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Paleogene Calcareous Nannofossils of the South Dover Bridge core, Southern Maryland (USA)

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Abstract A well-preserved Paleogene calcareous nannofossil assemblage taken from cored material of the subsurface coastal plain of eastern Maryland, USA, is documented and described herein. Taxonomic and biostratigraphic analyses of 120 m of hemipelagic clays and silts have resulted in the identification of a nearly complete Paleocene/Eocene section. A lithologic break is identified across the Marlboro Clay/Nanjemoy Formation boundary and the corresponding upper part of Zone NP10 is missing (from 54.37-53.61 Ma), representing a hiatus of 760,000 years. Assemblages are compared to other documented hemipelagic sequences worldwide, and biostratratigraphic taxon ranges are adjusted accordingly. Five new species (*Braarudosphaera sequela, Daktylethra basilica, Ellipsolithus aubryae, Hornibrookina weimerae, Pemma bybelliae*) and one new combination (*Neochiastozygus tenansa*) are recorded.

Keywords Paleocene, Eocene, calcareous nannofossils, taxonomy

1. Introduction

Paleogene sediments of the Maryland Coastal Plain and the surrounding region have been identified and documented from river bluffs and creek beds for over one hundred years (Clark, 1895). Exposures along the Potomac River, Aquia Creek, Popes Creek, and the Pamunkey River allowed for easy access to sediments that were otherwise unattainable until the advent of modern coring practices. These bluffs have been variously analyzed for lithologic content (Clark & Martin, 1901), for stratigraphic purposes (Ward, 1985), for microfossil content (Nogan, 1964; Bybell & Gibson, 1991), for mapping (Rader & Evans, 1993), and as teaching guides (Gibson & Bybell, 1991). Starting in the 1980s (as a means of obtaining fresh sediment for analysis and for providing information on subsurface geologic and hydrogeologic frameworks), a series of coreholes were drilled by the U.S. Geological Survey (USGS), the Maryland Geologic Survey, and the Virginia Division of Mineral Resources as an aid to surficial and geologic mapping. Analyses of cored material included calcareous nannofossil biostratigraphy and taxonomy of the Paleogene section (Gibson et al., 1980; Bybell & Gibson, 1991; Bybell & Gibson, 1994; Gibson & Bybell, 1994).

Recent drilling of the South Dover Bridge (SDB) core by the USGS for the Atlantic Watershed Project has resulted in the recovery of a Paleogene section that contains exceptionally well-preserved calcareous nannofossils (Figure 1). The corehole reached a total depth of 214.6 m, and bottomed out in the glauconite-rich, quartz sand of the Aquia Formation (Figure 2). The age of the Aquia is late Paleocene (calcareous nannofossil Zones NP 5-NP 9a) but only the uppermost Aquia (Zone NP 9a) was reached at SDB. The Aquia Formation is conformably overlain by a relatively thick (~15.2 m) section of the Marlboro Clay, which consists of finely micaceous and faintly, but persistently, laminated clayey silt to silty clay. Scattered shell fragments, foraminifera, and ostracodes are present in minor amounts. Previous palynomorph and calcareous nannofossil data (Gibson et al., 1980; Bybell & Gibson, 1991) suggested that the Marlboro Clay was late Paleocene to early Eocene in age. This age is corroborated in the SDB core, where a nearly complete Paleocene/Eocene Thermal Maximum (PETM) section and carbon isotope excursion (CIE) have been identified (Willard et al., 2009; Self-Trail et al., 2010). The basal Marlboro

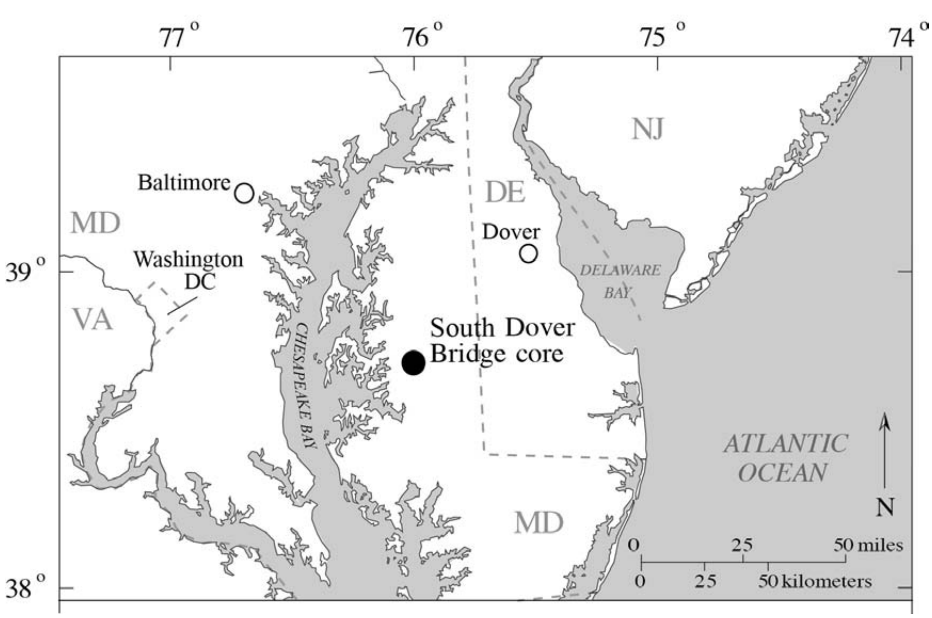

Figure 1. Map showing the location of the South Dover Bridge core, southeastern Maryland, USA. Nearby cities are designated by open circles.

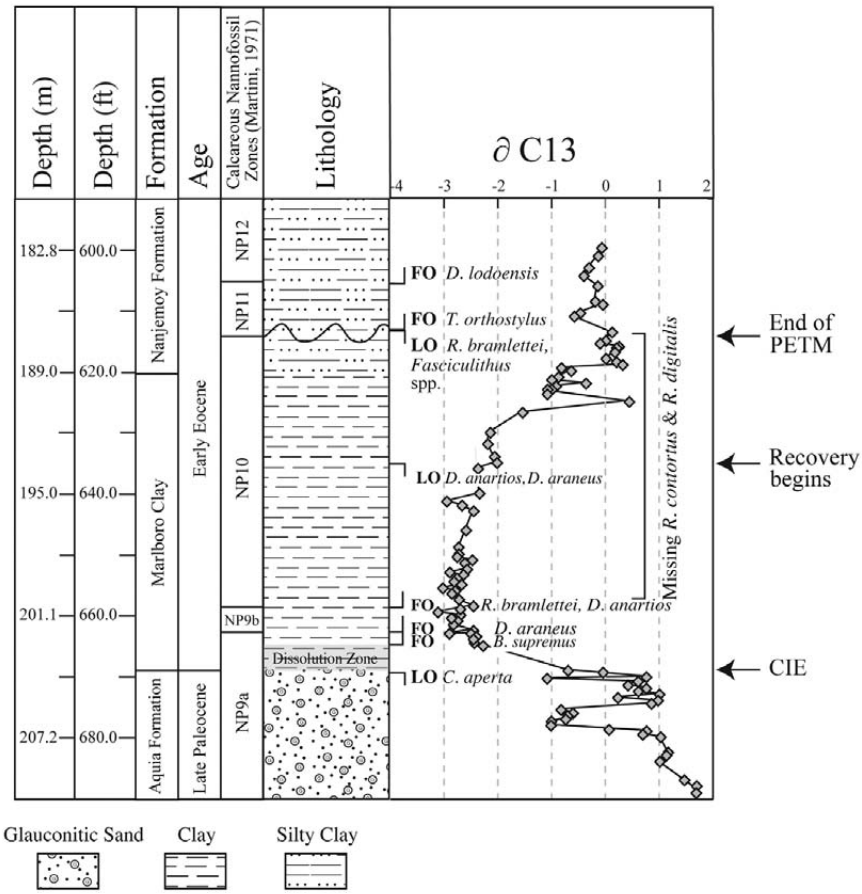

Figure 2. Stratigraphic column of the Paleocene/Eocene boundary in the South Dover Bridge core. The carbon isotope excursion (CIE) marks the Paleocene/Eocene boundary and an unconformity marks the end of the Paleocene Eocene Thermal Maximum (PETM). The absence of *Rhomboaster contortus* and *Rhomboaster digitalis* suggests that Zone NP10 is truncated and that upper Zone NP 10 is missing at this site. A zone of possible drilling mud injection is present at the Marlboro Clay/Nanjemoy Formation contact.

Clay is assigned to calcareous nannofossil Zone NP9a, which includes a 1.8 m thick dissolution zone. The Marlboro Clay is unconformably overlain by the Nanjemoy Formation, a silty, sandy clay that grades gradually up into a glauconite-rich clayey sand. The contact between the Marlboro and the Nanjemoy is intensely burrowed. Previous dinoflagellate and calcareous nannofossil data place the Nanjemoy in calcareous nannofossil Zones NP 10 through NP 13 (early Eocene in age) (Gibson & Bybell, 1995; Goodman, 1991). An unnamed unit of alternating sandy clay and clayey sand, rich in benthic foraminifera, overlies the Nanjemoy Formation, and is approximately 39 m thick. This unit has previously been identified from clasts in the Exmore Formation of the Chesapeake Bay impact structure (Frederiksen et al., 2005), but has no known surface exposure. It is middle Eocene (upper Zone NP14 to NP16) in age. The overlying Piney Point Formation consists of a coarse to fine glauconitic quartz sand (Figure 3). Ward (1985) placed the Piney Point in the middle Eocene based on the foraminifera and ostracode data of Brown et al., (1972), and DiMarzio (1984) placed the Piney Point of Virginia into calcareous nannofossil Zone NP16, an age that is corroborated herein.

The calcareous nannofossil assemblages discussed in this paper most closely resemble the material documented by Bown (2005), Bown & Dunkley Jones (2006) and Bown & Pearson (2009) from Tanzania, assemblages documented by Gibbs et al., (2006) from the Wilson Lake core, New Jersey, and assemblages from various New Jersey cores identified by Bybell & Self-Trail (1995). All are representative of shelfal depositional environments. Semi-quantitative analyses serve to highlight the abundant and diverse assemblages of calcareous nannofossils that are present in the SDB core. Post-drilling diagenesis and loss of the calcareous nannofossil assemblages was prevented by the rapidity of sampling following the coring process. Samples extracted from outcrop samples and older cores of the Marlboro Clay are typically barren of, or contain very sparse, calcareous nannofossils (Bybell & Gibson, 1991; Bybell & Gibson, 1994; Gibson & Bybell, 1994). However, samples obtained from the SDB core immediately after coring contain common to abundant calcareous nannofossil assemblages throughout the Marlboro Clay.

This paper documents the well-preserved Paleogene calcareous nannofossil assemblages of the SDB core. The taxonomy presented herein provides a review of Paleogene taxa, with special emphasis on documentation of new species identified by Bown (2005) and Bown & Dunkley Jones (2006) from Tanzania, with the intent of refining biostratigraphic ranges. Five new taxa are identified and described, and one new combination is recorded.

2. Methods and Materials

The SDB corehole is located in Talbot County, Maryland, at N38.74704 latitude and W76.00697 longitude (Figure 1). Core was recovered in October, 2007, and a total depth of 214.6 m was attained. The Paleogene section in this core comprises approximately 120 m of sands, silts, and clays. The site was cored using a Mobile B-61 drill rig running a wireline coring system. Cores are archived at the USGS in Reston, VA.

Sediment to be examined for calcareous nannofossil content was extracted from the central portion of freshly broken core in order to avoid contamination. Slides were prepared at the drillsite within one day of coring, using the double slurry smear slide method of Blair & Watkins (2009) in order to avoid the rapid dissolution that is common in organic-rich sediments of the Atlan-

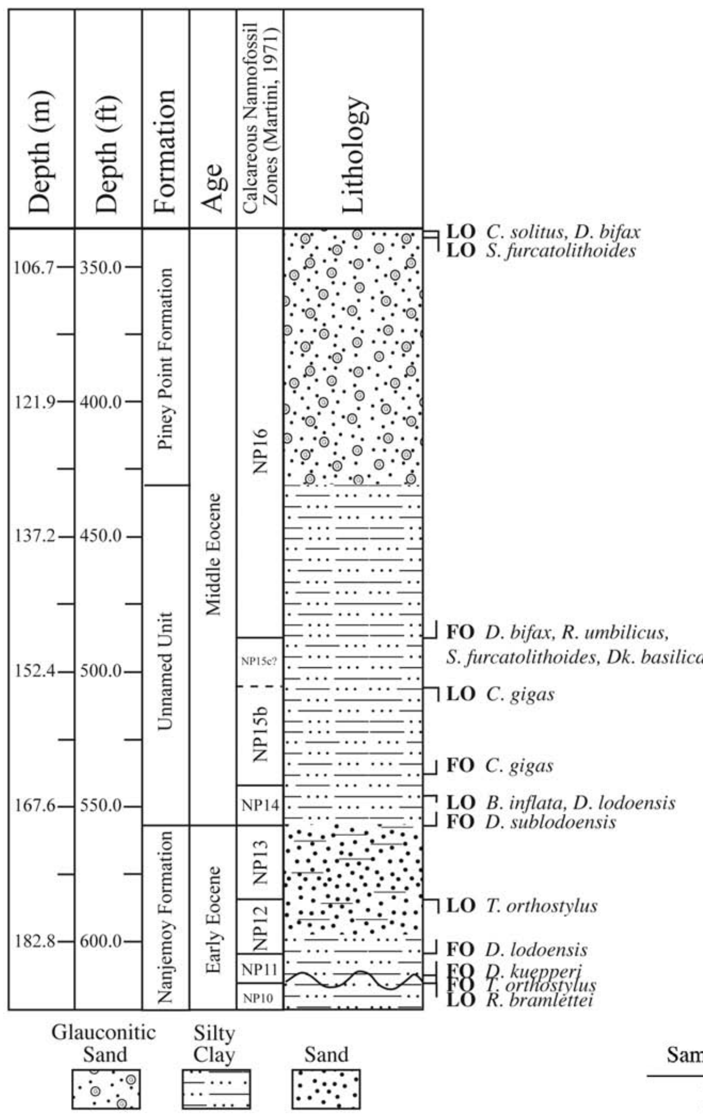

Figure 3. Stratigraphic column of the early to middle Eocene section of the South Dover Bridge core. The unnamed middle Eocene unit is age-equivalent to the Shark River Formation of New Jersey.

tic Coastal Plain (Self-Trail & Seefelt, 2005). Cover slips were affixed to slides using Norland Optical Adhesive 61. More closely spaced samples were later collected across the PETM in the calcareous nannofossil laboratory in Reston, VA, in order to augment the initial sample set. Samples were analyzed using a Zeiss Axioplan 2 microscope at x1250 magnification in cross-polarized light (XPL); phase-contrast (PC) was used as an additional method for identifying discoasters. Table 1 shows each sample with its unique number, depth, calcareous nannofossil zone, and age. Identification of biozones was based primarily on the Martini (1971) zonation and augmented by the bioevents identified by Okada & Bukry (1980). According to Aubry (1999) and Aubry et al. (2000), identification of the NP9a/b boundary is based on the simultaneous lowest occurrences of *Rhomboaster calcitrapa, R. spineus, Discoaster anartios,* and *D. araneus*. However, analysis of multiple Atlantic Coastal Plain sections (Bybell and Self-Trail, unpub. data, 2010) suggests that the first occurrence (FO) of *D. araneus* is oldest, followed in quick succession by the FO's of *D. anartios, R. spineus,* and *R. bramlettei*, and rarely do all events occur in the same studied section. Therefore, the NP9a/b boundary is identified in SDB by the FO of *D. araneus*.

3. Results

Calcareous nannofossils indicate that Paleogene sediments between 210 m and 102.2 m in the SDB core are late Paleocene to middle Eocene in age. A lithologic change from the sands of the Nanjemoy Formation below to the silts of the overlying Calvert Formation reflects a hiatus spanning the late Eocene to earliest Miocene. This is corroborated by a change in the calcareous nannofossil assemblages. A minor hiatus (<760,000 yrs) is indicated by the burrowed contact between the Marlboro Clay and the overlying Nanjemoy Formation, and this coincides with an increase in calcareous nannofossil first and last occurrences (LO) at the same interval. The upper part of Zone NP10 is missing at this contact, as evidenced by the absence of the species *Rhomboaster contortus* and *R. digitalis* (Figure 2). Calcareous nannofossils are predominantly common to abundant in both the Marlboro and Nanjemoy, and show moderate to very good preservation (Tables 2-4).

Although species richness from the SDB core is not on par with the diversity recorded by Bown (2005) and Bown & Pearson (2009) from Tanzania, averaging only approximately

Sample Number	Depth (m)	Zone	Age
N12662	103.7	NP 16	M. Eocene
N12402	139.0	NP 16	M. Eocene
N12403	142.5	NP 16	M. Eocene
N12404	145.2	NP 16	M. Eocene
N12405	148.1	NP 16	M. Eocene
N12406	151.0	NP 15c?	M. Eocene
N12410	163.4	NP 15b	M. Eocene
N12411	166.1	NP 14	M. Eocene
N12412	169.2	NP 14	M. Eocene
N12413	172.2	NP 13	E. Eocene
N12472	182.6	NP 12	E. Eocene
N12417	185.9	NP 11	E. Eocene
N12475	186.1	NP 11	E. Eocene
N12476	186.8	NP 11	E. Eocene
N12672	187.1	NP 11	E. Eocene
N12482	193.0	NP 10	E. Eocene
N12486	196.6	NP 10	E. Eocene
N12487	197.8	NP 10	E. Eocene
N12488	198.7	NP 10	E. Eocene
N12489	199.8	NP 10	E. Eocene
N12727	202.7	NP 9a	E. Eocene
N12423	204.3	NP 9a	L. Paleocene
N12495	206.9	NP 9a	L. Paleocene
N12496	207.6	NP 9a	L. Paleocene
N12498	209.1	NP 9a	L. Paleocene

Table 1. Sample depth, number and age for illustrated calcareous nannofossil specimens from the South Dover Bridge core, Maryland. Calcareous nannofossil zones from Martini (1971).

