29. COCCOLITH STRATIGRAPHY LEG 6, DEEP SEA DRILLING PROJECT

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Leg 6 of the Deep Sea Drilling Project, through the northwestern Pacific Ocean from Hawaii to Guam, June-August 1969, recovered 124 cores. Approximately 700 samples from these cores were examined for coccoliths by light-microscope, and selected ones were viewed by an electron microscope. A general discussion of the results is presented first. After this some coccolith species in selected samples from each drilling site, listed by biostratigraphic zone, follow a summary of the coccolith stratigraphy of each area. The coccolith zones used in this report are based on the tentative ones described by Bukry and Bramlette (1970a) in the report on Leg 3. During the study of the Leg 6 material, M. N. Bramlette, of Scripps Institution of Oceanography, provided generous interest and support. His valuable suggestions were of help in the stratigraphic assignment of these cores. The coccolith species considered in this report are listed below.

TABLE 1
Coccolith Species Considered in this Report

Apertapetra gronosa (Stover)
Arkhangelskiella cymbiformis Vekshina
Bramletteius serraculoides Gartner
Campylosphaera dela (Bramlette and Sullivan)
Catinaster calyculus Martini and Bramlette
Catinaster sp. cf. *C. calyculus* Martini and Bramlette
Catinaster coalitus Martini and Bramlette
Ceratolithus cristatus Kamptner
Ceratolithus rugosus Bukry and Bramlette
Ceratolithus tricorniculatus Gartner
Chiasmolithus bidens (Bramlette and Sullivan)
Chiasmolithus californicus (Sullivan)
Chiasmolithus consuetus (Bramlette and Sullivan)
Chiasmolithus grandis (Bramlette and Riedel)
Chiasmolithus solitus (Bramlette and Sullivan)
Chiastozygus disgregatus (Stover)
Chiphragmalithus calathus Bramlette and Sullivan
Coccolithus bisectus (Hay, Mohler, and Wade) Bramlette and Wilcoxon
Coccolithus sp. aff. *C. bisectus* (Hay, Mohler, and Wade) Bramlette and Wilcoxon

TABLE 1 – *Continued*

Coccolithus cavus Hay and Mohler
Coccolithus sp. cf. *C. crassus* Bramlette and Sullivan
Coccolithus sp. cf. *C. doronicoides* Black and Barnes
Coccolithus eopelagicus Bramlette and Riedel
Coccolithus pelagicus (Wallich)
Coccolithus sp.
Coronocyclus sp. cf. *C. serratus* Hay, Mohler, and Wade
Cretarhabdus? anthophorus (Deflandre)
Cretarhabdus crenulatus Bramlette and Martini
Cribrosphaera ehrenbergi Arkhangelsky
Cruciplacolithus tenuis (Stradner)
Cyclococcolithus formosus Kamptner
Cyclococcolithus gammation (Bramlette and Sullivan)
Cyclococcolithus leptoporus (Murray and Blackman)
Cyclococcolithus macintyrei Bukry and Bramlette
Cyclococcolithus neogammation Bramlette and Wilcoxon
Cyclolithella? annula (Cohen)
Cyclolithella? robusta (Bramlette and Sullivan)
Cylindralithus gallicus Bramlette and Martini
Cylindralithus sp.
Diazomatolithus lehmani Noël
Discoaster aulakos Gartner
Discoaster barbadiensis Tan
Discoaster brouweri Tan
Discoaster calcaris Gartner
Discoaster challengeri Bramlette and Riedel
Discoaster sp. cf. *D. challengeri* Bramlette and Riedel
Discoaster deflandrei Bramlette and Riedel
Discoaster diastypus Bramlette and Sullivan
Discoaster druggi Bramlette and Wilcoxon
Discoaster sp. cf. *druggi* Bramlette and Wilcoxon
Discoaster exilis Martini and Bramlette
Discoaster sp. aff. *D. exilis* Martini and Bramlette
Discoaster sp. aff. *D. gemmeus* Stradner

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

TABLE 1 – *Continued*

Discoaster hamatus Martini and Bramlette
Discoaster kuepperi Stradner
Discoaster kugleri Martini and Bramlette
Discoaster lenticularis Bramlette and Sullivan
Discoaster lodoensis Bramlette and Riedel
Discoaster sp. aff. *D. lodoensis* Bramlette and Riedel
Discoaster mirus Deflandre
Discoaster multiradiatus Bramlette and Riedel
Discoaster neohamatus Bukry and Bramlette
Discoaster pentaradiatus Tan
Discoaster perplexus Bramlette and Riedel
Discoaster quintatus Bukry and Bramlette
Discoaster sp. cf. *D. quintatus* Bukry and Bramlette
Discoaster robustus Haq
Discoaster saipanensis Bramlette and Riedel
Discoaster surculus Martini and Bramlette
Discoaster sp. cf. *D. surculus* Martini and Bramlette
Discoaster tani nodifera Bramlette and Riedel
Discoaster tani tani Bramlette and Riedel
Discoaster variabilis Martini and Bramlette
Discoaster sp. cf. *D. variabilis* Martini and Bramlette
Discoaster wemmelensis Achuthan and Stradner
Discoaster sp.
Discolithina asper (Stradner)
Discolithina rimosa (Bramlette and Sullivan)
Discolithina rugosa (Noël)
Discolithina sp.
Eiffellithus augustus Bukry
Eiffellithus eximius (Stover)
Eiffellithus turriseiffeli (Deflandre)
Ellipsolithus distichus (Bramlette and Sullivan)
Ellipsolithus macellus (Bramlette and Sullivan)
Fasciculithus involutus Bramlette and Sullivan
Fasciculithus tympaniformis Hay and Mohler
Fasciculithus sp.
Gartnerago concavum (Gartner)
Gephyrocapsa oceanica Kamptner
Gephyrocapsa protohuxleyi McIntyre
Gephyrocapsa sp.
Helicopontosphaera compacta (Bramlette and Wilcoxon)
Helicopontosphaera kamptneri Hay and Mohler
Helicopontosphaera obliqua (Bramlette and Wilcoxon)

