U.S. Department of the Interior
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Biostratigraphic data for the Cretaceous marine sediments in the USGS-St. George No. 1 core (DOR-211), Dorchester County, South Carolina

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards nor with the North American Stratigraphic Code.

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INTRODUCTION

The USGS-St. George corehole was drilled for the U.S. Geological Survey (USGS) by a commercial drilling company during 1982. The corehole is located within the Coastal Plain Province in northern Dorchester County, South Carolina, about three miles southeast of the town of St. George near the village of Byrd **(fig. 1)**. Coordinates for the corehole are 33°09'25"N latitude and 80°31'18"W longitude; ground elevation at the site is +78 feet (Reid and others, 1986). The St. George corehole is designated as USGS drill hole DOR-211.

The St. George corehole was drilled to a total depth of 2,067 ft. The hole was cored continuously with generally good recovery from 300 ft to its total depth. Spot cores were taken at selected intervals between the top of the hole and a depth of 300 ft (50-55 ft, 100-110 ft, 150-165 ft, 200-205 ft, and 250-255 ft); however, recovery was poor in most of these intervals. The St. George core currently is stored at the USGS National Center, Reston, VA (March, 1997).

The St. George corehole bottomed in basalt of probable early Mesozoic age beneath an Upper Cretaceous and Cenozoic sedimentary section. Reid and others (1986) placed the top of basalt saprolite at 1,962 ft in the hole. Our examination of the geophysical logs and original core descriptions suggests that the top of the saprolite is higher in the hole, at about 1,939 ft. The Cretaceous-Tertiary boundary was placed at or near 550 ft in the core by Reid and others (1986) and by Habib and Miller (1989).

In this report, we provide paleontologic data for marine sediments in the upper part of the Upper Cretaceous section in the St. George core. Biostratigraphic and paleoenvironmental data and interpretations based on the study of calcareous nannofossils and ostracodes from the Cretaceous section are discussed.

PREVIOUS WORK

Physical Stratigraphy

R.A. Renken (*in* Reid and others, 1986, their table 1) published the first lithologic description of the St. George core **(fig. 2)**. He described dominantly fine-grained, calcareous marine sediments between depths of 1,322 ft and 560 ft and assigned these sections to the Cretaceous Black Creek Formation (1,322 ft to 1,088 ft) and the overlying Cretaceous Peedee Formation (1,088 ft to 560 ft).

A sand-dominated section between 560 ft and 530 ft was assigned to the Paleocene Black Mingo Formation. Fluvial to possibly marginal-marine sediments below the Black Creek Formation were assigned to an unnamed clay unit (1,962 ft to 1,930 ft, which may be saprolite in part), to the Cape Fear Formation (1,930 ft to 1,375 ft), and to the Middendorf Formation (1,375 ft to 1,322 ft).

Habib and Miller (1989) used the same stratigraphic units and boundaries as Renken with the exception of moving the top of the Peedee Formation, and hence the Cretaceous-Tertiary boundary, to a depth of 550 ft. Gohn (1992a) assigned the section between 1,325 ft and 1,031 ft to three informal lithostratigraphic units, which he subsequently identified regionally as the Cane Acre, Coachman, and Bladen Formations of the Black Creek Group (Gohn, 1992b) (fig. 2). Gohn (1992a) did not study the section between 1,031 ft and 550 ft.

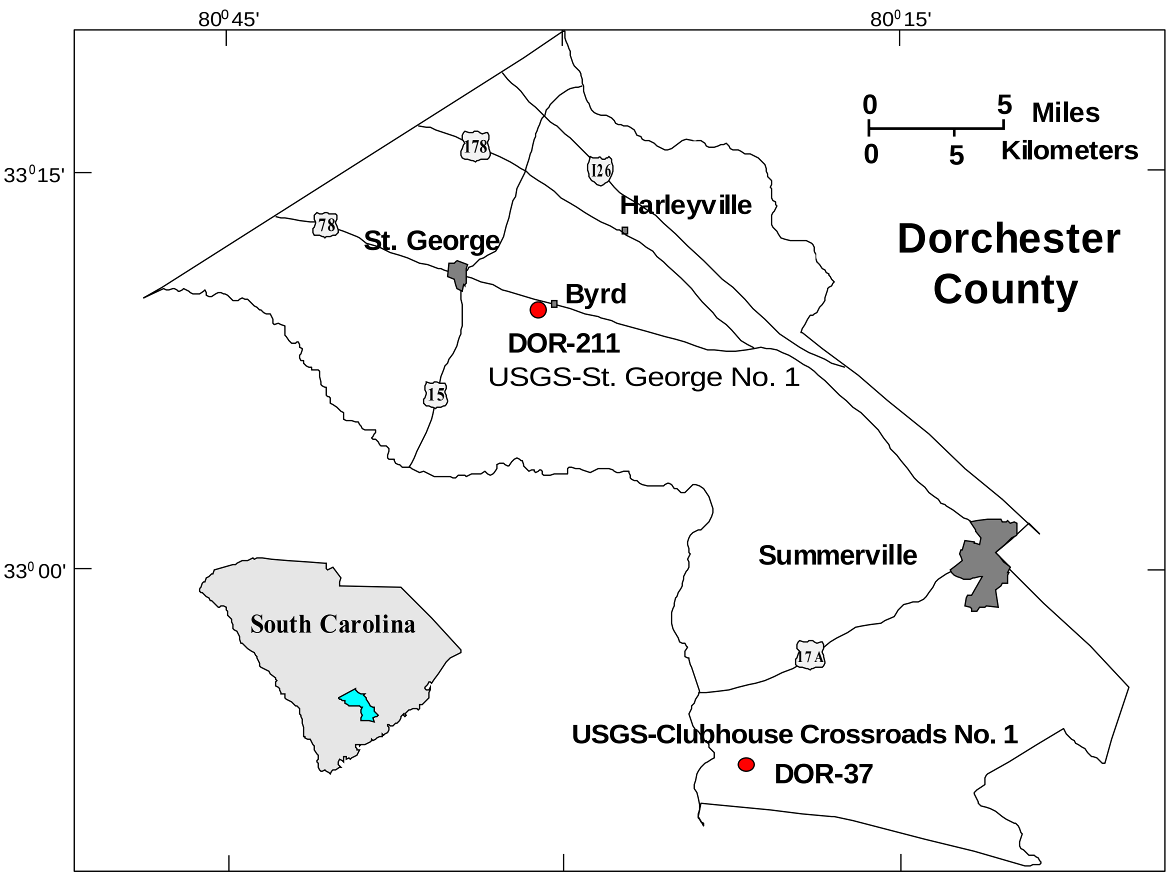

Figure 1. Map of Dorchester County showing the locations of the USGS-St. George No. 1 and USGS-Clubhouse Crossroads No. 1 coreholes.