Table 2. Calcareous nannofossil occurrences in the South Dover Bridge core, Maryland, for the Paleocene and early Eocene. Species abundance: A, abundant or 1 per every field of view (FOV); C, common or 2 per 1-10 FOV's; F, frequent or 1 per 11-100 FOV's; R, rare or 1 per >100 FOV's. Slide abundance: A, abundant or >10 specimens per FOV; C, common or 1-10 specimens per FOV; F, frequent or 1 specimen per 1-10 FOV's; R, rare or 1 specimen per 11-100 FOV's; B, barren of calcareous nannofossils. Preservation: VG, very good; G, good; M, moderate; P, poor. Other symbols: rw, reworked specimen; ct, contamination from higher in the core; ?, questionable occurrence. Shaded area indicates dissolution interval at the base of the Eocene.

late Paleocene																																											Series
Aquia										Marlboro Clay																																	Formation
NP 9a																							NP9b				NP 10																Zone (Martini, 1971)
210.0	209.1	208.2	207.6	207.4	206.9	205.7	204.7	204.3	204.1	203.9	203.8	203.6	203.5	203.4	203.1	203.0	202.8	202.7	202.5	202.4	202.2	202.1	201.9	201.7	201.6	201.3	200.5	199.8	198.7	198.2	197.8	196.6	195.7	195.3	194.8	193.9	193.0	192.3	192.1	190.8	190.0	189.1	Depth (m)
689.0	686.0	683.0	681.0	680.3	678.7	675.0	671.5	670.3	669.5	669.0	668.5	668.0	667.5	667.2	666.5	666.0	665.5	665.0	664.5	664.0	663.5	663.0	662.5	662.0	661.5	660.3	658.0	655.6	652.0	650.3	649.0	645.0	642.0	640.8	639.0	636.0	633.3	630.8	630.1	626.0	623.4	620.5	Depth (ft)
·	R	·	·	R	·	·	·	·	R	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	R	R	·	*Biantholithus astralis*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	R	·	·	·	*Biantholithus* sp.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	*Birkelundia arenosa*
·	R	R	F	F	·	·	·	F	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Biscutum constans*
·	·	·	R	·	R	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	*Biscutum harrisonii*
F	F	C	C	C	C	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	F	·	·	·	·	·	·	·	*Biscutum* sp.
·	·	·	·	?	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Bomolithus elegans*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	F	R	R	R	R	·	R	R	R	R	C	R	F	F	F	F	F	F	F	R	F	F	R	F	*Bomolithus supremus*
·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	*Braarudosphaera bigelowii*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	·	·	·	·	·	·	·	·	·	·	·	·	·	*Braarudosphaera sequela* n. sp.
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	F	·	F	·	·	R	F	·	*Calcidiscus? pacificus*
F	R	R	·	F	F	F	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Calcidiscus? parvicrucis*
C	C	C	C	C	C	C	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Calciosolenia aperta*
·	R	R	R	·	F	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	·	·	F	F	·	·	F	R	·	·	R	·	*Calciosolenia fossilis*
·	F	F	R	F	R	F	F	·	·	·	·	·	·	R	·	·	·	·	F	R	R	F	F	F	F	C	F	C	F	R	R	F	F	C	F	F	F	F	F	F	R	R	*Camplyosphaera dela*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	*Camplyosphaera differta*
C	A	C	C	A	C	C	C	C	R	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	F	F	F	R	F	*Chiasmolithus bidens*
R	R	R	·	F	R	F	F	·	·	·	·	·	·	·	·	·	·	R	R	R	R	F	R	R	R	·	·	F	F	C	F	·	·	R	R	F	R	F	F	F	R	·	*Chiasmolithus consuetus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	R	R	F	F	·	·	R	·	R	·	R	F	F	·	·	R	*Chiasmolithus frequens*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	F	·	·	·	·	·	·	·	·	·	·	F	F	R	R	·	*Clausicoccus fenestratus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	F	C	F	F	F	C	F	R	R	·	C	F	R	F	F	F	F	F	F	R	R	F	F	·	*Coccolithus bownii*
·	·	·	·	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Coccolithus latus*
C	C	C	A	A	A	A	C	C	C	R	·	·	·	F	·	·	·	F	C	·	A	C	A	A	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	*Coccolithus pelagicus*
·	F	R	F	R	F	F	·	R	·	·	·	·	·	·	·	·	·	·	F	R	F	C	F	R	F	C	F	C	C	C	F	F	F	F	F	F	C	C	C	F	C	R	*Coronocyclus bramlettei*
·	·	rw	rw	·	rw	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Cruciplacolithus cruciformis*
·	·	R	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	*Cruciplacolithus latipons*
F	R	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	R	·	·	*Cruciplacolithus primus*
·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Cruciplacolithus tenuis*
C	R	R	R	F	F	R	R	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	R	*Cyclagelosphaera prima*
·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Cyclicargolithus luminis*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	*Discoaster acutus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	F	F	F	F	C	F	R	R	R	·	·	·	·	·	·	*Discoaster anartios*
?	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	R	·	·	R	·	F	·	·	·	R	·	·	·	·	·	·	·	*Discoaster araneus*
·	F	·	F	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	F	·	·	·	·	·	*Discoaster binodosus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	?	·	·	·	·	·	·	·	·	?	·	·	·	·	·	*Discoaster diastypus*
F	·	·	·	F	F	R	F	R	F	·	·	·	·	R	·	·	·	F	F	F	F	F	R	R	R	F	F	F	R	F	F	F	F	F	C	F	F	F	R	R	R	·	*Discoaster falcatus*
F	R	F	F	F	F	F	·	R	F	·	·	·	·	R	·	·	·	R	R	·	F	R	·	F	R	·	F	R	R	R	F	R	R	·	F	F	F	R	F	F	F	F	*Discoaster lenticularis*
·	·	·	·	·	·	F	·	F	·	·	·	·	·	R	·	·	·	F	·	R	F	·	R	R	R	F	·	R	R	·	·	·	·	·	·	·	·	·	·	·	·	·	*Discoaster mediosus*
·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Discoaster megastypus*
·	·	F	F	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	R	·	R	R	R	F	F	·	·	F	F	·	·	R	·	·	·	R	·	·	·	·	·	·	*Discoaster* aff. *D. mohleri*
C	F	C	F	C	C	F	C	F	C	R	·	·	·	F	·	·	·	R	C	C	C	F	C	C	C	C	F	F	C	F	F	F	C	C	C	F	F	F	C	F	F	F	*Discoaster multiradiatus*
C	C	F	C	F	C	F	R	·	F	·	·	·	·	R	·	·	·	·	·	·	·	F	·	·	·	·	R	·	·	R	·	·	·	·	·	·	·	·	·	·	R	R	*Discoaster salisburgensis*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	R	R	R	·	·	·	·	·	F	F	F	F	·	F	·	·	·	F	R	·	R	·	R	·	*Discoaster splendidus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	*Discoaster wemmelensis*
·	·	·	R	F	·	·	R	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	F	F	·	·	·	·	·	·	F	·	·	·	·	·	R	R	R	*Discoaster* spp.
·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	R	R	R	·	·	·	·	F	R	R	·	F	R	·	·	·	·	*Ellipsolithus anadoluensis*
C	F	C	C	F	C	F	C	C	F	·	·	·	·	F	·	·	·	F	F	C	C	C	C	C	C	C	C	F	C	F	C	F	F	R	F	F	·	F	C	F	F	F	*Ellipsolithus distichus*
·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	F	·	R	·	*Ellipsolithus macellus*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Ericsonia cava*
·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	R	·	R	·	·	·	·	·	F	·	·	·	C	·	F	·	·	·	·	·	·	·	·	·	*Ericsonia robusta*
·	·	·	·	·	C	F	·	F	R	·	·	·	·	R	·	·	·	R	F	R	R	F	R	R	R	C	C	R	F	R	C	F	·	C	·	·	·	·	·	·	·	F	*Ericsonia subpertusa*
·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	R	·	·	F	·	·	·	·	·	R	·	·	·	·	*Fasciculithus aubertae*
C	C	C	F	F	C	C	R	F	R	R	·	·	·	R	·	·	·	R	F	F	F	F	F	R	R	F	C	F	F	C	F	C	F	C	C	C	C	F	F	R	F	R	*Fasciculithus involutus*
·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	*Fasciculithus mitreus*

Table 2 *(continued)*. Calcareous nannofossil occurrences in the South Dover Bridge core, Maryland, for the Paleocene and early Eocene. Species abundance: A, abundant or 1 per every field of view (FOV); C, common or 2 per 1-10 FOV's; F, frequent or 1 per 11-100 FOV's; R, rare or 1 per >100 FOV's. Slide abundance: A, abundant or >10 specimens per FOV; C, common or 1-10 specimens per FOV; F, frequent or 1 specimen per 1-10 FOV's; R, rare or 1 specimen per 11-100 FOV's; B, barren of calcareous nannofossils. Preservation: VG, very good; G, good; M, moderate; P, poor. Other symbols: rw, reworked specimen; ct, contamination from higher in the core; ?, questionable occurrence. Shaded area indicates dissolution interval at the base of the Eocene.

Series	late Paleocene																																										
Formation	Aquia										Marlboro Clay																																
Zone (Martini, 1971)	NP 9a																							NP9b				NP 10															
Depth (m)	210.0	209.1	208.2	207.6	207.4	206.9	205.7	204.7	204.3	204.1	203.9	203.8	203.6	203.5	203.4	203.1	203.0	202.8	202.7	202.5	202.4	202.2	202.1	201.9	201.7	201.6	201.3	200.5	199.8	198.7	198.2	197.8	196.6	195.7	195.3	194.8	193.9	193.0	192.3	192.1	190.8	190.0	189.1
Depth (ft)	689.0	686.0	683.0	681.0	680.3	678.7	675.0	671.5	670.3	669.5	669.0	668.5	668.0	667.5	667.2	666.5	666.0	665.5	665.0	664.5	664.0	663.5	663.0	662.5	662.0	661.5	660.3	658.0	655.6	652.0	650.3	649.0	645.0	642.0	640.8	639.0	636.0	633.3	630.8	630.1	626.0	623.4	620.5
Fasciculithus richardii	R	F	·	·	·	F	·	·	·	F	R	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fasciculithus schaubii	·	R	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Fasciculithus sidereus	·	·	F	F	R	F	F	·	·	·	·	·	·	·	·	·	·	·	R	R	·	F	F	·	R	·	F	R	F	·	F	·	·	·	·	·	·	·	·	·	·	·	·
Fasciculithus thomasii	F	F	R	F	·	F	F	·	·	F	·	·	·	·	R	·	·	·	·	F	·	·	·	·	·	R	F	·	R	R	R	·	·	R	R	·	R	·	·	R	·	R	·
Fasciculithus tympaniformis	F	R	·	·	F	·	·	F	F	F	·	·	·	·	·	·	·	·	·	R	·	·	F	R	R	·	·	·	·	·	F	R	R	·	R	·	·	F	R	·	·	F	·
Fasciculithus sp.	R	R	R	R	R	R	R	·	F	R	·	·	·	·	R	·	·	·	R	F	F	F	R	R	R	·	R	R	R	F	F	F	F	R	F	F	·	F	R	R	R	R	R
Goniolithus fluckigeri	·	·	·	·	·	·	·	R	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Heliolithus sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·
Holodiscolithus macroporus	·	·	·	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Holodiscolithus serus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Hornibrookina arca	·	·	·	·	·	·	·	A	A	C	·	·	·	·	R	·	·	·	·	F	·	·	F	·	·	·	R	·	F	F	·	R	·	·	·	·	F	·	·	·	·	·	·
Hornibrookina weimerae	C	F	·	C	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lanternithus sp.	·	·	·	·	·	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Leesella? sp.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Lophodolithus nascens	C	F	F	R	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	F	·	·	·	R	F	F	F	·	·	·	·	·	·	R	·	·	·	·	F	·
Markalius apertus	F	R	F	R	F	F	F	F	F	·	·	·	·	·	·	·	·	·	R	F	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	F	F	·	·	·	·	·	R
Markalius inversus	R	·	F	F	R	R	F	R	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	F	F	R	R	F	F	F	R	F	R	F	F	R	R	·
Micrantholithus excelsus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·
Neochiastozygus concinnus	·	·	·	·	·	·	·	C	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	C	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Neochiastozygus denticulatus	·	·	·	·	·	·	·	·	?	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Neochiastozygus digitosus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	R	·	R	·	·	·	·	·	·	·	·	·	·	·	·
Neochiastozygus distentus	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Neochiastozygus dubius	·	·	·	·	F	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	?	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Neochiastozygus junctus	R	·	F	·	·	F	·	F	·	R	·	·	·	·	R	·	·	·	F	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	F	C	C	C	C	C	C	C	C
Neochiastozygus rosenkrantzii	·	·	·	·	·	·	·	·	?	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	R	·	·	·	R	·	·	·	F	F	·	·	·	R	R	·
Neochiastozygus tenansa	R	·	F	F	R	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	R	·	·	·	R	R	·	·	·	·
Neococcolithes protenus	F	F	C	C	·	C	F	F	C	·	·	·	·	·	·	·	·	·	·	F	R	F	F	F	F	C	C	F	C	F	F	F	F	F	C	F	C	F	F	C	F	C	F
Neocrepidolithus sp.	·	F	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Placozygus sigmoides	·	R	R	C	F	F	R	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	C	R	R	·	·	·	·	·	F	F	C	F	R	·	·	·
Pontosphaera plana	·	?	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·	·	·	R	R	·	·	·	R	R	·	R	·	·	·	·	·	·	·	R	·	·	·
Pontosphaera sp.	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	R	·	·	·	·	·	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·
Prinsius bisulcus	R	R	R	R	F	R	R	F	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Prinsius dimorphosus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Rhomboaster bramlettei	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	R	F	R	F	R	R	R	F	F	F	F	F	F	R
Semihololithus biscayae	·	·	R	F	R	F	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Semihololithus dimidius	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·
Sphenolithus moriformis	·	·	R	·	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sphenolithus primus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	R	F	·	·	F	·	·	R	·
Toweius callosus	F	·	F	·	·	F	C	F	·	F	·	·	·	·	F	·	·	·	F	·	·	R	·	·	R	R	F	R	·	·	·	R	·	·	·	R	F	F	·	R	·	F	R
Toweius eminens var. *eminens*	C	C	C	C	F	F	C	C	C	R	·	·	·	·	R	·	·	·	R	R	R	F	C	R	C	R	F	F	R	·	·	R	·	·	R	·	·	·	F	·	C	·	F
Toweius eminens var. *tovae*	C	F	C	C	C	C	C	A	C	R	·	·	·	·	R	·	·	·	F	F	F	F	·	F	F	F	·	·	·	R	F	C	R	R	·	·	·	·	·	·	·	·	·
Toweius occultatus	F	R	C	F	R	·	F	F	R	·	·	·	·	·	·	·	·	·	F	F	F	F	F	R	C	F	C	C	F	R	·	·	·	·	·	·	·	·	R	·	C	F	F
Toweius pertusus	A	C	C	A	A	A	A	A	A	C	·	·	·	·	F	·	·	·	C	C	A	A	C	A	A	A	A	A	A	C	C	A	C	A	C	A	A	A	C	A	A	C	C
Toweius serotinus	·	·	ct	·	·	·	·	·	·	F	·	·	·	·	·	·	·	·	R	F	R	·	F	R	R	·	·	F	C	R	C	C	C	C	F	C	C	C	F	C	C	C	C
Transversopontis pulcher	·	·	·	·	·	·	·	F	R	·	·	·	·	·	·	·	·	·	·	R	·	·	·	R	·	·	R	F	C	F	C	F	F	C	R	C	F	C	C	C	C	C	F
Umbilicosphaera? jordanii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·	R	·	·	·	·	·	·
Zygodiscus herlynii	R	C	C	C	C	C	C	C	C	R	·	·	·	·	R	·	·	·	R	F	R	F	F	F	F	C	F	F	F	F	R	·	·	R	F	F	·	·	F	·	F	F	·
Zygodiscus sheldoniae	·	·	·	R	·	·	F	C	F	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Zygrhablithus bijugatus	·	·	·	F	F	F	C	R	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	F	·	·
Zygrhablithus bijugatus nolfii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	R	·
Calcareous dinoflagellates spp.	F	F	F	F	F	F	F	F	F	R	·	·	·	·	·	·	·	·	·	·	·	·	·	R	R	·	·	F	F	R	F	F	·	F	R	R	·	·	F	·	F	R	·
Indet. sp.	·	R	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Abundance	A-	C	C+	A	A+	A	A	A	A+	F	R	B	B	B	F	B	B	B	F	C	C	C	C	C	C	C	A	A	A	C+	A	C	C	C+	A	A-	C+	C	C	C	C+	C	C
Preservation	G	G	G	G	G	G	G	G	G	P+	P				M-				M	M	M	M	M+	M	M	G	G	G	G	G	G	G	G	G	M+	G	G	M+	M+	M+	G	G	M-

