SOME NEW AND STRATIGRAPHICALLY USEFUL CALCAREOUS NANNOFOSSILS OF THE CENOZOIC[1]

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CONTENTS

Abstract

Fifteen new species of calcareous nannofossils of probable stratigraphic significance are described here. Several of these—*Cyclococcolithus macintyrei, Discoaster neohamatus, Discoaster quintatus, Helicopontosphaera sellii, Micrantholithus procerus, Sphenolithus anarrhopus, Sphenolithus neoabies, Thoracosphaera prolata,* and *Triquetrorhabdulus inversus*—are among taxa known to be abundant with wide geographic ranges and thus particularly useful in developing worldwide zonations. This usefulness has been evident during preliminary studies of Deep Sea Drilling Project cores, and naming the taxa, therefore, is important. Other new species—*Helicopontosphaera papillata, Leptodiscus larvalis, Pemma snavelyi, Quinquerhabdus colossicus, Syracosphaera formosa,* and *Syracosphaera labrosa*—are presently known only from restricted regions or constitute only a minor part of worldwide assemblages. They, too, may prove useful because they are easily identified and seem to have restricted time ranges.

[1] Publication authorized by the Director, U. S. Geological Survey

I. Introduction

The new species of calcareous nannofossils described here can be effectively identified by light microscope and have proved to be useful in the stratigraphic interpretation of many assemblages. For example, *Thoracosphaera prolata* and *Triquetrorhabdulus inversus* are consistent indicators, on a worldwide basis, of middle Eocene strata. Within their range, other species, such as *Micrantholithus procerus* and *Syracosphaera labrosa,* help to delimit upper middle Eocene strata. In the upper Tertiary, the latest occurrences of *Cyclococcolithus macintyrei* and of abundant discoasters mark a boundary near that between the Pliocene and Pleistocene. The last occurrences of the abundant and widespread *Sphenolithus neoabies* and *Reticulofenestra pseudoumbilica* (Gartner) offer a useful boundary in the middle of the Pliocene.

II. Acknowledgment

We thank Frances L. Parker, Scripps Institution of Oceanography, and Stephen F. Percival, Jr., Princeton University, for constructive review of this paper.

Editorial Committee for this Paper:

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III. Samples by Region

Atlantic Ocean

Lamont core V3-153 (28°24′N., 77°56′W.).

Lamont core V12-5 (21°12′N., 45°21′W.).

Lamont core V16-21 (17°16′N., 48°25′W.).

JOIDES core 3 (21°30′N., 77°31′W.).

JOIDES core 4 (31°02′N., 77°43′W.).

JOIDES core 6 (30°05′N., 79°15′W.).

DSDP core 25 (0°31′S., 39°14′W.).

Gulf of Mexico

DSDP core 2 (23°27′N., 92°35′W.).

DSDP core 3 (23°01′N., 92°01′W.).

Pacific Ocean

Scripps core AMPH 116P (11°26′S., 149°17′W.).

Indian Ocean

Scripps dredge sample DODO 123D-1 (10°25′S., 63°15′E.).

Europe

Lower part of type Plaisancian, 200 meters south of Lugagnano in Torrente Arda, to south of Piacenza (Plaisance) in Po Valley, Italy.

Pliocene, Le Castella #81, Crotone, Calabria, southern Italy [see Emiliani, Mayeda, and Selli (1961)].

South America

Type locality, *Globorotalia pseudomenardii* Zone, lower part of Lizard Springs Formation, TLL 228, 674 (HGK 10832), Trinidad; sample supplied by H. M. Bolli.

North America

Middle Eocene, Cook Mountain Formation, Columbus Landing, Louisiana.

Middle Eocene, Formación Aragón, type locality, El Rio la Puerta, west-southwest of La Antiqua, Mexico.

Middle Eocene, Formación Guayabal, type locality, Galle-Camino de Potrero Hacienda de Tamatoco, Mexico.

Middle Eocene, Gosport Sand, Little Stave Creek, Jackson, Alabama, Bandy collecting locality 36.

Middle Eocene, Lisbon Formation, Little Stave Creek, Jackson, Alabama, Bandy collecting locality 30.

Eocene, Tillamook Volcanic Series, Tillamook County, northwest Oregon. The sample, supplied by P. D. Snavely, Jr., is an oil shale within this series.

Upper Eocene, type Yazoo Clay, 5 meters above base, east bank of Yazoo River in sec. 32, T. 12 N., R. 2 E., at Yazoo City, Mississippi. Sample from H. L. Levin.

Upper Eocene, Cocoa Sand Member of Yazoo Clay, 3.5 miles southeast of Isney on the road to Silas, Choctaw County, Alabama.

IV. Systematic Paleontology

Genus Cyclococcolithus Kamptner, 1954

Cyclococcolithus macintyrei Bukry and Bramlette, n. sp.

Pl. 1, figs. 1-3

Coccolithus leptoporus (Murray and Blackman) var. A, McIntyre, Bé, and Preikstas, 1967, p. 9-10, pl. 4, figs. C-D.

Cyclococcolithus leptoporus (Murray and Blackman). Gartner, 1967, p. 1, pl. 1, figs. 1, 2, 4a-4c; pl. 2, figs. 1, 3a-3c, 4a-4d.

