NEW TERTIARY CALCAREOUS NANNOFOSSILS[1]

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Abstract

Stratigraphic studies of Tertiary calcareous nannofossil assemblages from the JOIDES Deep Sea Drilling Project and Blake Plateau cores and from some outcrop localities in North America have indicated many undescribed nannofossil taxa, of which 27 are described here. The new taxa described include: *Campylosphaera eodela, Ceratolithina? vesca, Ceratolithus amplificus, Ceratolithus primus, Chiasmolithus altus, Cyclolithella pactilis, Dictyococcites abisectus* (n. comb.), *Dictyococcites bisectus* (n. comb.), *Dictyococcites scrippsae, Discoaster bellus, Discoaster mohleri, Discoaster prepentaradiatus, Discoaster variabilis pansus, Discoasteroides bramlettei, Discolithina latoculata, Discolithina segmenta, Ellipsolithus lajollaensis, Fasciculithus magnus, Helicopontosphaera granulata, Lophodolithus acutus, Lophodolithus rotundus, Micrantholithus articulatus, Reticulofenestra samodurovi* (n. comb.), *Reticulofenestra hillae, Scyphosphaera expansa, Scyphosphaera globulata, Sphenolithus capricornutus, Sphenolithus dissimilis, Syracosphaera? wechesensis,* and *Vermiculithina arca.*

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I. Introduction

Stratigraphic age determinations based on calcareous nannofossil assemblages have provided valuable data to guide coring operations of the Deep Sea Drilling Project from the D/V *Glomar Challenger.* The resistance to solution, diversity, and abundance of this group of fossils has contributed to their stratigraphic usefulness. In the course of stratigraphic studies of cores from Leg 1 and Leg 3 (Gulf of Mexico and Atlantic Ocean), and Leg 6 (Pacific Ocean) of the Deep Sea Drilling Project, several new taxa of calcareous nannofossils have been recognized. Comparative studies of nannofossil assemblages from Gulf Coastal Plain, Blake Plateau and California samples have led to recognition of new taxa and to additional information on nearshore and open-ocean aspects of nannofossil assemblages.

The most striking contrast between calcareous nannofossil assemblages from neritic and open-ocean depositional localities is seen in Eocene material that contains greatly diversified neritic assemblages. Commonly occurring are species of *Discolithina, Isthmolithus, Micrantholithus, Polycladolithus, Rhabdosphaera, Transversopontis, Zygolithus,* and holococcolith taxa. In the Eocene assemblages sampled by DSDP Leg 3 in the South Atlantic Ocean and by DSDP Leg 6 in the northwestern Pacific Ocean, only a few species of such taxa are represented (sparse *Isthmolithus recurvus* and *Zygolithus dubius*). The reduced taxonomic diversity in the open-ocean assemblages is the result of solution or ecologic exclusion. The rare occurrence of *I. recurvus* in deep-ocean samples and its contrasting common occurrence in neritic samples indicates that whereas the taxon was cosmopolitan, it was more susceptible to solution in the deep ocean. On the other hand, taxa such as *Polycladolithus* and *Transversopontis* are absent from open-ocean deposits, whether shallow or deep, and were probably ecologically restricted to neritic areas of deposition.

As more taxa are described and their geographic and geologic occurrences are recorded, the identification of ecologic and solution controls on assemblages will contribute to further refinement of the stratigraphic interpretations of calcareous nannofossils.

Some of the new taxa described here have been identified from both oceanic cores and land-outcrop localities, thereby indicating their wide geographic range and good preservability. For instance, *Campylosphaera eodela, Chiasmolithus altus, Dictyococcites abisectus, Dictyococcites bisectus, Dictyococcites scrippsae, Discoaster mohleri, Discoasteroides bramlettei, Discolithina segmenta, Reticulofenestra hillae,* and *Sphenolithus dissimilis* are present in open-ocean and land-outcrop samples. New taxa presently known only from open-ocean samples include *Ceratolithus amplificus, Ceratolithus primus, Cyclolithella pactilis, Discoaster bellus, Discoaster prepentaradiatus, Discoaster variabilis pansus, Fasciculithus magnus, Helicopontosphaera granulata, Scyphosphaera globulata, Sphenolithus capricornutus,* and *Vermiculithina arca.* The ranges of these taxa are likely to be increased as detailed studies of land-outcrop areas are undertaken. Some species, such as *Ceratolithina? vesca, Discolithina latoculata, Ellipsolithus lajollaensis, Lophodolithus acutus, Lophodolithus rotundus, Micrantholithus articulatus, Scyphosphaera expansa,* and *Syracosphaera? wechesensis*, are known from only a few localities but they are morphologically distinctive and could prove useful in stratigraphic and paleoecologic determinations. *S.? wechesensis*, for example, is common in certain middle Eocene land outcrops in Texas, U.S.A., and the Caucasus, U.S.S.R., but has not been recognized in ocean cores. It may be an indicator of shallow water or nearshore depositional environment.

II. Acknowledgment

Most of the oceanic-core samples examined in the preparation of this paper were provided by the National Science Foundation through the Deep Sea Drilling Project. Many of the outcrop samples were made available by M. N. Bramlette, Scripps Institution of Oceanography, who suggested the need for description of some of these species and provided valuable discussion on the taxonomic status of *Dictyococcites bisectus.* We thank R. G. Douglas and M. N. Bramlette for constructive review of this paper.

III. Systematic Paleontology

Genus Campylosphaera Kamptner, 1963

Campylosphaera eodela Bukry and Percival, n. sp.

Pl. 1, figs. 1–4

Description: This small species is characterized by a broad, subrectangular rim outline and a central opening that is largely filled by a cross structure aligned with the long and short axes of the coccolith. The rim cycle is composed of about 30 elements; in cross-polarized light, the rim is faint, with the margin at the central area being brightest. The cross is also faint in cross-polarized light.

Remarks: *Campylosphaera eodela* is distinguished from *Campylosphaera dela* (Bramlette and Sullivan) by its smaller size, more elongate shape, and corresponding smaller central opening with respect to rim width. *Campylosphaera eodela* is distinguished from species of *Cruciplacolithus* by subrectangle shape, and curving of the rim in side view and faint appearance of cross structure in cross-polarized light. This form was mentioned by Bramlette and Sullivan (1961) as a possible subspecies of *C. dela.*

Occurrence: *Campylosphaera eodela* has wide geographic range, occurring in samples from the Atlantic and Pacific Oceans and from California and Trinidad. Stratigraphically it has a limited range of upper Paleocene. It is best developed in the upper part of the *Discoaster multiradiatus* Zone.

Size: 6 to 10 microns.

Holotype: USNM 169171 (Pl. 1, figs. 1–2).

Paratypes: USNM 169172 and 169173.

Type locality: JOIDES core 4, 84 meters, Blake Plateau, Atlantic Ocean.

Genus Ceratolithina Martini, 1967

Ceratolithina? vesca Bukry and Percival, n. sp.

Pl. 1, figs. 5–8

Description: This small asymmetric species has one straight and narrow arm and one slightly curved and thicker arm. The narrow arm is the shorter and is tapered from the pointed tip, whereas the broad arm tapers only near the tip. The arms meet at an 80° to 90° angle and both arms are part of one crystallographic unit. In cross-polarized light this species shows maximum brightness when the arms are parallel to the directions of polarization.

Remarks: *Ceratolithina? vesca* is distinguished from species of *Ceratolithina* Martini and *Ceratolithus* Kamptner by the much wider angle formed by the arms and by the smaller arch. *Ceratolithina? vesca* is distinguished from *Ceratolithoides kamptneri* Bramlette and Martini by being a single crystallographic unit instead of each arm being a distinct unit.

Occurrence: *Ceratolithina? vesca* occurs abundantly in certain upper middle Eocene samples from the Hospital Hill Marl in Trinidad. It is also present in a sample of approximately equivalent age from southwestern U.S.S.R. (M. N. Bramlette, personal commun., 1970).

Size: 6 to 10 microns.

Holotype: USNM 169174 (Pl. 1, figs. 5–6).

Paratype: USNM 169175.

Type locality: Type locality of *Porticulosphaera mexicana* Zone of Bolli (1957b), Navet Formation, Hospital Hill Marl, Trinidad.

Genus Ceratolithus Kamptner, 1950

Ceratolithus amplificus Bukry and Percival, n. sp.

Pl. 1, figs. 9–11

Description: This basically horseshoe-shaped species has a broadly pointed extension on the outer part of the arch. One arm, generally that bearing a row of simple tooth-like structures, is straighter than the other, which has a slight inward bend toward the tip. In cross-polarized light this subspecies is moderately bright (moderate birefringence in plan view).

Remarks: The external shape and crystallographic orientation of *Ceratolithus amplificus* are intermediate between those of *Ceratolithus tricorniculatus*, which has a horn-like extension and slender curved arms but is wholly dark (no birefringence) in cross-polarized light, and those of *Ceratolithus rugosus*, which lacks a horn-like extension, has thick arms, but is very bright in cross-polarized light (high birefringence) when oriented in plan view at 45° to the direction of polarization. *C. amplificus* is probably a transitional form between those two species, distinguished by its horned arch and moderately bright appearance in cross-polarized light.

Occurrence: The stratigraphic occurrence of *C. amplificus*, in the uppermost Miocene and lower Pliocene assemblages of the *Ceratolithus rugosus* Zone, agrees with the transitional morphology of this species as *C. rugosus* first occurs in this zone and completely replaces *C. tricorniculatus* in strata above this level. *C. amplificus* is present in both Atlantic and Pacific Ocean samples.

Size: 12 to 20 microns.

Holotype: USNM 169176 (Pl. 1, figs. 9–10).

Paratype: USNM 169177.

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

CERATOLITHUS PRIMUS
Bukry and Percival, n. sp.
Pl. 1, figs. 12–14

Description: This small crescent-shaped species is characterized by short arms and very thick arch. In cross-polarized light this form is dark (no birefringence).

Remarks: Though possessing the crystallographic orientation of *Ceratolithus tricorniculatus*, this new species is easily distinguished by its lack of long slender arms and by its consistently different overall outline—a broad crescent shape resulting from the dominance of the arch over the arms.

Occurrence: *Ceratolithus primus* occurs in upper Miocene marine sediment from the Atlantic and Pacific Oceans. Its stratigraphic range is limited to the lower part of the *Ceratolithus tricorniculatus* Zone, where it occurs slightly lower or in conjunction with *C. tricorniculatus.*

Size: 7 to 10 microns.

Holotype: USNM 169178 (Pl. 1, fig. 12).

Paratypes: USNM 169179 and 169180.

Type locality: DSDP core 56.2-1-3, 0–3 cm, Caroline Rise, Pacific Ocean.

