# 8. PALEOGENE AND UPPER CRETACEOUS CALCAREOUS NANNOFOSSILS FROM DEEP SEA DRILLING PROJECT LEG 74[1]

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**ABSTRACT**

Calcareous nannofossils were obtained from all sites. Lower Maestrichtian through Pleistocene assemblages characteristic of temperate water masses were recognized.

The Cretaceous/Tertiary boundary was identified in four continuous sequences, well characterized by nannofossil biotas typical of middle latitudes.

"*Braarudosphaera* chalk" was recovered only in the Oligocene interval at the shallowest site of the transect.

Preservation of nannofossils varies as a function of the paleobathymetry of the sites and reflects the degree of diagenesis in the sediments; it is generally poorer near hiatuses.

## INTRODUCTION

Five sites, 525–529, were drilled during Leg 74, closely spaced in a transect approximately 230 km long on the Walvis Ridge, about 800 km off the coast of Africa (Fig. 1), and covering a depth range of over 3 km. Calcareous nannofossils obtained in the five sites represent a complete mid-latitude record from the lower Maestrichtian through the upper Oligocene. The biostratigraphic ages and zonal assignments of the cores (Table 1) are based on light microscope observations and scanning microscopic studies of the best samples. The zonal schemes used are those of Martini (1971) for the Tertiary and Thierstein (1976) for the Upper Cretaceous. Continuous sequences across the Cretaceous/Tertiary boundary were studied in four sites with the scanning electron microscope. Basaltic basement was reached at three sites (525 to 528) and could be dated by nannofossils recovered from fossiliferous sediments within the basement. Nannofossils are generally moderately well preserved, though substantial volcanic material was added to sediments below the Cretaceous/Tertiary boundary at all sites and into the Paleocene at Site 525. Generally, in all sites, preservation of nannofossils corresponds to the paleobathymetry of the sites, with an episode of poorer preservation in middle Eocene sediments.

Nannofossils considered in this report are listed in an Appendix to this chapter.

## SITE SUMMARIES

### Site 525

Site 525 (29°04.24′S, 02°59.12′E; 2467 m water depth), drilled on the western section of the Walvis Ridge, is the shoalest site of a transect into the Angola Basin. The three holes drilled recovered a stratigraphically complete carbonate section consisting of 574 m of sediment and 103 m of basaltic basement rocks.

Sediments from Holes 525A and 525B contain abundant nannofossils; their preservation fluctuates from moderate to poor as a consequence of dissolution.

### Hole 525A

Hole 525A was drilled to 678.1 m BSF. Basalt was encountered in Core 53 at a depth of 574.6 m. The oldest sediments above and sandwiched within the basalt are early Maestrichtian. An apparently continuous Cretaceous/Tertiary boundary was recovered in Core 40. A major hiatus from upper Oligocene to middle Eocene was observed in Core 19, but a complete middle Eocene through Maestrichtian section was recovered below.

#### *Miocene–Oligocene (260.1 m)*

Core 525A-17 contains an assemblage characteristic of the transition from the Miocene to the Oligocene, with abundant *Cyclicargolithus floridanus* and *Discoaster* cf. *D. deflandrei* and very rare *Dictyococcites bisectus,* without *Sphenolithus ciperoensis.*

#### *Oligocene (267.6–278.21 m)*

Samples 525A-17,CC to 525A-19-6, 111 cm, contain typical *Sphenolithus ciperoensis* and are assigned to *S. ciperoensis* Zone (NP25). Very rare *S. distentus, S. predistentus* (forms with strong overgrowth), and *Reticulofenestra umbilica,* found in Samples 525A-18,CC and 525A-19-6, 111 cm, were possibly reworked from lower Oligocene and upper Eocene sediments. A hiatus immediately below this interval supports this conclusion.

#### *Eocene (278.9–371.35 m)*

A hiatus occurs between 525A-19-6, 111 cm and 525A-19-7, 20 cm (277.11–278.90 m). The entire lower Oligocene and upper Eocene (roughly 14 m.y.) are missing at this site.

An upper middle Eocene assemblage was recognized in the interval from 525A-19-7, 20 cm to 525A-20-3,

[1] Moore, T. C., Jr., Rabinowitz, P. D., et al., *Init. Repts. DSDP,* 74: Washington (U.S. Govt. Printing Office).

Table 1. Zone and geologic age assignments of Leg 74, based on calcareous nannofossils.

| m.y. | Age | | Boundary Species for Leg 74 | Zones used in Leg 74 | Standard Zonation (Martini, 1971) |
|---|---|---|---|---|---|
| | | late | *Sphenolithus ciperoensis* *Helicosphaera recta* | *Triquetrorhabdus carinatus* | NN1 |
| 25 | | | *Sphenolithus distentus* | *Sphenolithus ciperoensis* | NP25 |
| 30 | Oligocene | middle | | *S. distentus* | NP24 |
| | | | *S. ciperoensis* | *S. predistentus* | NP23 |
| | | | *Reticulofenestra umbilica* | | |
| 35 | | early | *Cyclococcolithus formosus* | *Helicosphaera reticulata* | NP22 |
| | | | *Discoaster saipanensis* *D. barbadiensis* | *Ericsonia subdisticha* | NP21 |
| 40 | | late | *S. pseudoradians* | *S. pseudoradians* | NP20 |
| | | | *Ismolithus recurvus* | *Ismolithus recurvus* | NP19 |
| | | middle | *Chiasmolithus oamaruensis* | *Chiasmolithus oamarunsis* | NP18 |
| 45 | Eocene | | *R. umbilica* | *Reticulofenestra umbilica* | NP17 |
| | | | *C. gigas* | *Nannotetrina fulgens* | NP16 |
| | | | *Nannotetrina fulgens* | | NP15 |
| | | early | *D. sublodoensis* | *Discoaster sublodoensis* | NP14 |
| 50 | | | *Tribrachiatus orthostylus* | *D. lodoensis* | NP13 |
| | | | *D. lodoensis* | *Tribrachiatus orthostylus* | NP12 |
| | | | | *D. binodosus* | NP11 |
| | | | *T. contortus* | *T. contortus* | NP10 |
| | | late | *Campylosphaera dela* | *D. multiradiatus* | NP9 |
| 55 | | | *D. multiradiatus* | *Heliolithus riedeli* | NP8 |
| | | middle | *Heliolithus riedeli* | *D. mohleri* | NP7 |
| | Paleocene | | *D. mohleri* | *H. kleinpellii* | NP6 |
| | | | *H. kleinpellii* | *Fasciculithus tympaniformis* | NP5 |
| | | | *Fasciculithus tympaniformis* | | |
| | | early | *Neocrepidolithus perfectus* | *Ellipsolithus macellus* | NP4 |
| | | | *Ellipsolithus macellus* | | |
| 62 | | late | *Prinsius martinii* | *Chiasmolithus danicus* | NP3 |
| | | | *Cruciplacolithus notus* | | |
| | Danian | | *Chiasmolithus* cf. *danicus* | | |
| | | early | *Cruciplacolithus edwardsii* | *Cruciplacolithus tenuis* | NP2 |
| | | | *P. dimorphosum* | | |
| 65 | | | *C. primus* | *C. primus* • *Biantholithus sparsus* | NP1 |
| | | | *Biantholithus sparsus* | Transitional interval C/T Boundary | C/T |
| 66 | | late | *Micula prinsii* | *Micula prinsii* | *M. murus* |
| | | | *M. murus* | *M. murus* | |
| | Maestrichtian | middle | *Nephrolithus frequens* | | |
| | | | *Lithraphidites quadratus* | *Lithraphidites quadratus* | *L. quadratus* |
| 70 | | | *Tetralithus trifidus* *L. quadratus* | *Arkhangelskiella cymbiformis* | *A. cymbiformis* |
| 72 | | early | *Reinhardites levis* | *Quadrum trifidum* | *Quadrum trifidum* |
| | Campanian | late | *Quadrum trifidum* | | |
| | | | *T. gothicus* | | |

Table 1. (Continued.)

| Hole (core-section, level in cm) | | | | | | | |
|---|---|---|---|---|---|---|---|
| 525A | 525B | 526A | 526C | 527 | 528 | 528A | 529 |
| 13-5/17-2 | | 22-2/30,CC | | | 4-5/6,CC | | 9-16/13-4 |
| 17,CC/19-6 | | 31-3/32,CC | | | 7-1/7,CC | 28-1/30-1 | 13-5/15-5 |
| | 50-1 | 33-2 | | | 8-1, 45 | | 15-6 |
| | | 35,CC | | | | 30,CC | |
| | | 36,CC | | | | | |
| | 51,CC | 37,CC | | | 8,CC | | |
| | | 38,CC/42-1, 20 | 4,CC | | 9-1/10-4 | | 18-3 |
| | | | 5,CC/6-1, 20 | 14-7/14,CC | 11-2/11,CC | | 18-4/20-3 |
| | | | 6-1, 30 | | 12-2/12,CC | | 20-4/22-1, 128 |
| | | 42-1, 50 | 6-1, 50 | 15-2 | 13-1, 17 | | 22-1, 130/23-3 |
| | | 43,CC | 8,CC | | 14-1 | | 23-4/24-1 |
| | | 44,CC | 9,CC | | 14-2, 40 | | 24-3, 120 |
| | | 45,CC/46,CC | | | | | 24-3, 125 |
| 19-7 | | | 14,CC | | 14-2, 85/15-1 | | 24-4, 40 |
| 20-3 | 52,CC | | | 15,CC | | | 24-5, 45 |
| 20-5/21-2<br>21-4 | 53,CC | | | 16-2/17-3 | 15,CC/16-1 | | 24,CC |
| 22,CC | | | | 17-5/18-1 | | | |
| 23-3/25-5 | | | | 18-4 | 16-2/17-4 | | |
| 25,CC/26,CC | | | | 18,CC | 17,CC/19-2 | | 26-1, top/27-1, 80 |
| 27,CC | | | | | 19-3/20,CC | | |
| 28-1/30-5 | | | | 19-2/21,CC | 21-3/21-6, top | | 27-1, 150/29-7 |
| 30,CC/39,CC | | | 15,CC/17,CC | 22,CC/26-2 | 21,CC/22-1 | | 29-2, 30/31-1 |
| 35-2/35-5 | | | | | 22-2/24-2 | | |
| | | | 18,CC | 26-3/27-3 | | | 31-1, 90/36-1, top |
| 35,CC/36-3 | | | | | 24-3/25-5 | | |
| 36,CC | | | 20,CC | 27,CC | | | 34-4, 40/34,CC |
| 37-1/37,CC | | | | 28-7/28-6 | | | 35-1, top/35,CC |
| 38-2, 40 | | | | 28,CC/29-3, 28 | 26-1/29-2 | | 36-1/37,CC |
| | | | | | | | 38-1, 44 |
| 38-3, 72 | | | | 29,CC | 29-2, 125 | | |
| 39-2, 28 | | | | 30-2, 53 | 29,CC | | 39,CC |
| 39-3, 28 | | | | 30,CC | 30-2, 100 | | 40-3, 84 |
| 39-4, 120 | | | | 31-4, 88 | 30-3, 70 | | 41-1, 42 |
| 39-5, 20 | | | | 31-5, 40 | 30-4, 28 | | 41-2, 85 |
| 39-6, 20 | | | | 31-6, 100 | 31-2, 60 | | 41-3, 129 |
| 39-6, 120 | | | | 31,CC | 31-4, 149 | | 41-4, 47 |
| 39-7, 54 | | | | 32-2, 150 | 31-5, 150 | | 41-6, 13 |
| 40-2, 7 | | | | 32-4, 40 | 31,CC | | 41-6, 129 |
| 40-2, 15/40-2, 22 | | | | 32-4, 42/32-4, 60 | 32-1, top | | 41-6, 130 |
| 40-2, 120 | | | | 32-4, 90 | 32-1, 98 | | 41,CC |
| 41-4, 103<br>41-5, 90 | | | | 32-5, 90/34-4, 27 | 32-1, top/33-5, 44 | | 41-6, 130/43,CC |
| 41-6, 90/43-2, 60 | | | | 34-6, 20/38-3, 45 | 33,CC/37-6, 50 | | |
| 43-3, 60/46,CC | | | | 38-4, 45/42-1, 61 | 38-2, 80/46-1, 113 | | |
| 47-4, 84 | | | | | | | |
| 51,CC/60-7, 3 | | | | | | | |

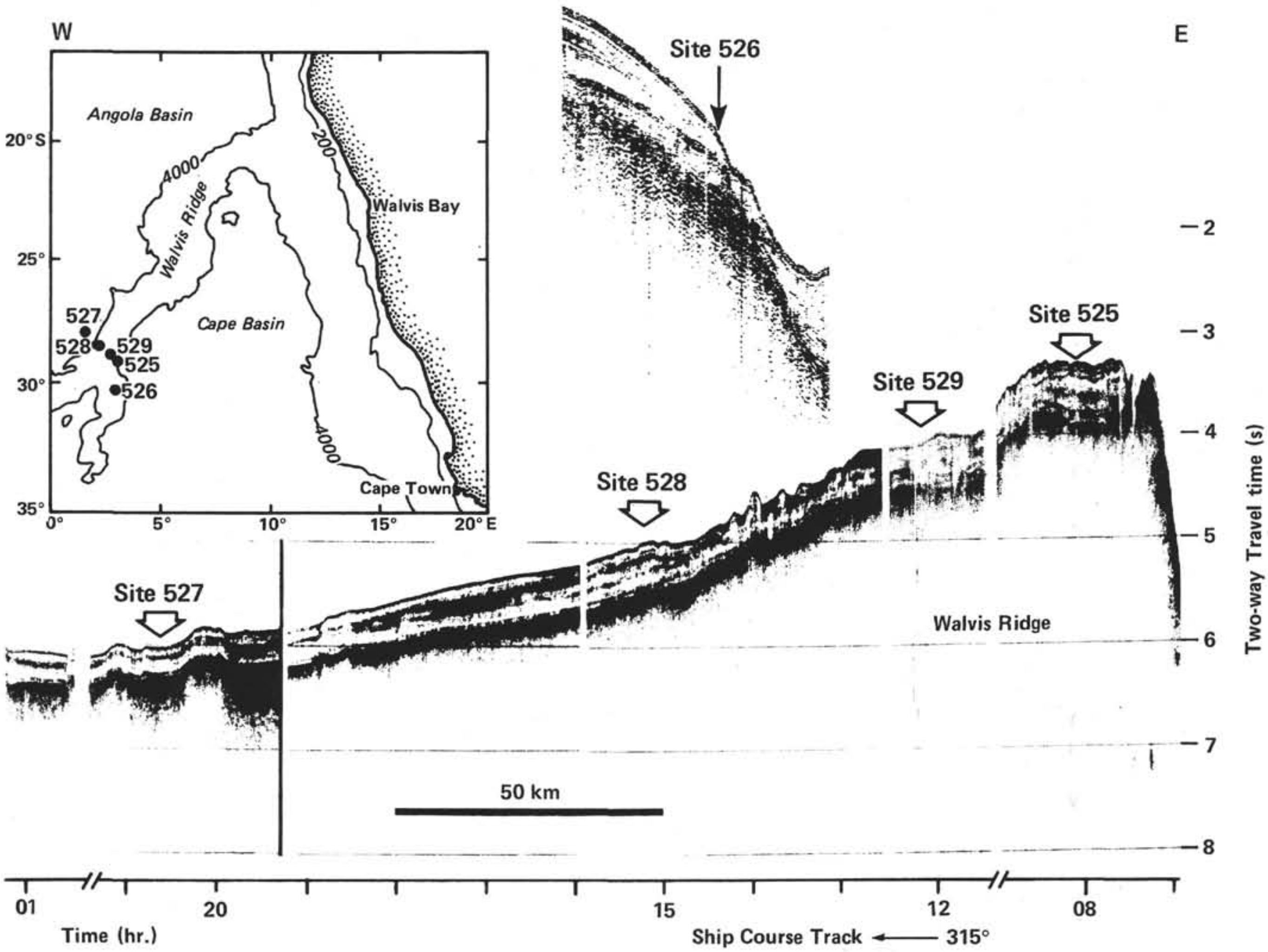


Figure 1. Location of Leg 74 sites.