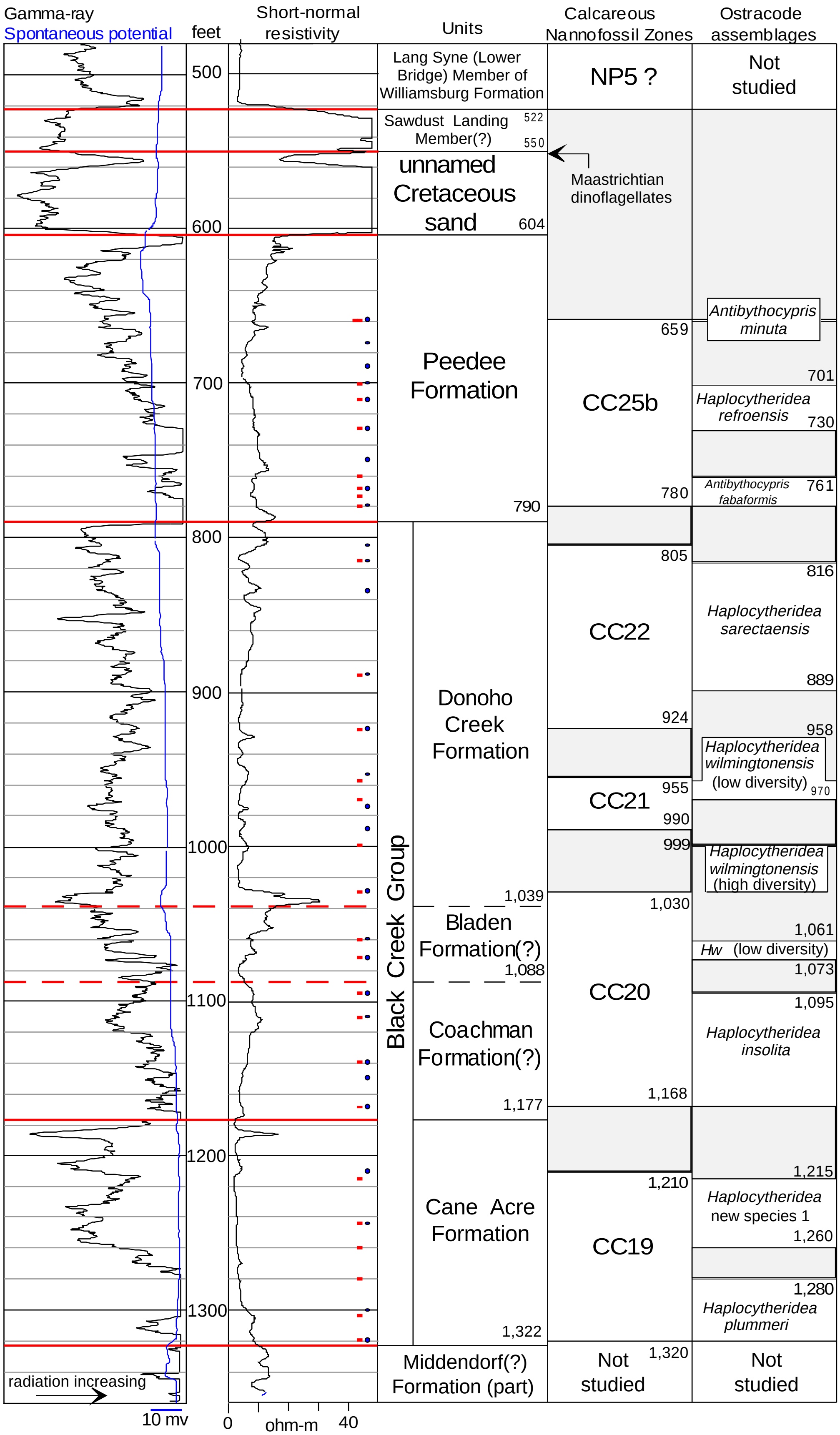

Figure 2. Stratigraphic section, fossil zones and assemblages, and geophysical logs for the marine Cretaceous sediments in the St. George core. Gray areas indicate unsampled sections at the boundaries between calcareous nannofossil zones and between ostracode assemblages. Rectangles indicate the locations of ostracode samples; circles indicate the locations of calcareous nannofossil samples.

In this report, we use a provisional lithostratigraphy based on the stratigraphy proposed by Gohn (1992b) for the USGS-Clubhouse Crossroads core located in southern Dorchester County (fig. 1). At St. George, the section between 1,322 ft and 790 ft is assigned to the Black Creek Group; the section between 790 ft and 604 ft is assigned to the Peedee Formation; and the section from 604 ft to 550 ft is assigned to an unnamed Cretaceous sand unit (fig. 2).

Gohn (1992b) recognized four formations in the Black Creek Group of the Clubhouse Crossroads core. These fine-grained, calcareous marine units are provisionally recognized in the St. George core (fig. 2). At a depth of 1,322 ft, the Cane Acre Formation, which is the basal Black Creek unit, overlies noncalcareous, oxidized sediments that are assigned to the Middendorf Formation(?). An unconformity (mantled by a thin phosphate-pebble bed) at 1,177 ft is the contact between the Cane Acre Formation and the overlying Coachman Formation(?). The section between 1,177 ft and 1,039 ft is assigned to the Coachman Formation(?) and Bladen Formation(?) with the formational contact questionably placed at 1,088 ft. The base of the Donoho Creek Formation is questionably placed at 1,039 ft, and its top is placed at the unconformity at 790 ft. In other South Carolina drill holes, Donoho Creek sections contain one and locally two unconformities, in addition to the unit's lower and upper contacts. It is likely that the Donoho Creek Formation will be subdivided in the future.

The Black Creek Group-Peedee Formation contact in the St. George core is an unconformity overlain by a thin phosphate-pebble bed at the base of the Peedee Formation. The calcareous clayey silts and muddy very fine sands between this unconformity at 790 ft and the base of the overlying unnamed sand unit at 604 ft are lithologically similar to the section assigned to the Peedee Formation in the Clubhouse Crossroads core and occur at the same stratigraphic position (Gohn, 1992b).

The unnamed Cretaceous sand unit between depths of 604 ft and 550 ft was poorly recovered in cores. The available core samples consist of sparingly shelly, slightly muddy, fine to medium or locally coarse sand. A 10-ft-thick clay bed that contains Cretaceous dinoflagellates is present at the top of the unit (Habib and Miller, 1989). The unnamed sand unit is not present in the Clubhouse Crossroads core (Gohn, 1992b).

A second sand-dominated unit from 550 ft to 522 ft is virtually unrepresented by cores. This interval may represent the Paleocene Sawdust Landing Member, which Muthig and Colquhoun (1988) assigned to the Rhems Formation of the Black Mingo Group. Although the interval between 550 ft and 522 ft may represent a continuation of the unnamed Cretaceous sand unit, we provisionally assign it to the Sawdust Landing Member(?). Fine-grained marine deposits of middle Paleocene age overlie the Sawdust Landing Member(?).

Biostratigraphy

J.A. Miller (*in* Reid and others, 1986, table 1) reported several foraminifers and ostracodes from the Upper Cretaceous marine section in the St. George core but did not recognize specific zones or ages. Habib and Miller (1989) discussed dinoflagellate species and organic facies found throughout the Upper Cretaceous section in the core. They assigned a late Campanian age to the section between 1,319 ft and 1,202 ft and a late Campanian to earliest Maastrichtian age to the section between 1,202 ft and 1,028 ft. In addition, they assigned an early Maastrichtian age to the section between 1,028 ft and 794 ft and a late Maastrichtian age to the section between 778 ft and 550 ft. Our calcareous nannofossil data suggest slightly older ages for each of these intervals, as discussed in following sections. Gohn (1992a, his table 21.1) assigned a Campanian age to the section between 1,320 ft and 1,031 ft on the basis of calcareous nannofossil data provided by P.C. Valentine (*in* Gohn, 1992a, his table 21.1) and selected ostracode data. Gohn (1992a) placed the Campanian-Maastrichtian boundary at 1,031 ft; herein, we place this stage boundary at a higher stratigraphic position, as described in following sections.

BIOSTRATIGRAPHIC DATA

Methods

A total of twenty-nine Cretaceous sediment samples were selected for the study of calcareous nannofossils. Samples to be examined for calcareous nannofossil content were extracted from the center of freshly broken core segments in order to avoid contamination by drilling mud. These samples were dried in a convection oven at 50ºC to remove any residual water and then stored in plastic vials until slides could be prepared. Sampling intervals varied on the basis of core availability, core integrity, and the presence or absence of calcium carbonate. Where possible, sample splits for calcareous nannofossils and ostracodes were taken from the same core segments to permit direct comparison of biostratigraphic and paleoenvironmental data derived from the study of the two fossil groups.

Calcareous nannofossil slides were prepared using standard settling techniques and Norland Optical Adhesive, a bonding agent that cures by exposure to ultraviolet light. Calcareous nannofossils were examined and identified to the species level using a Zeiss Photomicrosope III. A complete species list is provided in the **Appendix**.

Twenty-eight ostracode samples were prepared using standard microfossil techniques. The samples were partially crushed, soaked for several days in deionized water, and sieved. Soap floating and other special processing techniques were not needed because the generally fine-grained Cretaceous sediments produced good microfossil concentrates upon sieving. Material passing the number 18 sieve (U.S. Standard Mesh; 1.00 mm) was collected on the number 35 (0.50 mm), number 60 (0.25 mm) and number 120 (0.125 mm) sieves. Ostracode valves were picked from the material, or splits of the material, collected on the number 35 and number 60 sieves and placed on standard micropaleontology slides for sorting and identification. Material collected on the number 120 sieve was scanned for adult specimens of species not collected on the coarser sieves. Dry sample weights were not recorded but were in the approximate range of 5 to 7 oz (150 to 200 gms) per sample. The methodology used in preparing the ostracode samples provides only semi-quantitative estimates of the relative proportions and absolute abundances of individual ostracode taxa within each sample. A complete list of ostracode species is given in the **Appendix**.

Calcareous Nannofossil Zonation and Stage Boundaries

The calcareous nannofossil zonation of Perch-Nielsen (1985) is used in this report **(figs. 3, 4; table 1)**. This zonation, which follows in large part from the zones defined or emended by Sissingh (1977), commonly is applied in calcareous nannofossil studies of the Cretaceous System and is especially applicable to low- to middle-latitude sections.

