

18. COCCOLITH AGE DETERMINATIONS LEG 3, DEEP SEA DRILLING PROJECT¹

David Bukry, U. S. Geological Survey, La Jolla, California
and

M. N. Bramlette, Scripps Institution of Oceanography, La Jolla, California

This report combines the results of study of the coccoliths in 289 samples from the 102 cores recovered during Leg 3 of the Deep Sea Drilling Project, December-January 1968-1969. Light-microscope techniques have been used to identify the coccolith assemblages. Following a summary of the coccolith zonation, a few of the age-diagnostic species in selected samples from each drilling site are listed.

The sample numbers, which identify the relative position of samples in the holes, consist of a series of numbered and lettered entries separated by hyphens in the following sequence: (cruise-leg number)—(drill-hole designation, consisting of site number plus a letter, if more than one hole)—(core designation)—(core-section number). This series is followed by the interval below the top of each core section in centimeters. For example, 3-13A-1³, 140-144 centimeters, means the sample came from Leg 3, Hole 13A (at Site 13), the first barrel of core recovered, the top section of that core, and from 140-144 centimeters below the top of the section. Most core runs were 9.1 meters long, but occasionally the core liners were not full. Recoveries are arbitrarily placed at the top of the core runs, and an approximate depth in meters below the sea floor follows samples about which further information is given in this report.

As many of the cores from Leg 3 were taken during continuous coring of coccolith ooze, important biostratigraphic information can result from detailed study of this material. Table 1 is a systematic list of the coccolith species considered in this report. The tentative zones used here (Table 2) incorporate and supplement the biostratigraphic units proposed by Bramlette and Sullivan (1961), Hay, Mohler, Roth, Schmidt, and Boudreaux (1967), and Bramlette and Wilcoxon (1967). Further revision and refinement of this zonation will doubtless prove necessary as the intensive study of additional, well-defined taxa and their range relations in various parts of the world is continued. Only then may generally acceptable concurrent-range zones be expected. Following this table, in alphabetical order, are the defining characteristics of the coccolith zones

used for the assemblages in these cores. The intervals of each core including these zones is shown in Table 3. The final section of this chapter is a listing of the age-diagnostic coccoliths from selected samples.

TABLE I
Coccolith Species Considered in This Report

<i>Apertapetra gronosa</i> (Stover)
<i>Arkhangelskiella cymbiformis</i> Vekshina
<i>Braarudosphaera rosa</i> Levin and Joerger
<i>Bramletteius serraculoides</i> Gartner
<i>Broinsonia parca</i> (Stradner)
<i>Campylosphaera dela</i> (Bramlette and Sullivan)
<i>Ceratolithoides kamptneri</i> Bramlette and Martini
<i>Ceratolithus cristatus</i> Kamptner
<i>Ceratolithus rugosus</i> Bukry and Bramlette
<i>Ceratolithus tricorniculatus</i> Gartner
<i>Chiphragmalithus cristatus</i> (Martini)
<i>Chiphragmalithus quadratus</i> Bramlette and Sullivan
<i>Chiphragmalithus</i> sp. aff. <i>C. spinosus</i> (Stradner)
<i>Chiphragmalithus</i> sp.
<i>Chiasmolithus bidens</i> (Bramlette and Sullivan)
<i>Chiasmolithus consuetus</i> (Bramlette and Sullivan)
<i>Chiasmolithus gigas</i> (Bramlette and Sullivan)
<i>Chiasmolithus grandis</i> (Bramlette and Riedel)
<i>Chiasmolithus solitus</i> (Bramlette and Sullivan)
<i>Chiasmolithus staurion</i> (Bramlette and Sullivan)
<i>Chiasmolithus</i> sp.
<i>Coccolithus bisectus</i> (Hay, Mohler, and Wade) Bramlette and Wilcoxon
<i>Coccolithus</i> sp. aff. <i>C. bisectus</i> (Hay, Mohler, and Wade) Bramlette and Wilcoxon
<i>Coccolithus cavus</i> Hay and Mohler
<i>Coccolithus daronicoides</i> Black and Barnes
<i>Coccolithus</i> sp. aff. <i>C. scissurus</i> (Hay, Mohler, and Wade) Bramlette and Wilcoxon

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TABLE 1—Continued

<i>Coccolithus subdistichus</i> (Roth and Hay)
<i>Cribrosphaera ehrenbergi</i> Arkhangelsky
<i>Cruciplacolithus tenuis</i> (Stradner)
<i>Cyclococcolithus leptoporus</i> (Murray and Blackman) varieties A, B, and C McIntyre, Bé, and Preikstas
<i>Cyclococcolithus lusitanicus</i> (Black)
<i>Cyclococcolithus neogammation</i> Bramlette and Wilcoxon
<i>Cyclolithella robusta</i> (Bramlette and Sullivan)
<i>Cylindralithus gallicus</i> Bramlette and Martini
<i>Discoaster aulakos</i> Gartner
<i>Discoaster barbadiensis</i> Tan
<i>Discoaster brouweri</i> Tan
<i>Discoaster</i> sp. aff. <i>D. brouweri</i> Tan
<i>Discoaster calcaris</i> Gartner
<i>Discoaster challengerii</i> Bramlette and Riedel
<i>Discoaster colleti</i> (Parejas)
<i>Discoaster deflandrei</i> Bramlette and Riedel
<i>Discoaster diastypus</i> Bramlette and Sullivan
<i>Discoaster dilatus</i> Hay
<i>Discoaster distinctus</i> Martini
<i>Discoaster druggi</i> Bramlette and Wilcoxon
<i>Discoaster exilis</i> Martini and Bramlette
<i>Discoaster</i> sp. aff. <i>D. gemmeus</i> Stradner
<i>Discoaster hamatus</i> Martini and Bramlette
<i>Discoaster</i> sp. aff. <i>D. hamatus</i> Martini and Bramlette
<i>Discoaster lenticularis</i> Bramlette and Sullivan
<i>Discoaster lodoensis</i> Bramlette and Riedel
<i>Discoaster martinii</i> Stradner
<i>Discoaster</i> sp. aff. <i>D. mirus</i> Deflandre
<i>Discoaster multiradiatus</i> Bramlette and Riedel
<i>Discoaster pentaradiatus</i> Tan
<i>Discoaster perplexus</i> Bramlette and Riedel
<i>Discoaster saipanensis</i> Bramlette and Riedel
<i>Discoaster sublodoensis</i> Bramlette and Sullivan
<i>Discoaster</i> sp. aff. <i>D. sublodoensis</i> Bramlette and Sullivan
<i>Discoaster surculus</i> Martini and Bramlette
<i>Discoaster tani nodifera</i> Bramlette and Riedel
<i>Discoaster tani ornata</i> Bramlette and Wilcoxon
<i>Discoaster tani tani</i> Bramlette and Riedel
<i>Discoaster variabilis</i> Martini and Bramlette

TABLE 1—Continued

<i>Discoaster</i> sp.
<i>Discoasteroides kuepperi</i> (Stradner)
<i>Eiffellithus augustus</i> Bukry
<i>Eiffellithus turriseiffeli</i> (Deflandre)
<i>Ellipsolithus distichus</i> (Bramlette and Sullivan)
<i>Ellipsolithus macellus</i> (Bramlette and Sullivan)
<i>Fasciculithus tympaniformis</i> Hay and Mohler
<i>Gephyrocapsa oceanica</i> Kamptner
<i>Helicopontosphaera ampliaptera</i> (Bramlette and Wilcoxon)
<i>Helicopontosphaera compacta</i> (Bramlette and Wilcoxon)
<i>Helicopontosphaera intermedia</i> (Martini)
<i>Helicopontosphaera kamptneri</i> Hay and Mohler
<i>Helicopontosphaera parallela</i> (Bramlette and Wilcoxon)
<i>Helicopontosphaera reticulata</i> (Bramlette and Wilcoxon)
<i>Helicopontosphaera</i> sp. aff. <i>H. seminulum</i> (Bramlette and Sullivan)
<i>Helicopontosphaera truncata</i> (Bramlette and Wilcoxon)
<i>Heliolithus kleinPELLI</i> Sullivan
<i>Heliolithus riedeli</i> Bramlette and Sullivan
<i>Isthmolithus recurvus</i> Deflandre
<i>Lithraphidites quadratus</i> Bramlette and Martini
<i>Lucianorhabdus cayeuxi</i> Deflandre
<i>Marthasterites contortus</i> (Stradner)
<i>Marthasterites</i> sp. aff. <i>M. contortus</i> (Stradner)
<i>Marthasterites tribrachiatus</i> (Bramlette and Riedel)
<i>Micrantholithus</i> sp.
<i>Micula decussata</i> Vekshina
<i>Orthorhabdus serratus</i> Bramlette and Wilcoxon
<i>Prediscosphaera cretacea lata</i> Bukry
<i>Reticulofenestra dictyoda</i> (Deflandre)
<i>Reticulofenestra pseudoumbilica</i> (Gartner)
<i>Reticulofenestra umbilica</i> (Levin)
<i>Rhabdosphaera clavigera</i> Murray and Blackman
<i>Rhabdosphaera stylifera</i> Lohmann
<i>Rhabdothorax</i> sp.
<i>Sphenolithus</i> sp. aff. <i>S. abies</i> Deflandre
<i>Sphenolithus belemnus</i> Bramlette and Wilcoxon.
<i>Sphenolithus</i> sp. aff. <i>S. belemnus</i> Bramlette and Wilcoxon
<i>Sphenolithus ciperoensis</i> Bramlette and Wilcoxon
<i>Sphenolithus distentus</i> (Martini)