50–51 cm. *Reticulofenestra umbilica, S. pseudoradians, Discoaster saipanensis, Bramletteius serraculoides, Triquetrorhabdulus inversus, D. barbadiensis,* and *Cyclococcolithus formosus* were all found in this interval. This assemblage indicates the *D. saipanensis* (NP17) to *D. tani nodifer* (NP16) zonal interval. From 525A-20-5, 135 cm to 525A-21-2, 105 cm, samples contain rare *Chiphragmalithus fulgens* without *R. umbilica,* characteristic of the *C. fulgens* Zone (NP15). Sample 525A-21-4, 50 cm and 525A-22,CC contain *D. lodoensis, D. sublodoensis, D. barbadiensis, T. inversus,* and *Zygrhablithus bijugatus* (short form), which suggest the presence of the *D. sublodoensis* Zone (NP14), or part of the *C. fulgens* Zone (NP15). *D. diastypus, D. multiradiatus,* and *Chiasmolithus consuetus,* which indicate basal Eocene (NP10 to NP11), are found between 525A-27,CC and 525A-30-5.

### Eocene

*Tribrachiatus orthostylus* was first encountered in Sample 525A-25,CC, in a well-diversified flora, with many giant specimens. The entire interval from 525A-27,CC to 525A-30-5, 75 cm contains an assemblage composed of *T. orthoslylus, Discoaster dinodosus, D. diastypus, D. multiradiatus,* and *Chiasmolithus consuetus,* which indicate basal Eocene (NP11 to NP12).

### Paleocene (374.1–451.71 m)

Coccoliths and discoasters from the Paleocene sequence of Hole 525A are few to abundant and are poorly to moderately preserved. Samples 525A-30,CC through 525A-34,CC contain common *Discoaster multiradiatus,* which is an index species of Zone NP9. Other important species found in this interval are *Toweius eminens, T. craticulus, Chiasmolithus bidens, D. lenticularis,* and *D. mohleri.* The absence of *D. multiradiatus* and the presence of *Heliolithus* cf. *H. riedeli* place Samples 525A-35,CC and 525A-36-3, 100–101 cm in either the *D. mohleri* Zone (NP7) or the *H. riedeli* Zone (NP8). The co-occurrence of *D. mohleri* and *H. kleinpellii* assigns Sample 525A-36,CC to the *D. mohleri* Zone (NP7). In Samples 525A-37-1, 100 cm and 525A-37,CC, *Discoaster mohleri* is absent, and the assemblage is dominated by *T. eminens, Sphenolithus moriformis, Ericsonia cava* and *Cyclococcolithus robustus.* The rare presence of *H. kleinpellii,* however, in the core-catcher sample indicates the presence of the *H. kleinpellii* Zone. In Sample 525A-38-2, 40 cm (433 m) a poorly preserved assemblage of calcareous nannofossils is dominated by common *C. tenuis, T. eminens,* and *Fasciculithus tympaniformis,* which place this core in Zone NP5. Samples 525A-38-3, 72 cm through 525A-39-2, 28 cm (434.82–442.38 m) are assigned to Zone NP4 on the basis of the common occurrence of *Ellipsolithus macellus, Prinsius bisulcus,* and *Neochiastozygus perfectus.* In the interval from 525A-39-3, 28 cm through 525A-39-5, 20 cm, *P. martinii, Cruciplacolithus notus,* frequent *E. cava* and *Chiasmolithus* cf. *C. danicus* indicate presence of the NP3 zone. Sample 525A-39-6, 20 cm (448.30 m), contains *Cruciplacolithus edwardsii* and *N. modestus,* and in Sample 525A-39-6, 120 cm *P. tenuiculum* also occurs. This assemblage represents Zone NP2 of the early Danian. The first small *C. primus* are found in Sample 525A-39-7, 54 cm (450.4 m) with frequent *Placozygus sigmoides* and *Thoracosphaera* sp. The small taxon *Toweius petalosus* is absent in all samples from Leg 74. The assemblage in Samples 525A-39-7, 54 cm belongs to upper part of NP1. Samples 525A-40-2, 11.5 (pale green), 525A-40-2, 15 cm (light brown) and 525A-40-2, 17 cm (pale brown), however, contain a curious assemblage. Nannofossil preservation is extremely poor, and most species are fragmented. Rare *Markalius astroporus* are found mixed with rare to common Cretaceous species in this interval. Many calcite particles in these slides look like isolated elements of *Braarudosphaera bigelowi,* although very rare complete specimens of *B. bigelowi* were observed. Thus a transitional interval exists between the basal Danian and the Cretaceous/Tertiary boundary (Fig. 2), that is, between 525A-40-2, 11 cm and 525A-40-2, 22 (451.71–451.82 m). The Cretaceous/Tertiary contact itself in this hole should be placed between 525A-40-2, 11 cm and 525A-40-2, 11.5 cm, corresponding to a minor lithological color change.

### *Maestrichtian (451.82–516.6 m)*

Samples 525A-40-2, 22 cm (451.82 m) and 525A-40-2, 67 cm to 525A-41-3, 60 cm are assigned to the *Micula murus* zone of the uppermost Cretaceous. These samples contain an abundant and poorly preserved Cretaceous nannofossil assemblage. *Arkhangelskiella cymbiformis, Micula staurophora, Cylindralithus gallicus,* and *Lithraphidites quadratus* are common, but *Micula murus, Thoracosphaera* spp., *Markalius astroporus,* and *Placozygus sigmoides* are rare in these samples. *Micula prinsii* was found at 525A-40-2, 120 cm. The presence of *M. murus* indicates that this interval belongs to the *M. murus* Zone of the upper Maestrichtian. There appears to be no stratigraphic discontinuity across the Cretaceous/Tertiary boundary in Hole 525A.

Samples 525A-41-4, 103 cm and 525A-41-5, 90 cm (466.50 m) contain rare *Nephrolithus frequens* and *M. praemurus* without *M. murus.* They probably belong to Perch-Nielsen's (1977) *N. frequens* Zone. Samples 525A-41-6, 90 cm (468 m) through 525A-43-2, 60 cm (482.70 m) contain *L. quadratus* without *N. frequens* and are attributed to the *L. quadratus* Zone. *The A. cymbiformis* zone is indicated in Samples 525A-43-3,

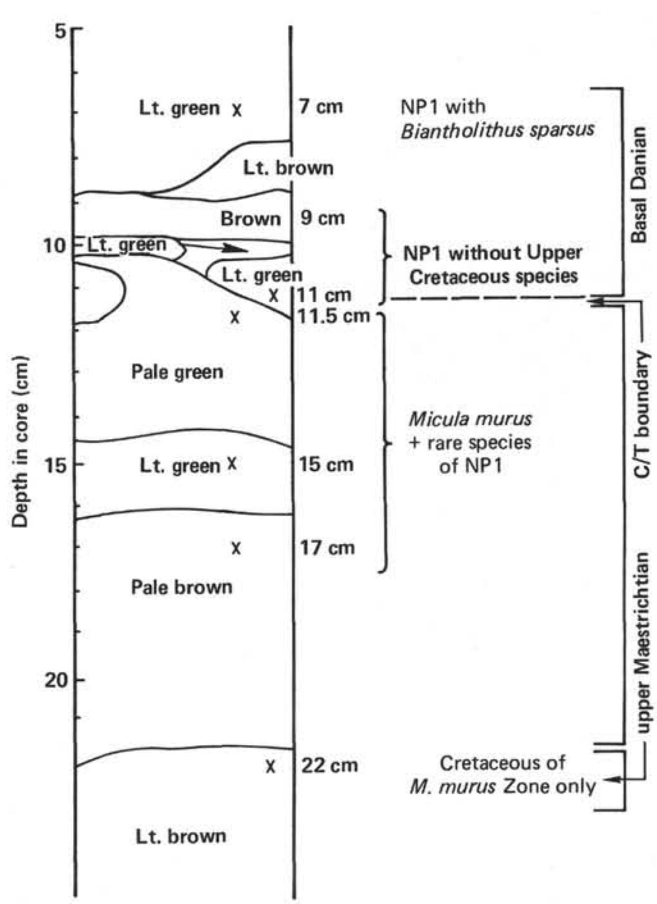


Figure 2. Cretaceous/Tertiary boundary at Hole 525A. (x indicates location of sample.)

60 cm, 525A-44,CC and 525A-46-6, 105 cm (482.20–515.65 m). The top of this zone is defined by the first occurrence of *L. quadratus* and the base by the last occurrence of *Quadrum trifidum.*

In Sample 525-46,CC (516.6 m) *Broinsonia parca* and *Reinhardites levis* appear. This sample does not contain *Q. trifidum* and therefore belongs to the lower part of the *A. cymbiformis* Zone.

### *Maestrichtian–Campanian (521.94–574.50 m)*

Samples 525A-47-4, 84 cm (521.9 m) through 525A-52,CC are within the *Quadrum trifidum* zone because *Q. trifidum* occurs consistently although in low abundances. Basalt was encountered in Section 1 of Core 53. The two layers of sediments sandwiched within the basalts in Samples 525A-58,CC and 525A-60,CC still belong to the *Q. trifidum* zone. Because the Maestrichtian/Campanian boundary is within the *Q. trifidum* Zone, it is difficult to decide if the basal sediments of this site reach the upper Campanian or are still within the lower Maestrichtian.

## Hole 525B

Nannofossils are present in all cores of the HPC-drilled Hole 525B, and their preservation is, in general, moderate. Discoasters, however, show strong overgrowth from 525B-31,CC downward.

### *Eocene/Oligocene Hiatus (276.8–281.2 m)*

The Eocene/Oligocene hiatus was encountered in this hole between Samples 525B-51,CC and 525B-52,CC. The calcareous nannofossil assemblages from immediately above and below the contact indicate an age for the hiatus different from the assemblages found in Hole 525A. Samples 525B-50, top, and 525B-51,CC contain *Sphenolithus distentus, S. predistentus, S. pseudoradians, Dictyococcites bisectus*, and *Cyclicargolithus floridanus*, which suggest the *S. predistentus* Zone (NP23) of the upper to middle Oligocene. Three samples from the core above, 525B-50-1, 50 cm, 525B-50-1, 70 cm and 525B-50,CC, contain a lower Oligocene assemblage, including *Reticulofenestra umbilica, Cyclococcolithus formosus, Discoaster* cf. *D. tani, Bramletteius serraculoides, Hayella situliformis, S. pseudoradians*, and *Dictyococcites bisectus*. Because no *Discoaster saipanensis* and *D. barbadiensis* were found in these samples, they are assigned to the *Helicosphaera reticulata* (NP22) or to the *Ericsonia? subdisticha* (NP21) zonal interval of the lower Oligocene. Obviously, these lower Oligocene sediments are reworked into an upper Oligocene horizon.

Core 525B-52 contains *Reticulofenestra umbilica, Cyclococcolithus formosus, Triquetrorhabdulus inversus, Discoaster saipanensis, D. barbadiensis*, and *Sphenolithus radians*. The assemblage suggests the *D. tani nodifer* Zone (NP16) of the middle Eocene. In Sample 525B-53,CC, there is a substantial change in the nannoplankton assemblage. Large specimens of *R. umbilica* have disappeared, and common *Chiphragmalithus fulgens* and *C. cristatus* appear. The lowest core-catcher sample of Hole 525B, therefore, reaches the *C. fulgens* Zone (NP15) of the middle Eocene.

## Site 526

Site 526 (30°07.36′S, 3°08.28′E; water depth 1054 m), near the crest of block to the southwest of the Walvis Ridge, is the shallowest site drilled in the transect.

### Hole 526A

The sedimentary section contains carbonate-rich oozes and shallow-water calcareous sands with abundant and well-preserved calcareous fossils in the oozes. Winnowing of the deposits by bottom currents has, however, apparently removed much of the finer grained material, and the nannofossils are well to moderately well preserved throughout the Neogene and the upper Oligocene.

Preservation is only moderate throughout the remainder of the Oligocene and poor in the upper and middle Eocene; below this level, nannofossils are reduced in diversity and poorly preserved.

Two hiatuses are recognizable, one in the earliest Oligocene and a another one from the middle Eocene to the late Paleocene. The temperate-water nannofossil assemblages resemble those of the other sites of Leg 74, except for the upper Oligocene where abundant *Chiasmolithus altus*, a high-latitude species, occur.

### *Oligocene (160.0–208.6 m)*

The transition between the lower Miocene and the upper Oligocene is observed in Sample 526A-29,CC (151.2–155.6 m) where very rare *Dictyococcites bisectus* are present, but the first Oligocene Zone NP25 is found in Sample 526A-30,CC (160.0 m), which contains *D. bisectus* and *Zygrhablithus bijugatus. Sphenolithus ciperoensis*, marker of NP25, was first encountered in 526A-31-3. Core 526A-31 to Section 526A-33-2 belong to the upper Oligocene, whereas Core 526A-33 to Sample 526A-35,CC (168.8–182.0 m) are considered to belong to Zone NP25 of the upper Oligocene because *S. distentus* appears. The base of Zone NP24, either in 526A-36,CC or 526A-37,CC (182.0–190.8 m) is difficult to determine because of the scarcity of *S. ciperoensis* in this interval.

Zone NP23 can be traced down to Sample 526A-42-1, 20–21 cm. Early Oligocene Zones NP22 and NP21 are missing. The Oligocene interval in Hole 526A contains unusual nannofossil assemblages which were not encountered at other sites during this leg. First, *Chiasmolithus altus*, a high-latitude species, commonly occurs at this site and ranges up to the upper part of Zone NP25. Second, in Zone NP24 (cores 526A-33 and 526A-34; 168.8–177.6 m), abundant *Braarudosphaera* cf. *bigelowii* were found. This, species occurs sporadically downhole throughout the middle Oligocene, in lesser abundance.

These "*Braarudosphaera* chalks" are a typical feature in South Atlantic upper Oligocene sediments. The significance of the presence of *Braarudosphaera* in various amounts has been discussed by Roth (1974) and Takayama (1972). The braarudosphaerids are able to persist in lower salinities than other genera and appear to prefer hemipelagic environments. The possibility that the thin *Braarudosphaera* acme intervals found at deeper sites might have been due to sediment transport from hemipelagic regions cannot be excluded.

In Hole 526A, the earliest Oligocene is missing.

### *Eocene (208.9–228.8 m)*

Samples 526A-42-1, 52–53 cm and 526A-42-1, 75 cm are assigned to Zone NP20 of the upper Eocene on the basis of the rare occurrence of *Discoaster saipanensis* (mostly with six arms). Cores 526A-42 and 526A-43 definitely belong to Zone NP20 because they contain common *D. barbadiensis, D. saipanensis*, and *Sphenolithus pseudoradians*. The rare occurrence of *Isthmolithus recurvus* limits the age of Sample 526A-44,CC (217.2–221.6 m) to not older than Zone NP19. The rare occurrence of *Chiasmolithus oamaruensis* in Samples 526A-45,CC and 526A-46,CC (226–228.8 m) indicates an age not older than Zone NP18 (late Eocene). However, it is worth mentioning that rare *S. pseudoradians* were still found in Samples 526A-44,CC through 526A-46,CC. Tentatively they are considered to be contaminants, because the recovered sediments were rather soupy.

### Hole 526C

*Oligocene (194.5–213.7 m)*

In the third hole, 526C, lower Pliocene and upper Miocene sections were recovered above Oligocene sediments in Core 526C-4 (194.5 m). These contain common *Cyclicargolithus floridanus, Dictyococcites bisectus, Chiasmolithus altus, Sphenolithus predistentus*, and *Zygrhablithus bijugatus*, together with rare *Helicosphaera compacta*. This assemblage belongs to Zone NP23. Core 526C-5 is assigned to Zone NP22 of the lower Oligocene, based on the presence of *Reticulofenestra umbilica*. Zone NP22 can be traced down to Sample 526C-6-1, 20–21 cm, where it is underlain by upper Eocene sediments.

*Eocene (213.8–289.5 m)*

Samples 526C-6-1, 30–31 cm and 526C-6-1, 50–51 cm are tentatively assigned to Zone NP20 of the upper Eocene because they contain rare *Discoaster saipanensis*. Cores 526C-6 through 526C-8 (218.0–232.5 m) are also considered to belong to the same zone because, beside common *D. barbadiensis* and *D. saipanensis*, the core-catcher samples contain *Chiasmolithus oamaruensis, Isthmolithus recurvus* and *Sphenolithus pseudoradians*.