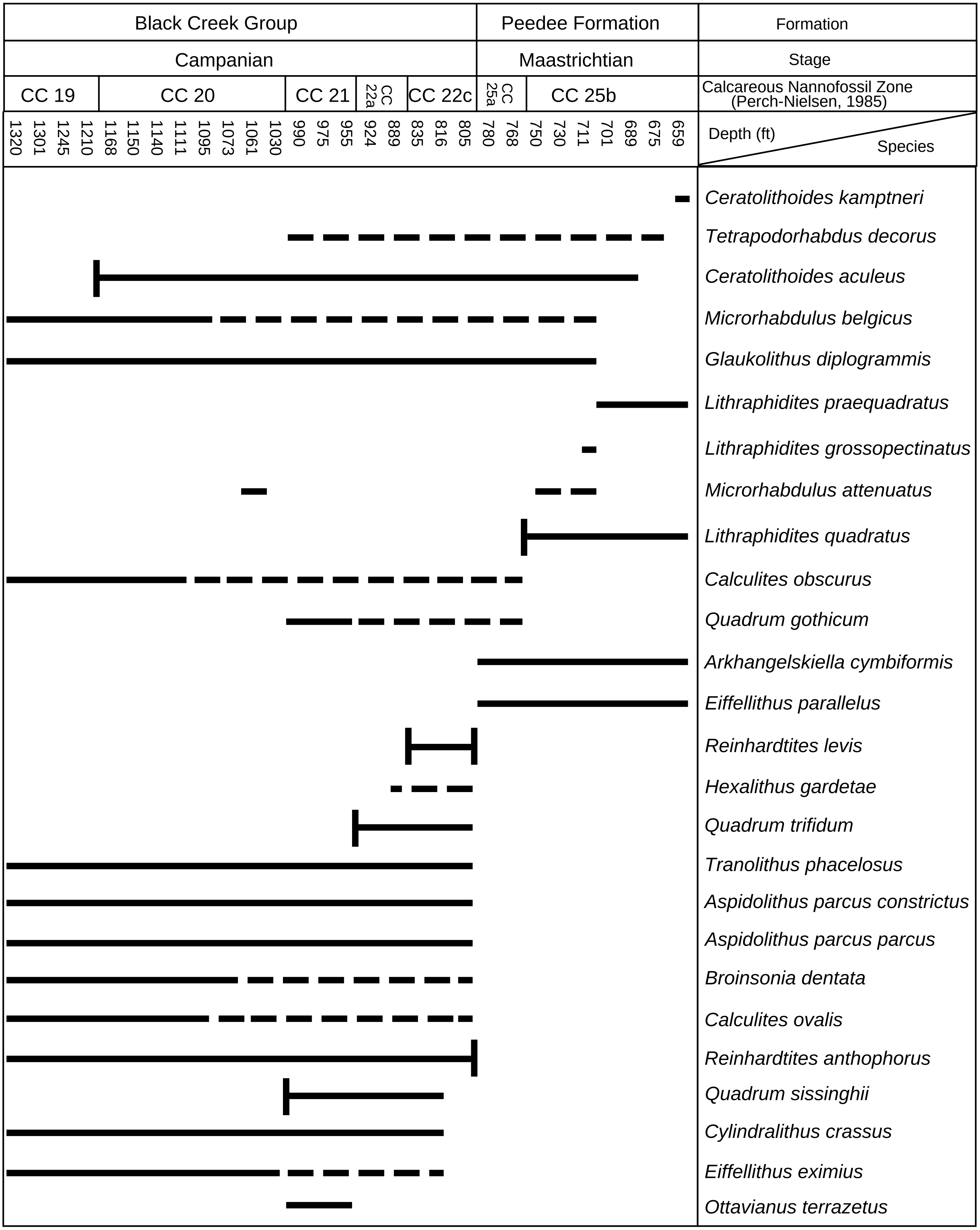

Figure 3. Distribution of biostratigraphically important Cretaceous calcareous nannofossils in the St. George core. First and last appearance datums marked with short bars define the zone and subzone boundaries. Solid occurrence bars indicate the presence of a given species in all samples in the marked interval; dashed occurrence bars indicate the discontinuous presence of a given species through the marked interval.

Formation	Black Creek Group																				Peedee Formation								
Stage	Campanian																				Maastrichtian								
Calcareous Nannofossil Zone (Perch-Nielsen, 1985)	CC 19				CC 20								CC 21			CC 22a		CC 22c			CC 25a		CC 25b						
Species / Depth (ft)	1320	1301	1245	1210	1168	1150	1140	1111	1095	1073	1061	1030	990	975	955	924	889	835	816	805	780	768	750	730	711	701	689	675	659
Ahmuellerella octoradiata	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	
Arkhangelskiella cymbiformis		?																			●	●	●	●	●	●	●	●	●
Arkhangelskiella specillata	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Aspidolithus parcus constrictus	●	●	●	●	●		●	●		●			●	●	●	●		●	●	●									
Aspidolithus parcus expansus	●							●	●						●	●	●												
Aspidolithus parcus parcus	●	●		●	●	●	●		●	●		●		●		●			●	●									
Biscutum constans	●	●	●	●	●	●	●	●	●				●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	
Biscutum notaculum																							?	●					
Braarudosphaera bigelowii	●	●	●																			●	●						
Braarudosphaera obscurus	●		●													●													
Broinsonia dentata	●				●	●	●	●	●	●			●			●				●									
Calculites obscurus	●	●	●			●	●	●				●						●				●							
Calculites ovalis	●	●		●	●		●	●	●							●				●									
Ceratolithoides aculeus					●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●		●	●	●	●		
Chiastozygus amphipons	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●		●	●	●	●				
Chiastozygus litterarius	●	●	●	●		●			●				●	●		●	●		●	●	●			●	●		●	●	
Chiastozygus propagulis				●		●		●	●		●	●	●				●			●		●			?	●		●	●
Corollithion exiguum						●	●	●					●	●					●			●					●		
Corollithion signum	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●		●	●			
Cretarhabdus conicus	●		●			●		●	●						●	●	●			●					●		●		
Cretarhabdus loriei			?								●																		
Cribrosphaerella ehrenbergii	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Cribrosphaerella schizobrachiatus																					●								
Cyclagelosphaera margerelii		●	●	●				●				●	●	●			●			●	●	●	●			●			●
Cylindralithus crassus	●	●	●	●	●	●	●	●	●			●	●		●	●	●		●										
Discorhabdus ignotus																			●										
Eiffellithus eximius	●	●	●		●	●	●	●	●	●	●	●		●					●										
Eiffellithus parallelus																							●	●	●			●	
Eiffellithus turriseiffelii	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Gartnerago obliquum	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●	●				
Glaukolithus compactus	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●						●	●			
Glaukolithus diplogrammis		●	●			●	●	●	●	●			●		●	●			●	●		●			●				
Goniolithus fluckigeri													●								●								
Hexalithus gardetae																	●			●									
Kamptnerius magnificus	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●		●		●	●	●	●	●	●	●	●	●
Lithastrinus grillii	●	●	●	●									●			●													
Lithraphidites carniolensis	●	●	●		●		●	●	●				●	●	●	●		●	●		●	●	●	●	●	●	●		
Lithraphidites praequadratus																									●	●		●	
Lithraphidites quadratus																							●	●	●		●	●	
Lucianorhabdus arcuatus						●		●																					
Lucianorhabdus cayeuxii	●	●	●	●			●	●	●			●	●			●			●										
Lucianorhabdus grossopectinatus																									●				

Figure 4. Calcareous nannofossil occurences in the St. George Core (Dor-211). Abundance: A, abundant or greater than 10 specimens per field of view at X640; C, common or 1 to 10 specimens per field of view at X640; F, frequent or 1 specimen per 1 to 10 fields of view at X640. Preservation: V, very good; G, good; F, fair. Other symbols: ?, possible occurrence.

Formation	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Black Creek Group	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation	Peedee Formation
Stage	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Campanian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian	Maastrichtian
Calcareous Nannofossil Zone (Perch-Nielsen, 1985)	CC 19	CC 19	CC 19	CC 19	CC 20	CC 20	CC 20	CC 20	CC 20	CC 20	CC 20	CC 20	CC 21	CC 21	CC 21	CC 22a	CC 22a	CC 22c	CC 22c	CC 22c	CC 25a	CC 25a	CC 25b	CC 25b	CC 25b	CC 25b	CC 25b	CC 25b	CC 25b
Depth (ft) / Species	1320	1301	1245	1210	1168	1150	1140	1111	1095	1073	1061	1030	990	975	955	924	889	835	816	805	780	768	750	730	711	701	689	675	659
Lucianorhabdus maleformis	●	●																											
Manivitella pemmatoidea	●	●		●	●	●	●	●	●	●	●	●	●		●	●					●		●				●		●
Markalius inversus																								●					
Microrhabdulus attenuatus											●												●		●				
Microrhabdulus belgicus	●	●	●				●	●	●				●			●					●				●				
Microrhabdulus decoratus	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	
Microrhabdulus undosus																									●				
Micula concava	●	●			●		●	●	●	●			●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●
Micula decussata	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Ottavianus terrazetus													●		●														
Parhabdolithus embergerii/ Zeugrhabdotus pseudanthophorus	●											●				●	●		●	●	●		●						
Placozygus fibuliformis	●	●		●	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Placozygus sigmoides	●		●			●		●				●	●		●		●		●	●	●	●		●		●			
Prediscosphaera cretacea	●			●	●	●		●	●	●	●		●	●	●	●		●	●		●	●	●	●	●		●		
Prediscosphaera grandis																									●				
Prediscosphaera intercisa		●	●		●	●	●		●				●	●		●	●	●		●	●	●	●	●	●	●		●	●
Prediscosphaera spinosa	●	●	●		●		●	●	●		●		●					●			●					●		●	
Prediscosphaera stoveri																								●	●	●			
Quadrum gothicum							●			●			●	●	●				●			●							
Quadrum sissinghii													●	●	●	●	●		●										
Quadrum trifidum																●	●	●	●	●									
Reinhardtites anthophorus	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●									
Reinhardtites levis																		●		●									
Repagalum parvidentatum								●																					
Rhagodiscus angustus		●	●	●		●	●				●	●	●	●		●	●				●	●	●	●	●			●	
Rhagodiscus splendens			●					●					●		●		●					●	●	●	●	●	●		
Scapholithus fossilis																					●								
Stradnaria crenulata	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●			●	●	●	●	●
Tegumentum sp. cf. *T.stradneri*		●			●	●																			●				
Tetrapodorhabdus decorus													●		●	●	●					●	●					●	
Tranolithus gabalus	●																												
Tranolithus phacelosus	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●									
Vekshinella aachena			●			●	●		●			●	●			●		●	●				●	●	●	●		●	●
Vekshinella stradneri			●					●	●			●	●	●	●	●			●		●	●	●		●	●		●	
Watznaueria barnesae	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Watznaueria biporta			●	●	●	●	●	●	●	●					●		●				●								
Watznaueria supracretacea	●	●			●	●												●				●	●			●			
Zeugrhabdotus erectus			●		●	●	●		●			●		●								●		●			●		
Abundance	A	A	A	A	F	C	A	C	A	F	F	C	A	C	A	A	C	C	A	C	C	A	C	A	C	C	F	C	F
Preservation	F	G	G	G	G	G	G	G	G	F	F	F	G	G	G	V	F	F	G	G	F	G	G	G	G	G	F	F	F

