.	X	X	.	.	.
Samlandia chlamydophora sensu Stover and Hardenbol (1993)	.	.	.	X	X	.	.	.
Pentadinium laticinctum Gerlach 1961 (knobby)	.	.	.	X	.	.	.	.
Palaeocystodinium golzowense Alberti 1961	.	.	X	.	.	X	X	.
Selenopemphix Benedek 1972 spp.	.	.	X	.	.	X	.	.
Corrudinium sp. I of Edwards (1984)	.	.	X	.	.	.	.	.
Heteraulacacysta porosa Bujak et al. 1980	.	.	X	.	.	.	.	.
Homotryblium Davey & Williams 1966 sp.	.	.	X	.	.	.	.	.
Lentinia serrata Bujak 1980	.	.	X	.	.	.	.	.
Charlesdowniea coleothrypta (Wms. & Downie1966) Lentin & Vozzh. 1989	.	X	X	X	X	.	X	X
Rottnestia borussica (Eisenack 1954) Cookson & Eisenack 1961	.	X	.	X	.	.	.	X
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970	.	X	X	X	X	X	X	X
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969	.	X	X	X	X	X	X	.
Cordosphaeridium Eisenack 1963 spp.	.	X	.	X	X	.	X	.
Dinopterygium cladoides sensu Morgenroth 1966	.	X	X	.	X	X	X	.
Millioudodinium sp. I of Edwards (1984)	.	X	X	.	.	X	.	.
Ennaedocysta Stover & Williams 1995 spp.	.	?	.	.	.	X	.	.
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984	X	.	.	.	X	.	X	X
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965	X	X	X	X	.	X	.	X
Homotryblium plectilum Drugg & Loeblich Jr. 1967	X	X	X	X	X	X	X	X
Lejeunecysta Artzner & Dorhofer 1978 sp.	X	X	X	.	X	X	X	X
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967	X	X	X	X	X	.	X	X
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969	X	.	X	X	X	X	.	X
Tectatodinium pellitum Wall 1967	X	.	X	X	.	?	X	X
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960	X	X	X	X	X	X	X	X
Spiniferites Mantell 1850 spp.	X	X	X	X	X	X	.	X
miscellaneous areoligeracean forms	X	X	X	X	X	X	X	X
Operculodinium Wall 1967 spp.	X	.	.	X	X	X	X	.
Samlandia chlamydophora Eisenack 1954	X	X	X	X	X	X	X	.
Distatodinium ellipticum (Cookson 1965) Eaton 1976	?	X	.	X	X	X	.	.
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955	X	X	X	X	X	X	.	.
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971	X	X	X	X	.	X	.	.
Hafniasphaera Hansen 1977 sp.	X	X	.	X	.	.	.	.
Pentadinium goniferum Edwards 1982	X	X	X	.	.	.	.	.
Pentadinium polypodum Edwards 1982	X	X	X	.	.	.	.	.
Rhombodinium draco Gocht 1955/*R. glabrum* (Cookson 1956) Vozzh. 1967	X	X	X	X	.	.	.	.
"*Areosphaeridium*" *polypetalum* Islam 1983	X	.	.	.	.	.	.	.
Eocladopyxis sp. of Williams and Brideaux (1975)	X	.	.	.	.	.	.	.
Glaphyrocysta cf. *G.? vicina* (Eaton 1976) Stover & Evitt 1978	X	.	.	.	.	.	.	.
Hystrichostrogylon membraniphorum Agelopoulous 1964	X	.	.	.	.	.	.	.
Pentadinium Gerlach 1961 n. sp. D	X	.	.	.	.	.	.	.
Rhombodinium sp. I of Edwards (1984)	X	.	.	.	.	.	.	.
small peridiniacean forms	.	.	.	.	.	.	.	R
Eocladoyxis Morgenroth 1966 n. sp.	.	.	.	R	R	.	.	.

Figure 6. Eocene dinocysts from the Cannon Park core. X, present; ?, questionably present; R, reworked.

Formation	Rhems Fm.																Lower Bridg		Ch
Cannon Park core Depth (ft)	713.7	710.0	705.0	699.6	695.1	684.7	679.7	670.0	665.0	660.0	655.0	645.0	635.0	630.0	625.0	620.0	492.0	439.0	378.0
Species Sample	S	T	U	V	AA	AB	AC	AE	AF	AG	AH	AI	AJ	AK	AL	AM	W	X	Y
Aesculiidites circumstriatus	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X
Bombacacidites nacimientoensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Bombacacidites reticulatus	X	X	X	.	X	X	X	X	X	.	X	X	X	X	X	X	.	X	X
Carya <29µm	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	P	.	X
Caryapollenites prodromus group	.	.	.	.	.	.	.	P	.	.	.	.	.	P	.	.	?	X	.
Choanopollenites alabamicus	.	.	.	.	X	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Favitricolporites baculoferus	.	X	X	X	X	X	X	X	X	X	.	X	X	X	X	.	X	.	.
Intratriporopollenites pseudinstructus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Lanagiopollis cribellatus	.	.	.	.	.	.	.	.	X	.	.	.	.	.	X	.	.	.	.
Longapertites sp.	.	.	.	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.
Milfordia minima	.	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	X	.	.
Momipites coryloides	X	X	X	X	X	X	X	.	X	?	.	.	X	X	X	.	X	X	X
Momipites dilatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.
Momipites flexus	.	.	.	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.
Momipites microfoveolatus	X	X	.	.	.	.	.	.	X	X	.	.	.	.	.	.	.	.	.
Momipites strictus	.	.	.	.	.	.	.	X	.	X	.	.	.	.	X	.	.	X	.
Momipites tenuipolus group	.	.	.	.	.	.	X	X	X	.	.	.	.	.	X	X	X	X	X
Myocolpopollenites reticulatus	.	.	.	.	.	.	.	.	.	P	.	.	.	.	.	.	.	.	.
Nudopollis endangulatus	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Nudopollis terminalis	.	X	X	.	X	X	X	.	X	X	.	X	X	X	X	X	X	X	X
Nudopollis thiergartii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Piolencipollis endocuspoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
Plicatopollis triorbicularis type	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X
Plicatopollis triradiatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	X
Polyatriopollenites sp.	X	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Porocolpopollenites ollivierae	X	.	.	.	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.
Pseudoplicapollis cf. *P. endocuspis*	.	.	.	.	.	.	.	.	X	.	.	X	.	.	.	.	.	.	.
Pseudoplicapollis limitatus	X	X	X	X	X	X	.	X	X	P	.	X	X	X	X	.	X	X	.
Pseudoplicapollis serenus	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psilodiporites iszkaszentgyorgyi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.
Retitrescolpites anguloluminosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	.	.
Sparganiaceaepollenites sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X
Spinaepollis spinosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X	X	.
Subtriporopollenites anulatus	1	.	.	X	.	.	X	.	.	.	.	.	.	.	.	.	X	X	.
Subtriporopollenites nanus	.	.	X	.	.	X	X	.	X	.	X	X	.	.	.	.	X	X	.
Thomsonipollis magnificus	.	.	X	X	.	.	.	.	.	.	.	.	.	.	.	X	.	.	.
Triatriopollenites subtriangulus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.
Triatriopollenites triangulus	.	.	.	.	.	.	.	.	.	.	X	.	.	P	.	.	?	.	.
Tricolpites asper	.	X	X	X	.	X	.	.	.	.	.	.	.	.	.	.	X	X	.
Trudopollis spp.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ulmipollenites krempii	.	.	.	X	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ulmipollenites tricostatus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	X

Figure 7. Pollen from the Cannon Park core. Lower Bridge, Lower Bridge Member of the Williamsburg Formation; Ch, Chicora Member of the Williamsburg Formation; X, present, P, probable occurrence ; ?, questionable occurrence.

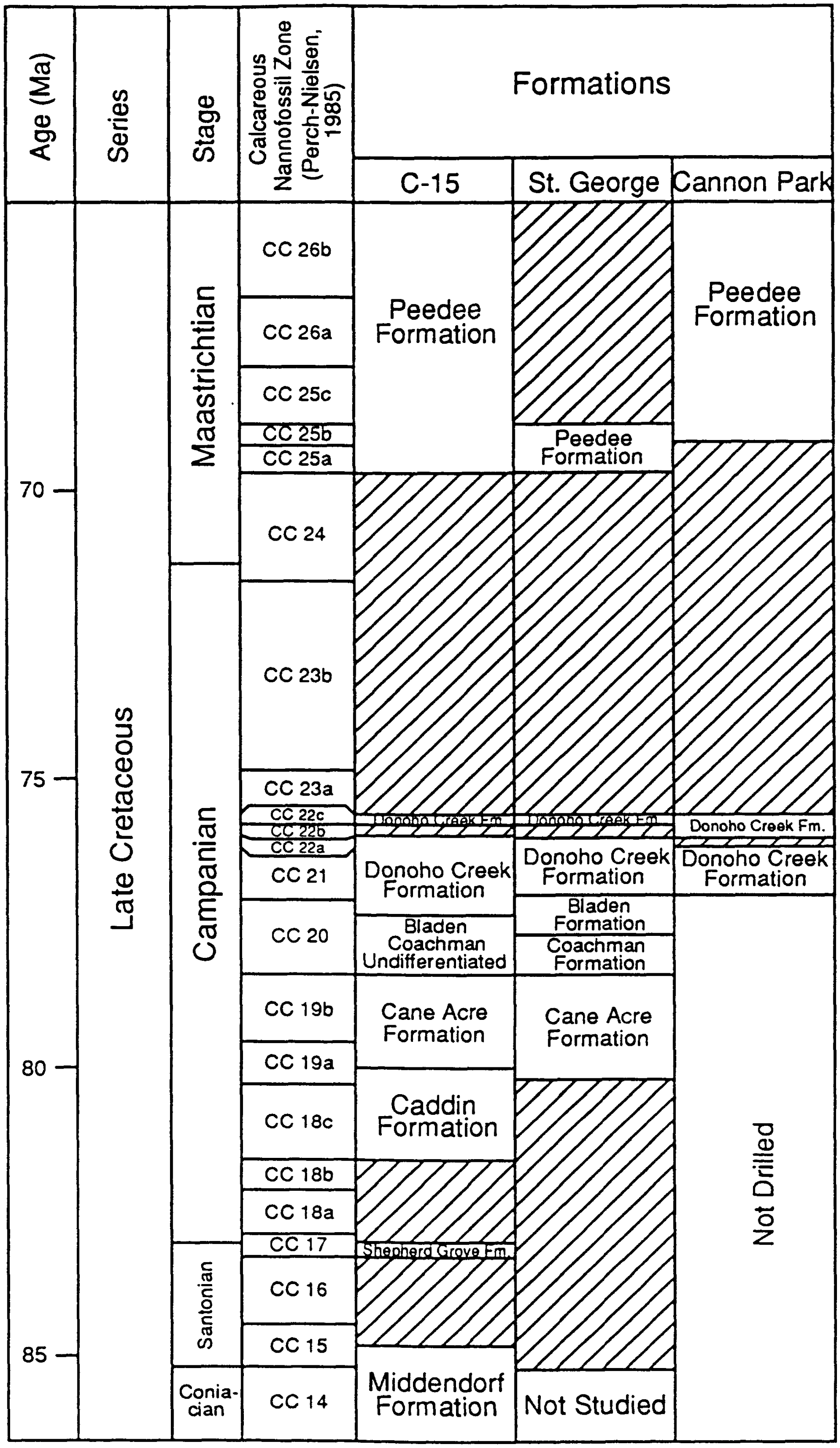

Figure 8. Series, stages, calcareous nannofossil zones, and formations in the Mesozoic portion of the Cannon Park core and other studied cores. The time scale is modified from Gradstein and others (1995). Placement of the Campanian-Maastrichtian boundary is from Odin, compiler (1996). Angled line pattern indicates that there are no sediments of this age in the core.

CC 22c (fig. 3). Preservation of calcareous nannofossils from the Donoho Creek Formation is moderate to good, and floral abundances are abundant to common. The lowest seven samples, from 1,010.4 to 960.7 ft, are placed in Zone CC 21 based on the co-occurrence of *Quadrum sissinghii* (FAD marks the base of Zone CC 21) and *Ceratolithoides aculeus* (FAD marks the base of Zone CC 20) and the absence of *Quadrum trifidum* (FAD marks the base of Zone CC 22). It cannot be determined whether the Cannon Park corehole reached the base of Zone CC 21.

The physical unconformity at 954.1 ft also is recorded by the calcareous nannofossil assemblage as the boundary between Zones CC 21 and CC 22. In the Cannon Park core, Subzone CC 22a is missing, and Zone CC 21 is possibly truncated. This unconformity also is present in other South Carolina cores (St. George and C-15; figs. 1, 8)(Self-Trail and Gohn, 1996; Self-Trail and Bybell, 1997) where it is overlain either by Subzone CC 22a or Subzone CC 22b. Due to the paucity of marker species in the Cannon Park core, however, this hiatus is not evident when viewing the sediment accumulation plot (fig. 9).

The samples from 953.0 to 930.3 ft are placed in Subzone CC 22b based on the absence of *Lithastrinus grillii* (LAD marks the top of Subzone CC 22a) and *Reinhardtites levis* (FAD marks the base of Subzone CC 22c) and the presence of *Quadrum trifidum* (FAD marks the base of Subzone CC 22a) and *Reinhardtites anthophorus* (LAD marks the top of Subzone CC 22c). It should be noted, however, that *L. grillii* becomes somewhat sporadic near the top of its range, and it is therefore possible that these three samples belong in Subzone CC 22a rather than CC 22b. However, because *L. grillii* does occur in sediments lower in the section, it is more probable that its true range is represented in this core. The remaining 13 samples (926.3 to 838.3 ft) from the top of the formation are placed in Subzone CC 22c based on the co-occurrence of *Reinhardtites levis* and *Reinhardtites anthophorus*.

At 826.6 ft, the Donoho Creek Formation is truncated by an unconformity that encompasses the Campanian/Maastrichtian boundary. This unconformity has been recorded elsewhere in South Carolina (fig. 8)(Self-Trail and Bybell, 1997), as well as from New Jersey (Sugarman and others, 1995).

PEEDEE FORMATION

826.6-743.8 ft

Late Maastrichtian

Subzones CC 25b, CC 26a, CC 26b

LITHOSTRATIGRAPHY

The Peedee Formation is approximately 83 ft thick between the basal contact at 826.6 ft and the Peedee-Rhems Formation contact (Cretaceous-Tertiary boundary) at 743.8 ft. The sharp contact between the Donoho Creek Formation and the Peedee Formation at 826.6 ft is burrowed, and 2 inches of relief are seen in the core. The upper foot of the Donoho Creek consists of calcite-cemented, silty, very fine to fine sand. The basal 3.5 ft of the Peedee consists of bioturbated, calcareous, muddy, very fine to fine sand with common calcite-cemented intraclasts, small molluscan fragments, and phosphate sand and granules. Phosphate constitutes 5 to 10 percent of the sediment at the base of the Peedee, but decreases in abundance upward.

The Peedee section above its basal 3.5 ft consists of massive to thoroughly bioturbated and texture-mottled, strongly calcareous, clayey quartz silt. Very fine quartz sand is present in the upper 10 to 20 ft of the Peedee section. Disseminated, sand-sized molluscan fragments are sparse, but an abundant microfauna is present. Mica and glauconite are present in small to trace amounts.

CALCAREOUS NANNOFOSSILS

The Peedee Formation consists of sediments of late Maastrichtian age (Zones CC 25 and CC 26). Calcareous nannofossils were examined from nine samples taken from the Peedee Formation (fig. 3). Calcareous nannofossil preservation throughout the Peedee Formation was moderate to good, and abundances were typically high. The lower two samples (825.2 and 823.3 ft.) are placed in Subzone CC 25b based on the presence of *Lithraphidites quadratus* (FAD defines the base of Subzone CC 25b) and the absence of *Nephrolithus frequens* and *Ceratolithoides kamptneri* (FAD's define the base of Zone CC 26), *Micula murus* (FAD defines the base of Subzone CC 25c), and *Reinhardtites levis* (LAD marks the top of Zone CC 24).

Subzone CC 26a extends from 810.2 to 771.0 ft and is represented by five samples. Identification

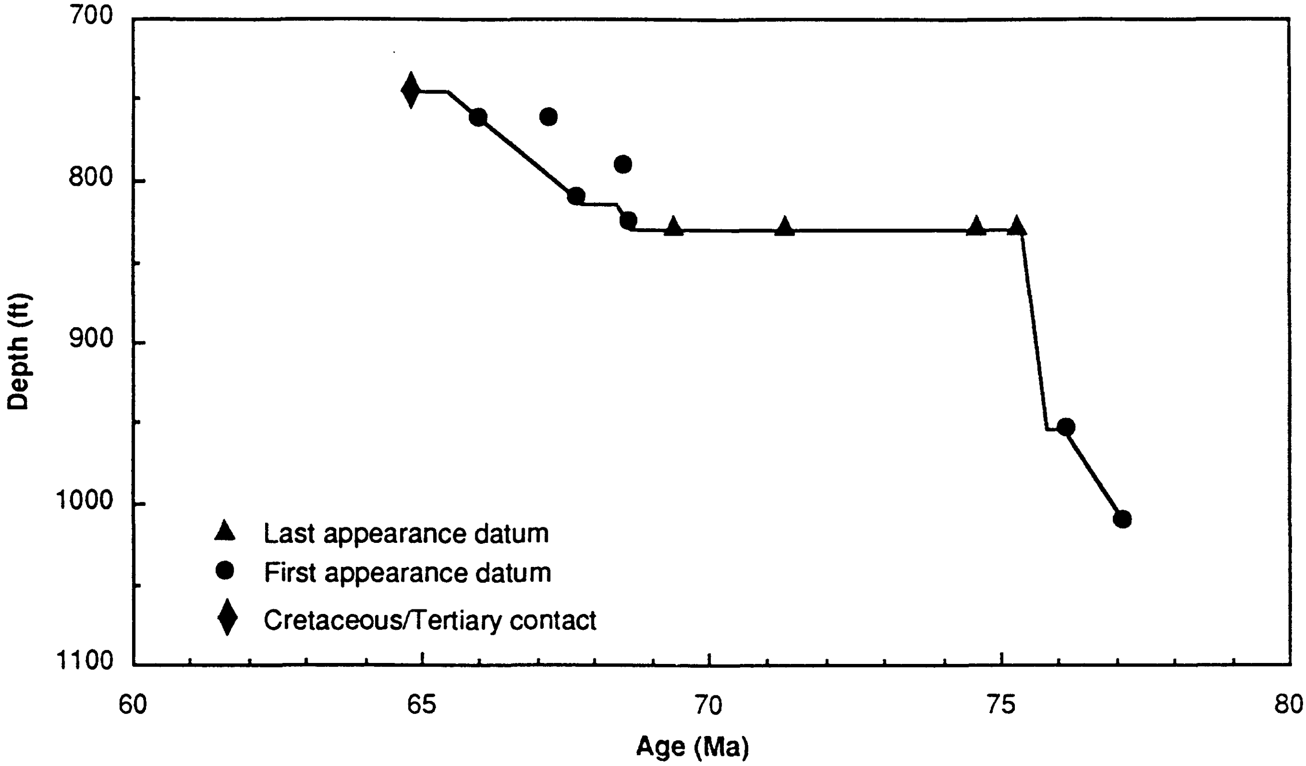

Figure 9. Cretaceous age-depth relationship in Cannon Park core, S.C., using calcareous nannofossil datums. Ages of datums are assinged by Henriksson (1994), Berggren and others (1995), and Erba and others (1995).