Below Core 526C-9, all the sediments recovered are coarse sands. The calcareous nannofossils extracted from the matrix are very rare and very poorly preserved. Some *S. moriformis, Coccolithus pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Discoaster barbadiensis* and *Reticulofenestra umbilica* were found sporadically in Cores 526C-9 through 526C-14. These assemblages roughly indicate an upper Eocene age. In Core 526C-14 (280–289.5 m) very rare *D. multiradiatus*, an upper Paleocene nannofossil, were found.

The lithology does not change much between Cores 526C-14 and 526C-15; however, the color of the sediments changes significantly. This change also corresponds to a sharp floral change. The fine fractions extracted from Cores 526C-15 through 526C-20 yield some poorly preserved *Toweius eminens, T. craticulus, Coccolithus pelagicus* and *Cyclicoccolithus* cf. *robustus*, which are typical of the upper Paleocene. Cores 526C-15 and 526C-17 belong to NP9 of the upper Paleocene, based on the presence of *D. multiradiatus*. Sample 526C-19,CC (327.5–337 m) contains very rare *D. mohleri*, a species not older than Zone NP7. Therefore it is possible that all the coarse sands recovered from Cores 15 through 20 belong to the upper Paleocene.

### Site 527

Site 527 (28°02.49′S, 01°45.80′E ; 4428 m water depth), is at the base of the western slope of a NNW–SSE trending block of the Walvis Ridge and is the deepest site of a transect across the Walvis Ridge into the Angola Basin. One rotary-drilled hole gives a complete section from the seafloor down through the upper 43 m of the basement. A depositional hiatus was encountered between Cores 527-13 and 527-14, where the sediments are dominated by clay. Lower middle Miocene through upper Oligocene sediments are missing. This mid-Tertiary hiatus is spanned by an interval of increased dissolution. The Cretaceous/Tertiary boundary was recovered in Core 527-32. Though there is a minor lithological change at this contact, the sequence is paleontologically continuous. Basalt was encountered at the base of Core 38.

*Preservation*

Except for the pure red clay intervals, coccoliths and discoasters at Site 527 are generally abundant, but moderately to poorly preserved. In the interval above the upper Miocene (above Core 527-12), nannofossils are slightly corroded or show slight overgrowth. Their state of preservation is moderate. In Core 527-13, most of the coccolith species were dissolved, but discoasters are enriched and well preserved because of their strong resistance to dissolution. Below the hiatus, lower Oligocene through upper Paleocene nannofossils show strong overgrowth. A number of relatively small species were not found, probably because they were dissolved.

Except for the very base of the Tertiary, nannofossils recovered from the lower Paleocene and Upper Cretaceous at this site show moderate, sometimes moderate to good preservation, corresponding to the higher sedimentation rate during that time at this site.

*Oligocene (113.84–123.0 m)*

Nannofossils in Cores 14 and 13 are strongly etched, but Sample 527-14,CC contains an abundant, yet poorly preserved nannofossil assemblage. The common occurrence of *Dictyococcites bisectus, Cyclicargolithus floridanus*, and *Sphenolithus predistentus*, with *Helicosphaera compacta* and *Reticulofenestra umbilica* but without *Discoaster barbadiensi* or *D. saipanensis*, indicates Zone NP22 (NP21?) of the lower Oligocene. Two white calcareous mottles in Samples 527-14-1, 34 cm and 527-14-2, 118 cm contain less abundant nannofossil assemblages of probably the same age as Sample 527-14,CC. The rare occurrence of *D. barbadiensis* and *D. saipanensis* in Sample 527-14-1, 34 cm is tentatively interpreted as being due to reworking.

*Eocene (125.2–184.5 m)*

Upper Eocene assemblage were encountered only in Sample 527-15-2, 70 cm (125.20 cm), which contains common *Dictyococcites bisectus* and some *Reticulofenestra umbilica, Discoaster saipanensis, D. barbadiensis*, and *Helicosphaera compacta*. This assemblage represents the zonal interval from Zones NP16 to NP20. Detailed zonal assignment is impossible because of the absence of upper Eocene index fossils. In Samples 527-16-2, 100 cm, 527-16,CC and 527-17-3, 40 cm, *R. umbilica* is absent; but the presence of *Chiphragmalithus fulgens* and *Chiasmolithus gigas* limits these samples to Zone NP15 of the middle Eocene. In Samples 527-17-5, 20 cm and 527-18-2, 22 cm, *D. lodoensis, D. sublodoensis, Triquetrorhabdulus inversus*, and *Cyclococcolithus gammation* are present, indicating Zone NP14 or the lower part of Zone NP15.

The presence of *Tribrachiatus orthostylus*, first encountered in Sample 527-18,CC, indicates the presence of Zone NP12 of the lower Eocene. Sample 527-18-4, 22 cm still contains rare *D. sublodoensis*, the first occurrence of which defines the base of Zone NP13.

In Samples 527-19-4, 70 cm, 527-19,CC and 527-21,CC, *D. lodoensis* is absent. The assemblage is dominated by *Toweius* spp., *D. diastypus, D. salisburgensis*, and other lower Eocene species. Both cores are assigned to Zones NP11 to NP10 of the lower Eocene.

### *Paleocene (189.5–280.0 m)*

Cores 527-22,CC through 527-26-2, 125 cm (189.5–220.75 m) contain abundant *Coccolithus pelagicus* and *Toweius* spp., and are typical of Zone NP9 of the upper Paleocene.

The absence of *D. multiradiatus* and the presence of *Heliolithus* cf. *H. riedeli* in Sample 527-26,CC (227.5 m) indicates that this core belongs to Zone NP7 or NP8. The co-occurrence of *D. mohleri* and *H. kleinpellii*, on the other hand, places Sample 527-27,CC in Zone NP7. The presence of *H. kleinpellii* in Samples 527-28-1, 90 cm through 527-28-4, 60 cm assigns this interval to Zone NP6.

In Sample 527-28,CC (246.5 m) both *D. mohleri* and *H. kleinpelli* are absent, and the assemblage is dominated by *Toweius* cf. *T. eminens, Ericsonia cava*, and *Fasciculithus tympaniformis*, which suggest the presence of Zone NP5 of the upper Paleocene. Samples 527-29,CC (256 m) through 527-30-2, 150 cm contain some *Ellipsolithus macellus, Chiasmolithus bidens*, and *Prinsius bisulcus* without *F. tympaniformis*, and are assigned to Zone NP4.

Samples 527-30-2, 70 cm through 527-31-5, 90 cm contain an assemblage dominated by *P. martinii* with frequent *P. tenuiculum, Ericsonia cava, Cruciplacolithus notus*, and *Chiasmolithus* cf. *C. danicus*. The *Chiasmolithus* found in these cores have a very small central opening and very tiny crossbars which are not found in the true *C. danicus*. Nevertheless, Sections 527-30-2 and 527-31-5 are placed in Zone NP3 of the lower Paleocene.

Sample 527-31-5, 135 cm (272.85 m) are found the highest *Cruciplacolithus edwardsii* with *Neochiastozygus modestus* and *C. tenuis*, but without *Chiasmolithus* sp. The same assemblage is present through 527-31,CC and 527-32-1, 21 cm; it belongs to Zone NP2 of the Paleocene. *Prinsius dimorphosus* occurs in Sample 527-31-6, 43 cm (273.43 m).

In Sample 527-32-2, 150 cm the highest *Cruciplacolithus primus* (small forms $<7$ $\mu$m) are found, along with *Neochiastozygus primitivus*, fragments of *Thoracosphaera* and rare *P. sigmoides*. These species are typical of Zone NP1 of early Danian age. This lower part of the Danian is indicated in 527-32-4, 50 cm by the presence of *Biantholithus sparsus*, associated with fragments of *Thoracosphaera* sp. *Braarudosphaera bigelowi, Markalius astroporus, Placozygus sigmoides, Cyclagelosphaera alta*, and some Upper Cretaceous species such as *Micula prinsii, M. murus, Prediscosphaera grandis*, and *Nephrolithus frequens* are present.

The interval between 527-32-4, 50 cm and 527-32-4, 60 cm is transitional, with mixed Upper Cretaceous species and a typical assemblage of basal Danian.

### *Cretaceous/Tertiary Boundary*

This boundary is placed in Sample 527-32-4, 52 cm (280.02 m), with a majority of Cretaceous forms and only fragments of *Thoracosphaera* sp.

### *Maestrichtian*

Samples 527-32-4, 60 cm through 527-33,CC (280.10–294.0 m) represent the uppermost Cretaceous *Micula murus* Zone, with abundant Cretaceous species including *M. murus, C. kamptneri, Prediscosphaera majungae*, and *P. grandis. M. prinsii* was observed in Sample 527-32-4, 90 cm (280.40 m).

Samples 527-34-3, 27 cm and 527-34,CC (303.5 m) contain rare *Nephrolithus frequens* without *M. murus*. They probably belong to the *M. murus/Lithraphidites quadratus* zonal interval or to Perch-Nielsen's (1977) *N. frequens* Zone. Sample 527-35-2, 95 cm (305.95 m) to 527-38-4, 45 cm (335.45 m) contain *L. quadratus* without *N. frequens* and therefore are assigned to the *L. quadratus* Zone.

The interval from 527-38-4, 45 cm to 527-42-1, 61 cm is placed in the *Arkhangelskiella cymbiformis* Zone based on the absence of *L. quadratus, Broinsonia parca, Reinhardites levis*, and *Quadrum trifidum*.

Basalt was encountered at the very base of Core 38. The oldest sediments above the basalt and sandwiched within the basalt, in Cores 41 and 42, are within the *A. cymbiformis* zone.

## Site 528

At Site 528 (28°31.49′S, 02°19.44′E; water depth 3812 m), on the western section of the Walvis Ridge, a nearly continuous section was drilled in two holes from the seafloor through the upper 80 m of basement, encountered at 475 m sub-bottom depth. Short and small breaks in the record may occur in the upper Oligocene and at the top of the lower Paleocene. The Oligocene section at Site 528 is more complete than in the adjacent shoaler and deeper Sites 525 and 527.

### *Preservation*

At Site 528 the preservation of calcareous nannofossils ranges from moderate to poor throughout the section and frequently shows patterns of dissolution and diagenetic alteration similar to those noted at the shallower and deeper sites. Changes in preservation tend to parallel the changes in accumulation rates. Lower Miocene and upper Oligocene sediments in general yield moderately preserved nannofossils. The preservation of these minute fossils, however, deteriorates downward from the lower Oligocene to upper Paleocene. Dissolution, overgrowth, and fragmentation are so extensive that small specimens were totally eliminated, whereas large specimens such as discoasters and chiasmoliths, are strongly overgrown.

## Hole 528

Except for the first core, which sampled the topmost layer of sediments, continuous cores were taken from 12.20 m down to basement. A continuous lower Miocene to middle Maestrichtian sequence was recognized.

The Cretaceous/Tertiary boundary was recovered in Sample 528-31,CC and Section 528-32-1. Basalt was encountered in Section 528-39-1.

The sediments immediately above the basalt belong to the upper part of the *Arkhangelskiella cymbiformis* Zone. The oldest sediments sandwiched in Core 46, however, are located within the lower part of the *A. cymbiformis* Zone, based on the presence of *Reinhardites levis*.

### *Oligocene (169.8–226.7 m)*

In Sample 528-7-1, 30–32 cm, *Sphenolithus ciperoensis* was first encountered and indicates Zone NP25 of the upper Oligocene. Sample 528-7,CC (179 m) still contains *S. ciperoensis*, without *S. distentus*, and remains in Zone NP25. *S. distentus* first appears in Sample 528-8-1, 45–47 cm, which places this sample in Zone NP24. Sample 528-8,CC contains *S. distentus* with very rare *S. ciperoensis* and still belongs in Zone NP24. Sample 528-9-1, 122 cm contains common isolated elements of *Braarudosphaera bigelowi*. This horizon might be correlated to one of the so-called "*Braarudosphaera* chalks" found in Oligocene intervals on Legs 3, 40, and 73. Samples 528-9,CC and 528-10,CC (198–207.5 m) still belong in Zone NP23 because of the absence of *Reticulofenestra umbilica*.

The highest *R. umbilica* were encountered in Sample 528-11-2, 27–29 cm, which indicates that the sample is located in Zone NP22 of the lower Oligocene. Zone NP22 continues to Sample 528-11,CC. Then the last appearance datum of *Cyclicoccolithus formosus* together with *Isthmolithus recurvus* occurs in Sample 528-12-2, 116–118 cm, which indicates that this sample belongs to Zone NP21 of the lowermost Oligocene. Sample 528-12,CC (226.5 m) still belongs to Zone NP21 because of the absence of *D. saipanensis* and *D. barbadiensis*.

### *Eocene (226.7–312.0 m)*

*Discoaster saipanensis* and *D. barbadiensis* were found in Sample 528-13-1, 17–19 cm (226.7 m), which belongs to Zone NP20 of the uppermost Eocene. Both species are very rare in this sample but become common in Sample 528-13,CC, where *Sphenolithus pseudoradians, Isthmolithus recurvus, Bramletteius serraculoides, Discoaster tani* and *Hayella situliformis*, which constitute a typical assemblage of Zone NP20, are also found. *I. recurvus* is reported to be a species typical of high latitudes (cool form ?). Its common presence at this site may indicate cooling during late Eocene and early Oligocene time.

In Sample 528-14-2, 40–42 cm, the presence of *I. recurvus* and the absence of *S. pseudoradians* limit the sample to Zone NP19. The highest *Chiasmolithus grandis* are encountered in Sample 528-14-2, 85 cm, which indicates the NP17–NP18 zonal interval. The highest occurrence of *Reticulofenestra umbilica* occurs in Sample 528-15-2, 90–92 cm, in which *S. furcatolithoides* is also present. This sample is, therefore, attributed to Zone NP16 of the middle Eocene. In Sample 528-15,CC (255.0 m), the absence of *R. umbilica* and the presence of *Chiphragmalithus fulgens* and *Chiasmolithus gigas* indicate an assemblage of Zone NP15.

The interval from 528-16-2, 51–52 cm down to 528-17-4, 60–62 cm, including Sample 528-16,CC (264.5 m) contains *D. lodoensis, D. sublodoensis*, and *Triquetrorhabdulus inversus*, which are typical of Zone NP14. However, since *D. sublodoensis* extends down and overlaps with the range of *Tribrachiatus orthostylus* in Holes 525A and 527, the interval at this site could cover both Zones NP14 and NP13.

*Tribrachiatus orthostylus*, index fossil of Zone NP12 of the lower Eocene, first occurs in Sample 528-17,CC. Assemblages of Zone NP12 continue down to Sample 528-19-2, 60–62 cm, where *D. lodoensis* first occurs. Samples 528-19,CC through 528-20,CC can be assigned to the NP11–NP10? zonal interval because of the absence of *D. lodoensis*. A sample taken from a layer of brownish clay in Sample 528-21-3, 106–107 cm contains a special assemblage which is characterized by moderately to well-preserved *T. orthostylus* (long-armed type), *T. contortus, D. multiradiatus, D. diastypus*, and *M. bramlettei*?. This assemblage obviously belongs to Zone NP10 of the basal Eocene. Section 528-21-6 contains an assemblage of the Eocene/Paleocene transition with some *D.* cf. *diastypus*. The Paleocene/Eocene boundary is therefore placed at 310 m.

### *Paleocene (310.0–407.0 m)*

Cores 528-22 and 528-23 contain common *Discoaster multiradiatus* with abundant *Toweius* spp. and are typical of Zone NP9 of the upper Paleocene. In Cores 528-24-3, 90–91 cm, 528-24,CC, and 528-25,CC, *D. multiradiatus* are absent. The presence of *D. mohleri* and some *Heliolithus* spp., then, suggest the NP8–NP7 zonal interval. Samples 528-26-1 through 528-29-1, 15 cm, on the other hand, contain *Fasciculithus tympaniformis*, without *H. kleinpellii*, and are typical of Zone NP5. The thickness of Zone NP5 at this site is about 30 m, which is high compared with that of Holes 525A and 527. Zone NP6 appears to be missing because of a break of sedimentation.