Description: These large circular coccoliths are constructed of two shields with a connecting tube. Each shield is formed by a single cycle of about 40 elements. The interelement sutures are slightly curved on the distal surface of the distal shield; otherwise the sutures are radial and straight. In cross-polarized light only the smaller proximal shield is bright.

Remarks: Although McIntyre, Bé, and Preikstas considered this to be one of three varieties of *Cyclococcolithus leptoporus* (Murray and Blackman), *Cyclococcolithus macintyrei* may be easily distinguished by a consistently larger number of elements (approximately 40 versus about half that number in other varieties) and by its large size (approximately 11 microns versus about 6 microns). *C. macintyrei* is therefore distinguished as a new species.

Distribution: Whereas *C. macintyrei* ranges only from middle Miocene to upper Pliocene, or sparsely to lowermost Pleistocene, other varieties of *C. leptoporus* range from lower Miocene to Holocene. *C. macintyrei* is abundant in samples from all oceans and from land strata. Much information on the taxonomic problems and distribution of *Cyclococcolithus leptoporus* has been presented by McIntyre, Bé, and Preikstas (1967) and by Gartner (1967).

Size: 8-12 microns.

Holotype: USNM 651407 (Pl. 1, fig. 1).

Paratype: USNM 651408.

Type locality: Lower Pliocene, type Plaisancian, Lugagnano, Italy.

Genus DISCOASTER Tan, 1927
DISCOASTER NEOHAMATUS
Bukry and Bramlette, n. sp.
Pl. 1, figs. 4-5

Description: This species has six long slender rays, the outer ends of which bend consistently in one direction (in plan view) and terminate in points. No distinct central area nor ornamentation is present.

Remarks: Where overgrown with secondary calcite, the rays appear to be more curved than otherwise. This species may have developed from five-rayed *Discoaster hamatus* Martini and Bramlette or six-rayed *Discoaster calcaris* Gartner, but both these species have tips that bend more abruptly and possess distinctive spurs not found on *Discoaster neohamatus*.

Distribution: The first occurrence of *D. neohamatus* is found in the lower part of the upper Miocene; the last occurrence is also within the upper Miocene. Because of this restricted range this species is useful in helping delimit the lower part of the upper Miocene. The tentative *Triquetrorhabdulus rugosus* Zone, as used by Bukry and Bramlette (in press) for these strata, is better characterized by the range of *D. neohamatus* and we propose that name change. The *Discoaster neohamatus* Zone is thus assigned to the lower part of the upper Miocene and is defined at the base by the last occurrence of *D. hamatus* and at the top by the first occurrence of *Ceratolithus tricorniculatus* Gartner. *D. neohamatus* has a wide geographic distribution and is particularly common in open-ocean deposits.

Size: 10-15 microns.

Holotype: USNM 651409 (Pl. 1, fig. 4).

Paratype: USNM 651410.

Type locality: Blake Plateau, JOIDES core 3, 21 meters.

DISCOASTER QUINTATUS
Bukry and Bramlette, n. sp.*
Pl. 1, figs. 6-8

Discoaster brouweri Tan, BANDY and WADE, 1967, pl. 1, figs. 3 and 4.

Description: This symmetric, consistently five-rayed species has a pentagonal central area that may occupy up to a third of the overall diameter. There is a star-shaped knob on the concave side, the rays of which bisect the angle between the extended rays of the discoaster. This central knob is commonly less developed in the later part of the range of the species (Pl. 1, figs. 7-8). The robust rays are straight in plan view and taper uniformly.

Remarks: This species is distinguished by the tapered straight rays (in plan view) and robust central area, which has a five-rayed central knob. *Discoaster brouweri* Tan lacks these features, but in late occurrences of *D. quintatus*, where the knob is less prominent, some specimens may closely resemble a five-rayed *D. brouweri*. The unusual crystallographic orientations of the rays of some specimens (orientations similar to *Micrantholithus*) and the five-rayed construction indicate that *Discoaster quintatus* is structurally similar to *D. pentaradiatus*, which shows both of these features. *D. quintatus* differs, however, in its lack of bifurcating rays, by distinctly tapered rays, and by its star-shaped central knob. Electron micrographs of "*Discoaster* sp." in the Leg-1 Report of the Deep Sea Drilling Project (Bukry and Bramlette, 1969) are referable to this new species.

Distribution: *D. quintatus* is a common species in lower upper Miocene into lower Pliocene strata in many regions.

Size: 8-16 microns.

Holotype: USNM 651411 (Pl. 1, fig. 7).

Paratypes: USNM 651412 and 651413.

Type locality: Lamont core V3-153, 531 cm.

Genus HELICOPONTOSPHAERA
Hay and Mohler, 1967
[*nom. subst. pro Helicosphaera* Kamptner, 1954]

HELICOPONTOSPHAERA PAPILLATA
Bukry and Bramlette, n. sp.
Pl. 2, figs. 1-2

Description: This large species is broadly elliptical in outline and the central area is biconvex. The surfaces of both the rim and central area possess a distinctive fine papillate ornamentation. In cross-polarized illumination the rim and central area are bright.

