14. PHYTOPLANKTON STRATIGRAPHY, DEEP SEA DRILLING PROJECT LEG 20, WESTERN PACIFIC OCEAN

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INTRODUCTION

Leg 20 of the Deep Sea Drilling Project, September to November 1971, in the western Pacific Ocean from Yokohama, Japan, to Suva, Fiji, recovered 57 cores at nine drilling sites (Figure 1). Light-microscope techniques were used to study the coccoliths and silicoflagellates of 75 samples from these cores.

Coccoliths are the most stratigraphically useful fossil group in Leg 20 sediment owing to their common occurrence in most samples and the similarity of their assemblages to those previously zoned in the eastern tropical Pacific (Bukry, 1973). Reworking and overgrowth characterize many of the coccolith assemblages examined. Samples from the shallowest site, DSDP 200, are dominated by foraminifers. Of the nine drilling sites, only DSDP 200 and DSDP 199 yielded biostratigraphically diagnostic material in moderately complete sections.

Systematic paleontology and illustrations of coccoliths from Leg 20 are followed by stratigraphic summaries of the sites and some selected species lists.

SYSTEMATIC PALEONTOLOGY

Genus DISCOASTER Tan, 1927

Discoaster blackstockiae n. sp.

(Plate 1, Figures 1-4)


Description: Discoaster blackstockiae, a four-rayed species, has a small oblong central area. The four narrowly tapering, blade-like rays end in simple points. The rays form two large and two small angles. The two small angles are opposite each other and typically are identical at about 60 degrees. Variation from 52 degrees to 62 degrees has been observed for some specimens.

Remarks: Discoaster blackstockiae is distinguished from D. tanalis by the arrangement of adjacent rays at about 60 or 120 degrees instead of all at 90 degrees, from Discoaster quadratus by its simply terminated rays and non-birefringence in cross-polarized light in plan view. The angular relation between the rays and the ray morphology suggests that D. blackstockiae was derived from D. brouweri through suppression of one set of rays.

Occurrence: As these four-rayed forms are never common and previously have been considered variants or broken specimens of D. pentaradiatus or D. brouweri, their full stratigraphic and paleogeographic ranges are not determined. Discoaster blackstockiae has been noted most commonly in the Pleocene and latest Miocene of tropical sites from Legs 20, 21, and 23, at Sites DSDP 173, 199, 203, 219, 225, and 228. It may prove to be a useful ecological indicator for tropical assemblages that are dominated by discoasters for preservation reasons, such as strong dissolution.

Size: 8-20 microns

Holotype: USNM 188509 (Plate 1, Figure 1)

Genus FASCIICULITHUS Bramlette and Sullivan, 1961

Fasciculithus pileatus n. sp.

(Plate 1, Figures 7-9; Plate 2, Figures 1-5)


Description: Fasciculithus pileatus is a medium-sized species with smooth straight walls that extend from the base to the apex. Therefore, the body is basically a truncated cone. A large, convex-topped, lens-shaped cap covers the entire top of the body and can extend beyond it. A central suture may connect the cap and body in some specimens. In cross-polarized light, side views have a straight dark line bisecting the body and a straight dark line separating the body and cap, forming three bright areas.

Remarks: Fasciculithus pileatus is unique among other species of the genus owing to its strong-reflect three-part division in side view. The only similar species, F. ulii, is distinguished by its concave body walls and small flat-topped apex that fails to cap the entire body and gives only weak optical relief in side view. Examination of samples from the type core of F. ulii, DSDP 119-25 [not DSDP 119-37] as was indicated in the captions of the type illustrations; Perch-Nielsen, 1971], confirms these distinctions. No wholly and brightly capped Fasciculithus specimens occur in DSDP 119-25.1, 133-134 cm or DSDP 119-25.2, 65-66 cm. F. pileatus is distinguished from potential overgrowth forms of F. ulii by the cap acting as a single crystallographic unit, instead of bilateral units in cross-polarized light. Its long stratigraphic range through the Paleocene is matched only by F. tympaniformis, a conservative, parallel-sided, cylindric form with no distinctive ornamentation.