TABLE 1—Continued

<i>Sphenolithus furcatolithoides</i> Locker
<i>Sphenolithus heteromorphus</i> Deflandre
<i>Sphenolithus moriformis</i> (Brönnimann and Stradner)
<i>Sphenolithus predistentus</i> Bramlette and Wilcoxon
<i>Sphenolithus pseudoradians</i> Bramlette and Wilcoxon
<i>Sphenolithus radians</i> Deflandre
<i>Tetralithus murus</i> Martini
<i>Tetralithus nitidus nitidus</i> Martini
<i>Tetralithus nitidus trifidus</i> (Stradner)
<i>Thoracosphaera</i> sp.
<i>Toweius eminens</i> (Bramlette and Sullivan)

TABLE 1—Continued

<i>Triquetrorhabdulus carinatus</i> Martini
<i>Triquetrorhabdulus</i> sp. cf. <i>T. carinatus</i> Martini
<i>Triquetrorhabdulus</i> sp. aff. <i>T. carinatus</i> Martini
<i>Triquetrorhabdulus rugosus</i> Bramlette and Wilcoxon
<i>Triquetrorhabdulus</i> sp.
<i>Watznaueria barnesae</i> (Black)
<i>Zygodiscus deflandrei</i> Bukry
<i>Zycolithus chiastus</i> Bramlette and Sullivan
<i>Zycolithus distentus</i> Bramlette and Sullivan
<i>Zycolithus dubius</i> Deflandre
<i>Zygrhablithus bijugatus</i> (Deflandre)

TABLE 2
Stratigraphic Position of Tentative Coccolith Zones in Leg 3 Cores

Series and Sub-series or Stage	Tentative Zone
PLEISTOCENE, UPPER	<i>Gephyrocapsa oceanica</i>
PLEISTOCENE, LOWER	<i>Coccolithus doronicoides</i>
PLIOCENE, UPPER	<i>Discoaster brouweri</i>
PLIOCENE, LOWER	<i>Reticulofenestra pseudoumbilica</i>
PLIOCENE OR MIOCENE	<i>Ceratolithus rugosus</i>
MIOCENE, UPPER	<i>Ceratolithus tricorniculatus</i>
	<i>Triquetrorhabdulus rugosus</i>
MIOCENE, MIDDLE	(Not represented)
MIOCENE, LOWER	<i>Sphenolithus heteromorphus</i>
	<i>Helicopontosphaera ampliapertura</i>
MIOCENE OR OLIGOCENE	<i>Sphenolithus belemnos</i>
	<i>Triquetrorhabdulus carinatus</i>
OLIGOCENE, UPPER	<i>Sphenolithus ciperoensis</i>
OLIGOCENE, MIDDLE	<i>Sphenolithus distentus</i>
OLIGOCENE, LOWER	<i>Sphenolithus predistentus</i>
	<i>Helicopontosphaera reticulata</i>
EOCENE, UPPER	<i>Discoaster barbadiensis</i>
	<i>Reticulofenestra umbilica</i>
EOCENE, MIDDLE	<i>Chiphragmalithus quadratus</i>
	<i>Discoaster sublodoensis</i>
	<i>Discoaster lodoensis</i>
EOCENE, LOWER	<i>Marthasterites tribrachiatus</i>
	<i>Discoaster diastypus</i>

TABLE 2—Continued

Series and Sub-series or Stage	Tentative Zone
PALEOCENE, UPPER	<i>Discoaster multiradiatus</i>
PALEOCENE, MIDDLE	(Not represented)
PALEOCENE, LOWER	<i>Cruciplacolithus tenuis</i>
UPPER CRETACEOUS, MAESTRICHTIAN	<i>Tetralithus murus</i>
	<i>Lithraphidites quadratus</i>
UPPER CRETACEOUS, MAESTRICHTIAN OR CAMPANIAN	<i>Tetralithus nitidus trifidus</i>
UPPER CRETACEOUS, CAMPANIAN	<i>Eiffelithus augustus</i>

DESCRIPTION OF TENTATIVE COCCOLITH ZONES

Ceratolithus rugosus Zone

The top of the zone corresponds with the extinction of *Ceratolithus tricorniculatus*, and the base by the first occurrence of *Ceratolithus rugosus*. Common species are the same as those listed for the *Reticulofenestra pseudoumbilica* Zone. Within the zone there is a marked decrease in the abundance of an undescribed discoaster that was figured as "*Discoaster* sp." in the Leg 1 report.

Ceratolithus tricorniculatus Zone

The top of the zone is marked by the first occurrence of *Ceratolithus rugosus*; the base is marked by the first occurrence of *Ceratolithus tricorniculatus*. Within the zone the dominant discoasters are *Discoaster challengerii*, *Discoaster pentaradiatus*, *D.* sp. [undescribed], with *Discoaster surculus* being present.

Chiphragmalithus quadratus Zone

The top of this zone is marked by the first occurrence of *Reticulofenestra umbilica* and the last occurrence of *Chiphragmalithus quadratus*. The base is marked by the first occurrence of *C. quadratus* and the last common occurrence of *Discoaster sublodoensis*. Commonly occurring within this zone is a plexus of *Chiphragmalithus* spp., *Chiasmolithus gigas*, and *Chiasmolithus staurion*.

Coccolithus dornicoides Zone

As described by S. Gartner (personal communication, 1968), the basal Pleistocene is characterized by strata in which *Coccolithus dornicoides* is dominant, with *Gephyrocapsa oceanica* and *Discoaster brouweri* rare, if present. Also characteristic is the presence in lesser numbers of the common Pliocene form of large, many-element *Cyclococcolithus leptoporus*. Both *Ceratolithus cristatus* and *C. rugosus* may be present.

Cruciplacolithus tenuis Zone

The top of the zone is marked by the first occurrence of *Fasciculithus tympaniformis*. The base of the zone is marked by the first occurrence of *Cruciplacolithus tenuis*. (This is the lowest zone of the Tertiary samples from the South Atlantic Ocean. A disturbed sequence is evident, either natural or from coring, at the base of the Tertiary at Site 20, but a sample from 3-20C-6-5 at 15 centimeters was the basal part of this zone and the Danian equivalent.)

Discoaster barbadiensis Zone

The top of this zone (tentatively identified as the top of the Eocene) is marked by the extinction of *Discoaster barbadiensis*, *Discoaster saipanensis*, and a definite reduction in the abundance of *Isthmolithus recurvus*. The base is marked by the last occurrence of *Chiasmolithus grandis* and by the first common occurrence of *Discoaster tani tani*. *D. saipanensis* and *Reticulofenestra umbilica* are prominent throughout the zone.

Discoaster brouweri Zone

Discoaster brouweri or *D. pentaradiatus* typically dominate this zone. The top is recognized by an abrupt reduction in the abundance of *D. brouweri* or *D. pentaradiatus*, *Cyclococcolithus leptoporus* var. A and *Ceratolithus rugosus*. The base of the zone is marked by the upper limit of *Reticulofenestra pseudoumbilica* and *Sphenolithus* sp. aff. *S. abies* [small]. *Coccolithus dornicoides* is abundant throughout the zone. In the upper part of the zone three-rayed forms of *D. brouweri* may be common.

Discoaster diastypus Zone

The top of the zone is marked by the first occurrences of *Discoaster lodoensis* and *Chiasmolithus grandis*, and by

the last occurrence of *Discoaster diastypus*. The base is marked by the first occurrences of *D. diastypus*, *Marthasterites contortus* and *Marthasterites tribrachiatus*, and the last occurrences of *Discoaster lenticularis* and *Discoaster multiradiatus*.

Discoaster lodoensis Zone

The top of this zone is marked by the first occurrence of *Discoaster sublodoensis*, the base of the zone by the last occurrence of *Marthasterites tribrachiatus*. *Discoaster lodoensis* and *Discoasteroides kuepperi* are usually common within the zone.

Discoaster multiradiatus Zone

The top of the zone is marked by the last occurrence of *Discoaster lenticularis* and *Discoaster multiradiatus* in conjunction with the first occurrences of *Discoaster diastypus* and *Marthasterites contortus*. The base is marked by the first occurrence of *D. multiradiatus* and the last occurrence of *Helolithus riedeli*. (The *Helolithus riedeli* Zone was not encountered in the cores penetrating the Paleocene strata.)

Discoaster sublodoensis Zone

The top of the zone is marked by the first occurrence of *Chiphragmolithus quadratus*, the base by the first occurrence of *Discoaster sublodoensis*.

Eiffellithus augustus Zone

The top of this zone is marked by the last occurrence of *Eiffellithus augustus*. The base is marked by the first occurrence of *Broinsonia parca*. (This lower or middle Campanian Zone was also cored during Leg 2 at Site 10, 433-449 meters, in the North Atlantic Ocean.)