Remarks: The unique surface ornamentation, and imperforate, biconvex central

* See page 142.

area distinguish this species from all others described in this genus.

Distribution: This species occurs in the type Formación Aragón in Mexico, which has a very abundant assemblage of coccoliths indicating correlation with lower middle Eocene strata in other regions. Some of the species in this formation were described by Stradner and Papp (1961).

Size: 11-15 microns.

Holotype: USNM 651414 (Pl. 2, fig. 1).

Paratype: USNM 651415.

Type locality: Type Formación Aragón, La Antigua, Mexico.

HELICOPONTOSPHAERA SELLII
Bukry and Bramlette, n. sp.
Pl. 2, figs. 3-7

Description: The central area of this small species contains a large elliptical opening bridged by a single bar that may be either parallel to the short axis of the coccolith or distinctly oblique. Phase-contrast and cross-polarized lighting show the crossbar to be in optical continuity with the surrounding coccolith structure.

Remarks: *Helicopontosphaera sellii* is distinguished from the usually associated *Helicopontosphaera kamptneri* Hay and Mohler by having a large elliptical central opening bridged by a bar instead of being "imperforate or with two small slits." Other species of the genus from the lower Tertiary that have crossbars are typically larger forms and in cross-polarized light show different structural patterns than *H. sellii.*

Distribution: *H. sellii* is common in the upper Miocene and Pliocene of many regions: Italy, Atlantic Ocean, Gulf of Mexico, and the tropical Pacific Ocean.

Size: 6-12 microns.

Holotype: USNM 651416 (Pl. 2, figs. 3-4).

Paratype: USNM 651417.

Type locality: Le Castella 81, Calabria, southern Italy.

LEPTODISCUS LARVALIS
Bukry and Bramlette, n. gen., n. sp.
Pl. 2, figs. 8-11

Description: These circular coccoliths are constructed of a single cycle of 31-37 slightly inclined elements constituting a single shield. On one side the sutures are straight and on the opposite side curved. The small open central area is encircled by a collar and occupies less than 20 percent of the coccolith diameter.

Remarks: This species is extremely thin and is best observed in phase-contrast illumination. In cross-polarized illumination, only the central collar yields more than a faint image. *Leptodiscus larvalis* is distinguished from other concurrent circular coccoliths, *Cyclococcolithus lusitanicus* (Black) and *Cyclococcolithus neogammation* Bramlette and Wilcoxon, by the thin single-shield construction with little imbri-

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PLATE 1
Magnification 2000 ×

Figures		Page
1-3	*Cyclococcolithus macintyrei* Bukry and Bramlette, n. sp. (1) holotype USNM 651407, type Plaisancian; (2) V12-5, 700 cm, USNM 651408; (3) cross-polarized.	132
4-5	*Discoaster neohamatus* Bukry and Bramlette, n. sp. (4) holotype USNM 651409, J3, 21 meters; (5) DSDP-25, 20 meters, USNM 651410.	133
6-8	*Discoaster quintatus* Bukry and Bramlette, n. sp. (6) DSDP-3, 538 meters USNM 651412; (7) holotype USNM 651411, V3-153, 531 cm; (8) J3, 3 meters, USNM 651413.	133
9-14	*Triquetrorhabdulus inversus* Bukry and Bramlette, n. sp. (9) holotype USNM 651436, J3, 163 meters, parallel to polarizer; (10) perpendicular to polarizer; (11) 45° to polarizer, cross-polarized; (12) J3, 163 meters, parallel to polarizer, USNM 651437; (13) perpendicular to polarizer; (14) 45° to polarizer, cross-polarized.	142