Paratypes: USNM 188510 to 188512

Type locality: Laccadive-Chagos Ridge (DSDP 219-6-5, 110-111 cm).

Discoaster quadratus n. sp.

(Plate 1, Figures 5-6)


Description: Discoaster quadratus, a four-rayed species, has ray-tip bifurcations that are broadly rounded. The rays may make angles of 90 degrees or 60 degrees and 120 degrees. Like Discoaster pentaradiatus, both forms show faint bifurcations in cross-polarized light in plan view. The small central area has a faint four-sided knob.

Remarks: Discoaster quadratus is distinguished from D. tanalis and D. blackstockiae by its bifurcate ray tips or faint cross-polarized light image, from D. pentaradiatus by its lack of pentameral symmetry.

Occurrence: This rare species has been reported in the Pliocene of Castell d’Arquato, Italy (Stradner and Papp, 1961; Takayama, 1967), Philippine Sea core V21-98 (Takayama, 1969) and in the Pliocene of the Laccadive-Chagos Ridge (DSDP 219). It is missing in the Pliocene samples of DSDP Leg 20.

Size: 10-20 microns.

Holotype: USNM 188513 (Plate 1, Figures 5-6).

Type locality: Laccadive-Chagos Ridge (DSDP 219-6-5, 110-111 cm).

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Figure 1. Location of drilling sites of Deep Sea Drilling Project Leg 20, western Pacific Ocean.

Occurrence: Fasciculithus pileatus is presently known from the Paleocene of tropical parts of the Pacific, Indian, Atlantic, and Caribbean. It occurs in DSDP 199-10-2, 34-35 cm; 199-9, CC; and 199-7-1, 76-77 cm, in the Discoaster multidiscatus Zone. It occurs in the Heliolithus kleinpellii Zone in DSDP 144A-3A-3, 114-115 cm and in the Fasciculithus tympaniformis Zone in DSDP 237-50-1, 55-56 cm; 167-39-1, 115-116 cm; and 152-7-4, 105-106 cm; and reworked into the middle Eocene of DSDP 171-9-3, 90-91 cm.

Size: 5-12 microns.

Holotype: USNM 188514 (Plate 2, Figures 2-5).

Paratypes: USNM 188515 to 188517.

Type locality: Caroline Abyssal Plain (DSDP 199-10-2, 34-35 cm).

Genus HAYASTER n. gen.

Description: Flat discoidal fossils of approximately circular outline modified by straight peripheral edges of several triangular-outlined crystallites composing the disk. Crystallites radiate from a simple center point and are essentially equant. Interstrataline sutures are simple and straight, although they may be curved on one side of the disk. The disk is nonbirefringent and is dark in cross-polarized light in normal plan view. A small, thin, accessory, central disk, on well-preserved specimens, is birefringent.

Type species: Discoaster perplexus Bramlette and Riedel, 1954.

J. Paleontology, v. 28, p. 400, pl. 39, fig. 9.

Remarks: Hayaster is distinguished from superficially similar genera by a combination of characters. Its nonbirefringence in plan view distinguishes it from Brugnoliopsis. Its straight peripheral crystallite margins and flat surface distinguish it from Discoaster and Ellipsoidiscoaster. Its thickness and closed center distinguish it from Pedinocyclus.

Hayaster perplexus (Bramlette and Riedel) n. comb.


Remarks: Thickly overgrown specimens of Hayaster perplexus show more thickening along the medial axis of the crystallites than along the sutures. In well-preserved specimens, a small central disk, first observed by Black and Barnes (1961), can be seen in light microscopy at high magnification and crosspolarized light because it is heliolithid and birefringent (Boudreaux and Hay, 1967). Because of its thinness and small diameter, less than a third of the main disk, it is not apparent at low magnification.