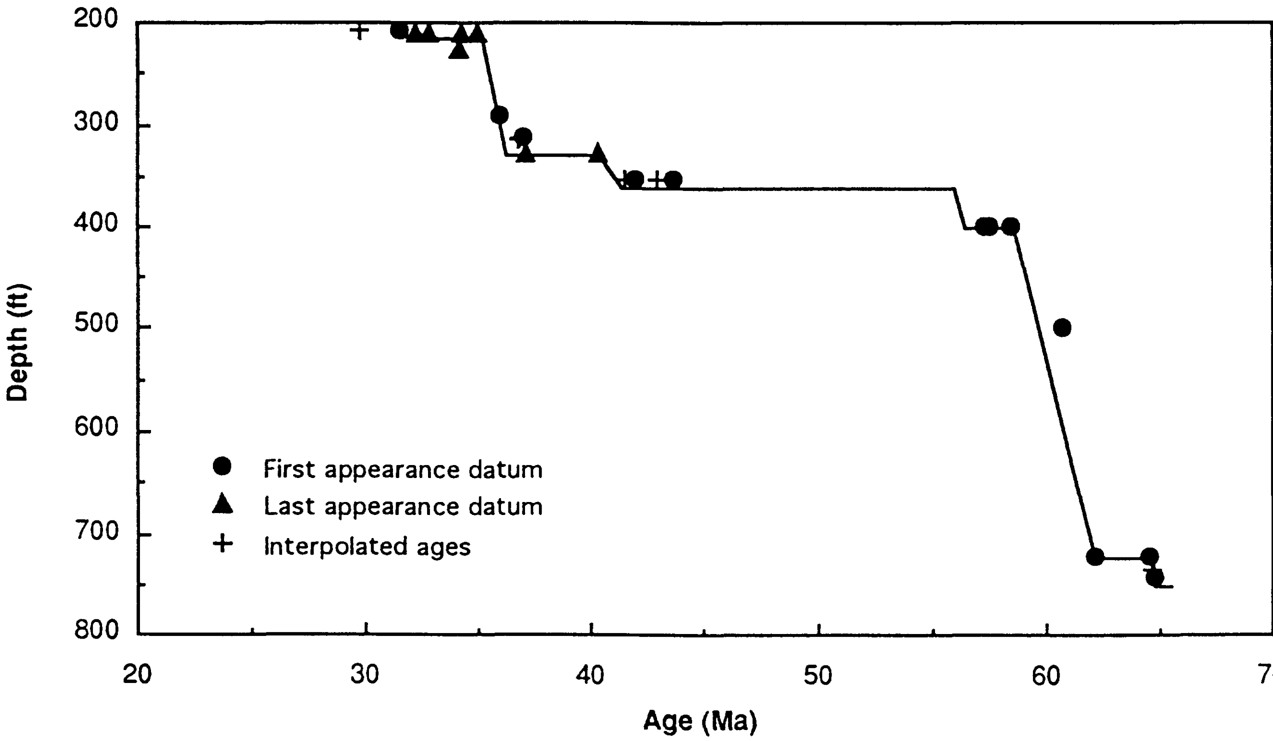

Figure 10. Tertiary age-depth relationship in Cannon Park core, S.C., using calcareous nannofossil datums. Ages of datums are as assigned by Berggren and others (1995). Interpolated ages are based on Berggren and others (1995) and unpublished data. The ages assigned to these datums are preliminary and are in the process of being refined and calibrated.

of this subzone was based on the first appearance of *Ceratolithoides kamptneri* at 810.2 ft, a species whose FAD often is used as a proxy for the Subzone CC 25c/26a boundary. The latest Maastrichtian Subzone CC 26b is represented by two samples (760.9 and 745.2 ft) that contain both *Nephrolithus frequens* and *Micula prinsii* (FAD defines the base of Subzone CC 26b)(figs. 2, 3). Thus, the Peedee Formation from the Cannon Park core contains a fairly complete uppermost Cretaceous sequence.

Use of the calcareous nannofossil zonation for the late Maastrichtian can be uncertain at times due to the diachronous nature of some of the marker species. For example, the FAD of *Nephrolithus frequens* is used by many calcareous nannofossil experts to delineate the base of Subzone CC 26a (Perch-Nielsen, 1985). However, Huber and Watkins (1992) demonstrated the diachronous nature of *N. frequens* by showing that it first appears in the lower Maastrichtian at high paleolatitudes and does not occur in the low latitudes until the latest Maastrichtian (well into Subzone CC 26b). This delayed appearance is observed in the Cannon Park core in South Carolina, where *N. frequens* does not appear until latest Maastrichtian Subzone CC 26b, where it co-occurs with *M. prinsii* (fig. 3).

An unconformity, representing at least Subzone CC 25c, probably is present between Subzones CC 25b and CC 26a in the Cannon Park core. *Micula murus*, whose FAD typically marks the base of Subzone CC 25c, has its first appearance at 790.1 ft, approximately 20 ft higher in the section than the FAD of *Ceratolithoides kamptneri* (810.2 ft), the proxy marker for the base of Subzone CC 26a. However, *Micula murus* typically is found to have its first occurrence higher in the section in South Carolina than is reported elsewhere, and it is possible that variation in its overall range may be due changes in the paleoenvironment such as variation in water depth. If the latter case is true, then *M. murus* cannot be used to define the base of Subzone CC 25c in South Carolina.

RHEMS FORMATION

Black Mingo Group

743.8-498.0 ft

Early and late Paleocene

Zone NP 1 and upper Zone NP 4

LITHOSTRATIGRAPHY

The Rhems Formation occurs between a basal unconformable contact at 743.8 and an upper unconformable contact at 498.0 ft, a thickness of approximately 246 ft. There is an additional unconformable contact within the Rhems section at 724.0 ft.

The thin section between 743.8 and 724.0 ft consists of bioturbated, calcareous, muddy, very fine to fine sand. Just above its base, this unit contains 10 to 15 percent phosphate, sand, granules, and small pebbles in its basal few feet. These phosphatic sediments overlie strongly bioturbated, calcareous, muddy, very fine sand at the top of the Peedee Formation along a sharp, strongly burrowed contact. The Rhems section between 724.0 and 498.0 ft consists of a monotonous section of bioturbated, moderately calcareous silty clays, clayey silts, and muddy very fine sands. A few feet of phosphate- and glauconite-rich sediments overlie the contact at 724.0 ft.

CALCAREOUS NANNOFOSSILS

Twenty-nine calcareous nannofossil samples were examined from the Rhems Formation between 743.2 and 510.0 ft (fig. 4). All of these samples had abundant to common calcareous nannofossil floras with generally moderate to poor preservation. There are reworked Cretaceous specimens throughout the Rhems Formation. The oldest calcareous nannofossil zone in the Paleocene is Zone NP 1 (Martini, 1971). As reported by van Heck and Prins (1987), there is a series of first occurrences (FAD's) in the lower part of Zone NP 1 that can be used to subdivide this zone. From oldest to youngest, these include the FAD's of *Cruciplacolithus primus*, *Placozygus sigmoides*, *Cruciplacolithus intermedius*, and *Cruciplacolithus asymmetricus*, which are present in the Cannon Park Core. Above these datums, the FAD of *Cruciplacolithus tenuis* defines the base of Zone NP 2.

Six samples were examined from the base of the Rhems at 743.8 ft to a lithologic contact at 724.0 ft (743.2, 741.2, 736.0, 733.0, 731.0, and 726.0 ft)(fig. 4). The presence of numerous specimens of the genus *Thoracosphaera* clearly places this interval within the Paleocene rather than the Cretaceous. In addition, all six of these samples can be placed more accurately in the upper part of Zone NP 1 because they contain the species *C. primus, P. sigmoides,* and *Cruciplacolithus intermedius. Cruciplacolithus asymmetricus* first appears in the third sample above the base of the Rhems Formation at 736.0 ft. *Cruciplacolithus tenuis* does not occur in any of these lower six samples. The Rhems Formation in the C-15 sidewall cores from Jasper County, S.C. (fig. 1) also contains upper Zone NP 1 sediments (fig. 11)(Self-Trail and Bybell, 1997).

The lithologic contact at 724.0 ft is an unconformity that includes all of Zones NP 2 and NP 3. The first sample examined above the unconformity, at 723.3 ft, can be placed in Zone NP 4 based on the presence of *Ellipsolithus bollii* and *Toweius pertusus* (FAD's in Zone NP 4) and the absence of any species that first appear in Zone NP 5. A total of twenty-three samples was examined between the depths of 723.3 and 510.0 ft, and they all indicate Zone NP 4. Berggren and others (1995) placed the early-late Paleocene boundary in the middle of Zone NP 4. Therefore, the Zone NP 4 samples from Cannon Park are either early or late Paleocene in age or both, based solely on calcareous nannofossils. The upper part of the Rhems Formation in the C-15 material could not be dated (Self-Trail and Bybell, 1997).

DINOCYSTS

Eight samples were examined from the Rhems Formation for dinocysts (fig. 5). The sample from 736.0 ft has fair diversity and moderate preservation with no one species dominating the assemblage. *Cyclapophysis monmouthensis* occurs in the Late Cretaceous and early Paleocene in Maryland (Benson, 1976), and *Deflandrea* n. sp. aff. *D. truncata* is found in the early Paleocene in cores from Georgia. These forms are consistent with the Zone NP 1 age determination made with the calcareous nannofossils.

The remaining seven samples between 695.1 and 510.0 ft were placed in Zone NP 4 using calcareous nannofossils. All of these samples have low diversity dinocyst assemblages that are dominated by small, pale peridiniacean forms. Similar forms are common in Paleocene sediments in the Ellenton Formation in South Carolina (Prowell and others, 1985) and in Georgia (Leeth and others, 1996; Huddlestun and Summerour, 1996). There is reworking of Cretaceous forms in two of these samples.

POLLEN

Twenty-four samples were examined for pollen from the Rhems Formation (fig. 7). Eight of these samples were barren of pollen, and eleven samples contained pollen taxa with nondiagnostic ranges (appendix 7). However, five samples contained age-diagnostic taxa. A sample from 710.0 ft contains *Pseudoplicapollis serenus,* whose range top coincides with the boundary between the early and late Paleocene. The sample from 705.0 ft lacks the lower Paleocene species *P. serenus.* It contains *Subtriporopollenites nanus,* which is not known to range lower than the Coal Bluff Marl Member of the Naheola Formation (Zone NP 5) of the eastern Gulf Coastal Plain. However, this species is absent in the well-studied Clubhouse Crossroads core in South Carolina, so the range base of the species is not reliably known at present. If this species ranges down into Zone NP 4, as it does in the Cannon Park core, then its range base is more likely to be in the upper part rather than the lower part of that zone. In other words, in combination with nannofossils indicative of Zone NP 4, the presence of *Subtriporopollenites nanus* presumably indicates a position in upper Zone NP 4 or in the late Paleocene. For the purposes of this paper, we tentatively are placing the early-late Paleocene boundary between 710.0 and 705.0 ft in the Cannon Park core. The sample from 699.6 ft contains *Aesculiidites circumstriatus,* which has its range base very close to the Zone NP 4-NP 5 boundary in both the eastern Gulf Coast and in the Clubhouse Crossroads core. Therefore, this sample seems to be high up in Zone NP 4 (late Paleocene).

The sample from 670.0 ft contains a specimen that probably belongs to the *Caryapollenites prodromus* group, which has its FAD very close to the Zone NP 4-NP 5 boundary in both the eastern Gulf Coast and in the Clubhouse Crossroads core. Therefore, this sample also seems to be high up in Zone NP 4. The sample from 655.0 ft contains *Triatriopollenites triangulus,* which has its range base in the lowermost part of the Oak Hill Member of the Naheola Formation, close to the Zone NP 4-NP 5 boundary, in the eastern Gulf Coast. Therefore, this sample also seems to be high up in Zone NP 4 (late Paleocene).

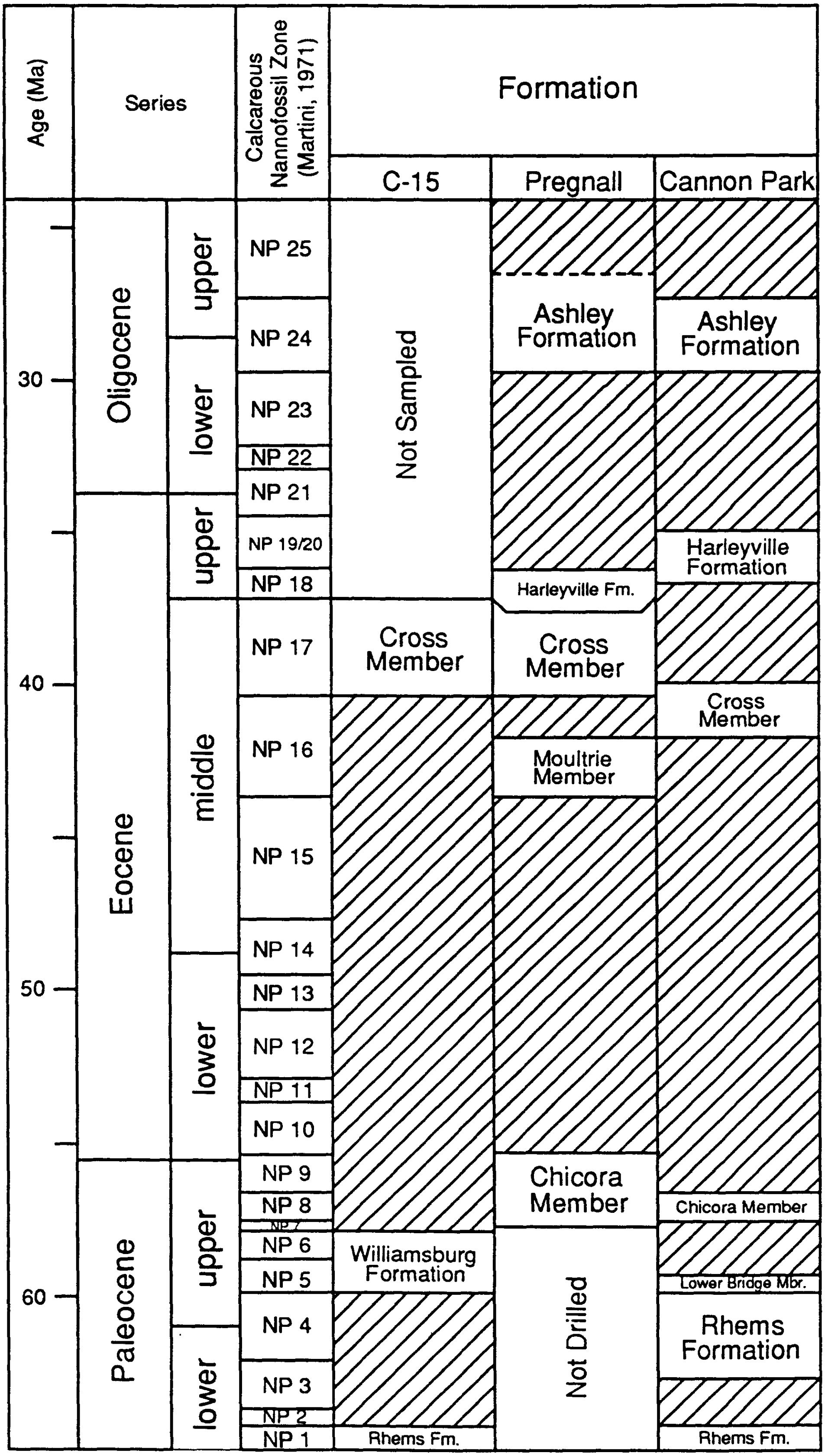

Figure 11. Series, stages, calcareous nannofossil zones, and formations in the Cenozoic portion of the Cannon Park core and other studied cores. The time scale is modified from Berggren and others (1995). Angled line pattern indicates that there are no sediments of this age in the core.

LOWER BRIDGE MEMBER
Williamsburg Formation (Black Mingo Group)
498.0-429.0 ft
Late Paleocene - lower Zone NP 5

LITHOSTRATIGRAPHY

The Lower Bridge Member of the Williamsburg Formation is present from 498.0 to 429.0 ft in the Cannon Park core, a thickness of 69 ft. Sediments in this interval resemble those of the underlying Rhems Formation, but are separated from the Rhems by an unconformable contact at 498.0 ft that is mantled by calcareous, muddy fine sand, which contains common phosphate granules and pebbles at the base of the Lower Bridge. The Lower Bridge is a homogeneous section of bioturbated, moderately calcareous, clayey quartz silts and muddy, very fine quartz sands. Microfossils and comminuted molluscan fragments are moderately common.

