16. CALCAREOUS NANNOFOSSILS: LEGS 51 AND 52 OF THE DEEP SEA DRILLING PROJECT

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INTRODUCTION

Sites 417 and 418 are near the southern end of the Bermuda Rise (Figure 1). Several holes were drilled at these sites during DSDP Legs 51 and 52. The purpose of this report is (1) to record the distribution of calcareous nannofoils present, together with their relative abundance and preservation, and (2) to date samples from cores obtained at these two sites.

Table 1 lists species epithets of the calcareous nannofoils mentioned in this report.

SITES 417

(25°06.69′N, 68°02.82′W, 5480 m water depth)

Five holes were drilled at this site (Holes 417 to 417D), recovering single mudline cores at Holes 417 and 417B, and no cores from the aborted drilling attempt at 417C. Hole 417A was cored continuously to 417 meters sub-bottom. The sedimentary sequence is 211 meters thick here, but only the uppermost unit contains nannofossils (Quaternary; 417A was cored continuously to 417 meters sub-bottom).

Hole 417B is about 30 meters west of Hole 417A. A single core of nannofossil-bearing clay and nannofossil marl was obtained here. This core contains rare, poorly preserved Quaternary nannofossils in Section 417B-2-4 and Sample 417B-2, CC. The following species occur: Ceratolithus cristatus, Cyclcoccolithus leptopus, C. macintyrei, Gephyrocapsa oceanica, Gephyrocapsa spp., Helicosphaera carteri, H. sellii, Pseudoemiliania lacunosa, Rhebishorax cf. R. geranus, Sympychaera globulosa, S. pulcherrima, Thoracosphaera heimi, T. saxeii, and Umbilicosphaera sibogae.

Most specimens of Gephyrocapsa are small and lack crossbars; other very rare specimens appear to have crossbars, and I assign these to G. oceanica. The absence of crossbars may be due to dissolution, although early Pleistocene gephyrocapsids often have open centers in any case. Some authors would probably assign these to G. doronicoideus, because of their lack of crossbars, although Gartner (1977) points out that they should not be assigned to the genus Gephyrocapsa for that very reason; i.e., they lack crossbars. Several species of Gephyrocapsa may occur in this core, but taxonomic resolution is very difficult with the light microscope. I have accordingly lumped them into only one category: Gephyrocapsa spp. I assign this core to the early Pleistocene because it contains C. macintyrei and Helicosphaera sellii, and Pseudoemiliania lacunosa.

Cores 2 through 15 in Hole 417D are barren or contain very rare, poorly preserved specimens. One specimen in Core 417D-5 resembles Cyclococcolithus floridanus (which has a middle Eocene to middle Miocene age range) but the identification is not definite. Cores 8 through 15 in Hole 417D contain rare specimens of Watznaueria barnesae. This long-ranging (Jurassic-Maestrichtian) form is robust and highly resistant to solution. I assign Cores 8 through 15 of Hole 417D to the Late Cretaceous on the basis of their stratigraphic position above Core 417D-17 (late Albian to late Cenomanian). Core 417D-16 is also probably Late Cretaceous; it contains a few poorly preserved specimens of Cretarhabdus cf. C. crenulatus, Parhabdolithus asper, and Watznaueria barnesae.

identification of *Hayesites albiensis* is correct, this core can be assigned to the late Albian.

Sections 4 and CC of Cores 417D-17 and 417D-18 are barren or contain very rare specimens; the age is indeterminate.

Cores 417D-19 to Section 417D-21-3 contain rare to abundant nannofossils. Preservation is poor in all Core 417D-19 samples, but is somewhat better in Core 417D-20 where fossils are also generally more common. Species in these cores include: *Assipetra infracretacea*, *Bidiscus* sp., *Chiastozygus litterarius*, *Cretarhabdus crenulatus*, *Cruciellipsis chiasta*, *Cylindralithus aff. C. serratus*, *Lithastrinus floralis*, *Lithraphidites carniolensis*, *Manivitella pematoida*, *Markalius circumradiatus*, *Parhabdolithus asper*, *P. embergeri*, *P. splendens*, *Podorhabdus decorus*, *Rucinolithus irregularis*, *Stephanolithion laffitti*, *Vagalapilla elliptica*, *V. imbricata*, *Watznaueria barnesae*, *W. communis*, *Zygodiscus diplogrammus*, and *Z. elegans*. Some specimens resemble *Vagalapilla matalosa* in the light microscope, but SEM examination shows that the resemblance is caused by calcite overgrowths thickening the tips of the crossbars of *V. imbricata*. This assemblage indicates a late Aptian to early Albian age.