Gephyrocapsa oceanica Zone

This zone is characterized by the abundance of *Gephyrocapsa oceanica* and the presence of small forms of *Cyclococcolithus*—*C. leptoporus* vars. B and C, along with *Ceratolithus cristatus* and *Helicopontosphaera kamptneri*.

Helicopontosphaera ampliaperta Zone

The top of this zone is marked by the extinction of *Helicopontosphaera ampliaperta* in most regions; and, the base is marked by the extinction of *Sphenolithus belemnus* and by the first appearance of *Sphenolithus heteromorphus*. *Cyclococcolithus neogammation* is abundant, but *Cyclococcolithus leptoporus*, like *Reticulofenestra pseudoumbilica*, first appears here in small numbers.

Helicopontosphaera reticulata Zone

The last occurrence of *Cyclococcolithus lusitanicus*, *Helicopontosphaera reticulata* and *Reticulofenestra umbilica* mark the top of this zone. The base of the zone

(here considered to be the Oligocene-Eocene boundary) is marked by the last occurrence of *Discoaster barbadiensis* and *Discoaster saipanensis*. *Isthmolithus recurvus*, which is most abundant in the underlying zone, is sparsely present.

Lithraphidites quadratus Zone

The top of the zone is marked by the first occurrence of *Tetralithus murus*. The base is marked by the first occurrence of *Lithraphidites quadratus*.

Marthasterites tribrachiatus Zone

The top of the zone is marked by the last occurrence of *Marthasterites tribrachiatus*, and the base by the first occurrence of *Discoaster lodoensis*. The base of the zone is further characterized by the first occurrence of *Chiasmolithus grandis* and the last occurrence of *Discoaster diastypus*.

Reticulofenestra pseudoumbilica Zone

The top of this zone is marked by the extinction of the common, large form of *Reticulofenestra pseudoumbilica* and *Sphenolithus* sp. aff. *S. abies*. The base is marked by the extinction of *Ceratolithus tricorniculatus*. Common species within this zone are: *Ceratolithus rugosus*, *Discoaster brouweri*, *Discoaster pentaradiatus*, *Discoaster surculus*, *R. pseudoumbilica*, and *S. sp. aff. S. abies*.

Reticulofenestra umbilica Zone

The top of this zone is marked by the last occurrence of *Chiasmolithus grandis* and the first occurrence of *Discoaster tani tani*. The base is marked by the first occurrence of *Reticulofenestra umbilica*, which also approximates the extinction of *Chiphragmalithus* spp.

Sphenolithus belemnus Zone

The last occurrence of *Sphenolithus belemnus* and the first occurrence of *Sphenolithus heteromorphus* mark the top of this zone. The base is marked by the latest occurrence of *Triquetrorhabdulus carinatus*, by an increase in the abundance of *S. belemnus*, and by *Helicopontosphaera ampliaperta* which is consistently smaller than the specimens from the *Helicopontosphaera ampliaperta* Zone.

Sphenolithus ciperoensis Zone

The extinction of *Sphenolithus ciperoensis*, *Helicopontosphaera* sp. aff. *H. seminulum*, and *Coccolithus bisectus* mark the top of this zone. The base is marked by the extinction of *Sphenolithus distentus*, *Coccolithus* sp. aff. *C. scissurus*, and the first occurrence of *Triquetrorhabdulus carinatus*.

Sphenolithus distentus Zone

The top of this zone is marked by the gradation of typical *Sphenolithus distentus* to *Sphenolithus*

ciperoensis. The base is marked by the first occurrence of *Coccolithus* sp. aff. *C. bisectus* and *Helicopontosphaera* sp. aff. *H. seminulum*, as well as by the last occurrence of *Discoaster tani tani* and *Sphenolithus pseudoradians*.

Sphenolithus heteromorphus Zone

The extinction of *Sphenolithus heteromorphus* marks the top of this zone; the extinction of *Helicopontosphaera ampliaperta* marks the base of the zone in most regions (not yet recognized in these cores). The zone is, however, further characterized by the first appearance of *Discoaster exilis* and by a marked reduction in the frequency of *Discoaster deflandrei*. Ranges of the abundant and long-ranging *Cyclococcolithus leptoporus* and *Cyclococcolithus neogammation* overlap in the zone.

Sphenolithus predistentus Zone

The top of this zone is marked by the first occurrence of *Helicopontosphaera truncata* and *Coccolithus* sp. aff. *C. bisectus*, and by the gradation of typical *Sphenolithus predistentus* to the succeeding *Sphenolithus distentus*. Other markers are the extinctions of *Discoaster tani tani* and sparse *Sphenolithus pseudoradians*. The base of the zone is well marked by the last occurrences of the common *Cyclococcolithus lusitanicus*, *Helicopontosphaera reticulata*, *Reticulofenestra umbilica*, and the near extinction of *Helicopontosphaera compacta*.

Tetralithus murus Zone

The range of *Tetralithus murus* defines the uppermost zone of the Cretaceous.

Tetralithus nitidus trifidus Zone

The range of *Tetralithus nitidus trifidus* defines this zone, which is transitional between Maestrichtian and Campanian (see Bukry and Bramlette, 1969, and Bukry and Kennedy, 1969).

Triquetrorhabdulus carinatus Zone

The top of this zone is marked by the extinction of *Triquetrorhabdulus carinatus*, and by the first common occurrence of *Sphenolithus belemnus* and a small variety of *Helicopontosphaera ampliaperta*. The base is marked by the last common occurrence of both *Coccolithus bisectus* and typical *Sphenolithus ciperoensis*. When present, *Orthorhabdus serratus* and *Discoaster druggi* mark the upper part of the zone.

Triquetrorhabdulus rugosus Zone

The first appearance of *Ceratolithus tricorniculatus* and *Discoaster surculus* marks the top of this zone; the base is marked by the extinction of *Discoaster hamatus*. This zone is characterized by the occurrence of several long-rayed species of discoasters: *Discoaster brouweri*, *Discoaster calcaris* and *Discoaster* sp. aff. *D. hamatus* [six-rayed]. Also, consistently present is *Triquetrorhabdulus rugosus*.

COCCOLITH ZONATION OF SAMPLES

A tabulation of the zones recognized for all of the samples studied here is presented for each site in Table 3. Drilling gaps, representing intervals from which no cores were taken, are indicated within the sample sequence. Redrilling overlaps are also indicated.

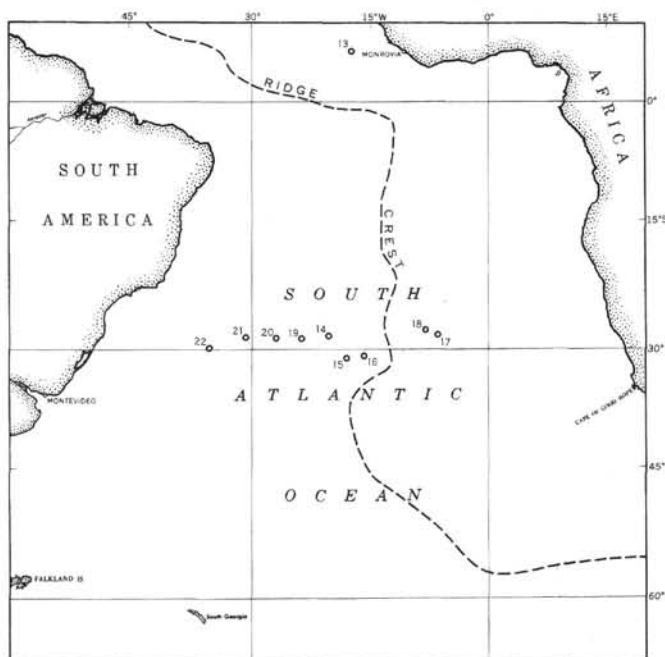


Figure 1. Location of Sites drilled on Leg 3.