Series	Formation	Zone (Martini, 1971)	Depth (m)	Depth (ft)	*Biantholithus astralis*	*Biscutum* sp.	*Blackites creber*	*Blackites fustis*	*Blackites gladius*	*Blackites gamai*	*Blackites herculesii*	*Blackites morionum*	*Blackites* cf. *B. morionum*	*Blackites perlongus*	*Blackites spinosus*	*Blackites stilus*	*Blackites truncatus*	*Blackites* sp.	*Bomolithus supremus*	*Braarudosphaera sequela* n. sp.	*Calcidiscus? bicircus*	*Calcidiscus? pacificus*	*Calcidiscus? parvicrucis*	*Calcidiscus? protoannulus*	*Campylosphaera dela*	*Campylosphaera* sp.	*Chiasmolithus bidens*	*Chiasmolithus consuetus*	*Chiasmolithus eograndis*	*Chiasmolithus expansus*	*Chiasmolithus frequens*	*Chiasmolithus grandis*	*Chiasmolithus nitidus*	*Chiasmolithus titus*	*Chiasmolithus* sp.	*Chiphragmalithus armatus*	*Chiphragmalithus barbatus*	*Clausicoccus fenestratus*	*Clausicoccus subdistichus*	*Coccolithus pelagicus*
early Eocene	Nanjemoy	NP 13	172.2	564.9	.	.	R	.	R	.	.	.	.	.	R	R	.	R	.	.	R	F	R	.	F	.	C	.	.	F	.	.	R	.	.	C	.	R	R	A
			175.3	575.0	.	.	F	.	.	.	.	.	.	F	.	.	.	.	.	.	.	R	F	.	R	.	C	.	.	F	.	F	.	R	.	.	.	.	F	A
		NP 12	178.3	585.0	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	F	?	C	.	F	.	C	F	.	.	.	.	.	.	.	F	R	A
			181.6	595.8	.	.	.	.	.	.	R	.	.	F	.	.	.	.	.	.	.	.	F	.	F	.	.	.	C	.	R	F	.	.	F	.	.	.	.	A
			182.6	599.2	.	.	.	R	.	.	.	.	R	.	R	.	C	.	.	.	.	.	R	.	C	.	C	F	.	.	F	C	.	.	.	.	.	.	R	A
			184.2	604.4	.	R	.	.	.	.	F	.	.	.	R	.	F	.	.	.	.	.	F	.	F	.	.	R	.	.	F	F	.	.	.	.	.	R	F	C
		NP 11	185.0	607.0	.	.	.	.	.	.	C	R	.	F	.	.	.	.	.	.	.	R	R	C	C	.	C	F	.	.	R	F	.	.	.	.	R	.	R	A
			185.8	609.8	.	.	.	.	R	.	F	.	.	.	.	.	R	F	.	.	.	F	.	.	C	.	C	F	.	.	.	.	.	.	.	.	.	.	.	A
			186.1	610.5	.	.	.	.	.	R	C	.	.	F	.	.	.	.	.	R	.	F	F	.	C	R	C	F	F	.	.	.	.	.	.	.	.	.	R	A
			186.8	613.0	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.	C	F	C	C	.	.	F	R	.	.	.	.	.	F	.	A
			187.1	613.7	.	.	F	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	F	.	C	.	C	.	.	.	F	.	.	.	.	.	.	.	F	C
		NP 10	187.5	615.1	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	C	.	.	.	F	.	.	.	.	.	.	.	R	C
			187.8	616.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	F	R	C	R	.	.	.	.	.	.	.	.	.	F	.	A
			188.0	619.9	R	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.	.	R	.	C	R	.	.	F	.	.	.	.	.	.	R	.	C

Series	Formation	Zone (Martini, 1971)	Depth (m)	Depth (ft)	*Coccolithus* sp.	*Coronocyclus bramlettei*	*Cruciplacolithus latipons*	*Cruciplacolithus primus*	*Cruciplacolithus vanheckae*	*Cruciplacolithus* sp.	*Cyclagelosphaera prima*	*Cyclicargolithus luminis*	*Daktylithus punctulata*	*Discoaster acutus*	*Discoaster barbadiensis*	*Discoaster binodosus*	*Discoaster deflandrei*	*Discoaster diastypus*	*Discoaster distinctus*	*Discoaster falcatus*	*Discoaster gemmeus*	*Discoaster kuepperi*	*Discoaster lenticularis*	*Discoaster lodoensis*	*Discoaster mediosus*	*Discoaster* aff. *D. mohleri*	*Discoaster multiradiatus*	*Discoaster salisburgensis*	*Discoaster* spp.	*Ellipsolithus anadoluensis*	*Ellipsolithus aubryae* n. sp.	*Ellipsolithus distichus*	*Ellipsolithus macellus*	*Ellipsolithus* sp.	*Ericsonia cava*	*Ericsonia subpertusa*	*Fasciculithus involutus*	*Fasciculithus* sp.	*Girgisia gammation*	*Goniolithus fluckigeri*
early Eocene	Nanjemoy	NP 13	172.2	564.9	C	F	.	.	.	R	.	.	.	.	F	C	F	.	R	.	.	C	R	C	.	.	.	F	F	.	.	.	.	.	.	F	.	.	R	.
			175.3	575.0	C	C	.	.	.	.	.	.	.	.	F	F	.	.	C	.	.	C	.	C	.	.	.	F	F	.	.	.	.	.	.	C	.	.	.	.
		NP 12	178.3	585.0	R	.	.	.	.	.	.	F	.	.	.	R	F	.	.	.	.	C	.	R	.	.	.	.	R	.	.	.	.	.	.	F	.	.	F	.
			181.6	595.8	.	F	.	.	.	.	.	.	F	.	F	R	F	.	.	.	.	C	.	F	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	R
			182.6	599.2	.	F	.	.	?	.	.	.	.	.	.	R	.	F	.	.	.	C	.	F	.	.	.	F	.	R	.	.	.	.	F	.	.	.	F	.
			184.2	604.4	.	F	.	.	.	.	.	R	.	F	.	F	R	.	.	.	.	C	R	R	.	.	.	R	.	.	.	.	R	.	F	R	.	.	R	.
		NP 11	185.0	607.0	.	F	.	.	.	.	R	.	.	.	F	F	.	F	.	.	.	F	.	.	.	.	.	R	F	R	.	.	F	.	F	.	.	.	.	.
			185.8	609.8	.	F	.	.	.	.	.	C	.	.	R	F	.	F	.	.	.	.	F	.	.	?	R	.	F	R	.	.	C	.	.	.	.	.	.	.
			186.1	610.5	.	F	.	.	.	.	F	.	.	.	F	F	.	.	.	.	.	F	.	.	.	.	.	.	.	R	F	.	C	.	.	R	.	.	R	F
			186.8	613.0	R	C	R	R	.	.	F	.	.	.	C	F	.	.	.	.	?	F	.	.	.	.	F	F	F	.	R	.	F	R	F	.	.	.	.	.
			187.1	613.7	.	C	.	.	.	.	R	.	.	.	C	.	.	F	.	.	F	.	.	.	R	.	F	R	.	.	R	F	C	.	.	.	.	R	.	.
		NP 10	187.5	615.1	.	F	.	F	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	R	?	F	F	.	F	.	F	F	.	.	F	.	F	.	.
			187.8	616.3	.	C	.	.	.	.	R	.	.	.	F	F	.	R	.	.	.	.	.	.	.	R	C	R	R	.	.	F	.	.	.	F	F	R	.	F
			188.0	619.9	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	R	.	F	.	.	R	.	C	R	.	.	F	.	?	.	.

Series	Formation	Zone (Martini, 1971)	Depth (m)	Depth (ft)	*Helicosphaera seminulum*	*Holodiscolithus geisenii*	*Holodiscolithus macroporus*	*Holodiscolithus solidus*	*Hornibrookina arca*	*Hornibrookina weimerae* n. sp.	*Lophodolithus nascens*	*Lophodolithus reniformis*	*Lophodolithus* spp.	*Markalius apertus*	*Markalius inversus*	*Micrantholithus astrum*	*Micrantholithus* sp.	*Neochiastozygus concinnus*	*Neochiastozygus distentus*	*Neochiastozygus junctus*	*Neochiastozygus rosenkrantzii*	*Neochiastozygus tenansa*	*Neochiastozygus* spp.	*Neococcolithes dubius*	*Neococcolithes minutus*	*Neococcolithes protenus*	*Neocrepidolithus bukryi*	*Neocrepidolithus* sp.	*Pedinocyclus larvalis*	*Pontosphaera distincta*	*Pontosphaera duocava*	*Pontosphaera multipora*	*Pontosphaera pectinata*	*Pontosphaera plana*	*Pontosphaera pulchra*	*Pontosphaera versa*	*Pontosphaera* sp.	*Reticulofenestra dictyoda*	*Reticulofenestra lockeri*	*Reticulofenestra minutus*
early Eocene	Nanjemoy	NP 13	172.2	564.9	F	R	.	.	.	.	C	F	.	.	C	.	.	.	.	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	.	C	.	C
			175.3	575.0	F	.	.	.	.	.	.	.	.	F	R	.	.	.	.	.	.	.	.	.	F	C	.	.	.	.	.	.	.	.	.	.	.	C	?	.
		NP 12	178.3	585.0	F	.	.	.	.	.	.	R	.	.	F	.	.	F	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	F	.	C	.	.
			181.6	595.8	.	.	.	.	.	.	F	F	R	.	F	.	.	.	.	.	.	.	.	.	F	F	.	.	.	.	.	.	.	R	.	C	.	.	.	.
			182.6	599.2	.	.	.	.	.	.	F	.	.	.	C	R	R	.	.	.	.	.	.	.	C	C	.	.	.	.	R	F	.	R	.	C	.	.	.	.
			184.2	604.4	.	.	.	.	.	.	R	.	.	F	F	.	.	.	.	.	.	.	.	.	F	C	.	.	.	.	.	.	.	.	.	C	.	.	.	.
		NP 11	185.0	607.0	.	.	F	.	.	.	C	.	.	.	F	.	.	.	.	.	.	.	F	.	C	C	.	.	.	.	.	.	.	C	.	F	.	.	.	.
			185.8	609.8	.	.	.	.	.	.	F	.	.	.	F	.	.	.	C	.	C	.	.	C	F	C	.	.	.	.	.	.	.	.	F	F	.	.	.	.
			186.1	610.5	.	.	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	.	.	F	C	.	.	R	.	.	.	.	F	.	F	F	.	.	.
			186.8	613.0	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	R	.	.	.	F	C	.	.	.	.	.	.	.	F	.	F	.	.	.	.
			187.1	613.7	.	.	.	R	R	.	R	.	.	.	F	.	.	.	.	F	.	R	.	.	F	F	R	.	.	.	.	R	R	.	.	.	.	F	.	.
		NP 10	187.5	615.1	.	.	.	.	F	R	.	.	.	.	.	.	.	R	.	F	R	R	F	.	.	F	R	F	.	F	.	.	.	F	.	.	.	.	.	.
			187.8	616.3	.	.	.	.	F	.	.	.	.	R	.	.	.	.	.	F	F	.	.	.	F	F	.	F	.	.	.	.	.	F	.	.	.	.	.	.
			188.0	619.9	.	.	.	.	.	.	.	.	R	.	F	.	.	.	.	C	.	.	.	.	F	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Series	Formation	Zone (Martini, 1971)	Depth (m)	Depth (ft)	*Rhabdosphaera pinguis*	*Rhomboaster bramlettei*	*Scapholithus fossilis*	*Scyphosphaera* sp.	*Semihololithus biscayae*	*Sphenolithus anarrhopus*	*Sphenolithus editus*	*Sphenolithus primus*	*Sphenolithus radians*	*Sphenolithus* cf. *S. radians*	*Sphenolithus spiniger*	*Toweius callosus*	*Toweius eminens*	*Toweius? magnicrassus*	*Toweius occultatus*	*Toweius pertusus*	*Toweius serotinus*	*Toweius* sp. 2 of Bown	*Transversopontis ocellata*	*Transversopontis pulcher*	*Transversopontis pulcheroides*	*Tribrachiatus orthostylus*	*Umbilicosphaera? jordanii*	*Zygodiscus herlynii*	*Zygrhablithus bijugatus*	*Zygrhablithus bijugatus nolffi*	Calcareous dinoflagellate spp.	Cret. species	Abundance	Preservation
early Eocene	Nanjemoy	NP 13	172.2	564.9	.	.	.	.	.	.	.	F	.	.	.	R	.	.	A	.	.	.	F	A	.	.	.	.	C	.	.	.	A+	G
			175.3	575.0	.	.	.	.	.	.	.	.	F	.	.	.	.	.	A	F	rw	.	F	A	F	.	.	.	C	.	.	rw	A+	G
		NP 12	178.3	585.0	.	.	.	R	.	.	.	.	R	.	.	C	.	.	A	.	.	.	F	C	.	F	.	.	R	.	.	.	A	G
			181.6	595.8	.	.	F	.	.	F	F	C	C	.	.	A	.	.	C	F	.	R	F	C	F	F	.	R	C	R	F	.	A+	G
			182.6	599.2	.	.	F	.	.	F	.	F	C	.	.	A	.	C	C	A	.	.	.	C	.	F	.	.	C	F	C	.	A	G
			184.2	604.4	.	.	.	.	.	F	.	F	F	.	.	A	.	C	C	A	.	.	.	C	F	F	.	.	C	.	.	.	A	G
		NP 11	185.0	607.0	.	.	F	.	.	F	.	C	F	.	?	C	.	C	F	A	.	.	.	C	.	C	.	F	R	.	F	.	A	G
			185.8	609.8	F	.	.	.	.	F	R	C	F	.	.	A	.	C	C	F	.	.	C	C	.	C	.	F	R	.	F	.	A+	G
			186.1	610.5	.	.	.	.	.	C	F	C	F	F	.	A	.	C	F	A	.	.	F	A	.	.	.	C	F	.	F	.	A	G
			186.8	613.0	.	.	.	.	.	F	.	R	F	.	.	A	.	C	F	C	.	.	R	C	.	F	.	F	F	.	F	.	A	G
			187.1	613.7	.	rw	.	.	R	.	.	F	R	.	.	C	.	F	F	A	rw	.	.	C	.	R	.	F	F	F	.	.	A	G
		NP 10	187.5	615.1	.	R	F	.	R	.	.	F	.	.	.	C	F	C	.	A	.	.	.	C	.	.	F	C	C	.	F	.	A	G
			187.8	616.3	.	R	.	.	.	.	.	F	.	.	.	A	.	F	F	A	.	.	.	F	.	.	.	F	.	.	F	.	A	M
			188.0	619.9	.	F	.	.	.	.	.	.	.	.	.	C	F	.	F	C	C	.	.	F	.	.	.	R	R	.	R	.	C+	G

Table 3. Calcareous nannofossil occurrences in the South Dover Bridge core, Maryland, for the early Eocene. Species abundance: A, abundant or 1 per every field of view (FOV); C, common or 2 per 1-10 FOV's; F, frequent or 1 per 11-100 FOV's; R, rare or 1 per >100 FOV's. Slide abundance: A, abundant or >10 specimens per FOV; C, common or 1-10 specimens per FOV. Preservation: G, good; M, moderate. Other symbols: rw, reworked specimen; ?, questionable occurrence.