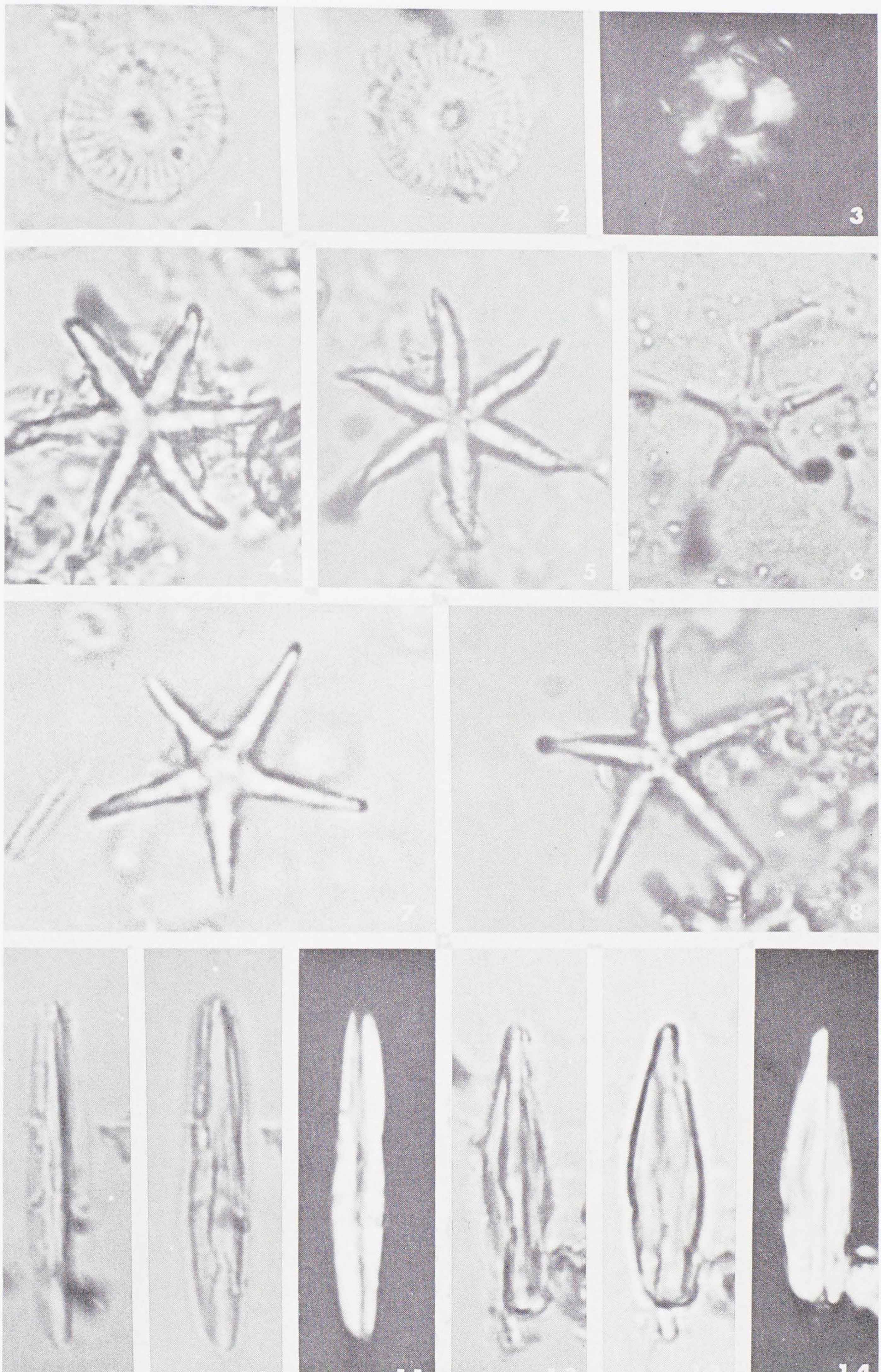

PLATE 1

cation of the rim elements and by the central collar.

Most circular single-shield coccoliths have been referred to the genus *Calcidiscus* Kamptner, 1950. However, the type species and others assigned to that genus apparently are all fragments derived from species of the two-shield genus *Cyclococcolithus* Kamptner, 1954.

Distribution: *Leptodiscus larvalis* is known from the upper Eocene type Yazoo Clay of Mississippi, and from the lower Oligocene of JOIDES cores on the Blake Plateau, J3, 130 to 136 meters and J6, 30 to 48 meters.

Size: 10 to 13 microns.

Holotype: USNM 651418 (Pl. 2, figs. 8-9).

Paratypes: USNM 651419 and 651420.

Type locality: Blake Plateau, JOIDES core 6, 34 meters.

Genus MICRANTHOLITHUS Deflandre, 1950

MICRANTHOLITHUS PROCERUS
Bukry and Bramlette, n. sp.
Pl. 2, figs. 12-15

Description: In plan view, each of the five triangular segments has a slight median indentation in the rounded marginal side. In side view, the usual orientation in study slides, this large species is seen to be very tall (one to two times the greater diameter of the base). Well-preserved specimens are widest at their flat base, tapering upwards to a rounded termination, and show a multilamellar structure which is parallel to the base.

Remarks: The extraordinary height compared with the basal diameter causes specimens to be almost invariably oriented on their sides and results in high birefringence, which make this species readily recognizable. The marginal outline of *Micrantholithus procerus* resembles that of *Micrantholithus basquensis crassus* Bouché. *M. procerus* is easily distinguished by its very tall and slightly tapering shape in side view.

Distribution: *M. procerus* occurs in upper middle Eocene strata in France, Indian Ocean (DODO 123 D-1), Louisiana, Alabama, Mexico, and Brazil. It is unusually abundant in JOIDES core 3 from 155 to 163 meters, Blake Plateau.

Size: height, 10-20 microns.

Holotype: USNM 651421 (Pl. 2, fig. 13).

Paratypes: USNM 651422 to 651424.

Type locality: Type Formación Guayabal, Mexico.

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PLATE 2

Magnification 2000 ×

Figures		Page
1-2	*Helicopontosphaera papillata* Bukry and Bramlette, n. sp. (1) holotype USNM 651414, type Formación Aragón; (2) type Formación Aragón, cross-polarized, USNM 651415.	133
3-7	*Helicopontosphaera sellii* Bukry and Bramlette, n. sp. (3) holotype USNM 651416, Le Castella 81; (4) cross-polarized; (5) V16-21, 200 cm, USNM 651417; (6) cross-polarized; (7) V16-21, 150 cm, figured specimen, cross-polarized.	134
8-11	*Leptodiscus larvalis* Bukry and Bramlette, n. gen., n. sp. (8) holotype USNM 651418, J6, 34 meters; (9) phase-contrast; (10) J6, 34 meters, phase-contrast, USNM 651419 and 651420; (11) cross-polarized.	134
12-15	*Micrantholithus procerus* Bukry and Bramlette, n. sp. (12) holotype USNM 651421, type Formación Guayabal, side view; (13) type Formación Guayabal, cross-polarized, USNM 651422; (14) Cook Mountain Formation, USNM 651423; (15) J3, 155 meters, end view, USNM 651424.	136
16-19	*Pemma snavelyi* Bukry and Bramlette, n. sp. (16) holotype USNM 651425, Lisbon Formation; (17) cross-polarized; (18) Tillamook Volcanic Series, single segment, cross-polarized, USNM 651426; (19) Gosport Sand, cross-polarized, USNM 651427.	138