Core 417D-21 contains this same assemblage down to at least 14 cm below the top of Section 3. However, a sample taken at 130-131 cm in Section 3 contains a much different assemblage, which I also found in Section 4. The assemblage includes all the species noted from Core 417D-19 to Sample 417D-21-3, 13-14 cm (with the exception of *Lithastrinus floralis*) plus the significant addition of *Braarudosphaera bigelowi*, *Corollithion acutum*, *C. ellipticum*, *Cretarhabdus aff. C. coronadventis*, *Hayesites sp.*, *Micrantholithus obtusus*, *Nannoconus bucheri*, *N. cf. N. kamptneri*, *N. wassalli*, *Podorhabdus dietzmanni*, *Reinhardtites fenestratus*, *Rhabdolithus cf. R. rectus*, and *Tranolithus gabalus*.

*Micrantholithus obtusus* is fairly common in these samples. This species ranges up to the top of the lower Aptian (Thierstein, 1973, 1976). *Nannoconus wassalli* also occurs up to about the same level (Roth and Thierstein, 1972). The presence of *Chiastozygus litterarius* and the absence of *Lithastrinus floralis* suggest that this interval is restricted to the lower Aptian, and can be referred to the *Chiastozygus litterarius* Zone (Roth and Thierstein, 1972), which more or less coincides with the boundaries of the lower Aptian. The lower Aptian has an age range of 112 to 115 m.y. (van Hinte, 1976).

It is uncommon to find *Corollithion ellipticum* in this zone. Thierstein (1973) reported that this species "...occurs in the Oxfordian of Great Britain, in all other localities it is known from the Upper Aptian to the Maastrichtian."

Scrapings from limestone deposited on a basalt cobble in Sample 417D-22, CC contain rare, poorly preserved specimens of *Watznaueria* and *Cretarhabdus*. Cores 22, 29, and 48 of Hole 417D contain basalt with occasional layers of well-indurated limestone. These thin limestone layers have only rare, poorly preserved specimens of *Watznaueria* cf. *W. barnesae*.