TABLE 1 – *Continued*

Helicopontosphaera parallela (Bramlette and Wilcoxon)
Helicopontosphaera sellii Bukry and Bramlette
Heliolithus kleinpelli Sullivan
Heliolithus riedeli Bramlette and Sullivan
Isthmolithus recurvus Deflandre
Leptodiscus larvalis Bukry and Bramlette
Lithastrinus floralis Stradner
Lophodolithus nascens Bramlette and Sullivan
Markalius astroporus (Stradner)
Marthasterites tribrachiatus (Bramlette and Riedel)
Marthasterites sp. cf. *M. tribrachiatus* (Bramlette and Riedel)
Microrhabdulus decoratus Deflandre
Micula decussata Vekshina
Micula sp. aff. *M. decussata* Vekshina
Micula sp. cf. *M. decussata* Vekshina
Orthorhabdus serratus Bramlette and Wilcoxon
Parhabdolithus angustus (Stradner)
Parhabdolithus embergi (Noël)
Prediscosphaera columnatus (Stover)
Prediscosphaera cretacea cretacea (Arkhangelsky)
Prediscosphaera cretacea lata Bukry
Reticulofenestra sp. cf. *R. dictyoda* (Deflandre)
Reticulofenestra pseudoumbilica (Gartner)
Reticulofenestra umbilica (Levin)
Reticulofenestra sp. cf. *R. umbilica* (Levin)
Rhabdolithus sp. cf. *R. sceptrum* Deflandre of Lezaud
Rhabdosphaera clavigera Murray and Blackman
Rhabdosphaera stylifera Lohmann
Rhomboaster cuspis Bramlette and Sullivan
Rucinolithus hayi Stover
Scyphosphaera sp. cf. *S. apsteinii* Lohmann
Scyphosphaera pulcherrima Deflandre
Sphenolithus abies Deflandre
Sphenolithus anarrhopus Bukry and Bramlette
Sphenolithus belemnos Bramlette and Wilcoxon
Sphenolithus sp. aff. *S. belemnos* Bramlette and Wilcoxon
Sphenolithus ciperoensis Bramlette and Wilcoxon
Sphenolithus sp. cf. *S. ciperoensis* Bramlette and Wilcoxon
Sphenolithus distentus (Martini)
Sphenolithus sp. aff. *S. distentus* (Martini)
Sphenolithus heteromorphus Deflandre

TABLE 1 – *Continued*

Sphenolithus moriformis (Brönnimann and Stradner)
Sphenolithus sp. aff. *S. moriformis* (Brönnimann and Stradner)
Sphenolithus predistentus Bramlette and Wilcoxon
Sphenolithus pseudoradians Bramlette and Wilcoxon
Sphenolithus radians Deflandre
Stephanolithion sp. aff. *S. bigoti* Noël
Stephanolithion laffittei Noël
Syracosphaera pulchra Lohmann
Tetralithus murus Martini
Tetralithus sp. cf. *T. murus* Martini
Tetralithus pyramidus Gardet
Thoracosphaera prolata Bukry and Bramlette
Toweius eminens (Bramlette and Sullivan)
Toweius craticulus Hay and Mohler
Triquetrorhabdulus carinatus Martini
Triquetrorhabdulus sp. cf. *carinatus* Martini
Triquetrorhabdulus rugosus Bramlette and Wilcoxon
Triquetrorhabdulus inversus Bukry and Bramlette
Umbilicosphaera mirabilis Lohmann
Vagalapilla octoradiata (Gorka)
Watznaueria actinosa (Stover)
Watznaueria barnesae (Black)
Watznaueria britannica (Stradner)
Watznaueria coronata (Gartner)
Watznaueria sp. cf. *W. coronata* (Gartner)
Zygodiscus fibulus (Stradner)
Zygodiscus phacelosus (Stover)
Zygodiscus sigmoides Bramlette and Sullivan
Zygodiscus simplex (Bramlette and Sullivan)
Zygodiscus sp. cf. *Z. theta* (Black)
Zygolithus ponticulus Deflandre
Zygolithus xenotus Stover

DISCUSSION

Stratigraphic Zonation

Effective stratigraphic subdivision of the geologic record, as represented in oceanic sediment, may result from recognition of an evolutionary sequence of skeletal hardparts. Distinctly shaped forms or particularly abundant ones can be used to characterize an assemblage and thus a stratigraphic interval. Geographic ranges of the organisms producing such fossils and the relative preservability of the skeletons in sediment are limiting factors in recognizing zones based on both a single form and on an assemblage of forms. A system of zones based on assemblages has wider geographic applicability and is useful, because the ecologic and preservational factors that affect a single species do not necessarily affect all members of the assemblage. Thus a concurrent-range zone such as the *Helicopontosphaera ampliaperta* Zone can be identified, even in the absence of *H. ampliaperta* itself, by the other members of the assemblage: *Cyclococcolithus neogammation, Discoaster deflandrei* and *Sphenolithus heteromorphus.* Concurrent-range zones have been used in this study; those identified in the Leg 6 material are listed in Table 2.

Although latitudinal distribution of cores obtained during Leg 6 ranges only from 8° North to 32° North, the geologic age ranges from Late Jurassic to Holocene. The extensive Caroline Ridge Miocene-Oligocene collection and the unusually complete Shatsky Plateau Paleocene section are particularly useful in terms of stratigraphic zonation.

TABLE 2
Named Coccolith Zones Recognized in Cores from Leg 6. For Description of these Tentative Zones See Bukry and Bramlette (1969b, 1970a).