CALCAREOUS NANNOFOSSILS

Three calcareous nannofossil samples were examined from the Lower Bridge Member (497.7, 492.0, and 439.0 ft)(fig. 4). All three samples are placed in the lower part of Zone NP 5 based on the presence of *Chiasmolithus bidens* (FAD occurs near the base of Zone NP 5) and the absence of any species that first appear in the upper part of Zone NP 5 (for example, *Heliolithus cantabriae*) or in Zone NP 6 (for example, *Heliolithus kleinpellii*). Both of these species do occur in overlying Cannon Park sediments. *Fasciculithus tympaniformis* (FAD defines the base of Zone NP 5) is absent in the Cannon Park core. In fact, members of the genus *Fasciculithus* never have been observed in large numbers in any South Carolina sediments. In the C-15 sidewall cores, the Williamsburg Formation, which was not differentiated into members, contains sediments from Zone NP 5, as well as from Zone NP 6 (fig. 11)(Self-Trail and Bybell, 1997).

DINOCYSTS

One sample from the Lower Bridge (497.7 ft) was examined for dinocysts (fig. 5). Unlike the underlying samples, small peridiniacean forms do not dominate this sample. The lowest occurrence of *Deflandrea delineata* is in this sample and may prove to be a useful correlation datum in the lower part of the upper Paleocene.

POLLEN

Three samples were examined from the Lower Bridge for pollen (fig. 7; appendix 7). The sample from 497.7 ft was barren, and the samples from 492.0 and 439.0 ft contained nondiagnostic taxa.

CHICORA MEMBER
Williamsburg Formation (Black Mingo Group)
429.0-355.0 ft
Late Paleocene - Zone NP 8

LITHOSTRATIGRAPHY

The Chicora Member of the Williamsburg Formation extends from 429.0 to 355.0 ft in the Cannon Park core. The Chicora Member is 74 ft thick and is lithologically the most heterogeneous unit encountered in the core. The Lower Bridge-Chicora contact is sharp between the muddy, very fine quartz sands of the Lower Bridge and the better sorted, macrofossiliferous quartz sands of the Chicora. In addition to the macrofossiliferous sands, quartzose shell limestones with high moldic porosities, muddy very fine quartz sands, muddy quartz silts, and silty clays are present in the Chicora.

CALCAREOUS NANNOFOSSILS

Five samples were examined from the Chicora Member for calcareous nannofossils (fig. 4). The lowest sample at 412.2 ft contained abundant downhole contamination from the overlying middle Eocene Santee Limestone and could not be dated. Three samples from 399.0, 378.1, and 378.0 ft have common calcareous nannofossils with moderate preservation. All three samples were placed in Zone NP 8 based on the presence of *Heliolithus riedelii* (FAD defines the base of Zone NP 8) and the absence of any species that first occur in Zone NP 9 or younger zones. The uppermost calcareous nannofossil sample from the Chicora at 367.4 ft also contained a substantial amount of downhole contamination from the Santee Limestone and could not be dated. The Pregnall core in Dorchester County, S.C. (fig. 1) contains Chicora Member sediments that can be placed in undifferentiated

Zone NP 7/8, as well as in Zone NP 9 (fig. 11)(Edwards and others, 1997). No sediments of comparable age were found in the C-15 sidewall cores (fig. 11).

DINOCYSTS

Two samples were examined from the Chicora for dinocysts (fig. 5, appendix 6). The lower sample (412.2 ft) has downhole contamination of late Oligocene and possibly Eocene age. The calcareous nannofossil sample from the same depth also had downhole contamination. The upper dinocyst sample (378.1 ft) has a low-diversity assemblage, which is dominated by *Turbiosphaera* sp. aff. *T. magnifica* of Edwards (1989). The overlap of *Damassadinium californicum* and *Kallosphaeridium brevibarbatum* indicates a late Paleocene age, which is consistent with the Zone NP 8 placement based on calcareous nannofossils.

POLLEN

Three samples were examined from the Chicora Member for pollen (fig. 7; appendix 7). The two samples from 412.2 and 378.1 ft were barren of pollen. The sample from 378.0 ft contains *Sparganiaceaepollenites* sp. and *Nudopollis thiergartii*. The range base of *Sparganiaceae-pollenites* sp. is probably in calcareous nannofossil Zone NP 6 or NP 7, and the range top of *Nudopollis thiergartii* is generally at about the top of Zone NP 8, although the species may continue as rare specimens (possibly reworked) into Zone NP 9. The presence of these two species indicates an age that is most probably from Zone NP 6 to Zone NP 8, which is consistent with the Zone NP 8 placement based on calcareous nannofossils.

CROSS MEMBER
Santee Limestone
355.0-312.6 ft
Middle Eocene - Zones NP 16 and NP 17

LITHOSTRATIGRAPHY

The Cross Member of the Santee Limestone is present from 355.0 to 312.6 ft in the Cannon Park core, a thickness of approximately 42 ft. The contact of the Cross Member with the underlying Chicora Member of the Williamsburg Group is sharp and is mantled by a 4-inch-thick bed of phosphate granules and pebbles at the base of the Cross Member. The Cross Member consists of a monotonous section of massive to faintly mottled, partially silicified, fine-grained limestone. Glauconite and clay occur in trace amounts in the Cross Member, and comminuted macrofossils are sparse.

CALCAREOUS NANNOFOSSILS

Five samples from the Cross Member were examined for calcareous nannofossils (fig. 4). Calcareous nannofossils are abundant in all five samples, and there is moderate to poor preservation. The lower four samples from 353.0, 345.0, 331.7, and 326.0 ft were placed in the middle Eocene Zone NP 16 based on the presence of large specimens of *Reticulofenestra umbilicus* (FAD very near the base of Zone NP 16) and *Chiasmolithus bidens* (LAD defines the top of Zone NP 16). Recent work in South Carolina by one of the authors (LMB) has shown that there is a series of FAD's within Zone NP 16 that offer the potential for further subdividing this zone. Preliminary data indicate that this series of FAD's from oldest to youngest includes *Dictyococcites bisectus*, *Cribrocentrum reticulatum*, *Pemma papillatum*, *Helicosphaera compacta*, and *Helicosphaera reticulata*. It is expected that examination of additional wells in South Carolina in the future will be able to confirm or disprove this hypothesis. If this subdivision is accurate, then the presence of *Dictyococcites bisectus*, *C. reticulatum*, *P. papillatum*, and, most importantly, *H. compacta* throughout the Cross Member indicates placement within the upper part of Zone NP 16. *Helicosphaera reticulata* is only present at 331.7 ft. The uppermost Cross Member sample at 315.0 ft is placed in Zone NP 17 based on the absence of both *Chiasmolithus bidens* (LAD defines the top of Zone NP 16) and *Chiasmolithus oamaruensis* (FAD defines the base of Zone NP 18). The Cross Member in the C-15 sidewall cores is younger than in the Cannon Park core and contains calcareous nannofossils only from Zone NP 17 (Self-Trail and Bybell, 1997), while the Cross Member in the Pregnall core contains sediments from both Zones NP 17 and NP 18 but lacks sediments of Zone NP 16 age (Edwards and others, 1997)(fig. 11). Older middle Eocene limestones in the Pregnall core (lower part of Zone NP 16), which are assigned to the Moultrie Member of the Santee Limestone, are absent in the Cannon Park core.

DINOCYSTS

Three samples were examined for dinocysts from the Cross Member (fig. 6, appendix 6). All contain *Homotryblium plectilum*, *Pentadinium goniferum*, and the late middle Eocene species *Pentadinium polypodum*. Preservation is good. The lowest sample (353.0 ft) shows moderate diversity and dominance by *H. plectilum* and *Rhombodinium draco*, whereas the upper samples (331.7 and 315.0 ft) show high diversity with no one species dominating. The lowest occurrences of *Cordosphaeridium cantharellus* (331.7 ft) and *Heteraulacacysta porosa* (315.0 ft) may prove to be important dinocyst datums in the upper part of the middle Eocene.

POLLEN

All three samples from the Cross Member that were examined for pollen (353.0, 331.7, 315.0 ft) were barren (appendix 7).

HARLEYVILLE FORMATION

Cooper Group

312.6-208.0 ft

Late Eocene - Zones NP 18-19/20

LITHOSTRATIGRAPHY

The Harleyville Formation is present between 312.6 ft and 208.0 ft in the core for a total thickness of 104.6 ft. The basal 10 ft of the Harleyville section contains abundant glauconite. About 30 to 40 percent of very fine to medium-grained glauconite sand is present at the base of the unit, which decreases to about 20 to 30 percent 5 ft above the base. The basal contact of the Harleyville Formation with the underlying Cross Member of the Santee Limestone is highly burrowed with glauconite-filled burrows extending down at least 4 ft from the contact into the Cross Member. The Harleyville sediments are similar to the fine-grained limestones of the Cross Member. However, the Harleyville section contains more terrigenous clay, and most of the unit is a marl (as used by Pettijohn, 1957, p. 410) that has subequal amounts of clay and fine-grained calcium carbonate.

CALCAREOUS NANNOFOSSILS

Nine samples were examined for calcareous nannofossils from the Harleyville Formation (fig. 4). Calcareous nannofossils were abundant in all nine samples, and the preservation ranged from good to moderate. The lowest four samples from 311.8, 308.6, 302.3, and 295.3 ft can be placed in Zone NP 18 based on the presence of *Chiasmolithus oamaruensis* in the lower two samples and the absence of *Isthmolithus recurvus* (FAD defines the base of Zone NP 19/20) in all four samples. The five samples from the upper part of the Harleyville at 291.0, 279.0, 262.0, 226.0, and 210.5 are placed in Zone NP 19/20 because they contain *I. recurvus*, as well as *Discoaster saipanensis*, *Discoaster barbadiensis*, or *Cribrocentrum reticulatum* (all three species have their LAD's very near or at the top of Zone NP 19/20). A very thin section of the Harleyville Formation in the Pregnall core is in Zone NP 18 only and is overlain by Oligocene sediments (Edwards and others, 1997)(fig. 11). There are no sediments from Zone NP 19/20; hence the Pregnall core contains neither the upper part of the Harleyville Formation or the younger upper Eocene Parkers Ferry Formation (also Zone NP 19/20 in age). The Harleyville Formation in the Clubhouse Crossroads #1 core contains sediments that can be placed in both Zone NP 18 and NP 19/20, and the Parkers Ferry in this core also contains sediments of Zone NP 19/20 age. There is no direct physical evidence that the sediments in the Cannon Park core from Zone NP 19/20 would be other than a continuation of the Harleyville Formation (for example, there is no evidence of an unconformity or change in lithology).

DINOCYSTS

Five samples were examined for dinocysts from the Harleyville Formation (fig. 6, appendix 6). All have good preservation and contain the late Eocene species *Batiacasphaera baculata* and *Batiacasphaera compta*. The lower two samples (302.3 and 295.3 ft) have high diversity assemblages with no single dominant species and contain specimens that are probably reworked (of early middle Eocene age). The calcareous nannofossils from these depths indicate placement in Zone NP 18. The upper three samples (262.0, 241.5, and 210.5 ft) represent a more inshore environment than the samples below, as they are dominated by *Homotryblium plectilum*. They are assigned to calcareous nannofossil Zone NP 19/20. The lowest occurrence of *Cordosphaeridium funiculatum* (262.0 ft) may prove an important datum in the upper Eocene.

POLLEN

All five samples that were examined from the Harleyville Formation for pollen were barren (appendix 7).

ASHLEY FORMATION
Cooper Group
208.0-74.0 ft
Late Oligocene - Zone NP 24

LITHOSTRATIGRAPHY

The Ashley Formation is present from 208.0 to 74.0 ft in the Cannon Park core. This 134-ft-thick section consists of massive to bioturbated, abundantly microfossiliferous, phosphatic, muddy, very fine quartz sand. The contact of the Ashley Formation with the underlying Harleyville Formation is sharp and unconformable with abundant phosphate granules and pebbles in the lower few feet of the Ashley Formation section above the contact.

CALCAREOUS NANNOFOSSILS

Nine samples were examined for calcareous nannofossils from the Ashley Formation from 208.0 to 74.6 ft (fig. 4). Calcareous nannofossils are abundant to frequent, and the preservation ranges from good to moderate. All nine samples can be placed in Zone NP 24 based on the presence of *Helicosphaera recta* (FAD occurs within Zone NP 24) and *Sphenolithus distentus* (LAD defines the top of Zone NP 24) throughout this interval and the occasional presence of *Sphenolithus ciperoensis* (FAD defines the base of Zone NP 24). The Ashley Formation in the Pregnall core also contains sediments that can be placed definitely in Zone NP 24, as well as one sample that questionably has been placed in Zone NP 25 (Edwards and others, 1997)(fig. 11). The Ashley Formation in the Clubhouse Crossroads #1 core consists entirely of sediments placed in Zone NP 24.

DINOCYSTS AND POLLEN

No samples were examined from the Ashley Formation for dinocysts or pollen.

SEDIMENT ACCUMULATION RATES

Sediment accumulation rates were calculated using calcareous nannofossil datums from the interval between 1,010.4 and 207.0 ft. This 803-ft-thick cored interval represents approximately 47 my. Ages and core depths for the calcareous nannofossil datums that were used to calculate the sediment accumulation rates are listed in Table 1 and plotted on figures 9 and 10.

Only one major hiatus is recorded from the Late Cretaceous of the Cannon Park hole (fig. 9). This disconformity occurs across the Campanian-Maastrichtian boundary and represents at least 6.7 Ma. Minimum sedimentation rates below this unconformity average 83.1 ft/my and decrease dramatically above the unconformity to approximately 29.0 ft/my. Low sedimentation rates persisted throughout the latest Maastrichtian and into the earliest Paleocene (calcareous nannofossil Zones NP 1 and NP 4). Based on the sediment accumulation rate plot, the late Maastrichtian package of sediment appears to be fairly complete at this site, with only a small disconformity recorded between calcareous nannofossil Subzones CC 25b and CC 26a (figs. 2, 8). Although the uppermost Maastrichtian calcareous nannofossil Subzone CC 26b and lowermost Paleocene Zone NP 1 are present in the Cannon Park core, there is an unconformity at the Cretaceous-Tertiary boundary. This is based on a change in the sedimentation rate across the Cretaceous-Tertiary boundary, a lithologic change in the sediments, and the absence of the lowest part of Zone NP 1.

The oldest Paleocene sediments (lowest Zone NP 1) are known to be missing at Cannon Park because *Cruciplacolithus primus* occurs in the lowest Tertiary sample (743.2 ft) (fig. 10). This species first occurs in the lower part of Zone NP 1 but not at the base of Zone NP 1 (van Heck and Prins, 1987). In complete Danian sections, a brief period of rapid nannofossil evolution occurs right above the Cretaceous-Tertiary boundary, which is represented

	Species	Age	Depth (ft)
FAD	*Helicosphaera recta* (+)	29.80	207.0
FAD	*Sphenolithus distentus*	31.50	207.0
LAD	*Reticulofenestra umbilica*	32.30	210.5
LAD	*Cyclococcolithus formosus*	32.80	210.5
LAD	*Discoaster saipanensis*	34.20	226.0
LAD	*Discoaster barbadiensis*	34.30	210.5
LAD	*Cribrocentrum reticulatum*	35.00	210.5
FAD	*Isthmolithus recurvus*	36.00	291.0
FAD	*Chiasmolithus oamaurensis*	37.00	311.8
LAD	*Pseudotriquetrarhabdulus inversus* (+)	37.02	315.0
LAD	*Camplyosphaera dela* (+)	37.05	315.0
LAD	*Chiasmolithus grandis*	37.10	326.0
LAD	*Chiasmolithus solitus/bidens*	40.40	326.0
FAD	*Helicosphaera compacta* (+)	41.50	353.0
FAD	*Cribrocentrum reticulatum*	42.00	353.0
FAD	*Dictyococcites bisectus* (+)	43.00	353.0
FAD	*Reticulofenestra umbilicus*	43.70	353.0
FAD	*Heliolithus riedelii*	57.30	399.0
FAD	*Discoaster mohleri*	57.50	399.0
FAD	*Heliolithus kleinpelli*	58.40	399.0
FAD	*Chiasmolithus bidens*	60.70	497.7
FAD	*Ellipsolithus* spp.	62.20	723.3
FAD	*Cruciplacolithus tenuis*	64.50	723.3
FAD	*Cruciplacolithus asymmetricus* (+)	64.65	736.0
FAD	*Cruciplacolithus intermedius* (+)	64.75	743.2
FAD	*Cruciplacolithus primus*	64.80	743.2
	Cretaceous/Tertiary Boundary	65.00	743.8
FAD	*Micula prinsii*	66.00	760.9
FAD	*Nephrolithus frequens*	67.20	760.9
FAD	*Ceratolithoides kamptneri*	67.70	810.2
FAD	*Micula murus*	68.50	790.1
FAD	*Lithraphidites quadratus*	68.60	825.2
LAD	*Reinhardtites levis*	69.40	828.3
LAD	*Quadrum trifidum*	71.30	828.3
LAD	*Aspidolithus parcus*	74.60	828.3
LAD	*Reinhardtites anthophorus*	75.30	828.3
FAD	*Quadrum trifidum*	76.10	953.0
FAD	*Quadrum sissinghii*	77.10	1010.4

Table 1. Cretaceous and Tertiary nannofossil datums used to calculate sediment accumulation rates for Cannon Park core, S.C. FAD, first appearance datum of species; LAD, last appearance datum of species. Ages of datums are from Henriksson (1994), Berggren and others (1995), and Erba and others (1995). Interpolated ages are based on Berggren and others (1995) and unpublished data of Bybell.

by blooms of the genera *Thoracosphaera*, *Neobiscutum*, and *Futyania* (Pospichal, 1996). At Cannon Park, these events were not recorded. In addition, a hiatus occurs within the lower Paleocene section between Zones NP 1 and NP 4 and spans approximately 2 my. Following this hiatus, the sedimentation rate for the upper Paleocene Zone NP 4 increased to 85.3 ft/my, which is the highest value for the entire core.

The late Paleocene is largely unrepresented at Cannon Park. The date for the FAD of *Chiasmolithus bidens* at 60.7 my, which was taken from Berggren and others (1995), is too old and plots off the curve in figure 10. There is a new species of *Chiasmolithus* that is similar to *C. bidens*, which first occurs in Zone NP 4 at approximately 60.7 my. It is probable that Berggren and others (1995) used the FAD of this new species instead of the FAD of *C. bidens*. Zone NP 5 sediments are overlain unconformably by Zone NP 8 sediments, which represents a hiatus of at least 1.1 my. Uppermost upper Paleocene (Zone NP 9) through lower middle Eocene (Zone NP 15) sediments are absent at this site. A similar pattern was recorded from this interval in the C-15 core in Jasper County (fig. 1, Self-Trail and Bybell, 1997), where approximately 20 my was not recorded.