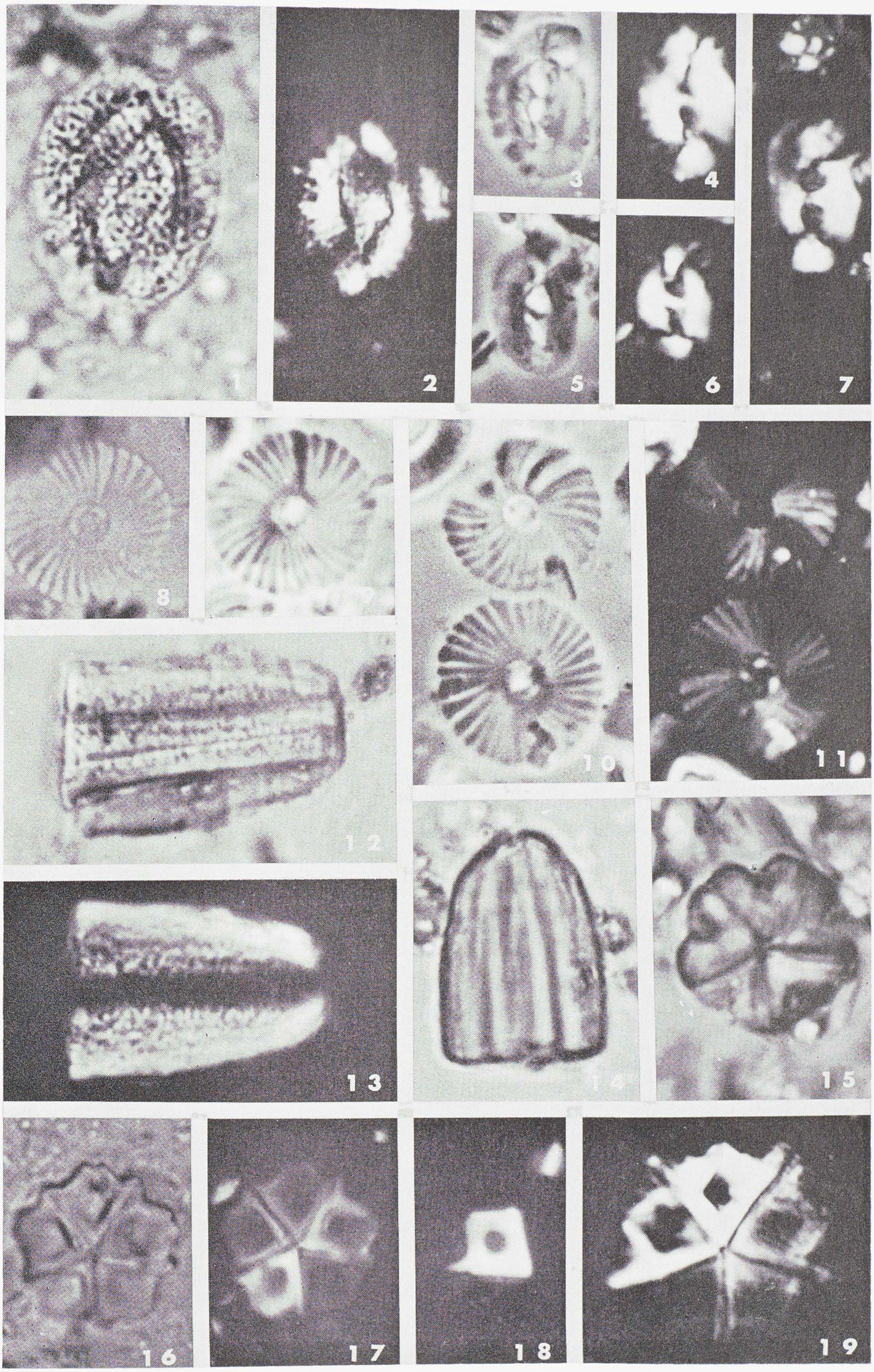

PLATE 2

Genus PEMMA Klumpp, 1953

PEMMA SNAVELYI

Bukry and Bramlette, n. sp.

Pl. 2, figs. 16-19

Description: These pentaliths are characterized by slender extensions along the radial sutures of each segment that extend beyond the pentagonal periphery, and by a distinctive broad, angular, median protrusion from the margin of the five segments. A rounded or diamond-shaped depression is present at the center of each segment.