AGE	ZONE
PLEISTOCENE	*Gephyrocapsa oceanic*
	Coccolithus doronicoides
PLIOCENE	*Discoaster brouweri*
	Reticulofenestra pseudoumbilica
PLIOCENE OR MIOCENE	*Ceratolithus rugosus*
MIOCENE	*Ceratolithus tricorniculatus*
	Discoaster neohamatus
	Discoaster hamatus
	Catinaster coalitus
	Discoaster kugleri
	Sphenolithus heteromorphus
	Helicopontosphaera ampliaperta
	Triquetrorhabdulus carinatus (*Discoaster druggi* (Subzone)
OLIGOCENE	*Triquetrorhabdulus carinatus* (*Coccolithsu* sp. aff. *C. bisectus* Subzone)

TABLE 2 – *Continued*

AGE	ZONE
OLIGOCENE	*Sphenolithus ciperoensis*
	Sphenolithus predistentus
	Helicopontosphaera reticulata
EOCENE	*Discoaster barbadiensis*
	Reticulofenestra umbilica
	Discoaster lodoensis
	Marthasterites tribrachiatus
	Discoaster diastypus
PALEOCENE	*Discoaster multiradiatus*
	Discoaster gemmeus
	Heliolithus riedeli
	Heliolithus kleinpelli
	Cruciplacolithus tenuis
MAESTRICHTIAN	*Tetralithus murus*
	Lithraphidites quadratus

TABLE 3
Comparison of Lower Miocene-Upper Oligocene Coccolith Zonation

	Trinidad, W.I.	Western Pacific, Leg 6
LOWER MIOCENE	*Helicopontosphaera ampliaperta*	*Helicopontosphaera ampliaperta*
	Sphenolithus belemnos	
		Upper *Triquetrorhabdulus* (*Discoaster druggi* Subzone)
	Triquetrorhabdulus carinatus	
UPPER OLIGOCENE		Lower *Triquetrorhabdulus carinatus* (*Coccolithsu* sp. aff. *C. bisectus* Subzone)
	Sphenolithus ciperoensis	*Sphenolithus ciperoensis*

The *T. carinatus* Zone, as defined in Trinidad, is represented extensively in cores and samples from tropical areas and includes strata tentatively assigned to the upper Oligocene and lower Miocene. This designation is, in part, based on the assignment of the *Globorotalia kugleri* Zone (foraminifers) of Bolli (1966), as the youngest zone of the Oligocene, and the *Catapsydrax dissimilis* Zone (foraminifers) of Bolli, as the oldest zone of the Miocene. The suggestion that such species as *Discoaster druggi* and *Orthorhabdus serratus,* when present, mark the upper part of the *T. carinatus* Zone (Bukry and Bramlette, 1970a) has been used in the stratigraphic assignment of cores from the western Pacific. For the purposes of this report the upper part of the *T. carinatus* Zone, considered lower Miocene, can be designated the *Discoaster druggi* Subzone in some cores (Site 56 and 58). See Table 3.

In the lower part of the *T. carinatus* Zone, considered upper Oligocene, these western Pacific cores are characterized by *Coccolithus* sp. aff. *C. bisectus.* This common occurrence contrasts with the consistent absence, or only rare presence, of this species in the upper *T. carinatus* Zone or *D. druggi* Subzone of the same locality. It should be noted that whereas this species allowed further distinction of the upper and lower *T. carinatus* Zone here, it commonly ranges throughout the zone in samples from the Atlantic basin (Trinidad and South Atlantic sites of Leg 3).

A complete upper Paleocene sequence of four widely recognized coccolith zones in Cores 47.2-8 and 47.2-9 is identified by diverse species of large size. But the lower Paleocene assemblages are dominated by small coccolith species that will require examination by electron microscope to help differentiate units within the single zone now recognized. The upper Paleocene *Discoaster multiradiatus* Zone is represented by assemblages containing *Campylosphaera dela* (small narrow variety), *Chiasmolithus bidens, Discoaster lenticularis, D. multiradiatus, Discolithina rimosa, Ellipsolithus distichus, E. macellus, Lophodolithus nascens, Rhomboaster cuspis, Sphenolithus anarrhopus* and *Toweius craticulus.* The assemblages of the *Discoaster gemmeus* Zone and *Heliolithus riedeli* Zone are similar; prominent species include: *C. bidens, C. californicus, C. consuetus, Cyclolithella robusta, Discoaster* sp. aff. *D. gemmeus, E. distichus, E. macellus, Heliolithus riedeli, Fasciculithus involutus, F. tympaniformis, S. anarrhopus* and *T. craticulus.* The *Heliolithus kleinpelli* Zone is represented through most of Core 47.2-9. The most prominent species present include: *C. californicus, C. consuetus, D.* sp. aff. *D. gemmeus, E. macellus, F. tympaniformis, Heliolithus kleinpelli, S. anarrhopus, T. craticulus* and *Zygodiscus sigmoides. Cruciplacolithus tenuis* is sparse here, but it is quite prominent in the lower Paleocene section represented throughout Core 47.2-10.

TABLE 4
Comparison of Upper Tertiary Pacific Assemblages for Ecologic Interpretation

	Cool Temperate DSDP 5/32-37	Warm Temperate DSDP 6/47-48	Tropical DSDP 6/55-58
UPPER PLEISTOCENE	*C. pelagicus* *C.* sp. (small) *G. oceanica*	*C. cristatus* *C.* cf. *doronicoides* *C. pelagicus* *C. leptoporus* *C.* ? *annula* *G. oceanica* *G. protohuxleyi* *H. kamptneri* *H. sellii* *R. clavigera* *S. pulchra* *U. mirabilis*	*C. cristatus* *C. leptoporus* *C.* ? *annula* *G. oceanica* *H. kamptneri* *H. sellii* *R. clavigera* *U. mirabilis*
LOWER PLEISTOCENE	*C.* cf. *doronicoides* *C. pelagicus* *C. leptoporus* *C.* ? *annula* *H. sellii*	*C.* cf. *doronicoides* *C. pelagicus* *C. leptoporus* *C.* ? *annula* *H. kamptneri* *H. sellii* *R. clavigera* *S.* cf. *apsteinii*	*C. cristatus* *C. rugosus* *C.* cf. *doronicoides* *C. leptoporus* *C.* ? *annula* *H. kamptneri* *H. sellii* *R. clavigera*