Figure 4. Continued.

Table 1. Campanian and Maastrichtian calcareous nannofossil zones following Perch-Nielsen (1985). The positions of the stage boundaries follow Burnett and others (1992) and Burnett (1996). In addition to their formal names, the zones also have alpha-numeric designations (for example, Zone CC 26).

***Markalius inversus* Zone (NP1)**	**Tertiary (part)**

***Nephrolithus frequens* Zone (CC 26)**	
***Arkhangelskiella cymbiformis* Zone (CC 25)**	**Maastrichtian**
***Reinhardtites levis* Zone (CC 24)**	
--- *Tranolithus phacelosus* Zone (CC 23) -----------------------------	**-----------------------------**
***Quadrum trifidum* Zone (CC 22)**	
***Quadrum sissinghii* Zone (CC 21)**	
***Ceratolithoides aculeus* Zone (CC 20)**	**Campanian**
***Calculites ovalis* Zone (CC 19)**	
***Aspidolithus parcus* Zone (CC 18)**	
--- *Calculites obscurus* Zone (CC 17) -----------------------------	**-----------------------------**
	Santonian (part)

Many calcareous nannofossil workers use the first appearance datum (FAD) of *Aspidolithus parcus parcus* to define the Santonian-Campanian Stage boundary (for example, Dowsett, 1989, p. 5). This datum is located in the short interval between two planktic foraminiferal datums, the FAD of *Globotruncanita elevata* and the younger last appearance datum (LAD) of *Dicarinella asymetrica*, which have been used by foraminiferal workers to define the stage boundary. The FAD of *Aspidolithus parcus parcus* defines the base of the *Aspidolithus parcus* Zone (Zone CC 18). Recently, however, Burnett (1996) placed this stage boundary at an older level within calcareous nannofossil zone CC17, as originally suggested by Sissingh (1978). In this report, we use Burnett's (1996) concept of the position of the Santonian-Campanian boundary. However, all Cretaceous marine sediments in the St. George core are younger than Zone CC18 and are therefore of Campanian or younger age by all definitions.

Burnett and others (1992) discussed the position of the Campanian-Maastrichtian Stage boundary relative to macro-, micro-, and nannofossil zonations. Based on biostratigraphic data for European sections, they concluded that the Campanian-Maastrichtian Stage boundary is best characterized by the FAD of the belemnite *Belemnella lanceolata*. This datum is closely approximated by the LAD of the ammonite *Nostoceras (N.) hyatti*. Both macrofossil datums lie within Subzone CC 23a of the calcareous nannofossil *Tranolithus phacelosus* Zone, (Zone CC 23), which is defined by the LAD of *Reinhardtites anthophorus* and the younger LAD of *Aspidolithus parcus constrictus*.

Placement of the Campanian-Maastrichtian boundary within Zone CC 23 represents a change from its traditional biochronostratigraphic position in Atlantic Coastal Plain sections. For at least two decades, the widespread *Exogyra cancellata* Mollusk Zone has been assigned an early Maastrichtian age (Sohl and Owens, 1991). However, South Carolina Coastal Plain sections assigned to the *E. cancellata* Zone typically contain the calcareous nannofossils *Reinhardtites anthophorus*, *Quadrum trifidum*, and *Quadrum sissinghii*, which indicate assignment to Zone CC 22 and Zone CC 21 (data in Hattner and Wise, 1980; J.M. Self-Trail, unpublished data). Following Burnett and others (1992), the *Exogyra cancellata* Zone is considered to be late Campanian rather than early Maastrichtian in age.

Ostracode Biostratigraphy

The ostracodes in the St. George samples are divided into nine empirically defined ostracode assemblages **(table 2)**. Each assemblage is primarily characterized by a single species that occurs in abundance within that assemblage and is rare in other assemblages. Additional common species are used as secondary characteristics of the assemblages. Ages assigned to each assemblage on the basis of known total ranges for a few selected species (Hazel and Brouwers, 1982; Pitakpaivan and Hazel, 1994; Puckett, 1992, 1994, 1996; and Gohn, 1995) are compatible with the ages indicated by the calcareous nannofossil data. The assemblages are discussed individually relative to their occurrence within the formations and calcareous nannofossil zones.

Established ostracode interval zones for the Coniacian through Maastrichtian sections of the Atlantic and Gulf of Mexico Coastal Plains (Hazel and Brouwers, 1982; Pitakpaivan and Hazel, 1994) have not been applied to the

Table 2. Distribution of ostracode assemblages relative to the calcareous nannofossil zones recognized in the St. George core.

Ostracode assemblages:	Calcareous nannofossil Zones:
Antibythocypris minuta **assemblage** ***Haplocytheridea renfroensis*** **assemblage** ***Antibythocypris fabaformis*** **assemblage**	**Zone CC 25**
	[Maastrichtian]
	[Campanian]
Haplocytheridea sarectaensis **assemblage**	**Zone CC 22**
Haplocytheridea wilmingtonensis **low diversity assemblage**	**Zone CC 21**
Haplocytheridea wilmingtonensis **high diversity assemblage** ***Haplocytheridea wilmingtonensis*** **low diversity assemblage** ***Haplocytheridea insolita*** **assemblage**	**Zone CC 20**
Haplocytheridea **new species 1 assemblage** ***Haplocytheridea plummeri*** **assemblage**	**Zone CC 19**

Upper Cretaceous Series of the St. George core. Strong paleoenvironmental controls on Cretaceous ostracode distributions in South Carolina tend to produce significant variations in local species ranges that inhibit use of the formal zonation. The ostracode assemblages used in this report do have limited local stratigraphic distributions and could be viewed as local assemblage zones, or as local ecozones in the sense of Martinsson (1973; also see Colin and Lethiers, 1988). Paleoenvironmental interpretations inferred from the ostracode assemblages are based on published paleoecologic information (Hazel and Brouwers, 1982; Puckett, 1992, 1996) and the authors' unpublished data for numerous South Carolina Cretaceous sections.

CALCAREOUS NANNOFOSSILS

Black Creek Group

Twenty samples from the Black Creek Group of the St. George core indicate late early Campanian to late Campanian ages. Calcareous nannofossil Zones CC 19, CC 20, CC 21, and CC 22 are present in this section (figs. 3, 4).

Four samples from 1,320 ft to 1,210 ft in the Cane Acre Formation can be placed in lower Campanian Zone CC 19 (*Calculites ovalis* Zone). Samples from this interval do not contain *Marthasterites furcatus*, whose LAD defines the top of Zone CC 18, nor do they contain *Ceratolithoides aculeus* whose FAD marks the base of Zone CC 20. The presence of *Calculites ovalis*, *Eiffellithus eximius*, and *Aspidolithus parcus constrictus* in this interval, and the presence of *C. aculeus* at 1,168 ft, support assignment of the interval from 1,320 ft to 1,210 ft to Zone CC 19. The unsampled interval between 1,210 ft and 1,168 ft also is within Zone CC 19 by definition. The calcareous nannofossils in Zone CC 19 are typically abundant and well preserved.

Perch-Nielsen (1985) divided Zone CC 19 into two subzones using the LAD of *Bukryaster hayi*, a small and seldom observed species. We do not attempt to differentiate between Subzones CC 19a and CC 19b in the St. George core (where *B. hayi* is absent) because the absence of *B. hayi* more often reflects its rarity than its true stratigraphic range.