Remarks: The only species similar to *Pemma snavelyi* is *Micrantholithus basquensis* Martini, 1959. *P. snavelyi* is distinguished by the relative lengths of the marginal protrusions. The overall outline of *M. basquensis* is circular, all depressions or protrusions being the same size, with four equal marginal protrusions per segment, whereas the overall outline of *P. snavelyi* is a pentagon having long protrusions at the segment sutures, with three protrusions per segment.

Distribution: *P. snavelyi* occurs in the upper middle Eocene Cook Mountain Formation of Louisiana, in the approximately equivalent Lisbon Formation of Alabama, and in an oil shale within the Eocene Tillamook Volcanic Series of Oregon.

Size: 10 to 17 microns.

Holotype: USNM 651425 (Pl. 2, figs. 16-17).

Paratypes: USNM 651426 and 651427.

Type locality: Lisbon Formation, Little Stave Creek, Alabama.

QUINQUERHABDUS COLOSSICUS

Bukry and Bramlette, n. gen., n. sp.

Pl. 3, figs. 1-4

Description: In plan view the base of this peculiar species is seen to be oval shaped and composed of five segments (oriented as in *Micrantholithus*). Owing to the large size and high tapering shape of the segments, the species is rarely seen in any orientation but a side view, where it shows an approximately triangular outline. In side view two of the five segments are seen meeting along the apical axis of the coccolith. The base of the segments is thick, however, and the structure thins upwards into vanes that terminate in a point.

Remarks: This unusual form seems related to *Braarudosphaera* and *Micrantholithus* by its pentameral symmetry of the base (vaguely shown in Pl. 3, fig. 3). Very different from these genera, however, is the abrupt concave taper from the base. Although the thickened portion of segments always shows this concave taper, some with flaring thin vanes may show a convex out- →

PLATE 3

Magnification 2000 ×

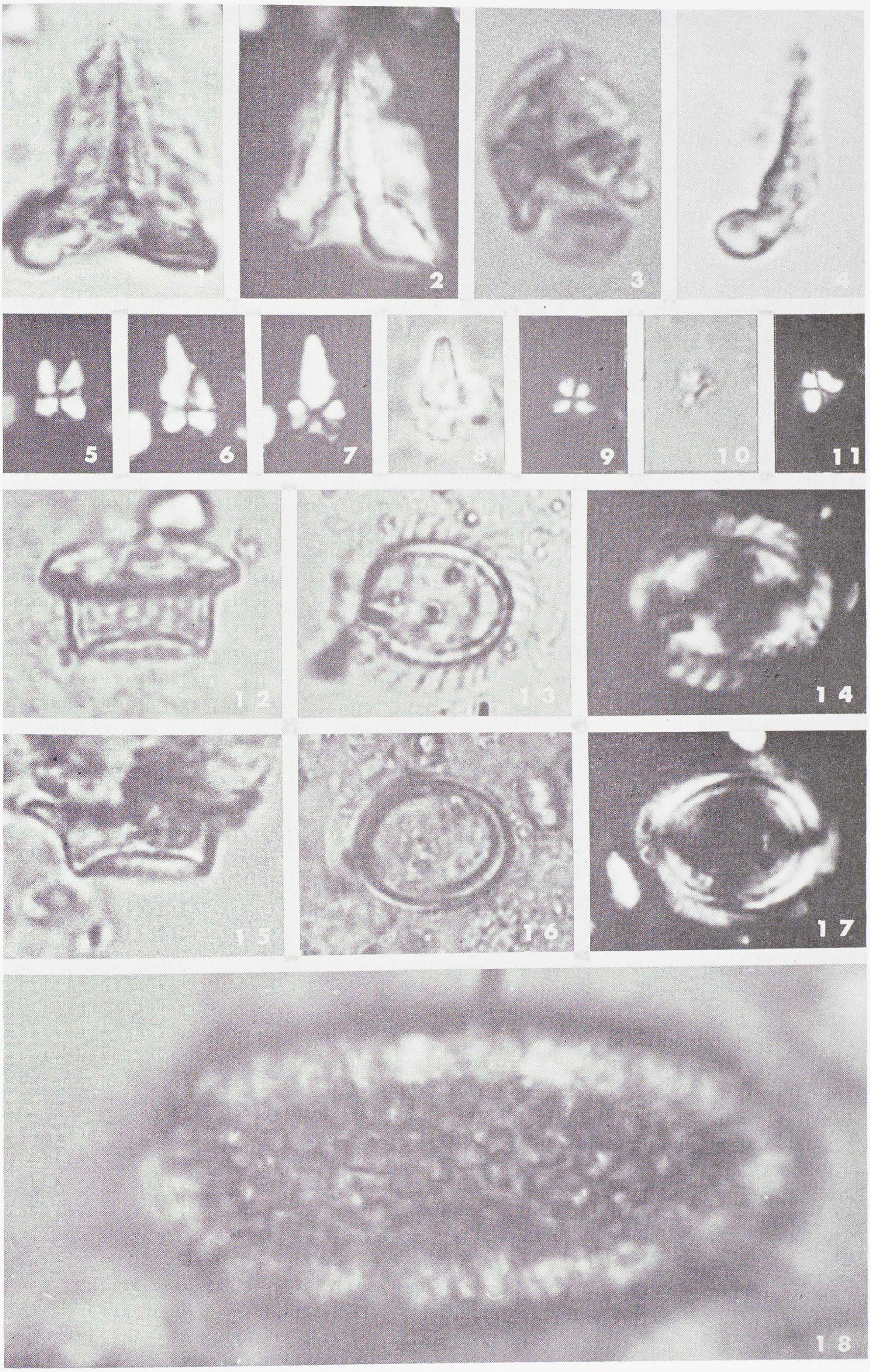

PLATE 3

line of this thin edge. The five segments are easily separated and usually are abundant in samples containing *Q. colossicus.*

Distribution: *Q. colossicus* is presently known only from the lower Oligocene of the Blake Plateau, east of Florida, from JOIDES core 3, 118 to 144 meters, and core 6, 19 to 43 meters.