The lower upper Eocene sediment accumulation rate is a minimum of 50.6 ft/my. The uppermost Eocene and lowermost Oligocene are missing at this site, resulting in a hiatus of at least 2.7 my.

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APPENDIX 1. Useful Cenozoic calcareous nannofossil datums.

The following calcareous nannofossil species can be used to date sediments of Paleocene to late Oligocene age. Many, but not all, of these species are present in the Cannon Park core. FAD is a first appearance datum, and LAD is a last appearance datum. Zonal markers for the Martini (1971) NP zones are indicated with an *, and a # indicates a zonal marker for the Bukry (1973, 1978) and Okada and Bukry (1980) CP zones. One of us (Bybell) has found the remaining species to be biostratigraphically useful in the Gulf of Mexico and Atlantic Coastal Plains.

LAD *Zygrhablithus bijugatus* - top of Zone NP 25, late Oligocene
LAD *Dictyococcites bisectus* - top of Zone NP 25, late Oligocene
LAD *#*Sphenolithus distentus* - top Zone NP 24, top Zone CP 19a, late Oligocene
FAD *Helicosphaera recta* - lower Zone NP 24, early Oligocene
FAD *#*Sphenolithus ciperoensis* - base of Zone NP 24, base Zone CP 19a, early Oligocene
FAD *Sphenolithus distentus* - within Zone NP 23, base Zone CP 18, early Oligocene
LAD *#*Reticulofenestra umbilicus* - top of Zone NP 22, top Zone CP 16c, early Oligocene
LAD **Cyclococcolithus formosus* - top Zone NP 21, early Oligocene
LAD *Isthmolithus recurvus* - within Zone NP 21, early Oligocene
LAD *#*Discoaster saipanensis* - top of Zone NP 19/20, top Zone CP 15b, late Eocene
LAD #*Discoaster barbadiensis* - top of Zone NP 19/20, to of Zone CP 15b, late Eocene; actually has its LAD slightly below the LAD of *D. saipanensis*
LAD *Cribrocentrum reticulatum* - very near top of Zone NP `19/20, late Eocene
FAD **Isthmolithus recurvus* - base of Zone NP 19/20, late Eocene
FAD *#*Chiasmolithus oamaruensis* - base of Zone NP 18, base Zone CP 15a, late Eocene
LAD *Pseudotriquetrorhabdulus inversus* - within Zone NP 17, middle Eocene
LAD *Campylosphaera dela* - within Zone NP 17, middle Eocene
LAD *Daktylethra punctulata* - within Zone NP 17, middle Eocene
LAD *Chiasmolithus grandis* - within Zone NP 17, middle Eocene
LAD *Chiasmolithus bidens/solitus* - top of Zone NP 16, middle Eocene; these two species are not differentiated in this study.
FAD *Helicosphaera reticulata* - upper Zone NP 16, middle Eocene
FAD *Helicosphaera compacta* - upper Zone NP 16, middle Eocene
FAD *Cribrocentrum reticulatum* - lower Zone NP 16, middle Eocene
FAD *Dictyococcites bisectus* - lower Zone NP 16, middle Eocene
FAD #*Reticulofenestra umbilicus* - large forms first appear near base of Zone NP 16, base Zone CP 14a, middle Eocene
FAD *Neochiastozygus junctus* - within Zone NP 8, late Paleocene
FAD **Heliolithus riedelii* - base of Zone NP 8, late Paleocene
FAD #*Discoaster mohleri* - probably equivalent to base Zone NP 7, base CP 6, late Paleocene
FAD **Heliolithus kleinpellii* - base Zone NP 6, late Paleocene
FAD *Heliolithus cantabriae* - upper Zone NP 5, late Paleocene
FAD *Toweius eminens* var. *tovae* - within Zone NP 5, late Paleocene
FAD *Chiasmolithus bidens* - lower Zone NP 5, late Paleocene
FAD *#*Fasciculithus tympaniformis* - base of Zone NP 5, base CP 4, late Paleocene
FAD *Toweius pertusus* - within Zone NP 4
FAD *Ellipsolithus distichus* - near base of Zone NP 4, early Paleocene
FAD *Ellipsolithus bollii* - near base of Zone NP 4, early Paleocene
FAD **Ellipsolithus macellus* - base of Zone NP 4, early Paleocene
FAD *Chiasmolithus consuetus* - within Zone NP 3, early Paleocene
FAD **Chiasmolithus danicus* - base of Zone NP 3, early Paleocene
FAD *#*Cruciplacolithus tenuis* - base Zone NP 2, early Paleocene
FAD *Cruciplacolithus asymmetricus* - upper Zone NP 1, early Paleocene
FAD *Cruciplacolithus intermedius* - within Zone NP 1, early Paleocene
FAD *Placozygus sigmoides* - within Zone NP 1, early Paleocene

FAD *Cruciplacolithus primus* - within Zone NP 1, early Paleocene
FAD increased *Thoracosphaera* specimens - lower Zone NP 1, early Paleocene

APPENDIX 2. Cretaceous calcareous nannofossil species considered in this report (in alphabetical order by genus).

Acuturris scotus (Risatti 1973) Wind & Wise *in* Wise and Wind (1977)
Ahmuellerella octoradiata (Gorka 1957) Reinhardt 1964
Ahmuellerella regularis (Gorka 1957) Reinhardt & Gorka 1967
Arkhangelskiella cymbiformis Vekshina 1959
Arkhangelskiella speciallata Vekshina 1959
Aspidolithus parcus constrictus (Hattner, Wind, & Wise 1980) Perch-Nielsen 1984
Aspidolithus parcus expansus Wise & Watkins *in* Wise (1983)
Aspidolithus parcus parcus (Stradner 1963) Noël 1969
Axopodorhabdus albianus (Black 1967) Wind & Wise 1983
Biscutum constans (Gorka 1957) Black *in* Black and Barnes (1959)
Biscutum notaculum Wind & Wise *in* Wise and Wind (1977)
Biscutum zulloi Covington 1994
Braarudosphaera bigelowii (Gran & Braarud 1935) Deflandre 1947
Broinsonia dentata Bukry 1969
Broinsonia enormis (Shumenko 1968) Manivit 1971
Calculites obscurus (Deflandre 1959) Prins & Sissinghi *in* Sissingh (1977)
Centosphaera barbata Wind & Wise *in* Wise and Wind (1977)
Ceratolithoides aculeus (Stradner 1961) Prins & Sissingh *in* Sissingh (1977)
Ceratolithoides arcuatus Prins & Sissingh *in* Sissingh (1977)
Ceratolithoides kamptneri Bramlette & Martini 1964
Chiastozygus amphipons (Bramlette & Martini 1964) Gartner 1968
Chiastozygus litterarius (Gorka 1957) Manivit 1971
Chiastozygus propagulis Bukry 1969
Corollithion? completum Perch-Nielsen 1973
Corollithion exiguum Stradner 1961
Corollithion signum Stradner 1963
Cretarhabdus conicus Bramlette & Martini 1964
Cretarhabdus multicavus Bukry 1969
Cretarhabdus schizobrachiatus (Gartner 1968) Bukry 1969
Cribrocorona gallica (Stradner 1963) Perch-Nielsen 1973
Cribrosphaerella ehrenbergii (Arkhangelsky 1912) Deflandre *in* Piveteau (1952)
Cyclagelosphaera margerellii Noël 1965
Cylindralithus crassus Stover 1966
Cylindralithus duplex Perch-Nielsen 1973
Cylindralithus nudus Bukry 1969
Cylindralithus serratus Bramlette & Martini 1964
Discorhabdus ignotus (Gorka 1957) Perch-Nielsen 1968
Eiffellithus eximius (Stover 1966) Perch-Nielsen 1968
Eiffellithus gorkae Reinhardt 1965
Eiffellithus parallelus Perch-Nielsen 1973
Eiffellithus turriseiffellii (Deflandre *in* Deflandre and Fert, 1954) Reinhardt 1964
Gartnerago diversum Thierstein 1972
Gartnerago obliquum (Stradner 1963) Noël 1970
Gephyrorhabdus coronadventis (Reinhardt 1966) Hill 1976
Glaukolithus compactus (Bukry 1969) Perch-Nielsen 1984
Glaukolithus diplogrammus (Deflandre *in* Deflandre and Fert, 1954) Reinhardt 1964
Goniolithus fluckigeri Deflandre 1957
Hexalithus gardetae Bukry 1969
Kamptnerius magnificus Deflandre 1959
Kamptnerius punctatus Stradner 1963

Lithastrinus grillii Stradner 1962
Lithastrinus septinarius Forchheimer 1972
Lithraphidites carniolensis Deflandre 1963
Lithraphidites grossopectinatus Bukry 1969
Lithraphidites kennethii Perch-Nielsen 1984
Lithraphidites praequadratus Roth 1978
Lithraphidites quadratus Bramlette & Martini 1964
Loxolithus armillus (Black *in* Black and Barnes, 1959) Noël 1965
Lucianorhabdus arcuatus Forchheimer 1972
Lucianorhabdus cayeuxii Deflandre 1959
Lucianorhabdus maleformis Reinhardt 1966
Manivitella pemmatoidea (Deflandre *in* Manivit, 1965) Thierstein 1971
Markalius inversus (Deflandre *in* Deflandre and Fert, 1954) Bramlette & Martini 1964
Micula concava (Stradner *in* Martini and Stradner, 1960) Verbeek 1976
Micula decussata Vekshina 1959
Micula murus (Martini 1961) Bukry 1973
Micula praemurus (Bukry 1973) Stradner & Steinmetz 1984
Micula prinsii Perch-Nielsen 1979
Microrhabdulus attenuatus (Deflandre 1959) Deflandre 1963
Microrhabdulus belgicus Hay & Towe 1963
Microrhabdulus decoratus Deflandre 1959
Monomarginatus pleniporus Wind & Wise *in* Wise and Wind (1977)
Nephrolithus frequens Gorka 1957
Ottavianus terrazetus Risatti 1973
Percivalia porosa Bukry 1969
Placozygus fibuliformis (Reinhardt 1964) Hoffmann 1970
Placozygus sigmoides (Bramlette & Sullivan 1961) Romein 1979
Pontosphaera multicarinata (Gartner 1968) Shafik & Stradner 1971
Prediscosphaera arkhangelskyi (Reinhardt 1965) Perch-Nielsen 1984
Prediscosphaera cretacea (Arkhangelsky 1912) Gartner 1968
Prediscosphaera grandis Perch-Nielsen 1979
Prediscosphaera intercisa (Deflandre *in* Deflandre and Fert, 1954) Shumenko 1976
Prediscosphaera majungae Perch-Nielsen 1973
Prediscosphaera spinosa (Bramlette & Martini 1964) Gartner 1968
Prediscosphaera stoveri (Perch-Nielsen 1968) Shafik & Stradner 1971
Quadrum gothicum (Deflandre 1979) Prins & Perch-Nielsen *in* Manivit, Perch-Nielsen, and others (1977)
Quadrum sissinghii Perch-Nielsen 1986
Quadrum trifidum (Stradner *in* Stradner and Papp, 1961) Prins & Perch-Nielsen *in* Manivit and others (1977)
Reinhardtites anthophorus (Deflandre 1959) Perch-Nielsen 1968
Reinhardtites levis Prins & Sissingh *in* Sissingh (1977)
Repagulum parvidentatum (Deflandre & Fert 1954) Forchheimer 1972
Retacapsa angustiforata Black 1971
Retemediaformus teneraretis Varol 1991
Rhagodiscus angustus (Stradner 1963) Reinhardt 1971
Rhagodiscus reniformis Perch-Nielsen 1973
Rhagodiscus splendens (Deflandre 1953) Verbeek 1977
Rhombolithion rhombicum (Stradner & Adamiker 1966) Black 1973
Rotellapillus crenulatus (Stover 1966) Perch-Nielsen 1984
Rotellapillus munitus (Perch-Nielsen 1973) Perch-Nielsen 1984
Rucinolithus magnus Bukry 1975
Scapholithus fossilis Deflandre *in* Deflandre and Fert (1954)
Sollasites barringtonensis Black 1967
Sollasites lowei (Bukry 1969) Roth 1970
Stovarius asymmetricus (Bukry 1969) Perch-Nielsen 1984
Stovarius biarcus (Bukry 1969) Perch-Nielsen 1984
Stovarius coronatus (Bukry 1969) Perch-Nielsen 1984
Stradneria crenulata (Bramlette & Martini 1964) Noël 1970
Tetrapodorhabdus decorus (Deflandre *in* Deflandre and Fert, 1954) Wind & Wise *in* Wise and Wind (1977)

Tranolithus gabalus Stover 1966
Tranolithus minimus (Bukry 1969) Perch-Nielsen 1984
Tranolithus phacelosus Stover 1966
Vekshinella aachena Bukry 1969
Vekshinella parma Wind & Wise *in* Wise and Wind (1977)
Vekshinella stradneri Rood and others 1971
Watznaueria barnesae (Black *in* Black and Barnes, 1959) Perch-Nielsen 1968
Watznaueria biporta Bukry 1969
Watznaueria supracretacea (Reinhardt 1965) Wind & Wise 1976
Zeugrhabdotus acanthus Reinhardt 1965
Zeugrhabdotus erectus (Deflandre *in* Deflandre and Fert, 1954) Reinhardt 1965
Zeugrhabdotus obliqueclausus Varol 1991
Zeugrhabdotus pseudanthophorus (Bramlette & Martini 1964) Perch-Nielsen 1984

APPENDIX 3. Cenozoic calcareous nannofossil species considered in this report (in alphabetical order by genus).

Blackites creber (Deflandre *in* Deflandre and Fert, 1954) Stradner & Edwards 1968
Blackites spinosus (Deflandre & Fert 1954) Hay & Towe 1962
Blackites tenuis (Bramlette & Sullivan 1961) Sherwood 1974
Braarudosphaera bigelowii (Gran & Braarud 1935) Deflandre 1947
Braarudosphaera discula Bramlette & Riedel 1954
Braarudosphaera stylifer Troelsen & Quadros 1971
Bramletteius serraculoides Gartner 1969
Campylosphaera dela (Bramlette & Sullivan 1961) Hay & Mohler 1967
Cepekiella lumina (Sullivan 1965) Bybell 1975
Chiasmolithus bidens (Bramlette & Sullivan 1961) Hay & Mohler 1967
Chiasmolithus consuetus (Bramlette & Sullivan 1961) Hay & Mohler 1967
Chiasmolithus expansus (Bramlette & Sullivan 1961) Hay, Mohler, & Wade 1966
Chiasmolithus grandis (Bramlette & Riedel 1954) Hay, Mohler, & Wade 1966
Chiasmolithus oamaruensis (Deflandre *in* Deflandre and Fert, 1954) Hay, Mohler, & Wade 1966
Chiasmolithus solitus (Bramlette & Sullivan 1961) Hay, Mohler, & Wade 1966
Chiasmolithus titus Gartner 1970
Coccolithus cribellum (Bramlette & Sullivan 1961) Stradner 1962
Coccolithus eopelagicus (Bramlette & Riedel 1954) Bramlette & Sullivan 1961
Coccolithus pelagicus (Wallich 1877) Schiller 1930
Coronocyclus nitescens (Kamptner 1963) Bramlette & Wilcoxon 1967
Cribrocentrum reticulatum (Gartner & Smith 1967) Perch-Nielsen 1971
Cruciplacolithus asymmetricus van Heck & Prins 1987
Cruciplacolithus edwardsii Romein 1979
Cruciplacolithus intermedius van Heck & Prins 1987
Cruciplacolithus primus Perch-Nielsen 1977
Cruciplacolithus tenuis (Stradner 1961) Hay & Mohler *in* Hay, Mohler, and others (1967)
Cyclagelosphaera alta Perch-Nielsen 1979
Cyclagelosphaera prima (Bukry 1969) Bybell & Self-Trail 1995
Cyclagelosphaera reinhardtii (Perch-Nielsen 1968) Romein 1977
Cyclococcolithus formosus Kamptner 1963
Cyclococcolithus protoannulus (Gartner 1971) Haq & Lohmann 1976
Cyclococcolithus robustus (Bramlette & Sullivan 1961) Locker 1973
Dictyococcites bisectus (Hay, Mohler, & Wade 1966) Bukry & Percival 1971
Dictyococcites scrippsae Bukry & Percival 1971
Discoaster barbadiensis Tan Sin Hok 1927
Discoaster mohleri Bukry & Percival 1971
Discoaster saipanensis Bramlette & Riedel 1954
Discoaster tanii Bramlette & Riedel 1954
Discoaster woodringii Bramlette & Riedel 1954