Middle Campanian Zone CC 20 (*Ceratolithoides aculeus* Zone) is represented by eight samples between the depths of 1,168 ft and 1,030 ft (figs. 3, 4). The base of Zone CC 20 is defined by the FAD of *Ceratolithoides aculeus*, and the top is defined by the FAD of *Quadrum sissinghii*. This zone includes at least 138 ft of section and is the thickest of the Campanian zones in the St. George core. This interval is represented by the Coachman Formation(?), the Bladen Formation(?), and the lower part of the Donoho Creek Formation. Zone CC 20 extends upward through the unsampled interval from 1,030 ft to 990 ft; *Quadrum sissinghii* first occurs at 990 ft. The calcareous nannofossils typically are well preserved near the base of Zone CC 20 but become increasingly less well preserved toward the top.

The FAD of *Ceratolithoides aculeus* is generally considered to be reliable marker. However, Hattner and Wise (1980) and Hattner and others (1980) reported sporadic occurrences of this species in the USGS-Clubhouse Crossroads No. 1 core (fig.1). In that core, *C. aculeus* first appears at a depth of 1,500 ft but does not reappear until 1,360 ft, a gap attributed to poor preservation. We also recognized discrepancies in the range of this species in the Dover Je32-04 core in Delaware, where it seemingly does not appear below Zone

CC 22 (J.M. Self-Trail, un- published data, 1996). It is possible that the distribution of this species is influenced by preservational and (or) latitudinal controls.

Three samples between depths of 990 ft and 955 ft in the St. George core are assigned to Zone CC 21 (*Quadrum sissinghii* Zone). The base of this upper Campanian zone is defined by the FAD of *Q. sissinghii,* and the top is defined by the FAD of *Quadrum trifidum* (figs. 3, 4). This zone occurs in the lower part of the section assigned to the Donoho Creek Formation. Calcareous nannofossils are abundant and well-preserved in this relatively short interval.

Upper Campanian Zone CC 22 (*Quadrum trifidum* Zone) is represented by five samples between the depths of 924 ft and 805 ft in the upper half of the Donoho Creek Formation (figs. 3, 4). Perch-Nielsen (1985) defined three subzones within Zone CC 22. From oldest to youngest, they are: (1) Subzone CC 22a (FAD of *Quadrum trifidum* to LAD of *Lithastrinus grillii*), (2) Subzone CC 22b (LAD of *L. grillii* to FAD of *Reinhardtites levis*), and Subzone CC 22c (FAD of *R. levis* to LAD of *Reinhardtites anthophorus*). Subzone CC 22a is present at 924 ft and 889 ft and Subzone CC 22c is present at 835 ft, 816 ft, and 805 ft. Subzone CC 22b is not recognized in the St. George core but could be present in the unsampled interval between 889 ft and 835 ft. The calcareous nannofossils in Zone CC 22 are common to abundant, and preservation is variably fair to very good.

The small species *Hexalithus gardetae* is present in Subzones CC 22a and CC 22c of the St. George core (fig. 3). Although this species commonly is not used for bio-stratigraphy, its range appears to be limited to latest Zone CC 21 and Zone CC 22 in the Atlantic Coastal Plain from South Carolina to New Jersey (Self-Trail and Bybell, 1995). D.K. Watkins (University of Nebraska, oral commun., 1995) indicates that the range of *Hexlithus gardetae* also is restricted to those zones in the midcontinent region of North America. Hence, the presence of this species at 889 ft and 805 ft in the St. George core further corroborates assignment of this interval to Zone CC 22.

Black Creek Group - Peedee Formation Contact

The Black Creek Group-Peedee Formation boundary is an unconformity of considerable magnitude. The calcareous nannofossils *Reinhardtites anthophorus*, *Aspidolithus parcus constrictus*, *Quadrum trifidum*, *Tranolithus phacelosus*, and *Reinhardtites levis* all have their last appearances in the highest studied Black Creek sample at 805 ft. In complete sections, the sequential extinctions of *R. anthophorus*, *T. phacelosus*, and *R. levis* define the tops of Zones CC 22, CC 23, and CC 24 respectively. Hence, their simultaneous last appearances at 805 ft suggest placement of that sample in Subzone CC 22c (*R. anthophorus* plus *R. levis*) and the absence of Zones CC 23 and CC 24 in the core.

It is possible that Zones CC 23 and CC 24 are present in the unsampled interval (805 ft to 780 ft) that contains the Black Creek-Peedee contact. However, our study of several cores from South Carolina, and the data in Hattner and Wise (1980), suggest that the marker species listed above typically have simultaneous extinctions at the Black Creek-Peedee boundary and that Zones CC 23 and CC 24 are most likely absent in South Carolina. We typically find that Subzone CC 25a or Subzone CC 25b overlies Zone CC 22 at the Black

Creek-Peedee contact. This unconformity appears to be a regional feature; in New Jersey, the unconformable Mount Laurel-Navesink formational contact typically separates Zone CC 22 in the upper part of the Mount Laurel Sand from Zone CC 25 in the lower part of the overlying Navesink Formation (Self-Trail and Bybell, 1995; Sugarman and others, 1995).

Peedee Formation

Nine calcareous nannofossil samples from the Peedee Formation in the St. George core indicate a Maastrichtian age and assignment to Zone CC 25 (*Arkhangelskiella cymbiformis* Zone). Perch-Nielsen (1985) defined three subzones within Zone CC 25, as follows (base to top): Subzone CC 25a (LAD of *Reinhardtites levis* to FAD of *Lithraphidites quadratus*), Subzone CC 25b (FAD of *L. quadratus* to FAD of *Micula murus*), and Subzone CC 25c (FAD of *M. murus* to FAD of *Nephrolithus frequens*).

Samples at 780 ft and 768 ft are assigned to Subzone CC 25a. This assignment is based on the absence of *Reinhardtites levis* (present in underlying samples), the absence of *Lithraphidites quadratus* (present in overlying samples), and the presence of *Arkhangelskiella cymbiformis* at 780 ft and and 768 ft (fig. 3).

Seven samples from 750 ft to 659 ft contain *Lithraphidites quadratus* and do not contain *Micula murus*, *Micula prinsii*, nor *Nephrolithus frequens* (figs. 3, 4). This interval is assigned to Zone CC 25b. The presence of *Lithraphidites grossopectinatus* at 711 ft is further evidence for assignment to Subzone CC 25b (Perch-Nielsen, 1985).

The presence of *Ceratolithoides kamptneri* at 659 ft, a species thought to have its FAD at the base of Zone CC 26 along with *Nephrolithus frequens* (Perch-Nielsen, 1985), raises questions about the validity of using it as a secondary zonal marker. We consistently find the FAD of this species to occur lower in South Carolina sections (in Zone CC 25b) than previously thought (J. Self-Trail, unpub. data). The distribution of *C. kamptneri* may have been controlled by paleooceanographic conditions that caused its first appearance to vary latitudinally.

Relatively high abundance and good preservation are typical of the calcareous nannofossils in the lower part of Zone CC 25. However, decreases in the abundance and quality of preservation were noted in the highest three samples in this zone, and the lowest species diversity occurs in the topmost sample at 659 ft. Samples from higher in the Peedee Formation are barren of calcareous nannofossils. These reductions in sample quality may indicate a weathering zone at the top of the Peedee section.

Unnamed Cretaceous Sand Unit

Calcareous nannofossils were not recovered from the unnamed sand unit above the Peedee Formation. However, the presence of the dinoflagellate *Dinogymnium euclaense* at 550 ft (Habib and Miller, 1989), and the Maastrichtian age of the underlying Peedee Formation, indicate a Maastrichtian age for the unnamed sand unit.

OSTRACODES

Black Creek Group

<u>Equivalents to calcareous nannofossil Zone CC 19</u>. Ostracodes from six samples between depths of 1,320 ft and 1,215 ft represent most of the interval assigned to calcareous nannofossil Zone CC 19 and the

Cane Acre Formation **(table 3)**. This interval contains two ostracode assemblages, each represented by three samples. The lower *Haplocytheridea plummeri* assemblage, which is present at 1,320 ft, 1,304 ft, and 1,280 ft, is characterized by abundant valves of *H. plummeri* accompanied by large numbers of *Brachycythere crenulata, Cytherella* spp., *Veenia ozanana,* and an undescribed species of *Brachycythere* (table 3). Compared qualitatively to the other assemblages, diversity is moderately high, and valve abundance is moderately high to very high in this assemblage.

The overlying *Haplocytheridea* new species 1 assemblage is present at 1,260 ft, 1,245 ft, and 1,215 ft. In this assemblage, the undescribed species *Haplocytheridea* n. sp. 1 replaces *Haplocytheridea plummeri*, which is absent, as the dominant form. *Brachycythere crenulata* and *Veenia spoori* are abundant at 1,260 ft but are absent from the two higher samples where *Fissocarinocythere gapensis* and *Haplocytheridea wilmingtonensis* (1,215 ft only) occur in substantial numbers. Valve abundance is high throughout this assemblage, whereas diversity is variably moderate to high.

These two assemblages also are present in calcareous nannofossil Zone CC 19 (data in Hattner and Wise, 1980; Hattner and others, 1980) in the Clubhouse Crossroads core in southern Dorchester County. Diversity is generally lower in the Clubhouse Crossroads samples with a resulting stronger dominance by *Haplocytheridea plummeri* and *Haplocytheridea* n. sp. 1 in their respective assemblages.