TABLE 4 – *Continued*

	Cool Temperate TE DSDP 5/32-37	Warm Temperate DSDP 6/47-48	Tropical DSDP 6/55-58
			C. cristatus
	C. cf. *doronicoides*	*C. cristatus*	*C. rugosus*
	C. pelagicus	*C. rugosus*	*C.* cf. *doronicoides*
	C. leptoporus	*C.* cf. *doronicoides*	*C. pelagicus*
	C. macintyrei	*C. pelagicus*	*C. leptoporus*
UPPER	*D. brouweri*	*C. leptoporus*	*C. macintyrei*
PLIOCENE	*D. challengeri*	*C. macintyrei*	*D. brouweri*
	D. exilis	*D. brouweri*	*D. challengeri*
	D. pentaradiatus	*D. exilis*	*D. pentaradiatus*
	D. surculus	*D.* cf. *surculus*	*D. surculus*
	D. variabilis	*H. kamptneri*	*D.* cf. *variabilis*
	H. sellii (rare)	*R. stylifera*	*H. sellii*
			S. cf. *apsteinii*
		C. rugosus	
		C. tricorniculatus	
	C. tricorniculatus	*C. leptoporus*	*C. rugosus*
	C. pelagicus	*C. macintyrei*	*C. tricorniculatus*
	C. leptoporus	*D. brouweri*	*C. leptoporus*
LOWER	*C. macintyrei*	*D. challengeri*	*C. macintyrei*
PLIOCENE	*D. brouweri*	*D. exilis*	*D. brouweri*
OR	*D. challengeri*	*D. pentaradiatus*	*D. challengeri*
UPPER	*D. exilis*	*D. quintatus*	*D. pentaradiatus*
MIOCENE	*D. pentaradiatus*	*D. surculus*	*D. quintatus*
	D. quintatus	*D. variabilis*	*D. surculus*
	D. variabilis	*D.* sp. (asymmetric)	*R. pseudoumbilica*
	R. pseudoumbilica	*H. kamptneri*	*S.* cf. *apsteinii*
	S. abies (rare)	*H. sellii*	*S. abies*
		R. pseudoumbilica	*T. rugosus*
		S. pulcherrima	
		S. abies (rare)	

In the lower Paleocene assemblages, assigned to the *Cruciplacolithus tenuis* Zone, the few large coccoliths include *Coccolithus cavus* (=*Coccolithus pelagicus s.l.*), *C. tenuis, Fasciculithus* sp., and *Z. sigmoides.* The basal Paleocene is recognized in the upper part of Core 47.2-11, as elsewhere, on the basis of abundant minute coccoliths (M. N. Bramlette and W. W. Hay, personal communication), *C. cavus,* and *C. tenuis.* There is substantial reworking of Cretaceous material in these basal samples as represented by such species as *Arkhangelskiella cymbiformis, Tetralithus murus,* and possibly *Markalius astroporus.*

Although the array of species in this Paleocene section is somewhat different from the previously described Paleocene sections (Bramlette and Sullivan, 1961; Bramlette and Martini, 1964; and Hay and Mohler, 1967), probably owing to the offshore environment represented at Site 47, the important guide species are present. More detailed study of this section should produce significant results on the lower Tertiary stratigraphy of calcareous nannoplankton.

Paleoecology

A preliminary comparison of late Tertiary nannoplankton from the area of the cool California Current west of northern California (Leg 5, Sites 32 through 37), that of the warm Japan Current northeast of Japan (Leg 6, Sites 47 and 48), and the warm area of the Caroline Islands where the Northern Equatorial Current and Equatorial Counter Current are present (Leg 6, Sites 55 through 58), shows differences in coccolith floras of the same age (Table 4). Many species, such as, *Ceratolithus tricorniculatus, Cyclococcolithus leptoporus, Discoaster brouweri,* and *Reticulofenestra pseudoumbilica* appear to be cosmopolitan throughout the samples considered. Other species are commonly present only in warm-water areas, for example, *Ceratolithus cristatus, C. rugosus, Helicopontosphaera kamptneri, Rhabdosphaera clavigera, R. stylifera, Scyphosphaera* sp. cf. *S. apsteinii, S. pulcherrima, Sphenolithus abies* and *Triquetrorhabdulus rugosus.* Species of *Discoaster* seem generally cosmopolitan, but *D. exilis s.l.* and *D. variabilis s.l.* are more abundant in the cooler, more northerly sites.

COCCOLITH STRATIGRAPHY OF CORES FROM LEG 6

Sample numbers given under the biostratigraphic zones for each site represent, in the following sequence: (cruise-leg number)–(drill-hole designation, consisting of site number plus a decimal suffix, if more than one hole)–(core designation)–(core-section number), and the interval below the top of each core section in centimeters. For example, 6-47.2-8-3, 75-76 cm, indicates that the sample came from Leg 6, Hole 47.2 (at Site 47), the eighth barrel of core recovered, the third section from the top of that core, and from 75 to 76 centimeters below the top of the section. The core sections are 1.5 meters long; most core runs were 9.1 meters long, but occasionally the core liners were not full. In this report, recoveries are arbitrarily placed at the top of the core runs, and an approximate depth in meters below the sea floor follows each sample number.

HOLE 44.0
(lat 19°18.5'N, long 169°00.0'W, depth 1478 meters)

Summary of Coccolith Stratigraphy

In Core 1 most of the coccolith assemblages represent the *Sphenolithus predistentus* Zone. Rare *Bramletteius serraculoides, Cyclococcolithus formosus* and *Reticulofenestra umbilica* at the top of the core and gradually increasing numbers of these species downward through the core suggest that only the lower *S. predistentus* Zone is represented. Most coccolith assemblages of the lowest Oligocene (*Helicopontosphaera reticulata* Zone) contain abundant *B. serraculoides, C. formosus* and *R. umbilica,* but such an assemblage is apparently not present in Core 1; however, it may have been represented in the lower three meters of this core, which was lost. The top of Core 2 contains an Eocene *Discoaster barbadiensis* Zone assemblage, that includes common large *Discoaster tani tani* along with *D. barbadiensis* and *D. saipanensis,* indicating a late Eocene age for the whole core. In Core 3, however, the absence of common large *D. tani tani* and the presence of *Chiasmolithus grandis* and *Thoracosphaera prolata,* along with large specimens of *R. umbilica,* indicate an assignment of this core to the middle Eocene *R. umbilica* Zone.