Samples 528-29-2, 125 cm through 528-30-2, 25 cm are assigned to Zone NP4 on the basis of the common occurrence of characteristic species of Zone NP4, such as *Ellipsolithus macellus, Prinsius bisulcus, Chiasmolithus bidens*, and *Sphenolithus primus*.

In Samples 528-30-2, 100 cm through 528-30-4, 88 cm (390.5–392.78 m) the lowest *P. martinii* occurs, with *Cruciplacolithus notus, Ericsonia cava*, and *E. subpertusa*. This assemblage, with *Chiasmolithus danicus*, places these cores in Zone NP3.

Core 528-31-2, 60 cm (379.60 m) belongs to Zone NP2 with the lowest occurrence of *Cruciplacolithus edwardsii* (synonym of *C. tenuis* of Martini). *Neochiastozygus modestus* and *Prinsius tenuiculum* are present in Sample 528-31-4, 149 cm with *C. edwardsii*, so the upper sections of Core 31 belong to NP2.

The top of Zone NP1 is placed below Sample 528-31-5, 150 cm (405.50 m), where the first *C. primus* were observed, with *N. primitivus* and some reworked? Upper Cretaceous species.

In Samples 528-31-6, 23 cm and 528-31,CC (407.0 m) the nannofossil assemblage is dominated by *Thoracosphaera* sp. and isolated elements of *Braarudosphaera* *bigelowi* with some *Biantholithus sparsus, Markalius astroporus*, and *Placozygus sigmoides.* These species are typical of lowermost Tertiary nannofossil Zone NP1.

### *Maestrichtian (407.0 m to basement)*

Samples from the top of Core 32 (407.0 m) contain abundant Upper Cretaceous forms, including *Micula murus*, and belong to the *M. murus* Zone of the uppermost Maestrichtian. The Cretaceous/Tertiary boundary is between Sample 528-31,CC and the top of Core 32. *M. prinsii*, which evolved from *Micula murus*, was encountered in Sample 528-32-1, 98 cm (407.98 m) and indicates the presence of the upper part of Maestrichtian. Samples 528-32,CC through 528-33-5, 44 cm (416.5–422.94 m) contain *M. murus* and *Nephrolithus frequens* and are assigned to the *M. murus* Zone.

Samples 528-33,CC through 528-37-6, 50–51 cm (426.0–462.5 m), in contrast, are attributed to the *Lithraphidites quadratus* Zone, based on the absence of *M. murus* and the presence of *L. quadratus*. The highest *Lucianorhabdus cayeuxi* were encountered in Sample 528-36,CC (454.50 m); however, their occurrence is not consistent downward. Sample 528-37,CC is barren. Samples 528-38,CC and 528-39-1, 90–93 cm (the oldest sediments right above basalt) are within the upper part of the *Arkhangelskiella cymbiformis* Zone, based on the absence of *L. quadratus, Broinsonia parca*, and *Reinhardites levis*. Several layers of sediment sandwiched within basalts were also investigated for their nannofossil content. Among them, Samples 528-43,CC, 528-44-1, 111 cm, 528-45-1, top, 528-46-1, 113–114 cm, and 528-46,CC (546.0 m) contain *R. levis*, which suggests the presence of the lower part of the *A. cymbiformis* Zone. The extinction levels of *B. parca* and *Quadrum trifidum* were not reached at Site 528.

## Site 529

At Site 529 (28°55.83′S, 02°46.08′E; water depth 3035 m), on the western arm of the Walvis Ridge, 44 cores retrieved by rotary coring contained a section from Pleistocene to upper Maestrichtian.

Although Site 529 is located between Sites 525 and 528, the post-Paleocene sedimentary sequence recovered resembles neither site. A hiatus occurs between Sample 529-4,CC and Core 5, where lower Pliocene sediments are underlain by middle Miocene. Three apparently slumped intervals were observed at this site; one occurs during the lower Pleistocene (Zone NN19), one during the lower part of the middle Miocene or upper part of lower Miocene (Zones NN5–4), and one during the upper Paleocene (Zone NP8).

Sample 529-9-6, 30 cm is assigned to the lower Miocene Zone NN1. Samples 529-10,CC through 529-13-4, 30–31 cm contain rare *Discoaster bisectus* and *Zygrhablithus bijugatus* without *Sphenolithus ciperoensis* and characterize the Miocene/Oligocene transition.

### *Preservation*

The preservation of calcareous nannofossils recovered at this site is in general moderate. The discoasters found in the middle Miocene through upper Paleocene show strong overgrowth. Nannofossil assemblages with fairly good preservation are found only in an interval ranging from Zones NP8 to NP3.

### *Oligocene (119.3–199.8 m)*

Samples 529-13-4, 30–31 cm through 529-15-5, 40–41 cm belong to the upper Oligocene Zone NP25, based on the presence of *Sphenolithus ciperoensis*. The highest occurrence of *S. distentus* is in Sample 529-15-6, 40–41 cm thus marks the top of Zone NP24. Samples 529-15,CC through 529-18-3, 90–91 cm (139.90 m) could be assigned to the NP24/NP23 zonal interval because of the absence of *Reticulofenestra umbilica* and presence of *Helicosphaera compacta.* Differentiation between Zones NP24 and NP23 is, however, impossible because of the scarcity of *S. ciperoensis* near its lowest occurrence.

Rare *R. umbilica* were first encountered in Sample 529-18-4, 90–91 cm (165.90 m) and thus indicate Zone NP22 of the lower Oligocene. The highest occurrences of *Cyclicargolithus formosus, Isthmolithus recurvus* and *Bramletteius serraculoides* are observed in Sample 529-20-3, 80–81 cm, i.e., Zone NP21, which can be traced down to Sample 527-22-1, 128 cm, where a sharp color change occurs in the sediments.

### *Eocene (199.8–265.0 m)*

Common *Discoaster barbadiensis* and *D. saipanensis* have their highest occurrences in Sample 529-22-1, 130 cm, where the top of the Eocene (i.e., top of NP20) is placed (199.80 m). Floras from Cores 22 and 23 belong to the same zone, as is indicated by the presence of *Sphenolithus pseudoradians.* In Core 24, the nannoplankton assemblages change very quickly. Closely spaced samples were studied and the results are as follows:

| | | |
|---|---|---|
| 529-24-3, 125 cm<br>529-24-3, 145 cm | NP17 (18?) | *D. saipanensis, Bramletteius serraculoides, Hayella situliformis,* and *Chiasmolithus grandis* |
| 529-24-4, 40 cm | NP16 | *Triquetrorhabdulus inversus, C. solitus,* and *B. serraculoides* |
| 529-24-5, 45 cm | NP15 | *C. gigas* and *Reticulofenestra umbilica* |
| 529-24,CC | NP15 | As above, with *S. furcatolithoides* |

It seems that no hiatus occurs during the upper Eocene at this site. However, the sedimentation rate was so low that the entire interval from Zones NP16 to NP19 is present in only a few meters.

There was no recovery in Core 25. Core 26 belongs to Zone NP12 of the lower Eocene, based on the co-occurrence of *Tribrachiatus orthostylus* and *D. lodoensis.* Therefore it is uncertain whether or not a hiatus occurs in Core 25.

Zone NP12 can be traced down to Sample 529-27-1, 80 cm. Samples 529-27-1, 150 cm through 529-29-1, 30–31 cm (247.50–265.30 m) contain *T. orthostylus* without *D. lodoensis* and are attributed to the NP11–NP10 zonal interval.

### *Paleocene (266.30–387.8 m)*

Sample 529-29-2, 30–31 cm (266.30 m) is attributed to the Paleocene (Zone NP9) because of the common presence of *Discoaster multiradiatus* and the absence of *D. diastypus* and *Tribrachiatus orthostylus*. There was no recovery in Core 30. Sample 529-31-1, 90–91 cm (275.4 m) belongs to Zone NP8, based on the common presence of *D. mohleri* and rare *Heliolithus riedeli*. Cores 32 and 33 contain slumped sediments. These materials range from Zones NP4 (NP3?) to NP6. The top of Core 34 is attributed to Zone NP8, by the same criteria. It is apparent that the slumping occurred during deposition of sediments of Zone NP8. In Sample 529-34,CC, *D. mohleri* is common; however, no *H. riedeli* were found, indicating deposition during Zone NP7 or after.

Common *H. kleinpellii*, without *D. mohleri*, are present throughout the entire Core 35 (322.0–331.5 m) and indicate presence of Zone NP6. In Samples 529-36-1, 70 cm and 529-37,CC, *H. kleinpellii* is absent. The presence of *Fasciculithus tympaniformis* then limits these two cores to Zone NP5. Cores 529-38-1, 44 cm, 529-32,CC, and 529-39,CC (350.44 to 369.5 m) are assigned to Zone NP4 of the lower Eocene, based on the common occurrence of rare *Ellipsolithus macellus, Sphenolithus primus*, and *Neochiastozygus perfectus*.

In Sample 529-40-2, 105 cm (369.55 m) occur the highest *Prinsius martinii* and *Cruciplacolithus notus*, without *Chiasmolithus danicus*. Therefore Zone NP3 can be traced down to that level. In Sample 529-40-3, 84 cm (373.34 m) *Chiasmolithus* cf. *C. danicus* is found, but it is not the true *C. danicus*. Samples 529-41-1, 44 cm through 529-41-2, 85 cm contain *P. tenuiculum* and *N. modestus* and can thus be assigned to Zone NP3. *Cruciplacolithus edwardsii* shows its highest occurrence in Sample 529-41-3, 129 cm and is associated with *P. dimorphosum* in 529-41-4, 47 cm (383.97 cm). This places Sections 529-41-3, and 529-41-4 in Zone NP2 of the early Danian. The presence of the lowest small *C. primus* and *N. primitivus* in Sample 529-41-6, 13 cm (386.73 m) indicates Zone NP1. In Sample 529-41-6, 127 cm (387.77 m), *Biantholithus sparsus* is associated with *Placozygus sigmoides, Markalius astroporus*, and fragments of *Thoracosphaera* and represents an assemblage typical of the basal Danian.

The Cretaceous/Tertiary boundary occurs in Sample 529-41-6, 130 cm (378.80 m), where a sharp color change from light brown (529-41-6, 127 cm) in the upper part to light blue in the lower part is observed.

Sample 529-41-6, 130 cm contains a complete assemblage of late Maestrichtian age, with *Micula murus, Cribrosphaera daniae*, and *Nephrolithus frequens* present. *Micula prinsii*, however, was not found at Site 529.

In Samples 529-41,CC, 529-42,CC and the lowest sample, 529-44-1, 11 cm, the presence of *Micula murus* and *Lithraphidites quadratus* limits the oldest fossiliferous sediments to the uppermost Cretaceous *Micula murus* zone.

## REMARKS

### Biostratigraphy

In the transect of Leg 74 we have made the following biostratigraphic observations: *Helicosphaera recta*, whose highest occurrence is used to define the top of NP25 elsewhere, and *Rhabdosphaera* species, which are generally important in the middle Eocene interval and are considered hemipelagic species, are not found in Leg 74 sites. Besides, the range of *Discoaster sublodoensis*, a middle Eocene species whose lowest occurrence defines the base of NP14, extends down and overlaps with that of *Tribrachiatus orthostylus*, a lower Eocene species whose lowest occurrence defines the top of NP12. This was consistently observed for all sites drilled during Leg 74. Mixing or contamination cannot account for this phenomenon. Therefore, the boundary definitions of Zone NP13 should be revised.

### Preservation

At all sites, the preservational variability of nannofossils mostly reflects the degrees of diagenesis of the sediments. In intervals of poor preservation, dissolution fragments placoliths, etches many small species, and produces overgrowth on *Discoaster* and *Chiasmiolithus* spp. This is particularly well observed at Site 528. Except for the middle Miocene at Site 527, discoasters show strong overgrowth from the middle Miocene downward in all sites. Thus it is impossible to identify many discoaster forms down to the species level. The nannofossil assemblages with the best preservation were observed within Paleocene intervals ranging from NP8 to NP3. Upper and middle Oligocene nannoplankton are moderately well preserved at Sites 528 and 525, but are markedly affected by dissolution at Sites 529 and 526. At Site 527, red clays are observed throughout this interval.

In the middle and early Eocene the diagenetic alteration reported previously from many other South Atlantic sites was noted also in the sites of the Leg 74 transect; coccoliths are overgrown and etched, and solution-resistant species are concentrated. The preservation of calcareous nannoplankton is generally poorer near hiatuses.

### Paleobiogeography

Nannofossil species found in sediments from Leg 74 are characteristic of temperate water masses throughout the Tertiary and upper Maestrichtian. At Site 525 the common occurrence of *Scyphosphaera* indicates subtropical conditions during the Pliocene. At all Leg 74 Sites (525–529) we can define some characteristic mid-latitude assemblages in Paleocene sediments.

1) A thoracosphaerid assemblage composed of common *Thoracosphaera* sp. associated to *Markalius astroporus*, in the early Danian (Zone NP1)

2) An assemblage with peculiar, small, circular coccoliths referred to as *Prinsius dimorphosum* associated with *Placozygus sigmoides*, in the Danian (Zone NP2). This assemblage was also observed in the Danian of Denmark.

3) An assemblage with dominant *Ericsonia cava* and *E. subpertusa* in the early Paleocene (Zone NP3).

4) A fourth assemblage dominated by *Prinsius martinii*, associated with *Cruciplacolithus notus* (synonym of *C. tenuis*) and *Chiasmolithus* cf. *C. danicus*. This assemblage is found in significant numbers in the later part of the early Paleocene.

5) The mid-Paleocene (Zones NP4–NP5) is dominated by a small coccolith species, *Toweius craticulus*, with *Coccolithus pelagicus* or *E. ovalis*.

In the lower to middle Eocene at Site 525 the *Discoaster/Chiasmolithus* ratio is high, suggesting warm conditions.

## ACKNOWLEDGMENTS

I thank Katharina Perch-Nielsen for her help and valuable discussions and criticism. A critical review of the manuscript by Hans Thierstein is gratefully acknowledged. Research was supported through a grant by ATP–IPOD.