Depth (m)	102.2	103.7	105.8	113.7	119.8	139.0	142.5	145.2	148.1	151.0	154.2	157.3	160.3	163.4	166.1	169.2
Depth (ft)	335.3	340.2	347.2	373.0	393.0	456.0	467.5	476.5	486.0	495.5	506.0	516.0	526.0	536.0	545.0	555.0
Series	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene
Formation	Piney Point	Piney Point	Piney Point	Piney Point	Piney Point	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit
Zone (Martini, 1971)	NP 16?	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 15c?	NP 15b	NP 15b	NP 15b	NP 15b	NP 14 upper	NP 14 upper
Birkelundia arenosa	.	F	.	.	.	.	R	.	F	.	F	.	R	.	.	F
Biscutum constans	.	F	.	.	.	F	.	.	F	.	F	.	R	.	.	F
Biscutum sp.	.	.	F	.	F	.	.	.	F	.	.	.	.	.	.	.
Blackites cf. *B. bullatus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.
Blackites cf. *B. clavus*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Blackites creber	.	.	.	.	F	F	.	.	F	C	.	.	.	.	F	.
Blackites dupuisii	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
Blackites gladius	.	R	.	.	.	R	F	.	R	.	R	R	F	F	F	R
Blackites gamai	.	.	.	.	.	.	.	R	.	F	.	.	.	.	.	.
Blackites globosus	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.
Blackites inflata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	R
Blackites morionum	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Blackites perlongus	.	F	R	.	R	R	C	F	C	F	F	F	F	F	R	F
Blackites rotundus	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.
Blackites spinosus	.	F	F	F	R	C	C	C	R	.	F	R	F	F	R	R
Blackites stilus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R
Blackites sp.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
Braarudosphaera bigelowii	.	.	.	F	F	F	C	F	F	C	F	F	F	R	.	.
Bramletteius serraculoides	.	.	.	.	.	.	F	.	F	F	.	.	.	.	.	.
Calcidiscus? bicircus	.	F	.	.	.	R	F	.	.	.	F	.	.	.	F	F
Calcidiscus? parvicrucis	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	F
Calcidiscus? protoannulus	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.
Calciosolenia alternans	.	F	.	.	.	.	.	R	F	.	.	.	.	.	.	.
Calciosolenia fossilis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
Camplyosphaera dela	.	F	.	.	.	.	.	R	.	F	.	.	.	.	.	F
Camplyosphaera sp.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chiasmolithus consuetus	.	.	.	.	.	.	.	.	F	.	F	F	.	F	F	.
Chiasmolithus expansus	.	.	.	.	.	.	F	.	.	R	F	F	F	R	F	R
Chiasmolithus gigas	.	.	.	.	.	.	.	.	.	.	C	F	.	R	.	.
Chiasmolithus grandis	.	.	.	.	.	R	R	F	F	.	.	.	.	.	.	R
Chiasmolithus nitidus	F	R	.	.	.	F	.	.	.	.	F	.	.	.	.	.
Chiasmolithus solitus	C	C	C	C	C	A	A	A	C	A	C	C	C	A	A	C
Chiasmolithus titus	.	F	R	R	.	.	.	.	.	.	.	.	.	.	.	.
Clathrolithus ellipticus	.	.	.	.	.	F	F	.	.	.	.	.	.	.	.	.
Clausicoccus fenestratus	.	.	.	.	.	C	.	.	F	F	R	F	F	.	.	.
Clausicoccus subdistichus	.	.	R	.	C	F	F	.	.	R	F	F	.	F	C	C

Depth (m)	102.2	103.7	105.8	113.7	119.8	139.0	142.5	145.2	148.1	151.0	154.2	157.3	160.3	163.4	166.1	169.2
Depth (ft)	335.3	340.2	347.2	373.0	393.0	456.0	467.5	476.5	486.0	495.5	506.0	516.0	526.0	536.0	545.0	555.0
Series	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene
Formation	Piney Point	Piney Point	Piney Point	Piney Point	Piney Point	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit
Zone (Martini, 1971)	NP 16?	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 15c?	NP 15b	NP 15b	NP 15b	NP 15b	NP 14 upper	NP 14 upper
Coccolithus latus	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.
Coccolithus mutatus	.	.	.	.	.	.	.	.	.	.	.	.	R	F	F	R
Coccolithus pelagicus	C	C	C	C	C	A	A	A	A	A	A	A	A	A	A	A
Coccolithus staurion	.	.	.	.	.	.	.	.	.	.	.	R	.	.	.	R
Coccolithus sp.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coronocyclus bramlettei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Coronocyclus nitescens	.	.	F	R	.	F	F	.	.	F	F	F	.	F	F	.
Cribrocentrum reticulatum	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.
Cruciplacolithus cruciformis	.	.	.	.	.	.	.	R	R	.	.	.	.	.	.	.
Cruciplacolithus latipons	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.	.
Cyclagelosphaera prima	.	.	.	R	R	F	.	.	.	.	.	.	F	.	?	.
Cyclicargolithus floridanus	.	F	.	.	.	.	F	R	.	.	.	.	.	F	R	F
Cyclicargolithus luminis	.	F	.	.	.	F	F	F	R	F	F	C	F	F	C	F
Daktylethra basilica n. sp.	.	.	.	.	.	C	C	C	F	.	.	.	.	.	.	.
Daktylithus punctulata	.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.
Dictyococcites bisectus	.	?	?	.	.	.	F	?	.	.	.	.	F	.	?	.
Dictyococcites callidus	.	.	.	.	.	.	A	C	F	C	F	C	F	F	.	.
Dictyococcites daviesii	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dictyococcites scrippsae	.	.	.	.	.	.	.	.	.	.	.	.	.	?	.	.
Discoaster barbadiensis	.	R	.	.	.	F	R	C	F	C	.	C	F	C	F	F
Discoaster bifax	.	R	.	.	R	.	C	C	C	.	.	.	.	.	.	.
Discoaster binodosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Discoaster deflandrei	.	F	.	.	.	.	F	C	F	F	.	F	.	R	F	F
Discoaster distinctus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Discoaster gemmifer	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
Discoaster germanicus	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.
Discoaster kuepperi	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C
Discoaster lodoensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	F
Discoaster cf. *D. mahmoudii*	.	R	.	.	.	.	.	R	F	.	.	.	.	.	.	.
Discoaster saipanensis	.	.	.	.	.	R	C	.	.	.	R	.	.	F	C	R
Discoaster sublodoensis	.	.	.	.	.	.	.	.	.	.	.	.	R	R	F	.
Discoaster wemmelensis	.	.	.	.	.	R	C	F	F	F	.	F	F	C	F	.
Discoaster spp.	.	R	F	.	F	F	.	C	F	F	.	.	.	.	C	F
Ellipsolithus lajollaensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
Ericsonia cava	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
Ericsonia formosa	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	R

Depth (m)	102.2	103.7	105.8	113.7	119.8	139.0	142.5	145.2	148.1	151.0	154.2	157.3	160.3	163.4	166.1	169.2
Depth (ft)	335.3	340.2	347.2	373.0	393.0	456.0	467.5	476.5	486.0	495.5	506.0	516.0	526.0	536.0	545.0	555.0
Series	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene
Formation	Piney Point	Piney Point	Piney Point	Piney Point	Piney Point	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit
Zone (Martini, 1971)	NP 16?	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 15c?	NP 15b	NP 15b	NP 15b	NP 15b	NP 14 upper	NP 14 upper
Ericsonia subpertusa	F	F	.	.	.	C	C	C	C	C	C	F	C	C	C	C
Girgisia gammation	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R
Goniolithus fluckigeri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	R
Helicolithus compactus	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
Helicosphaera bramlettei	.	R	.	.	R	.	.	.	F	.	.	.	.	.	.	.
Helicosphaera lophota	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	F
Helicosphaera reticulata	.	.	.	.	.	R	R	F	F	.	.	.	.	.	.	.
Helicosphaera seminulum	.	.	.	.	F	C	F	C	C	C	.	F	R	R	F	C
Holodiscolithus geisenii	.	.	.	.	.	R	.	R	.	.	.	.	.	.	.	.
Holodiscolithus macroporus	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.
Lanternithus arcanus	.	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.
Lithostromation operosum	.	.	.	.	.	F	.	.	.	.	.	R	.	.	.	.
Lithostromation perdurum	.	.	.	.	.	.	.	.	.	.	R	.	.	.	.	.
Lithostromation simplex	.	F	.	.	.	F	F	F	F	F	.	.	.	.	.	R
Lophodolithus acutus	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Lophodolithus mochloporus	.	.	.	.	.	.	.	.	.	.	.	R	.	.	R	.
Lophodolithus nascens	.	.	.	.	.	.	.	.	.	R	.	.	.	.	R	.
Markalius apertus	.	.	.	.	F	R	.	.	.	.	.	.	.	.	.	R
Markalius inversus	.	F	R	R	F	F	R	C	F	F	F	F	R	R	F	F
Micrantholithus astrum	.	.	.	.	.	.	R	.	.	.	.	.	.	?	.	.
Micrantholithus attenuatus	.	.	.	.	.	.	.	.	.	.	.	.	C	A	.	R
Nannotetrina cristata	.	.	.	.	.	.	.	?	.	.	.	.	.	.	.	C
Nannotetrina sp.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.
Neochiastozygus dubius	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Neochiastozygus spp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
Neococcolithes minutus	F	F	R	F	F	C	C	A	C	C	C	C	C	C	C	F
Neococcolithes protenus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.
Pedinocyclus larvalis	.	F	.	.	.	.	.	.	.	.	.	.	R	R	F	.
Pemma basquense	F	F	R	F	F	R	C	F	F	F	.	.	R	.	.	.
Pemma bybelliae n. sp.	.	.	.	.	.	R	R	.	.	.	.	.	.	.	.	.
Pontosphaera clinosulcatus	R	F	R	R	R	.	.	.	.	.	.	.	.	.	.	.
Pontosphaera distincta	.	.	.	.	.	.	R	.	C	C	.	.	.	.	.	.
Pontosphaera formosa	.	.	.	.	.	.	.	R	F	R	.	.	.	.	.	.
Pontosphaera multipora	.	R	.	.	F	F	C	C	C	C	C	C	F	R	F	.
Pontosphaera perforomarginata	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.
Pontosphaera plana	.	F	.	.	.	R	.	F	F	C	R	F	F	F	.	F

Depth (m)	102.2	103.7	105.8	113.7	119.8	139.0	142.5	145.2	148.1	151.0	154.2	157.3	160.3	163.4	166.1	169.2
Depth (ft)	335.3	340.2	347.2	373.0	393.0	456.0	467.5	476.5	486.0	495.5	506.0	516.0	526.0	536.0	545.0	555.0
Series	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene	middle Eocene
Formation	Piney Point	Piney Point	Piney Point	Piney Point	Piney Point	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit	Unnamed Unit
Zone (Martini, 1971)	NP 16?	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 16	NP 15c?	NP 15b	NP 15b	NP 15b	NP 15b	NP 14 upper	NP 14 upper
Pontosphaera punctosa	.	.	.	.	.	R	.	.	.	R	.	.	.	.	.	.
Pontosphaera cf. *P. clinosulcata*	.	.	.	.	.	R	.	.	F	.	.	.	.	.	.	.
Pseudotriquetrorhabdulus inversus	.	.	.	.	R	.	R	C	C	.	C	C	F	F	C	.
Reticulofenestra dictyoda	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	A
Reticulofenestra minutus	A	A	A	C	A	C	A	A	A	A	C	A	A	C	A	C
Reticulofenestra umbilicus	F	F	C	F	R	F	F	.	F	.	.	.	.	.	.	.
Scyphosphaera sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R
Sphenolithus furcatolithoides	.	F	F	.	F	F	R	C	F	.	.	.	.	.	.	.
Sphenolithus moriformis	.	.	.	.	.	F	.	C	F	C	F	F	F	F	C	.
Sphenolithus radians	.	R	.	.	.	F	.	R	.	.	.	.	F	F	F	F
Sphenolithus spiniger	.	F	.	.	.	F	F	F	F	F	R	F	R	F	F	.
Syracosphaera? tanzanensis	.	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.
Toweius crassus	.	.	.	.	.	.	.	.	.	.	.	C	R	F	.	.
Toweius pertusus	.	.	.	.	.	.	.	.	.	.	.	.	C	C	.	.
Transversopontis ocellata	.	.	.	.	.	F	.	.	.	.	F	R	.	.	F	R
Transversopontis cf. *T. ocellata*	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Transversopontis pulcher	R	C	R	F	F	C	A	A	C	C	C	A	C	C	A	A
Transversopontis pulcheroides	F	F	F	.	R	C	C	F	F	C	R	F	F	C	F	F
Transversopontis pulchriporous	.	R	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Transversopontis zigzag	C	F	C	C	C	F	C	F	C	C	.	.	F	.	F	.
Trochastrites hohnensis	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.
Variolia gracilimura	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Youngilithus sp.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	R	.
Zygrhablithus bijugatus	.	C	.	F	F	C	C	C	C	C	C	C	C	C	C	C
Zygrhablithus bijugatus cornutus	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.
Calcareous dinoflagellate spp.	.	F	.	.	.	R	.	.	.	.	.	.	R	.	F	F
Indet. sp.	.	.	.	.	.	R	.	.	.	.	.	.	.	.	.	.
Abundance	C	A	A	C-	A	A+	A+	A+	A+	A+	A+	A+	A+	A+	A+	A+
Preservation	M	G	G	M	G	VG	G	G	G	VG	M	M+	M+	M+	G	VG

Table 4. Calcareous nannofossil occurrences in the South Dover Bridge core, Maryland, for the middle Eocene. Species abundance: A, abundant or 1 per field of view (FOV); C, common or 1 per 1-10 FOV's; F, frequent or 1 per 11-100 FOV's; R, rare or 1 per >100 FOV's. Slide abundance: A, abundant or >10 specimens per FOV; C, common or 1-10 specimens per FOV. Preservation: VG, very good; G, good; M, moderate. Other symbols: ?, questionable occurrence.

35 species per sample, abundances of individual specimens in the SDB core are much higher than in the Tanzania material, and many species occur as frequent to common (one specimen per 11-100 fields of view (FOV) to 1 specimen per 2-10 FOV, respectively) throughout their range.

3.1.1. The Paleocene/Eocene Boundary

Calcareous nannofossil biostratigraphy, coupled with a gradual, rather than sharp, lithologic change at the Aquia/Marlboro Clay contact and a well-defined CIE, shows that the Paleocene/Eocene boundary in the SDB core is complete. The PETM hyperthermal event is documented in the SDB core by the presence of calcareous nannofossil excursion taxa (*D. anartios*, *D. araneus*, *Rhomboaster* spp., and *C. bownii*), an increase in the abundance of the dinoflagellate species *Apectodineum augustum*, a fern spike, and a dissolution interval (Willard et al., 2009; Self-Trail et al., 2010). This event and the identification of restricted taxa are documented from numerous Paleocene/Eocene boundary sites in both shallow and deep-sea settings (Kahn & Aubry, 2004; Lourens et al., 2005; Raffi et al., 2005; Gibbs et al., 2006; Jiang & Wise, 2006; Sluijs & Brinkhuis, 2009).

Missing section at the Marlboro Clay/Nanjemoy Formation contact has removed the top of the PETM interval, as well as evidence for additional hyperthermals such as the Eocene Thermal Maximum 2 (ETM2) at approximately 53.7 Ma and the H2 event (at approximately 53.3 Ma; Stap et al., 2010). These transient events ushered in a period of extreme global warmth, the Early Eocene Climatic Optimum (EECO), which lasted from approximately 51-53 million years ago (Zachos et al., 2008). Evidence for the EECO should be present in the Nanjemoy Formation of the SDB core and therefore this section of the core requires additional work.

3.1.2. Braarudosphaeraceae

Analyses of fossil and modern pentalith assemblages suggest that *Braarudosphaera* and some *Micrantholithus* species thrive in nearshore hyposaline conditions influenced by increased nutrients (Bukry, 1974; Street and Bown, 2000), although some evidence suggests that they could also flourish in areas of upwelling of cold, nutrient-rich, low salinity water (Peleo-Alampay et al., 1999; Bartol et al., 2008). During the early to middle Eocene, rapid diversification and speciation of *Pemma*, *Micrantholithus*, and *Braarudosphaeara* occurred, and Eocene representatives of this family are present in hemipelagic and shelfal settings worldwide (Bybell, 1975).

Although the paleoceanographic and paleobiogeographic conditions at SDB seem favorable for pentalith production and preservation, including location in a shelf environment, high terrigenous input, and probable hyposaline conditions, the diversity of pentaliths in SDB is relatively low (two species of *Pemma*, three species of *Micrantholithus*, and two species of *Braarudosphaera*). For comparison, Bown (2005) recorded 18 species of pentaliths from Tanzania. The difference in pentalith diversity may reflect different sedimentary conditions. The majority of previously described sections, whether dominated by terrigenous sediments (e.g. Svabenicka, 1999), clays and marls (Bybell, 1975; Bartol et al., 2008), mudstones (Bown, 2005) or deep-ocean chalks (Peleo-Alamay et al., 1999), are predominantly fine-grained. However, sediments from the SDB core are somewhat coarser grained, containing quartz-rich to glauconite-rich sand or sandy silt, especially in the Aquia Formation. Pentaliths are more abundant in the SDB core in the fine-grained Marlboro Clay and in the basal Nanjemoy Formation, which is also clay rich. The coarser grained sediments of the Aquia Formation are correlative with low planktic/benthic (P/B) ratios (Willard et al., 2009), indicating inner to middle neritic water depths, and suggest that water depth played a role in pentalith diversity.

3.1.3. Coccolithaceae

Previous work has suggested that the genus *Chiasmolithus* was typically restricted to cooler or more temperate regimes (Bukry, 1973; Wei & Wise, 1992; Persico & Villa, 2004), and analysis of sediments from the Atlantic Coastal Plain supports this interpretation. In general, *Chiasmolithus* marker species are sporadic or absent from sediments south of Cape Hatteras (Self-Trail, unpubl. data, 2010; Bybell, unpubl. data, 2010), but become more abundant and consistent north of Cape Hatteras, NC (Table 2-4). Nine *Chiasmolithus* species are consistently present from SDB and are rare to abundant in occurrence. Diversity of chiasmoliths in SDB is lowest during the Paleocene, but rapidly increases into the middle Eocene.

3.1.4. Discoasteraceae

Discoasters were typically at their most abundant in oligotrophic open-ocean, warm-water environments (Bukry, 1973; Aubry, 1992). The middle- to outer nertic setting of the SDB core was not conducive to discoaster propagation, and thus their diversity and abundance in the SDB core are relatively low when compared to open-ocean sites. Twenty-seven species were identified, with diversity being lowest in the late Paleocene and increasing to its greatest amounts in the early Eocene, during the CIE (Self-Trail et al., 2010). Discoaster diversity remained fairly stable throughout the early and middle Eocene.

3.1.5. Prinsiaceae

Specimens of the genus *Toweius* dominate the calcareous nannofossil assemblage from the late Paleocene through the early Eocene, becoming less diverse and less abundant in lower middle Eocene sediments.