Occurrence: Hayaster perplexus is most prominent in tropical oceanic assemblages. Stratigraphically it ranges from earliest Miocene through Pleistocene. Sediment sections containing prominent H. perplexus occur at DSDP 62, 98, and 199.

Genus HELICOPONTOSPHERA Hay and Mohler, 1967

Helicoipontosphera euphratis (Haq) n. comb.


Helicoipontosphera recta (Haq) n. comb.

Helicoipontosphera seminulum recta Haq, 1966. Stockholm Contrib. Geol., v. 15, no. 3, p. 34, pl. 2, fig. 6; pl. 3, fig. 4.


Genus TETRALITHUS Gardet, 1955

Tetralithus praemurus n. sp.

(Plate 2, Figures 6-9)

Description: This compact species has a rounded quadrant to circular outline with no extensions. In cross-polarized light, four equant quadrants are bounded by two S-shaped black suture lines that intersect at the center. Focusing through the various levels in the fossil shows that the curvature of the sutures is more pronounced at one side of the fossil than the other. All four quadrants become black together as the fossil is rotated relative to the direction of cross-polarization.

Remarks: Tetralithus praemurus is distinguished from T. obscurus and T. ovatus by its radially symmetric form and equant quadrants, from T. pyramida by its rounded outline and S-shaped sutures, from Mucila mura by the more subdued curvature of its sutures and its lack of peripheral extensions.

Tetralithus praemurus, unlike M. mura, shows little variation in form. M. mura, as presently constituted, may be a composite taxon. The abbreviated appendages and high relief of the M. mura holotype (Martini, 1961) is repeated in later scanning-electronmicrograph illustrations of Mucila by Ciocchiatti (1971). Yet hypotype illustrations by Bramlette and Martini (1964) do not suggest a Mucila structure. Single specimens resembling both M. decussata at the core and M. mura at the periphery occur at DSDP 47, 2-13-3 and 199-10-2. Several explanations are possible: (1) Overgrown specimens of slightly evolved Maastrichtian M. decussata mimic Tetralithus mura; (2) Mucila decussata of the Maastrichtian provides a template that patterns an overgrowth structure that may become separated and independently identified as M. mura of Bramlette and Martini; (3) Mucila converges with Tetralithus in the Maastrichtian to form a similar structure. Electronmicroscopy of critical samples will be required to solve the problem.

Occurrence: Tetralithus praemurus occurs in the middle part of the Maastrichtian section of the Shatsky Rise and reworked into the Paleocene of Caroline Abyssal Plain in the western Pacific Ocean. It occurs just below the appearance of M. mura.

Size: 5-10 microns.

Holotype: USNM 188518 (Plate 2, Figures 7-9).

Paratype: USNM 188519.

Type locality: Caroline Abyssal Plain (DSDP 199-10-2, 34-35 cm).
TABLE 1  Percentage and Total Count of Sparse Silicoflagellates in Single Smear Slides from DSDP 194

<table>
<thead>
<tr>
<th>Silicoflagellates</th>
<th>Samples</th>
<th>194-1-2</th>
<th>194-2-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietyocha aspera</td>
<td></td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>D. episodon</td>
<td></td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>D. fibula</td>
<td></td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>D. navicula</td>
<td></td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Distephanus sp. cf. D. crux</td>
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<td>3</td>
<td>0</td>
</tr>
<tr>
<td>D. speculum</td>
<td></td>
<td>0</td>
<td>19</td>
</tr>
<tr>
<td>Mesocena elliptica</td>
<td></td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total count</td>
<td></td>
<td>40</td>
<td>21</td>
</tr>
</tbody>
</table>

SITE SUMMARIES

DSDP 194
(lat 35°58.68'N, long 148°48.64'E, depth 5754 m)