Table 2 shows the age, zonation, abundance, preservation, and distribution of calcareous nannofossils at Site 417.
<table>
<thead>
<tr>
<th>Nannofossil Species Considered in This Report (alphabetical order of species epithets)</th>
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<tbody>
<tr>
<td>Corollithion acutum Thierstein in Roth and Thierstein, 1972</td>
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<td>Parhabdolithus asper (Stradner) Manivit, 1971</td>
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<tr>
<td>Watznaueria bamesae (Black) Perch-Nielsen, 1968</td>
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<td>Brahmodorhabdus bigelowi (Gran and Braarud) Deflandre, 1947</td>
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<td>Nannococcus bucherti Brönning, 1955</td>
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<tr>
<td>Gephyrocapsa caribbeanica Boudreaux and Hay in Hay, Mohler, Roth, Schmidt, and Boudreaux, 1967</td>
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<tr>
<td>Lithraphidites carniolensis Deflandre, 1963</td>
</tr>
<tr>
<td>Helicosphaera carteri (Wallich) Kamptner, 1954</td>
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<tr>
<td>Crucielipsis chiastra (Worsley) Thierstein in Roth and Thierstein, 1972</td>
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<tr>
<td>Markalus stearnradiatus (Stover) Perch-Nielsen, 1968</td>
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<tr>
<td>Rhodosphera claviger (Murray and Blackman) Kamptner, 1944</td>
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<tr>
<td>Watznaueria communis (Black) Perch-Nielsen, 1968</td>
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<tr>
<td>Cretarhabdus coronadventis Reinhardt, 1966</td>
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<tr>
<td>Cretarhabdus crenulatus (Deflandre) Martini, 1966 emend. Thierstein, 1971</td>
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<tr>
<td>Prediscosphaera cretacea (Arkhangelsky) Gartner, 1968</td>
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<tr>
<td>Ceratolithus cristatus (Gartner) Bukry, 1969</td>
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<tr>
<td>Chiaztogysus cuneatus (Lyuf'eva) Cepek and Hay, 1969</td>
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<tr>
<td>Podorhabdus decorus (Deflandre) Thierstein in Roth and Thierstein, 1972</td>
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<tr>
<td>Podorhabdus dietzmanni (Reinhardt) Reinhardt, 1967</td>
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<tr>
<td>Zygodiscus diplogrammus Deflandre and Fert, 1954</td>
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<tr>
<td>Vegalapilla elliptica (Gartner) Bukry, 1969</td>
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<tr>
<td>Corollithion ellipticum Bukry, 1969</td>
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<tr>
<td>Parhabdolithus embergeri (Noël) Stradner, 1963</td>
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<tr>
<td>Reinhardtites fenestratus (Worsley) Thierstein in Roth and Thierstein, 1972</td>
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<tr>
<td>Lithastrinus florata Stradner, 1962</td>
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<tr>
<td>Cyclicargolithus floridatus (Roth and Hay) Bukry, 1971</td>
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<td>Scapholithus fossili Deflandre in Deflandre and Fert, 1954</td>
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<td>Tranolithus gabali Stover, 1966</td>
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<td>Rhabdolithus geranus Kamptner, 1967</td>
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<td>Scyphosphaera globulosa Kamptner, 1955</td>
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<td>Thoracosphaera heiniti (Loehmann) Kamptner, 1941</td>
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<td>Vegalapilla imbricate (Gartner) Bukry, 1969</td>
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<td>Parhabdolithus infinitus (Worsley) Thierstein in Roth and Thierstein, 1972</td>
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<td>Astipetra infracretacea (Thierstein) Roth, 1973</td>
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<td>Rucinolithus irregularis Thierstein in Roth and Thierstein, 1972</td>
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<td>Nannoconus kamptneri Brönnimann, 1955</td>
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<tr>
<td>Pseudomneta lucacumosa (Kamptner) Gartner, 1969</td>
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<tr>
<td>Stephanolithion laffittei Noël, 1957</td>
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<tr>
<td>Cyclococcolithus leptoporus (Murray and Blackman) Kamptner, 1954</td>
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<tr>
<td>Chiaztogysus littorarius (Gorka) Manivit, 1971</td>
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<tr>
<td>Cretarhabdus loriel Gartner, 1968</td>
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<td>Cyclococcolithus macintyre Bukry and Bramlette, 1969</td>
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<td>Vegalapilla matalosa (Stover) Thierstein, 1973</td>
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<td>Micrantholithus obtusus Stradner, 1963</td>
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<tr>
<td>Gephyrocapsa oceanica Kamptner, 1943</td>
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<tr>
<td>Tranolithus orionatus (Reinhardt) Reinhardt, 1966</td>
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<tr>
<td>Coccolithus pelagicus (Wallich) Schiller, 1930</td>
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<tr>
<td>Menitrilla pemmatoides (Deflandre) Thierstein, 1971</td>
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<td>Scyphosphaera pulcherrima Deflandre, 1942</td>
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<td>Hayesites radiatus (Worsley) Thierstein, 1976</td>
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<td>Rhodolithus rectus Deflandre, 1954</td>
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<td>Bidiscus rotatorius Bukry, 1969</td>
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<td>Thoracosphaera saxae Stradner, 1961</td>
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<td>Helicosphaera seilii (Bukry and Bramlette) 1969</td>
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<td>Cylindricalithus serratus Bramlette and Martini, 1964</td>
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<td>Umbilicosphaera sibogae (Weber-van Bosse) Gaarder, 1970</td>
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<td>Prediscosphaera spinosa (Bramlette and Martini) Gartner, 1968</td>
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<td>Parhabdolithus splendens (Deflandre) Noël, 1969</td>
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<tr>
<td>Ceratolithus telesmus Norris, 1965</td>
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<tr>
<td>Eiffellithus turrissefeli (Deflandre) Reinhardt, 1965</td>
</tr>
<tr>
<td>Nannococcus wassalli Brönnimann, 1955</td>
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### TABLE 2

<table>
<thead>
<tr>
<th>Sample (Interval in cm)</th>
<th>Zone</th>
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<tr>
<td>417 B 1-2 20-21</td>
<td>Late Cretaceous</td>
</tr>
<tr>
<td>417 D 1-1 54-55</td>
<td>Late Aptian to Early Albian</td>
</tr>
<tr>
<td>417 D 1-3 134-135</td>
<td>Early Albian</td>
</tr>
<tr>
<td>417 D 1-4 14-15</td>
<td>Early Aptian</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calcareous Nannofossils at Holes 417B and 417D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>417 B 1-2 20-21</td>
</tr>
<tr>
<td>417 D 1-1 54-55</td>
</tr>
<tr>
<td>417 D 1-3 134-135</td>
</tr>
<tr>
<td>417 D 1-4 14-15</td>
</tr>
</tbody>
</table>

**Note:** Abundance: A - Abundant, C - Common, E - Few, R - Rare. Preservation: G - Good, M - Moderate, P - Poor.
SITE 418
(25°02.08’N, 68°03.45’W, 5511 m water depth)

Site 418 is located about 4.5 km SSW of Site 417 (Figure 1). We drilled three holes at this site. Holes 418 (a single mudline core) and 418A are adjacent holes; Hole 418B is about 130 meters north of the other two (I have not examined samples from Hole 418B).