3.1.6. Rhabdospheraceae

Abundant and diverse rhabdoliths are recorded from the sediments of the SDB core. Although Perch-Nielsen (1985) suggested a shelfal habitat for fossil rhabdoliths, Bown (2005) pointed out that extant species are found in both oceanic and shallow-marine conditions and suggested that their paucity in many fossil assemblages may be a result of their low preservation potential. Previous work by Bybell & Gibson (1994) and Gibson & Bybell (1994) from cores in Virginia and Maryland documented only minor assemblages of rhabdoliths from these regions.

A total of seventeen species of rhabdoliths are documented from SDB, including seven that have only been previously reported from Tanzania. Diversity increases from nine species in the early Eocene to twelve in the middle Eocene, with representatives of the informal *Blackites perlongus* group being the most common. Only two species (*B. herculesii* and *B. truncatus*) are common in the early Eocene.

Although Bown & Pearson (2009) record the presence of rhabdoliths from upper Paleocene (Zone NP 9a) sediments in Tanzania, none were found in this interval in the SDB core. The absence of rhabdoliths from cored material of Paleocene age across the Atlantic Coastal Plain, including sediments from Georgia, South Carolina, North Carolina, Virginia, Maryland and New Jersey (Self-Trail, unpubl. data, 2010; Bybell, unpubl. data, 2010), suggests that fossil rhabdoliths were responding to as yet unidentified environmental controls.

4. Systematic Paleontology

A comprehensive taxonomic review of calcareous nannofossils identified from the SDB core follows below. All illustrated taxa are included, along with short descriptions of those species only recently identified or rarely illustrated. Descriptions are also included for new taxa, problematic taxa, and those taxa requiring clarification. The classification systems of Young et al. (2003) and Young & Bown (1997) are used herein. All images are at the same magnification (x2000). Type material and digital images are stored in the calcareous nannofossil laboratory at the USGS National Center, Reston, VA. Calcareous nannofossil occurrence data from the SDB core are recorded in Tables 2-4 and comparison of occurrence data with other published sections is noted in the text.

4.1. Placolith coccoliths

Order ISOCHRYSIDALES **Pascher, 1910**
Family **PRINSIACEAE** Hay & Mohler, 1967 emend. Young & Bown, 1997

Girgisia gammation
(Bramlette & Sullivan, 1961) Varol, 1989c
Pl. 1, fig 8.

A circular form placed in the genus *Girgisia, G. gammation* is characterized by an indistinct proximal shield covered by a distal shield of almost the same diameter with a closed central area. The central area is characterized by a strongly birefringent extinction cross in the shape of a swastika. Perch-Nielsen (1985) recorded this species from NP 11-NP 16. *Girgisia gammation* is rare to frequent in lower to upper Eocene sediments of SDB. **Occurrence**: NP 11-upper NP 14.

Hornibrookina arca Bybell & Self-Trail, 1995
Pl. 1, figs 16-18.

A convexly arched species of *Hornibrookina* with a wide central area filled with transverse laths and a longitudinal bar. It has only been described from shelfal sequences (Bybell & Self-Trail, 1995; Bown, 2005; Gibbs et al., 2006). It occurs in common to abundant amounts in SDB (Table 2), and up to common amounts in the Wilson Lake core, NJ (Gibbs et al., 2006), just prior to the onset of the CIE. **Occurrence**: NP 9a-NP 10.

Hornibrookina weimerae sp. nov.
Pl. 1, figs 19-21.

Derivation of name: After the late Lisa Weimer, a graduate student in micropaleontology and physical science technician for the USGS. **Diagnosis**: Small species of *Hornibrookina* with somewhat rounded ends and a narrow central area filled by a central longitudinal bar. Individual transverse laths are impossible to discern with the light microscope. The proximal shield is relatively bright in XPL. **Differentiation**: *Hornibrookina weimerae* most closely resembles *H. teuriensis* in being elongate oval with a relatively bright distal shield. However, it is much smaller in length and diameter, with a narrower central area (Table 5). **Dimensions**: L = 2.0-2.6 μm; W = 1.2-1.7 μm. **Holotype**: Pl. 1, fig. 21. **Paratype**: Pl. 1, fig. 20. **Type locality**: SDB core, Talbot County, MD (USA). **Type level**: Upper Paleocene, Sample N12496, 207.6m (Zone NP 9a). **Occurrence**: NP 9a.

Length (μm)	Width (μm)
2.6	1.6
2.6	1.6
2.4	1.6
2.0	1.2
2.4	1.6
2.6	1.7
2.6	1.7
2.4	1.2
2.6	1.6
2.6	1.6

Table 5. Length and width measurements for *Hornibrookina weimerae* specimens.

Toweius callosus Perch-Nielsen, 1971
Pl. 1, figs 1-2.

Toweius eminens (Bramlette & Sullivan, 1961)
Gartner, 1971 var. *eminens* Bybell & Self-Trail, 1995
Pl. 1, figs 3-4.

The taxonomy of Bybell & Self-Trail (1995) for *Toweius eminens* var. *eminens* is followed herein; the two varieties of *T. eminens* are distinguished based on the number of pores in the central area. The last occurrence of *T. eminens* var. *eminens* in SDB is at the top of Zone NP 10. **Occurrence**: NP 9a-NP 10.

Toweius eminens (Bramlette & Sullivan, 1961)
Gartner, 1971 var. *tovae* Perch-Nielsen, 1971
Pl. 1, figs 5-7.

The taxonomy of Bybell & Self-Trail (1995) for *Toweius eminens* var. *tovae* is followed herein. **Occurrence**: NP 9a-NP 10.

Toweius? magnicrassus (Bukry, 1971) Romein, 1979
Pl. 1, figs 9-11.

Large, robust, elliptical species of *Toweius* with a bright central area in XPL. The proximal shield may have as many as three rows of elements around the central area (Plate 1, fig. 11). This species is identified based on its large size and very bright birefringence in XPL. Bukry (1971) identified this species from the *Discoaster lodoen-*

sis zone (NP 12); it is identified in SDB from Zone NP 11 to mid-NP 12, where it is common. Its occurrence in the uppermost two NP 10 samples is most likely due to burrowing across the unconformity between the Marlboro Clay and the overlying Nanjemoy Formation. **Occurrence**: NP 11-NP 12.

Toweius occultatus (Locker, 1967) Perch-Nielsen, 1971
Pl. 1, fig 12.

Toweius pertusus (Sullivan, 1965) Romein, 1979
Pl. 1, fig 13.

Toweius serotinus Bybell & Self-Trail, 1995
Pl. 1, figs 14-15.

Family **NOELAERHABDACEAE** Jerkovic, 1979
emend. Young & Bown, 1997

Reticulofenestra dictyoda (Deflandre *in* Deflandre & Fert, 1954) Stradner *in* Stradner & Edwards, 1968
Pl. 1, fig 22.

Reticulofenestra umbilicus (Levin, 1965)
Martini & Ritzkowski, 1968
Pl. 1, fig 23.

Order COCCOSPHAERALES **Haeckel, 1894 emend. Young & Bown, 1997**
Family **COCCOLITHACEAE** Poche, 1913 emend.
Young & Bown, 1997

Coccolithus mutatus (Perch-Nielsen, 1971) Bown, 2005
Pl. 1, fig 24.

Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Pl. 1, fig 25.

Coccolithus bownii Jiang & Wise, 2007
Pl. 1, figs 26-27. A subcircular placolith with a wide central area which occupies almost half the diameter of the nannofossil. Jiang and Wise (2007) documented this species from Zone NP 10 of the Demerara Rise, stating that it has an acme event within the PETM interval. A similar acme event is documented in Tanzania (Bown & Pearson, 2009) and from SDB (Table 2). **Occurrence**: NP 9a-NP 10.

Ericsonia subpertusa Hay & Mohler, 1967
Pl. 1, figs 28. This species is distinguished from *Coccolithus pelagicus* by its more subcircular outline and by the raised, rather than recessed, outer edge of the inner collar. Identification of heavily overgrown specimens of this species can be difficult. Bybell and Self-Trail (1995) document the presence of *E. subpertusa* into the early Eocene. **Occurrence**: NP 9a-NP 16.

Camplyosphaera dela (Bramlette & Sullivan, 1961)
Hay & Mohler, 1967
Pl. 1, figs 29-30.

Camplyosphaera differta Bown, 2010
Pl. 1, fig 31.
A medium-sized nannofossil with a narrow central area filled by two broad axial bars. This species of *Camplyosphaera* is longer and somewhat thin, and lacks the open central area, of *C. dela*. It is documented from NP 9b-NP 10 by Bown (2005, 2010). **Occurrence**: NP 10.

Cruciplacolithus frequens
(Perch-Nielsen, 1977) Romein, 1979
Pl. 1, figs 32-33.

Chiasmolithus bidens
(Bramlette & Sullivan, 1961) Hay & Mohler, 1967
Pl. 1, figs 34-35.

Chiasmolithus grandis
(Bramlette & Riedel, 1954) Hay, Mohler & Wade, 1966
Pl. 2, fig 1.

Chiasmolithus nitidus Perch-Nielsen, 1971
Pl. 2, fig 8.
A relatively small chiasmolith having a split cross that almost entirely fills up the central area. This species is similar to *C. frequens*, but can be distinguished based on its smaller size, the split cross, and the lack of discernable feet. **Occurrence**: NP 13-NP 16.

Clausicoccus fenestratus
(Deflandre & Fert, 1954) Prins, 1979
Pl. 2, figs 9-10.

?Family **CALCIDISCACEAE** Young & Bown, 1997

Coronocyclus bramlettei
(Hay & Towe, 1962) Bown, 2005
Pl. 2, figs 11-12.
Circular placolith having a narrow, bright inner cycle with non-axial extinction lines and a dark, narrow outer cycle. This species is similar to *C. nitescens*, but is smaller and narrower in overall width of the cycles and lacks the serrated appearance of the distal rim in XPL. **Occurrence**: NP 9a-NP 14.

Calcidiscus? bicircus Bown, 2005
Pl. 2, fig 13.
Circular to subcircular medium-sized placolith with a bicyclic central rim and non-birefringent distal shield. The central area is partially filled by a narrow, bright tube-cycle and can have a small, central opening. Similar to *Calcidiscus? parvicrucis*, but lacking the central axial cross. Bown (2005) recorded this species from NP 15a-17. It is recorded at SDB in lower to mid-Eocene sediments. Late Eocene sediments are missing from this site. **Occurrence**: NP 13-NP 16.

Calcidiscus? pacificanus (Bukry, 1971) Varol, 1989
Pl. 2, fig 16.

Calcidiscus? parvicrucis Bown, 2005
Pl. 2, figs 14-15.

Circular to semi-circular placoliths with a non-birefringent distal shield, and a small birefringent tube-cycle. A small axial cross fills the central area and distinguishes this species from *Calcidiscus? bicircus*. Bown (2005) recorded this species from lower Eocene sediments (Zones NP 10-11). It is recognized in Maryland from upper Paleocene through mid-Eocene sediments, although its sporadic occurrence in middle Eocene sediments may be due to reworking. This species is commonly frequent in abundance where it occurs, but gaps in its occurrence suggest that it may have been sensitive to changing paleoenvironmental parameters. **Occurrence**: NP 9a-NP 14, possibly NP 16.

4.1.1. Placolith coccoliths *incertae sedis*

Ellipsolithus anadoluensis Varol, 1989
Pl. 2, figs 17-20.

Inconspicuous *Ellipsolithus* species with a very bright inner tube cycle and a dark distal plate. A thin, non-birefringent central area structure can occasionally be distinguished, and faint scalloping on the inner rim in some specimens is suggestive of a possible net. In his original description, Varol (1989) states that the central structure is similar to *E. bollii*, although this is not visible from the photomicrographs. Bown (2005) reported the first occurrence of this species in Zone NP 9b in Tanzania, and Varol (1989) recorded its presence in NP 12. This biostratigraphic range is corroborated at SDB, where *Ellipsolithus anadoluensis* is first recorded from Zone NP9a (Table 2) and occurs sporadically throughout its range. **Occurrence**: NP 9a-NP 12.

Ellipsolithus distichus
(Bramlette & Sullivan, 1961) Sullivan, 1964
Pl. 2, fig 5.

Ellipsolithus macellus
(Bramlette & Sullivan, 1961) Sullivan, 1964
Pl. 2, figs 2, 6.

Ellipsolithus aubryae sp. nov.
Pl. 2, figs 3-4, 7.

Derivation of Name: Named in honour of Marie-Pierre Aubry, who first recognized this species in sediments from the NJ Coastal Plain. **Diagnosis**: Large *Ellipsolithus* consisting of closely appressed proximal and distal shields and a wide central area that is 2x wider than the sum of the two outer rims. The central area is covered by a net of variably sized small to medium round pores that are somewhat randomly distributed in two loose rings. A thin longitudinal bar bisects the central area. This species can be distinguished from *E. bollii* by its larger pores and wider central area and from *E. distichus* by the random placement of pores in the two rings in the central area. **Remarks**: *Ellipsolithus aubryae* was illustrated by Bybell & Self-Trail (1997, Pl. 4, figs. 3-5) from DSDP Site 605 in the Atlantic Ocean

Length (μm)	Width (μm)
12.0	7.5
10.5	6.8
12.0	9.0
13.6	9.6
12.8	8.8
12.8	8.8
13.6	8.8
10.4	6.4
12.8	8.0
12.8	8.0

Table 6. Length and width measurements for *Ellipsolithus aubryae* specimens.

and has been observed by Bybell (unpubl. data, 2010) and Aubry (pers. comm., 2009) from Coastal Plain sediments of Alabama, Virginia, Maryland, and New Jersey. It is restricted to sediments of early Eocene age (NP 10-NP 11). **Dimensions**: L = 10.4-13.6μm; W = 6.4-9.6μm (Table 6). **Holotype**: Pl. 2, fig. 4. **Paratype**: Pl. 2, fig. 7. **Type Locality**: SDB core, Easton, MD (USA). **Type level**: Early Eocene, Sample N12672, 187.1 m, (Zone NP 11). **Occurrence**: NP 11.

Markalius apertus Perch-Nielsen, 1979
Pl. 5, figs 2-4.

Markalius inversus (Deflandre *in* Deflandre & Fert, 1954) Bramlette & Martini, 1964
Pl. 5, figs 5, 10.

4.2. Murolith coccoliths

Order EIFFELLITHALES **Rood et al., 1971**
Family **CHIASTOZYGACEAE** Rood et al., 1973

Placozygus sigmoides
(Bramlette & Sullivan, 1961) Romein, 1979
Pl. 2, fig 21.

Order ZYGODISCALES **Young & Bown, 1997**
Family **HELICOSPHAERACEAE** Black, 1971

Helicosphaera bramlettei
(Muller, 1970) Jafar & Martini, 1975
Pl. 2, figs 22-23.

An elliptical form with a wide central area, an optically distinct, slightly oblique central bridge and a terminal flange folded relatively close to the body with a small notch. The bridge in *H. bramlettei* is more oblique than the transverse bridge seen in *H. seminulum*. This species is rare in SDB (Table 4). **Occurrence**: NP 16.

Helicosphaera lophota
(Bramlette & Sullivan, 1961) Locker, 1973
Pl. 2, figs 24-25.

A large, elliptical form with an oblique, optically distinct bridge that spans the relatively wide central area at greater than 45°. The terminal flange is folded close to the body of the helicosphaere and has no terminal notch. This species is relatively rare and sporadic in SDB, and is present only in middle Eocene sediments. **Occurrence**: NP 14-NP 15b.

Helicosphaera seminulum Bramlette & Sullivan, 1961
Pl. 2, figs 26-27.

A large, elliptical to ovoid helicosphaere with an optically distinct, nearly vertical central bridge. The terminal flange is folded close to the body and lacks a distinctive notch. This species can be difficult to separate from *H. bramlettei*, which overlaps in range in the middle Eocene (Perch-Nielsen, 1985). **Occurrence**: NP 12-NP 16.

Family **PONTOSPHAERACEAE** Lemmermann, 1908

Pontosphaera is used herein to describe species with many small perforations in the basal plate or species with no discernable perforations in the basal plate. *Transversopontis* is distinguished from *Pontosphaera* by the presence of two large perforations in the basal plate. These perforations can vary in size and it can sometimes be difficult to distinguish between the two genera. Specimens having two large perforations along with smaller perforations in the central area are placed in the genus *Pontosphaera*.

Pontosphaera cf. *P. clinosulcata* Bown, 2005
Pl. 2, fig 30.

Medium-sized, elliptical coccolith with one row of perforations near the outer rim and an indistinct series of perforations in the central area. Two central, longitudinal slits are inclined to near horizonal. This species differs from *P. clinosulcata* in that it lacks the inclined furrows and elongate pores present in that species. **Occurrence**: NP 16.

Pontosphaera distincta
(Bramlette & Sullivan, 1961) Roth & Thierstein, 1972
Pl. 2, fig 31.

Pontosphaera multipora
(Kamptner, 1948 ex Deflandre, 1959) Roth, 1970
Pl. 2, figs 28-29.

Transversopontis ocellata
(Bramlette & Sullivan, 1961) Locker, 1971
Pl. 2, fig 32.

Transversopontis cf. *T. ocellata*
(Bramlette & Sullivan, 1961) Locker, 1971
Pl. 2, fig 33.