It is evident that the original outline of discoasters in high-carbonate oceanic sediment, as in other relatively permeable sediment (Bramlette and Sullivan, 1961), is commonly obscured by a secondary overgrowth of calcite. For example, *Discoaster tani nodifera* is typically a 6-rayed form with parallel-sided rays bearing lateral nodes half way along each ray. The rays terminate bluntly with a slight indentation at the end. In oceanic samples, however, calcite overgrowths on this species produce diamond-shaped rays, the lateral nodes forming two apices of the diamond. The terminal indentation also disappear.

In Cores 4 and 5, the assemblages are slightly different with *Campylosphaera dela* and *Triquetrorhabdulus inversus* being present. These assemblages, as well as those of Core 3, are considered to belong to the middle Eocene *R. umbilica* Zone.

The relative abundance of some species fluctuates greatly in samples through these cores, indicating that they may prove useful in future ecologic studies on Eocene assemblages.

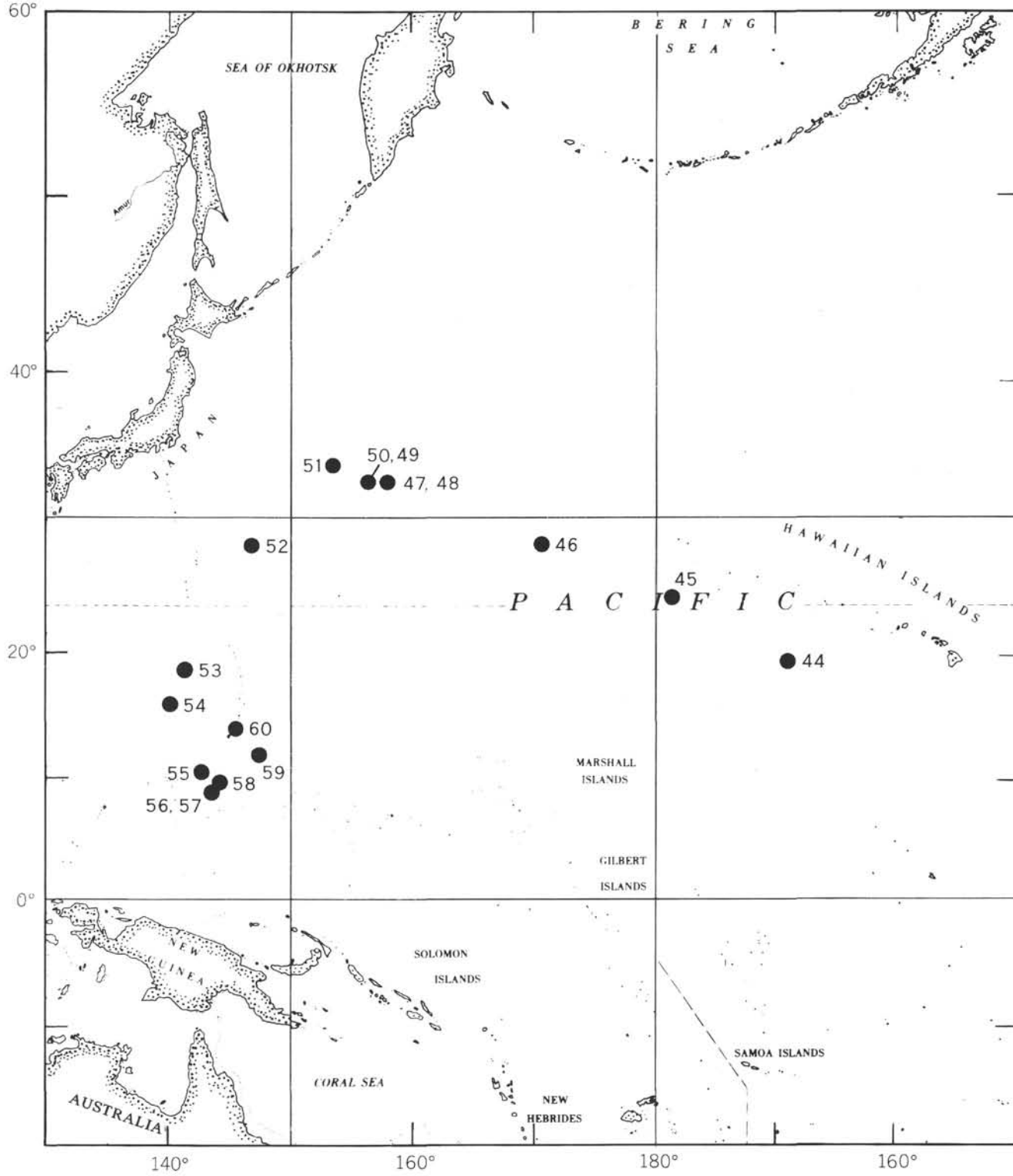

Figure 1. *Sites drilled on Leg 6 of the Deep Sea Drilling Project.*

Coccoliths in Selected Samples, Hole 44.0

Lower Oligocene
(Lower *Sphenolithus predistentus* Zone)

6-44.0-1-1, 1 cm (40 m):
Coccolithus bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, D. tani tani, Sphenolithus predistentus, S. pseudoradians.

6-44.0-1-4, 145-150 cm (46 m):
Bramletteius serraculoides, C. bisectus, C. neogammation, D. deflandrei, D. tani tani, S. predistentus, S. pseudoradians.

Upper Eocene
(*Discoaster barbadiensis* Zone)

6-44.0-2-1, 145-150 cm (51 m):
B. serraculoides, C. bisectus, C. formosus, Discoaster barbadiensis, D. deflandrei, D. saipanensis, D. tani nodifera, D. tani tani, Reticulofenestra umbilica, Sphenolithus sp. aff. *S. moriformis, S. pseudoradians.*

6-44.0-2-6, 145-150 cm (58 m):
B. serraculoides, C. bisectus, Coccolithus eopelagicus, C. formosus, D. barbadiensis, D. tani tani, Leptodiscus larvalis, R. umbilica, S. sp. aff. *S. moriformis, S. pseudoradians.*

Middle Eocene
(*Reticulofenestra umbilica* Zone)

6-44.0-3-Top (58 m):
B. serraculoides, Chiasmolithus grandis, C. bisectus, C. eopelagicus, C. formosus, D. barbadiensis, D. tani nodifera, Helicopontosphaera compacta, R. umbilica, S. sp. aff. *S. moriformis, S. pseudoradians, Thoracosphaera prolata.*