TABLE 3
Coccolith Zonation of Samples Studied

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
Site 13				
PLIOCENE	UPPER	<i>Discoaster brouweri</i>	1-1, 75 cm 1-4, 78-79 cm 1-6, 74-75 cm GAP-12 m 2-1, 75-76 cm 2-2, 75-76 cm	8
PLIOCENE	LOWER	<i>Reticulofenestra pseudumbilica</i>	2-3, 75-76 cm	25
?			2-4, 2-5 cm GAP 106 cm 3-1, 103-104 cm 3-6, 75-76 cm GAP-32 m	
EOCENE	MIDDLE	<i>Discoaster sublodoensis?</i>	1A-1, 140-144 cm	179
?			GAP-63 m	
UPPER CRETACEOUS	UPPER	<i>Tetralithus nitidus trifidus</i>	2A-1, 127-128 cm GAP-57 m 3A-1, 141-142 cm 3A-4, 86-87 cm GAP-64 m 4A-1, 79-80 cm	308
		---	GAP-30 m 5A-1, 77-79 cm GAP-28 m 6A, CC GAP-12 m 7A-1, 107-108 cm	
Site 14				
MIOCENE	LOWER	<i>Sphenolithus belemnos</i>	1A-1, 77-78 cm	1
MIOCENE OR OLIGOCENE		<i>Triquetrorhabdulus carinatus</i>	1A-3, 73-74 cm 1A-4, 74-75 cm 1A-5, 78-79 cm 1A-6, 78-79 cm GAP-3 m	4
			2-2, 73-74 cm 2-3, 73-74 cm 2-4, 73-74 cm 2-5, 73-74 cm	16

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
?			GAP-12 m	
OLIGOCENE	UPPER	<i>Sphenolithus ciproensis</i>	3-1, 75-76 cm 3-2, 76-77 cm 3-6, 77-78 cm	34
	?		GAP-10 m	
OLIGOCENE	MIDDLE	<i>Sphenolithus distentus</i>	4-1, 41-42 cm	53
	LOWER	<i>Sphenolithus predistentus</i>	5-3, 77-78 cm 5-4, 75-76 cm 5-5, 78-79 cm 6-1, 88-89 cm 6-2, 79-80 cm 7-1, 78-79 cm 7-6, 78-79 cm	68
			8-3, 82-83 cm 8-6, 148-150 cm 9-2, 70-71 cm 9-3, 148-150 cm 9-4, 78-79 cm 9-5, 77-78 cm 9-6, 87-88 cm	98
Site 15				
PLEISTOCENE	LOWER	<i>Coccolithus doronicoides</i>	1-1, 72-73 cm 1-6, 79-80 cm	8
?			GAP-9 m	
PLEISTOCENE OR PLIOCENE	---	---	2-1, 74-75 cm 2-2, 73-74 cm	21
PLIOCENE	UPPER	<i>Discoaster brouweri</i>	2-3, 76-77 cm 2-4, 72-73 cm 2-5, 74-75 cm 2-6, 78-80 cm	22
	?		GAP-9 m	
	LOWER	<i>Reticulofenestra pseudumbilica</i>	3-1, 79-80 cm	37
PLIOCENE OR MIOCENE	---	<i>Ceratolithus rugosus</i>	3-2, 78-79 cm 3-3, 73-74 cm	39

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
MIOCENE	UPPER	<i>Ceratolithus tricorniculatus</i>	3-4, 79-80 cm	49
			3-5, 79-80 cm	
			3-6, 78-79 cm	
	4-1, 77-78 cm			
	4-2, 71-72 cm			
	4-3, 78-79 cm			
	4-4, 80-81 cm			
4-5, 79-80 cm				
4-6, 78-80 cm				
		?	GAP-22 m	
		<i>Triquetrorhabdulus rugosus</i>	5-1, 79-80 cm 5-6, 79-80 cm	85
	?		GAP-19 m	
	LOWER	<i>Sphenolithus heteromorphus</i>	6-1, 72-73 cm	106
6-2, 79-80 cm				
<i>Sphenolithus heteromorphus</i> or <i>Helicopontosphaera reticulata</i> <i>comp. a part</i>		6-3, 77-78 cm 6-4, 77-78 cm 6-5, 79-80 cm 6-6, 79-80 cm 7-1, 79-80 cm	113	
<i>Helicopontosphaera ampliaperta</i>		7-6, 78-79 cm	122	
MIOCENE OR OLIGOCENE	---	<i>Triquetrorhabdulus carinatus</i>	8-1, 148-150 cm 8-2, 74-75 cm 8-3, 79-80 cm 8-4, 79-80 cm 8-5, 79-80 cm 8-6, 79-80 cm	128
MIOCENE	LOWER	<i>Helicopontosphaera ampliaperta</i>	9-1, 72-73 cm 9-2, 78-79 cm	135
MIOCENE OR OLIGOCENE	---	<i>Triquetrorhabdulus carinatus</i>	9-5, 79-80 cm 9-6, 78-79 cm	
Site 16				
PLEISTOCENE	UPPER	<i>Gephyrocapsa oceanica</i>	1-1, 79-80 cm	1
	?		GAP-9 m	
	LOWER	<i>Coccolithus doronicoides</i>	2-1, 150 cm 2-2, 150 cm 2-3, 150 cm	20

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
PLEISTOCENE OR PLIOCENE	---	---	2-4, 150 cm 2-5, 150 cm	
PLIOCENE	UPPER	<i>Discoaster brouweri</i>	2-6, 77-78 cm GAP-9 m 3-1, 150 cm 3-2, 150 cm 3-4, 150 cm 3-6, 150 cm	46
	?		GAP-9 m	
	LOWER	<i>Reticulofenestra pseudoumbilica</i>	4-1, 79-80 cm 4-2, 79-80 cm 4-4, 77-78 cm 4-6, 150 cm	64
?			GAP-22 m	
MIOCENE	UPPER	<i>Ceratolithus tricorniculatus</i>	5-1, 150 cm GAP-9 m 6-1, 150 cm 6-2, 150 cm 6-3, 150 cm 6-4, 150 cm 6-5, 150 cm 6-6, 150 cm 7-1, 150 cm 7-2, 150 cm 7-4, 150 cm 7-6, 150 cm GAP-3 m 8-1, 150 cm 8-2, 150 cm 8-3, 150 cm 8-4, 150 cm 8-5, 150 cm 8-6, 150 cm	93
		<i>Triquetrorhabdulus rugosus</i>	9-1, 150 cm 10-1, 150 cm 11-1, 150 cm 11-6, 150 cm	162

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
Site 17				
PLEISTOCENE	UPPER	<i>Gephyrocapsa oceanica</i>	1-1, 74-75 cm 1-5, 75-76 cm	1 7
?			GAP-10 m	
PLIOCENE OR MIOCENE	---	<i>Ceratolithus rugosus</i>	2-1, 77-78 cm 2-2, 74-75 cm 2-3, 82-83 cm	20
MIOCENE	UPPER	<i>Ceratolithus tricorniculatus</i>	2-4, 74-75 cm 2-5, 77-78 cm 2-6, 74-75 cm	27
	LOWER	<i>Helicopontosphaera ampliaperta</i>	1A-1, 75-76 cm 1A-2, 73-74 cm 1A-3, 74-75 cm 1A-4, 74-75 cm 1A-5, 77-78 cm 1A-6, 77-78 cm	34
MIOCENE OR OLIGOCENE	---	<i>Triquetrorhabdulus carinatus</i>	2A-1, 73-74 cm 2A-4, 77-78 cm	43
OLIGOCENE	UPPER	<i>Sphenolithus ciperoensis</i>	2A-6, 77-78 cm	
	?		GAP-39 m	
	MIDDLE	<i>Sphenolithus distentus</i>	3A-1, 74-75 cm 3A-6, 148-150 cm	
	LOWER	<i>Sphenolithus predistentus</i>	4A-2, 77-78 cm 4A-5, 0-2 cm 4A-6, 78-79 cm	
OLIGOCENE	UPPER	<i>Sphenolithus ciperoensis</i>	OVERLAP-16 m 1B-1, 78-79 cm 1B-4, 77-78 cm 1B-6, 72-73 cm 2B-1, 74-75 cm 2B-4, 78-79 cm 2B-6, 78-79 cm	95
	MIDDLE	<i>Sphenolithus distentus</i>	3B-1, 75-76 cm 3B-2, 74-75 cm 3B-3, 77-78 cm 3B-4, 74-75 cm 3B-6, 74-75 cm	107

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
OLIGOCENE	LOWER	<i>Sphenolithus predistentus</i>	4B-1, 75-76 cm 4B-2, 74-75 cm 4B-3, 75-76 cm 4B-4, 73-74 cm 4B-5, 77-78 cm 4B-6, 74-75 cm	121
Site 18				
PLEISTOCENE	UPPER	<i>Gephyrocapsa oceanica</i>	1-5, 74-75 cm	7
?			GAP-113 m	
MIOCENE	LOWER	<i>Sphenolithus belemnus</i>	2-1, 0-2 cm 2-3, 148-150 cm	121
MIOCENE OR OLIGOCENE	---	<i>Triquetrorhabdulus carinatus</i>	2-5, 148-150 cm 2-6, 148-150 cm GAP-11 m 3-1, 148-150 cm 3-4, 148-150 cm 3-6, 148-150 cm 4-2, 0-2 cm 4-5, 148-150 cm 5-1, 148-150 cm 5-3, 148-150 cm 5-6, 0-2 cm 6-1, 76-77 cm 6-3, 148-150 cm 6-4, 148-150 cm 6-6, 78-79 cm	173
Site 19				
PLEISTOCENE OR PLIOGENE	---	---	1-1, 77-78 cm	1
?			GAP-27 m	
OLIGOCENE	UPPER	<i>Sphenolithus ciperoensis</i>	3-1, 75-76 cm	37
	UPPER OR MIDDLE	<i>Sphenolithus ciperoensis</i> or <i>Sphenolithus distentus</i>	3-3, 74-75 cm 3-4, 77-78 cm 3-6, 77-78 cm	
	?		GAP-11 m	