Medium to large-sized, elliptical coccolith with faint perforations in the basal plate and two large central, inclined pores. This species differs from *T. ocellata* in the size and slight inclination of the central pores. **Occurrence**: NP 16.

Pontosphaera plana
(Bramlette & Sullivan, 1961) Haq, 1971
Pl. 3, figs 1-2.

Simple, plain plate with little or no rim visible in XPL and two thin, indistinct slits oriented parallel to the long axis. This species is present in sporadic occurrences from the late Paleocene and into the middle Eocene. **Occurrence**: NP 9a-NP 16.

Transversopontis pulcher (Deflandre *in* Deflandre & Fert, 1954) Perch-Neilsen, 1967
Pl. 3, figs 3-7.

Elliptical discoliths with a transverse bar aligned with the short axis of the ellipse. The bar has a distinctive break aligned with the long axis of the ellipse. Rim perforations can sometimes be present, but are often lacking, possibly due to dissolution. The species concept of Bybell & Self-Trail (1995) is followed herein and *T. pulcher* as figured in this paper most likely combines *Pontosphaera pulchra* and *Pontosphaera exilis* as illustrated by Bown (2005). The FO of *T. pulcher* occurs just before the onset of the CIE in the upper Aquia Formation of Maryland and is a useful secondary marker for the PETM. **Occurrence**: NP 9a-NP 16.

Transversopontis pulcheroides
(Sullivan, 1964) Baldi-Beke, 1971
Pl. 3, figs 9-10.

Medium sized discolith having a pronounced oblique, transverse bar and an outer rim pierced by faint to strongly visible furrows and elongate pores. **Occurrence**: NP 12-NP 16.

Transversopontis pulchriporus
(Reinhardt, 1967) Sherwood, 1974
Pl. 3, figs 8, 11.

Small to medium sized discolith having an oblique, transverse bar and an outer rim pierced by circular pores. Similar to *T. pulcheroides*, but lacking the furrows that line the outer rim. **Occurrence**: NP 16.

Pontosphaera punctosa
(Bramlette & Sullivan, 1961) Perch-Nielsen, 1984
Pl. 3, figs 12-13.

Discolith having a thin rim with furrows and a wide central area covered by a perforate plate. **Occurrence**: NP 15-NP 16.

Transversopontis zigzag Roth & Hay in Hay et al., 1967
Pl. 3, figs 14-16.

Small discolith with a narrow rim and a transverse bar with a distinct kink, centrally located. Small pores can be present on the basal plate, and faint scalloping of the rim is present in some specimens. **Occurrence**: NP 14-NP 16.

Family **ZYGODISCACEAE** Hay & Mohler, 1967

Lophodolithus nascens Bramlette & Sullivan, 1961
Pl. 3, figs 17-18.

Zygodiscus herlyni Sullivan, 1964
Pl. 3, fig 19.

Zygodiscus sheldoniae Bown 2005
Pl. 3, figs. 20-21.

Medium-sized murolith with distinctive disjunct bar. Occurs sporadically in the Aquia Formation, but never in great abundance. Bown (2005) reported the presence of this species in late Paleocene Zone NP 9b from Tanzania. Its biostratigraphic range is extended herein. **Occurrence**: NP 9a.

Neochiastozygus junctus
(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971
Pl. 3, figs 22-23

Neochiastozygus tenansa
(Deflandre *in* Deflandre & Fert, 1954) comb. nov.
Pl. 3, figs 24-29.

Basionym: *Zygolithus tenansa* Deflandre *in* Deflandre & Fert, 1954, p. 19, pl. 11, fig. 18-19; *Annales de Paleontologie*, 40: 115-176. **Remarks**: Elliptical coccolith with two thin vertical walls and a central cross that is slightly oblique to the major and minor axes. Previous illustrations show only one strut along the long axis of the coccolith (Deflandre & Fert, 1954), giving this species a superficial resemblance to species from *Pontosphaera* or *Transversopontis*. However, a slender, delicate strut along the minor axis is clearly visible in some specimens from the SDB core (Pl. 3, fig. 26, 27), although it is almost always missing (Pl. 3, fig. 24, 25, 28, 29). The outer cycle is typically not visible in XPL. Although this species was originally described from the Oligocene, its small size makes it easy to overlook in the microscope and its delicate structure probably makes it prone to dissolution. **Dimensions**: L = 2.0-3.2 μm; W = 1.2-2.4μm (Table 7). **Occurrence**: NP 9a-NP 11; SDB core. Oligocene (Deflandre & Fert, 1954).

Length (μm)	Width (μm)
3.2	2.4
2.8	2.0
3.1	2.4
3.2	1.7
3.2	2.4
2.8	1.7
3.2	2.0
2.2	1.2
2.4	1.2
2.0	1.6

Table 7. Length and width measurements for *Neochiastozygus tenansa* specimens.

Neococcolithes protenus
(Bramlette & Sullivan, 1961) Black, 1967
Pl. 4, figs 2-5.

This species has its FO in the Paleocene, and has an X-shaped central cross with bars of slightly unequal length and a rounded elliptical outline. **Occurrence**: NP 9a-NP 14.

Neococcolithes minutus
(Perch-Nielsen, 1967) Perch-Nielsen, 1971
Pl. 4, figs 8-10.

This species is present from the early Eocene, and is distinguished from *N. protenus* by its H-shaped central cross and by its more long elliptical outline and slightly pointed ends. **Occurrence**: NP 10-NP 16.

Order SYRACOSPHAERALES **Hay, 1977 emend. Young et al., 2003**
Family **CALCIOSOLENIACEAE** Kamptner, 1927

The taxonomy of Bown (2005) for the genus *Calciosolenia* is followed herein.

Calciosolenia alternans Bown & Dunkley Jones, 2006
Not figured. This species is documented only sporadically from middle Eocene sediments of the SDB core and its range is concurrent with the findings of Bown and Dunkley Jones (2006) from Tanzania. **Occurrence**: NP 16.

Calciosolenia aperta (Hay & Mohler, 1967) Bown, 2005
Pl. 3, figs 30-31.

The last occurrence datum of *C. aperta* is useful as a proxy for the Paleocene/Eocene Boundary and for the beginning of the CIE. Bybell & Self-Trail (1995) noted the concurrence of the LO of *C. aperta* with the Vincentown/Manasquan formational boundary, now considered to be synonomous with the PETM and the Aquia/Marlboro contact in the SDB core (Kopp et al., 2009). **Occurrence**: NP 9a.

Calciosolenia fossilis (Deflandre *in* Deflandre & Fert, 1954) Bown *in* Kennedy et al., 2000
Pl. 3, fig 32.

Family **RHABDOSPHAERACEAE** Haeckel, 1894

Blackites cf. *B. bullatus* Bown, 2005
Pl. 3, fig 33.

A species of *Blackites* with a hollow, doubly inflated spine and a relatively broad rim. Superficially resembles *B. bullatus* of Bown (2005; see his Pl. 22, fig. 8), but is characterized by a spine that has two bulges instead of one. **Occurrence**: NP 14.

Blackites cf. *clavus* Bown, 2005
Pl. 3, figs 34-35.

A species of *Blackites* with a relatively short, tapering spine and a broad rim cycle. The general morphology is reminiscent of a traffic cone. Similar to *B. clavus* from Zone NP10 in Tanzania. This species is identified from only one sample in the SDB core (N12412, 169.2 m) and is middle Eocene in age. **Occurrence**: NP 14.

Blackites creber (Deflandre *in* Deflandre & Fert, 1954) Stradner & Edwards, 1968
Pl. 4, fig 26-27

Blackites dupuisii (Steurbaut, 1990) Bown, 2005
Pl. 4, fig 6.

Rhabdolith with a tapering, hollow stem and a distinct collar that appears to consist of two or more cycles. This species was originally described from Zone NP 11 (Steurbaut, 1990), but its range was extended by Bown (2005) to include Zones NP 9b-NP15. **Occurrence**: NP 16.

Blackites fustis Bown, 2005
Pl. 4, fig 7.

A small, hollow-stemmed rhabdolith whose spine is parallel-sided near the base and flaring towards the top. A small papilla is present on the distal end of the spine. This species, as figured by Bown (2005), shows a great deal of variation in the shape of the spine. *Blackites fustis* is rare in SDB and was identified from only one early Eocene sample. **Occurrence**: NP 12.

Blackites gamai Bown, 2005
Pl. 4, fig 11.

A distinctive species of *Blackites* with a bullet-shaped, broadly tapering spine and narrow, but distinct, collar. Occurs sparsely and sporadically in lower to middle Eocene sediments of the SDB core. Its geologic range is extended herein. **Occurrence**: NP 11-NP 16.

Blackites gladius (Locker, 1967) Varol, 1989
Pl. 4, figs 12-14

Blackites globosus Bown, 2005
Pl. 4, fig 15.

A species of *Blackites* having an inflated, hollow spine with a narrow collar attached to a small basal cycle. It is distinguished from *B. morionum* by its exaggerated, roundly inflated spine and its narrower collar. This species is very rare in the SDB core. **Occurrence**: NP 16.

Blackites herculesii
(Stradner, 1969) Bybell & Self-Trail, 1997
Pl. 4, figs 16-19.

Rhabdoliths with a claviform spine that widens towards the distal end. Spine displays outer serrated surface. Bybell & Self-Trail (1997) recorded its presence in New Jersey in Zone NP10 and Bown (2005) recorded its presence in Tanzania in NP9b/10-11 (early Eocene). *Blackites herculesii* is present in SDB in lower Eocene sediments. **Occurrence**: NP 10-NP 12.

Blackites inflatus
(Bramlette & Sullivan, 1961) Kapellos & Schaub, 1973
Pl. 4, figs 21-23

Blackites morionum
(Deflandre in Deflandre & Fert, 1954) Varol, 1989
Pl. 4, figs 20, 25.

Blackites rotundus Bown, 2005
Pl. 5, fig 1.

Rhabdolith with an inflated, hollow spine that is narrow at the base and quickly inflates to a rounded globe at its distal end. Basal coccolith has a prominent collar. Bown (2005) recorded *B. rotundus* from middle Eocene sediments of Tanzania (NP 15b-c), and the biostratigraphic range of this species is extended slightly in this study. **Occurrence**: NP 16.

Blackites spinosus
(Deflandre & Fert, 1954) Hay & Towe, 1962
Pl. 4, figs 1, 24, 29.

This species is somewhat morphologically difficult to separate from *B. tenuis* using the light microscope (LM). In well-preserved specimens, the attachment of the spine to the base in *B. tenuis* is very abrupt and presents an angular appearance (Pl. 4, fig. 28), whereas the attachment of the spine to the base in *B. spinosus* is gradual (Pl. 4, fig. 29). **Occurrence**: NP 12-NP 16.

Blackites? stilus Bown 2005
Pl. 4, fig 30.

A tapering rhabdolith having a central canal of variable width. This species is placed questionably in *Blackites* due to the lack of a clear basal plate. Observed and figured specimens do not appear to be broken and it is assumed that the small or absent plate is real. Bown (2005) recorded this species from the middle Eocene (NP 14b/15a-15c) of Tanzania. *Blackites? stilus* is present only sporadically from SDB in lower Eocene sediments and its basal range is extended slightly in this study. **Occurrence**: NP 13-NP 14.

Blackites tenuis
(Bramlette & Sullivan, 1961)
Pl. 4, fig 28

Blackites truncatus
(Bramlette & Sullivan, 1961) Varol, 1989
Pl. 5, figs 6-7

4.3. Holococcoliths

Family **CALYPTROSPHAERACEAE**
Boudreaux & Hay, 1967

Holodiscolithus geisenii Bown, 2005
Pl. 5, fig 9.

Small, elliptical coccolith with diagnostic gently curving axial sutures along patches of higher birefringence. Overall birefringence is low, and the outer rim is dark in XPL. Bown (2005) described this species from the lower Oligocene of Tanzania and recorded its range from the lower to mid-Eocene (NP 11-23). Self-Trail et al. (2009; supplemental material) reported the sporadic occurrence of *H. geisenii* from the mid-Eocene Exmore Formation of the Chesapeake Bay impact crater. It is present sporadically in SDB in rare abundances from middle to upper Eocene sediments. **Occurrence**: NP 13-NP 16.

Holodiscolithus serus Bown, 2005
Not figured.

This small holococcolith is very rare in sediments from the SDB core and is recorded from only one sample (199.2m). Its occurrence in lower Eocene sediments concurs with the findings of Bown (2005). **Occurrence**: NP 10

Semihololithus biskayae Perch-Nielsen, 1971
Pl. 5, figs 8, 13-14.

Holococcoliths are comprised of a compact, solid, and domed distal plate on a thick proximal plate. They are most often seen in side view. Distal views show that the dome contains a central plug (Pl. 5, fig. 8). This species is present in SDB in the upper Paleocene Aquia Formation in frequent abundances and is very limited in its range. Bown and Pearson (2009) recorded its presence in Tanzania from Zone NP 9a. **Occurrence**: NP 9a.

Semihololithus aff. *S. biscayae* Perch-Nielsen, 1971
Pl. 5, figs 11-12.

Similar in size and shape to *S. biscayae,* but basal plate is crystallographically continuous with the dome and a small central plug is visible in side view. **Occurrence**: NP 9a.

Semihololithus dimidius Bown, 2005
Not figured.

This small holococcolith is distinctive in side view, having a central cavity sectioned in half by a thin wall. It is present in sediments from SDB in only two samples (190.0 m and 205.7 m) of late Paleocene and early Eocene age. Bown (2005) recorded its presence from Zone NP 9b. **Occurrence**: NP 9a-NP 10.

Daktylethra basilica sp. nov.
Pl. 5, figs 15-20.

Derivation of name: From the Latin for a "colonnaded house", a reference to its resemblance to St. Peter's Basilica in Rome, Italy. **Diagnosis**: A cavate holococcolith, seen in side view, with a thick basal plate extending up to one-third the height of the specimen and forming slight protruding wings to the side, and a domed distal cover showing perforations. The basal plate and dome are crystallographically continuous and bright at 45° in XPL (Pl. 5, fig. 16), darkening slightly when rotated to 0° (Pl. 5, fig. 17). The central cavate area forms an almost perfect "O" (Pl. 5, fig. 15). **Differentiation**: *Daktylethra basilica* differs from *D. unitatus* (Bown and Dunkley Jones 2006, also from Zone NP 16) in having a thicker basal plate that extends away from the central dome and in having an almost perfectly circular central cavity. *Daktylethra unitatus* has a subcircular central cavity that is somewhat flattened at its base and lacks prominent basal colonnades. It differs from *D. punctulata* in having prominent wings and a well-defined cavate central area. **Dimensions**: H = 2.4-3.2μm; W = 2.8-4.4μm (Table 8). **Holotype**: Pl. 5, fig. 15. **Paratype**: Pl. 5, fig. 16 (figs. 17-18 same specimen). **Type locality**: SDB core, Easton, MD (USA). **Type level**: Middle Eocene, Sample N12402, 139.0 m (Zone NP 16). **Occurrence**: NP 16.

Height (μm)	Width (μm)
3.2	4.4
2.8	2.8
2.8	3.2
2.8	3.2
2.8	3.6
3.2	3.4
2.8	3.6
2.6	3.6
2.4	4.0
3.2	4.0

Table 8. Height and width measurements for *Daktylethra basilica* specimens.

Zygrhablithus bijugatus bijugatus
(Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959
Pl. 5, figs 21-24

Zygrhablithus bijugatus (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *cornutus* Bown, 2005
Pl. 5, figs 25-28.

Medium-sized holococcolith with a tall central spine and a basal process. Central spire has a narrow axial canal and tapers towards the distal end, which is decorated by two small horns. Bown (2005) recorded this species from lower Oligocene sediments of Tanzania (NP 23). Bybell (1975, Pl. 24, figs. 2, 3) figured *Z. bijugatus cornutus* from middle Eocene sediments of Little Stave Creek, AL, and Gartner and Smith (1967; Pl. 8, figs. 1, 5a) figured specimens from the late Eocene of Louisiana. *Zygrhablithus bijugatus cornutus* is documented from middle Eocene sediments of the SDB core, thus extending its biostratigraphic range. **Occurrence**: NP 16.

Zygrhablithus bijugatus (Deflandre *in* Deflandre & Fert, 1954) Deflandre, 1959 *nolfii* Steurbaut, 1990
Pl. 5, figs 29-30.

Medium-sized holococcolith with shortened central spire, a wide axial canal, and a pronounced notch above the basal plate. Occurs sporadically in the SDB core throughout its range. **Occurrence**: NP 10-NP 12.

4.4. Nannoliths

Family **BRAARUDOSPHAERACEAE**
Deflandre, 1947

Braarudosphaera bigelowii
(Gran & Braarud, 1935) Deflandre, 1947
Pl. 5, figs 31-33

Braarudosphaera sequela sp. nov.
Pl. 5, figs 34-35

Derivation of name: From the Latin *sequela*, meaning "that which follows", referring to its higher stratigraphic position and younger age than *Braarudosphaera hockwoldensis*, which it resembles. **Diagnosis**: Large *Braarudosphaera* with protruding, diamond-shaped pentalith segments. Similar to *B. hockwoldensis,* which was first described in the Lower Cretaceous Gault Clay (Black, 1973). Bown (2005) tentatively used the name *Br*. cf. *B. hockwoldensis* for specimens recorded from the Eocene/Oligocene of Tanzania. However, the large stratigraphic gap between *B. hockwoldensis* and *B. sequela* argues in favor of iterative evolution and that they are two separate species. **Dimensions**: H = 10.4-14.4μm; W = 9.6-12.0μm (Table 9). **Holotype**: Pl. 5, fig. 34. **Paratype**: Pl. 5, fig. 35. **Type locality**: SDB core, Easton, MD (USA). **Type level**: Lower Eocene, Sample N12488, 198.7 m (Zone NP 10). **Occurrence**: NP 10-NP 11.