Most ostracode species in the *Haplocytheridea plummeri* assemblage and the *Haplocytheridea* new species 1 assemblage are compatible with the late early Campanian age indicated by the calcareous nannofossils (Hazel and Brouwers, 1982; Puckett, 1994; Gohn, 1995). Some species in the 1,320-ft sample, such as *"Cythereis" bicornis*, *Haplocytheridea nanifaba*, and rare *Alatacythere cheethami*, suggest an older Campanian age (*Alatacythere cheethami* Interval Zone) according to Hazel and Brouwers (1982). However, other studies report these species from upper lower Campanian sections that are chronostratigraphically equivalent to the Cane Acre Formation (Ross and Maddocks, 1985; Gohn, 1995).

The ostracode assemblages in the Cane Acre Formation suggest a shoaling upward pattern of sedimentation. The lowest sample at 1,320 ft contains the most diverse assemblage and the greatest number of trachyleberid specimens. In contrast, the highest sample at 1,215 ft contains significant numbers of *Haplocytheridea wilmingtonensis, Loxoconcha minardi*, and *Fissocarinocythere gapensis*, species that tend to occur in nearshore areas. This distribution of taxa suggests a transition from a relatively deep-water (perhaps middle neritic) paleoenvironment to a nearshore (inner-neritic) paleoenvironment.

<u>Equivalents to calcareous nannofossil Zone CC 20</u>. The section included in calcareous nannofossil Zone CC 20 is represented by eight ostracode samples between depths of 1,168 ft and 999 ft inclusive **(tables 4, 5)**. The *Haplocytheridea insolita* assemblage is present in four samples between 1,168 ft and 1,095 ft that represent the Coachman Formation(?). A low-diversity *Haplocytheridea wilmingtonensis* assemblage is present at 1,073 ft and 1,061 ft in the Bladen Formation(?). A sample at 1,030 ft in the lower part of the Donoho Creek Formation produced only 16 valves, most of which represent undescribed species. This sample is not considered further in this report. Although it occurs in a thick interval that was not

Table 3. Preliminary list of ostracodes from the Cane Acre Formation of the Black Creek Group. USGS-St. George core (DOR-211), Dorchester County, South Carolina.

Species: / Depth (feet):	1,320	1,304	1,280	1,260	1,245	1,215	Species Totals	% of Total
Haplocytheridea n. sp. 1	18	0	0	341	158	326	843	24.39%
Haplocytheridea plummeri	18	206	351	0	0	0	575	16.63%
Brachycythere crenulata	65	87	112	310	0	0	574	16.60%
Cytherella spp.	304	57	0	26	0	1	388	11.22%
Haplocytheridea nanifaba	122	4	0	0	0	0	126	3.64%
Veenia spoori	0	0	0	125	0	0	125	3.62%
Veenia ozanana	58	51	1	0	0	0	110	3.18%
Fissocarinocythere gapensis	0	0	8	12	16	65	101	2.92%
Fissocarinocythere pittensis	4	11	9	76	0	0	100	2.89%
Brachycythere n. sp.	39	32	10	8	0	4	93	2.69%
Schuleridea sp.	88	0	4	0	0	0	92	2.66%
Haplocytheridea wilmingtonensis	0	0	0	0	0	79	79	2.29%
"Cythereis" bicornis	68	0	0	0	0	0	68	1.97%
"Cythereis" hannai	44	0	0	0	0	0	44	1.27%
Loxoconcha minardi	0	0	0	6	0	30	36	1.04%
Cytherelloidea spp.	32	0	0	0	0	0	32	0.93%
Brachycythere pyriforma	11	3	0	0	0	0	14	0.40%
Orthonotacythere(?) sulcata	2	0	2	7	1	0	12	0.35%
Alatacythere sp.	10	0	0	0	0	0	10	0.29%
Antibythocypris sp.	0	0	0	0	0	8	8	0.23%
Loxoconcha sp.	6	0	0	0	0	0	6	0.17%
Argilloecia(?) sp.	0	0	0	0	2	2	4	0.12%
Eocytheropteron striatum	0	0	0	2	0	2	4	0.12%
Paracypris(?) sp.	2	0	0	0	0	2	4	0.12%
Brachycythere sp.	0	0	0	0	2	0	2	0.06%
Orthonotacythere sp.	0	0	0	0	2	0	2	0.06%
"Cythereis" levis	0	1	0	0	0	0	1	0.03%
Alatacythere cheethami	0	1	0	0	0	0	1	0.03%
Bairdoppilata sp.	0	1	0	0	0	0	1	0.03%
Loxoconcha sp.	0	0	0	0	1	0	1	0.03%
Schizoptocythere(?) compressa	0	0	0	1	0	0	1	0.03%
Total valves:	891	454	497	914	182	519	3457	100.00%

Table 4. **Preliminary list of ostracodes from the Coachman Formation(?) and Bladen Formation(?) of the Black Creek Group. USGS-St. George core (DOR-211), Dorchester County, South Carolina.**

Species: / Depth (feet):	1,168	1,140	1,111	1,095	1,073	1,061	Species Totals	% of Total
Haplocytheridea wilmingtonensis	2	3	0	2	99	254	360	46.27%
Haplocytheridea n. sp. h4	0	0	0	0	101	50	151	19.41%
Cytherella spp.	0	10	19	36	0	0	65	8.35%
Brachycythere porosa sp. complex	10	10	16	18	0	0	54	6.94%
Haplocytheridea n. sp. h3	0	0	15	23	0	0	38	4.88%
Haplocytheridea insolita	9	11	4	6	0	0	30	3.86%
Haplocytheridea n. sp. 1	4	25	0	0	0	0	29	3.73%
Haplocytheridea n. sp. h2	0	13	8	4	0	0	25	3.21%
Veenia n. sp.	0	4	2	0	0	0	6	0.77%
Haplocytheridea cf. *H. plummeri*	5	0	0	0	0	0	5	0.64%
Orthonotacythere(?) sulcata	4	1	0	0	0	0	5	0.64%
Ascetoleberis plummeri	0	0	4	0	0	0	4	0.51%
Antibythocypris sp.	0	0	0	2	0	0	2	0.26%
Fissocarinocythere gapensis	0	0	0	2	0	0	2	0.26%
Antibythocypris fabaformis	0	0	1	0	0	0	1	0.13%
Brachycythere sp.	1	0	0	0	0	0	1	0.13%
Total valves:	35	77	69	93	200	304	778	100.00%

Table 5. **Preliminary list of ostracodes from the Donoho Creek Formation of the Black Creek Group. USGS-St. George core (DOR-211), Dorchester County, South Carolina.**

Species: / Depth (feet):	1,030	999	970	958	924	889	816	Species Totals	% of Total
Haplocytheridea wilmingtonensis	0	69	3	211	0	0	0	283	36.14%
Haplocytheridea sarectaensis	0	0	0	0	0	34	107	141	18.01%
Haplocytheridea everetti	0	96	1	0	2	0	0	99	12.64%
Antibythocypris minuta	0	12	0	0	0	0	45	57	7.28%
Cytherella spp.	2	31	0	0	0	0	10	43	5.49%
Loxoconcha minardi	0	19	5	2	0	6	0	32	4.09%
Haplocytheridea renfroensis	0	1	0	0	0	0	24	25	3.19%
Orthonotacythere(?) sulcata	0	24	0	0	0	0	0	24	3.07%
Haplocytheridea n. sp. h5	0	20	0	0	0	0	0	20	2.55%
Loxoconcha spp.	0	19	0	0	0	0	0	19	2.43%
Paracypris sp.	0	0	0	0	0	0	8	8	1.02%
Antibythocypris spp.	6	0	0	0	0	0	0	6	0.77%
Cytheropteron spp.	0	3	2	0	0	0	0	5	0.64%
Brachycythere porosa sp. complex	0	2	2	0	0	0	0	4	0.51%
Antibythocypris fabaformis	0	3	0	0	0	0	0	3	0.38%
Anticythereis scuffletonensis	1	0	0	0	0	0	2	3	0.38%
Antibythocypris gooberi	0	2	0	0	0	0	0	2	0.26%
Bairdoppilata sp.	2	0	0	0	0	0	0	2	0.26%
Cytherelloidea sp.	2	0	0	0	0	0	0	2	0.26%
Fissocarinocythere pidgeoni	2	0	0	0	0	0	0	2	0.26%
Krithe(?) sp.	0	2	0	0	0	0	0	2	0.26%
Brachycythere sp.	1	0	0	0	0	0	0	1	0.13%
Total valves:	16	303	13	213	2	40	196	783	100.00%

sampled for calcareous nannofossils, the ostracode sample at 999 ft is below the FAD of the calcareous nannofossil *Quadrum sissinghii* and is technically within calcareous nannofossil Zone CC 20. This sample contains a high-diversity *Haplocytheridea wilmingtonensis* assemblage.