6-44.0-3-Core catcher (63 m):
B. serraculoides, C. grandis, C. bisectus, C. eopelagicus, Coronocyclus sp. cf. *C. serratus, C. formosus, D. barbadiensis, D. tani nodifera, R. umbilica, S. pseudoradians, T. prolata.*

6-44.0-4-2, 145-150 cm (69 m):
B. serraculoides, Campylosphaera dela, C. grandis, C. bisectus, C. eopelagicus, C. formosus, D. barbadiensis, D. tani nodifera, H. compacta, R. umbilica, Sphenolithus sp. aff. *S. distentus, S. radians, T. prolata, Triquetrorhabdulus inversus.*

6-44.0-4-Core catcher (73 m):
B. serraculoides, C. dela, C. grandis, Chiasmolithus solitus, C. eopelagicus, C. formosus, D. barbadiensis, D. tani nodifera, Reticulofenestra sp. cf. *R. dictyoda, R. umbilica, S. radians, T. inversus.*

6-44.0-5-Core catcher (75 m):
B. serraculoides, C. dela, C. grandis, C. eopelagicus, D. barbadiensis, R. umbilica, T. prolata, T. inversus.

HOLE 45.1
(lat 24°15.9′N., long 178°30.5′W., depth 5507 meters)

Summary of Coccolith Stratigraphy

In Core 1, the upper clay is barren, but volcanic ash layers in the lower part of the core contain sparse and poorly preserved coccoliths that indicate an Oligocene age. The center-bit and core-catcher samples, representing the only recovery in Core 2, contain a sparse assemblage from the Upper Eocene *Discoaster barbadiensis* Zone.

From Core 3 only a core-catcher sample was recovered. The material is a block of chalk and a sandy residue. The coccolith assemblage associated with the sand and in the chalk is Upper Cretaceous. The more extensive assemblage from the sand is considered Cenomanian. A long-ranging species *Watznaueria barnesae* dominates the assemblage from the chalk. These differences are apparently the result of the sand being a residue from marl layers that were penetrated, but not recovered.

Coccoliths in Selected Samples, Hole 45.1

Oligocene
(? Zone)

6-45.1-1-5, 60 cm (7 m):
Coccolithus sp. aff. *C. bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Reticulofenestra* sp. cf. *R. umbilica, Sphenolithus* sp. cf. *S. ciperoensis, S. moriformis.*

Upper Eocene
(*Discoaster barbadiensis* Zone)

6-45.1-2-Core catcher (47 m):
Bramletteius serraculoides, Cyclococcolithus formosus, C. neogammation, Discoaster barbadiensis, D. tani tani, Reticulofenestra umbilica.

Upper Cretaceous (Cenomanian)
(? Zone)

6-45.1-3-Core catcher (86 m):
Apertapetra gronosa, Eiffellithus eximius, E. turriseiffeli, Lithastrinus floralis, Micula sp. aff. *M. decussata, Parhabdolithus angustus, Prediscosphaera columnatus, P. cretacea cretacea, Watznaueria actinosa, W. barnesae, Zygolithus ponticulus, Z. xenotus.*

HOLE 46.0
(lat 27°53.8′N., long 171°26.3′E., depth 5773 meters)

Summary of Coccolith Stratigraphy

The dominant species *(Coccolithus bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Sphenolithus predistentus)* among the sparse, poorly preserved coccoliths of this core suggest an early Oligocene age, but mixing of lithologies and rare Eocene discoasters,

such as, *D. barbadiensis* and *D. saipanensis,* prevent definite assignment to either the early Oligocene or the late Eocene.

Coccoliths in Selected Samples, Hole 46.0

Upper Eocene or Lower Oligocene, with Mixing

6-46.0-1-2, 149-150 cm (3 m):
Bramletteius serraculoides, Coccolithus bisectus, Cyclococcolithus formosus, C. neogammation, Discoaster barbadiensis, Reticulofenestra umbilica, Sphenolithus predistentus, S. radians.

6-46.0-1-Core catcher (9 m):
B. serraculoides, C. bisectus, C. sp. aff. *C. bisectus, Coccolithus eopelagicus, C. formosus, C. neogammation, D. barbadiensis, Discoaster deflandrei, D. saipanensis, D. tani tani, Sphenolithus moriformis, S. predistentus, R.* sp. cf. *R. umbilica.*

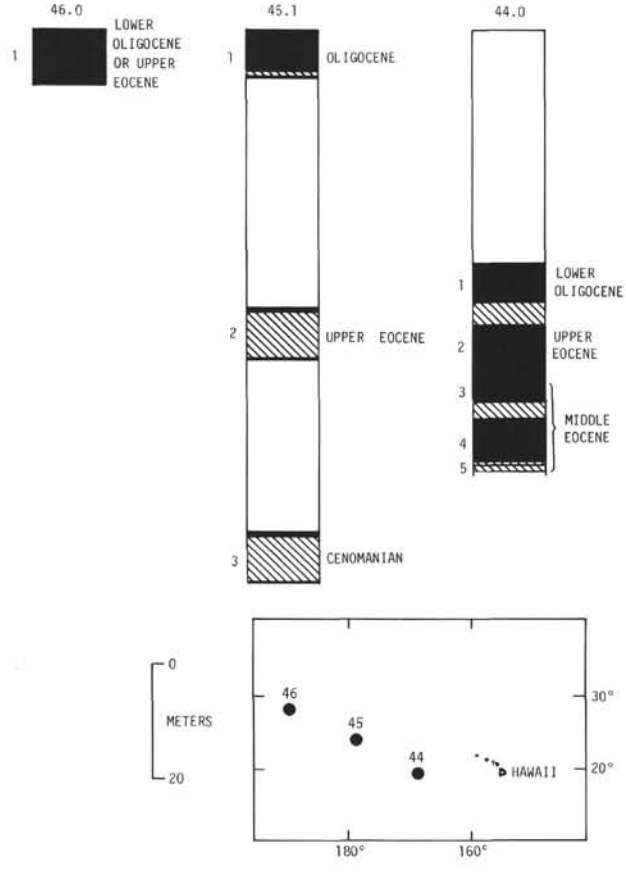

Figure 2. *Series represented in cores of holes at Horizon Ridge (Site 44) and the abyssal northwestern Pacific (Sites 45 and 46) based on coccolith assemblages. Core number to left of column. Diagonal pat represents unrecovered part of cored interval.*

HOLES 47.0, 47.1, 47.2

(lat 32°26.9'N., long 157°42.7'E., depth 2689 meters)

Summary of Coccolith Stratigraphy

Single cores of coccolith ooze from each of the first holes, 47.0 and 47.1, recovered Pleistocene at 0 to 9 meters and Paleocene at 96 to 105 meters. This section was then continuously cored in Hole 47.2, which terminated in a Maestrichtian coccolith ooze at 129 meters. The Middle Miocene through Upper Eocene section is not present, despite good recovery of that interval; otherwise the section is fairly complete.