Height (μm)	Width (μm)
10.4	9.6
13.6	12.0
14.4	11.2
12.0	10.4
10.4	9.6

Table 9. Height and width measurements for *Braarudosphaera sequela* specimens.

Micrantholithus astrum Bown, 2005
Pl. 6, figs 1-3.

A large nannolith with deeply indented sides and pointed ray terminations. It is difficult to distinguish from *M. attenuatus*, which is more angular and has thinner rays, and differs from *M. vesper* in having a more acute inner ray angle and blunter ray terminations. This species is rare in SDB. **Occurrence**: NP 12-NP 16.

Micrantholithus attenuatus Bramlette & Sullivan, 1961
Pl. 6, fig 4.

Occasional zones of abundant *M. attenuatus* pieces are documented from the middle Eocene of SDB and a nearby core in Cambridge, MD. Whole specimens are rarely documented. **Occurrence**: Upper NP 14-NP 15b.

Micrantholithus excelsus Bown, 2005
Not figured.

This nannolith is present in rare abundances in sediments of early Eocene age from only one sample (195.7 m) of the SDB core. Bown (2005) documented this species from the early Eocene (NP 11) through early Oligocene (NP 23). Its biostratigraphic range is extended herein. **Occurrence**: NP 10.

Pemma basquense basquense
(Martini, 1959) Bybell & Gartner, 1972
Pl. 6, figs 5-6.

Pemma bybelliae sp. nov.
Pl. 6, figs 7-10.

Deriviation of name: Named in honor of Laurel M. Bybell, a Cenozoic nannofossil paleontologist, in recognition of her early work on taxonomy and morphology of the *Pemma* genus. **Diagnosis**: Large, circular *Pemma* that exhibits a diagnostic thin base with peripheral crenulated edges. Central area consists of a layer of basal thickenings superimposed on the base, resulting in a hazy appearance of the outer edge of the nannolith and a central area more highly birefringent than the edges. This species is similar in shape to *P. rotundum*, which lacks the thin base exhibited by *P. bybelliae*. *Pemma balium* is the only other described member of this genus to exhibit a thin base, and it is easily distinguished from *P. bybelliae* by its subcircular outline. **Dimensions**: D = 7.5-13.5μm (Table 10). **Holotype**: Pl. 6, fig. 7. **Paratype**: Pl. 6, fig. 9. **Type locality**: SDB core, Easton, MD (USA). **Type level**: Middle Eocene, Sample N12402, 139.0 m (Zone NP 16). **Occurrence**: NP 16.

Diameter (μm)
9.0
8.0
8.0
11.0
13.5
13.0
7.5

Table 10. Diameter measurements for *Pemma bybelliae* specimens.

Family **DISCOASTERACEAE** Tan, 1927

Discoaster anartios Bybell & Self-Trail, 1995
Pl. 6, figs 11-16.

A stellate, multi-rayed discoaster, exhibiting variable ray lengths and angles between the rays, that is frequent to common in sediments of the PETM interval in the SDB core. This species is commonly rare or absent in sediments of pelagic origin (i.e., Jiang & Wise, 2006; Mutterlose et al., 2007) and more abundant in sediments deposited in a shelf setting (i.e., Gibbs et al., 2006; Angori et al., 2007). Typically, it is abundant if *D. araneus* is rare and vice versa. In the SDB core, *D. anartios* has its FO at 200.5 m, at the same interval that the first rare specimens of *Rhomboaster* spp. appear (Table 2). It is consistently present throughout the lower PETM, but disappears from the section at 193.9 m, coinciding with a change in bulk carbon isotope values that is interpreted to represent the beginning of the PETM recovery (Self-Trail et al., in prep). **Occurrence**: NP 10.

Discoaster araneus Bukry, 1971
Pl. 6, fig 17.

Stellate, 7-9 rayed discoaster having variable angles between individual rays and often having variable ray lengths. Distinguished from *Discoaster anartios* by fewer rays and by having $^{1}/_{2}$ to $^{2}/_{3}$ free ray length. *Discoaster araneus* is extremely rare in SDB sediments and is quite often overgrown. It was identified by Kahn & Aubry (2004) as being restricted to the PETM. In the SDB core, this species is restricted to the basal PETM. Its FO is at 201.9 m, slightly below the FO of *D. anartios* and *Rhomboaster* spp. and its LO is at 194.8 m, just below the LO of *D. anartios*. **Occurrence**: NP 9b-NP 10.

Discoaster barbadiensis Tan Sin Hok, 1927
Pl. 6, figs 18-20.

Discoaster deflandrei Bramlette & Riedel, 1954
Pl. 7, figs 15-16.

Discoaster distinctus Martini, 1958
Pl. 6, figs 21-24.

Distinctive stellate, six-rayed discoaster with nodes on either side of the ray tip bifurcations. It is present for only a short interval during the early to mid-Eocene of SDB. **Occurrence**: NP 13-NP 14.

Discoaster falcatus Bramlette & Sullivan, 1961
Pl. 7, fig 1.

Discoaster gemmifer Stradner, 1961
Pl. 7, fig 17.

A discoaster with 8 bifurcating rays that displays no prominent central knob. The rays form an overlapping pattern that spirals dextrally and is distinctive of this species. *D. gemmifer* is present in only one sample from SDB (166.1 m). **Occurrence**: Upper NP 14.

Discoaster kuepperi Stradner, 1959
Pl. 7, figs 2-4, 8.

Discoaster lenticularis Bramlette & Sullivan, 1961
Pl. 7, figs 5-6, 9-10.

Discoaster lodoensis Bramlette & Riedel, 1954
Pl. 7, figs 7, 11-12.

Discoaster mediosus Bramlette & Sullivan, 1961
Pl. 7, figs 13-14.

Discoaster multiradiatus Bramlette & Riedel, 1954
Pl. 7, figs 21-24.

Discoaster salisburgensis Stradner, 1961
Pl. 7, fig 18.

Discoaster splendidus Martini, 1960
Pl. 7, figs 19-20.

A multi-rayed discoaster having 9-12 rays with raised outer ridges and depressed central areas. A broad, flat stem occupies 2/3 of the central area. *Discoaster splendidus* is present in the CIE interval in SDB in frequent to rare amounts, and first occurs at the top of the dissolution zone. Bybell & Self-Trail (1995) recorded its presence from Zones NP 8 to NP 9 in the New Jersey Coastal Plain. **Occurrence**: NP 9a-NP 10.

Discoaster sublodoensis Bramlette & Sullivan, 1961
Pl. 8, figs 1-2.
A medium-sized discoaster with 5 pointed rays with straight sides. Smaller than *D. lodoensis* and lacking the distinctive curving rays. **Occurrence**: NP14-NP15b.

Family **FASCICULITHACEAE** Hay & Mohler, 1967

Fasciculithus involutus Bramlette & Sullivan, 1961
Pl. 8, figs 5-7.

Fasciculithus richardii Perch-Nielsen, 1971
Pl. 8, figs 8-10.
A robust, large fasciculith with a somewhat cubic outline, columnar depressions, and a moderately tall cone. This species is restricted to the late Paleocene Aquia Formation and the dissolution zone of SDB. Perch-Nielsen (1985) recorded this species from Zone NP 9. **Occurrence**: NP 9a.

Fasciculithus schaubii Hay & Mohler, 1967
Pl. 8, figs 11-12.

Fasciculithus thomasii Perch-Nielsen, 1981
Pl. 8, figs 13-14.

Family **HELIOLITHACEAE** Hay & Mohler, 1967

Bomolithus supremus Bown & Dunkley-Jones, 2006
Pl. 8, figs 15-16.
Circular nannolith consisting of three distinct cycles. The inner cycle shows high-order birefringence in XPL and has a small central opening. The outermost cycle is dark in XPL, and consists of approximately 30 sinistrally curving elements. Bown & Dunkley-Jones (2006) recorded its presence in Tanzania from upper Paleocene Zone NP 9. *Bomolithus supremus* is restricted to the PETM lower Eocene Marlboro Clay in the SDB core. **Occurrence**: NP 9a-lower NP10.

Family **LITHOSTROMATIONACEAE**
Deflandre, 1959

Lithostromation operosum
(Deflandre *in* Deflandre & Fert, 1954) Bybell, 1975
Pl. 8, fig 17.
A nannofossil with numerous circular depressions and raised projections. This species appears to be restricted to the middle Eocene. *Lithostromation operosum* occurs only sporadically in the SDB core. **Occurrence**: NP 15b-NP 16.

Lithostromation simplex (Klumpp, 1953) Bybell, 1975
Pl. 8, figs 18-19.
A stellate nannofossil with numerous circular depressions, raised ridges, and short rays. This species is most often prevalent in middle Eocene sediments, and can occur in common abundances locally. It is consistently present in the sediments of the unnamed unit in SDB. **Occurrence**: NP 14-NP 16.

Family **RHOMBOASTERACEAE** Bown, 2005

According to Bown (2005), the *Rhomboasteraceae* comprise two nannolith genera of differing, yet related, morphologies; rhombic (*Rhomboaster*) through triradiate (*Tribrachiatus*). Bybell & Self-Trail (1995) placed the genus *Tribrachiatus* into synonomy with *Rhomboaster*, citing similarity of construction as the reason and thus making *Tribrachiatus* a junior synonym of *Rhomboaster*. Over a decade of research by this author has led to the conclusion that *Tribrachiatus*, as defined by Shamrai (1963) and with *T. orthostylus* as the type species, is a valid genus, although the author continues to place *R. contortus* into synonomy with *Rhomboaster*, based on basic construction of the nannolith. The taxonomy of Bybell & Self-Trail (1995) is followed herein with regards to the *Rhomboaster bramlettei/cuspis* plexus.

Rhomboaster bramlettei (Bronnimann & Stradner, 1960)
Bybell & Self-Trail, 1995
Pl. 8, figs 20-21.

Tribrachiatus orthostylus Shamrai, 1963
Pl. 8, figs 3-4.

Family **SPHENOLITHACEAE** Deflandre, 1952

Sphenolithus anarrhopus Bukry & Bramlette, 1969
Pl. 8, figs 22-23, 26-7.

Sphenolithus furcatolithoides Locker, 1967
Pl. 8, figs 24, 28-29.
Small sphenolith having two long apical spines that diverge distally and are often overgrown. Specimens are bright in XPL at 0° and are dark and inconspicuous at 45°. *Sphenolithus furcatolithoides* is typically present in middle Eocene sediments. **Occurrence**: NP 16.

Sphenolithus spiniger Bukry, 1971
Pl. 8, figs 25, 30-32.
A relatively small sphenolith with a modest apical spine and a proximal shield approximately one-half to two-thirds the height of the specimen. **Occurrence**: NP 14-NP 16.

4.5. *Incertae sedis* nannoliths

Leesella? sp.
Pl. 8, figs 33-34.
Leesella was first described by Bown & Dunkley Jones (2006) to document small nannoliths with a proximal

basal disc and a tall trumpet shaped cone with an axial canal. The specimen figured from SDB is smaller than *L. procera*, with a wider axial canal and a less pronounced trumpet shape. The basal disc is small, but prominent. Bown & Dunkley Jones (2006) recorded *L. procera* from the middle Eocene (NP 16). **Occurrence**: NP 9a-NP 9b.