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## APPENDIX
### Nannofossil Species Considered in this Report

*Ahmuellerella octoradiata* (Gorka) Perch-Nielsen, 1968
*Arkhangelskiella cymbiformis* Vekshina, 1959
*Biantholithus sparsus* Bramlette and Martini, 1964
*Biscutum constans* (Gorka), Black, 1967
*B.* cf. *parvulum* Romein, 1977
*Braarudosphaera bigelowii* (Gran and Braarud), Deflandre, 1947 (Plate 1, Fig. 1)
*Bramletteius* cf. *serraculoides* Bramlette, 1969
*Broinsonia enormis* (Shumenko) Manivit, 1971
*B. parca* (Stradner), Bukry, 1969
*Campylosphaera dela* (Bramlette and Sullivan), Hay and Mohler, 1967
*Ceratolithoides aculeus* (Stradner), Prins and Sissingh, 1977
*Chiasmolithus altus* Bukry and Percival, 1971
*C. bidens* (Bramlette and Sullivan) Hay and Mohler, 1967 (Plate 7, Fig. 7)
*C. californicus* (Sullivan) Hay and Mohler, 1967 (Plate 3, Fig. 5)
*C. consuetus* (Bramlette and Sullivan) Hay and Mohler, 1967 (Plate 3, Fig. 2, Plate 6, Fig. 4)
*C. danicus* (Brotzen) Hay and Mohler, 1967
*C. gigas* (Bramlette and Sullivan) Radomski, 1968
*C. grandis* (Bramlette and Riedel) Radomski, 1968 (Plate 3, Figs. 1, 4)
*C. modestus* Perch-Nielsen, 1973 (Plate 4, Fig. 7)
*C. oamaruensis* (Deflandre) Hay, Mohler, and Wade, 1966
*C. solitus* (Bramlette and Sullivan) Locker, 1968
*Chiastozygus litterarius* (Gorka) Manivit, 1971
*Chiphragmalithus calatus* Bramlette and Sullivan, 1961
*Coccolithus eopelagicus* (Bramlette and Riedel), Bramlette and Sullivan, 1961
*C. pelagicus* (Wallich) Schiller, 1930
*C. crassus* Bramlette and Sullivan, 1961
*Corollithion exiguum* Stradner, 1961 (Plate 11, Fig. 2)
*Coronocyclus nitescens* (Kramptner) Bramlette and Wilcoxon, 1967 (Plate 1, Fig. 7)
*Crepidolithus* sp.
*Cretarhabdus conicus* Bramlette and Martini, 1964
*C. crenulatus* Bramlette and Martini emend. Thierstein, 1971
*C. surirellus* (Deflandre) Reinhardt, 1970
*Cribrocorona gallica* (Stradner) Perch-Nielsen, 1973
*Cribrosphaerella ehrenbergi* (Arkhangelsky) Deflandre, 1952 (Plate 11, Fig. 1)
*C. daniae* Perch-Nielsen, 1973
*Cruciplacolithus edwardsii* Romein, 1979 (Plate 8, Figs. 7–8)
*C. notus* Perch-Nielsen, 1977 (Plate 8, Fig. 4)
*C. primus* Perch-Nielsen, 1977 (Plate 8, Figs. 6, 9)
*C. tenuis* (Stradner), Hay and Mohler, 1967
*Cyclagelosphaera reinhardtii* (Perch-Nielsen) Romein, 1977
*Cyclicargolithus floridanus* (Roth and Hay) Bukry, 1971
*C. formosus* Kamptner, 1963
*C. gammation* (Bramlette and Sullivan) Sullivan, 1966
*Cylindralithus serratus* Bramlette and Martini, 1964
*Dictyococcites abisectus* (Muller) Bukry and Percival, 1971
*D. bisectus* (Hay, Mohler and Wade) Bukry and Percival, 1971 (Plate 2, Figs. 1–2)
*Discoaster barbadiensis* Tan Sin Hok, 1927 (Plate 2, Fig. 5)
*D. cruciformis* Martini, 1958 (Plate 4, Fig. 5)
*D. deflandrei* Bramlette and Riedel, 1952 (Plate 1, Fig. 4–5, 8)
*D. diastypus* Bramlette and Sullivan, 1961
*D. distinctus* Martini, 1958
*D. lenticularis* Bramlette and Sullivan, 1961
*D. lodoensis* Bramlette and Riedel, 1954 (Plate 4, Fig. 4)
*D. mohleri* Bukry and Percival, 1971 (Plate 7, Figs. 4, 9)
*D. multiradiatus* Bramlette and Riedel, 1954 (Plate 5, Fig. 2)
*D. nobilis* Martini, 1961
*D. robustus* Haq, 1969 (Plate 4, Fig. 9)
*D. saipanensis* Bramlette and Riedel, 1954
*D. salisburgensis* Stradner, 1961
*D. sublodoensis* Bramlette and Sullivan, 1961
*D. tani* Bramlette and Riedel, 1954
*D. trinadensis* Haq, 1967
*Discoasteroides kuepperi* Bramlette and Sullivan, 1961 not pictured
*D. megastypus* Bramlette and Sullivan, 1961
*Discorabdus ignotus* (Gorka) Perch-Nielsen, 1968
*Eiffelithus gorkae* Reinhardt, 1965
*E. turriseiffeli* (Deflandre) Reinhardt, 1965
*Ellipsolithus distichus* (Bramlette and Sullivan) Sullivan, 1964 (Plate 6, Fig. 1)
*E. macellus* (Bramlette and Sullivan) Sullivan, 1964
*Ericsonia brotzenii* Perch-Nielsen, 1969 (Plate 6, Fig. 5)
*E. cava* Hay and Mohler) Perch-Nielsen, 1969 (Plate 5, Figs. 4, 7; Plate 6, Fig. 3)
*E. formosa* (Kamptner) Wilcoxon (Plate 2, Fig. 8)
*E. insolita* Perch-Nielsen, 1969
*E. ovalis* Black, 1964 (Plate 3, Fig. 8)
*E. subdisticha* (Roth and Hay) Roth, 1969
*E. subpertusa* Hay and Mohler, 1967 (Plate 8, Fig. 2)
*Fasciculithus involutus* Bramlette and Sullivan, 1961
*F. tympaniformis* Hay and Mohler, 1967 (Plate 7, Fig. 6)
*Hayella situliformis* Gartner, 1969
*Helicosphaera compacta* Bramlette and Wilcoxon, 1967
*H. euphratis* Haq, 1966
*H. hiezenii* (Bukry) Jafar, and Martini, 1974 (Plate 2, Fig. 7)
*H. recta* (Haq) Jafar and Martini, 1975
*Heliolithus kleinpellii* Sullivan, 1964
*H. riedeli* Bramlette and Sullivan, 1961
*Isthmolithus recurvus* Deflandre, 1954
*Lanternithus minutus* Stradner, 1962
*Lapideacassis blackii* Perch-Nielsen, 1977 (Plate 8, Fig. 3)
*Lithraphidites praequadratus* Roth, 1978
*L. quadratus* Bramlette and Martini, 1969 (Plate 12, Figs. 1–2)
*Lucianorhabdus cayeuxi* Deflandre, 1959
*Manivitella pemmatoidea* (Deflandre) Thierstein, 1971
*Markalius astroporus* (Stradner) Hay and Mohler, 1967
*M. circumradiatus* (Stover) Perch-Nielsen, 1968
*M. inversus* (Stradner) Hay and Mohler, 1967 (Plate 9, Figs. 4–5)
*Microrhabdulus belgicus* Hay and Towe, 1963 (Plate 12, Fig. 6)

*M. decoratus* Deflandre, 1959
*Microrhabdulus stradneri* Bramlette and Martini, 1964 (Plate 12, Fig. 7)
*Micula murus* (Martini) Bukry, 1973 (Plate 10, Figs. 1–2)
*M. praemurus* Bukry, 1973 (Plate 11, Fig. 5)
*M. prinsii* Perch-Nielsen, 1979 (Plate 10, Figs. 3, 6)
*M. staurophora* (Gardet) Stradner, 1963 (Plate 11, Figs. 3–4, 6)
*Nannotetrina cristata* (Martini) Perch-Nielsen, 1971
*N. fulgens* (Stradner) Stradner, 1969
*Neochiastozygus modestus* Perch-Nielsen, 1971 (Plate 6, Figs. 6–7)
*N. perfectus* Perch-Nielsen, 1971
*N. primitivus* Perch-Nielsen, 1971
*N. saepes* Perch-Nielsen, 1971
*Nephrolithus frequens* Gorka 1957 (Plate 12, Figs. 4–5)
*Parhabdolithus angustus* (Stradner) Stradner, Adamiker, and Maresch, 1968
*P. embergeri* (Noël) Stradner, 1963
*P. splendens* (Deflandre) Noël, 1969
*Pedinocyclus larvalis* (Bukry and Bramlette) Loeblich and Tappan, 1973
*Peritrachelina joidesa* Bukry and Bramlette, 1968
*Phanulithus obscurus* (Deflandre) Wind and Wise, 1976
*Placozygus sigmoides* (Bramlette and Sullivan) Romein, 1979 (Plate 9, Figs. 1, 6, 9)
*Prediscosphaera cretacea* (Arkhangelsky) Gartner, 1968 (Plate 12, Fig. 3)
*P. grandis* Perch-Nielsen, 1979
*P. majungae* Perch-Nielsen, 1973
*P. spinosa* (Bramlette and Martini) Gartner, 1968
*P. stoveri* (Perch-Nielsen) Noël, 1969
*Prinsius bisulcus* (Stradner) Hay and Mohler, 1967 (Plate 7, Fig. 2)
*P. martinii* (Perch-Nielsen) Haq, 1971 (Plate 7, Fig. 3)
*P. dimorphosus* (Perch-Nielsen) Perch-Nielsen, 1977
*P. tenuiculum* (Okada and Thierstein) Perch-Nielsen, 1979 (Plate 9, Figs. 2–3)
*Quadrum gothicum* (Deflandre) Prins and Perch-Nielsen, 1977
*Q. trifidum* (Stradner) Prins and Perch-Nielsen, 1977
*Reinhardites levis* Prins and Sissingh, 1978
*Reticulofenestra dictyoda* (Deflandre and Fert) Stradner, 1968
*R. umbilica* (Levin) Martini and Ritzkowski, 1968 (Plate 2, Fig. 9)
*Rhabdosphaera tenuis* Bramlette and Sullivan, 1961
*Sphenolithus anarrhopus* Bukry and Bramlette, 1969
*S. ciperoensis* Bramlette and Wilcoxon, 1967
*S. conicus* Bukry, 1971 (Plate 2, Fig. 4)
*S. editus* Perch-Nielsen, 1971 (Plate 4, Fig. 1)
*S. distentus* (Martini) Bramlette and Wilcoxon, 1967
*S. furcatolithoides* Locker, 1967
*S. moriformis* (Bronnimann and Stradner) Bramlette and Wilcoxon, 1967, (Plate 4, Fig. 8)
*S. predistentus* Bramlette and Wilcoxon, 1967
*S. primus* Perch-Nielsen, 1971 (Plate 7, Fig. 8)
*S. pseudoradians* Bramlette and Wilcoxon, 1967 (Plate 2, Fig. 6)
*S. radians* Deflandre, 1952
*Thoracosphaera deflandrei* Kamptner, 1956
*T. operculata* Bramlette and Martini, 1964 (Plate 6, Fig. 2)
*Toweius craticulus* Hay and Mohler, 1967
*T. eminens* (Bramlette and Sullivan) Gartner, 1971 (Plate 7, Fig. 1)
*T. petalosus* Ellis and Lhoman, 1973
*Tranolithus orionatus* (Reinhardt) Reinhardt, 1966
*Tribrachiatus contortus* (Stradner, 1958) Bukry, 1972
*T. orthostylus* Bramlette and Riedel, Schamrai, 1968 (Plate 4, Fig. 6)
*Triquetrorhabdulus carinatus* Martini, 1965
*T. inversus* Bukry and Bramlette
*Watznaueria barnesae* (Black) Perch-Nielsen, 1968
*W. ovata* Bukry, 1969
*Zygodiscus diplogrammus* (Deflandre) Gartner, 11968
*Z. plectopons* Bramlette and Sullivan, 1961
*Z. spiralis* Bramlette and Martini, 1964
*Z. tarboulensis* Shafik and Stradner, 1971
*Zygrhablithus bijugatus* (Deflandre) Deflandre, 1959

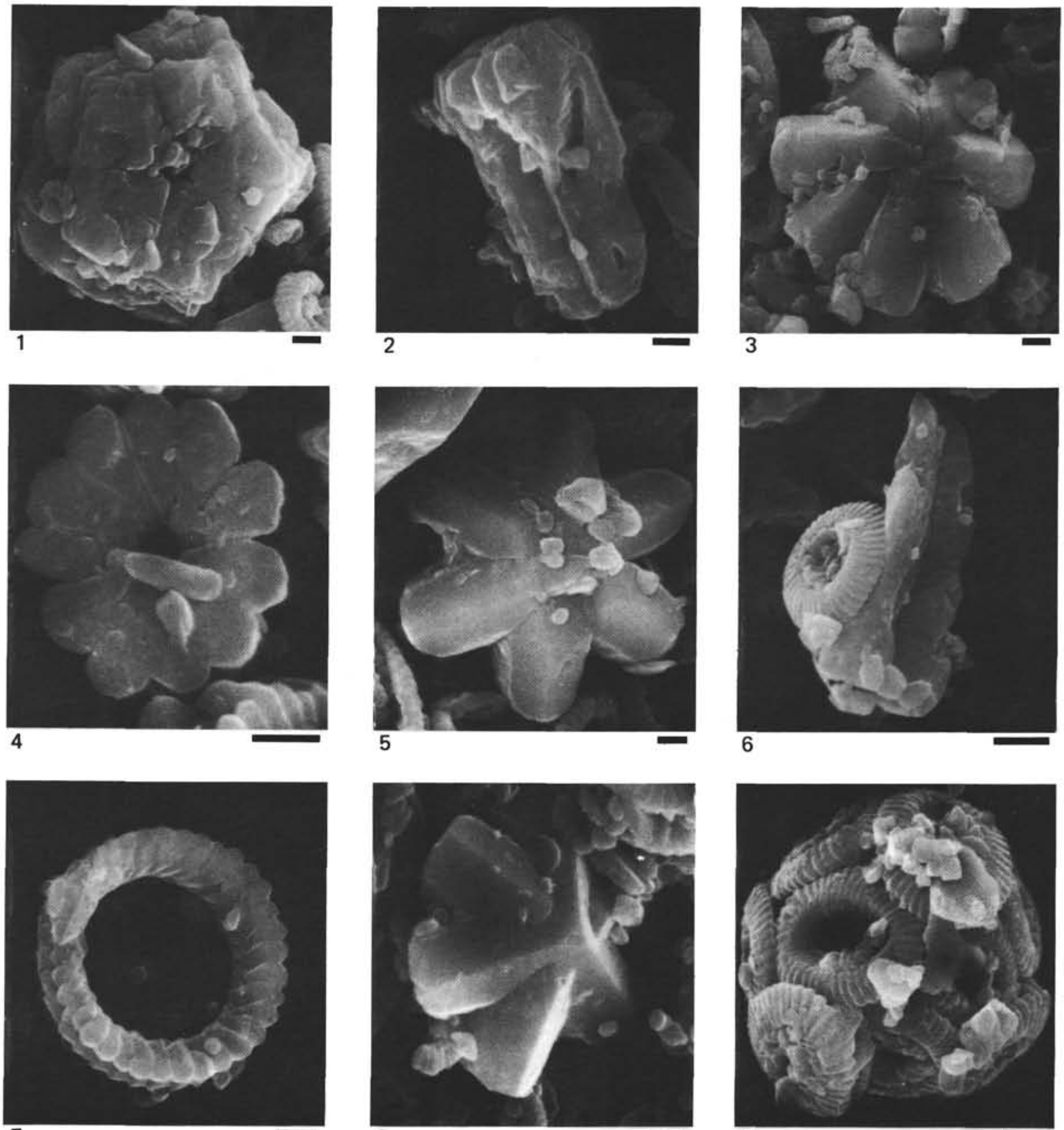


Plate 1. Nannofossils, Sample 526-33-1, 105–106 cm. (Scale bar = 1 μm.) **1.** *Braarudosphaera bigelowi*, ×4000. **2, 6.** *Zyghrablithus bijugatus*, (2) ×5000, (6) ×4250. **3.** *Discoaster* sp., ×4000. **4–5, 8.** *Discoaster* cf. *D. deflandrei* group, (4) ×10000, (5) ×4000, (8) ×5000. **7.** *Coronocyclus nitescens*, ×6000, distal view. **9.** Coccosphere of *Dictyococcites* sp., ×6000.