The faunal composition and moderate diversity of taxa in the *Haplocytheridea insolita* assemblage contrast with the underlying and overlying assemblages (table 4). *Haplocytheridea insolita*, *Ascetoleberis plummeri*, and three undescribed species of *Haplocytheridea* are confined to the *H. insolita* assemblage in the St. George core and the Clubhouse Crossroads core. The presence of *H. insolita* with *Fissocarinocythere gapensis*, *A. plummeri*, and a single specimen of *Antibythocypris fabaformis* suggests a late early Campanian to middle Campanian age within the chronozones of the *Ascetoleberis plummeri* Interval Zone and the *Limburgina verricula* Interval Zone of Hazel and Brouwers (1982). This age is compatible with the presence of this assemblage in calcareous nannofossil Zone CC 20. The dominance of *Haplocytheridea* species in this assemblage suggests an inner-neritic paleoenvironment.

The *Haplocytheridea wilmingtonensis* assemblage at 1,073 ft and 1,061 ft consists only of large numbers of *H. wilmingtonensis* and an undescribed species of the genus *Haplocytheridea* (table 4). No independent inferences of age or stratigraphic position can be made from this limited assemblage. The very low diversity of this assemblage suggests a paleoenvironmentally restricted inner-neritic site of deposition. The low diversity could have resulted from reduced salinity or low oxygen content in the water column, or a high sedimentation rate, or some combination of these factors.

The higher diversity *Haplocytheridea wilmingtonensis* assemblage at 999 ft is dominated by species of the genera *Haplocytheridea* and *Antibythocypris*. This assemblage indicates an inner-neritic paleoenvironment; *H. wilmingtonensis*, *Antibythocypris minuta*, and *Loxoconcha minardi* are particularly indicative of nearshore paleoenvironments. No independent assessment of biostratigraphic age can be made from this assemblage, although a late Campanian age can be assigned from the presence of *Fissocarinocythere pidgeoni* at 1,030 ft and *H. wilmingtonensis* at 999 ft.

<u>Equivalents to calcareous nannofossil Zone CC 21</u>. Two ostracode samples were processed from the interval assigned to calcareous nannofossil Zone CC 21 within the lower part of the Donoho Creek Formation (table 5). Of these, the sample at 958 ft contains a low-diversity *Haplocytheridea wilmingtonensis* assemblage that consists only of abundant *H. wilmingtonensis* and very sparse *Loxoconcha minardi*. The sample at 970 ft yielded only 13 valves and is of limited utility, although the presence of *H. wilmingtonensis* and *L. minardi* suggests an affinity with the assemblage at 999 ft. These low-diversity assemblages suggest an inner-neritic paleoenvironment similar to that proposed for the 1,073-ft and 1,061-ft samples.

<u>Equivalents to calcareous nannofossil Zone CC 22</u>. Three ostracode samples were processed from the interval assigned to calcareous nannofossil Zone CC 22, which occurs within the upper part of the Donoho Creek Formation (table 5). The sample at 924 ft produced only two valves of *Haplocytheridea everetti* and is of limited biostratigraphic use. The samples at 889 ft and 816 ft are assigned to the *Haplocytheridea sarectaensis* assemblage.

The *Haplocytheridea sarectaensis* assemblage is dominated by *H. sarectaensis* with low to moderate numbers of other species, compared to the other assemblages. We consistently find that assemblages containing and typically dominated by *H. sarectaensis* are present only in the upper part of calcareous nannofossil Zone CC 22 in South Carolina (G. Gohn, unpublished data). The presence of *Antibythocypris minuta* and *Loxoconcha minardi* suggests an inner-neritic paleo-environment.

Peedee Formation

Equivalents to calcareous nannofossil Zone CC 25. Three ostracode assemblages occur within the Peedee Formation in the St. George core **(table 6)**. We also recognize these assemblages, and several additional assem- blages, in Peedee sections assigned to calcareous nannofossil Zone CC 25 throughout South Carolina. However, an age can not be independently assigned to these ostracode assemblages with any degree of confidence. Virtually all of the Peedee species also are present in Campanian sections in South Carolina and elsewhere (Hazel and Brouwers, 1982; Puckett, 1996; Gohn, 1995).

The *Antibythocypris fabaformis* assemblage is present at 780 ft, 774 ft, 768 ft, and 761 ft. This assemblage is characterized by the presence of *A. fabaformis* in moderately diverse to very diverse, high-abundance assemblages. *Escharacytheridea magna-mandibulata* and *Loxoconcha nuda* seemingly are restricted to this assemblage in South Carolina, and *Orthonotacythere hannai* is restricted to this assemblage within intervals assigned to Zone CC 25 and the Peedee Formation.

The *Haplocytheridea renfroensis* assemblage is present at 730 ft, 711 ft and 701 ft (table 6). This relatively low-diversity assemblage typically contains few, if any, specimens of *Antibythocypris fabaformis* or *Antibythocypris minuta* and is dominated by *H. renfroensis* and *Haplocytheridea everetti*.

The *Antibythocypris minuta* assemblage is present in two closely spaced samples at 660 ft and 659 ft (table 6). This low-diversity assemblage is dominated by *A. minuta* and typically lacks *A. fabaformis* and *Haplocytheridea renfroensis* in the St. George core and other South Carolina Cretaceous sections.

The sequence of ostracode assemblages seen in the Peedee Formation in the St. George core also is present in other South Carolina drill holes (G. Gohn, unpublished data). The upward progression in assemblages (*Antibythocypris fabaformis* assemblage through *Haplocytheridea renfroensis* assemblage to *Antibythocypris minuta* assemblage) typically accompanies an upward change in lithology from silty clay to muddy fine sand. We infer an upward change from middle neritic depositon to inner neritic deposition from the characteristics of the ostracode assemblages and the lithologic trend.

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Table 6. Preliminary list of ostracodes from the Peedee Formation. USGS-St. George core (DOR-211), Dorchester County, South Carolina.

Species: / Depth (feet):	780	774	768	761	730	711	701	660	659	Species Totals	% of Total
Haplocytheridea renfroensis	6	257	13	197	56	163	41	0	0	733	28.89%
Haplocytheridea everetti	122	21	178	46	17	74	117	10	35	620	24.44%
Antibythocypris fabaformis	42	93	96	6	0	0	0	0	0	237	9.34%
Cytherella spp.	43	71	3	57	1	19	9	2	4	209	8.24%
Antibythocypris minuta	0	0	0	0	0	0	0	56	146	202	7.96%
Brachycythere rhomboidalis	59	40	9	3	0	3	1	5	0	120	4.73%
Brachycythere ovata	0	50	0	0	0	15	20	0	0	85	3.35%
Veenia arachoides	6	20	56	0	0	0	0	0	0	82	3.23%
Antibythocypris gooberi	50	1	10	1	0	0	0	0	0	62	2.44%
Orthonotacythere hannai	0	2	41	1	0	1	0	0	0	45	1.77%
Loxoconcha n. sp.	4	0	36	1	0	0	0	0	0	41	1.62%
Fissocarinocythere pidgeoni	5	7	0	0	0	0	0	4	20	36	1.42%
Cytheropteron fossatum	1	0	19	0	0	0	0	0	0	20	0.79%
Amphicytherura curta	13	5	0	0	0	0	0	0	0	18	0.71%
Escharacytheridea magnamandibulata	9	2	0	0	0	0	0	0	0	11	0.43%
Loxoconcha nuda	8	0	0	0	0	0	0	0	0	8	0.32%
Loxoconcha cretacea	2	0	0	0	0	0	0	0	1	3	0.12%
Limburgina verricula	2	0	0	0	0	0	0	0	0	2	0.08%
Ascetoleberis hazardi	0	0	0	1	0	0	0	0	0	1	0.04%
Cytherelloidea sp.	1	0	0	0	0	0	0	0	0	1	0.04%
Cytheropteron sp.	0	0	1	0	0	0	0	0	0	1	0.04%
Total valves:	373	569	462	313	74	275	188	77	206	2537	100.00%

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APPENDIX

Table A-1. Alphabetical list (by Genera) of calcareous nannofossil species listed in the text or figures, or recorded from the samples.