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Plate 1

Placolith coccoliths

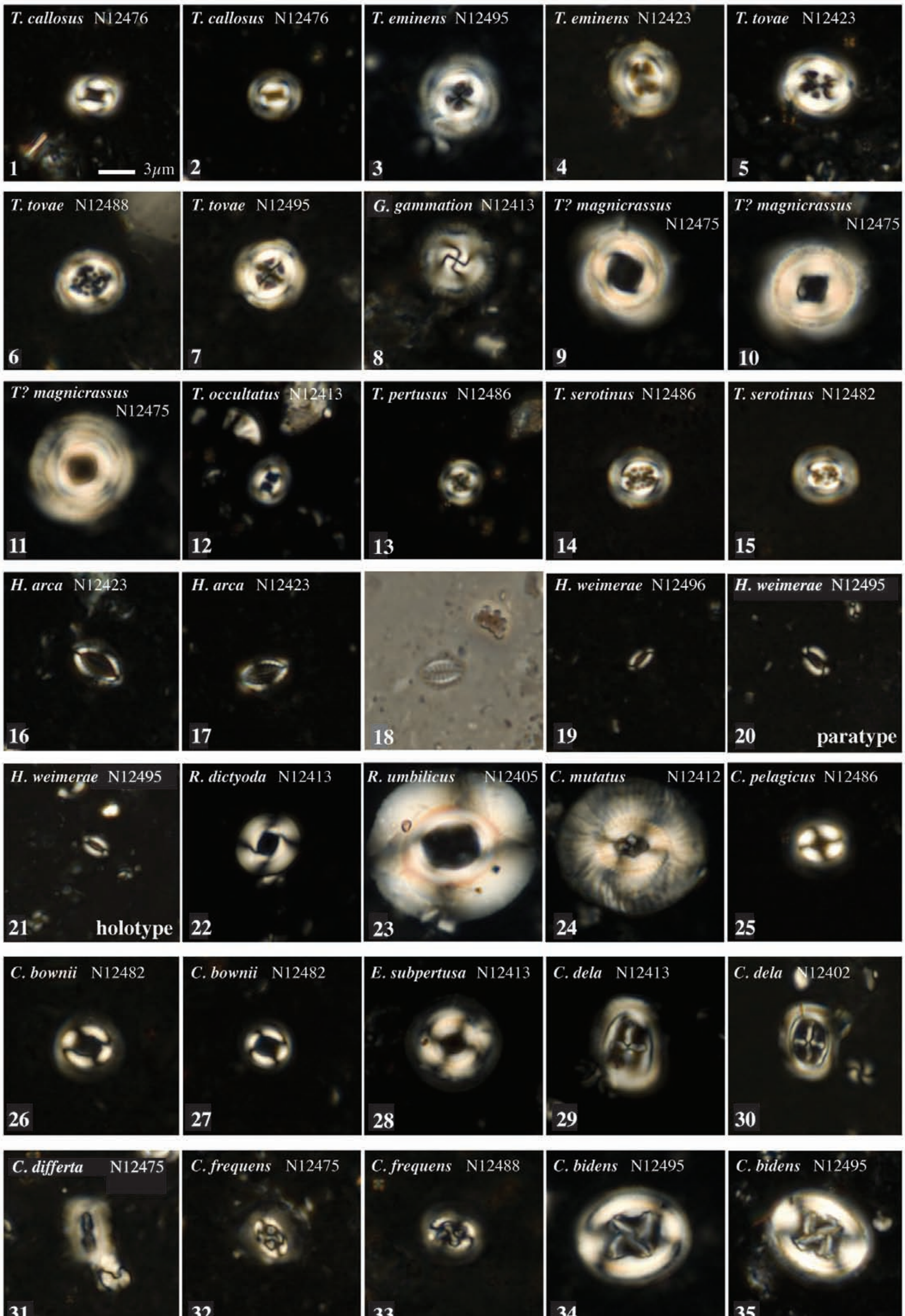

Plate 2

Murolith coccolithus

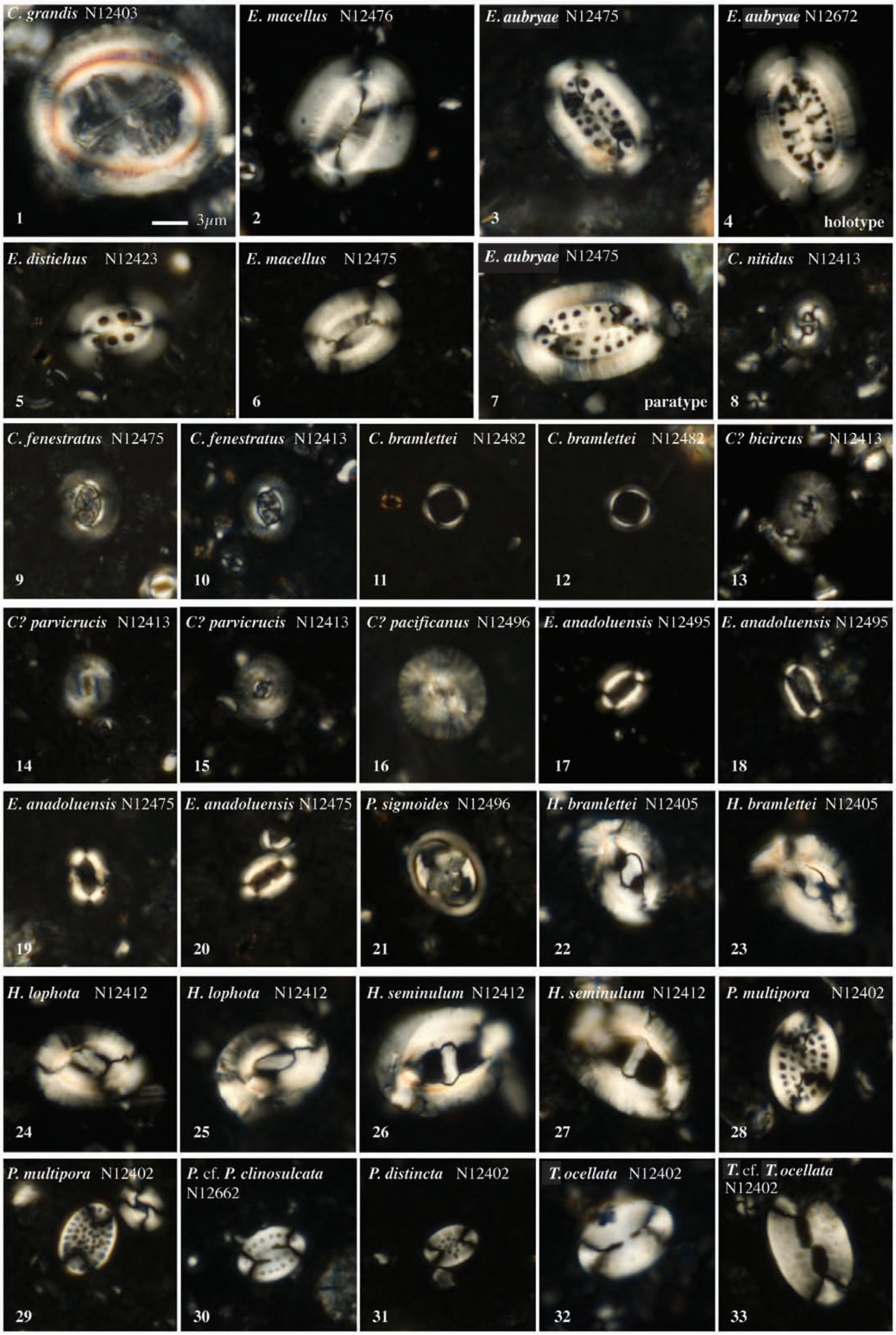

Plate 3

Pontosphaeraceae; Zygodiscaceae; Calciosoleniaceae; Rhabdosphaeraceae

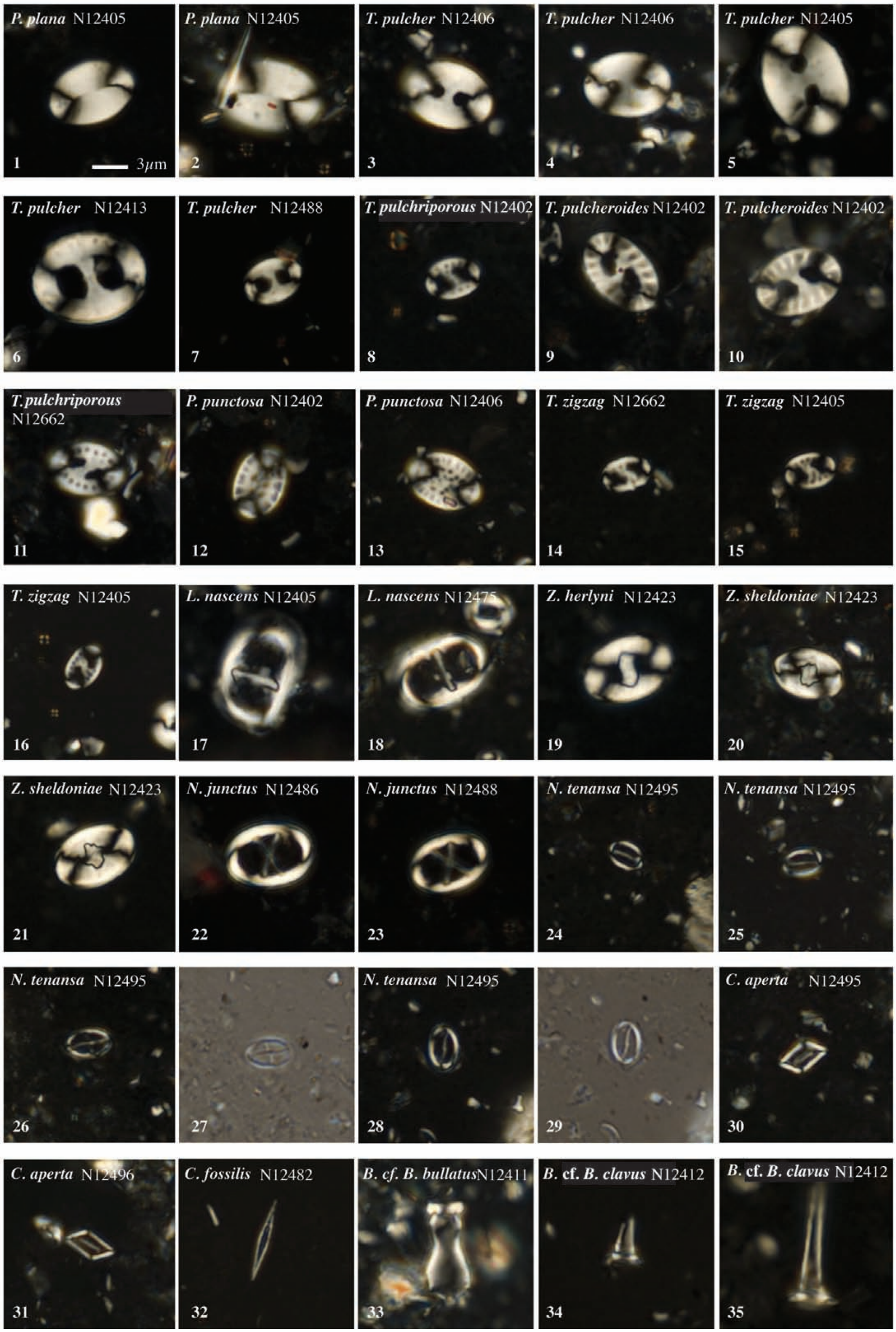

Plate 4

Rhabdosphaeraceae; Zygodiscaceae

Plate 5

Rhabdosphaeraceae; Holococcoliths; Nannoliths

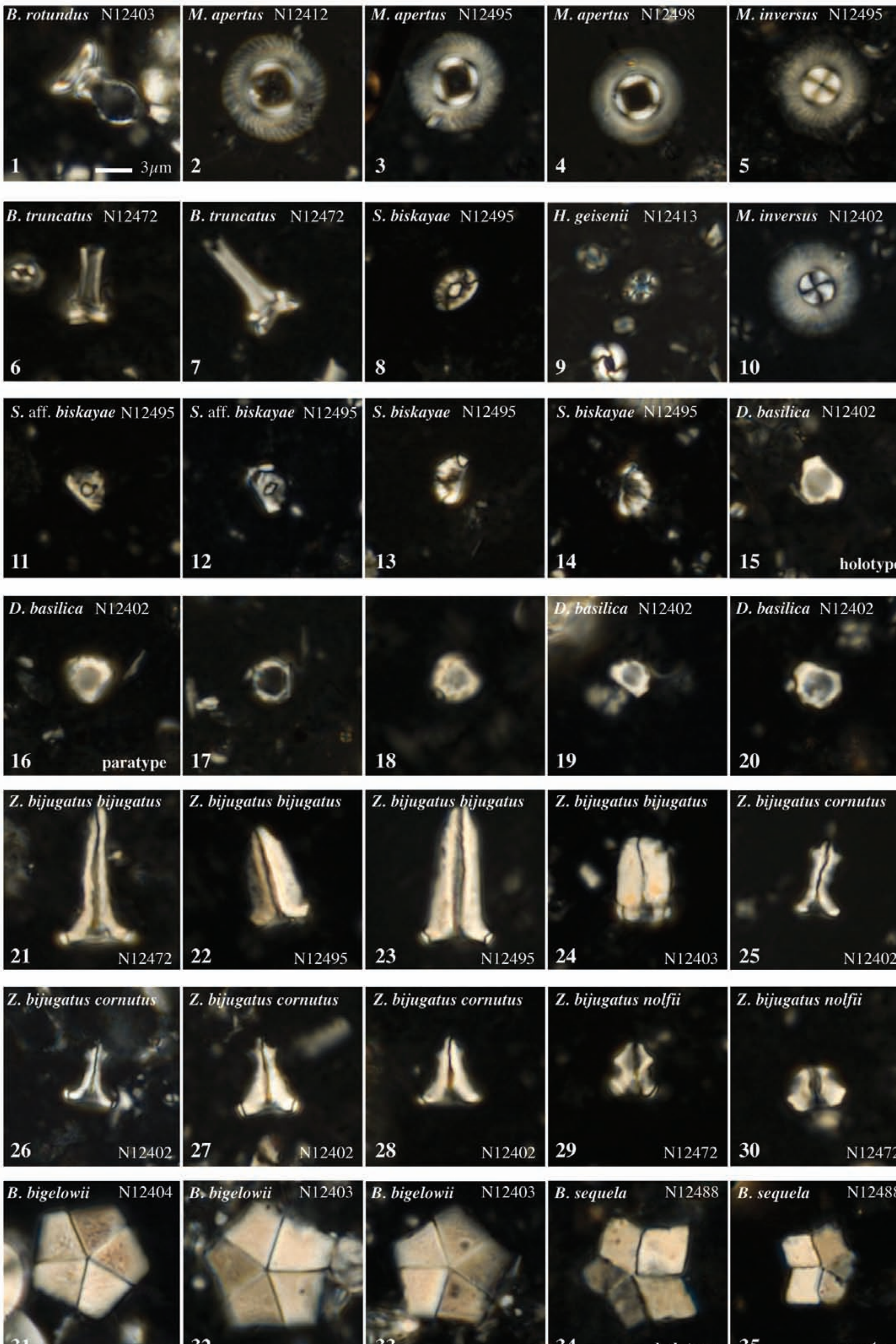

Plate 6

Nannoliths: Braarudosphaeraceae, Discoasteraceae

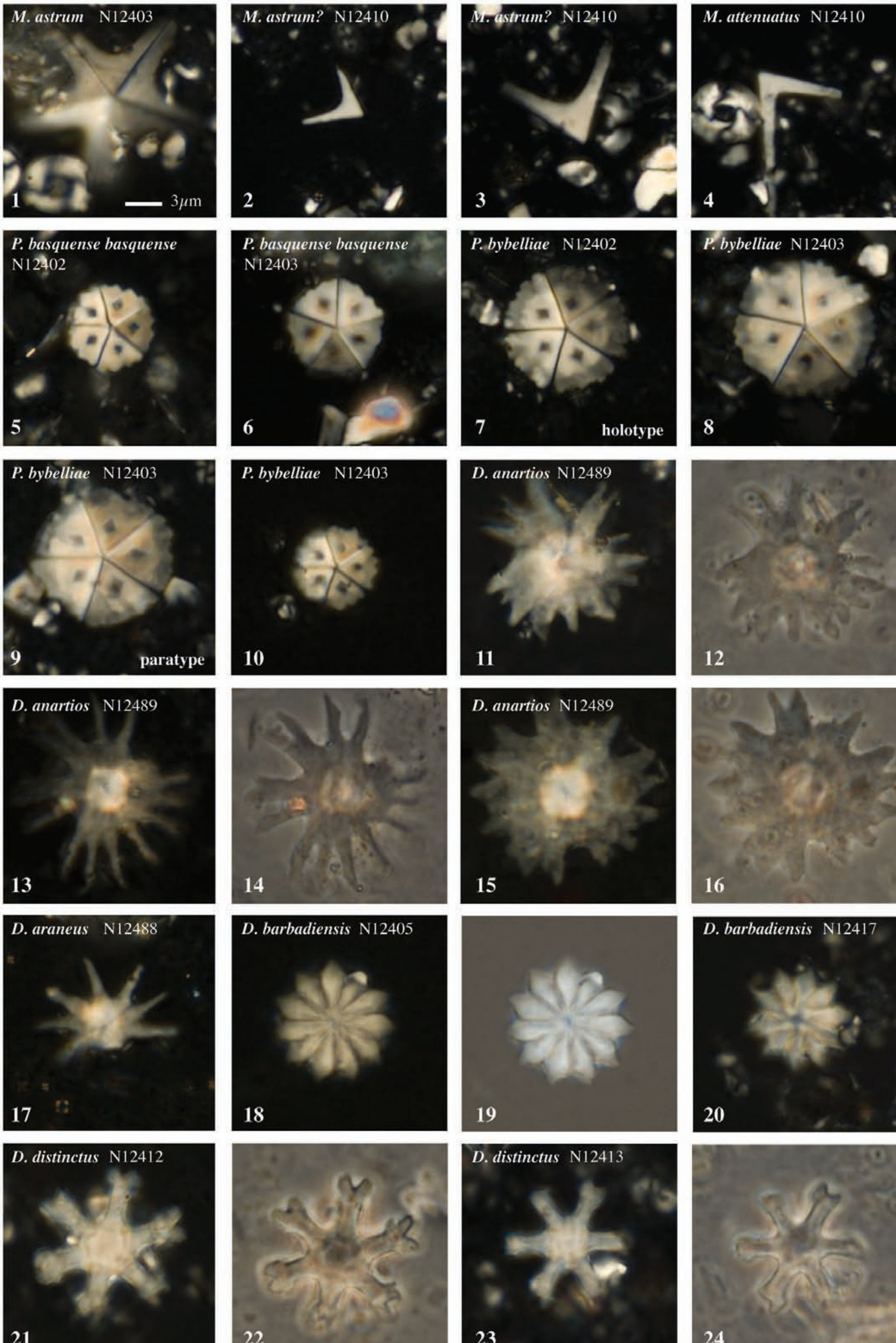

Plate 7

Nannoliths: Discoasteraceae

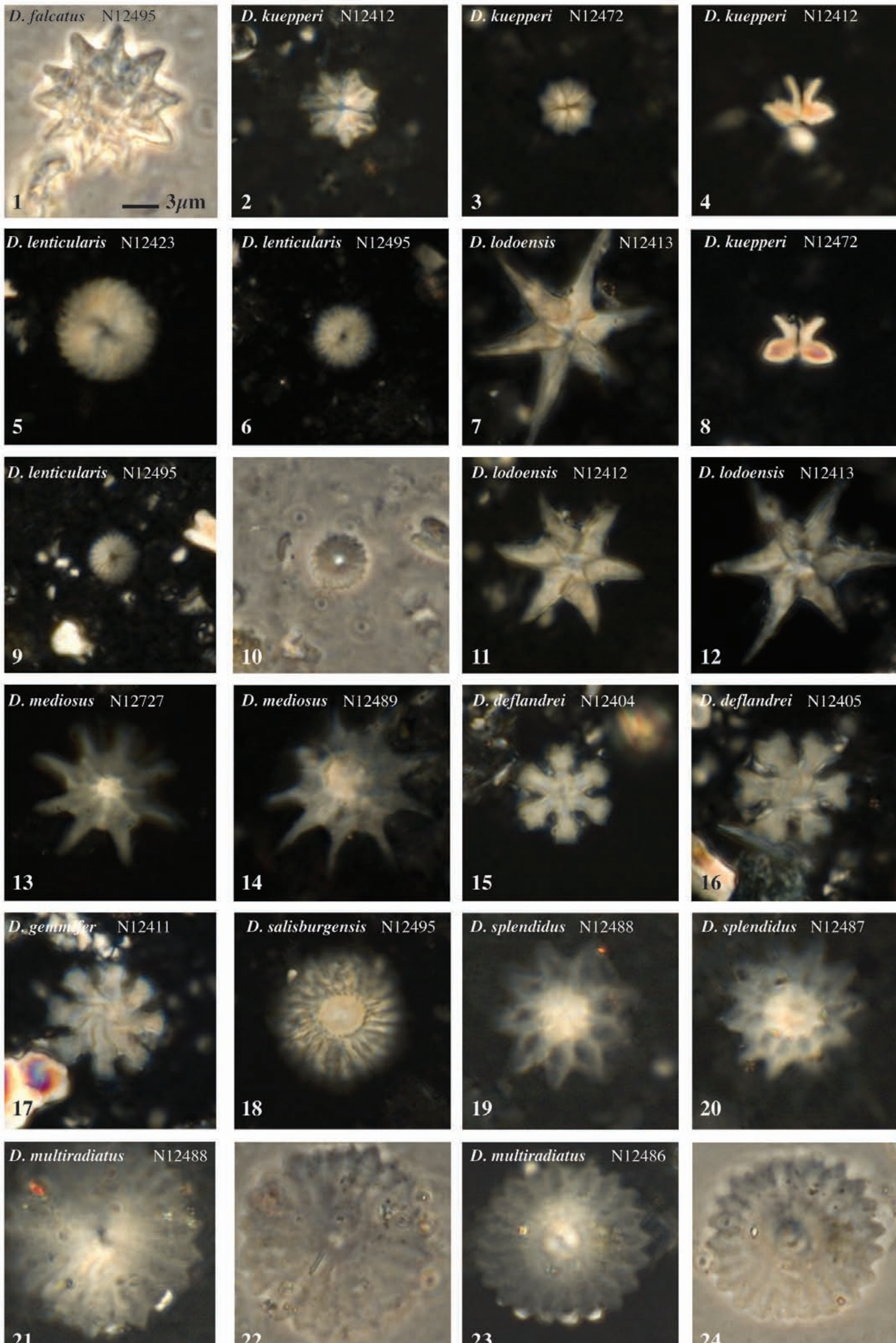

Plate 8

Nannoliths