Genus CHIASMOLITHUS Hay, Mohler and Wade, 1966

CHIASMOLITHUS ALTUS
Bukry and Percival, n. sp.
Pl. 2, figs. 1–2

Description: This small elliptic species is characterized by an elliptic to oblong central opening that is spanned by a delicate x-shaped crossbar. Typically the bars meet at 90° angles; on some specimens one set of bars is slightly offset. Measured along the short axis, the central area opening is equal to one third the total width of the coccolith. The rim is composed of about 60 elements and is faint in the outer portion in cross-polarized light.

Remarks: *Chiasmolithus altus* is distinguished from the similar species, *Chiasmolithus oamaruensis* (Deflandre) by the smaller central opening and crossbar angles of 90°. *Chiasmolithus oamaruensis* has a central opening equal to one half the coccolith diameter along the short axis and has crossbar angles of approximately 45° and 135° (Pl. 2, fig. 3). *Chiasmolithus solitus* (Bramlette and Sullivan) is about the same size as *C. altus* but has a narrower rim that is bright to the margin in cross-polarized light and the crossbar has one set of bars widely offset (see Bramlette and Sullivan 1961, pl. 2, figs. 4a–4c, and Locker, 1968, pl. 1, figs. 5–6).

Occurrence: *Chiasmolithus altus* is known from sediment of late Eocene to early Miocene age. At the beginning of its range in late Eocene and earliest Oligocene *C. altus* occurs with *C. oamaruensis*, but through the remainder of the Oligocene it is the only species of *Chiasmolithus* present and represents the youngest species assigned to the genus.

Size: 10 to 18 microns.

Holotype: USNM 169181 (Pl. 2, figs. 1–2).

Type locality: JOIDES core 6, 39 meters, Blake Plateau, Atlantic Ocean.

Genus CYCLOLITHELLA Loeblich and Tappan, 1963

CYCLOLITHELLA PACTILIS
Bukry and Percival, n. sp.
Pl. 2, figs. 4–6

Description: This small, circular to subcircular species is composed of about 20 moderately imbricate rim elements. The outer margin of the rim cycle is slightly serrate and the margin of the open central area is smooth. The central opening occupies about 40 percent of the coccolith width.

Remarks: *Cyclolithella pactilis* is distinguished from *Cyclolithella prionion* (Deflandre and Fert) by its smaller central opening with respect to rim width and by the smooth inner margin of the rim. It is distinguished from *Cyclolithella inflexa* (Kamptner ex Deflandre) by having about half as many rim elements and by its more circular form.

Occurrence: *Cyclolithella pactilis* occurs most commonly in the upper middle Eocene of DSDP Site 19, Leg 3 in the Atlantic Ocean and DSDP Site 44, Leg 6 in the Pacific Ocean.

Size: 4 to 6 microns.

Holotype: USNM 169183 (Pl. 2, figs. 4–5).

Paratype: USNM 169184.

Type locality: DSDP core 44-4-2, 145 cm, Horizon Guyot, northwestern Pacific Ocean.

Genus DICTYOCOCCITES Black, 1967

DICTYOCOCCITES ABISECTUS (Müller) Bukry and Percival, n. comb. Pl. 2, figs. 9–11

Coccolithus aff. *C. bisectus* (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 9–10.
Coccolithus? *abisectus* MÜLLER, 1970, p. 92, pl. 9, figs. 9–10; pl. 12, fig. 1.

Remarks: These large circular to subcircular placoliths have a small circular to subcircular central area surrounded by a thick collar that shows high relief when seen in transmitted light. The broad distal rim is composed of 40 to 60 crystallite elements that are radial or have very slightly counterclockwise inclination. In cross-polarized light, the distal shield is bright and the black extinction lines narrow and dissipate from the periphery towards the center and are disjunct from the lines at the center, inside the central area collar.

Dictyococcites abisectus is distinguished from *D. bisectus* by the circular to subcircular shape of the central area, with a small circular opening at the very center, thick collar, and the circular to subcircular rim outline. *D. abisectus* is distinguished from *Cyclococcolithus neogammation* Bramlette and Wilcoxon by its large size, thick collar cycle, and discontinuous extinction lines. Structurally and stratigraphically, *D. abisectus* appears to have been derived from *D. bisectus*.

Occurrence: *Dictyococcites abisectus* is rarely present in middle Oligocene *Sphenolithus distentus* Zone assemblages but replaces *D. bisectus* in the upper Oligocene *Sphenolithus ciperoensis* Zone and is most common in this zone and the overlying lower Miocene lower *Triquetrorhabdulus carinatus* Zone. *D. abisectus* is a consistent indicator for this age in the Atlantic and Pacific Oceans, and Cipero Formation of Trinidad.

Size: 12 to 16 microns.

Hypotypes: USNM 169186 and 169187.

DICTYOCOCCITES BISECTUS (Hay, Mohler and Wade) Bukry and Percival, n. comb. Pl. 2, figs. 12–13

Syracosphaera bisecta HAY, MOHLER and WADE, 1966, (*partim*), p. 393, pl. 10, figs. 4–6.
Coccolithus pseudocarteri HAY, MOHLER and WADE, 1966, (*partim*), p. 385, pl. 2, figs. 2–4.
Cyclococcolithus dictyodus (Deflandre and Fert). HAQ, 1966, (*partim*), p. 31, pl. 2, fig. 2; pl. 6, figs. 2 and 6.
Coccolithus stavensis LEVIN and JOERGER, 1967, p. 165, pl. 1, figs. 7a–7d.
Coccolithus bisectus (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 11–13.
?*Coccolithus* sp. cf. *C. scissurus* (Hay, Mohler and Wade). BRAMLETTE and WILCOXON, 1967, p. 102, pl. 4, figs. 1–2.
?*Dictyococcites danicus* BLACK, 1967, p. 141, fig. 2.
?*Reticulofenestra dictyoda* (Deflandre and Fert). STRADNER and EDWARDS, 1968, (*partim*), p. 19, pl. 13, figs. 1–2; pl. 14, figs. 2–5.
Reticulofenestra placomorpha (Kamptner). STRADNER and EDWARDS, 1968, (*partim*), p. 22, pl. 21, figs. 1–2.
Stradnerius dictyodus (Deflandre and Fert). HAQ, 1968, (*partim*), p. 31, pl. 2, figs. 5–8; pl. 3, figs. 1–8.

Remarks: This large subcircular placolith has a distal shield that is bright, in cross-polarized light from the center to the peripheral margin. The elliptic central area is slightly concave and extinction lines are obscure here, typically being disjunct from the broad straight extinction lines of the rim. Large specimens have high interference color and a radial line pattern in the central area formed by large lath-shaped crystallites.

Dictyococcites bisectus is distinguished from the similar *Dictyococcites scrippsae* by its normally larger size, more nearly circular shape and extinction lines that are broad and nearly straight in the rim but obscure or disjunct in the central area.

Occurrence: *Dictyococcites bisectus* has a limited stratigraphic range of upper Eocene to middle Oligocene, but has a wide geographic range in open-ocean and nearshore deposits from areas such as the Gulf Coast of the U.S.A., Europe, and the Atlantic and Pacific Oceans.

Hypotype: USNM 169188.

DICTYOCOCCITES SCRIPPSAE
Bukry and Percival, n. sp.
Pl. 2, figs. 7–8

Syracosphaera bisecta HAY, MOHLER and WADE, 1966, (*partim*), p. 393, pl. 10, figs. 1–3.
Dictyococcites dictyodus (Deflandre and Fert). MARTINI, 1969, (*partim*), p. 133, pl. 1, figs. 5–6.

Description: These small elliptic placoliths have a solid central area composed of radial calcite laths. In cross-polarized light the extinction lines are continuous from the center to the periphery but bend sharply at the central area border, being distinctly broad and flared in the rim and narrow in the central area.

Remarks: *Dictyococcites scrippsae* is distinguished from the similar *Dictyococcites bisectus* by its generally smaller size, more elliptic outline, and continuous, sharply bent extinction lines.

Occurrence: *Dictyococcites scrippsae* is a cosmopolitan taxon that occurs abundantly in neritic and open-ocean assemblages ranging from middle Eocene to upper Oligocene.

Size: 6 to 12 microns.

Holotype: USNM 169185 (Pl. 2, figs. 7–8).

Type locality: Red Bluff Clay, Chickasawhay River, Shubuta, Mississippi.

Genus DISCOASTER Tan, 1927

DISCOASTER BELLUS
Bukry and Percival, n. sp.
Pl. 3, figs. 1–2

Description: These small, simple, five-rayed discoasters lack any central knob or central area development and have straight rays that taper slightly and terminate in points. Rarely a tiny spur is present at the ray points.

Remarks: *Discoaster bellus* is distinguished from *Discoaster hamatus* Martini and Bramlette by consistently smaller size and lack of large ray-tip spur. It lacks the delicate non-tapered rays and long bifurcations of *D. pentaradiatus* and the distinctive central knob of other upper Miocene five-rayed discoasters such as *D. berggrenii* and *D. quinqueramus*.

Occurrence: *Discoaster bellus* is distinctly smaller and more abundant than *D. hamatus* in oceanic samples (Pacific Ocean, DSDP Leg 6) of the lower upper Miocene (Tortonian) *Discoaster hamatus* Zone and persists above *D. hamatus* into the overlying *Discoaster neohamatus* Zone.

Size: 8 to 14 microns.

Holotype: USNM 169189 (Pl. 3, fig. 1).

Paratypes: USNM 169190 and 169191.

Type locality: DSDP core 55.0-4-1, 130–131 cm, Caroline Rise, Pacific Ocean.

DISCOASTER MOHLERI
Bukry and Percival, n. sp.
Pl. 3, figs. 3–5

Discoaster gemmeus Stradner. HAY and MOHLER, 1967, p. 1538, pl. 204, figs. 19–21; pl. 205, figs. 1–3; pl. 206, figs. 3, 5–6, 8.

Description: This discoaster is composed of 9 to 16 radial straight rays that have essentially no separation and terminate in broad points. There is a slight depression at the center and no central knob structure. The inter-ray sutures are depressed below the general level of the rays that have a median ridge.