Site DSDP 194 was drilled 630 km east of the Japan Trench in the abyssal northwestern Pacific to determine the age and composition of regional subbottom acoustic reflectors. Five cores were taken in the 256 meters penetrated. Two samples lacking coccoliths, but containing silicoflagellates, diatoms, and common volcanic ash were examined. Late Quaternary assemblages of the tropical Dietyocha episodon Zone of silicoflagellates and the Roepora tessellata Zone of diatoms are present in the upper sample, DSDP 194-1-2, 73-75 cm (39 m). Volcanic ash is more abundant in the lower sample, DSDP 194-2-1, 127-129 cm (142 m), and the silicaceous microfossil assemblage is less diagnostic, late Miocene or Pliocene in age. Silicoflagellates are sparse (Table 1); solution-thinned fragments of the diatom Ethnomodiscus rex are the most conspicuous siliceous microfossil.

DSDP 195
(lat 32°46.40'N, long 146°58.73'E, depth 5968 m)

Site DSDP 195 was drilled approximately 100 km southwest of DSDP 194 to penetrate the upper opaque acoustic-reflector layer. A sample above this horizon, 195-1-6, 75-77 cm (71 m), contains volcanic ash and an abundance of solution-thinned silicoflagellate and diatom species indicating a probable Pliocene age. A count of 300 silicoflagellates yields the following percentages: 77% Dietyocha fibula, 14% Dietyocha aspera, 5% Distephanus quinquerangellus, 2% Distephanus speculum, and <1% Dietyocha hexacantha. The large percentage of Dietyocha relative to Distephanus indicates a tropical depositional environment with a temperature of 27°C by the silicoflagellate paleothermometer curve (extrapolated) of Mandra (1969).

All deeper samples available from the site are Early Miocene cooccolith- rich carbonates of the lower transparent layer, which is similar in age and lithology to the lower transparent layer at DSDP 49 and DSDP 50 on the western flank of Shatsky Rise (Bukry and others, 1971; Douglas and Moullade, 1972).

Diversity is generally low with no pelletalithid or nannoconid taxa present. Assemblages from the highest and lowest samples, at 278 meters and 392 meters, are similar, containing Cretarhabdus angustiforatus, Cruellipsis cuvillieri, Cyclagelosphaera margereli, Diazoniatolithus lehmani, Markallus circumradiatus, Parhabdolithus embergeri, Stephanothrix sp., Watznaueria barnesae, and W. britannica. The ranges of C. cuvillieri and M. circumradiatus indicate a Valanginian or Hauterivian age (Thierstein, 1971).

DSDP 196
(lat 30°06.97'N, long 148°34.49'E, depth 6194 m)

Site DSDP 196 was drilled approximately 250 km southeast of DSDP 195 in a continued attempt to reach basaltic basement below the coccolithic limestone and chert of the lower transparent layer. Only two samples were available: 196-3-1, 139-140 cm (198 m), and 196-4, CC (301-310 m). Both contain poor assemblages dominated by Watznaueria barnesae and by fine calcareous debris indicating moderate to strong diagenetic effects. The few specimens of Cretarhabdus angustiforatus, Cruellipsis cuvillieri, Cyclagelosphaera margereli, Lithraphidites caninensis, and Parhabdolithus embergeri, also present in the samples, suggest an Early Cretaceous (Valanginian or Hauterivian) age similar to DSDP 195. Mesozoic radiolarians are reported from deeper core samples to the bottom of the site at 196-6 (376-377 m).

DSDP 197
(lat 30°17.44'N, long 147°40.46'E, depth 6153 m)

No samples available; see report of shipboard scientists.

DSDP 198
(lat 25°49.54'N, long 154°35.05'E, depth 5958 m)

No samples available; see report of shipboard scientists.