Size: height, 10-18 microns.

Holotype: USNM 651428 (Pl. 3, figs. 1-2).

Type locality: Blake Plateau, JOIDES core 6, 34 meters.

Genus SPHENOLITHUS Deflandre, 1952

SPHENOLITHUS ANARRHOPUS

Bukry and Bramlette, n. sp.

Pl. 3. figs. 5-8

Description: This small species shows a relatively compact (nonflaring) group of basal spines and an unusual apical spine. As in other species of *Sphenolithus*, the specific structural features are best observed in cross-polarized light. In side view when the axis of the apical spine is aligned to either of the polarizing directions, only the basal structure can be seen, whereas when rotated to a position of 45°, the spine is bright and appears to be a monolithic structure. The apical spine is asymmetric in this position; however, the asymmetry is more distinct in the 10° to 20° position where the spine appears to be tilted (Pl. 3, fig. 6).

Remarks: The asymmetry of the spine distinguishes *Sphenolithus anarrhopus* from the similar *Sphenolithus heteromorphus* Deflandre, which has a symmetric apical spine. In cross-polarized illumination, populations of these two species are further distinguished by the four nearly equal-area divisions of the base in *S. anarrhopus* (Pl. 3, fig. 5) and the unequal division (lower two usually larger) in *S. heteromorphus. Sphenolithus radians* Deflandre has a symmetric spine with distinct median separation apparent under crossed polarizers.

Distribution: *S. anarrhopus* is present in Thanetian equivalents of the Paleocene in widely scattered areas such as California, central Atlantic Ocean, Blake Plateau JOIDES core 4, 137 to 178 meters, and the *Globorotalia pseudomenardii* Zone of Trinidad.

Size: height, 5-8 microns.

Holotype: USNM 651429 (Pl. 3, figs. 5-8).

Type locality: Blake Plateau, JOIDES core 4, 150 to 153 meters.

SPHENOLITHUS NEOABIES

Bukry and Bramlette, n. sp.

Pl. 3, figs. 9-11

Sphenolithus? sp. MARTINI and BRAMLETTE, 1963, p. 855, pl. 102, figs. 6-7.

Description: This small species lacks the prominent apical spine typical of most species of the genus; however it does possess the radial array of tiny spines typical of the basal structure of *Sphenolithus*. Owing to its small size, this species is clearly visible only in cross-polarized illumination.

Remarks: *Sphenolithus neoabies* is distinguished by its lack of a prominent apical spine and by its very small size (2 to 4 microns). The only other species without a prominent apical spine, *S. moriformis* (Brönnimann and Stradner), appears to be similar in cross-polarized illumination, but is much larger. *S. neoabies* is distinguished from equally small circular coccoliths, as seen under crossed polarizers, by having a digitate, instead of a smooth, margin. It is similar to the closely related *S. abies*, but is smaller and less conical because the apical spines are less extended.

Distribution: *S. neoabies* is commonly associated with *S. abies* in the upper Tertiary of many regions, but either dominates or becomes the only species of *Sphenolithus* in the latest occurrences near the middle of the Pliocene.

Size: 2 to 4 microns.

Holotype: USNM 651430 (Pl. 3, figs. 9-11).

Type locality: Lamont core V16-21, 475 cm.

Genus SYRACOSPHAERA Lohmann, 1902

SYRACOSPHAERA FORMOSA

Bukry and Bramlette, n. sp.

Pl. 3, figs. 12-14

Description: This high-walled species has a distinctively curving cycle of 26-32 elements in the flaring flange portion of the wall structure. The central structure is evidently very thin and gives no distinctive pattern in light microscopy.

Remarks: *Syracosphaera formosa* is similar to *Syracosphaera labrosa* Bukry and Bramlette, n. sp., but *S. labrosa* shows only a faint rim in which individual elements are not evident in either normal bright-field or cross-polarized light microscopy. *S. formosa* is distinguished from *Syracosphaera fimbriata* (Bramlette and Sullivan) by its lack of two distinctive central-area perforations.

Distribution: *S. formosa* occurs in the middle Eocene Formación Aragón of Mexico.

Size: 13-17 microns.

Holotype: USNM 651431 (Pl. 3, figs. 13-14).

Paratype: USNM 651432.

Type locality: Type Formación Aragón, Mexico.

SYRACOSPHAERA LABROSA Bukry and Bramlette, n. sp.