The single core obtained at Hole 418 contains mostly pelagic clay. I found calcareous nannofossils only in Sections 3, 4, and CC. The fossils are poorly to moderately preserved and are abundant only in Section 4. The following species occur: Braarudosphaera bigelowi, Ceratolithus cristatus, C. telesmus, Cyclococcolithus mackinweyi, C. leptoporus, Gephyrocapsa oceanica, Gephyrocapsa spp., Helicosphaera carteri, H. sellii, Pseudoemiliania lacunosa, Syracosphaera sp., Scyphosphaera pulcherrima, and Thoracosphaera saxea. Several reworked Neogene discoasters are present. As with Site 417, I assign this core to the early Pleistocene.

We drilled to a sub-bottom depth of 868 meters at Hole 418A. The sedimentary section penetrated is 324 meters thick. We began coring at 111 meters sub-bottom and cored continuously from there to basalt, with the exception of washed intervals of 19 meters between Cores 7 and 8, 28.5 meters between Cores 8 and 9, and 28.5 meters between Cores 9 and 10. Five lithologic units are present. They consist of brown pelagic clay with interbedded layers of nannofossil ooze at the top, grading downward into orange and brown zeolite and radiolarian pelagic clays. The lowermost units consist of blue-green and gray pelagic and nannofossil clays overlying brown, pink, gray, and green nannofossil ooze, clay, and chalk.

Cores 1 through 9 in Hole 418A are barren of calcareous nannofossils except for several poorly preserved specimens of Coccolithus pelagicus in Section 3-1 and Cyclicarolithus floridanus in Section 6-2.

Cores 10 to 11 in Hole 418A contain rare to common, mostly poorly preserved calcareous nannofossils. Cores 12, 13, and 14 have an abundant, mostly moderately preserved assemblage. Species in Cores 10 through 14 include: Asipetra infrarrectaceae, Braarudosphaera bigelowi, Chias-toygus littorarius, Cretarhabdus conicus, C. cremulatus, Cylindricalithus aff. C. serratus, Lithastrinus floralis, Lithraphidites carniolensis, Manivitella pemmatoidea, Markallus circumradiatus, Parhabdolithus cf. P. angustus, P. asper, Podorhabdus decorus, P. embergeri, P. splendens, Rucinolithus cf. R. irregularis, Stephanolithion lajfittei, Vagalapilla elliptica, V. imbricata, Watznaueria barnesae, Zygoidiscus diplogrammatus, and Z. elegans. This assemblage suggests a late Aptian to early Albian age, at least for Cores 12, 13, and 14 of Hole 418A.

Core 418A-15 contains a well-bedded nannofossil chalk immediately overlying basalt. I found an abundant and moderate to well-preserved assemblage in the chalk. It contains all the species present in Cores 10 through 14 (with the exceptions of Lithastrinus floralis, Parhabdolithus cf. P. angustus, and Braarudosphaera bigelowi), and has, in addition: Bidiscus rotatorius, Watznaueria communis, Hayesites radiatus, Micranholithus obtusus, Reinhardites fenestratus, Rhabdolithus cf. R. recurvatus, and Tetralithus sp. The last five species are especially significant since they occur only in Core 21 which overlies basalt in Hole 417D. The notable exception is Nannoconus, which is common in Core 21 at Hole 417D but does not occur in Hole 418A. This distinctive assemblage is not found in any cores above 21 at 417D, nor above Core 15 at this site.

I thus tentatively date Core 418A-15 as early Aptian on the basis of its close similarity to the early Aptian assemblage in Core 417D-21. This interpretation is supported by the absence of Lithastrinus floralis, which first appears at the base of the late Aptian. However, it is difficult to explain the absence of Nannoconus and the rarity of Micranholithus obtusus in sediments of the same age such as a short distance away from Hole 417D.

Table 3 shows the age, abundance, preservation, and distribution of calcareous nannofossils at Site 418.