Ellipsolithus bollii Perch-Nielsen 1977
Ellipsolithus macellus (Bramlette & Sullivan 1961) Sullivan 1964
Ericsonia obruta Perch-Nielsen 1971
Ericsonia subpertusa Hay & Mohler 1967
Fasciculithus billii Perch-Nielsen 1971
Fasciculithus involutus Bramlette & Sullivan 1961
Fasciculithus janii Perch-Nielsen 1971
Fasciculithus tympaniformis Hay & Mohler *in* Hay and others (1967)
Goniolithus fluckigeri Deflandre 1957
Hayella situliformis Gartner 1969
Helicosphaera bramlettei (Müller 1970) Jafar & Martini 1975
Helicosphaera carteri (Wallich 1877) Kamptner 1954
Helicosphaera compacta Bramlette & Wilcoxon 1967
Helicosphaera euphratis Haq 1966
Helicosphaera intermedia Martni 1965
Helicosphaera lophota (Bramlette & Sullivan 1961) Locker 1973
Helicosphaera recta (Haq 1966) Jafar & Martini 1975
Helicosphaera reticulata Bramlette & Wilcoxon 1967
Helicosphaera seminulum Bramlette & Sullivan 1961
Heliolithus cantabriae Perch-Nielsen 1971
Heliolithus kleinpellii Sullivan 1964
Heliolithus riedelii Bramlette & Sullivan 1961
Hornibrookina arca Bybell & Self-Trail 1995
Isthmolithus recurvus Deflandre *in* Deflandre and Fert (1954)
Lanternithus duocavus Locker 1967
Lanternithus minutus Stradner 1962
Lithostromation operosum (Deflandre *in* Deflandre and Fert, 1954) Bybell 1975
Lithostromation perdurum Deflandre 1942
Lithostromation simplex (Klumpp 1953) Bybell 1975
Markalius apertus Perch-Nielsen 1979
Markalius inversus Bramlette & Martini 1964
Neochiastozygus concinnus (Martini 1961) Perch-Nielsen 1971
Neochiastozygus imbriei Haq & Lohmann 1975
Neochiastozygus junctus (Bramlette & Sullivan 1961) Perch-Nielsen 1971
Pedinocyclus larvalis Bukry & Bramlette 1971
Pemma basquense (Martini 1959) Bybell & Gartner 1972
Pemma papillatum Martini 1959
Placozygus sigmoides (Bramlette & Sullivan 1961) Romein 1979
Pontosphaera alta Roth 1970
Pontosphaera multipora (Kamptner ex Deflandre 1959) Roth 1970
Pontosphaera punctosa (Bramlette & Sullivan 1961) Perch-Nielsen 1984
Pontosphaera pygmaea (Locker 1967) Bystrická & Lehotayová 1974
Pseudotriquetrorhabdulus inversus (Bukry & Bramlette 1969) Wise *in* Wise and Constans (1976)
Reticulofenestra abisecta (Müller 1970) Roth & Thierstein 1972
Reticulofenestra daviesii (Haq 1968) Haq 1971
Reticulofenestra floridana (Roth & Hay *in* Hay and others, 1967) Theodoridis 1984
Reticulofenestra hillae Bukry & Percival 1971
Reticulofenestra pseudolockeri Jurasova 1974
Reticulofenestra umbilicus (Levin 1965) Martini & Ritzkowski 1968
Rhabdosphaera vitrea (Deflandre *in* Deflandre and Fert, 1954) Bramlette & Sullivan 1961
Scyphosphaera expansa Bukry & Percival 1971
Sphenolithus ciperoensis Bramlette & Wilcoxon 1967
Sphenolithus distentus (Martini 1965) Bramlette & Wilcoxon 1967
Sphenolithus moriformis (Brönnimann & Stradner 1960) Bramlette & Wilcoxon 1967
Sphenolithus obtusus Bukry 1971
Sphenolithus predistentus Bramlette & Wilcoxon 1967
Sphenolithus primus Perch-Nielsen 1971
Sphenolithus pseudoradians Bramlette & Wilcoxon 1967

Sphenolithus radians Deflandre *in* Grassé (1952)
Toweius eminens var. *eminens* (Bramlette & Sullivan 1961) Gartner 1971
Toweius eminens var. *tovae* (Perch-Nielsen 1971) Bybell & Self-Trail 1995
Toweius pertusus (Sullivan 1965) Romein 1979
Transversopontis pulcher (Deflandre *in* Deflandre and Fert, 1954) Perch-Nielsen 1967
Transversopontis pulcheroides (Sullivan 1964) Báldi-Beke 1971
Transversopontis zigzag Roth & Hay *in* Hay and others (1967)
Zygodiscus herlyni Sullivan 1964
Zygrhablithus bijugatus (Deflandre *in* Deflandre and Fert, 1954) Deflandre 1959

APPENDIX 4. Cenozoic dinoflagellate species considered in this report (in alphabetical order by genus).

Amphorosphaeridium multispinosum (Davey & Williams 1966) Sarjeant 1981
? *Andalusiella rhombohedra* of Edwards and others (1984)
Andalusiella sp. aff. *A. polymorpha* of Edwards (1980)
Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdowniea coleothrypta (Williams & Downie 1966) Lentin & Vozzhennikova 1989
Chiropteridium lobospinosum (Gocht 1956) Gocht 1960
Cleistosphaeridium polypetallum (Islam 1983) Stover & Williams 1995
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium funiculatum Morgenroth 1966
Cordosphaeridium Eisenack 1963 spp.
Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978
Corrudinium sp. I of Edwards (1984)
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Cyclapophysis monmouthensis Benson 1976
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al. 1980
Deflandrea delineata Cookson & Eisenack 1965
Deflandrea phosphoritica Eisenack 1938
Deflandrea phosphoritica Eisenack 1938/*D. heterophlycta* Deflandre & Cookson 1955
Deflandrea spinulosa Alberti 1959
Deflandrea sp. cf. *D. diebelii* Alberti of Drugg (1967)
Deflandrea n. sp. aff. *D. truncata* Eisenack 1938
Remarks: a rather large, circumcavate form with a granulate endocyst.
Dinopterygium cladoides sensu Morgenroth 1966
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Distatodinium ellipticum (Cookson 1965) Eaton 1976
Ennaedocysta Stover & Williams 1995 sp.
Eocladopyxis Morgenroth 1966 n. sp. A
Remarks: The processes resemble those of *Polysphaeridium zoharyi* (Rossignol 1962) Bujak et al. 1980, but the separation of the individual paraplates requires placement in the genus *Eocladopyxis* Morgenroth 1966.
Eocladopyxis sp. of Williams and Brideaux (1975)
Exochosphaeridium Davey et al. 1966 sp.
Fibradinium annetorpense Morgenroth 1968
Fibrocysta Stover & Evitt 1978 sp.
Glaphyrocysta sp. cf. *G.? vicina* (Eaton 1976) Stover & Evitt 1978
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Hafniasphaera Hansen 1977 sp.
Heteraulacacysta porosa Bujak et al. 1980
Homotryblium plectilum Drugg & Loeblich 1967
Homotryblium Davey & Williams 1966 sp.
Hystrichokolpoma cinctum Klumpp 1953
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955

Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937
Hystrichostrogylon coninckii Heilmen-Clausen 1985
Hystrichostrogylon membraniphorum Agelopoulous 1964
Impagidinium Stover & Evitt 1978 sp.
Kallosphaeridium brevibarbatum de Coninck 1969
Lejeunecysta Artzner & Dörhöfer 1978 spp.
Lentinia serrata Bujak 1980
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Melitasphaeridium pseudorecurvatum (Morgenroth 1966) Bujak et al. 1980
Membranophoridium aspinatum Gerlach 1961
Membranosphaera maastrichtica Samoilovitch 1961
Millioudodinium sp. I of Edwards (1984)
Oligosphaeridium complex (White 1842) Davey & Williams 1966
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Operculodinium Wall 1967 sp.
Palaeocystodinium golzowense Alberti 1961
Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967
Palaeoperidinium Alberti 1967 sp.
Pentadinium goniferum Edwards 1982
Pentadinium laticinctum Gerlach 1961 (knobby)
Pentadinium laticinctum Gerlach 1961 (verm.)
Pentadinium laticinctum Gerlach 1961 subsp. *laticinctum*
Pentadinium membranaceum (Eisenack 1965) Stover & Evitt 1978
Pentadinium polypodum Edwards 1982
Pentadinium Gerlach 1961 n. sp. D

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.

Phelodinium sp. of Edwards (1989)
Phelodinium Stover & Evitt 1978 spp.
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Phthanoperidinium Drugg & Loeblich 1967 sp.
Polysphaeridium zoharyi (Rossignol 1962) Bujak et al. 1980
Rhombodinium draco Gocht 1955
Rhombodinium draco Gocht 1955/*R. glabrum* (Cookson 1956) Vozzhennikova 1967
Rhombodinium sp. I of Edwards (1984)
Rottnestia borussica (Eisenack 1954) Cookson & Eisenack 1961
Samlandia chlamydophora Eisenack 1954
Samlandia chlamydophora sensu Stover and Hardenbol (1993)
Selenopemphix Benedek 1972 spp.
Spinidinium densispinatum Stanley 1965
Spinidinium Cookson & Eisenack 1962 sp.
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tanyosphaeridium xanthiopyxides (Wetzel 1933) Stover & Evitt 1978
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
Thalassiphora Eisenack & Gocht 1960 sp.
Turbiosphaera sp. aff. *T. magnifica* Eaton 1976 of Edwards (1989)
Wetzeliella Eisenack 1938 spp.

APPENDIX 5. Cenozoic pollen taxa considered in this report (in alphabetical order by genus).

Aesculiidites circumstriatus (Fairchild *in* Stover, Elsik, and Fairchild, 1968)
Bombacacidites nacimientoensis (Anderson 1960) Elsik 1968
Bombacacidites reticulatus Krutzsch 1961
Carya <29 mm of Frederiksen and Christopher (1978)
Caryapollenites prodromus group of Frederiksen (1991)
Choanopollenites alabamicus (Srivastava 1972) Frederiksen 1979
Favitricolporites baculoferus (Pflug *in* Thompson and Pflug, 1953) Srivastava 1972
Intratriporopollenites pseudinstructus Mai 1961
Lanagiopollis cribellatus (Srivastava 1972) Frederiksen 1988
Milfordia minima Krutzsch 1970
Momipites coryloides Wodehouse 1933
Momipites dilatus Fairchild *in* Stover, Elsik, and Fairchild (1966)
Momipites flexus Frederiksen 1979
Momipites microfoveolatus (Stanley 1965) Nichols 1973
Momipites strictus Frederiksen & Christopher 1978
Momipites tenuipolus group of Frederiksen and Christopher (1978)
Myocolpopollenites reticulatus Elsik *in* Stover, Elsik, and Fairchild (1966)
Nudopollis endangulatus (Pflug *in* Thomson and Pflug, 1953) Pflug 1953
Nudopollis terminalis (Pflug & Thomson *in* Thomson and Pflug, 1953) Elsik 1968
Nudopollis thiergartii (Thomson & Pflug 1953) Pflug 1953
Piolencipollis endocuspoides Frederiksen 1979
Plicatopollis triorbicularis type of Frederiksen & Christopher (1978)
Plicatopollis triradiatus (Nichols 1973) Frederiksen & Christopher 1978
Porocolpopollenites ollivierae (Gruas-Cavagnetto 1976) Frederiksen 1983
Pseudoplicapollis limitatus Frederiksen 1978
Pseudoplicapollis serenus Tschudy 1975
Pseudoplicapollis sp. cf. *P. endocuspis* Tschudy 1975 of Frederiksen (1979)
Psilodiporites iszkaszentgyorgyi (Kedves 1965) Elsik 1988
Retitrescolpites anguloluminosus (Anderson 1960) Frederiksen 1979
Spinaepollis spinosus (Potonié 1931) Krutzsch 1961
Subtriporopollenites anulatus Pflug & Thomson *in* Thomson & Pflug (1953)
Subtriporopollenites nanus (Pflug & Thomson *in* Thomson & Pflug, 1953) Frederiksen 1980
Thomsonipollis magnificus (Pflug *in* Thomson & Pflug, 1953) Krutzsch 1960
Triatriopollenites subtriangulus (Stanley 1965) Frederiksen 1979
Triatriopollenites triangulus Frederiksen 1979
Tricolpites asper Frederiksen 1978
Ulmipollenites krempii (Anderson 1960) Frederiksen 1979
Ulmipollenites tricostatus (Anderson 1960) Frederiksen 1980

APPENDIX 6. Dinocyst data

Rhems Formation
R5093 Q (736.0-736.3 ft)
Preservation: fair, Diversity: moderate, nothing dominates.
Age: Calcareous nannofossil Zone NP 1; *Cyclapophysis monmouthensis* Benson 1976 is late Cretaceous and early Paleocene in Maryland (Benson, 1976); *Deflandrea* n. sp. aff. *D. truncata* Eisenack 1938 is early Paleocene in cores in Georgia.

?*Andalusiella rhombohedra* of Edwards and others (1984)
Andalusiella sp. Aff. *A. polymorpha* of Edwards (1980)
Cordosphaeridium Eisenack 1963 spp.
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Cyclapophysis monmouthensis Benson 1976
Damassadinium californicum (Drugg 1967) Fensome et al. 1993

Deflandrea cf. *D. diebelii* Alberti of Drugg (1967)
Deflandrea n. sp. aff. *D. truncata* Eisenack 1938
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Exochosphaeridium Davey et al. 1966 sp.
Hafniasphaera septata (Cookson & Eisenack (1967) Hansen 1977
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937
Membranosphaera maastrichtica Samoilovitch 1961
Oligosphaeridium complex (White 1842) Davey & Williams 1966
Palaeocystodinium golzowense Alberti 1961
Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967
Phelodinium Stover & Evitt 1978 spp.
Spinidinium densispinatum Stanley 1965
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 19960
miscellaneous areoligeracean forms

A contact within the Rhems is at 724 ft.

R5093 AA (695.1-695.4 ft)
Preservation: good; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies.
?*Andalusiella rhombohedra* of Edwards and others (1984)
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Hafniasphaera Hansen 1977 sp.
Oligosphaeridium complex (White 1842) Davey & Williams 1966 ?
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeocystodinium golzowense Alberti 1961
Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967
Palaeoperidinium Alberti 1967 sp.
Spiniferites Mantell 1850 sp.
miscellaneous areoligeracean forms
small peridiniacean forms

R5093 P (690.0-690.3 ft)
Preservation: fair; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies.
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993 ?
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965 ?
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Hafniasphaera Hansen 1977 sp.
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Palaeocystodinium golzowense Alberti 1961
Palaeocystodinium Alberti 1961
Spiniferites Mantell 1850 spp.
miscellaneous areoligeracean forms
small peridiniacean forms

R5093 AE (670.0-670.3 ft)
Preservation: fair; Diversity: low dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies, first good *Phelodinium* sp. of Edwards (1989).
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993 ?
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965 ?
Hafniasphaera Hansen 1977 sp.

Oligosphaeridium complex (White 1842) Davey & Williams 1966 ?
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeocystodinium golzowense Alberti 1961
Palaeocystodinium Alberti 1967 sp.
Phelodinium sp. of Edwards (1989)
Tanyosphaeridium xanthiopyxides (Wetzel 1933) Stover & Evitt 1978
miscellaneous areoligeracean forms
small peridiniacean forms

R5093 O (650.0-650.3 ft)
Preservation: fair; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies.
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Hafniasphaera Hansen 1977 sp.
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Oligosphaeridium complex (White 1842) Davey & Williams 1966 ?
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeocystodinium Alberti 1967 sp.
Phelodinium sp. of Edwards (1989)
Spiniferites Mantell 1850 spp.
miscellaneous areoligeracean forms
small peridiniacean forms

R5093 N (605.0-605.3 ft)
Preservation: fair, sparse; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies.
Cordosphaeridium Eisenack 1963 sp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Spiniferites Mantell 1850 spp.
miscellaneous areoligeracean forms
small peridiniacean forms

R5093 M (550.0-550.3 ft)
Preservation: fair; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies. Contains Cretaceous reworking.
?*Andalusiella rhombohedra* of Edwards and others (1984)
Cordosphaeridium Eisenack 1963 spp.
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Hafniasphaera Hansen 1977 sp.
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeocystodinium golzowense Alberti 1961
Palaeocystodinium Alberti 1967 sp.
Phelodinium sp. of Edwards (1989)
Spinidinium Cookson & Eisenack 1962 sp.
Spiniferites Mantell 1850 sp.
miscellaneous areoligeracean forms
small peridiniacean forms
reworked Cretaceous specimen

R5093 L (510.0-510.3 ft)
Preservation: fair; Diversity: low, dominated by small peridiniacean forms.
Age: Calcareous nannofossil Zone NP 4. Paleocene small, pale peridiniacean facies. Contains Cretaceous reworking.
?*Andalusiella rhombohedra* of Edwards and others (1984)
Cordosphaeridium Eisenack 1963 spp.

Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Fibradinium annetorpense Morgenroth 1968
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Palaeocystodinium golzowense Alberti 1961
Palaeocystodinium Alberti 1967 sp.
Phelodinium sp. of Edwards (1989)
Spiniferites Mantell 1850 sp.
miscellaneous areoligeracean forms
small peridiniacean forms
reworked Cretaceous specimens

Rhems/Williamsburg contact is at 498 ft.

Lower Bridge Member of the Williamsburg Formation
R5093 K (497.7-498.0 ft)
Preservation: good; Diversity: low, nothing dominates (NOT dominated by small peridiniacean forms).
Age: Calcareous nannofossil lower Zone NP 5. Paleocene, facies change, lowest *Deflandrea delineata* Cookson & Eisenack 1965.
Amphorosphaeridium multispinosum (Davey & Williams 1966) Sarjeant 1981
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Deflandrea delineata Cookson & Eisenack 1965
Fibradinium annetorpense Morgenroth 1968
Hafniasphaera septata (Cookson & Eisenack 1967) Hansen 1977
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeoperidinium pyrophorum (Ehrenberg 1838) Sarjeant 1967
Spinidinium Cookson & Eisenack 1962 sp.
Spiniferites Mantell 1850 sp.
miscellaneous areoligeracean forms
small peridiniacean forms

Lower Bridge/Chicora contact is at 429 ft.

Chicora Member of the Williamsburg Formation
R5093 J (412.2-412.4 ft)
Preservation: fair; diversity: low, few in-place specimens; dominated by foraminiferal linings.
Age: Mixed; Paleocene with late Oligocene and possibly Eocene contamination.
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Deflandre 1937
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Spiniferites Mantell 1850 sp.
Turbiosphaera sp. aff. *T. magnifica* Eaton 1976 of Edwards (1989)
miscellaneous areoligeracean forms
+*Chiropteridium lobospinosum* (Gocht 1956) Gocht 1960 ? (frag)
+*Deflandrea phosphoritica* Eisenack 1938/*Deflandrea heterophlycta* Deflandre & Cookson 1955
+*Deflandrea spinulosa* Alberti 1959
+*Membranophoridium aspinatum* Gerlach 1961
+*Pentadinium laticinctum* Gerlach 1961 (verm.)
+*Wetzeliella* Eisenack 1938 spp.
(+ = not known from the Paleocene; presumably a contaminant)

R5093 I (378.1-378.3 ft)
Preservation: fair, sparse; Diversity: low, dominated by *Turbiosphaera* sp. aff. *T. magnifica* Eaton 1976 of Edwards (1989).
Age: Calcareous nannofossil Zone NP 8. Late Paleocene, overlap of *Damassadinium californicum* (Drugg 1967) Fensome et al. 1993 and *Kallosphaeridium brevibarbatum* de Coninck 1969.
?*Andalusiella rhombohedra* of Edwards and others (1984)
Cordosphaeridium Eisenack 1963 spp.
Damassadinium californicum (Drugg 1967) Fensome et al. 1993
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965

Kallosphaeridium brevibarbatum de Coninck 1969
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Phelodinium sp. of Edwards (1989)
Spiniferites Mantell 1850 sp.
Turbiosphaera sp. aff. *T. magnifica* Eaton 1976 of Edwards (1989)
miscellaneous areoligeracean forms

The Williamsburg/Santee contact is at 355 ft.