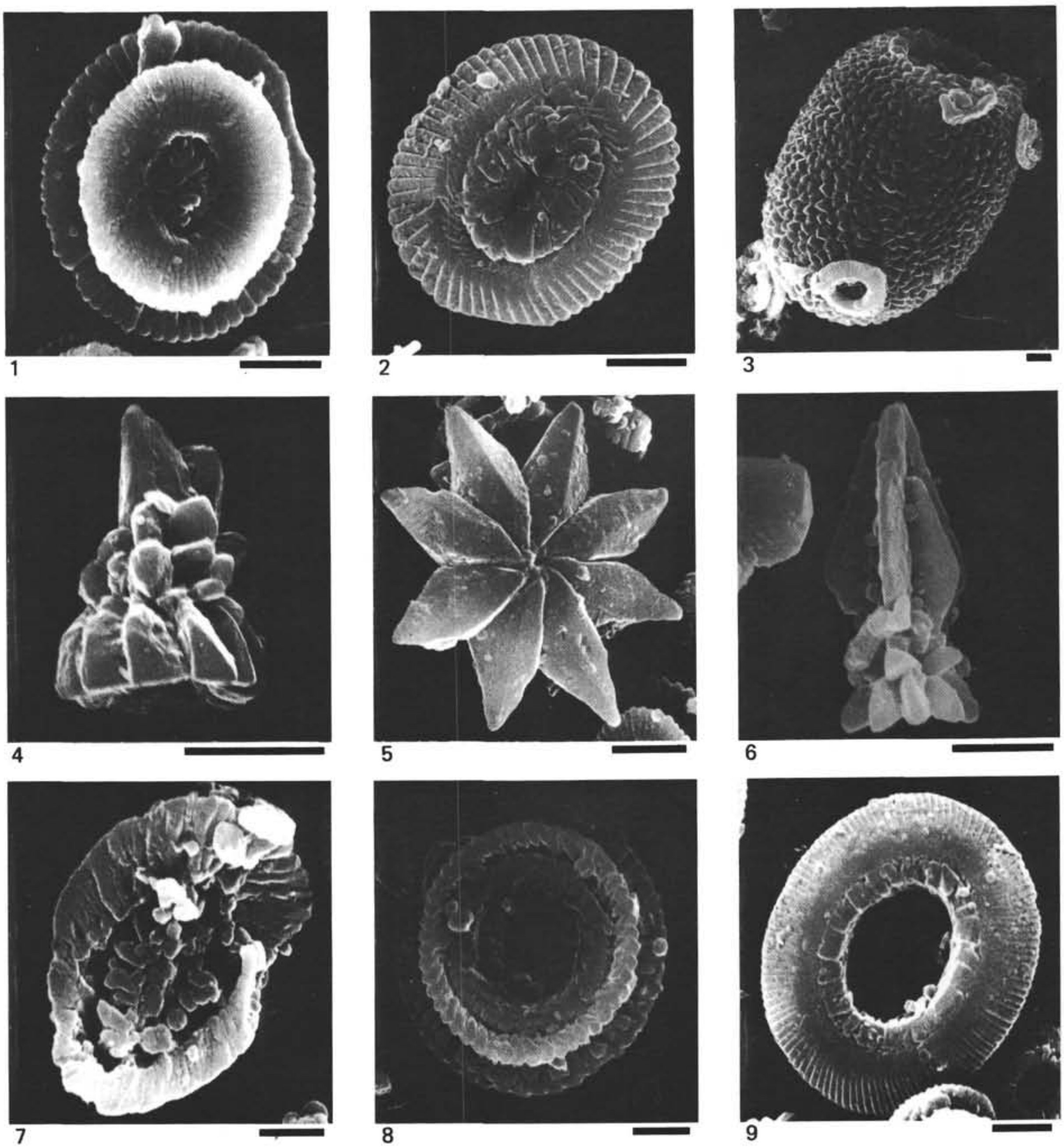

Plate 2. Nannofossils from Sample 529-23-1, 100–101 cm. (Scale bar = 3 μm.) **1–2.** *Dictyococcites bisectus*, (1) ×4000, proximal view, (2) ×4000, distal view. **3.** *Thoracosphaera ellipsoidea*, ×1200. **4.** *Sphenolithus conicus*, ×7000. **5.** *Discoaster barbadiensis*, ×3750, distal view. **6.** *Sphenolithus pseudoradians*, ×5000. **7.** *Helicosphaera heezenii*, ×3250, distal view. **8.** *Ericsonia formosa*, ×2750, proximal view. **9.** *Reticulofenestra umbilica*, ×3000.

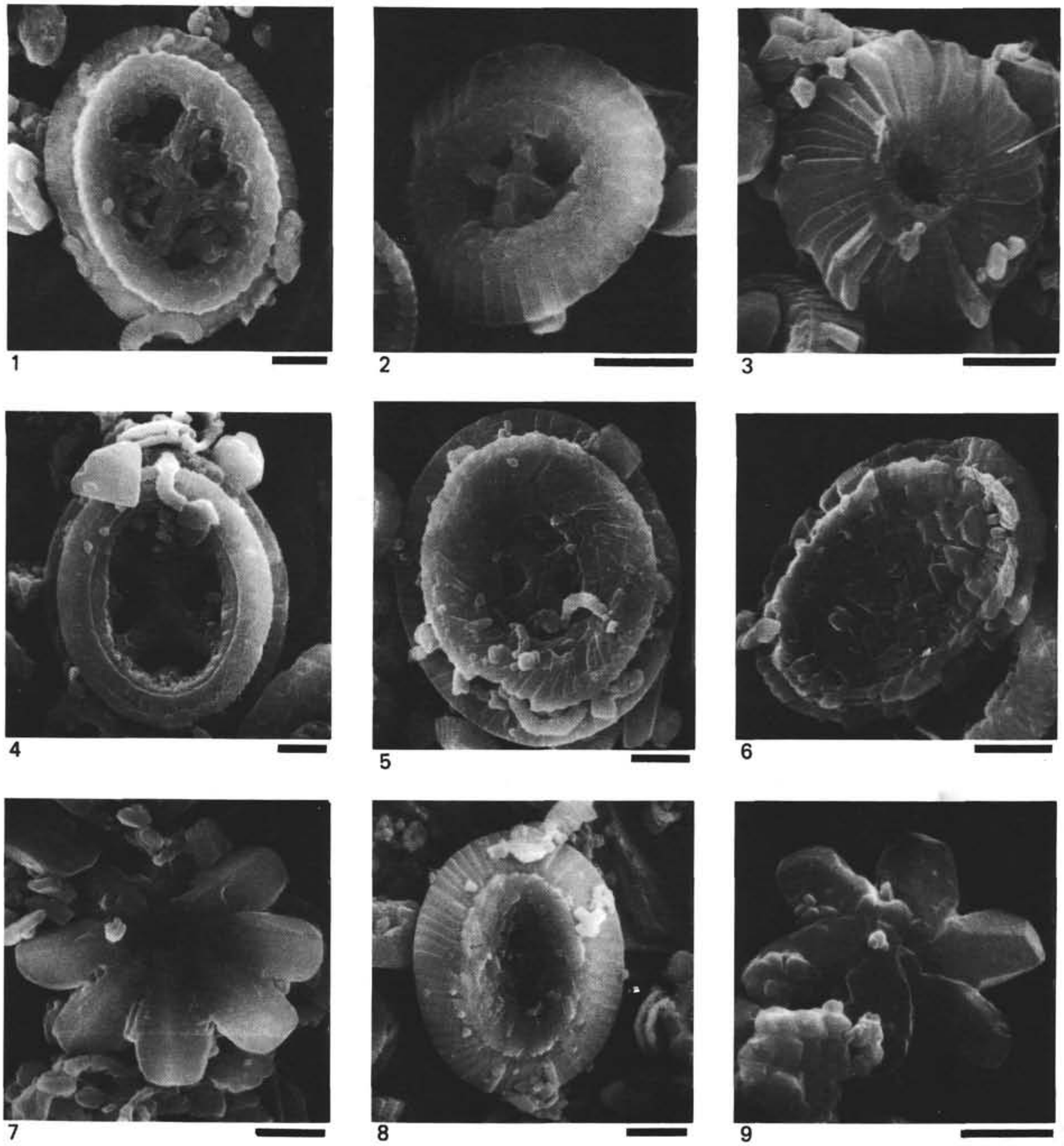

Plate 3. Coccoliths from Sample 529-24-5, 40–41 cm, except Fig. 8. (Scale bar = 3 μm.) **1, 4.** *Chiasmolithus grandis*, (1) ×2750, distal view, (4) ×2500, proximal view. **2.** *Chiasmolithus* cf. *C. consuetus*, ×5000, distal view. **3.** *Ericsonia* cf. *E. insolita*, ×4500, distal view. **5.** *Chiasmolithus* cf. *C. californicus*, ×3000, proximal view. **6.** *Chiasmolithus* cf. *C. cribellum*, ×4000. **7, 9.** *Discoaster* sp. (7) ×3500, (9) ×4500. **8.** *Ericsonia* cf. *ovalis*, ×3000, distal view, Sample 526-33-1, 105–106 cm.

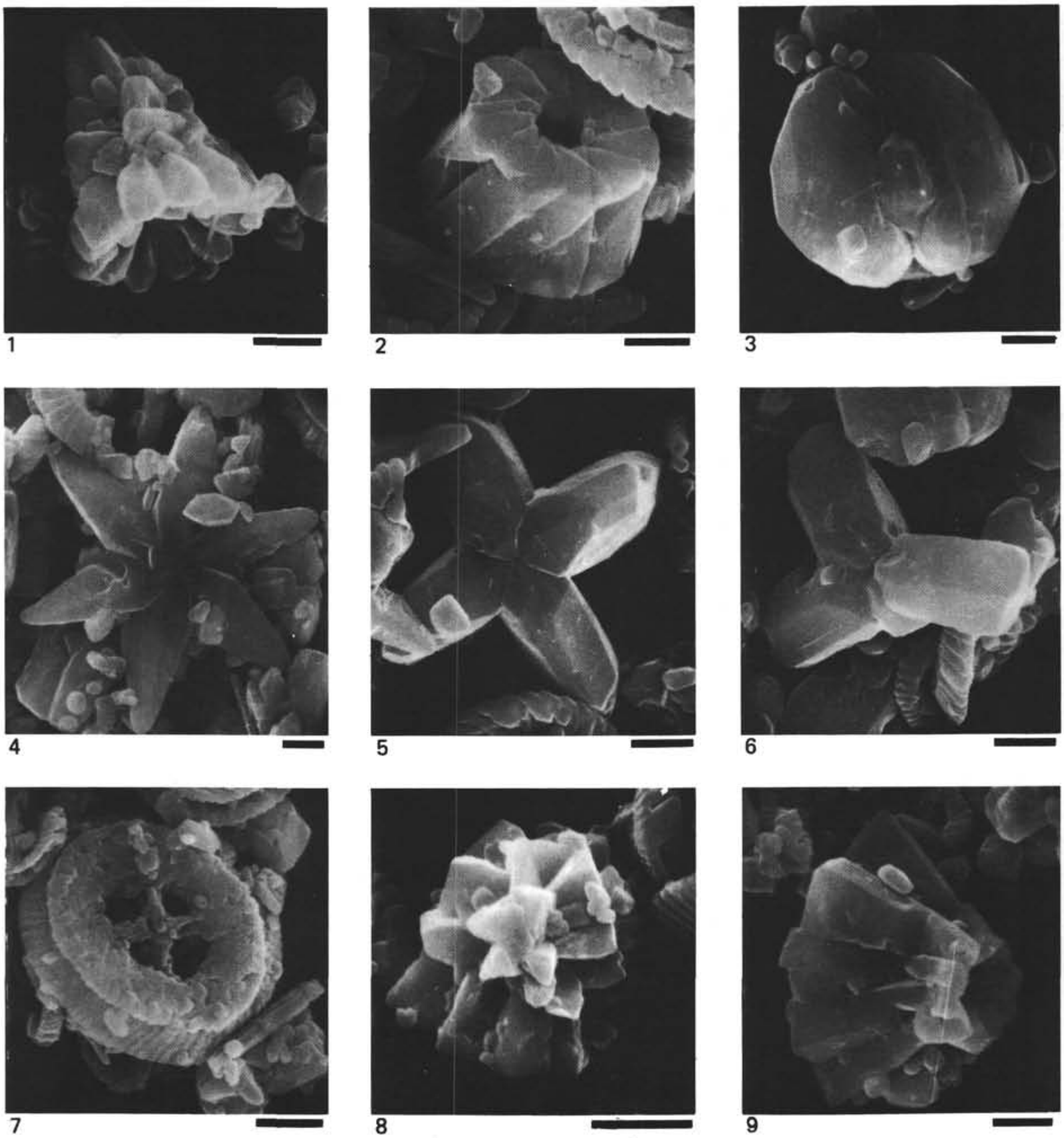


Plate 4. Nannofossils from Sample 525-25-2, 70–71 cm unless otherwise indicated. (Scale bar = 2 $\mu$m.) **1.** *Sphenolithus editus*, ×5000. **2–3.** Nannoliths, (2) ×5000, (3) ×4000. **4.** *Discoaster* cf. *D. lodoensis*, ×3000. **5.** *Discoaster cruciformis*, ×4500. **6.** *Tribrachiatus orthostylus*, ×4500. **7.** *Chiasmolithus modestus*, ×5000, distal view, Sample 529-24-5, 4-5 cm. **8.** *Sphenolithus moriformis*, ×7500, Sample 529-33-1, 147–148 cm. **9.** *Discoaster* cf. *D. robustus*, ×4500.

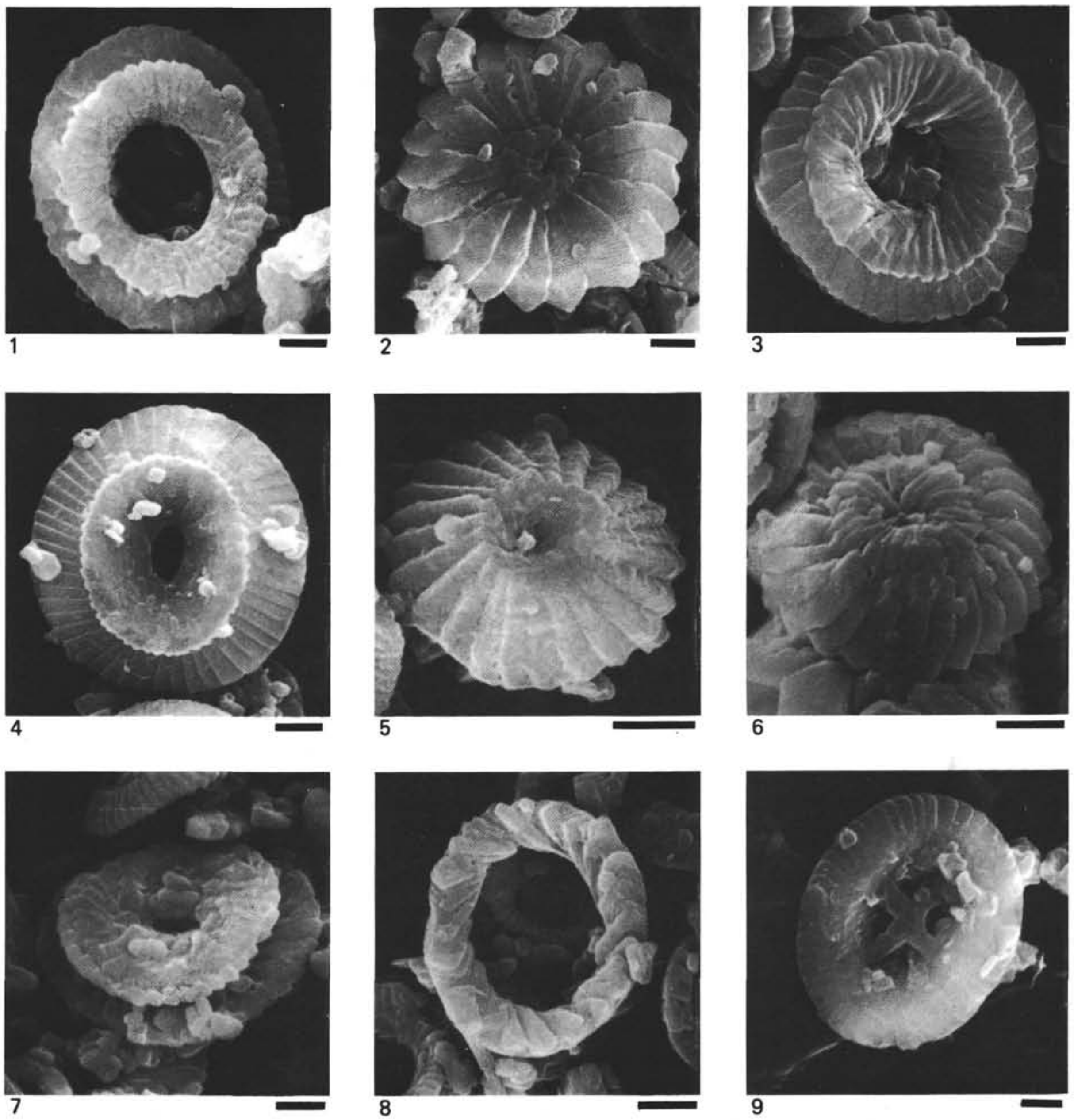


Plate 5. Nannofossils from Sample 529-29-3, 55-56 cm, unless otherwise indicated. (Scale bar = 2 μm.) **1, 3.** *Ericsonia* sp., (1) ×3500, proximal view, (3) ×3500, distal view. **2.** *Discoaster multiradiatus*, ×3000, distal view. **4, 7.** *Ericsonia cava*, (4) ×3500, distal view, (7) ×3500, proximal view. **5.** *Conococcolithus minutus*, ×6000, distal view. **6.** *Heliolithus megastypus*, ×5000, distal view. **8.** *Cyclolithella* sp., ×4500, distal view, Sample 529-31-1, 10–11 cm. **9.** *Chiasmolithus* cf. *C. consuetus*, ×3000, Sample 529-31-1, 10–11 cm.