ENVIRONMENTAL IMPLICATIONS

The presence or absence of calcareous nannofossils in these samples is related to the position of Sites 417 and 418 with respect to the carbonate compensation depth (CCD) during Late Cretaceous and Cenozoic times, and probably to the restricted circulation of the early Atlantic Ocean during Early and Middle Cretaceous times.

Abundant, well-preserved nannofossils immediately above basement indicate a well-oxygenated site of accumulation above the CCD during the early Aptian. Micranholithus, Nannoconus, and Braarudosphaera are all genera characteristic of nearshore waters. Nannoconids are known to prefer warm, calm, carbonate-rich waters. Rucinolithus irregularis and Hayesites radiatus also indicate tropical waters (Thierstein, 1976). This suggests that these sites were situated under warm waters fairly close to shore during the early Aptian.

Shortly after this time, intermittent layers of euxinic black claystones were deposited as the result of periodic stagnation of bottom waters, with attendant lowering of pH which dissolved calcium carbonate and prevented accumulation of calcareous biogenic sediments. These barren, euxinic layers were repeatedly followed by deposition of normal biogenic pelagic sediments. This episodic stagnation-oxygenation could be the result of periodic fluctuations in local oceanic circulation patterns, which would intermittently oxygenate otherwise stagnant basins of accumulation set in the rugged topography of the early Atlantic Ocean floor.

As the Atlantic continued to widen and deepen, these sites eventually subsided beneath the CCD and further calcareous sediments could not accumulate by normal processes. This probably happened during or just after the Cenomanian, as Core 417D-17 contains the last calcareous sediments prior to the Quaternary. This core also contains the last euxinic claystones, suggesting that the Atlantic had established a well-developed circulation pattern by Cenomanian times. Radiolarian and pelagic clays thus became the dominant sedimentary facies. Only in the Quaternary do we again find calcareous sediments. However, this thin calcareous zone probably represents rapid lateral transport (by slumping or a turbidity current) and burial of sediment derived from a topographically higher site of accumulation, as Sites 417 and 418 have certainly been below the CCD during all the Quaternary period.
### TABLE 3
Calcereous Nannofossils at Holes 418 and 418A

<table>
<thead>
<tr>
<th>Sample (Interval in cm)</th>
<th>Abundance</th>
<th>Preservation</th>
<th>Poecilocystis aurata</th>
<th>Heterohelix minutissima</th>
<th>Wettsteinicula concinna</th>
<th>Cothurnicula concinna</th>
<th>Cycladophora appendiculata</th>
<th>Stephanolinia leidyi</th>
<th>Calcisphaerina capensis</th>
<th>Quadricarinata sp.</th>
<th>Truncatulinella minuta</th>
<th>Lenticulina concinna</th>
<th>Cycladophora umbonata</th>
<th>Cycladophora discoides</th>
<th>Calcareous nannofossil sp.</th>
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</thead>
<tbody>
<tr>
<td>418A</td>
<td>3-1</td>
<td>121-122</td>
<td>R</td>
<td>P</td>
<td>R</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>R</td>
<td>R</td>
<td>P</td>
<td>P</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>1-2</td>
<td>20-21</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>F</td>
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<td>F</td>
<td>F</td>
<td>F</td>
<td>P</td>
<td>F</td>
<td>F</td>
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</tr>
<tr>
<td>Cretaceous (Early Aptian?)</td>
<td>10-1</td>
<td>60-61</td>
<td>R</td>
<td>R</td>
<td>P</td>
<td>P</td>
<td>F</td>
<td>F</td>
<td>F</td>
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<td>R</td>
<td>F</td>
<td>P</td>
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<tr>
<td>Early Albanian to Late Aptian</td>
<td>12-1</td>
<td>44-45</td>
<td>M</td>
<td>R</td>
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<td>R</td>
<td>F</td>
<td>F</td>
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<td>Late Aptian</td>
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<td>F</td>
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<td>31-32</td>
<td>R</td>
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<td>13 CC</td>
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<td>Early Aptian</td>
<td>14 CC</td>
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</tbody>
</table>

Note: Abundance; A - Abundant, C - Common, F - Few, R - Rare. Preservation; G - Good, M - Moderate, P - Poor.

### ACKNOWLEDGMENTS
Dr. Franca Proto Decima and Dr. Stefan Gartner kindly examined the manuscript and plates, and I thank them for their helpful comments. I also thank the Electron Microscopy Unit at the University of Cape Town for the use of its facilities.

### REFERENCES
Figure 1  Nannofossil assemblage, including *Watznaueria barnesae*, *Zygodiscus elegans*, *Hayesites* sp. and *Stephanolithion laffittei*. Samples 417D-17-1, 13-15 cm. Bar scale: 6 µm.