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
OLIGOCENE	LOWER	<i>Sphenolithus predistentus</i>	4-2, 78-79 cm 4-3, 148-150 cm	61
		<i>Helicopontosphaera reticulata</i>	4-6, 148-150 cm GAP-10 m 5-1, 148-150 cm 5-2, 73-74 cm	
EOCENE	UPPER	<i>Discoaster barbadiensis</i>	5-3, 78-79 cm 5-4, 79-80 cm GAP-1 m	81
			6-1, 148-150 cm 6-4, 148-150 cm 6-6, 148-150 cm	87
	MIDDLE	<i>Reticulofenestra umbilica</i>	7-1, 77-78 cm 7-2, 78-79 cm 7-3, 78-79 cm 7-4, 78-79 cm 8-1, 148-150 cm 8-4, 148-150 cm	97
			<i>Chiphragmalithus quadratus</i>	9-1, 148-150 cm 9-4, 148-150 cm GAP-1 m 10-1, 148-150 cm 10-3, 148-150 cm 11-1, 148-150 cm 11-2, 148-150 cm 11-3, 148-150 cm 11-4, 148-150 cm
Site 20				
PLIOCENE	---	---	1C-1, 76-77 cm	1
OLIGOCENE	UPPER OR MIDDLE	<i>Sphenolithus ciproensis</i> or <i>Sphenolithus distentus</i>	1C-3, 79-80 cm 1C-4, 77-78 cm 1C-5, 76-77 cm 1C-6, 75-76 cm OVERLAP-2 m 1B-1, 78-79 cm 1B-3, 78-79 cm 1B-4, 78-79 cm 1B-6, 78-79 cm	10

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
OLIGOCENE	LOWER	<i>Sphenolithus predistentus</i>	2A-1, 70-71 cm 2A-3, 78-79 cm 2A-4, 148-150 cm 2A-6, 148-150 cm	16
		?	GAP-1 m	
		<i>Helicopontosphaera reticulata</i>	2C-1, 148-150 cm 2C-3, 77-78 cm 2C-5, 148-150 cm 2C-6, 148-150 cm	35
?			GAP-2 m	
EOCENE	UPPER	<i>Discoaster barbadiensis</i>	3C-1, 73-74 cm 3C-4, 76-77 cm	38
	MIDDLE	<i>Reticulofenestra umbilica</i>	3C-5, 79-80 cm 3C-6, 72-73 cm GAP-1 m 4C-1, 72-73 cm	44
		<i>Chiphragmalithus quadratus</i>	5C-1, 148-150 cm 5C-2, 74-75 cm	59
		<i>Discoaster sublodoensis</i>	5C-3, 73-74 cm	61
	LOWER	<i>Discoaster diastypus</i>	5C-4, 73-74 cm 5C-5, 77-78 cm 5C-6, 78-79 cm	65
?			GAP-1 m	
PALEOCENE	UPPER	<i>Discoaster multiradiatus</i>	6C-1, 148-150 cm 6C-2, 77-78 cm 6C-3, 78-79 cm 6C-4, 74-75 cm	69
UPPER CRETACEOUS	UPPER	<i>Tetralithus murus</i>	6C-4, 117 cm	73
PALEOCENE	LOWER	<i>Cruciplacolithus tenuis</i>	6C-4, 130 cm	73
UPPER CRETACEOUS	UPPER	<i>Tetralithus murus</i>	6C-5, 29 cm 6C-5, 54 cm 6C-5, 59 cm 6C-5, 74-75 cm	73
		<i>Lithraphidites quadratus</i>	6C-5, 135 cm 6C-5, 141 cm	75

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
Site 21				
PLIOCENE	UPPER	<i>Discoaster brouweri</i>	1-1, 148-150 cm 1-4, 83-84 cm 1-6, 148-150 cm	22
?			GAP-17 m	
EOCENE	MIDDLE	<i>Chiphragmalithus quadratus</i>	1A-1, 148-150 cm 1A-6, 148-150 cm	55
	?		GAP-6 m	
	LOWER	<i>Discoaster lodoensis</i>	2A-1, 148-150 cm 2A-2, 148-150 cm 2A-3, 148-150 cm	65
		<i>Marthasterites tribrachiatius</i>	2A-5, 148-150 cm 2A-6, 148-150 cm	70
PALEOCENE	UPPER	<i>Discoaster multiradiatus</i>	3A-1, 148-150 cm 3A-2, 148-150 cm 3A-3, 148-150 cm 3A-4, 148-150 cm 3A-5, 85-86 cm 3A-6, 77-78 cm OVERLAP-2 m 2-1, 148-150 cm 2-3, 148-150 cm 2-5, 88-89 cm 2-6, 98 cm	74
UPPER CRETACEOUS	UPPER	<i>Tetralithus murus</i>	3-1, 148-150 cm 3-2, 148-150 cm 3-3, 148-150 cm 3-4, 148-150 cm 3-5, 75-76 cm 3-6, 148-150 cm	81
		<i>Tetralithus nitidus trifidus</i>	4-1, 148-150 cm 5-1, 82-83 cm	95
		?	GAP-3 m	
		<i>Eiffelithus augustus</i>	6-3, 77-78 cm 7-1, 148-150 cm 8-1, 0-2 cm 8-6, 70-71 cm	117

TABLE 3—Continued

Series	Sub-series	Coccolith Zone	Sample	Depth (meters)
Site 22				
PLEISTOCENE	LOWER	<i>Coccolithus daronicoides</i>	1-1, 148-150 cm 1-3, 148-150 cm 1-4, 148-150 cm	5
PLIOCENE	UPPER	<i>Discoaster brouweri</i>	1-6, 39-40 cm	8
?			GAP-38 m	
MIOCENE OR OLIGOCENE	---	<i>Triquetrorhabdulus carinatus</i>	2-1, 78-79 cm 2-6, 75-76 cm GAP-48 cm 3-1, 148-150 cm	55
OLIGOCENE	UPPER	<i>Sphenolithus ciperoensis</i>	3-4, 148-150 cm 3-6, 77-78 cm	113
	?		GAP-20 m	
	MIDDLE	<i>Sphenolithus distentus</i>	4-1, 74-75 cm 4-2, 87-88 cm 4-4, 80-81 cm 4-6, 80-81 cm	134
?			GAP-92 m	
EOCENE	MIDDLE	<i>Reticulofenestra umbilica</i>	5-1, 12-13 cm 5-2, 140-142 cm	237

AGE-DIAGNOSTIC COCCOLITHS IN SELECTED SAMPLES

The coccolith assemblages in some representative samples—designated in Table 3 by a number giving their approximate depth below the sea floor—are presented in this concluding section.

Holes 13 and 13A

(lat 6°02.4'N., long 18°13.7'W., depth 4585 meters)

Aside from the Pliocene cores, which have very abundant discoaster assemblages, the cores from Holes 13 and 13A contain meager coccolith assemblages.

Pliocene

(*Discoaster brouweri* Zone)

3-13-1-6, 74-75 cm, depth 8 m:

Ceratolithus rugosus, *Coccolithus daronicoides*, *Cyclococcolithus leptoporus* var. A, *Discoaster brouweri*, *D. pentaradiatus*.

Pliocene

(*Reticulofenestra pseudoumbilica* Zone)

3-13-2-3, 75-76 cm, depth 25 m:

Ceratolithus rugosus, *Discoaster brouweri*, *Discoaster challengerii*, *Reticulofenestra pseudoumbilica*.

Eocene

(*Discoaster sublodoensis?* Zone)

3-13A-1A-1, 140-144 cm, depth 179 m:

Chiasmolithus solitus, *Chiphragmalithus cristatus*, *Discoaster martinii*, *Discoaster* sp. aff. *D. mirus*, *Discoaster* sp. aff. *D. sublodoensis*, *Reticulofenestra dictyoda*.

Upper Cretaceous

(*Tetralithus nitidus trifidus* Zone)

3-13A-3A-1, 141-142 cm, depth 308 m:

Micula decussata, *Tetralithus nitidus nitidus*, *T. nitidus trifidus*.

Hole 14

(lat 28° 19.9'S., long 20° 56.5'W., depth 4343 meters)

There are no significant drilling gaps in these cores; and, every coccolith zone from lower Miocene to lower Oligocene is recognized here. The Oligocene sequence of *Sphenolithus* spp. described from the Ciperó section of Trinidad (Bramlette and Wilcoxon, 1967) is represented in these cores.

Miocene

(*Sphenolithus belemnus* Zone)

3-14-1A-1, 77-78 cm, depth 1 m:

Cyclococcolithus leptoporus [rare, small], *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus belemnus*.

Miocene or Oligocene

(*Triquetrorhabdulus carinatus* Zone)

3-14-1A-4, 74-75 cm, depth 4 m:

Cyclococcolithus neogammation, *Discoaster deflandrei*, *Discoaster druggi*.

3-14-2-3, 73-74 cm, depth 16 m:

Coccolithus sp. aff. *C. bisectus*, *Coccolithus bisectus* [few], *Cyclococcolithus neogammation*.

Oligocene

(*Sphenolithus ciperóensis* Zone)

3-14-3-1, 75-76 cm, depth 34 m:

Coccolithus bisectus [common], *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus ciperóensis*.

Oligocene

(*Sphenolithus distentus* Zone)

3-14-4-1, 41-42 cm, depth 53 m:

Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus distentus*.

Oligocene

(*Sphenolithus predistentus* Zone)

3-14-5-5, 78-79 cm, depth 68 m:

Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster tani tani*, *Helicopontosphaera compacta*, *Sphenolithus distentus*, *Sphenolithus predistentus*, *Sphenolithus pseudoradians*.