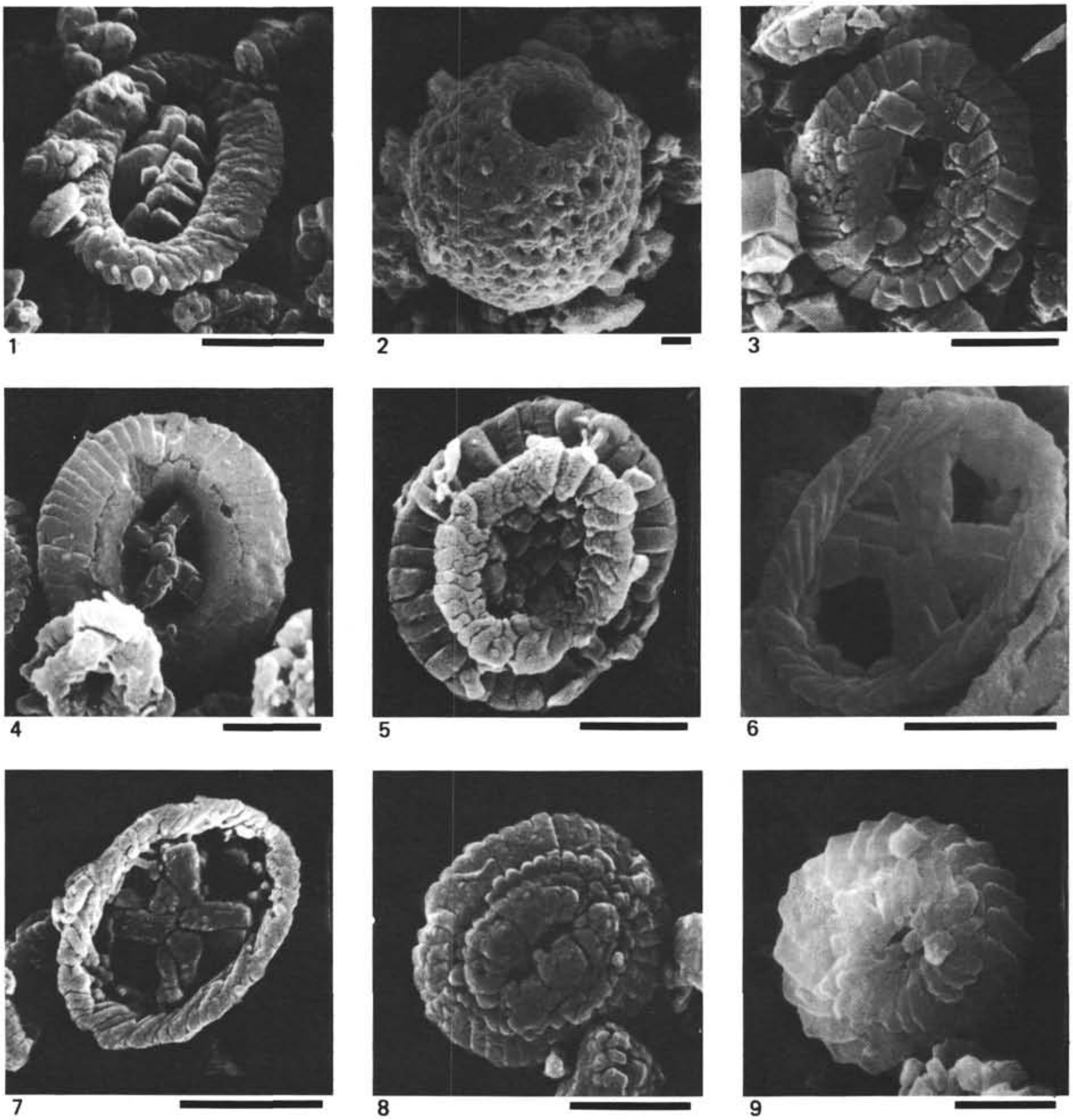

Plate 6. (Scale bar = 3 μm.) **1.** *Ellipsolithus distichus*, ×6000, distal view, Sample 528-29-1, 67–68 cm. **2.** *Thoracosphaera operculata*, ×1500, Sample 529-31-1, 10–11 cm. **3.** *Ericsonia cava*, ×5250, distal view, Sample 528-29-1, 67–68 cm. **4.** *Chiasmolithus consuetus*, ×4750, distal view, Sample 529-31-1, 10–11 cm. **5.** *Ericsonia brotzenii*, ×5250, proximal view, Sample 529-29-1, 30–31 cm. **6–7.** *Neochiastozygus modestus*, (6) ×7500, distal view, Sample 529-38-2, 7–9 cm, (7) ×7000, Sample 527-31-1, 33–34 cm. **8.** *Prinsius bisulcus*, ×6000, distal view, Sample 528-29-1, 67–68 cm. **9.** *Markalius* sp. (intermediate forms between *Markalius* and *Discoasteroides*), ×5000, Sample 529-29-1, 30–31 cm.

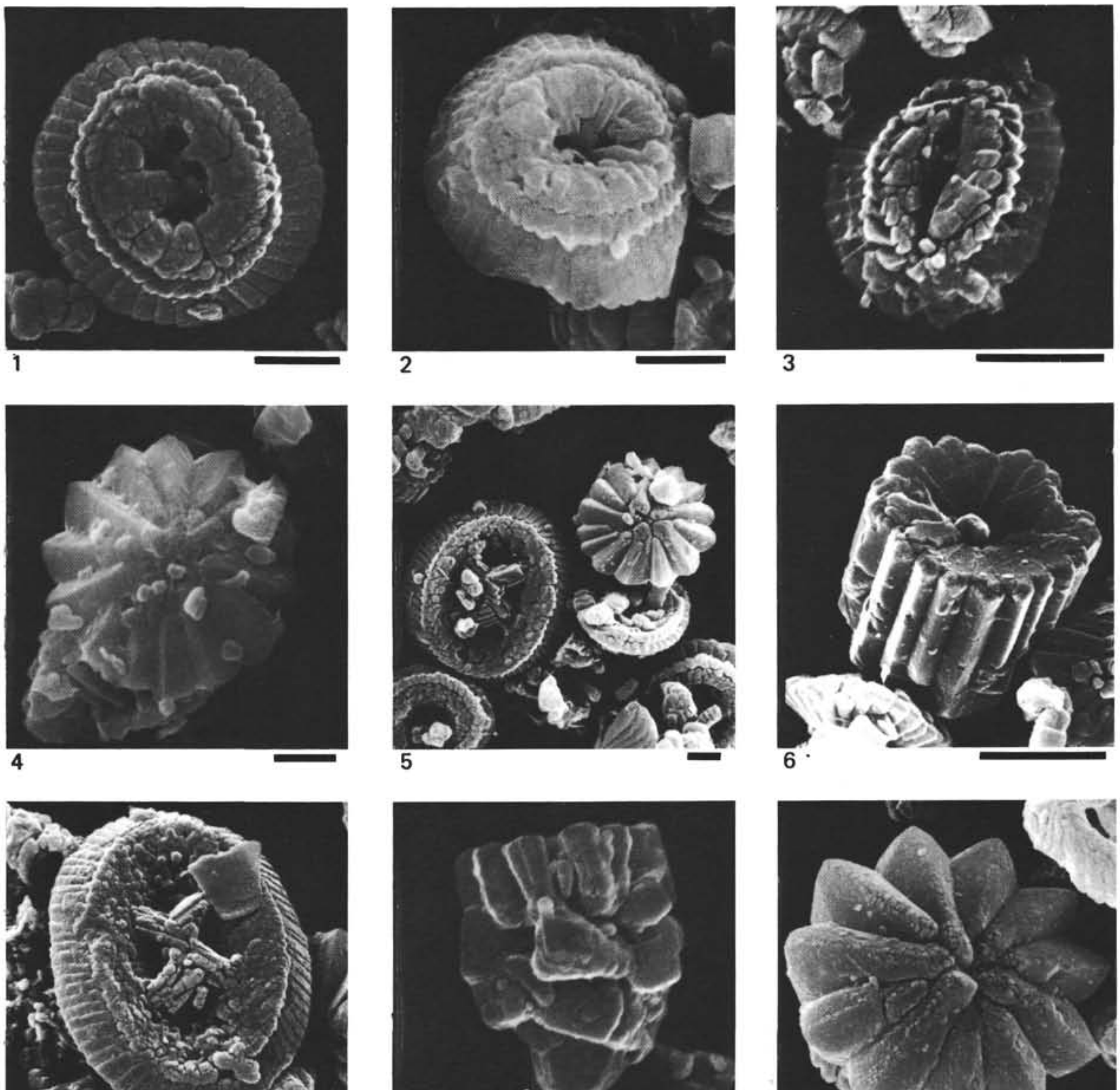

Plate 7. Nannofossils from Sample 528-29-1, 67–68 cm unless otherwise indicated. (Scale bar = 2 μm.) **1.** *Toweius eminens*, ×6000, distal view. **2.** *Prinsius bisulcus*, ×6400, Sample 528-29-3, 21–22 cm. **3.** *Prinsius martinii*, ×9000, distal view, Sample 528-29-3, 21–22 cm. **4, 9.** *Discoaster mohleri*, (4) ×4250, distal view, Sample 529-31-1, 147–148 cm, (9) ×4500. **5.** Association of *Discoaster mohleri* and *Chiasmolithus bidens*, ×2250. **6.** *Fasciculithus tympaniformis*, ×9000. **7.** *Chiasmolithus bidens*, ×5000, distal view. **8.** *Sphenolithus primus*, ×9000, Sample 528-29-3, 21–22 cm.

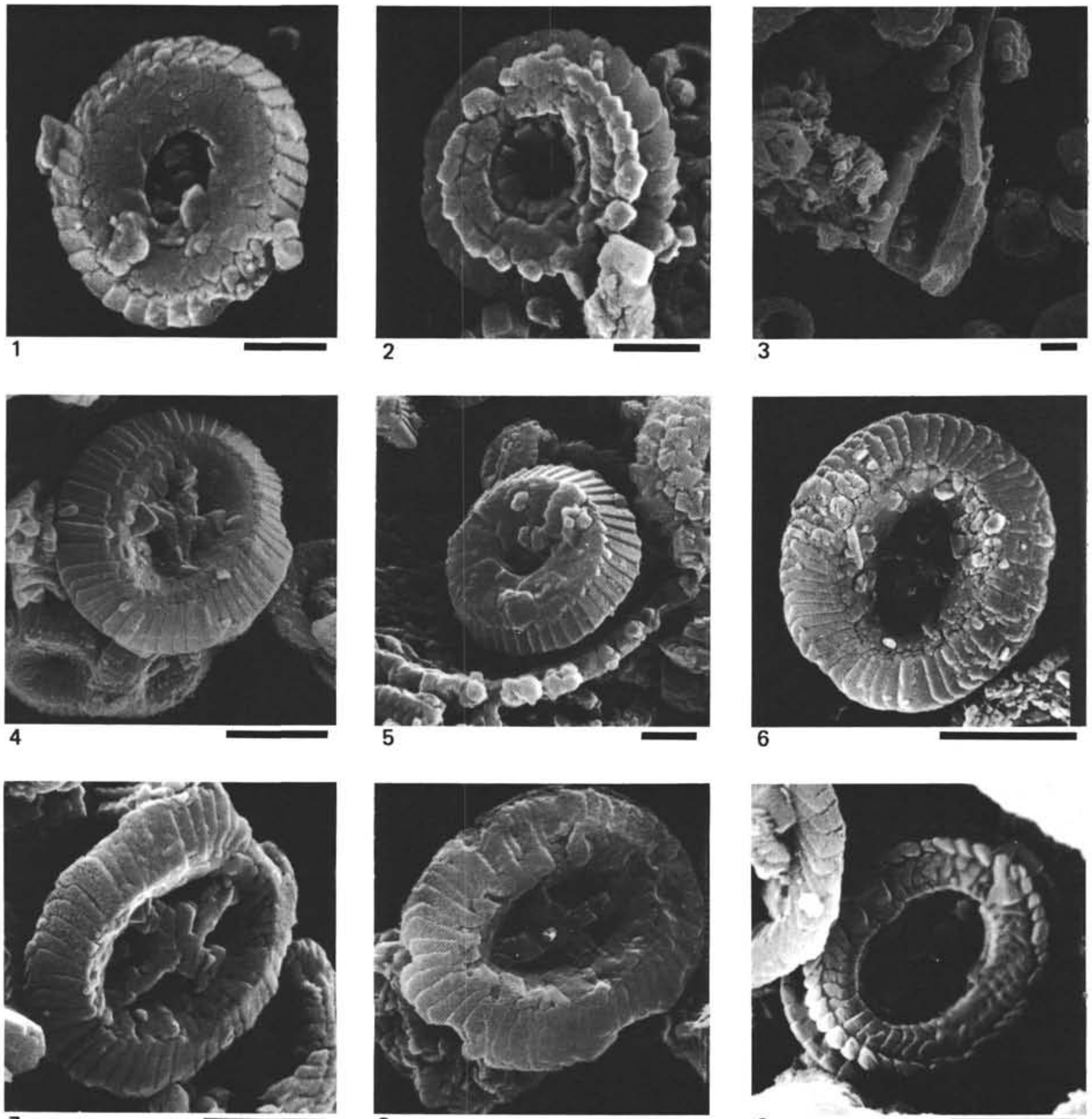

Plate 8. (Scale bar = 2 μm.) **1, 5.** *Ericsonia cava*, Sample 528-31-1, 21–22 cm, (1) ×6000, proximal view, (5) ×4000, distal view. **2.** *Ericsonia subpertusa*, ×6250, distal view, Sample 528-31-1, 21–22 cm. **3.** *Lapideacassis* cf. *L. blackii*, ×2500, Sample 528-31-1, 143–144 cm. **4.** *Cruciplacolithus notus*, ×7500, distal view, Sample 528-31-3, 143–144 cm. **4.** *Cruciplacolithus notus*, ×7500, distal view, Sample 528-31-3, 143–144 cm. **6, 9.** *Cruciplacolithus primus*, (6) ×10,000, distal view, (9) ×9000, proximal view. Sample 528-31-6, 23–24 cm, **7–8.** *Cruciplacolithus edwardsii*, Sample 528-31-1, 21–22 cm, (7) ×9000, distal view, (8) ×10,000.