Remarks: Excellent electronmicrographs of this new species have been published by Hay and Mohler (1967). A combination of the characters of small to moderate size, straight rays with median ridge, no free-ray length and lack of central knob distinguish *Discoaster mohleri* from other early Tertiary multiray discoaster species such as *D. lubinaensis* Bystricka, *D. multiradiatus* Bramlette and Riedel, *D. nobilis* Martini, and *D. ornatus* Stradner. Although the first description of *D. gemmeus* Stradner was attributed to a Paleocene occurrence (Stradner, 1959; Hay and Mohler, 1967), other species reported by Stradner to occur in the same "Paleocene sample" included *D. barbadiensis* Tan, *D. distinctus* Martini, *D. lodoensis* Bramlette and Riedel, *D. mirus* Deflandre, *D. rotans* Stradner, and *D. tribrachiatus* Bramlette and Riedel, now known to be lower or middle Eocene taxa. Stradner and Papp (1961) illustrated *D. gemmeus* from the middle Eocene (Lutetian) of Austria. The occurrence of *D. gemmeus* as originally figured has been noted in middle Eocene assemblages from oceanic cores where there is no evidence of reworking, as in the Lamont-Doherty core A-150-1, 92 cm, and the Deep Sea Drilling Project core 44-3-5, 145–150 cm. The rays of *D. gemmeus* imbricate more than those of *Discoaster mohleri.* Therefore, the much larger species having more rays, better developed pointed ray terminations and less central thickening than *D. gemmeus* is named *Discoaster mohleri. Discoaster mohleri* is common in many upper Paleocene samples and is the first discoaster.

Occurrence: *Discoaster mohleri* first occurs in the upper Paleocene *Heliolithus riedeli* Zone and is extinct by the end of the Paleocene. It is a cosmopolitan species present in deep-ocean cores from the Atlantic and Pacific Oceans and from land outcrops in France and Trinidad.

Size: 8 to 16 microns.

Holotype: USNM 169192 (Pl. 3, fig. 3).

Paratypes: USNM 169193 and 169194.

Type locality: DSDP core 47.2-9-6, 0–5 cm, Shatsky Rise, Pacific Ocean.

Discoaster prepentaradiatus
Bukry and Percival, n. sp.
Pl. 3, figs. 6–7

Description: This small symmetric five-rayed discoaster has no central area developed and has thin bifurcations at the ray tips. The bifurcate tips and rays lie in the same plane.

Remarks: *Discoaster prepentaradiatus* is basically comparable to *D. pentaradiatus* Tan but lacks the typical strongly downward bent rays of that species. Further, *D. prepentaradiatus* is distinguished from *D. asymmetricus* Gartner and *D. moorei* Bukry by being symmetric and is distinguished from *D. berggrenii* Bukry, *D. bellus* Bukry and Percival, and *D. quinqueramus* Gartner by having equant bifurcations at the tips of the rays.

Occurrence: *Discoaster prepentaradiatus* occurs in lower upper Miocene marine sediments from the Atlantic and Pacific Oceans.

Size: 9 to 12 microns.

Holotype: USNM 169195 (Pl. 3, fig. 6).

Paratype: USNM 169196.

Type locality: DSDP core 55.0-5-5, 126–127 cm, Caroline Rise, Pacific Ocean.

Discoaster variabilis pansus
Bukry and Percival, n. subsp.
Pl. 3, figs. 8–9

Discoaster aff. *D. variabilis* Martini and Bramlette, 1963, pl. 104, fig. 9.

Description: This large six-rayed discoaster has tapering rays that terminate in large broadly bifurcate tips. The large bifurcate limbs are almost perpendicular to the rays. There is a small central knob in the medium-sized central area.

Remarks: *Discoaster variabilis pansus* is distinguished from *D. variabilis decorus* Bukry, which has very long tapering rays terminating in very narrow, small bifurcations, by its wide large bifurcations nearly perpendicular to the moderately long rays. *Discoaster variabilis variabilis* Martini and Bramlette is considered to be the main stock, having more moderately sized and angled bifurcations between the two end members, *D. variabilis decorus* and *D. variabilis pansus. Discoaster challengeri* Bramlette and Riedel is six-rayed and has terminal bifurcations but is readily distinguished from *D. variabilis pansus* by having parallel-sided rays and no central area development.

Occurrence: *Discoaster variabilis pansus* occurs in upper Miocene and lower Pliocene marine sediments equivalent to the *Ceratolithus tricorniculatus* Zone, *Ceratolithus rugosus* Zone, and *Reticulofenestra pseudoumbilica* Zone in cores from the Atlantic and Pacific Oceans. Its first occurrence is after that of *D. variabilis variabilis* and before *D. variabilis decorus.*

Size: 15 to 25 microns.

Holotype: USNM 169197 (Pl. 3, fig. 8).

Paratype: USNM 169198.

Type locality: DSDP core 47.2-6-3, 114 cm, Shatsky Rise, Pacific Ocean.

Genus Discoasteroides Bramlette and Sullivan, 1961

Discoasteroides bramlettei
Bukry and Percival, n. sp.
Pl. 3, figs. 10–12

Description: This species is circular in plan view with a serrate outline and a main cycle composed of 17 to 21 straight, radial elements that are not in contact only at the broadly pointed tips forming the serrate margin. This main cycle of elements is dark in cross-polarized light. A smaller secondary cycle of 17 to 22 straight radial elements forms a central structure that rises slightly above the level of the main cycle and is bright in cross-polarized light with an extinction cross.

Remarks: The main cycle with recessed sutures, a high ridge on each element, and each element ending in a blunt point are characters similar to those of early species of *Discoaster.* But the small central cycle that is bright in cross-polarized light and occupies one half to one quarter of the diameter of the main cycle distinguishes *Discoasteroides bramlettei* from species of *Discoaster. Discoasteroides bramlettei* is distinguished from *Discoasteroides kuepperi* (Stradner) by having more than twice as many elements in each cycle and a much more closely appressed secondary cycle. It is distinguished from *Discoasteroides megastypus* Bramlette and Sullivan by having a prominent outer cycle with fewer rays and a serrate margin to the inner cycle rather than a high stem.

Occurrence: *Discoasteroides bramlettei* is common in samples of the upper Paleocene *Heliolithus kleinpelli* Zone of the Shatsky Rise in the northwestern Pacific Ocean at the type locality. This species has also been observed in samples of upper Paleocene sediment from Belus, France (M. N. Bramlette, personal commun., 1969).

Size: 9 to 11 microns.

Holotype: USNM 169200 (Pl. 3, figs. 11–12).

Paratype: USNM 169199.

Type locality: DSDP core 47.2-9-5, 77–78 cm, Shatsky Rise, Pacific Ocean.

Genus DISCOLITHINA Loeblich and Tappan, 1963

DISCOLITHINA LATOCULATA
Bukry and Percival, n. sp.
Pl. 4, figs. 1–3

Description: This large species is strongly elliptic (eccentricity: 1.3 to 1.5) and has a narrow unornamented rim. The central plate has vague concentric substructure and an elliptic central opening aligned with the long axis of the discolith. In cross-polarized light, the central opening appears larger when oriented 45° to the polarization directions than when oriented parallel to polarization directions owing to convergence of the extinction lines at the ends of the central opening in that position.

Remarks: The central opening and lack of ornamentation or crossbar distinguishes *Discolithina latoculata* from most other discolith taxa. The taxon most similar to *D. latoculata* is *Discolithina rimosa* (Bramlette and Sullivan); it is distinguished from *D. latoculata* by its great thickness and by lacking a distinct rim cycle. Though these differences could result from differential preservation, they probably represent evolutionary development, since *D. latoculata* occurs later than the latest occurrence of *D. rimosa.*

Occurrence: *Discolithina latoculata* occurs in the upper Eocene Yazoo Clay and lower Oligocene Red Bluff Clay of the Gulf Coast region of the United States.

Size: 12 to 16 microns.

Holotype: USNM 169201 (Pl. 4, figs. 1–3).

Type locality: Shubuta Member of the Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

DISCOLITHINA SEGMENTA
Bukry and Percival, n. sp.
Pl. 4, figs. 4–6

Description: This imperforate elliptic species is constructed of approximately 30 radially arrayed elements that extend from the long axis of the discolith. The interelement sutures are recessed along their length, giving the surface of the discolith a corrugated appearance and the peripheral margin a scalloped appearance. In cross-polarized light the extinction gyres are simply defined along the elements from the periphery to the central axis.

Remarks: No other species of *Discolithina* lacking a rim cycle has the typical corrugated solid surface that results from the simple construction of *Discolithina segmenta.* Other species of imperforate discoliths such as *Discolithina japonica* Takayama or *Discolithina plana* (Bramlette and Sullivan) have a smooth peripheral margin and no large constructional elements evident in light microscopy. *Discolithina ovata* Levin and Joerger lacks a rim but is distinguished by having fewer elements and two median sigmoidal slits. *Discolithina segmenta* probably developed from *D. ovata*, a lower Oligocene species.

Occurrence: Though occurring only in small numbers, *Discolithina segmenta* is often recognized in deep-ocean samples of late Oligocene sediment from the Atlantic and Pacific Oceans. It occurs in the late Oligocene strata of the Cipero Formation of Trinidad.

Size: 8 to 12 microns.

Holotype: USNM 169202 (Pl. 4, figs. 4–5).

Paratype: USNM 169203.

Type locality: JOIDES core 2, 100 meters, Blake Plateau, Atlantic Ocean.

Genus ELLIPSOLITHUS Sullivan, 1964

ELLIPSOLITHUS LAJOLLAENSIS Bukry and Percival, n. sp. Pl. 4, figs. 7–8

Description: This elongate species is characterized by rounded ends and long parallel sides of the rim and central area. The rim cycle is composed of about 35 to 40 radial elements. The central area, occupying less than a third of the coccolith width contains two rows of perforations. Each row is composed of 5 to 8 perforations. When examined with only one polarizer of the microscope, the entire coccolith—rim and central area—is in strong relief (medium refraction index 1.518) when the long axis is oriented parallel to the polarization direction; the relief is very weak when the long axis is perpendicular to the polarization direction. In cross-polarized light, and oriented parallel to a polarization direction, the extinction lines developed in the rim of the long coccolith sides are very weak and diffused and the central area structure is dark. At a 45° orientation the central area and rim is bright and extinction lines are narrowly defined at the rounded ends of the coccolith.

Remarks: *Ellipsolithus lajollaensis* is distinguished from the similarly constructed *Ellipsolithus distichus* (Bramlette and Sullivan) by having two parallel sides instead of an elliptic outline, a central area occupying less than a third of the coccolith width instead of more than a third, a greater number of perforations, a less prominent central rib, and fewer rim elements—35 to 40 instead of 50 to 60 (Hay and Mohler, 1967).

Occurrence: *Ellipsolithus lajollaensis* occurs sparsely in the lower middle Eocene Rose Canyon Shale of Hanna (1926) at La Jolla, California and in the Donzacq Marl, Donzacq, France.

Size: 8 to 12 microns.

Holotype: USNM 169204 (Pl. 4, figs. 7–8).

Type locality: Rose Canyon Shale of Hanna (1926); seacliff at Salk Institute, La Jolla, California.