Oligocene

(*Helicopontosphaera reticulata* Zone)

3-14-8-6, 148-150 cm, depth 98 m:

Bramletteius serraculoides, *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Cyclococcolithus neogammation*, *Discoaster tani ornata*, *Discoaster tani tani*, *Helicopontosphaera reticulata*, *Sphenolithus predistentus*, *Reticulofenestra umbilica*.

Hole 15

(lat 30° 53.4'S., long 17° 59.0'W., depth 3927 meters)

Cores from this site contain Pleistocene to transitional Miocene or Oligocene sediment. No definite middle Miocene sediment is present, possibly because of a 19-meter drilling gap between Cores 5 and 6. Samples from the upper two sections of Core 9 contain a younger coccolith assemblage (*Helicopontosphaera ampliapertura* Zone) than adjacent assemblages from the bases of Cores 8 and 9 (*Triquetrorhabdulus carinatus* Zone). The *H. ampliapertura* Zone was encountered higher at the site near the bottom of Core 7, so this unnatural sequence may be due to mislabeling or to drilling problems.

Pleistocene

(*Coccolithus doronicoides* Zone)

3-15-1-6, 79-80 cm, depth 8 m:

Ceratolithus cristatus, *Ceratolithus rugosus*, *Coccolithus doronicoides*, *Cyclococcolithus leptoporus* vars. B, C.

Pleistocene or Pliocene

(transitional)

3-15-2-2, 73-74 cm, depth 21 m:

Ceratolithus rugosus, *Coccolithus doronicoides*, *Cyclococcolithus leptoporus* vars. B, C, *Discoaster brouweri* [3- and 6-rayed, few].

Pliocene

(*Discoaster brouweri* Zone)

3-15-2-3, 76-77 cm, depth 22 m:

Ceratolithus rugosus, *Coccolithus doronicoides*, *Cyclococcolithus leptoporus* var. A, *Discoaster brouweri* [6- and 3-rayed; common].

Pliocene

(*Reticulofenestra pseudoumbilica* Zone)

3-15-3-1, 79-80 cm, depth 37 m:

Ceratolithus rugosus, *Cyclococcolithus leptoporus* vars. A, B, *Discoaster brouweri*, *Discoaster challengerii*, *Discoaster pentaradiatus*, *Discoaster surculus*, *Reticulofenestra pseudoumbilica*.

Pliocene or Miocene

(*Ceratolithus rugosus* Zone)

3-15-3-1, 78-79 cm, depth 39 m:

Ceratolithus rugosus, *Ceratolithus tricorniculatus*, *Cyclococcolithus leptoporus* vars. A, B, *Discoaster brouweri*, *Discoaster challengerii*, *Discoaster pentaradiatus*, *Discoaster surculus*, *Reticulofenestra pseudoumbilica*.

Miocene

(*Ceratolithus tricorniculatus* Zone)

3-15-4-3, 78-79 cm, depth 49 m:

Ceratolithus tricorniculatus, *Cyclococcolithus leptoporus* vars. A, B, *Discoaster* sp. aff. *D. brouweri*, *Discoaster*

challengeri, *Discoaster pentaradiatus*, *Discoaster surculus*, *Reticulofenestra pseudoumbilica*.

Miocene

(*Triquetrorhabdulus rugosus* Zone)

3-15-5-6, 79-80 cm, depth 85 m:

Cyclococcolithus leptoporus vars. A, B, *Discoaster brouweri*, *Discoaster* sp. aff. *D. brouweri*, *Discoaster challengeri*, *Discoaster* sp. aff. *D. hamatus* [6-rayed], *Triquetrorhabdulus rugosus*.

Miocene

(*Sphenolithus heteromorphus* Zone)

3-15-6-1, 72-73 cm, depth 106 m:

Cyclococcolithus leptoporus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster exilis*, *Discoaster variabilis*, *Reticulofenestra pseudoumbilica*, *Sphenolithus heteromorphus*.

Miocene

(*Sphenolithus heteromorphus* or *Helicopontosphaera ampliaptera* Zone)

3-15-6-6, 79-80 cm, depth 113 m:

Cyclococcolithus leptoporus [rare], *Cyclococcolithus neogammation*, *Discoaster aulakos*, *Discoaster deflandrei*, *Reticulofenestra pseudoumbilica*, *Sphenolithus heteromorphus*.

Miocene

(*Helicopontosphaera ampliaptera* Zone)

3-15-7-6, 78-79 cm, depth 122 m:

Cyclococcolithus leptoporus [rare], *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster dilatus*, *Discoaster exilis*, *Orthorhabdus serratus*, *Sphenolithus heteromorphus*.

Miocene or Oligocene

(*Triquetrorhabdulus carinatus* Zone)

3-15-8-3, 79-80 cm, depth 128 m:

Cyclococcolithus neogammation, *Discoaster deflandrei*, *Orthorhabdus serratus*, *Sphenolithus* aff. *S. belemnos*.

Miocene

(*Helicopontosphaera ampliaptera* Zone)

3-15-9-2, 78-79 cm, depth 135 m:

Cyclococcolithus neogammation, *Discoaster deflandrei*, *Discoaster dilatus*, *Sphenolithus heteromorphus*.

Miocene or Oligocene

(*Triquetrorhabdulus carinatus* Zone)

3-15-9-6, 78-79 cm, depth 141 m:

Cyclococcolithus neogammation, *Discoaster deflandrei*, *Sphenolithus* aff. *S. belemnos*.

Hole 16

(lat 30°20.2'S., long 15°42.8'W., depth 3527 meters)

Cores at this site contain coccoliths representing zones from Pleistocene to lower upper Miocene. Core 2 contains a transitional sequence of coccoliths from basal Pleistocene at the top to uppermost Pliocene at the bottom. Although the transition from basal Pliocene to uppermost Miocene is not represented because of a 22-meter drilling gap, an excellent sequence of upper Miocene calcareous ooze is present in Cores 5, 6, 7, 8, 9, 10 and 11. The *Ceratolithus tricorniculatus* Zone and *Triquetrorhabdulus rugosus* Zone are well represented in this sequence.

Pleistocene

(*Gephyrocapsa oceanica* Zone)

3-16-1-1, 79-80 cm, depth 1 m:

Ceratolithus cristatus, *Cyclococcolithus leptoporus* vars. B, C, *Gephyrocapsa oceanica*.

Pleistocene

(*Coccolithus daronicoides* Zone)

3-16-2-1, 150 cm, depth 20 m:

Ceratolithus rugosus, *Coccolithus daronicoides*, *Cyclococcolithus leptoporus* vars. B, C.

Pliocene

(*Discoaster brouweri* Zone)

3-16-3-6, 150 cm, depth 46 m:

Ceratolithus rugosus, *Coccolithus daronicoides*, *Cyclococcolithus leptoporus* var. A, *Discoaster brouweri*, *Discoaster pentaradiatus*, *Discoaster surculus*.

Pliocene

(*Reticulofenestra pseudoumbilica* Zone)

3-16-4-6, 150 cm, depth 64 m:

Ceratolithus rugosus, *Discoaster brouweri*, *Discoaster* sp. aff. *D. brouweri*, *Discoaster challengeri*, *Discoaster pentaradiatus*, *Discoaster surculus*, *Reticulofenestra pseudoumbilica*.

Miocene

(*Ceratolithus tricorniculatus* Zone)

3-16-6-5, 150 cm, depth 93 m:

Ceratolithus tricorniculatus, *Discoaster brouweri*, *Discoaster challengeri*, *Discoaster pentaradiatus*, *Discoaster variabilis*, *Reticulofenestra pseudoumbilica*.

Miocene

(*Triquetrorhabdulus rugosus* Zone)

3-16-11-6, 150 cm, depth 162 m:

Discoaster brouweri, *Discoaster challengeri*, *Discoaster* sp. aff. *D. hamatus* [6-rayed], *Discoaster pentaradiatus*, *Reticulofenestra pseudoumbilica*, *Triquetrorhabdulus rugosus*.

Holes 17, 17A, 17B
(lat 28°02.7'S., long 6°36.2'W., depth 4265 meters)

Recored of this site has provided two sequences of the Oligocene *Sphenolithus* Zones. Higher cores contain Pleistocene, transitional Pliocene or Miocene, and Miocene sediment. Samples from the Pleistocene (Core 1) show the younger *Gephyrocapsa oceanica* Zone underlying the *Coccolithus daronicoides* Zone. Stratigraphic inversions such as this are common in the uppermost cores, because the drill pipe is not firmly settled into the bottom during the coring.

Pleistocene
(*Coccolithus daronicoides* Zone)

3-17-1-1, 74-75 cm, depth 1 m:
Ceratolithus rugosus, *Coccolithus daronicoides*, *Cyclococcolithus leptoporus* var. C.

Pleistocene
(*Gephyrocapsa oceanica* Zone)

3-17-1-5, 75-76 cm, depth 7 m:
Coccolithus daronicoides, *Cyclococcolithus leptoporus* var. C, *Gephyrocapsa oceanica*.