Ahmuellerella octoradiata (Gorka, 1957) Reinhardt, 1964
Arkhangelskiella cymbiformis Vekshina, 1959
Arkhangelskiella specillata 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) Noel, 1969
Biscutum constans (Gorka, 1957) Black *in* Black and Barnes, 1959
Biscutum notaculum Wind & Wise *in* Wise and Wind, 1977
Braarudosphaera bigelowii (Gran & Braarud, 1935) Deflandre, 1947
Broinsonia dentata Bukry, 1969

Bukryaster hayi (Bukry, 1969) Prins & Sissinghi *in* Sissingh, 1977
Calculites obscurus (Deflandre, 1959) Prins & Sissingh *in* Sissingh, 1977
Calculites ovalis (Stradner, 1963) Prins & Sissingh *in* Sissingh, 1977
Ceratolithoides aculeus (Stradner, 1961) Prins & Sissingh *in* Sissingh, 1977
Ceratolithoides kamptneri Bramlette & Martini, 1964
Chiastozygus amphipons (Bramlette & Martini, 1964) Gartner, 1968
Chiastozygus propagulis Bukry, 1969
Corollithion exiguum Stradner, 1961
Corollithion signum Stradner, 1963
Cretarhabdus conicus Bramlette & Martini, 1964

Cretarhabdus loriei Gartner, 1968
Cribrosphaerella ehrenbergii (Arkhangelsky, 1912) Deflandre *in* Piveteau, 1952
Cribrosphaerella schizobrachiatus (Gartner, 1968) Bukry, 1969
Cyclagelosphaera margerelii Noel, 1965
Cylindralithus crassus Stover, 1966
Discorhabdus ignotus (Gorka, 1957) Perch-Nielsen, 1968
Eiffellithus eximius (Stover, 1966) Perch-Nielsen, 1968
Eiffellithus gorkae Reinhardt, 1965
Eiffellithus parallelus Perch-Nielsen, 1973
Eiffellithus turriseiffelii (Deflandre *in* Deflandre and Fert, 1954) Reinhardt, 1965

Gartnerago obliquum (Stradner, 1963) Noel, 1970
Glaukolithus compactus (Bukry, 1969) Perch-Nielsen, 1984
Glaukolithus diplogrammis (Deflandre *in* Deflandre and Fert, 1954) Reinhardt , 1964
Goniolithus fluckigeri Deflandre, 1957
Hexalithus gardetae Bukry, 1969
Kamptnerius magnificus Deflandre, 1959
Lithastrinus grillii Stradner, 1962
Lithraphidites carniolensis Deflandre, 1963
Lithraphidites grossopectinatus Bukry, 1969
Lithraphidites praequadratus Roth, 1978
Lithraphidites quadratus Bramlette & Martini, 1964
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 & Fert, 1954) Bramlette & Martini, 1964
Marthasterites furcatus (Deflandre *in* Deflandre and Fert, 1954) Deflandre, 1959
Microrhabdulus attenuatus (Deflandre, 1959) Deflandre, 1963
Microrhabdulus belgicus Hay & Towe, 1963
Microrhabdulus decoratus Deflandre, 1959

Microrhabdulus undosus Perch-Nielsen, 1973
Micula concava (Stradner *in* Martini and Stradner, 1960) Verbeek, 1976
Micula decussata Vekshina, 1959
Micula murus (Martini, 1961) Bukry, 1973
Micula prinsii Perch-Nielsen, 1979
Nephrolithus frequens Gorka, 1957
Ottavianus terrazetus Risatti, 1973
Parhabdolithus embergerii (Noel, 1965) Stradner, 1963
Placozygus fibuliformis (Reinhardt, 1964) Hoffmann, 1970
Placozygus sigmoides (Bramlette & Sullivan, 1961) Romein, 1979
Pontosphaera multicarinata (Gartner, 1968) Shafik & Stradner, 1971

Prediscosphaera cretacea (Arkhangelsky, 1912) Gartner, 1968
Prediscosphaera grandis Perch-Nielsen, 1979a
Prediscosphaera intercisa (Deflandre *in* Deflandre and Fert, 1954) Shumenko, 1976
Prediscosphaera spinosa (Bramlette & Martini, 1964) Gartner, 1968
Prediscosphaera stoveri (Perch-Nielsen, 1968) Shafik & Stradner, 1971
Quadrum gothicum (Deflandre, 1959) Prins & Perch-Nielsen *in* Manivit 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

Repagalum parvidentatum (Deflandre & Fert, 1954) Forchheimer, 1972
Rhagodiscus angustus (Stradner, 1963) Reinhardt, 1971
Rhagodiscus splendens (Deflandre, 1953) Verbeek, 1977b
Scapholithus fossilis Deflandre *in* Deflandre & Fert, 1954
Stradnaria crenulata (Bramlette & Martini, 1964) Noel, 1970
Tegumentum stradneri Thierstein *in* Roth and Thierstein, 1972
Tetrapodorhabdus decorus (Deflandre *in* Deflandre and Fert, 1954) Wind & Wise *in* Wise and Wind 1977
Tranolithus gabalus Stover, 1966
Tranolithus phacelosus Stover, 1966
Vagalipilla aachena Bukry, 1969

Vekshinella stradneri Rood and others, 1971
Watznaueria barnesae (Black *in* Black & Barnes, 1959) Perch-Nielsen, 1968
Watznaueria biporta Bukry, 1969
Watznaueria supracretacea (Reinhardt, 1965) Wind & Wise, 1976
Zeugrhabdotus erectus (Deflandre *in* Deflandre and Fert, 1954) Reinhardt, 1965

Table A-2. Alphabetical list (by species) of original designations and present nomenclature for Cretaceous ostracodes listed in this report.

Original	This report
Cythere arachoides Berry, 1925	*Veenia arachoides* (Berry, 1925)
Cythereis bicornis Israelsky, 1929	*"Cythereis" bicornis* Israelsky, 1929
Pterygocythereis (P.) cheethami Hazel and Paulson, 1964	*Alatacythere cheethami* (Hazel and Paulson, 1964)
Pterygocythereis (P.) compressa Hazel and Paulson, 1964	*Schizoptocythere*(?) *compressa* (Hazel and Paulson, 1964)
Brachycythere sphenoides crenulata Crane, 1965	*Brachycythere crenulata* Crane, 1965
Loxoconcha cretacea Alexander, 1936	*Loxoconcha cretacea* Alexander, 1936
Cythereis curta Jennings, 1936	*Amphicytherura curta* (Jennings, 1936)
Cytheridea everetti Berry, 1925	*Haplocytheridea everetti* (Berry, 1925)
Cytherella fabaformis Berry, 1925	*Antibythocypris fabaformis* (Berry, 1925)
Cytheropteron fossatum Skinner, 1956	*Cytheropteron fossatum* Skinner, 1956
Cythere gapensis Alexander, 1929	*Fissocarinocythere gapensis* (Alexander, 1929)
Antibythocypris gooberi Jennings, 1936	*Antibythocypris gooberi* Jennings, 1936
Cythereis hannai Israelsky, 1929	*"Cythereis" hannai* Israelsky, 1929
Cytheridea(?) hannai Israelsky, 1929	*Orthonotacythere hannai* (Israelsky, 1929)
Cythereis hazardi Israelsky, 1929	*Ascetoleberis hazardi* (Israelsky, 1929)
Cytheridea insolita Alexander and Alexander, 1933	*Haplocytheridea insolita* (Alexander and Alexander,1933)
Cythereis bicornis levis Crane, 1965	*"Cythereis" levis* Crane, 1965
Escharacytheridea magnamandibulata Brouwers and Hazel, 1978	*Escharacytheridea magnamandibulata* Brouwers and Hazel, 1978
Loxoconcha minardi Brouwers and Hazel, 1978	*Loxoconcha minardi* Brouwers and Hazel, 1978
Cytherideis minutus Berry, 1925	*Antibythocypris minuta* (Berry, 1925)
Haplocytheridea(?) nanifaba Crane, 1965	*Haplocytheridea nanifaba* Crane, 1965
Loxoconcha nuda Alexander, 1934	*Loxoconcha nuda* Alexander, 1934
Cythereis ovatus Berry, 1925	*Brachycythere ovata* (Berry, 1925)
Cythereis ozanana Israelsky, 1929	*Veenia ozanana* (Israelsky, 1929)
Cytheridea pidgeoni Berry, 1925	*Fissocarinocythere pidgeoni* (Berry, 1925)
Cythereis pittensis Swain and Brown, 1964	*Fissocarinocythere pittensis* (Swain and Brown,1964)
Cythereis plummeri Israelsky,1929	*Ascetoleberis plummeri* (Israelsky, 1929)
Cytheridea plummeri Alexander, 1929	*Haplocytheridea plummeri* (Alexander, 1929)
Brachycythere ledaforma porosa Crane, 1965	*Brachycythere porosa* Crane, 1965 species complex
Brachycythere (B.) pyriforma Hazel and Paulson, 1964	*Brachycythere pyriforma* Hazel and Paulson 1964
Haplocytheridea(?) renfroensis Crane, 1965	*Haplocytheridea renfroensis* Crane, 1965
Cythere rhomboidalis Berry, 1925	*Brachycythere rhomboidalis* (Berry, 1925)

Cytheridea (Haplocytheridea) sarectaensis Brown, 1957	*Haplocytheridea sarectaensis* Brown, 1957
Velarocythere scuffletonensis Brown, 1957	*Anticythereis scuffletonensis* (Brown, 1957)
Cythereis spoori Israelsky, 1929	*Veenia spoori* (Israelsky, 1929)
Cytheropteron (Eocytheropteron) striatum Brown, 1957	*Eocytheropteron striatum* Brown, 1957
Orthonotacythere sulcata Brown, 1957	*Orthonotacythere(?) sulcata* Brown, 1957
Cythereis verricula Butler and Jones, 1957	*Limburgina verricula* (Butler and Jones, 1957)
Cytheridea (Haplocytheridea) wilmingtonensis Brown, 1957	*Haplocytheridea wilmingtonensis* Brown, 1957