Genus FASCICULITHUS Bramlette and Sullivan, 1961

FASCICULITHUS MAGNUS Bukry and Percival, n. sp. Pl. 4, figs. 9–12

Description: This large species is characterized by a very deep concave depression at one end and by a distinctive narrowing of the cylindric body about halfway towards the other end. The body of the cylinder is solid, composed of about 20 high wedge-shaped elements. In side view, the outline slopes in toward the central axis from the larger portion of the cylinder (where the conical depression is) to the narrow part of the cylinder.

Remarks: *Fasciculithus magnus* is distinguished from *Fasciculithus schaubi* Hay and Mohler by lacking six concave sides and pit-and-ridge ornamentation. *Fasciculithus magnus* is distinguished from *Fasciculithus involutus* Bramlette and Sullivan and *Fasciculithus tympaniformis* by having a distinctive change in cylinder diameter half way along its length and by having a very deep conical depression at one end.

Occurrence: *Fasciculithus magnus* is common in the lower Paleocene carbonate ooze of the Shatsky Rise in the northwestern Pacific Ocean.

Size: 10 to 17 microns.

Holotype: USNM 169205 (Pl. 4, figs. 9–10).

Paratypes: USNM 169206 and 169207.

Type locality: DSDP core 47.2-10-5, 109–110 cm, Shatsky Rise, Pacific Ocean.

Genus HELICOPONTOSPHAERA Hay and Mohler, 1967

HELICOPONTOSPHAERA GRANULATA
Bukry and Percival, n. sp.
Pl. 5, figs. 1–2

Description: This elongate species with helicoid rim has an oblong-shaped central area. In bright-field illumination the central area appears granular, probably owing to the presence of a field of equidimensional crystallites. In cross-polarized light the central part of the central area is brighter than the ends.

Remarks: *Helicopontosphaera granulata* superficially resembles *Helicopontosphaera kamptneri* Hay and Mohler in lacking bars or large perforations in the elliptic to oblong central area. *Helicopontosphaera granulata* is distinguished from *H. kamptneri* by having a central-area structure that lacks the regularly aligned lath-shaped crystallites and median slit or suture. Thus in cross-polarized light the faint and granular pattern of the central area of *Helicopontosphaera granulata* is distinct from the bright field with median slit shown by *H. kamptneri.*

Occurrence: *Helicopontosphaera granulata* is most common in lower middle Miocene assemblages of the *Sphenolithus heteromorphus* Zone and *Discoaster exilis* Zone and persists through the upper Miocene in Deep Sea Drilling Project cores from the Atlantic (Leg 3) and Pacific (Leg 6) Oceans.

Size: 10 to 12 microns.

Holotype: USNM 169208 (Pl. 5, figs. 1–2).

Type locality: DSDP core 15-3-2, 78–79 cm, Mid-Atlantic Ridge, Atlantic Ocean.

Genus LOPHODOLITHUS Deflandre, 1954

LOPHODOLITHUS ACUTUS
Bukry and Percival, n. sp.
Pl. 5, figs. 3–5

Description: This broadly elliptic species has a narrow rim which is expanded into a flange on one side and one end, producing an asymmetric form. The large central area is open except for a single crossbar that spans the central opening in approximate alignment with the short axis of the elliptic outline. The narrow side and end of the rim meet at a distinctive right angle or slightly acute angle that contrasts the broadly rounded rim at the diagonally opposite position on the rim.

Remarks: The distinctive thinning of the rim toward one end with one limb almost a straight line, and the right angle or acute angle at one position in the rim distinguish *Lophodolithus acutus* from similar species such as *Lophodolithus mochlophorus* Deflandre, *Lophodolithus nascens* Bramlette and Sullivan, and *Lophodolithus rotundus* Bukry and Percival, all of which have broadly oval, bilaterally symmetric rims.

Occurrence: *Lophodolithus acutus* is known from the middle Eocene Aragon Formation of Mexico and has been observed

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PLATE 1
Magnification 2000×

Figures		Page
1–4	*Campylosphaera eodela* Bukry and Percival, n. sp. (1) holotype USNM 169171, J4, 87 meters; (2) cross-polarized; (3) J4, 84 meters, phase-contrast, USNM 169172; (4) J4, 83 meters, USNM 169173.	125
5–8	*Ceratolithina? vesca* Bukry and Percival, n. sp. (5) holotype USNM 169174, Hospital Hill Marl; (6) cross-polarized; (7) USNM 169175; (8) cross-polarized.	125
9–11	*Ceratolithus amplificus* Bukry and Percival, n. sp. (9) holotype USNM 169176, V3-153, 531 cm; (10) cross-polarized; (11) USNM 169177.	125
12–14	*Ceratolithus primus* Bukry and Percival, n. sp. (12) holotype USNM 169178, 56.2-1-3, 0–3 cm; (13) 56.2-1-4, 130–131 cm, USNM 169179; (14) 56.2-1-3, 0–3 cm, USNM 169180.	126

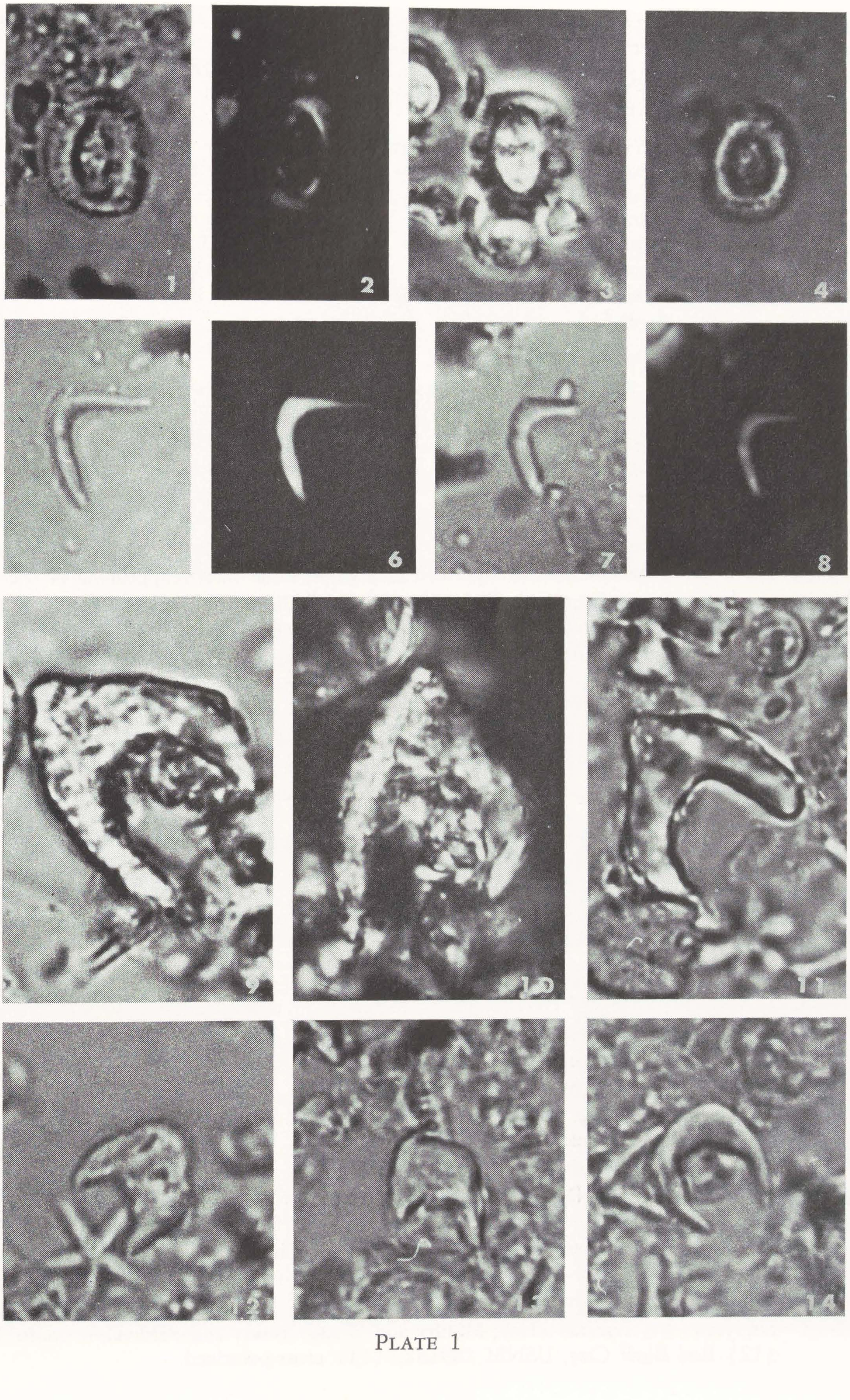

PLATE 1

from the middle Eocene of California (M. N. Bramlette, personal communication, 1970).

Size: 10 to 12 microns.

Holotype: USNM 169209 (Pl. 5, figs. 3–4).

Paratype: USNM 169210.

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

LOPHODOLITHUS ROTUNDUS
Bukry and Percival, n. sp.
Pl. 5, figs. 6–7

Description: This large species is bilaterally symmetric along the long axis but has an asymmetric enlargement of the flange such that the main subcircular body of the coccolith occupies only half of the total length and covers only one end of the coccolith. The asymmetric rim flange is composed of 50 to 70 straight, essentially radial elements. The outline of the rim flange is oblong to subelliptic and in cross-polarized light the extinction gyres in the rim have slight counterclockwise inclination in proximal view. The central area wall is prominent but there is no distinctive structure observed within the central area.

Remarks: *Lophodolithus rotundus* is distinguished from the similar species *Lophodolithus mochlophorus* Deflandre by the subcircular symmetric shape of the central area and by the lack of any central area crossbar structure or vestige.

Occurrence: *Lophodolithus rotundus* is present in a marine core sample from the South Pacific that contains other coccoliths of middle Eocene age.

Size: 16 to 23 microns.

Holotype: 169211 (Pl. 5, figs. 6–7).

Type locality: Scripps core DWBG-23B, core catcher sample, Pacific Ocean.

Genus MICRANTHOLITHUS Deflandre, 1954

MICRANTHOLITHUS ARTICULATUS, n. sp.
Bukry and Percival
Pl. 5, figs. 8–11

Description: This large symmetric species has five long slender rays with medial sutures. The outer half of the rays is unusually terminated, the medial sutures disappearing at a slight node then reappearing at the tip as the dividing line between two unequal segments. This arrangement may be the result of one segment of the ray passing under the other and reappearing at the tip.