R5093 H (353.0-353.2 ft)
Preservation: good, Diversity: moderate, dominated by *Homotryblium plectilum* Drugg & Loeblich 1967 and *Rhombodinium draco* Gocht 1955
Age: Calcareous nannofossil upper Zone NP 16. Late middle Eocene.
Cleistosphaeridium polypetallum (Islam 1983) Stover & Williams 1995
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Eocladopyxis sp. of Williams and Brideaux (1975)
Glaphyrocysta cf. *G.? vicina* (Eaton 1976) Stover & Evitt 1978
Hafniasphaera Hansen 1977 sp.
Homotryblium plectilum Drugg & Loeblich 1967
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Hystrichostrogylon membraniphorum Agelopoulous 1964
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Operculodinium Wall 1967 sp.
Pentadinium goniferum Edwards 1982
Pentadinium polypodum Edwards 1982
Pentadinium Gerlach 1961 n. sp. D
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Rhombodinium draco Gocht 1955/*R. glabrum* (Cookson 1956) Vozzhennikova 1967
Rhombodinium sp. I of Edwards (1984)
Samlandia chlamydophora Eisenack 1954
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
miscellaneous areoligeracean forms

R5093 G (331.7-332.0 ft)
Preservation: good; Diversity: moderate, nothing dominates.
Age: Calcareous nannofossil upper Zone NP 16. Late middle Eocene.
Charlesdowniea coleothrypta (Williams & Downie1966) Lentin & Vozzhennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium Eisenack 1963 sp.
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Distatodinium ellipticum (Cookson 1965) Eaton 1976
Ennaedocysta Stover & Williams 1995 sp. ?
Hafniasphaera Hansen 1977 sp.
Homotryblium plectilum Drugg & Loeblich 1967
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Millioudodinium sp. I of Edwards (1984)
Pentadinium goniferum Edwards 1982
Pentadinium polypodum Edwards 1982
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Rhombodinium draco Gocht 1955/*R. glabrum* (Cookson 1956) Vozzhennikova 1967
Rottnestia borussica (Eisenack 1954), Cookson & Eisenack 1961

Samlandia chlamydophora Eisenack 1954
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
miscellaneous areoligeracean forms

R5093 F (315.0-315.3 ft)
Preservation: good, Diversity: high, nothing dominates.
Age: Calcareous nannofossil Zone NP 17. Late middle Eocene, lowest occurrence of *Heteraulacacysta porosa* Bujak et al. 1980. Highest occurrence of *Pentadinium goniferum* Edwards 1982 and *Pentadinium polypodum* Edwards 1982.

Charlesdowniea coleothrypta (Williams & Downie1966) Lentin & Vozzhennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Corrudinium sp. I of Edwards (1984)
Dinopterygium cladoides sensu Morgenroth 1966
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
?*Eocladoyxis* Morgenroth 1966 n. sp.
Heteraulacacysta porosa Bujak et al. 1980
Homotryblium plectilum Drugg & Loeblich 1967
Homotryblium Davey & Williams 1966 sp.
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Lentinia serrata Bujak 1980
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Millioudodinium sp. I of Edwards (1984)
Palaeocystodinium golzowense Alberti 1961
Pentadinium goniferum Edwards 1982
Pentadinium polypodum Edwards 1982
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Rhombodinium draco Gocht 1955/*R. glabrum* (Cookson 1956) Vozzhennikova 1967
Samlandia chlamydophora Eisenack 1954
Selenopemphix Benedek 1972 spp.
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
miscellaneous areoligeracean forms

The Santee/Harleyville contact is at 312 ft.

Harleyville Formation

R5093 E (302.3-302.6 ft)
Preservation: good, Diversity: high, nothing dominates.
Age: Calcareous nannofossil Zone NP 18. Late Eocene, lowest occurrence of *Batiacasphaera baculata* Drugg 1970 and *Batiacasphaera compta* Drugg 1970. Probably contains reworked specimens (R) of early middle Eocene age (*Eocladopyxis* Morgenroth 1966 n. sp. A).

Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdownia variabilis (Bujak 1980) Lentin & Vozzennikova 1989
Charlesdowniea coleothrypta (Williams & Downie 1966) Lentin & Vozzhennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium Eisenack 1963 sp.
Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al. 1980
Deflandrea phosphoritica Eisenack 1938

Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Distatodinium ellipticum (Cookson 1965) Eaton 1976
(R)*Eocladopyxis* Morgenroth 1966 n. sp. A
Fibrocysta Stover & Evitt 1978 sp.
Hafniasphaera Hansen 1977 sp.
Homotryblium plectilum Drugg & Loeblich 1967
Hystrichokolpoma cinctum Klumpp 1953
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Impagidinium Stover & Evitt 1978 sp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Melitasphaeridium pseudorecurvatum (Morgenroth 1966) Bujak et al. 1980
Operculodinium Wall 1967 sp.
Pentadinium laticinctum Gerlach 1961 (knobby)
Pentadinium laticinctum Gerlach 1961 subsp. *laticinctum*
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Polysphaeridium zoharyi (Rossignol 1962) Bujak et al. 1980
Rhombodinium draco Gocht 1955
Rottnestia borussica (Eisenack 1954) Cookson & Eisenack 1961
Samlandia chlamydophora Eisenack 1954
Samlandia chlamydophora sensu Stover and Hardenbol (1993)
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
Thalassiphora Eisenack & Gocht 1960 sp.
miscellaneous areoligeracean forms

R5093 D (295.3-295.6 ft)
Preservation: good; Diversity: high, nothing dominates.
Age: Calcareous nannofossil Zone NP 18. Late Eocene. Probably contains reworked specimens of early middle Eocene age (*Eocladopyxis* Morgenroth 1966 n. sp. A).

Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdowniea coleothrypta (Williams & Downie1966) Lentin & Vozzhennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium Eisenack 1963 spp.
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al. 1980
Deflandrea phosphoritica Eisenack 1938/*D. heterophlycta* Deflandre & Cookson 1955
Dinopterygium cladoides sensu Morgenroth 1966
Distatodinium ellipticum (Cookson 1965) Eaton 1976
(R)*Eocladopyxis* Morgenroth 1966 n. sp. A
Homotryblium plectilum Drugg & Loeblich 1967
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Lejeunecysta Artzner & Dörhöfer 1978 sp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Melitasphaeridium pseudorecurvatum (Morgenroth 1966) Bujak et al. 1980
Operculodinium Wall 1967 sp.
Pentadinium laticinctum Gerlach 1961 (verm.)
Pentadinium laticinctum Gerlach subsp. *laticinctum*
Phthanoperidinium Drugg & Loeblich 1967 sp.
Samlandia chlamydophora Eisenack 1954
Samlandia chlamydophora sensu Stover and Hardenbol 1993
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960

Wetzeliella Eisenack 1938 spp.
miscellaneous areoligeracean forms

There is an environmental change between these two samples; more inshore stratigraphically above here.

R5093 C (262.0-262.3 ft)
Preservation: good; Diversity: high, dominated by *Glaphyrocysta* spp. and *Homotryblium plectilum* Drugg & Loeblich 1967.
Age: Calcareous nannofossil Zone NP 19/20. Late Eocene. Lowest *Cordosphaeridium funiculatum* Morgenroth 1966.

Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdownia variabilis (Bujak 1980) Lentin & Vozzennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium funiculatum Morgenroth 1966
Corrudinium incompositum (Drugg 1970) Stover & Evitt 1978
Deflandrea phosphoritica Eisenack 1938/*D. heterophlycta* Deflandre & Cookson 1955
Dinopterygium cladoides sensu Morgenroth 1966
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Distatodinium ellipticum (Cookson 1965) Eaton 1976
Ennaedocysta Stover & Williams 1995 sp.
Fibrocysta Stover & Evitt 1978 sp.
Glaphyrocysta cf. *G.*? *vicina* (Eaton 1976) Stover & Evitt 1978
Homotryblium plectilum Drugg & Loeblich 1967
Hystrichokolpoma cinctum Klumpp 1953
Hystrichokolpoma rigaudiae Deflandre & Cookson 1955
Hystrichostrogylon coninckii Heilmen-Clausen 1985
Lejeunecysta Artzner & Dorhofer 1978 spp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Millioudodinium sp. I of Edwards (1984)
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Palaeocystodinium golzowense Alberti 1961
Pentadinium laticinctum Gerlach 1961 (verm.)
Pentadinium laticinctum Gerlach subsp. *laticinctum*
Phthanoperidinium comatum (Morgenroth 1966) Eisenack & Kjellstrom 1971
Samlandia chlamydophora Eisenack 1954
Selenopemphix Benedek 1972 spp.
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tectatodinium pellitum Wall 1967 ?
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
miscellaneous areoligeracean forms

R5093 B (241.5-241.8 ft)
Preservation: good; Diversity: moderate, dominated by *Homotryblium plectilum* Drugg & Loeblich 1967.
Age: Calcareous nannofossil Zone NP 19/20. Late Eocene.

Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdowniea coleothrypta (Williams & Downie1966) Lentin & Vozzhennikova 1989
Cordosphaeridium cantharellus (Brosius 1963) Gocht 1969
Cordosphaeridium funiculatum Morgenroth 1966
Cordosphaeridium Eisenack 1963 spp.
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Dapsilidinium pseudocolligerum (Stover 1977) Bujak et al. 1980
Deflandrea phosphoritica Eisenack 1938
Dinopterygium cladoides sensu Morgenroth 1966
Homotryblium plectilum Drugg & Loeblich 1967

Lejeunecysta Artzner & Dorhofer 1978 spp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967
Operculodinium Wall 1967 sp.
Palaeocystodinium golzowense Alberti 1961
Pentadinium laticinctum Gerlach subsp. *laticinctum*
Polysphaeridium zoharyi (Rossignol 1962) Bujak et al. 1980
Samlandia chlamydophora Eisenack 1954
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
Wetzeliella Eisenack 1938 sp.
miscellaneous areoligeracean forms

R5093 A (210.5-210.7 ft)
Preservation: good; Diversity: moderate, dominated by *Homotryblium plectilum* Drugg & Loeblich 1967. Reworked specimens, (R).
Age: Calcareous nannofossil Zone NP 19/20. Late Eocene.
Batiacasphaera baculata Drugg 1970
Batiacasphaera compta Drugg 1970
Charlesdowniea coleothrypta (Williams & Downie1966) Lentin & Vozzhennikova 1989
Cordosphaeridium funiculatum Morgenroth 1966
Cribroperidinium giuseppei (Morgenroth 1966) Helenes 1984
Deflandrea phosphoritica Eisenack 1938/*D. heterophlycta* Deflandre & Cookson 1955
Diphyes colligerum (Deflandre & Cookson 1955) Cookson 1965
Homotryblium plectilum Drugg & Loeblich 1967
Lejeunecysta Artzner & Dorhofer 1978 spp.
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Pentadinium laticinctum Gerlach subsp.*laticinctum*
Pentadinium membranaceum (Eisenack 1965) Stover & Evitt 1978
Rottnestia borussica (Eisenack 1954) Cookson & Eisenack 1961
Spiniferites pseudofurcatus (Klumpp 1953) Sarjeant 1970
Spiniferites Mantell 1850 spp.
Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969
Tectatodinium pellitum Wall 1967
Thalassiphora pelagica (Eisenack 1954) Eisenack & Gocht 1960
Wetzeliella Eisenack 1938 sp.
miscellaneous areoligeracean forms
(R) small peridiniacean forms

APPENDIX 7. Summary of samples examined for pollen.

Thirty-eight samples from the Cannon Park corehole were examined for pollen, as shown on the following list.

Palynology No.		Depth	Stratigraphic Unit	Shown in pollen occurrence chart	Provides data about sample ages
R5093	A	210.5-210.7'	Harleyville Fm.		
	B	241.5-241.8'	do.		
	C	262.0-262.3'	do.		
	D	295.3-295.6'	do.		
	E	302.3-302.6'	do.		
	F	315.0-315.3'	Cross Mbr. Santee Ls		
	G	331.7-332.0'	do.		
	H	353.0-353.2'	do.		

Y	378.0'	Chicora Mbr. Williamsburg Fm.	X	X
I	378.1-378.3'	do.		
J	412.2-412.4'	do.		
X	439.0'	Lower Bridge Mbr. Williamsburg Fm.	X	
W	492.0'	do.	X	
K	497.7-498.0'	do.		
L	510.0-510.3'	Rhems Fm.		
M	550.0-550.3'	do.		
N	605.0-605.3'	do.		
AM	620.0-620.3'	do.	X	
AL	625.0-625.3'	do.	X	
AK	630.0-630.3'	do.	X	
AJ	635.0-635.3'	do.	X	
AI	645.0-645.3'	do.	X	
O	650.0-650.3'	do.		
AH	655.0-655.3'	do.	X	X
AG	660.0-660.3'	do.	X	
AF	665.0-665.3'	do.	X	
AE	670.0-670.3'	do.	X	X
AD	675.0-675.3'	do.		
AC	679.7-680.0'	do.	X	
A	684.7-685.0'	do.	X	
P	690.0-690.3'	do.		
AA	695.1-695.4'	do.	X	
V	699.6-699.9'	do.	X	X
U	705.0-705.3'	do.	X	X
T	710.0-710.3'	do.	X	X
S	713.7-714.0'	do.	X	
R	726.0-726.3'	do.		
Q	736.0-736.3'	do.		

Nineteen of the samples were barren of pollen or contained so little pollen that no analysis could be made, but 19 other samples contained enough taxa that they were worth recording on the accompanying chart, in which X = present; P = probably present; ? = possibly present. Six of the latter 19 samples had pollen taxa (listed in the chart) that provide some information about sample ages, and these ages are discussed in the text.

APPENDIX 8. Cenozoic lithologic data from the Cannon Park core

Pleistocene sediments

Run 2: 7.5-9 ft

Fill; SAND, fine to medium with brick fragments grading into wood fragments from 8 to 9 ft.

Run 3: 9-14 ft

CLAY, silty with macrofossil fragments; gray (2.5Y5/1).

Run 4: 14-19 ft

CLAY, silty; silt (2 to 5%); sand, very fine to fine; well-consolidated with trace heavy minerals; mica (1-5%); local shell fragments (1-5%), organic matter (10-15%); low-angled crossbeds in organic-rich layers; gray (2.5Y5/1).

Run 5: 19-24 ft

CLAY, silty; gray (2.5Y5/1); same as above.

Run 6: 24-29 ft

24-27.3 ft: CLAY, silty; silt (1-5%); sand, very fine to fine; well consolidated; mica (1-5%); organic matter (5-10%); gray (2.5Y5/1).

27.3-28 ft: Organic-rich layer; very dark gray (2.5Y3/1) with orange staining (oxidized); dark-yellow-brown (10YR4/6).

28-29 ft: SAND, fine to medium, angular, well sorted; clay matrix (2-5%); poorly consolidated; trace heavy minerals; mica (2-3%); organic matter (5-10%); light gray (2.5Y7/1).

Run 7: 29-34 ft

29-29.5 ft: SAND; same as above, grades into:

29.5-32 ft: SAND, clayey to SAND; quartz, fine to medium, subangular, well-sorted; organic-rich clay matrix (5-10%); poorly consolidated; trace heavy minerals; mica (1-2%); dark-gray (2.5Y4/1); grades into:

32 ft: Lag deposit: SAND; quartz, fine to coarse; quartz gravel (up to 5 mm); subangular to well rounded, poorly sorted; well-rounded phosphate gravel.

32-34 ft: SAND, quartz, fine to medium, subangular, well-sorted, poorly consolidated; clay matrix (1-3%); abundant shell fragments (20-30%); trace heavy minerals; mica (2-5%); light-brown-gray (2.5Y6/2); increase in clay content around 33 ft to (10-15%).

Run 8: 34-44 ft

34 ft: Possible contact; burrows filled with shell fragments and fine quartz sand from above.

34-42 ft: CLAY, silty, SILT, and SAND, very fine (5%) in thin laminations (2 mm thick); trace heavy minerals; thin lamination of shell fragments (2-5 mm thick); well-consolidated; gray (5Y6/1).

42-44 ft: No recovery.

Run 9: 44-49 ft

CLAY, silty with very fine to fine quartz sand in thin laminations (2-3 mm thick), subangular, well-sorted; well-consolidated; trace shell fragments; trace organic matter (<5%); trace mica (1-2%); gray (5Y6/1).

Run 10: 49-59 ft

CLAY, silty with very fine to fine quartz sand in thin laminations (2-3 mm thick); increase in quartz sand laminations as above; light-olive-gray (5Y6/2).

Run 11: 59-65 ft

59-61 ft: CLAY, silty with very fine to fine quartz sand laminations (same as above); grades into: (increase in sand content).

61-65 ft: SAND, clayey, silty; quartz, very fine to fine, angular to subangular, well-sorted, semi-consolidated in 10-20% clay matrix; parts as if thinly laminated (alternating clean sand with clayey sand); mica (1-2%); trace heavy minerals; light-yellow-brown (2.5Y6/3); grades into:

Run 12: 65-75 ft

65-71 ft: CLAY, silty with very fine to fine quartz sand lamination (<5%); well consolidated; light-brown-gray (2.5Y6/2); grades into: (increase in quartz sand lamination at 71 ft).

71-74 ft: CLAY, silty with very fine to fine quartz sand laminations (1-2 mm thick, 30-40%); in clay matrix (50-60%); quartz sand, subangular, well-sorted; well-consolidated; mica (1-2%); trace heavy minerals; increase in phosphate (20%) in sand laminations; light-brown-gray (2.5Y6/2).

Tertiary System

Upper Oligocene
Ashley Formation (Cooper Group)

74 ft: Contact: Top of Cooper Group, Ashley Fm.

At contact: SAND, fine to medium, subangular, and well sorted; phosphate gravel (2-6 mm).

74-75 ft: CLAY, calcareous, microfossiliferous, silty/sandy; quartz, fine to medium, angular (5-8%) in calcareous clay; foraminifers abundant; trace heavy minerals; partially to heavily bioturbated; well-consolidated; small macrofossil fragments (locally up to 30%), locally dissolved; pale-olive (brownish) (5Y6/4).