Figure 2  *Corollithion acutum*, distal side. Sample 417D-21-4, 40-41 cm. Bar scale: 4 µm.

Figure 3  *Corollithion acutum*, proximal side. Sample 417D-21-3, 130-131 cm. Bar scale: 2 µm.

Figure 4  *Parhabdolithus angustus*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.

Figure 5  *Parhabdolithus asper*, proximal side. Sample 418A-15-1, 14-15 cm. Bar scale: 4 µm.

Figure 6  *Parhabdolithus asper*, proximal side (lower left). *Stephanolithion laffittei*, proximal side (right center). *Watznaueria barnesae*, distal side (upper right). Sample 417D-21-4, 40-41 cm. Bar scale: 6 µm.

Figure 7  *Watznaueria barnesae*, distal side (coccoosphere). Sample 417D-21-4, 40-41 cm. Bar scale: 6 µm.

Figure 8  *Watznaueria barnesae*, proximal side. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.

Figure 9  *Nannoconus bucheri*. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.

Figure 10  *Nannoconus* sp. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.

Figure 11  *Nannoconus* sp. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.

Figure 12  *Lithraphidites carniolensis*, Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 13  *Lithraphidites carniolensis*, Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 14  *Cruciellipsis chiastia*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.

Figure 15  *Cruciellipsis chiastia*, proximal side. Sample 417D-21-4, 40-41 cm. Bar scale: 2 µm.

Figure 16  *Cruciellipsis chiastia*, distal side, and pyrite framboïd. Sample 417D-21-4, 40-41 cm. Bar scale: 4 µm.

Figure 17  *Watznaueria communis*, distal side. Sample 418A-15-1, 14-15 cm. Bar scale: 2 µm.

Figure 18  *Watznaueria communis*, proximal side. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.

Figure 19  *Cretarhabdus conicus*, distal side. Sample 417D-21-3, 130-131 cm. Bar scale: 2 µm.
PLATE 2
Scanning Electron Micrographs

Figure 1  Cretarhabdus aff. C. coronadventis, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 2  Cretarhabdus aff. C. coronadventis, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.
Figure 3  Cretarhabdus crenulatus, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 4  Cretarhabdus crenulatus, proximal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 5  Cretarhabdus sp. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.
Figure 6  Prediscosphaera cretacea. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 7  Prediscosphaera cretacea. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 8  Podorhabdus dietzmanni, distal side. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.
Figure 9  Zygodiscus diplogrammus, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 10  Zygodiscus diplogrammus, proximal side. Bar scale: 2 µm.
Figure 11  Zygodiscus elegans, distal side. Sample 417D-21-4, 40-41 cm. Bar scale: 2 µm.
Figure 12  Zygodiscus elegans, proximal side. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.
Figure 13  Vagalapilla elliptica, distal side. Sample 417D-21-4, 40-41 cm. Bar scale: 2 µm.
Figure 14  Vagalapilla elliptica, proximal side. Sample 417D-21-4, 40-41 cm. Bar scale: 2 µm.
Figure 15  Corollithion ellipticum, proximal side. Sample 417D-21-4, 40-41 cm. Bar scale: 1 µm.
Figure 16  Parhabdolithus sp., side view. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
Figure 17  Reinhardites fenestratus, distal side, and Bidiscus rotatorius, distal side. Sample 417D-21-4, 40-41 cm. Bar scale: 4 µm.
Figure 18  Lithastrinus floralis. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.
Figure 19  Lithastrinus floralis. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
PLATE 3
Scanning Electron Micrographs

Figure 1  *Scapholithus fossilis*. Sample 417D-21-4, 40-41 cm. Bar scale: 2 µm.

Figure 2  *Tranolithus gabalus*, proximal side. Sample 417D-21-3, 130-131 cm. Bar scale: 2 µm.

Figure 3  *Hayesites cf. H. albiensis*. Sample 417D-17-1, 13-15 cm. Bar scale: 1 µm.

Figure 4  *Vagalapilla imbricata*, distal side. Sample 418A-15-1, 14-15 cm. Bar scale: 2 µm.

Figure 5  *Vagalapilla imbricata*, proximal side (upper right) and *Vagalapilla elliptica*, distal side (lower left). Sample 418A-15-1, 14-15 cm. Bar scale: 4 µm.

Figure 6  *Rucinolithus irregularis*, distal side. Sample 417D-20-2, 30-31 cm. Bar scale: 2 µm.