Remarks: *Micrantholithus articulatus* is distinguished from other long, slender-rayed species such as *Micrantholithus attenuatus* Bramlette and Sullivan by the unique ar-

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PLATE 2
Magnification 2000×

Figures		Page
1–2	*Chiasmolithus altus* Bukry and Percival, n. sp. (1) holotype USNM 169181, J6, 39 meters; (2) cross-polarized.	126
3	*Chiasmolithus oamaruensis* (Deflandre) (3) Oamaru Diatomite, USNM 169182.	126
4–6	*Cyclolithella pactilis* Bukry and Percival, n. sp. (4) holotype USNM 169183, 44-4-2, 145 cm; (5) cross-polarized, (6) USNM 169184, cross-polarized.	126
7–8	*Dictyococcites scrippsae* Bukry and Percival, n. sp. (7) holotype, USNM 169185, Shubuta Member of Yazoo Clay; (8) cross-polarized.	128
9–11	*Dictyococcites abisectus* (Müller) Bukry and Percival, n. comb. (9) 55.0-13-1, 120–121 cm, USNM 169186; (10) cross-polarized; (11) USNM 169187, cross-polarized.	127
12–13	*Dictyococcites bisectus* (Hay, Mohler and Wade) Bukry and Percival, n. comb. (12) Red Bluff Clay, USNM 169188; (13) cross-polarized.	127

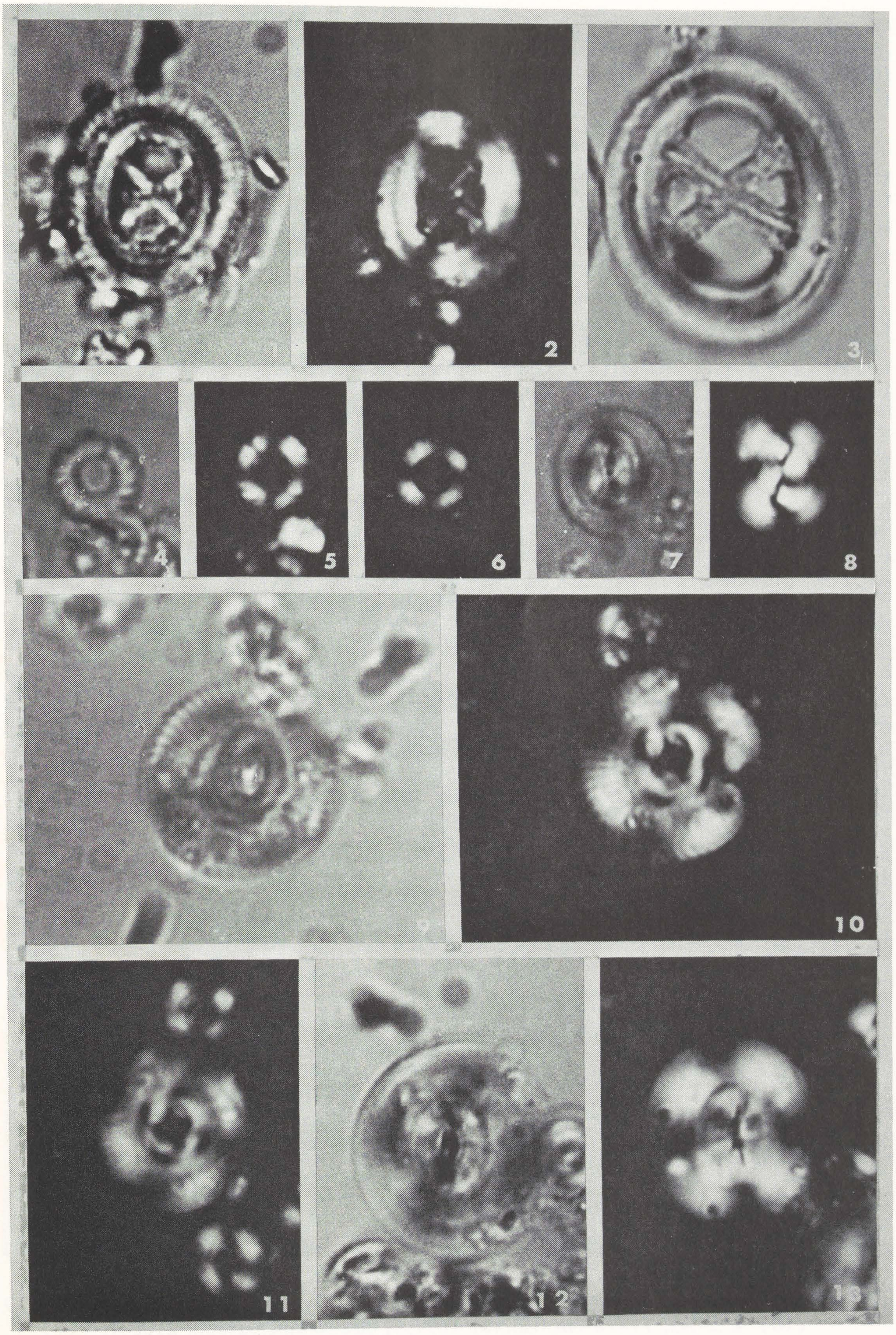

PLATE 2

rangement of the outer part of the ray segments which appear to cross over. No other species of *Micrantholithus* have such construction.

Occurrence: *Micrantholithus articulatus* is known only from the upper Eocene of the southwestern U.S.S.R. at Nal'chik in the Caucasus. Associated nannofossils from this locality have been described by Hay, Mohler and Wade (1966).

Size: 20 to 30 microns.

Holotype: USNM 169212 (Pl. 5, figs. 8–9).

Paratypes: USNM 169213 and 169214.

Type locality: Nal'chik, Caucasus, U.S.S.R.; Nal'chik-11.

RETICULOFENESTRA SAMODUROVI
(Hay, Mohler and Wade), n. comb.

Apertapetra samodurovi HAY, MOHLER and WADE, 1966, p. 388, pl. 6, figs. 1–7.

Remarks: The structure of the rim and collar cycles and the cross-polarized light image of this species matches that of species of *Reticulofenestra. Reticulofenestra samodurovi* is distinguished by its smaller size and stratigraphically lower first occurrence than other species of the genus.

RETICULOFENESTRA HILLAE
Bukry and Percival, n. sp.
Pl. 6, figs. 1–3

?*Discolithus* ?*cuvillieri* LEZAUD, 1968 (*partim*), p. 22, pl. 1, figs. 1–2.

Description: This large elliptic placolith has a thick, wide elliptic collar around a small central area opening that occupies less than a third of placolith length.

Remarks: *Reticulofenestra hillae* is distinguished from *Reticulofenestra umbilica* (Levin) by its more prominent, wider central area collar and by the correspondingly smaller central opening. It is distinguished from *Dictyococcites abisectus* by its elliptic shape and larger central opening.

Occurrence: *Reticulofenestra hillae* commonly occurs with *R. umbilica* in the upper Eocene and lower Oligocene, namely in the later part of the range of *R. umbilica.* It is most common in the lower Oligocene. Geographically it is present in sediments from the Atlantic and Pacific Oceans, the Gulf Coast of the United States and Europe.

Size: 14 to 20 microns.

Holotype: USNM 169215 (Pl. 6, figs. 1–2).

Paratype: USNM 169216.

Type locality: Shubuta Member of Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

RETICULOFENESTRA UMBILICA (Levin)

Coccolithus umbilicus LEVIN, 1965, p. 265, pl. 41, fig. 2.

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PLATE 3

Magnification 2000×, unless noted otherwise

Figures		Page
1–2	*Discoaster bellus* Bukry and Percival, n. sp. (1) holotype USNM 169189, 55.0-4-1, 130–131 cm; (2) USNM 169190 and 169191.	128
3–5	*Discoaster mohleri* Bukry and Percival, n. sp. (3) holotype USNM 169192, 47.2-9-6, 0–5 cm; (4) USNM 169193; (5) USNM 169194.	128
6–7	*Discoaster prepentaradiatus* Bukry and Percival, n. sp. (6) holotype USNM 169195, 55.0-5-5, 126–127 cm; (7) USNM 169196.	129
8–9	*Discoaster variabilis pansus* Bukry and Percival, n. subsp. (8) holotype USNM 169197, 47.2-6-3, 114 cm; (9) USNM 169198.	129
10–12	*Discoasteroides bramlettei* Bukry and Percival, n. sp. (10) 47.2-9-5, 77–78 cm, USNM 169199, electronmicrograph, 2500×; (11) holotype USNM 169200; (12) cross-polarized.	129