Run 13: 75-84 ft
CLAY, calcareous, microfossiliferous, silty/sandy; same as above; highly bioturbated, common small fossil fragments.

Run 14: 84-89 ft
Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 15: 89-95 ft
CLAY, calcareous, microfossiliferous, silty/sandy; same as above; quartz, very fine to fine, subangular; abundant microfossils, macrofossil fragments; bioturbated; shell fragments; trace heavy minerals; well-consolidated; pale-yellow (olive) (5Y7/4).

Run 16: 95-97 ft
CLAY, calcareous; same as above.

Run 17: 97-104 ft
97-98 ft: CLAY, calcareous, microfossiliferous, sandy; same as above; possible burrowing.

98-104 ft: No recovery.

Run 18: 104-105 ft
CLAY, calcareous; same as above; possible burrows.

Run 19: 105-110 ft
105-108 ft: CLAY, calcareous, microfossiliferous, silty/sandy; same as above.

106.7 ft: nodules (5-10 mm) within the matrix; higher calcite cement (<clay content); highly bioturbated.

Run 20: 110-120 ft
110-112 ft: CLAY, calcareous; same as above; bioturbated; abundant nodules; grades into:

112-117 ft: CLAY, calcareous, microfossiliferous, silty/sandy; quartz, very fine to fine, subangular; abundant foraminifers but decrease from section above; trace glauconite; trace heavy minerals; olive to pale-olive (5Y5/4).

117-120 ft: No recovery.

Run 21: 120-130 ft
120-125 ft: CLAY, calcareous; same as above; abundant foraminifers.

125-130 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 22: 130-140 ft
CLAY, calcareous; same as above; abundant foraminifers.

138.5 ft: pecten fragments.

Run 23: 140-150 ft
CLAY, calcareous, microfossiliferous, silty/sandy; same as above; foraminifers decreasing in size; pale-olive (5Y6/4).

Run 24: 150-160 ft
CLAY calcareous; same as above; abundant foraminifers; common pecten fragments; trace glauconite.

Run 25: 160-165 ft
Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 26: 165-171 ft
CLAY, calcareous; same as above.

Run 27: 171-181 ft
CLAY, calcareous; same as above; common shell fragments; trace glauconite.

Run 28: 181-191 ft
CLAY, calcareous; same as above; common shell fragments; glauconite (5%); trace phosphate.

186 ft: increase in glauconite (5-10%); trace pyrite; pecten fragments.

Run 29: 191-201 ft
CLAY, calcareous, microfossiliferous, silty/sandy; quartz, very fine to fine, subrounded; abundant foraminifers; glauconite (10-15%); phosphate (5-10%), very coarse; trace heavy minerals; phosphate pebbles (up to 2 mm); pale-olive (5Y6/3).

Run 30: 201-211
201-208 ft: CLAY, calcareous; same as above; quartz, fine to medium, subrounded to round (20-30%); foraminifers common to abundant; phosphate, fine to very coarse, black phosphate, subangular to round, brown phosphate, well-rounded, medium to coarse; glauconite (10%); trace heavy minerals; trace spicules; pale-olive (5Y6/3).

206-208 ft: increase in phosphate and glauconite content; increase in phosphate pebbles (2-10 mm).

Upper Eocene

Harleyville Formation (Cooper Group)

208 ft: Contact: Ashley Fm/Harleyville Fm

208-211 ft: CLAY, calcareous, microfossiliferous, fine, silty; very fine as compared with above formation.

Run 31: 211-219 ft
CLAY, calcareous, microfossiliferous, fine-grained, silty/sandy; quartz, very fine to fine, subangular to subrounded (10-15%); abundant to common foraminifers; trace glauconite; trace heavy minerals; pale-yellow (olive) (5Y7/3).

Run 32: 219-224 ft
Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 33: 224-232 ft
224-225 ft: Dense silicified zone.

225-232 ft: CLAY, calcareous; same as above.

Run 34: 232-239 ft

CLAY, calcareous; same as above; common shell fragments; trace glauconite; looks as if there are bedding features (clean sand with foraminifers interbedded with clayey beds <1 mm in thickness).

Run 35: 239-242 ft

239-241 ft: CLAY, calcareous; same as above; increase in phosphate, very fine (15-20%); spicules (15%); trace glauconite.

241-242 ft: No recovery.

Run 36: 242-252 ft

242-244.5 ft: CLAY, calcareous; same as above.

243.5-244.5 ft: Silicified zone; sheeting appearance (lenses).

244.5-252 ft: No recovery.

Run 37: 252-262 ft

252-253 ft: Dense silicified zone; more lithified than surrounding matrix.

253-256 ft: CLAY, calcareous, microfossiliferous, silty/sandy; quartz, very fine to fine, subangular to subrounded; abundant foraminifers (50+%); common glauconite (15-20%); trace phosphate; trace heavy minerals; clay matrix (15-20%); common shell fragments; common spicules; light-gray (2.5Y7/2).

255.5-256 ft: Dense silicified zone.

256-262 ft: No recovery.

Run 38: 262-272 ft

CLAY, calcareous; same as above; increase in shell fragments (common to abundant), possible burrows; increase in glauconite content.

268.5-269.5 ft: Dense silicified zone.

271.5-272 ft: Dense silicified zone.

Run 39: 272-277 ft

No recovery.

Run 40: 277-282 ft

CLAY, calcareous; same as above; abundant shell fragments.

277.5-278.5 ft: Dense silicified zone.

278.5 ft: Dissolution feature (~2cm thick).

Run 41: 282-292 ft

CLAY, calcareous, silty/sandy; quartz, very fine to fine, subangular to subrounded (10-20%); bioturbated, microfossiliferous, abundant foraminifers (40%+); abundant glauconite (15-20%); trace phosphate, trace heavy minerals, clay matrix (10-15%); common shell fragments; light-gray (2.5Y7/2).

282.7-283.9 ft: Sample with Frank Chapelle, USGS-WRD Columbia, SC.

284.5-285 ft: Dense silicified zone.

286.5-286.8 ft: Dense silicified zone.

289.8-290 ft: Dense silicified zone.

290 ft: Common to abundant oyster fragments.

Run 42: 292-302 ft

CLAY, calcareous; quartz, very fine to fine, subangular to subrounded (5% from 292-294 ft), decrease at about 294 ft to about 1-5%; abundant foraminifers (25-35%); abundant glauconite (15-20%); trace phosphate; trace heavy minerals; common shell fragments; clay matrix (15%); light-gray (2.5Y7/2).

295-295.4 ft: Dense silicified zone.

295.5-302 ft: Numerous burrows filled with higher content of glauconite and trace of phosphate and increase in sand content (10%); numerous shell fragments.

297.7-299.1 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 43: 302-312 ft

302-303 ft: Calcareous clay; same as above.

303-312 ft: CLAY, silty/sandy, calcareous; quartz, very fine to fine, subangular (1-5%), highly glauconitic, bioturbated, microfossiliferous; abundant foraminifers (15-20%); common shell fragments; abundant glauconite (20-30%); trace phosphate; trace heavy minerals; trace to common spicules; abundant burrows; trace to common oyster fragments from 306.5 ft down.

303 ft: Dense silicified zone; abundant spicules within 3 cm above silicified zone.

Higher glauconite content within burrows then surrounding matrix; burrows have a higher quartz content.

307 ft and 310 ft: small nodules or clasts.

Middle Eocene

Cross Member of the Santee Limestone

Run 44: 312-322 ft

312.6 ft: contact Harleyville Formation/Cross Member

LIMESTONE, fine-grained; quartz, very fine to fine (2-5%); bioturbated, abundant foraminifers, glauconite (20% from 312-320 ft; 5% from 320-322).

314-315 ft: Dense silicified zone; common to abundant radiolarian spicules above zone.

Run 45: 322-332 ft

322-324 ft: Dense silicified zone.

LIMESTONE, fine-grained; microfossiliferous, slightly clayey; quartz, very fine to fine (2-4%); abundant foraminifers (poorly preserved, silica replacement); trace glauconite; siliceous spicules; white (5Y8/1).

326.4-328.5 ft: Dense silicified zone.

Run 46: 332-342 ft

LIMESTONE, fine-grained; same as above.

Run 47: 342-352 ft

LIMESTONE, fine-grained; same as above; increase in phosphate content, subangular, fine to medium; trace glauconite.

351.7-352 ft: Dense silicified zone.

Run 48: 352-357 ft

352-355.0 ft: Lag deposit above 2-cm-thick phosphatic crust. LIMESTONE; quartz, fine to medium, subrounded to round (20-25%); abundant glauconite, medium to coarse, subrounded to round; common pyrite; common to abundant phosphate, sand and granules; bioturbated; white (N8/) with dark grains.

Upper Paleocene

Chicora Member of the Williamsburg Formation (Black Mingo Group)

355.0 ft: Contact: Cross Member/Chicora Member.

355.0-357 ft: LIMESTONE, molluscan, moldic, glauconite/quartz-rich; moderate to high, solution-enhanced, meso- to megamoldic porosity (20%); some calcite spar coatings on surfaces; molluscan dominated.

Run 49: 357-362 ft

LIMESTONE, molluscan, moldic, quartz-rich; quartz, fine to medium, subrounded (20-25%); abundant glauconite; meso- to megamoldic porosity (15-20%), voids (3-8 mm in length); spar cement coatings; common oyster shells; molluscan dominated.

357.7-362 ft: No recovery.

Run 50: 362-367

No recovery.

Run 51: 367-369 ft

367-368 ft: SANDSTONE, calcareous cemented; semi-consolidated; quartz, fine to coarse, subangular to subrounded (60-70%); trace to common glauconite; shell fragments (15%); rubble zone with clasts (10-40 mm in length), gray limestone above/below; greenish-gray (10Y6/1).

368-369 ft: No recovery.

Run 52: 369-371 ft

LIMESTONE, molluscan, moldic, quartz-rich; quartz, very fine to fine, subangular to subrounded (20%); trace glauconite/phosphate; shell fragments; meso- to megamoldic porosity (15-20%), voids (3-10 mm in length); gray (N6/).

369.5- 371 ft: No recovery.

Run 53: 371-376 ft

371-371.5 ft: SAND, fossiliferous, poorly consolidated to unconsolidated; quartz, fine to coarse, subangular to subrounded (60-70%); shell fragments (15%); trace foraminifers; trace heavy minerals.

371.5-372 ft: LIMESTONE, molluscan, moldic, quartz-rich; quartz, very fine to fine, subrounded (20-30%); spar cement coatings; meso- to megamoldic porosity (20%); light-gray (N7/).

372-376 ft: No recovery.

Run 54: 376-380 ft

376-377 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

377-379 ft: CLAY, silty with thin sand lamination (2 mm thick, fine), angular to subangular; grades into:

379-380 ft: SAND/MUD, calcareous; quartz, fine to fine angular to subangular (25-30%); shell fragments; trace phosphate/glauconite; common clasts of limestone, calcareous clay balls; light-gray (2.5Y7/1).

Run 55: 380-385 ft

380-382 ft: No recovery.

SAND/MUD, calcareous; interbedded with clasts of quartz-rich shelly limestone; quartz, very fine to fine; light-gray (n7/); same as above.

Run 56: 385-390 ft

SAND/MUD, calcareous with clasts of quartz-rich shelly limestone; same as above.

386.7-390 ft: No recovery.

Run 57: 390-395 ft

SAND/MUD, fossiliferous, calcareous with clast of quartz-rich shelly limestone; semi-consolidated; quartz, very fine to medium, angular to subrounded, 60%; shell fragments; common foraminifers 5%; trace phosphate/glauconite; spar cement coatings; interparticle to meso- to megamoldic porosity (15-20%); light-greenish-gray (10Y7/1).

Run 58: 395-400 ft

395-398 ft: SAND/MUD, fossiliferous, calcareous with intraclast of quartz-rich shelly limestone; same as above.

398-400 ft: SAND/MUD, bioturbated, calcareous; quartz, very fine to medium, subangular to subrounded; trace phosphate (<5%); trace glauconite; trace heavy minerals; foraminifers (<5%); shell fragments; greenish-gray (10Y6/1).

Run 59: 400-405 ft

SAND/MUD, bioturbated, calcareous with intraclast of quartz-rich shelly limestone; quartz, very fine to medium, subangular to subrounded; phosphate (<5%); trace glauconite; trace heavy minerals; foraminifers (<5%); spar cement coatings; greenish-gray (10Y6/1).

Run 60: 405-412 ft

405-410 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 61: 412-417 ft

SAND, fossiliferous, calcareous; quartz, fine to medium, subangular to rounded; glauconite (5%); trace phosphate; shell fragments; poorly to semi-consolidated; white (5Y8/1).

415-417 ft: No recovery.

Run 62: 417-418.5 ft

SAND, fossiliferous, calcareous; same as above.

Run 63: 418.5-422 ft

418.5-421 ft: SAND, fossiliferous, interbedded with quartz-rich glauconite shelly limestone clasts; glauconite (10-15%); poorly consolidated.

421-422 ft: No recovery.

Run 64: 422-425 ft

SAND, fossiliferous, glauconitic, calcareous with clasts of quartz-rich shelly limestone; same as above; semi- to well-consolidated; increase in quartz (50-60%) and glauconite (15-20%) content; increase in shell fragments; interparticle to meso- megamoldic porosity (15-20%).

Run 65: 425-427 ft

SAND, fossiliferous; same as above; quartz fine to medium, subrounded to rounded; glauconite (10-15%); trace phosphate; shell fragments; poorly to semi-consolidated; white (5Y8/1).

Run 66: 427-431 ft

427-429 ft: SAND, fossiliferous; same as above.

Upper Paleocene

Lower Bridge Member of the Williamsburg Formation (Black Mingo Group)

429 ft: contact between Chicora Member and the Lower Bridge Member of the Williamsburg Fm.

429-429.5 ft: LIMESTONE, shelly, moldic, glauconite/quartz-rich; quartz, fine to medium, subrounded to rounded; common glauconite (10%); trace phosphate; spar cement coating; meso- to megamoldic porosity (15-20%).

429.5-431 ft: No recovery.

Run 67: 431-432 ft

LIMESTONE, shelly, moldic, quartz-rich; same as above.

Run 68: 432-437 ft

CLAY (siltstone/claystone), bioturbated, silty/sandy, moderately calcareous; quartz, very fine to fine, angular to subangular (20-30%); sparse to common glauconite (<10%); common mica (10-15%); siliceous spicules; trace foraminifers; trace heavy minerals; trace phosphate; gray (5Y5/1).

Run 69: 437-442 ft

CLAY (siltstone), silty/sandy, bioturbated, moderately calcareous; same as above.

Run 70: 442-452 ft

CLAY, bioturbated, silty/sandy; same as above.

442-443 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 71: 452-462 ft

CLAY (siltstone), moderately calcareous, silty/sandy; well-indurated; quartz, very fine to fine, subangular to angular (20-30%); common glauconite; common mica (5%); siliceous spicules; trace heavy minerals; gray (5Y5/1) to (5Y6/1).

Run 72: 462-472 ft

CLAY (siltstone), silty/sandy, moderately calcareous; same as above.

Run 73: 472-482 ft

CLAY (siltstone), silty/sandy, moderately calcareous; same as above.

Run 74: 482-492 ft

CLAY, silty/sandy; same as above.

482-485 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 75: 492-502 ft

492-494 ft: CLAY, silty/sandy; same as above.

494-498 ft: CLAY, silty/sandy, bioturbated, glauconitic, calcareous; quartz, very fine to medium, subangular to subrounded (10-15%); abundant glauconite (10-15%); common phosphate, glauconite/phosphate pebbles (2-5 mm in diameter); trace pyrite; greenish-gray (4/2).

497.5-498 ft: Highly glauconitic (25-35%).

Lower and Upper Paleocene
Rhems Formation (Black Mingo Group)

498 ft: Contact between Williamsburg Formation and the Rhems Formation.

498-502 ft: CLAY, silty/sandy, bioturbated, moderately calcareous; decrease in glauconite content (<10%).

Run 76: 502-507 ft

CLAY, silty/sandy, moderately calcareous, interbedded with quartz sand; quartz, very fine to medium, subangular to angular (5-10%); common to trace glauconite; common mica; siliceous spicules; trace heavy minerals; gray (5Y6/1).

Run 77: 507-512 ft

CLAY, silty, moderately calcareous; same as above.

Run 78: 512-521 ft

CLAY, silty/sandy, moderately calcareous, interbedded with quartz sand lenses (5-10mm thick); same as above.

512-513.3 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 79: 521-531 ft

CLAY, silty/sandy, moderately calcareous, interbedded with quartz sand (trace to common); same as above.

Run 80: 531-541 ft

CLAY (siltstone), silty.

Run 81: 541-551 ft

CLAY, silty/sandy, moderately calcareous; well indurated; quartz, very fine to fine, subangular to angular (5-10%); common mica (5%); siliceous spicules; trace heavy minerals; gray (5Y6/1).

Run 82: 551-561 ft

CLAY, silty, moderately calcareous; same as above.

Run 83: 561-571 ft

CLAY, silty/sandy; same as above.

567.5-569 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 84: 571-581 ft

CLAY, sandy/silty clay; same as above; increase in sand content (10-15%).

Run 85: 581-590 ft

CLAY, sandy/silty; same as above.

Run 86: 590-600 ft

CLAY, silty to SAND, clayey; well indurated; quartz, very fine to medium, subangular (20%); moderately calcareous; common mica (5-10%); trace glauconite; trace foraminifers; siliceous spicules; moderately bioturbated; gray (5Y6/1).

590-590.5 ft: Dense silicified zone.

Run 87: 600-610 ft

CLAY, silty to SAND, clayey; same as above.

Run 88: 610-617 ft

SAND, clayey; same as above.

Run 89: 617-622 ft

CLAY, silty SAND, clayey; same as above.

617-619.8 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 90: 622-632 ft

CLAY, silty to SAND/SILT, clayey; well indurated; quartz, very fine to medium, subangular (25-35%); common mica (10-15%); trace foraminifers; bioturbated; siliceous spicules; gray (5Y6/1).

Run 91: 632-642 ft

CLAY. sandy to SAND, clayey; well indurated; common to abundant mica (15%); same as above.

637.4-642 ft: No recovery.

Run 92: 642-647 ft

CLAY, sandy to SAND, clayey; same as above.