Pliocene or Miocene
(*Ceratolithus rugosus* Zone)

3-17-2-1, 77-78 cm, depth 20 m:
Ceratolithus rugosus, *Ceratolithus tricorniculatus*, *Discoaster brouweri*, *Discoaster pentaradiatus*, *Discoaster surculus*, *Reticulofenestra pseudoumbilica*.

Miocene
(*Ceratolithus tricorniculatus* Zone)

3-17-2-6, 74-75 cm, depth 27 m:
Ceratolithus tricorniculatus, *Discoaster* sp. aff. *D. brouweri*, *Discoaster challengerii*, *Discoaster pentaradiatus*, *Reticulofenestra pseudoumbilica*.

Miocene
(*Helicopontosphaera ampliapertura* Zone)

3-17A-1A-4, 74-75 cm, depth 34 m:
Cyclococcolithus neogammation, *Discoaster deflandrei*, *Sphenolithus heteromorphus*.

Miocene or Oligocene
(*Triquetrorhabdulus carinatus* Zone)

3-17A-2A-4, 77-78 cm, depth 43 m:
Cyclococcolithus neogammation, *Discoaster deflandrei*, *Triquetrorhabdulus* sp. cf. *T. carinatus*.

Oligocene
(*Sphenolithus ciperoensis* Zone)

3-17B-1B-6, 72-73 cm, depth 95 m:
Coccolithus bisectus, *Coccolithus* sp. aff. *C. bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus ciperoensis*.

Oligocene
(*Sphenolithus distentus* Zone)

3-17B-3B-2, 74-75 cm, depth 107 m:
Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus distentus*, *Sphenolithus predistentus*.

Oligocene
(*Sphenolithus predistentus* Zone)

3-17B-4B-5, 77-78 cm, depth 121 m:
Chiasmolithus sp., *Coccolithus bisectus*, *Cyclococcolithus neogammation*, *Discoaster tani tani*, *Sphenolithus predistentus*.

Hole 18
(lat 27°58.7'S., long 8°00.7'W., depth 4018 meters)

Pleistocene, lower Miocene, and transitional Miocene or Oligocene coccolith assemblages are present in these cores. Most of the cores (2, 3, 4, 5, 6) contain coccoliths indicating the *Triquetrorhabdulus carinatus* Zone.

Pleistocene
(*Gephyrocapsa oceanica* Zone)

3-18-1-5, 74-75 cm, depth 7 m:
Ceratolithus cristatus, *Cyclococcolithus leptoporus* var. C, *Gephyrocapsa oceanica*.

Miocene
(*Sphenolithus belemnus* Zone)

3-18-2-1, 0-2 cm, depth 121 m:
Cyclococcolithus neogammation, *Discoaster deflandrei*, *Sphenolithus belemnus*, *Triquetrorhabdulus* sp. aff. *T. carinatus*.

Miocene or Oligocene
(*Triquetrorhabdulus carinatus* Zone)

3-18-2-6, 148-150 cm, depth 130 m:
Cyclococcolithus neogammation, *Discoaster deflandrei*, *Discoaster druggi*, *Orthorhabdus serratus*.

3-18-6-3, 148-150 cm, depth 173 m:
Coccolithus sp. aff. *C. bisectus*, *Coccolithus bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*.

Hole 19
(lat 28°32.1'S., long 23°40.6'W., depth 4677 meters)

After coring Pleistocene and Oligocene strata in the upper part of this hole, continuous coring from 75 to 145 meters below the bottom was carried out through a zonal sequence representing lower Oligocene to middle Eocene. The coccolith assemblages contain diagnostic species, along with a large variety of additional taxa, and these samples should prove useful in future refinement of the zonation of this interval.

**Pleistocene or Pliocene
(transitional)**

3-19-1-1, 77-78 cm, depth 1 m:
Ceratolithus cristatus, *Ceratolithus rugosus*, *Cyclococcolithus leptoporus* var. A, *Discoaster brouweri* [rare].

**Oligocene
(*Sphenolithus ciperoensis* Zone)**

3-19-3-1, 75-76 cm, depth 37 m:
Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus ciperoensis*.

**Oligocene
(*Sphenolithus predistentus* Zone)**

3-19-4-3, 148-150 cm, depth 61 m:
Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster tani tani*, *Sphenolithus distentus*, *Sphenolithus predistentus*.

**Oligocene
(*Helicopontosphaera reticulata* Zone)**

3-19-5-1, 148-150 cm, depth 77 m:
Bramletteius serraculoides, *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Cyclococcolithus neogammation*, *Discoaster tani tani*, *Reticulofenestra umbilica*, *Sphenolithus predistentus*, *Sphenolithus pseudoradians*.

**Eocene
(*Discoaster barbadiensis* Zone)**

3-19-5-4, 79-80 cm, depth 81 m:
Bramletteius serraculoides, *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Discoaster tani tani*, *Isthmolithus recurvus*, *Reticulofenestra umbilica*.

3-19-6-1, 148-150 cm, depth 87 m:
Bramletteius serraculoides, *Coccolithus bisectus*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Discoaster tani tani*, *Reticulofenestra umbilica*, *Sphenolithus predistentus*.

**Eocene
(*Reticulofenestra umbilica* Zone)**

3-19-7-2, 78-79 cm, depth 97 m:
Bramletteius serraculoides, *Campylosphaera dela*, *Chiasmolithus grandis*, *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Reticulofenestra umbilica*, *Sphenolithus radians*, *Thoracosphaera* sp. [prolate].

**Eocene
(*Chiphragmalithus quadratus* Zone)**

3-19-10-3, 148-150 cm, depth 128 m:
Bramletteius serraculoides, *Campylosphaera dela*, *Chiasmolithus grandis*, *Chiasmolithus solitus*, *Chiphragmalithus* sp. aff. *C. spinosus*, *Discoaster barbadiensis*,

Discoaster distinctus, *Discoaster martinii*, *Reticulofenestra dictyoda*, *Sphenolithus furcatolithoides*, *Triquetrorhabdulus* sp. [optically inverse].

**Holes 20A, 20B and 20C
(lat 28°31.5'S., long 26°50.7'W., depth 4518 meters)**

A broad range of geologic ages is represented by the coccolith assemblages in these cores. Core 1C contains Pliocene above upper Oligocene; a series of cores below this (Cores 1B, 2A, 2C) have middle to lower Oligocene assemblages. A continuously cored sequence (3C, 4C, 5C, 6C) beginning at 38 meters below the bottom and ending at 72 meters contains Eocene, Paleocene and Upper Cretaceous assemblages. The middle and lowermost Eocene is represented in Core 5C. The major part of the lower Eocene coccolith sequence (*Marthasterites tribrachiatus* Zone and *Discoaster lodoensis* Zone) is either not present or is condensed to a stratigraphic thickness of 1.5 meters (our sample interval). Although the main portion of the Paleocene sequence (only present in Core 6C) is assigned to the upper Paleocene *Discoaster multiradiatus* Zone, a single sample from the lower Paleocene *Cruciplacolithus tenuis* Zone also occurs. This assemblage does not, however, represent the lowermost Paleocene. The bottom of Core 6C contains the uppermost Upper Cretaceous *Tetralithus murus* Zone.

**Pliocene
(*Discoaster brouweri* Zone?)**

3-20C-1C, 76-77 cm, depth 1 m:
Ceratolithus rugosus, *Cyclococcolithus leptoporus*, *Discoaster brouweri*, *Discoaster surculus*.

**Oligocene
(*Sphenolithus ciperoensis* or *Sphenolithus distentus* Zone)**

3-20B-1B-3, 78-79 cm, depth 10 m:
Chiasmolithus sp., *Coccolithus bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Sphenolithus moriformis*.

**Oligocene
(*Sphenolithus predistentus* Zone)**

3-20A-2A-1, 70-71 cm, depth 16 m:
Coccolithus bisectus, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster tani tani*, *Helicopontosphaera compacta*, *Sphenolithus predistentus*.

**Oligocene
(*Helicopontosphaera reticulata* Zone)**

3-20C-2C-6, 148-150 cm, depth 35 m:
Coccolithus bisectus, *Coccolithus subdistichus*, *Cyclococcolithus lusitanicus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Discoaster tani tani*, *Helicopontosphaera compacta*, *Reticulofenestra umbilica*.

Eocene

(*Discoaster barbadiensis* Zone)

3-20C-3C-1, 73-74 cm, depth 38 m:

Coccolithus bisectus, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster distinctus*, *Discoaster saipanensis*, *Discoaster tani tani*, *Reticulofenestra umbilica*.

Eocene

(*Reticulofenestra umbilica* Zone)

3-20C-3C-5, 79-80 cm, depth 44 m:

Chiasmolithus grandis, *Chiphragmalithus* sp., *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster deflandrei*, *Discoaster saipanensis*, *Reticulofenestra umbilica*, *Sphenolithus furcatolithoides*.

Eocene

(*Chiphragmalithus quadratus* Zone)

3-20C-5C-1, 148-150 cm, depth 59 m:

Campylosphaera dela, *Chiasmolithus gigas*, *Chiasmolithus grandis*, *Chiphragmalithus cristatus*, *Chiphragmalithus quadratus*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster saipanensis*, *Reticulofenestra dictyoda*, *Sphenolithus furcatolithoides*, *Triquetrorhabdulus* sp. [optically inverse].