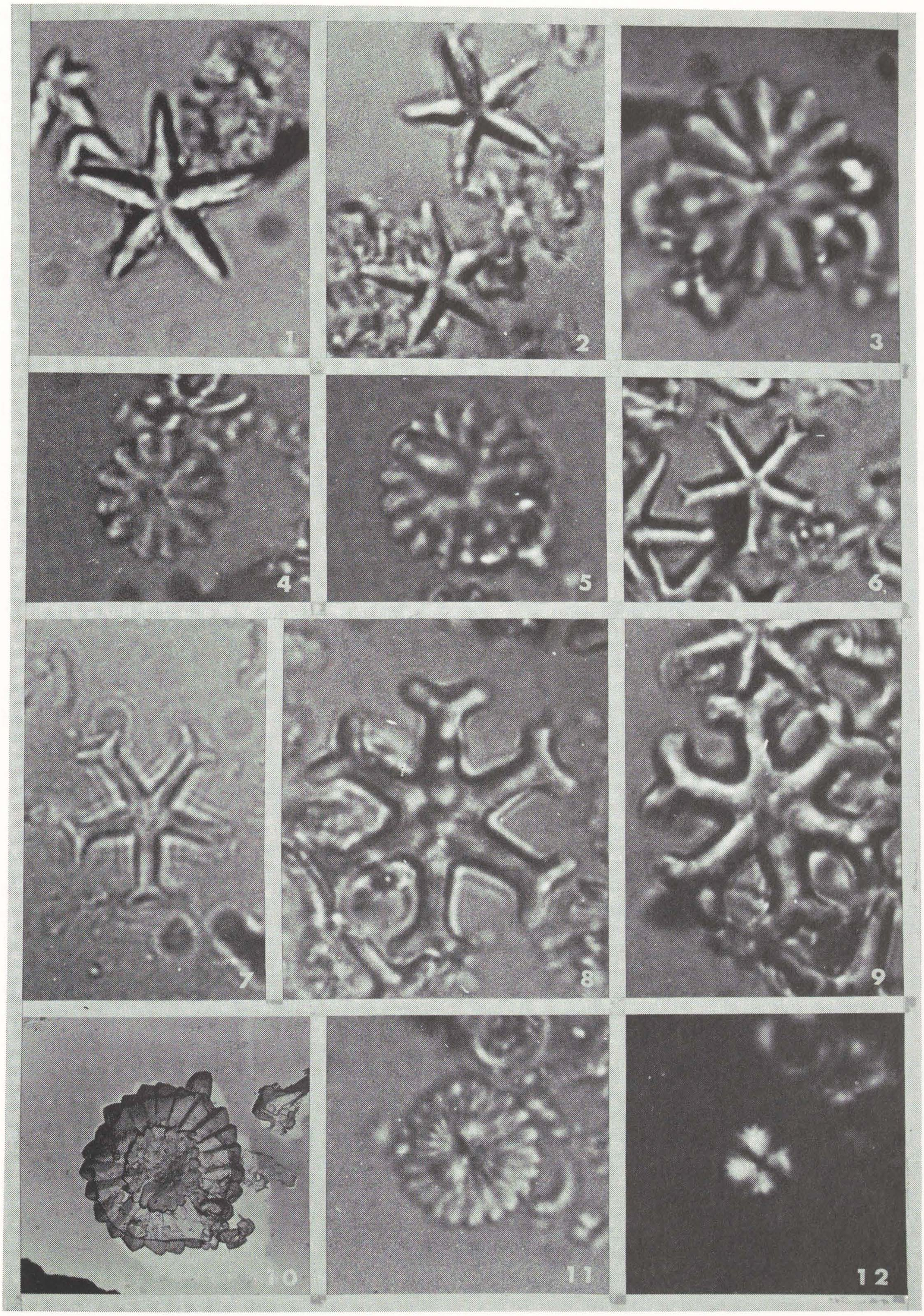

PLATE 3

Reticulofenestra caucasica HAY, MOHLER and WADE, 1966 (*partim*), p. 386, pl. 3, figs. 1–2; pl. 4, figs. 1–2.
Reticulofenestra umbilica (Levin). MARTINI and RITZKOWSKI, 1968, p. 245, pl. 1, figs. 11–12.

Remarks: The most common and long-ranging of the varieties of *Reticulofenestra umbilica* (Levin) has a large central opening occupying from a third to a half of the coccolith length. The central area is surrounded by a bright narrow collar (in cross-polarized light), and well-preserved specimens have a reticulate structure in the central area.

Occurrence: *Reticulofenestra umbilica* apparently developed from a smaller, more circular species, *Reticulofenestra samodurovi* (Hay, Mohler and Wade) during the middle Eocene. The large specimens of *R. umbilica* first occur in upper middle Eocene sediments and persist as an abundant cosmopolitan member of coccolith assemblages into the lower Oligocene.

Genus SCYPHOSPHAERA Lohmann, 1902

SCYPHOSPHAERA EXPANSA
Bukry and Percival, n. sp.
Pl. 6, figs. 10–13

Description: This simple, tall conical-shaped species has thin, high, straight walls that extend from the base at an angle of approximately 100° such that the diameter of the central opening gradually increases from the base to the open top. The exterior of the wall has the regular sculpture typical of *Scyphosphaera* and the wall terminates simply at the open end. The height of the wall is variable from about 18 to 36 microns, whereas the diameter of the base is consistently about 9 microns and the wall-to-base angle is consistently about 100°, so the open end always has a larger diameter than the base.

Remarks: *Scyphosphaera expansa* differs from other species of *Scyphosphaera* by having straight walls that terminate simply and are inclined such that the end is larger than the closed base. The only other species with largely outwardly inclined walls, *Scyphosphaera apsteinii* Lohmann var. *recta* Deflandre and *Scyphosphaera recurvata* Deflandre, have walls that are distinctly curved inward near the top.

Occurrence: *Scyphosphaera expansa* is one of the earliest scyphosphaerids. It is sparsely present in the lower middle Eocene sediment of the Aragon Formation of Mexico.

Size: 18 to 36 microns.

Holotype: USNM 169224 (Pl. 6, figs. 12–13).

Paratypes: USNM 169222 and 169223.

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

SCYPHOSPHAERA GLOBULATA
Bukry and Percival, n. sp.
Pl. 7, figs. 1–6

Description: In profile, this small species has curved walls that rise from a small base

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PLATE 4
Magnification 2000×

Figures		Page
1–3	*Discolithina latoculata* Bukry and Percival, n. sp. (1) holotype USNM 169201, Shubuta Member of Yazoo Clay; (2) cross-polarized, 0° to polarizer; (3) 45° to polarizer.	130
4–6	*Discolithina segmenta* Bukry and Percival, n. sp. (4) holotype USNM 169202, J2, 100 meters; (5) cross-polarized, 45° to polarizer; (6) USNM 169203, 55-7-5, 80 cm, cross-polarized, 0° to polarizer.	130
7–8	*Ellipsolithus lajollaensis* Bukry and Percival, n. sp. (7) holotype USNM 169204, Rose Canyon Shale of Hanna (1926); (8) cross-polarized, 45° to polarizer.	131
9–12	*Fasciculithus magnus* Bukry and Percival, n. sp. (9) holotype USNM 169205, 47.2-10-5, 109–110 cm; (10) cross-polarized; (11) USNM 169206, top view; (12) USNM 169207, surface.	131

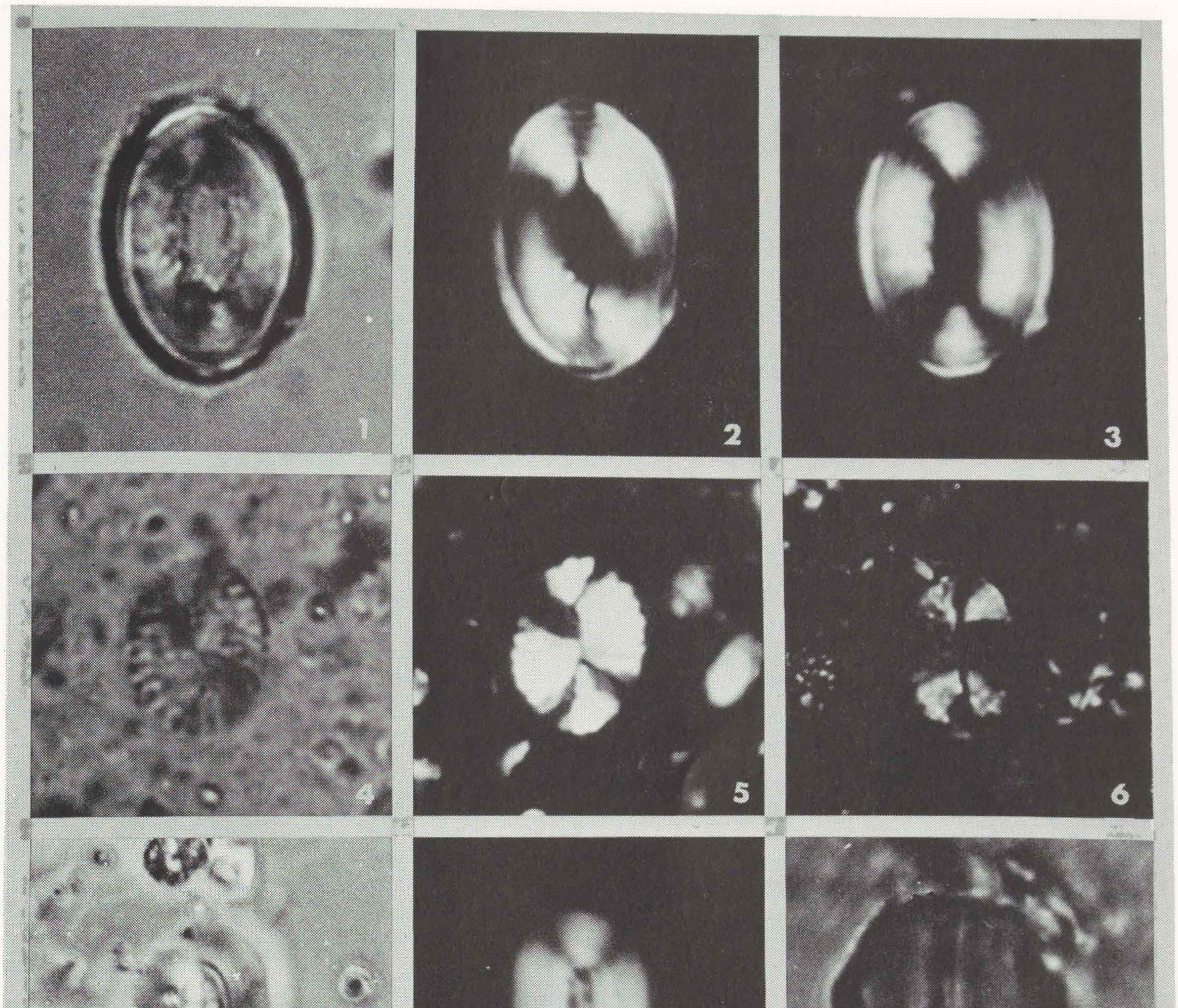

PLATE 4

and almost close at a small apical opening. The profile is almost circular and the surface of the globular form is characterized by longitudinal ribs (10 to 15 visible in side view). As in many species of *Scyphosphaera*, these longitudinal ribs have regularly spaced nodes giving rise to a reticulate appearance with the longitudinal ribs dominant.

Remarks: *Scyphosphaera globulata* is distinguished from other species of *Scyphosphaera* by its almost spherical shape and very small apical opening. The most similar species, *Scyphosphaera apsteinii* Lohmann, is somewhat elliptic in profile and has a much larger apical opening.

Occurrence: This species is most common in warm-water oceanic deposits of late Miocene age but may occur less frequently in early Pliocene deposits.

Size: 10 to 17 microns.

Holotype: USNM 169225 (Pl. 7, figs. 1–2).

Paratypes: USNM 169226 to 169228.

Type locality: Texas A and M core 64-A-9-5E, 150 cm, Gulf of Mexico. Sample from T. E. Pyle.

Genus SPHENOLITHUS Deflandre, 1952

SPHENOLITHUS CAPRICORNUTUS Bukry and Percival, n. sp.

Pl. 6, figs. 4–6

Description: This species has two prominent tapering, diverging spines and a comparatively short base. The lower part of the spines is broad and is separated along the central axis of the sphenolith at a distance above the base that is equivalent to the height of the base.

Remarks: *Sphenolithus capricornutus* is distinguished from *Sphenolithus furcatolithoides* Locker by a greater degree of divergence between the two spines and by divergence at a point much closer to the basal cycle.

Occurrence: *Sphenolithus capricornutus* is commonly present in upper Oligocene to lower Miocene samples from the South Atlantic Ocean (DSDP Leg 3, Site 14).

Size: 6 to 10 microns.

Holotype: USNM 169217 (Pl. 6, figs. 4–5).