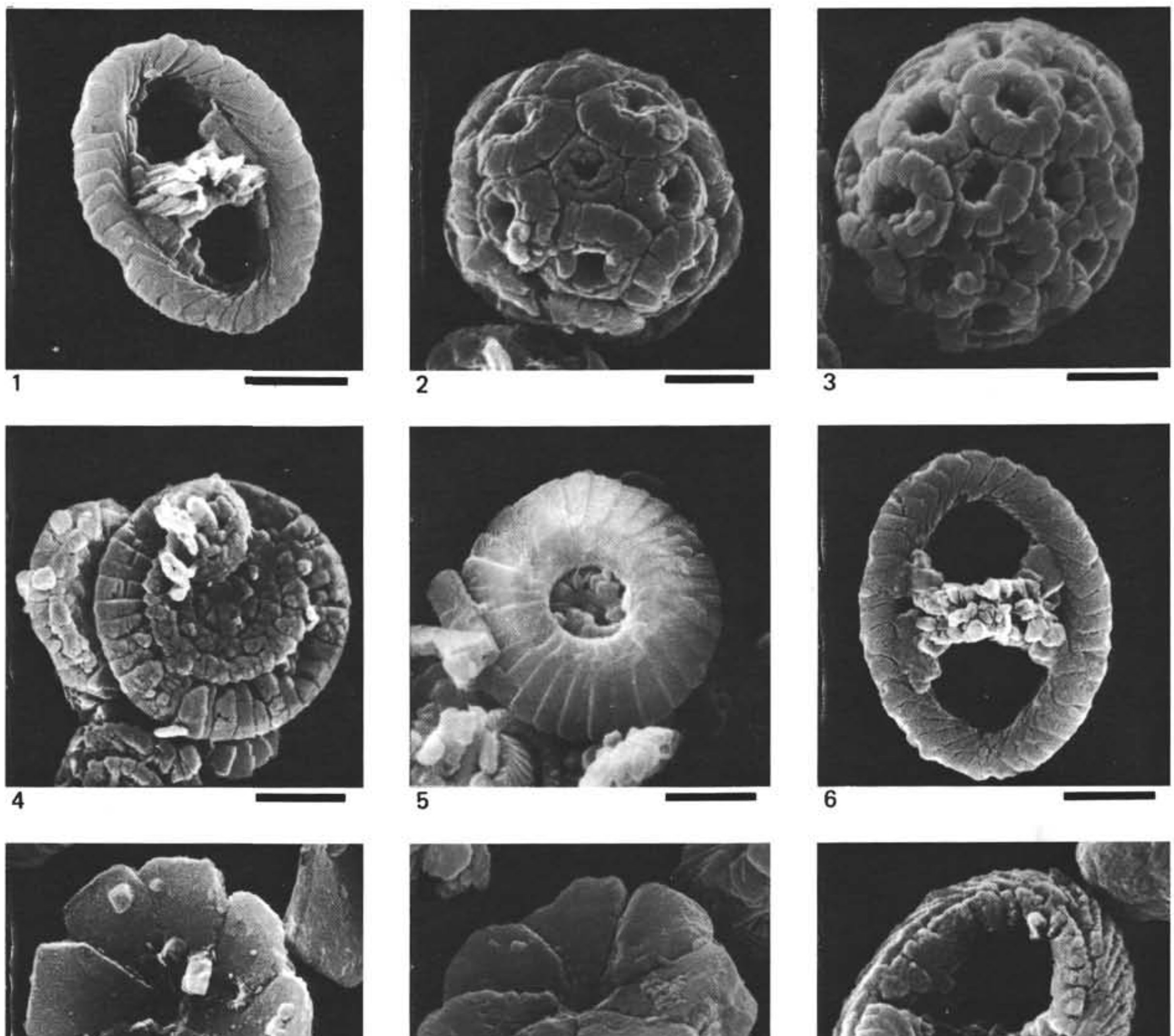


Plate 9. (Scale bar = 2 μm.) **1, 6, 9.** *Placozygus sigmoides*, Sample 528-31-1, 143–144 cm (1, 6) distal view, (1, ×7000; 6, ×6000), (9) ×6000, proximal view **2–3.** *Prinsius tenuiculum*, coccosphere, ×6000, Sample 528-31-3, 143–144 cm. **4–5.** *Markalius inversus*, (4) ×6000, proximal view, (5) distal view. **7–8.** *Biantholithus sparsus*, proximal view, Sample 525-40-2, 7–8 cm, (7) ×3000, (8) ×3500.

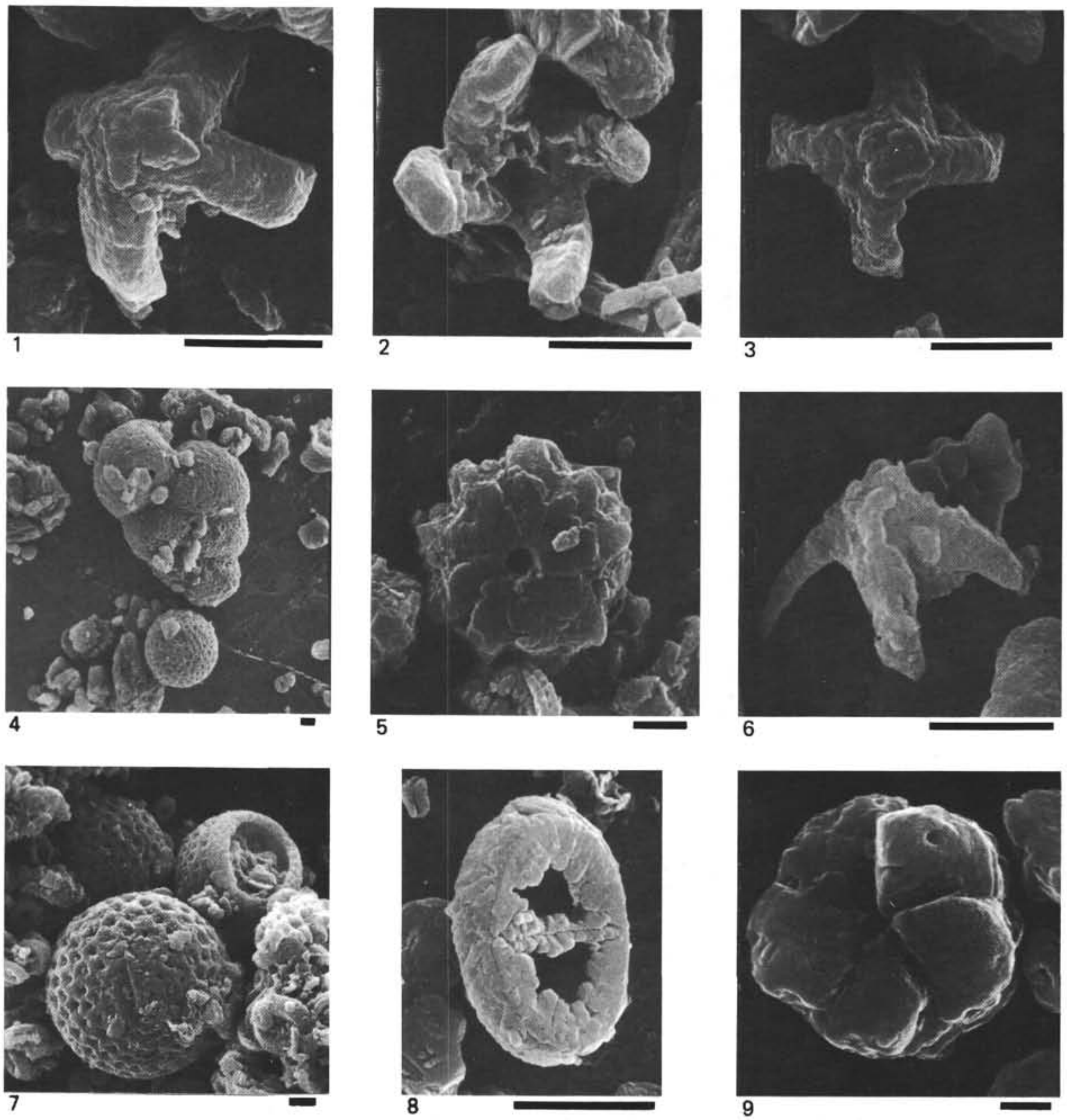

Plate 10. Nannofossils from Sample 527-32-4, 42–43 cm, unless otherwise indicated. (Scale bar = 3 μm.) **1, 2.** *Micula murus*, transitional forms between *M. murus* and *M. prinsii*, Sample 527-32-4, 42–43 cm, ×7000, (1) distal view, (2) proximal view. **3, 6.** *Micula prinsii*, ×6000, distal view. **4.** *Thoracosphaera* with foraminifers of *G. eugubina* Zone, ×500. **5.** *Biantholithus* sp. 1, ×2500, distal view, Sample 527-32-3, 50–51 cm. **7.** *Thoracosphaera* cf. *T. operculata*, ×1200, Sample 525-39-1, 28–29 cm. **8.** *Placozygus sigmoides*, ×7000, proximal view. **9.** *Braarudosphaera* sp., ×2500.

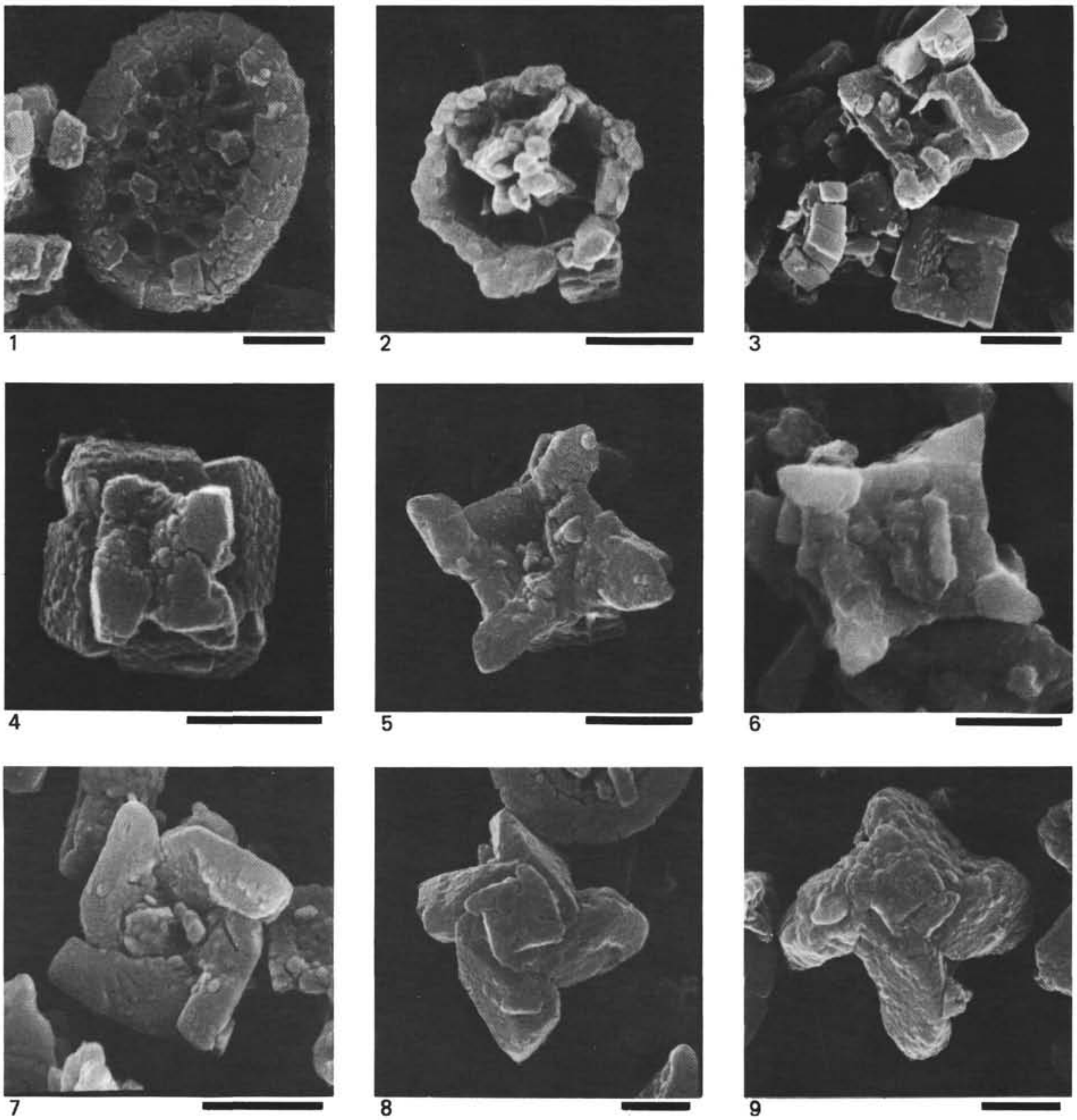


Plate 11. Nannofossils from Sample 525-40-2, 132–133 cm, unless otherwise indicated. (Scale bar = 2 $\mu$m.) **1.** *Cribrosphaerella ehrenbergi*, ×6000, distal view. **2.** *Corollithion exiguum*, ×8000, distal view, sample 527-32-4, 42–43 cm. **3–4, 6.** *Micula staurophora*, (3) ×6000, proximal view, (4) ×10000, distal view, (6) ×8000, proximal view with overgrowth. **5.** *Micula praemurus*, ×8000, proximal view. **7–9.** *Micula murus*, Sample 527-32-5, 90–91 cm, (7) ×9000 proximal view, (8–9) distal view (8, ×5000; 9, ×6000).

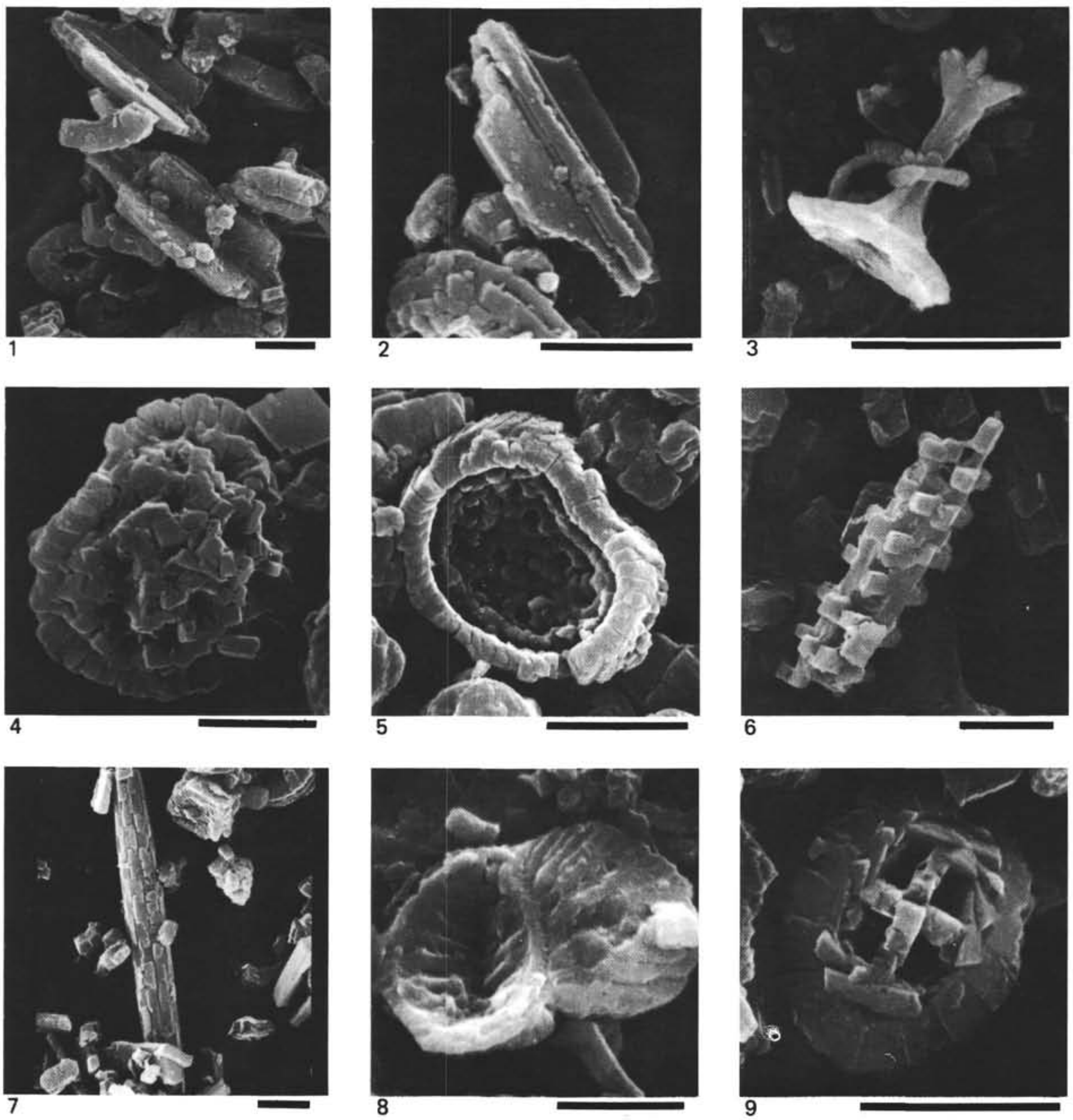

Plate 12. Nannofossils in Figures 1–2, 4–5, 9, Sample 525-41-6, 90-91 cm; in Figure 3, 6-8, Sample 525-40-2, 132-133 cm. (Scale bar = 3 $\mu$m.) **1–2.** *Lithraphidites quadratus*, (1) ×3000, one specimen on proximal side, (2) ×7500, side view. **3.** *Prediscosphaera cretacea*, ×10,500. **4–5.** *Nephrolithus frequens*, (4) ×6000, distal view, (5) ×7000, proximal view. **6.** *Microrhabdulus belgicus*, ×4500. **7.** *Microrhabdulus stradneri*, ×2500. **8.** *Kamptnerius magnificus*, ×6250, proximal view. **9.** *Prediscosphaera stoveri*, ×10,000, distal view.