Eocene

(*Discoaster sublodoensis* Zone)

3-20C-5C-3, 73-74 cm, depth 61 m:

Campylosphaera dela, *Chiphragmalithus quadratus*, *Chiasmolithus grandis*, *Discoaster barbadiensis*, *Discoaster colletti*, *Discoaster sublodoensis* [abundant], *Reticulofenestra dictyoda*, *Sphenolithus radians*, *Thoracosphaera* sp. [prolate], *Triquetrorhabdulus* sp.

Eocene

(*Discoaster diastypus* Zone)

3-20C-5C-6, 78-79 cm, depth 65 m:

Chiasmolithus bidens, *Chiasmolithus consuetus*, *Discoaster barbadiensis*, *Discoaster diastypus*, *Ellipsolithus macellus*, *Marthasterites* sp. aff. *M. contortus*, *Marthasterites tribrachiatus*.

Paleocene

(*Discoaster multiradiatus* Zone)

3-20C-6C-2, 77-78 cm, depth 69 m:

Cruciplacolithus tenuis, *Discoaster multiradiatus* [abundant], *Ellipsolithus distichus*, *Fasciculithus tympaniformis*. Younger taxa which represent drilling contamination: *Chiphragmalithus quadratus*, *Chiasmolithus grandis*, *Discoaster sublodoensis*.

Upper Cretaceous

(*Tetralithus murus* Zone)

3-20C-6C-4, 117 cm, depth 73 m:

Arkhangelskiella cymbiformis, *Ceratolithoides kamptneri*, *Lithraphidites quadratus*, *Prediscosphaera cretacea lata*, *Tetralithus murus*.

Paleocene

(*Cruciplacolithus tenuis* Zone)

3-20C-6C-4, 130 cm, depth 73 m:

Coccolithus cavus, *Cruciplacolithus tenuis*, *Zygodithus chianus*, *Zygodithus distentus*.

Upper Cretaceous

(*Tetralithus murus* Zone)

3-20C-6C-5, 29 cm, depth 73 m:

Same assemblage as 3-20C-6C-4, 177 centimeters.

Upper Cretaceous

(*Lithraphidites quadratus* Zone)

3-20C-6C-5, 141 cm, depth 75 m:

Arkhangelskiella cymbiformis, *Cribrosphaera ehrenbergi*, *Cylindralithus gallicus*, *Eiffellithus turriseiffeli*, *Lithraphidites quadratus*.

Holes 21, 21A

(lat 28° 35.1'S., long 30° 35.9'W., depth 2113 meters)

Pliocene, Eocene, Paleocene and Upper Cretaceous coccolith assemblages are present in the cores recovered at this site. The upper Paleocene *Discoaster multiradiatus* Zone is represented in two cores (Hole 21, Core 2 and Hole 21A, Core 3). Below these, six other cores represent the Upper Cretaceous. The oldest sediment sampled during Leg 3 is present in Cores 6, 7 and 8—lower or middle Campanian (*Eiffellithus augustus* Zone).

Pliocene

(*Discoaster brouweri* Zone)

3-21-1-1, 148-150 cm, depth 22 m:

Coccolithus doronicoides, *Cyclococcolithus leptoporus* var. A, *Discoaster brouweri*, *Discoaster pentaradiatus*.

Eocene

(*Chiphragmalithus quadratus* Zone)

3-21A-1A-6, 148-150 cm, depth 55 m:

Campylosphaera dela, *Chiasmolithus gigas*, *Chiasmolithus grandis*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Reticulofenestra dictyoda*, *Sphenolithus furcatolithoides*, *Sphenolithus radians*, *Thoracosphaera* sp. [prolate], *Triquetrorhabdulus* sp. [optically inverse].

Eocene

(*Discoaster lodoensis* Zone)

3-21A-2A-3, 148-150 cm, depth 65 m:

Campylosphaera dela, *Cyclococcolithus neogammation*, *Cyclococcolithus lusitanicus*, *Discoaster barbadiensis*, *Discoaster lodoensis*, *Discoasteroides kuepperi*, *Sphenolithus radians*, *Zygodithus dubius*.

Eocene

(*Marthasterites tribrachiatus* Zone)

3-21A-2A-6, 148-150 cm, depth 70 m:
Campylosphaera dela, *Chiasmolithus consuetus*, *Discoaster lodoensis*, *Marthasterites tribrachiatus*, *Sphenolithus radians*.

Paleocene

(*Discoaster multiradiatus* Zone)

3-21-2-5, 88-89 cm, depth 74 m:
Chiasmolithus bidens, *Chiasmolithus gigas*, *Cyclolithella robusta*, *Discoaster* sp. aff. *D. gemmeus*, *Discoaster lenticularis*, *Discoaster multiradiatus*, *Ellipsolithus distinctus*, *Ellipsolithus macellus*, *Fasciculithus tympaniformis*, *Toweius eminens*, *Zygodiscus distentus*.

Upper Cretaceous

(*Tetralithus murus* Zone)

3-21-3-3, 148-150 cm, depth 81 m:
Arkhangelskiella cymbiformis, *Cribrosphaera ehrenbergi*, *Cylindralithus gallicus*, *Lithraphidites quadratus*, *Tetralithus murus*, *Watznaueria barnesae*. Younger taxa which represent drilling contamination: *Coccolithus cavus*, *Cyclococcolithus leptoporus*, *Discoaster multiradiatus*, *Heliolithus kleinPELLI*, *Rhabdosphaera styliifera*, *Toweius eminens*.

Upper Cretaceous

(*Tetralithus nitidus trifidus* Zone)

3-21-5-1, 82-83 cm, depth 95 m:
Apertapetra gronosa, *Broinsonia parca*, *Eiffellithus turiseiffeli*, *Lucianorhabdus cayeuxi*, *Tetralithus pyramidus*, *T. nitidus trifidus*, *Zygodiscus deflandrei*.

Upper Cretaceous

(*Eiffellithus augustus* Zone)

3-21-7-1, 148-150 cm, depth 117 m:
Apertapetra gronosa, *Broinsonia parca*, *Cribrosphaera ehrenbergi*, *Eiffellithus augustus*, *Lucianorhabdus cayeuxi*, *Zygodiscus deflandrei*.

Hole 22

(lat 30°00.3'S., long 35°15.0'W., depth 2134 meters)

The Pleistocene-Pliocene boundary is present in Core 1. Cores 2 and 3 contain assemblages of the Miocene or Oligocene *Triquetrorhabdulus carinatus* Zone. Also present in the lower part of Core 3 and in Core 4 are the *Sphenolithus* Zones of the Oligocene. Finally, Core 5 contains an upper middle Eocene assemblage (*Reticulofenestra umbilica* Zone).

Pleistocene

(*Coccolithus daronicoides* Zone)

3-22-1-3, 148-150 cm, depth 5 m:
Ceratolithus rugosus, *Coccolithus daronicoides*, *Cyclococcolithus leptoporus* vars. A, B, C, *Discoaster perplexus*, *Rhabdosphaera clavifera*, *Rhabdosphaera styliifera*.

Pliocene

(*Discoaster brouweri* Zone)

3-22-1-6, 39-40 cm, depth 8 m:
Coccolithus daronicoides, *Cyclococcolithus leptoporus* var. A [common], *Cyclococcolithus leptoporus* vars. A, C, *Discoaster brouweri*, *Discoaster perplexus*.

Miocene or Oligocene

(*Triquetrorhabdulus carinatus* Zone)

3-22-2-6, 75-76 cm, depth 55 m:
Coccolithus sp. aff. *C. bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Helicopontosphaera parallela*, *Rhabdothorax* sp., *Sphenolithus* sp. aff. *S. belemnus*.

Oligocene

(*Sphenolithus ciperoensis* Zone)

3-22-3-6, 77-78 cm, depth 113 m:
Chiasmolithus sp., *Coccolithus bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Helicopontosphaera intermedia*, *Helicopontosphaera parallela*, *Sphenolithus ciperoensis*, *Zygrhablithus bijugatus*.

Oligocene

(*Sphenolithus distentus* Zone)

3-22-4-1, 74-75 cm, depth 134 m:
Braarudosphaera rosa [abundant], *Bramletteius serraculoides*, *Chiasmolithus* sp., *Coccolithus bisectus*, *Cyclococcolithus neogammation*, *Discoaster deflandrei*, *Micrantholithus* sp., *Sphenolithus distentus*, *Sphenolithus predistentus*.

Eocene

(*Reticulofenestra umbilica* Zone)

3-22-5-2, 140-142 cm, depth 237 m:
Bramletteius serraculoides, *Campylosphaera dela*, *Chiasmolithus grandis*, *Coccolithus bisectus*, *Cyclococcolithus lusitanicus*, *Cyclococcolithus neogammation*, *Discoaster barbadiensis*, *Discoaster distinctus*, *Discoaster saipanensis*, *Discoaster tani nodifera*, *Reticulofenestra dictyoda*, *Reticulofenestra umbilica*, *Thoracosphaera* sp. [prolate].

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