Paratype: USNM 169218.

Type locality: DSDP core 14-2-1, 72–73 cm, Mid-Atlantic Ridge, Atlantic Ocean.

SPHENOLITHUS DISSIMILIS Bukry and Percival, n. sp.

Pl. 6, figs. 7–9

Description: This small species is characterized by the three-part arrangement of its apical spine-like crystallites. The basal area of the sphenolith is usually wider than the upper portion. The basal portion, when observed in cross-polarized light, shows two kinds of crystallite orientation: a lower cycle of spines inclined to the central axis of the nannofossil and above it a set of spines arranged perpendicular to the axis (Pl. 6, fig. 7). The upper portion of the sphenolith has a group of appressed spines parallel or subparallel to the central axis. Commonly, about three spines are visible, in side view.

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PLATE 5

Magnification 2000×

Figures		Page
1–2	*Helicopontosphaera granulata* Bukry and Percival, n. sp. (1) holotype USNM 169208, 15-3-2, 78–79 cm; (2) cross-polarized.	132
3–5	*Lophodolithus acutus* Bukry and Percival, n. sp. (3) holotype USNM 169209, type Formación Aragón; (4) cross-polarized; (5) USNM 169210, cross-polarized.	132
6–7	*Lophodolithus rotundus* Bukry and Percival, n. sp. (6) holotype USNM 169211, DWBG-23B, core catcher; (7) cross-polarized.	134
8–11	*Micrantholithus articulatus* Bukry and Percival, n. sp. (8) holotype USNM 169212, Nal'chik-11; (9) cross-polarized; (10) USNM 169213; (11) USNM 169214, cross-polarized.	134

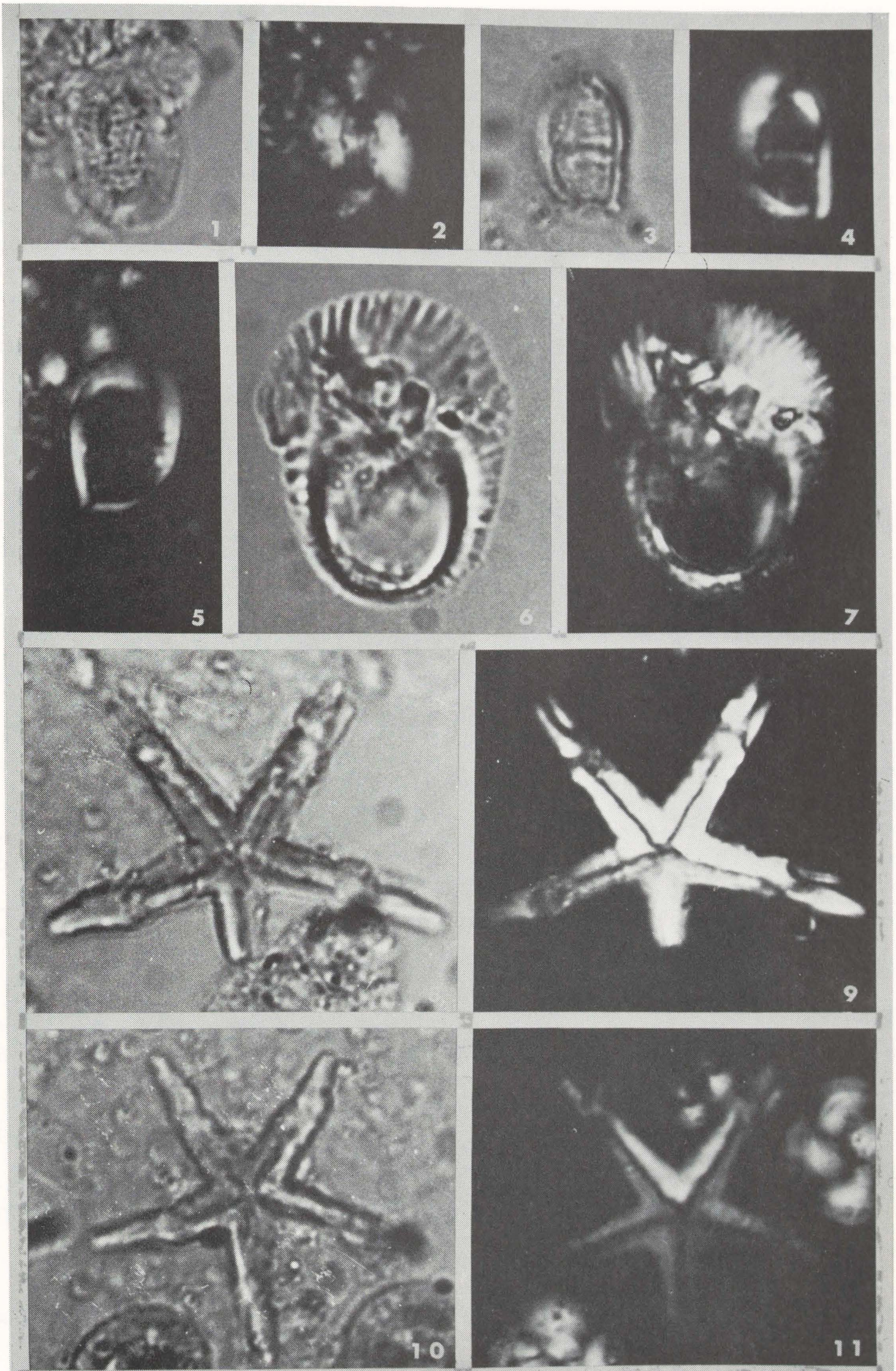

PLATE 5

Remarks: *Sphenolithus dissimilis* is distinguished from the somewhat similar *Sphenolithus abies* Deflandre and *Sphenolithus moriformis* (Brönnimann and Stradner) by having a clearly defined basal and upper portion of about equivalent height and an upper portion that is dominated by about three spines all parallel or subparallel to the central axis.

Occurrence: *Sphenolithus dissimilis* is abundant in late Oligocene and early Miocene marine carbonate ooze from Atlantic Ocean regions: Blake Plateau JOIDES cores, Cipero Formation of Trinidad, DSDP Leg 3 cores; and the northwestern Pacific: DSDP Leg 6 cores.

Size: 5 to 10 microns.

Holotype: USNM 169219 (Pl. 6, fig. 7).

Paratypes: USNM 169220 and 169221.

Type locality: Cipero Formation, Trinidad (T.L.L. 206, 264; Bo. 287), *Catapsydrax dissimilis* Zone of Bolli (1957a).

Genus SYRACOSPHAERA Lohmann, 1902

SYRACOSPHAERA? WECHESENSIS Bukry and Percival, n. sp.
Pl. 7, figs. 7–10

Description: This elliptic, high-walled species has a large elliptic central opening. The inside of the wall has a regularly spaced series of ridges. The ends of these ridges form a cycle of beads at the base of the wall, where there is a narrow inner flange. A narrow indistinct outer flange is sometimes present at the wider end of the wall cycle, but most specimens lack a flange.

Remarks: *Syracosphaera? wechesensis* is distinguished from other similar species such as *Syracosphaera labrosa* Bukry and Bramlette by having a distinctive cycle of wall ridges that appear at the juncture of the wall and small basal flange as a cycle of beads and a well-defined central opening, and by lacking a broad outer rim flange. *Transversopontis pulcher* (Deflandre) has a similar cycle of beads but is distinguished by having a broad crossbar in the central area and a broader inner flange.

Occurrence: *Syracosphaera? wechesensis* is common in certain lower middle Eocene deposits of the Weches Formation at San Augustine, Texas, and from the Caucasus region of the U.S.S.R. This species has not yet been recognized in marine sediment cores.

Size: 10 to 15 microns.

Holotype: USNM 169229 (Pl. 7, figs. 7–8).

Paratype: USNM 169230.

Type locality: Weches Formation, Roberts School, San Augustine, Texas.

GENERA INCERTAE SEDIS

Genus VERMICULITHINA Bukry and Percival, n. gen.

Description: This genus includes calcareous nannofossils that are cylindrical and

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PLATE 6

Magnification 2000×, unless noted otherwise

Figures		Page
1–3	*Reticulofenestra hillae* Bukry and Percival, n. sp. (1) holotype USNM 169215, Shubuta Member of Yazoo Clay; (2) cross-polarized; (3) USNM 169216.	136
4–6	*Sphenolithus capricornutus* Bukry and Percival, n. sp. (4) holotype USNM 169217, 14-2-1, 72–73 cm; (5) cross-polarized, 0° to polarizer; (6) USNM 169218, 14-2-2, 73–74 cm, cross-polarized.	140
7–9	*Sphenolithus dissimilis* Bukry and Percival, n. sp. (7) holotype USNM 169219, Cipero Formation, cross-polarized, 45° to polarizer; (8) USNM 169220, J2, 100 meters, cross-polarized, 45° to polarizer; (9) USNM 169221, Cipero Formation.	140
10–13	*Scyphosphaera expansa* Bukry and Percival, n. sp. (10) USNM 169222, type Formación Aragón, 1000×; (11) USNM 169223, 1000×; (12) holotype USNM 169224, 1000×; (13) cross-polarized.	138