The Pliocene-Pleistocene transition is recognized in the lower part of Core 2 by the joint occurrence of such species as *Ceratolithus rugosus, Cyclococcolithus macintyrei* and *Discoaster brouweri.* At the top of Core 6, the highest definite Miocene assemblage is present. In the core catcher of Core 6, burrowed zeolite-rich coccolith marl, containing such species as *Discoaster barbadiensis, D. deflandrei,* and *Isthmolithus recurvus,* is of a late Eocene or early Oligocene age. This brown and green core-catcher sediment contrasts with the cream-colored coccolith ooze above and in succeeding cores below.

Down-hole slumping apparently accounts for the recovery of Upper Miocene assemblages in the upper part of Core 7; the remainder of the core is Lower Eocene. A further complication in the Miocene sediment recovery is material from the Middle Miocene *Sphenolithus heteromorphus* Zone sandwiched between two lengths of Upper Miocene *Ceratolithus tricorniculatus* Zone in the middle of Section 1 of Core 7. This irregular succession probably results from drilling, as many cores in water-rich calcareous ooze show a diapiric flow structure, suggesting such cores were intruded instead of being cut by the bit. In all other cores there was sufficient cohesiveness in the sediment so that the stratigraphic sequence of coccolith zones is in normal order.

The top of the Upper Paleocene *Discoaster multiradiatus* Zone is recognized in the upper part of Core 8, Section 3. Assemblages lower in Cores 8 and 9 contain *Heliolithus kleinpelli* or *H. riedeli,* together with *Sphenolithus anarrhopus* and *Toweius craticulus;* hence, they are considered Upper Paleocene. The core-catcher sample of Core 9 and all of Core 10 contain Lower Paleocene assemblages, with common *Coccolithus cavus* and *Zygodiscus sigmoides* and a large undescribed species of *Fasciculithus.*

The upper two sections of Core 11 contain basal Paleocene assemblages, and reworked Cretaceous species are common. Below the bottom of Section 3, which was not opened, uncontaminated Upper Cretaceous (Upper Maestrichtian *Tetralithus murus* Zone) assemblages are present, and they continue through Core 12. Thus, on the basis of coccoliths, the Cretaceous-Tertiary boundary is within the unopened Section 3 of Core 11.

In Core 13, specimens of *T. murus* are an early variety indicative of the lower part of the *T. murus* Zone. Only one meter was cored for Core 14, but *T. murus* is absent and *Tetralithus pyramidus* is present, suggesting the Middle or Lower Maestrichtian *Lithraphidites quadratus* Zone.

Coccoliths in Selected Samples, Hole 47.0

Pleistocene
(*Gephyrocapsa oceanica* Zone)

6-47.0-1-2, 73-74 cm (2 m):
Ceratolithus cristatus, Coccolithus pelagicus, Cyclococcolithus leptoporus, Gephyrocapsa oceanica, ?Gephyrocapsa sp. (small, abundant), *Helicopontosphaera sellii, Rhabdosphaera clavigera.*

6-47.0-1-4, 77-78 cm (5 m):
C. cristatus, C. pelagicus, C. leptoporus, G. oceanica, Gephyrocapsa protohuxleyi (assigned a range from 0.95 to 0.10 million years B.P.), *Helicopontosphaera kamptneri, R. clavigera, Syracosphaera pulchra.*

Lower Pleistocene
(*Gephyrocapsa oceanica* or *Coccolithus doronicoides* Zone)

6-47.0-1-6, 79-80 cm (8 m):
Coccolithus sp. cf. *C. doronicoides, Cyclolithella? annula, G. oceanica* (rare), *H. kamptneri, R. clavigera.*

Coccoliths in Selected Samples, Hole 47.1

Upper Paleocene (*Discoaster gemmeus* Zone), with Eocene and Miocene Slumping

6-47.1-1-1, 145-150 cm (97 m):
Chiasmolithus consuetus, Discoaster sp. aff. *D. gemmeus, Ellipsolithus macellus, Fasciculithus tympaniformis, Sphenolithus anarrhopus, Toweius eminens;* Slumped Eocene: *Campylosphaera dela, Chiasmolithus grandis, Cyclococcolithus formosus, Discoaster barbadiensis, Reticulofenestra umbilica;* Slumped Miocene; *Ceratolithus tricorniculatus, Discoaster quintatus, D. surculus.*

Lower Paleocene

6-47.1-1-2, 83-84 cm (98 m):
Coccolithus cavus, Cruciplacolithus tenuis, Fasciculithus sp., *Toweius craticulus, Zygodiscus sigmoides.*

Coccoliths in Selected Samples, Hole 47.2

Pleistocene
(*Gephyrocapsa oceanica* Zone)

6-47.2-1-1, 135-136 cm (10 m):
Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithus leptoporus, Cyclolithella? annula, Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Rhabdosphaera clavigera, Umbilicosphaera mirabilis.*

Pleistocene
(*Coccolithus doronicoides* Zone)

6-47.2-1-4, 72-73 cm (14 m):
C. sp. c.f. *C. doronicoides, C. pelagicus, C. leptoporus, H. kamptneri.*

6-47.2-2-2, 78-79 cm (21 m):
C. sp. cf. *C. doronicoides, C. pelagicus, C. leptoporus, H. kamptneri, Helicopontosphaera sellii, Scyphosphaera* sp. cf. *S. apsteinii.*

Upper Pliocene
(*Discoaster brouweri* Zone)

6.47-2-2-6, 82-83 cm (27 m):
Ceratolithus cristatus, C. rugosus, C. sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithus macintyrei, Discoaster brouweri, H. kamptneri, H. sellii, Rhabdosphaera stylifera.*

6-47.2-3-4, 69-70 cm (33 m):
C. leptoporus, C. macintyrei, D. brouweri, H. kamptneri.