DSDP 199
(lat 13°30.78'N, long 156°10.34'E, depth 6100 m)

Site DSDP 199 was drilled east of Guam on the eastern margin of the Caroline Abyssal Plain. Coccolith assemblages from the 13 cores attempted, range from late Miocene Discoaster quinqueramus Zone in Core 1 at 58 meters to late Campanian Tetralithus trifidus Zone in Core 12 at 438 meters. Volcanic ash, zeolite minerals, and reworked coccoliths characterize most of the samples examined. Coccolith preservation is commonly poor but variable, with mixtures of specimens exhibiting many degrees of etching and overgrowth. Because of abundant reworking and discontinuous coring, biostratigraphic interpretations must be derived largely from first occurrences of youngest species in a given sample. Representative assemblages from selected samples are listed and discussed below:

Upper Miocene (Discoaster quinqueramus Zone, Ceratolithus primus Subzone)

199-1-2, 34-35 cm (59 m):
Angulolithina arca, Ceratolithus primus [rare], Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyre, Dis-

Upper Miocene
(Discaster quinquemerus Zone,
Discaster berggreni Subzone)

199-1-5, 5-6 cm (63 m):

Mixing of stratigraphically and preservationally discordant specimens is greatest at the top of Core 1. Discasters in 199-1-2 range in preservation from specifically indeterminant specimens having dissolved centers and ray tips (preservation stage -4) to blocky and irregular overgrown forms (+4). But some specimens are practically pristine, the original camber, taper, and delicate ornamentation being preserved. Stratigraphic assignment of samples from Core 1 is facilitated by the abundant and diverse discaster assemblages that can be identified. Key to the assignment in 196-1-2 is the occurrence of Discaster quinquemerus and D. surculus with Ceratolithus primus and Triquetrorhabdulus rugosus. In 199-1-5 the occurrence of Discaster berggreni, D. quinquemerus, D. surculus, and Triquetrorhabdulus rugosus are considered diagnostic of the lower D. quinquemerus Zone. The only apparent reworking in this sample is some admixed discasters characteristic of the zone directly below. Rare and sporadic Discaster asymmetricus in this core is not considered biostratigraphically significant, as the species has been noted previously as a rare member of other upper Miocene tropical assemblages (Bukry, 1971). Although recorded as D. asymmetricus here, the specimens might be asymmetric mutants of Discaster bellus, which is common in the core. In any case, the acme of D. asymmetricus is middle Pliocene in age, at which time it was associated with Ceratolithus rugosus, which would be preserved in this tropical deposit if it were Pliocene.

Coccoliths are rare in the ash-rich sediment of Cores 2 and 3; assemblages have been severely restricted by etching to stage -4. A few resistant placolith rims and discasters, some centerless, compose the trace assemblages. The sediment is probably upper Miocene down to 199-3-5, 35-36 cm (82 m), on the basis of the sporadic occurrence of Discaster sp. cf. D. bellus, D. berggreni, D. braarudii, D. sp. cf. D. neohamatus, D. pseudovariabilis, and D. variabilis. Placoliths are relatively common only near the bottom of Core 3.

**Middle Miocene**

**Discaster elitis Zone,**
**Discaster kugleri Subzone**

199-3-5, 35-36 cm (82 m):