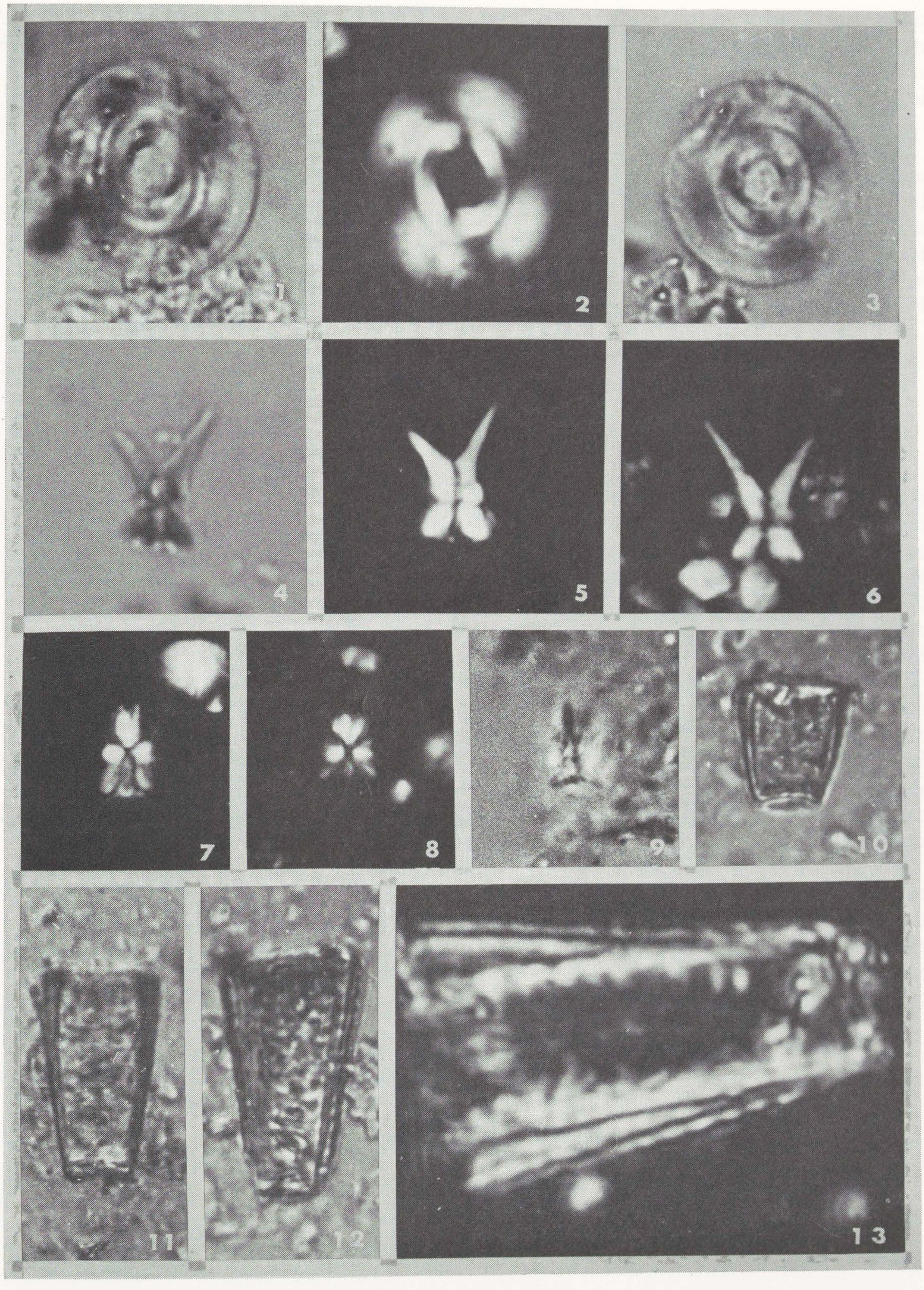

PLATE 6

taper slightly such that the ends are narrower than the middle part. There is a narrow central canal and the curving cylindrical wall is constructed of innumerable crystallites.

Type species: *Vermiculithina arca*, n. sp.

Remarks: Other genera of calcareous nannofossils that may have elongate shapes and be constructed of large numbers of very small elements such as *Thoracosphaera* Kamptner and *Nannoconus* Kamptner are never curved in the distinctive manner of *Vermiculithina.*

VERMICULITHINA ARCA
Bukry and Percival, n. gen., n. sp.
Pl. 7, fig. 11

Description: This species is a large, curved, cylindrical form that tapers towards the two smaller ends of the cylinder. A narrow central canal, occupying a third or less of the cylinder diameter, extends the entire length of the cylinder. The curvature of the cylinder consistently forms a semicircle. Innumerable radially arrayed tiny elements form the structure.

Remarks: The large doubly tapering cylinder in a semicircular shape is unlike any other species or genus of calcareous nannofossil. Though the outward shape and size somewhat resembles a sponge spicule, the complex ultrastructure of *Vermiculithina arca* suggests a fossil nannoplankton origin.

Occurrence: *Vermiculithina arca* is present in small numbers in lower Oligocene nannofossil ooze from the Blake Plateau in the Atlantic Ocean east of Florida (JOIDES core 3).

Size: 50 to 70 microns.

Holotype: USNM 169231 (Pl. 7, fig. 11).

Type locality: JOIDES core 3, 130 meters, Blake Plateau, Atlantic Ocean.

IV. SAMPLES

Pacific Ocean region

- DSDP core 44 (19°19′N., 169°00′W.).
- DSDP core 47.2 (32°27′N., 157°43′E.).
- DSDP core 55.0 (09°18′N., 142°33′E.).
- DSDP core 56.2 (08°22′N., 143°34′E.).
- DSDP core 57.1 (08°41′N., 143°32′E.).
- Scripps core DWBG-23B (16°42′S., 145° 48′W.).
- La Jolla Formation, Rose Canyon Shale Member, La Jolla, California.
- Oamaru Diatomite, Jacksons Paddock, New Zealand.

Atlantic Ocean region

- DSDP core 14 (28°20′S., 20°56′W.).
- DSDP core 15 (30°53′S., 17°59′W.).
- JOIDES core 2 (30°20′N., 80°20′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.).
- Lamont core V3-153 (28°24′N., 77°56′ W.).
- Cipero Formation, Trinidad, T.L.L. 206, 262; Bo. 285 and T.L.L. 206, 264; Bo. 287.
- Navet Formation, Hospital Hill Marl, Trinidad (T.L.L. 238, 622; Bo. 536).

Europe

- Nal'chik Marl, sample 11, Nal'chik, Caucasus, U.S.S.R.

Gulf Coast region

- Texas A and M core 64-A-9-5E (23°50′N., 92°24′W.).

→

PLATE 7

Magnification 2000×, unless noted otherwise

Figures		Page
1–6	*Scyphosphaera globulata* Bukry and Percival, n. sp. (1) holotype USNM 169225, 64-A-9-5E, 180 cm; (2) phase-contrast; (3) USNM 169226; (4) cross-polarized; (5) USNM 169227, 57.1-1-3, 68 cm, cross-polarized, top view; (6) USNM 169228, cross-polarized.	138
7–10	*Syracosphaera? wechesensis* Bukry and Percival, n. sp. (7) holotype USNM 169229, Weches Formation; (8) cross-polarized; (9) USNM 169230, Cook Mountain Formation; (10) cross-polarized.	142
11	*Vermiculithina arca* Bukry and Percival, n. sp., n. gen. (11) holotype USNM 169231, J3, 130 meters, 1000×.	144

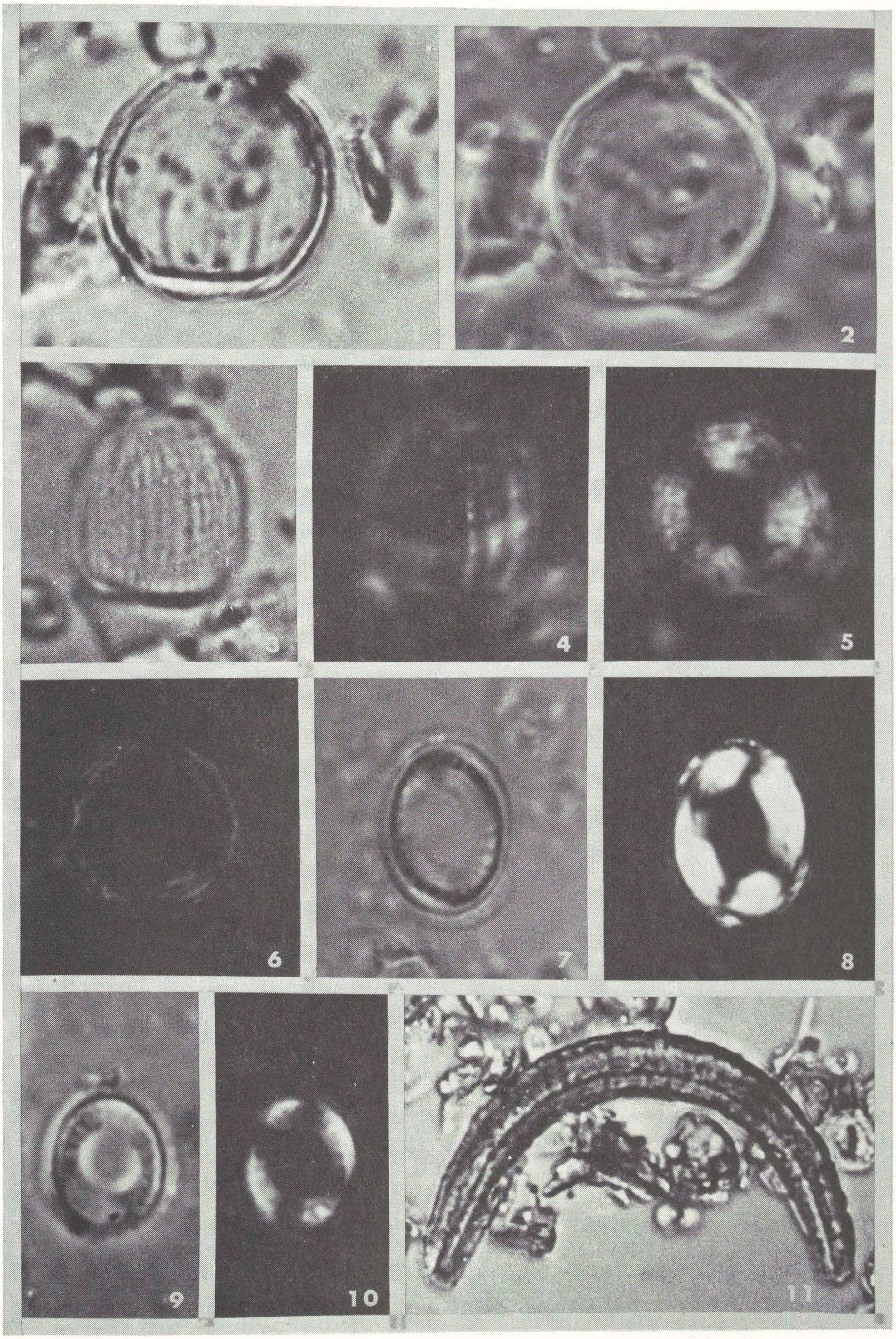

PLATE 7

Cook Mountain Formation, Columbus Landing, Sabine Parish, Louisiana.

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

Red Bluff Clay, Chickasawhay River, Shubuta, Mississippi.

Weches Formation, Roberts School, San Augustine, Texas.

Shubuta Member of Yazoo Clay, Chickasawhay River, Shubuta, Mississippi.

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April 12, 1971

RECENT BOOK

HUNTING FOR DINOSAURS, by Zofia Kielan-Jaworowska, translated from the Polish by the Israel Translation Society. Published by The MIT Press, Cambridge, Massachusetts, and London, England, 1970, xiv + 177 pp., illus., $7.95

This book describes the adventures of the woman leader of three paleontological expeditions organized by the Warsaw Academy of Sciences to collect fossil dinosaurs in the Gobi Desert. The text is entertaining, informative, and reveals the hardships that confront the field paleontologist even in these times. It is well illustrated by numerous and excellent photographs.