Run 93: 647-652 ft

CLAY, sandy to SAND, clayey; same as above.

Run 94: 652-661 ft

CLAY, sandy to SAND, clayey, bioturbated, well-indurated; quartz, very fine to medium, subangular to subrounded (30-40%); moderately calcareous; common to abundant mica (15%); foraminifers; siliceous spicules; burrows filled with clean sand, fine to medium, subangular to subrounded, well-sorted; gray (5Y6/1).

652-653.2 ft: Sample with Frank Chapelle, USGS-WRD, Columbia, SC.

Run 95: 661-671 ft

CLAY, sandy to SAND, clayey, bioturbated; same as above.

666-666.3 ft: Dense silicified zone.

669-671 ft: No recovery.

Run 96: 671-681 ft

CLAY, sandy to SAND, clayey, bioturbated; same as above.

Run 97: 681-691 ft

CLAY, sandy to SAND, clayey, bioturbated; same as above.

Run 98: 691-701 ft

CLAY, sandy to SAND, clayey, bioturbated; same as above.

Run 99: 701-710 ft

CLAY, sandy; to SAND, clayey, bioturbated; well indurated; quartz, very fine to medium, subangular to subrounded (30-40%); moderately calcareous; common to abundant mica (15%); foraminifers; siliceous spicules; sand filled burrows; gray (5Y6/1).

701.5-702 ft: Dense silicified zone with inclined bedding.

707-707.5 ft: Dense silicified zone.

Run 100: 710-720 ft

CLAY, sandy to SAND, clayey, bioturbated; same as above.

718-718.8 ft: Dense silicified zone; white (N8/).

Run 101: 720-730 ft

720-722.8 ft: SAND, clayey, highly bioturbated, well indurated; moderately calcareous; same as above.

722.8-725.5 ft: SAND, clayey, highly bioturbated, glauconite/phosphate-rich; abundant glauconite-filled burrows; phosphate pebbles (2-7 mm in diameter); trace macrofossils; common foraminifers, common to abundant siliceous spicules; common mica; dark-yellowish-brown (10YR4/2).

725.5 ft: contact.

Run 102: 730-740 ft

SAND, clayey, highly bioturbated, glauconitic, phosphatic; same as above.

738-740 ft: No recovery.

Run 103: 740-747 ft

740-743.8 ft: SAND, quartz, very fine to fine, muddy, poorly sorted; phosphate (5-15%, increasing downward, sand, granules, and small pebbles), glauconite (5%, sand-sized); common microfossils; irregular patches of calcium-carbonate cement; dark-greenish-gray (5GY4/1).

743.8 ft: Cretaceous-Tertiary boundary, sharp, burrowed.

Maastrichtian
Peedee Formation

743.8-747 ft: SAND, very fine, and SILT, quartz, clayey; mica (1-3%, silt); common microfauna; common 0.5-inch-diameter, unlined burrows containing quartz-phosphate sand from above; color- and texture-mottled (bioturbated); dark-greenish-gray (5GY4/1).

APPENDIX 9. Cretaceous lithologic data for the Cannon Park core

Run 103: 740-747 ft: REPEATED DESCRIPTION

Rhems Formation (part)

740-743.8 ft: SAND, quartz, very fine to fine, muddy, poorly sorted; phosphate (5-15%, increasing downward, sand, granules, and small pebbles), glauconite (5%, sand-sized); common microfossils; irregular patches of calcium-carbonate cement; dark-greenish-gray (5GY4/1).

743.8 ft: Cretaceous-Tertiary boundary, sharp, burrowed.

Maastrichtian
Peedee Formation

743.8-747 ft: SAND, very fine, and SILT, quartz, clayey; mica (1-3%, silt); common microfauna; common 0.5-inch-diameter, unlined burrows containing quartz-phosphate sand from above; color- and texture-mottled (bioturbated); dark-greenish-gray (5GY4/1).

Run 104: 747-750 ft
SAND, very fine, and SILT, quartz, clayey; mica (trace); common microfauna; color- and texture-mottled (bioturbated); brownish-gray (5YR4/1).

Run 105: 750-760 ft (No recovery)

Run 106: 760-770 ft
SILT, quartz, clayey; mica (1%, silt), sulfide nodule at 760.5 ft; abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated), common silt-filled burrows; dense; olive-gray (5Y4/1).

Run 107: 770-780 ft
SILT, quartz, clayey; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated), common silt-filled burrows; dense; olive-gray (5Y4/1).

Run 108: 780-790 ft
SILT, quartz, clayey; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated), common silt-filled burrows; dense; olive-gray (5Y4/1).

Run 109: 790-795 ft
SILT, quartz, clayey; mica (1%, silt), large wood fragment at 790.8 ft; abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated), common silt-filled burrows; dense, slightly waxy; olive-gray (5Y4/1).

Run 110: 795-800 ft
CLAY, silty; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated), common silt-filled burrows; dense, slightly waxy; olive-gray (5Y4/1).

Run 111: 800-810 ft
800-801.1 ft: SILT, quartz, clayey; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated); dense, slightly waxy; olive-gray (5Y4/1).

801.1-810 ft: No recovery.

Run 112: 810-820 ft
SILT, quartz, clayey; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated); sparse, incipient calcium-carbonate nodules (very light gray); dense, slightly waxy; olive-gray (5Y4/1).

Run 113: 820-830 ft
820-823 ft: SILT, quartz, clayey; mica (1%, silt); abundant microfauna; sparse, disseminated, sand-sized, molluscan fragments; massive to texture-mottled (bioturbated); dense, slightly waxy; olive-gray (5Y4/1). Broadly gradational down into lithology below.

823-826.6 ft: SAND, quartz, very fine to fine, muddy; phosphate (5-10% at base, decreasing upward; very fine sand to granules), common granule- to small-pebble-sized intraclasts of calcareous sandy mud; abundant microfossils; sparse to common, disseminated, sand- and granule-sized molluscan fragments; texture-mottled (bioturbated); dense; olive-gray (5Y4/1).

826.6 ft: MAJOR CONTACT - sharp, 2 inches of relief due to burrowing

Campanian
Donoho Creek Formation (part)

826.6-827.5 ft: SAND, quartz, very fine to fine; mica (trace); fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8). Gradational down into lithology below.

827.5-830 ft; SAND, quartz, very fine to fine, muddy; mica (1%, silt-very fine sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1).

Run 114: 830-840 ft

830-837.5 ft: SAND, quartz, very fine to fine, muddy; mica (1-3%, very fine-medium sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1).

837.5-840 ft: No recovery.

Run 115: 840-850 ft

840-841.2 ft: SAND, quartz, very fine to fine, muddy; mica (1%, silt-very fine sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1). Gradational down into lithology below.

841.2-843.2 ft: SAND, quartz, very fine to fine; mica (trace); fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8). Sharp basal contact.

843.2-844.2 ft: SAND, quartz, very fine to fine, muddy; mica (1%, silt-very fine sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1).

844.2-850 ft: No recovery.

Run 116: 850-853 ft

850-852.3 ft: SAND, quartz, very fine to fine, muddy; mica (1%, silt-very fine sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1).

852.3-853 ft: No recovery.

Run 117: 853-860 ft

SAND, quartz, very fine to fine, muddy; mica (1%, silt-very fine sand); sparse microfauna; sparse, disseminated, sand-sized, molluscan fragments; strongly bioturbated (isolated clay blebs are truncated burrow linings); brownish-gray (5YR4/1).

Run 118: 860-869 ft

860-863.7 ft: SAND, quartz, very fine to fine, muddy; mica (1-3%, very fine to medium), sparse microfauna; sparse to common, disseminated, sand-sized molluscan fragments; strongly bioturbated, abundant clay-lined burrows and unlined sand-filled burrows; brownish-gray (5YR4/1). Gradational down into lithology below.

863.7-865 ft: SAND, quartz, very fine to fine, silty; mica (1-3%, very fine to medium); strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8).

865-869 ft: CLAY, silty; mica (1%, silt); common microfauna; sparse, disseminated, sand-sized molluscan fragments; common, small, unlined, sand-filled burrows; common, 0.1-inch-thick, slightly inclined, discontinuous and continuous, silt laminae; dark-greenish-gray (5GY4/1).

Run 119: 869-874 ft

CLAY, silty; mica (1-3%, silt-very fine); common microfauna; bioturbated, dominantly unlined, silt-filled burrows; dominantly greenish-black (5G2/1).

Run 120: 874-880 ft

CLAY, silty; mica (1-3%, silt-very fine); common microfauna; bioturbated, dominantly unlined, silt-filled burrows; dominantly greenish-black (5G2/1).

Run 121: 880-890 ft

880-881.5 ft: SAND, quartz, very fine-fine, muddy; mica (1-3%, very fine-medium), glauconite (trace-1%, very fine-fine); common microfauna; sparse to common, disseminated, sand-sized, molluscan fragments; bioturbated, common clay-lined, sand-filled burrows and unlined sand-filled burrows; olive-gray (5Y4/1). Gradational down into lithology below.

881.5-883.5 ft: SAND, quartz, very fine-fine; phosphate and glauconite (3-5%, very fine-coarse); strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8). Gradational down into lithology below.

883.5-890 ft: SAND, quartz, very fine-fine, muddy; mica (1-3%, very fine-medium), glauconite (trace-1%, very fine-fine); common microfauna; sparse to common, disseminated, sand-sized, molluscan fragments; bioturbated, common clay-lined, sand-filled burrows and unlined sand-filled burrows; olive-gray (5Y4/1).

Run 122: 890-900 ft

SAND, quartz, very fine-fine, muddy; mica (1-3%, very fine-medium), glauconite (trace-1%, very fine-fine); common microfauna; sparse to common, disseminated, sand-sized, molluscan fragments; bioturbated, common clay-lined, sand-filled burrows and unlined sand-filled burrows; olive-gray (5Y4/1).

Run 123: 900-910 ft

900-905.2 ft: SAND, quartz, very fine-fine, muddy; mica (3-5%, very fine-medium), glauconite (1-3%, very fine-fine), common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated, common clay-line, sand-filled burrows and unlined sand-filled burrows, dominantly dark-greenish-gray (5GY4/1). Sharp lower contact.

905.2-906.3 ft: SAND, quartz, very fine-fine; phosphate and glauconite (3-5%, very fine-coarse); strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8).

906.3-910 ft: No recovery.

Run 124: 910-915 ft

SAND, quartz, very fine-fine (5% medium), muddy; mica (1%, very fine-medium), glauconite and phosphate (3-5%, very fine-fine); common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated; common clay-lined burrows and unlined, sand-filled burrows; dominantly brownish-gray (5YR4/1).

Run 125: 915-920 ft

SAND, quartz, very fine-fine (5% medium), muddy; mica (1%, very fine-medium), glauconite (1%, very fine-fine); common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated; common clay-lined burrows and unlined, sand-filled burrows; dominantly brownish-gray (5YR4/1).

Run 126: 920-930 ft

SAND, quartz, very fine-fine (5% medium), muddy; mica (1%, very fine-medium), glauconite (1%, very fine-fine); common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated; common clay-lined burrows and unlined, sand-filled burrows; dominantly brownish-gray (5YR4/1).

Run 127: 930 -940 ft

SAND, quartz, very fine-fine (5% medium), muddy; mica (1-3%, very fine-medium), glauconite (1%, very fine-fine); common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated; common clay-lined burrows and unlined, sand-filled burrows; dominantly brownish-gray (5YR4/1).

Run 128: 940-950 ft

SAND, quartz, very fine-fine (5% medium), muddy; mica (1%, very fine-medium), glauconite (1%, very fine-fine); common microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated; common clay-lined burrows and unlined, sand-filled burrows; dominantly brownish-gray (5YR4/1).

Run 129: 950-960 ft

950-954.1 ft: SAND, quartz, very fine-fine, muddy; phosphate and glauconite (1% increasing to 5-10% in basal 0.5 ft, very fine sand-granules); common microfauna; sparse, disseminated, sand-sized molluscan fragments - increasingly common and larger (up to 0.5 in.) in basal 0.5 ft; bioturbated; sparse clay-lined burrows; several cemented fine-grained intraclasts up to 0.5 in. in basal 0.5 ft; brownish-gray (5YR4/1).

954.1 ft: Major contact - sharp, 1 to 2 inches of relief due to burrowing.

954.1-955.3 ft: SAND, quartz, very fine-medium, slightly muddy; sparse microfauna; partially cemented (irregular nodules) by calcium carbonate, amount of cementation decreases downward; very light gray (N8).

955.3-960 ft: No recovery.

Run 130: 960-965 ft

960-962 ft: SAND, quartz, very fine-fine (5% medium), slightly muddy; sparse microfauna; sparse, disseminated, sand-sized molluscan fragments; strongly bioturbated to massive; dark-greenish-gray (5G4/1).

962-965 ft: No recovery.

Run 131: 965-967.5 ft

SAND, quartz, very fine to fine, muddy; sparse microfauna; sparse, disseminated, sand-sized molluscan fragments; bioturbated, at base, to massive; dark-greenish-gray (5G4/1).

Run 132: 967.5-968.5 ft

SAND, quartz, very fine-fine; strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8).

Run 133: 968.5-970 ft

968.5-969.5 ft: SAND, quartz, very fine-fine; strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8).

969.5-970 ft: No recovery.

Run 134: 970-975 ft

970-972.3 ft: SAND, quartz, very fine-fine, muddy; mica (trace, silt-very fine sand), glauconite (1%, very fine-fine); sparse microfauna; very sparse, disseminated, sand-sized molluscan fragments; bioturbated, common clay-lined burrows; dominantly greenish-gray (5GY6/1).

972.3 ft-973 ft: SAND, quartz, very fine-fine; strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; very light gray (N8).

973-975 ft: No recovery.

Run 135: 975-980 ft

975-977 ft: Sample removed; no description.

977-980 ft: No recovery.

Run 136: 980-990 ft

980-983 ft: SAND, quartz, very fine-fine, muddy; mica (1%, silt-very fine sand), glauconite (1-3%, very fine-fine); sparse microfauna; very sparse, disseminated, sand-sized molluscan fragments; bioturbated - common clay-lined burrows; dominantly greenish-gray (5GY6/1). Broadly gradation down into...

983-990 ft: SAND, quartz, very fine, and SILT, quartz, clayey; mica (1%, silt to very fine sand), glauconite (trace, silt to very fine sand), plant material (trace, silt to very fine sand); sparse to common microfauna; very sparse, disseminated, sand-sized molluscan fragments; bioturbated; dark-greenish-gray (5GY4/1).

Run 137: 990-1,000 ft

SAND, quartz, very fine, and SILT, quartz, clayey; mica (1%, silt to very fine sand), glauconite (trace, silt to very fine sand), plant material (trace, silt to very fine sand); sparse to common microfauna; very sparse, disseminated, sand-sized molluscan fragments; bioturbated; dark-greenish-gray (5GY4/1).

Run 138: 1,000-1,003.5 ft

SAND, quartz, very fine, and SILT, quartz, clayey; mica (1%, silt to very fine sand), glauconite (trace, silt to very fine sand), sparse to common microfauna; very sparse, disseminated, sand-sized molluscan fragments; bioturbated; dark-greenish-gray (5GY4/1).

Run 139: 1,003.5-1,012 ft

1,003.5-1,004.5 ft: SAND, quartz, very fine, and SILT, quartz; mica (1%, silt-very fine sand); strongly bioturbated; fabric-selective, calcium-carbonate cement replaces matrix; light-olive-gray (5Y6/1). Gradation at base down to...

1,004.5-1,010.8 ft: SAND, quartz, very fine, and SILT, quartz, clayey, mica (1%, silt-very fine sand), glauconite (trace, very fine-fine), plant material (trace, silt-very fine sand); common microfauna; bioturbated - common clay-lined burrows; olive-gray (5Y3/2).

1,010.8-1,012 ft: No recovery.

Bottom of core: 1,012 ft.

Figure Captions

Figure 1. Map of South Carolina showing location of coreholes discussed in text.
Figure 2. Stratigraphic column and gamma-ray log for Cannon Park corehole. Solid circles indicate position of microfossil samples.
Figure 3. Cretaceous calcareous nannofossil occurrences in the Cannon Park core. For figures 5 and 6, the following symbols are used in the body of the figure: X, present; C, specimens from downhole contamination; R, reworked specimens; ?, questionable occurrence. Abundances: A, abundant or greater than 10 specimens per field of view (FOV) at X1,250; C, common or 1 to 9 specimens per FOV at X1,250; F, frequent or 1 specimen per 1 to 10 FOV at X1,250. Preservation: G, good; M, moderate; P, poor.
Figure 4. Cenozoic calcareous nannofossil occurrences in the Cannon Park core. Abundances were determined for a field of view at X500 magnification.
Figure 5. Paleocene dinocysts from the Cannon Park core.
Figure 6. Eocene dinocysts from the Cannon Park core.
Figure 7. Pollen from the Cannon Park core.
Figure 8. Series, stages, calcareous nannofossil zones, and formations in the Mesozoic portion of the Cannon Park core and other studied cores. The time scale is modified from Gradstein and others (1995). Placement of the Campanian-Maastrichtian boundary is from Odin, compiler (1996).
Figure 9. Cretaceous age-depth relationship in Cannon Park core, S.C., using calcareous nannofossil datums. Ages of datums are assigned by Henriksson (1994), Berggren and others (1995), and Erba and others (1995).
Figure 10. Tertiary age-depth relationship in Cannon Park core, S.C., using calcareous nannofossil datums. Ages of datums are as assigned by Berggren and others (1995). Interpolated ages are based on Berggren and others (1995) and unpublished data. The ages assigned to these datums are preliminary and are in the process of being refined and calibrated.
Figure 11. Series, stages, calcareous nannofossil zones, and formations in the Cenozoic portion of the Cannon Park core and other studied cores. The time scale is modified from Berggren and others (1995). Angled line pattern indicates that there are no sediments of this age in the core.

Table 1. Cretaceous and Tertiary calcareous nannofossil datums used to calculate sediment accumulation rates for Cannon Park core, South Carolina. B = base, or first occurrence of species; T = top, or last occurrence of species. Ages of datums are from Henriksson (1994), Berggren and others (1995), and Erba and others (1995). Interpolated ages are based on Berggren and others (1995) and unpublished data of Bybell.