Core 4 contains poorly representative assemblages of middle Miocene age. In 199-4-3, 35-36 cm (89 m), six-ray discasters resembling D. elitis or D. variabilis occur, but thick irregular overgrowths (+4) prevent any definite identifications. Associated placoliths such as Coccolithus miopelagicus, C. pelagicus, and Reticulofenestra pseudoumbilica are more moderately overgrown (+2). In 199-4-4, 34-35 cm (90 m), preservation is mixed with both etched and overgrown discasters and placoliths. The assemblage is dominated by open and closed forms of Reticulofenestra pseudoumbilica. The rare occurrences of Cyclococcolithina macintyre s.s., Discaster deflandrei, and Sphenolithus heteromorphus indicate a middle Miocene age for Core 4. Core 5 is largely barren of coccoliths. Rare specimens are recorded only in 199-5-3, 34-35 cm (146 m), where etched Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus florianus, overgrown Discaster sp. cf. D. deflandrei, D. sp. cf. D. variabilis, Sphenolithus mortiffs, and Triquetrorhabdulus carinatus suggest an early Miocene age. Assemblages are more common and diverse in Core 6 (200-210 m) owing to admixture by reworking. Species present indicate erosion of Upper Cretaceous and middle or upper Eocene deposits. The host assemblage is probably upper Oligocene or lower Miocene on the basis of the presence of Discaster calclusus, D. sp. cf. D. variabilis, Helicopontosphaera intermedia, Sphenolithus helemnos, and S. conic. Eocene taxa include Chiasmolitthis grandis, Discaster barndies, and Triquetrorhabdulus inversus; Cretaceous taxa include Arkhangelskiella cymbiformis, Cribrosphaera ehrenbergii, Prediscosphaera cretacea, and Watznaueria baresna.

Samples available from Cores 7 to 9 (286-314 m) contain upper Paleocene assemblages and reworked Cretaceous. Diagnostic Paleocene species include Chiasmolithithus bidens, C. californicus, C. constans, Discaster moehleri, D. multiradiatus, D. nobilis, Discasteroides megastypus, Fasciulithus tympaniformis, and Toweius craticulus. Reworked Cretaceous species include Broznosia parva, Cretarhabdus cretaceous, Micula murus, Prediscosphaera cretacea, and Watznaueria baresna. Most specimens are moderately overgrown, and fine calcareous debris is common in the samples.

The upper part of Core 10, down through Sample DSDP 199-10-2, 34-35 cm (372 m), is assigned to the Discaster multiradiatus Zone of the upper Paleocene, as is the overlying interval of Cores 7 to 9. But a lower sample at 199-10-2, 112-113 cm (373 m), contains lower Paleocene species in a mixed assemblage that is predominantly Upper Cretaceous. This sample represents an early Paleocene deposit, probably near the Cretaceous-Tertiary boundary. Mixing within the Cretaceous assemblage is demonstrated
by the discordant association of *Micula mura* of the upper Maastrichtian with *Broinsonia parea* and *Tetratolithus trifidus* of the Campanian or lower Maastrichtian. Other Cretaceous species include *Arkhangelskella cymbiformis*, *Cylindraithus gliculus*, *Cretarhabdus schizobrachiatus*, *Eiffellithus turrisiefeli*, and *Prediscosphaera cretacea*. Early Tertiary species include *Coccolithus* sp. [small] and *C. pelagicus*.

Late Cretaceous coccoliths are diverse and abundant in Cores 11 (400-409 m) and 12 (438-447 m), although diagenesis has produced moderate overgrowth and etching. Core 11 is late Maastrichtian on the basis of *Micula mura* and the associated assemblage. Core 12 is late Campanian or early Maastrichtian on the basis of *Cylindraithus gliculus*, *Lucanorhabdus canyexui*, *Tetratolithus trifidus*, and the associated assemblage.

**DSDP 200**

(lat 12°50.20′N, long. 156°46.96′E, depth 1479 m)

Site DSDP 200 was drilled on Ita Maitai Seamount in order to investigate the stratigraphy of its 150-meter sediment section. A total of 114 meters of early Eocene to Quaternary foraminiferal sand was drilled before mechanical difficulties forced discontinuation of the drilling. Tropical coccolith assemblages are diverse and abundant. Species in representative samples are listed below.

**Pleniocene or Holocene**

(*Emiliania huxleyi* Zone)

200-1-1, bottom (2 m):

*Ceratolithus cristatus* [large], *Cyclococcolithina leptopora*, *Emiliania annula*, *E. huxleyi*, *Gephyrocapsa oceanica*, *Helicopontosphaera kamptneri*, *H. wallichii*, *Pontosphaera discopora*, *Rhabdosphaera stylifera* [common], *Sympyxis sp.* [rare], *S. pulcherrima*, *Syracosphaera sp.*, and *Thoracosphaera saxea*.