Figure 7  *Rucinolithus irregularis*, proximal side. Sample 417D-21-3, 130-131 cm. Bar scale: 2 µm.

Figure 8  *Stephanolithion laffittei*, distal side. Sample 417D-21-3, 130-131 cm. Bar scale: 2 µm.

Figure 9  *Stephanolithion laffittei*, proximal side. Sample 418A-15-1, 14-15 cm. Bar scale: 2 µm.

Figure 10  *Chiastozygus litterarius*, distal side. Sample 417D-21-4, 40-41 cm. Bar scale: 4 µm.

Figure 11  *Chiastozygus litterarius*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 2 µm.

Figure 12  *Micrantholithus obtusus*, segment. Sample 418A-15-1, 14-15 cm. Bar scale: 2 µm.

Figure 13  *Manivitella pemmatoidea*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 14  *Manivitella pemmatoidea*, proximal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 15  *Rhabdolithus cf. R. rectus*. Sample 417D-21-3, 130-131 cm. Bar scale: 4 µm.

Figure 16  *Rhabdolithus cf. R. rectus* and *Lithraphidites carniolensis*. Sample 417D-21-4, 40-41 cm. Bar scale: 6 µm.

Figure 17  *Bidiscus rotatorius*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 18  *Cylindricalithus aff. C. serratus*, side view. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.

Figure 19  *Parhabdolithus splendens*, distal side. Sample 417D-17-1, 13-15 cm. Bar scale: 4 µm.
PLATE 4
Scanning Electron Micrographs

Figure 1  

Figure 2  

Figure 3  

Figure 4  

Figure 5  
*Gephyrocapsa* sp., proximal side. Sample 417D-1-4, 14-15 cm. Bar scale: 1 µm.

Figure 6  

Figure 7  

Figure 8  
*Scyphosphaera globulosa*. Sample 417D-1-4, 14-15 cm. Barscale: 8 µm.

Figure 9  
*Thoracosphaera heimi*. Sample 417D-1-4, 14-15 cm. Bar scale: 10 µm.

Figure 10  

Figure 11  

Figure 12  
*Cyclococcolithus leptoporus*, distal side (lower right) and *Cyclococcolithus macintyrei*, distal side (upper left). Sample 417D-1-4, 14-15 cm. Bar scale: 6 µm.

Figure 13  

Figure 14  

Figure 15  

Figure 16  
PLATE 5
Light Micrographs

Figures 1, 2 Parhabdolithus angustus, 3300×. Sample 417D-17-1, 13-15 cm.
1. Crossed nicols.
2. Interference contrast.

Figures 3, 4 Parhabdolithus asper (lower right) and Lithraphidites carniolensis 1300×. Sample 417D-21-4, 40-41 cm.
3. Crossed nicols.
4. Interference contrast.

Figure 5 Watznaueria barnesae, 2900×. Sample 417D-17-1, 13-15 cm. Crossed nicols.

Figures 6, 7 Lithraphidites carniolensis, 1600×. Sample 417D-17-1, 13-15 cm.
6. Crossed nicols.
7. Interference contrast.

Figures 8, 9 Markalius circumradiatus, 2700×. Sample 417D-31-3, 130-131 cm.
8. Crossed nicols.

Figures 10, 11 Watznaueria communis, 2500×. Sample 417D-31-3, 130-131 cm.
10. Crossed nicols.

Figures 12, 13 Cretarhabdus conicus, 3000×. Sample 417D-21-4, 40-41 cm.
12. Crossed nicols.
13. Interference contrast.

Figures 14, 15 Cretarhabdus crenulatus, 2200×. Sample 417D-17-1, 13-15 cm.
15. Plane polarized light.

Figures 16, 17 Prediscosphaera cretacea, 2800×. Sample 417D-17-1, 13-15 cm.
17. Interference contrast.

Figures 18, 19 Zygodiscus diplogrammus, 4400×. Sample 417D-17-1, 13-15 cm.
18. Crossed nicols.
19. Interference contrast.

Figures 20, 21 Vagalapilla elliptica, 3200×. Sample 417D-21-4, 40-41 cm.
20. Crossed nicols.
Figures 1, 2  
Parhabdolithus embergeri, 2200×. Sample 417D-17-1, 13-15 cm.  
1. Crossed nicols.  
2. Interference contrast.

Figure 3  
Parhabdolithus embergeri, 1550×. Sample 417D-17-1, 13-15 cm.

Figures 4, 5  
Parhabdolithus embergeri, 2400×. Sample 417D-21-4, 40-41 cm.  
5. Interference contrast.