Pl. 3, figs. 15-17

Reticulofenestra caucasica HAY, MOHLER, and WADE, 1966 (*partim*), p. 386, pl. 2, figs. 6-8, not fig. 5, not pl. 3 nor pl. 4. LEVIN and JOERGER, 1967, p. 168, pl. 2, fig. 2a-b.

Description: This large high-walled, elliptical species has a flanged extension of the wall on the distal side. The flange is composed of a large number of narrow elements and thus appears smooth and translucent; only the side walls are conspicuous in normal transmitted light. In cross-polarized illumination, the optical extinction lines pass beyond the wall into the large central area, which indicates the presence of a thin basal structure.

Remarks: The taxonomy of *Syracosphaera labrosa* is confused. The type species of *Reticulofenestra* was *Reticulofenestra caucasica* Hay, Mohler, and Wade, 1966. However, our electron-microscope examination of topotype material of *Coccolithus umbilicus* Levin, 1965, has shown that the electron-micrograph holotype of *R. caucasica* = *C. umbilicus*. *C. umbilicus* is constructed of two distinct shields (a placolith) which produce a broad bright oval ring when observed in cross-polarized light. The light micrographs presented by Hay, Mohler, and Wade as paratypes, however, show a syracosphaerid single-rim type of wall. The electron micrographs of *Reticulofenestra oamaruensis* (Deflandre) Stradner and Edwards and the original light micrographs of Deflandre show that that species has a substantial central area structure with a distinctive median suture and a syracosphaerid-type rim without a flange (therefore, possibly referable to *Discolithina*). These features are quite different from those of *S. labrosa*.

Syracosphaera formosa Bukry and Bramlette, n. sp., and *Syracosphaera fimbriata* (Bramlette and Sullivan) are distinguished from *S. labrosa* by structural details that are obvious in light microscopy. *S. labrosa* has a translucent flange and a featureless central area; in contrast, *S. formosa* shows a definitely inclined cycle of 26 to 32 elements in the flange, and *S. fimbriata* has two large perforations in its base.

Distribution: Though not abundant, *S. labrosa* is present in the upper middle Eocene to lower Oligocene of many areas.

Size: 14-18 microns.

Holotype: USNM 651433 (Pl. 3, figs. 16-17).

Paratype: USNM 651434.

Type locality: Cook Mountain Formation, Columbus Landing, Louisiana.

Genus THORACOSPHAERA Kamptner, 1927

THORACOSPHAERA PROLATA Bukry and Bramlette, n. sp.

Pl. 3, fig. 18

Description: This is an unusually large thick-walled species with a shell in the shape of a very prolate spheroid. The shell is composed of a mosaic of irregular, thick interlocking elements. The surface is not "smooth," as the sutures are slightly depressed. Characteristically the eccentricity (long axis/short axis) of the shell is 2.0 or greater.

Remarks: No other species of *Thoracosphaera* has such a strongly prolate spheroidal shape as *Thoracosphaera prolata*. The distinctly "sculptured" appearance of the surface is also characteristic. There are ovoid (much less prolate) forms associated with *T. prolata*; these forms also occur in younger strata.

Distribution: *T. prolata* occurs in the middle Eocene of the three major oceans and in Lutetian equivalents in southwest France, Trinidad, USSR, and elsewhere.

Size: 25-50 microns.

Holotype: USNM 651435 (Pl. 3, fig. 18).

Type locality: Scripps core AMPH 116P, 488 cm, Pacific Ocean.

Genus TRIQUETRORHABDULUS Martini, 1965

TRIQUETRORHABDULUS INVERSUS
Bukry and Bramlette, n. sp.
Pl. 1, figs. 9-14

Description: The uniform crystallographic orientation of the keels of this three-edged rod is such that parallel to the polarizing direction the two side keels show distinct outlines (strong relief in 1.55 index medium), whereas perpendicular to the polarizing direction only the high upper keel is distinct, and the lower keels are faint owing to their thinness in this orientation. These effects are seen with one polarizer in the optic system. The position of maximum birefringence, as indicated by bright appearance in cross-polarized light, is at 45°. Although both ends of the rod taper, one end is usually more acute than the other. Secondary overgrowth of calcite commonly causes a ragged appearance on the keels.

Remarks: *Triquetrorhabdulus inversus* is distinguished from *Triquetrorhabdulus carinatus* Martini by having the opposite crystallographic orientation of the keels or long axis. With a single polarizer, *T. inversus* conversely gives a distinct outline in the direction for which *T. carinatus* shows a faint outline.

Further study has indicated that a suggested emendation, concerning the crystallographic orientation, of this genus (Bramlette and Wilcoxon, 1967) should be disregarded.

Distribution: *T. inversus* is common throughout the middle Eocene of all three major oceans, in Lutetian equivalents of southwest France, Trinidad, California, and many other areas.

Size: 12-22 microns.

Holotype: USNM 651436 (Pl. 1, figs. 9-11).

Paratype: USNM 651437.

Type locality: Blake Plateau, JOIDES core 3, 163 meters.

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* DISCOASTER QUINTATUS [see page 133]: *Discoaster quinqueramus* Gartner, 1969, Gulf Coast Assoc. Geol. Soc., Trans., v. 19, p. 598, pl. 1, figs. 6-7, was published while this paper was in press and has priority.

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