**Pleniocene**

(Lower *Gephyrocapsa oceanica* Zone)

200-1-5, bottom (8 m):

*Ceratolithus cristatus*, *Cyclococcolithina leptopora*, *Emiliania annula*, *E. ovata*, *Gephyrocapsa caribbeana*, *G. oceanica*, *Hayaster perplexus*, *Helicopontosphaera kamptneri* [abundant], *Oolithus antillarum*, *Pontosphaera discopora*, *Rhabdosphaera clavigera*, *R. stylinera*, *Sympyxis sp.* [abundant], *Thoracosphaera saxea* [common]. Retracted taxa: *Cyclococcolithina macintyrei* [rare], and *Sympyxis sp.* [rare].

**Pleniocene and Pliocene mixed**

200-2-1, bottom (11 m):

*Ceratolithus rugosus*, *Cyclococcolithina leptopora*, *C. macintyrei*, *Discoaster brouweri*, *D. pentaradiatus*, *D. tamalis*, *D. triradiatus*, *Discolithina japonica*, *Emiliania annula* [small, common], *Gephyrocapsa oceanica* [rare], *Hayaster perplexus*, *Helicopontosphaera kamptneri*, *Rhabdosphaera stylinera*, *Sympyxis sp.* [common], and *Thoracosphaera saxea*.

**Upper Pliocene**

(Discoaster brouweri Zone, Discoaster pentaradiatus Subzone)

200-2-2, bottom (12 m):


**Upper Pliocene**

(Discoaster brouweri Zone, Discoaster tamalis Subzone)

200-3-1, bottom (21 m):

*Ceratolithus rugosus*, *Coccolithus pelagicus*, *Cyclococcolithina leptopora*, *C. macintyrei*, *Discoaster asymmetricus*, *D. brouweri* [abundant], *D. challengeri*, *D. pentaradiatus*, *D. tamalis* [common], *Helicopontosphaera kamptneri*, *H. sellii* [abundant], *Reticulofenestra pseudoambulica*, *Sympyxis sp.* [abundant], *Sympyxis sp.* [common], *S. recurvata*, *Sphenolithus abies*, *S. neobalbinites*, and *Thoracosphaera saxea*.

**Lower Pliocene**

(Reticulofenestra pseudoambulica Zone, Discoaster asymmetricus Subzone)

200-3-2, bottom (22 m):

*Ceratolithus rugosus*, *Cyclococcolithina leptopora*, *C. macintyrei*, *Discoaster asymmetricus*, *D. brouweri* [abundant], *D. challengeri*, *D. pentaradiatus*, *D. tamalis* [common], *Helicopontosphaera kamptneri*, *H. sellii* [abundant], *Reticulofenestra pseudoambulica*, *Sympyxis sp.* [abundant], *Sympyxis sp.* [common], *S. recurvata*, *Sphenolithus abies*, *S. neobalbinites*, and *Thoracosphaera saxea*.

**Upper Pliocene**

(Discoaster brouweri Zone, Discoaster tamalis Subzone)

200-4-1, bottom (30 m):

*Angulolithina arca*, *Ceratolithus bizzarus*, *C. primus*, *C. rugosus*, *Coccolithus pelagicus*, *Cyclococcolithina leptopora* [abundant], *Discoaster asymmetricus*, *D. blackstockiae*, *D. brouweri*, *D. pentaradiatus*, *D. surculus*, *Reticulofenestra pseudoambulica*, and *Sympyxis sp.* [abundant]. Taxa whose absence is unusual: *Helicopontosphaera kamptneri*, and *Sphenolithus abies*.