Figures 6, 7  
Reinhardites fenestratus, 3800×. Sample 417D-21-4, 40-41 cm.  
6. Crossed nicols.  

Figures 8, 9  
Lithastrinus floralis, 1500×. Sample 417D-17-1, 13-15 cm.  
8. Crossed nicols.  
9. Interference contrast.

Figures 10, 11  
Lithastrinus floralis, 3400×. Sample 417D-20-2, 30-31 cm.  
10. Crossed nicols.  
11. Interference contrast.

Figures 12, 13  
Parhabdolithus infinitus, 1600×. Sample 417D-17-1, 13-15 cm.  
12. Crossed nicols.  

Figure 14  

Figure 15  

Figures 16, 17  
Chiastozygus litterarius, 1300×. Sample 417D-17-1, 13-15 cm.  
17. Interference contrast.

Figures 18, 19  
Micrantholithus obtusus, 1700×. Sample 417D-21-4, 40-41 cm.  
18. Crossed nicols.  
19. Interference contrast.

Figures 20, 21  
Micrantholithus obtusus, 3200×. Sample 417D-21-4, 40-41 cm.  
20. Crossed nicols.  
PLATE 7
Light Micrographs

Figures 1, 2  *Tranolithus orionatus*, 3500×. Sample 417D-17-1, 13-15 cm.
1. Crossed nicols.
2. Plane polarized light.

3. Crossed nicols.
4. Interference contrast.

Figures 5, 6  *Hayesites radiatus*, 3200×. Sample 417D-31-3, 130-131 cm.
5. Crossed nicols.

Figures 7, 8  *Hayesites* sp., 3000×. Sample 417D-31-3, 130-131 cm.
7. Crossed nicols.

10. Interference contrast.

Figures 11, 12  *Nannoconus wassalli*, 1900×. Sample 417D-21-3, 130-131 cm.
11. Crossed nicols.
12. Interference contrast.

Figures 13, 14  *Nannoconus* sp., 2100×. Sample 417D-21-4, 40-41 cm.
13. Crossed nicols.

Figures 15, 16  *Nannoconus* sp., 2700×. Sample 417D-31-3, 130-131 cm.
15. Crossed nicols.
16. Interference contrast.

Figure 17  *Eijfellithus turriseijfeli*, 3300×. Sample 417D-17-1, 13-13 cm. Crossed nicols.

Figures 18, 19  *Tetralithus* sp., 2700×. Sample 417D-21-3, 130-131 cm.
18. Crossed nicols.
19. Interference contrast.

Figures 20, 21  *Tetralithus* sp., 3200×. Sample 417D-21-4, 40-41 cm.
20. Crossed nicols.
PLATE 8
Light Micrographs

Figure 1  Helicosphaera carteri, 3700 x. Sample 418-1-4, 93-94 cm. Crossed nicols.

Figure 2  Helicosphaera carteri, 2200 x. Sample 418-1-4, 93-94 cm. Crossed nicols.

Figures 3, 4  Ceratolithus cristatus, 1900 x. Sample 418-1-4, 14-15 cm.
            3. Crossed nicols.
            4. Interference contrast.

Figures 5, 6  Scyphosphaera globulosa, 1500 x. Sample 418-1-4, 93-94 cm.
            5. Crossed nicols.

Figure 7  Gephyrocapsa sp., 5100 x. Sample 417D-1-4, 14-15 cm. Crossed nicols.

Figure 8  Cyclococcolithus leptoporus, 4600 x. Sample 417D-1-4, 14-15 cm. Crossed nicols.

Figures 9, 10  Cyclococcolithus macintyrei, 2800 x. Sample 418-1-4, 14-15 cm.
              10. Interference contrast.

Figure 11  Cyclococcolithus macintyrei, 3200 x. Sample 417D-1-4, 14-15 cm. Crossed nicols.

Figures 12, 13  Scyphosphaera pulcherrima, 2000 x. Sample 418-1-4, 93-94 cm.
               12. Crossed nicols.

Figures 14, 15  Thoracosphaera cf. T. saxeа, 1400 x. Sample 418-1-4, 93-94 cm.
                 15. Interference contrast.

Figures 16, 17  Thoracosphaera sp., 1400 x. Sample 418-1-4, 93-94 cm.
                 17. Interference contrast.

Figures 18, 19  Ceratolithus telesmus, 1900 x. Sample 418-1-4, 14-15 cm.
                 18. Crossed nicols.
                 19. Interference contrast.