**Mixed Oligocene to Pliocene**

200-5-1, bottom (39 m):

*Angulolithina arca*, *Ceratolithus cristatus*, *C. primus*, *C. rugosus*, *C. sp.* [abundant], *C. tricorniculatus*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus* [rare], *Cyclococcolithina leptopora*, *C. macintyrei*, *Discoaster asymmetricus*, *D. bellus*, *D. blackstockiae*, *D. brouweri*, *D. challengeri*, *D. neohamatus*, *D. pentaradiatus*, *D. sp.* cf. *D. quinqueramus*, *D. surculus*, *D. tamalis* [rare], *Discolithina japonica*, *Helicopontosphaera granulata*, *H. kamptneri*, *Reticulofenestra pseudoambulica*, *Sympyxis sp.* [abundant], *Sympyxis sp.* [common], and *Thoracosphaera saxea*. 

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S. pulcherrima, Sphenolithus abies, S. neoabies [abundant], S. predistentus [rare], and Thoracosphaera saxcea.

Middle Miocene

(upper Discoaster hamatus Zone)

200-6-1, bottom (49 m):

200-7, CC (57-67 m):

Middle Miocene

(lower Sphenolithus heteromorphus Zone)

200-9-1, bottom (87 m):

200-9-3, bottom (90 m):
Coccolithus miopalaeus, C. pelagicus, Coronocyclus sp., Cyclicargolithus floridanus [abundant], Cyclococcolithina macintyrei, Discoaster sp. cf. D. deflandrei [abundant, irregular overgrowth +4], D. sp. cf. D. exilis [abundant, irregular overgrowth +4], Discolithina sp. [large, imperforate], Helicopontosphaera granulata, Scyphosphaera recurvata, and Sphenolithus heteromorphus.

Lower Miocene

(Reticulofenestra pseudoumbilica Zone, Discoaster asymmetricus Subzone)

200-1, CC (49-59 m):

Upper Oligocene or lower Miocene

mixed with middle Eocene

200-2, CC (65-74 m):

REFERENCES


PLATE 1
Coccolith Photomicrographs, 2000 X
(BF = Bright-field; XN = Cross-polarized)
(Scale bar equals 5 microns)

Figures 1-4  *Discoaster blackstockae* n. sp.
1. Holotype, USNM 188509, DSDP 71.0-4-5, 63-64 cm; BF.
2. USNM 188510, DSDP 199-1-5, 5-6 cm; BF.
3. USNM 188511, DSDP 72A-3A-5, 63-64 cm; BF, with a specimen of *Discoaster triradiatus*.
4. USNM 188512, DSDP 219-6-5, 110-111 cm; BF.

Figures 5-6 *Discoaster quadratus* n. sp.
5. Holotype, USNM 188513, DSDP 219-6-5, 110-111 cm; XN.
6. BF.

Figures 7-9  *Fasciculithus pileatus* n. sp.
7. USNM 188515, DSDP 199-10-2, 34-35 cm; BF, 45°.
8. XN, 45°, with specimen of *Coccolithus pelagicus* s. a.
9. USNM 188516, DSDP 199-10-2, 34-35 cm; BF, 82°.
PLATE 2
Coccolith Photomicrographs, 2000 X
(BF = Bright-field, PC = Phase-contrast; XN = Cross-polarized)
Scale bar equals 5 microns

Figures 1-5 Fasciculithus pileatus n. sp.
1. USNM 188517, DSDP 199-10-2, 34-35 cm; BF, 45°.
2. Holotype, USNM 188514, DSDP 199-10-2, 34-35 cm; BF, 0°.
3. XN, 45°.
4. XN, 25°.
5. PC, 45°.

Figures 6-9 Tetralithus praemurus n. sp.
6. USNM 188519, DSDP 47.2-13-3, 80-81 cm; XN.
7. Holotype, USNM 188518, DSDP 199-10-2, 34-35 cm; XN [suture inked for emphasis].
8. Partial XN.
9. BF.