6-47.2-4-3, 77-78 cm (40 m):
C. rugosus, C. leptoporus, C. macintyrei, D. brouweri, Discoaster exilis s.l., D. pentaradiatus, D. surculus.

6-47.2-5-2, 104-105 cm (48 m):
C. macintyrei, D. brouweri, H. kamptneri.

Upper Miocene or Lower Pliocene
(*Ceratolithus rugosus* Zone)

6-47.2-5-3, 77-78 cm (50 m):
C. rugosus, Ceratolithus tricorniculatus, C. leptoporus, C. macintyrei, D. brouweri, D. exilis s.l., D. pentaradiatus, D. surculus, H. sellii, Reticulofenestra pseudoumbilica.

6-47.2-5-Core catcher (55 m):
C. rugosus, C. tricorniculatus, C. leptoporus, C. macintyrei, Discoaster challengeri, D. pentaradiatus, D. quintatus, D. surculus, H. kamptneri, H. sellii, R. pseudoumbilica, S. pulcherrima.

Upper Miocene
(*Ceratolithus tricorniculatus* Zone)

6-47.2-6-1, 20-21 cm (55 m):
C. tricorniculatus, C. leptoporus, C. macintyrei, D. challengeri, R. pseudoumbilica.

6-47.2-6-2, 83-84 cm (57 m):
C. tricorniculatus, C. leptoporus, C. macintyrei, D. brouweri, D. pentaradiatus, D. surculus.

Upper Eocene or Lower Oligocene

6-47.2-6-Core catcher (60 m):
Bramletteius serraculoides, Coccolithus bisectus, Cyclococcolithus formosus, C. neogammation, Discoaster barbadiensis [rare], *D. deflandrei, D. tani tani, Isthmolithus recurvus, Reticulofenestra umbilica.*

Upper Miocene
(*Ceratolithus tricorniculatus* **Zone**)

6-47.2-7-1, 4-5 cm (64 m):
C. tricorniculatus, D. brouweri, D. challengeri, D. quintatus, R. pseudoumbilica.

Middle Miocene
(*Sphenolithus heteromorphus* **Zone**)

6-47.2-7-1, 71-72 cm (65 m):
C. leptoporus, C. neogammation, D. brouweri s.l., D. challengeri, D. deflandrei, D. sp. aff. *D. exilis, Sphenolithus heteromorphus.*

Upper Miocene
(*Ceratolithus tricorniculatus* **Zone**)

6-47.2-7-1, 85-86 cm (65 m):
C. tricorniculatus, C. macintyrei, D. challengeri, D. quintatus, D. pentaradiatus, R. pseudoumbilica.

Lower Eocene
(*Discoaster lodoensis* **Zone**)

6-47.2-7-2, 83-84 cm (66 m):
Campylosphaera dela, Chiasmolithus grandis, Coccolithus sp. cf. *C. crassus, Cyclococcolithus gammation, D. barbadiensis, Discoaster kuepperi, D. lodoensis, D. mirus, Sphenolithus radians.*

Lower Eocene
(*Marthasterites tribrachiatus* **Zone**)

6-47.2-7-6, 134-135 cm (73 m):
C. dela, C. grandis, D. kuepepri, D. lodoensis, D. robusta, D. wemmelensis, Marthasterites tribrachiatus, S. radians.

Lower Eocene
(*Discoaster diastypus* **Zone**)

6-47.2-8-1, 71-72 cm (74 m):
C. dela [large], *Chiasmolithus bidens, C. consuetus, Chiphragmalithus calathus, Discoaster diastypus, D. lenticularis, D. multiradiatus, Ellipsolithus macellus, Lophodolithus nascens, Marthasterites* sp. cf. *M. tribrachiatus, S. radians.*

Upper Paleocene
(*Discoaster multiradiatus* **Zone**)

6-47.2-8-3, 72-73 cm (77 m):
C. dela [small], *C. bidens, D. lenticularis, D. multiradiatus, E. distichus, L. nascens, Rhomboaster cuspis, Sphenolithus anarrhopus, Toweius craticulus.*

Upper Paleocene
(*Heliolithus riedeli* **Zone**)

6-47.2-8-5, 120 cm (80 m):
C. bidens, Chiasmolithus californicus, C. consuetus, Cyclolithella? robusta, Discoaster sp. aff. *D. gemmeus, Discolithina rimosa, E. distichus, E. macellus, Fasciculithus involutus, F. tympaniformis, S. anarrhopus, T. craticulus.*

6-47.2-9-1, 81-82 cm (83 m):
C. californicus, C. consuetus, Cruciplacolithus tenius, D. sp. aff. *D. gemmeus, E. distichus, E. macellus, F. tympaniformis, Heliolithus riedeli, S. anarrhopus, T. craticulus, Zygodiscus sigmoides, Z. simplex.*

Upper Paleocene
(*Heliolithus kleinpelli* **Zone**)

6-47.2-9-2, 65-66 cm (84 m):
C. californicus, C. consuetus, C. tenuis, D. sp. aff. *D gemmeus, D. rimosa, E. distichus, E. macellus, F. involutus, F. tympaniformis, Heliolithus kleinpelli, S. anarrhopus, Z. sigmoides.*

6-47.2-9-6, 0-5 cm (90 m):
C. californicus, C. consuetus, D. sp. aff. *D. gemmeus, E. distichus, E. macellus, F. tympaniformis, H. kleinpelli, S. anarrhopus, T. craticulus.*

Lower Paleocene
(*Cruciplacolithus tenuis* **Zone**)

6-47.2-9-Core catcher (91 m):
C. tenuis, C.? robusta, Fasciculithus sp., *Z. sigmoides.*

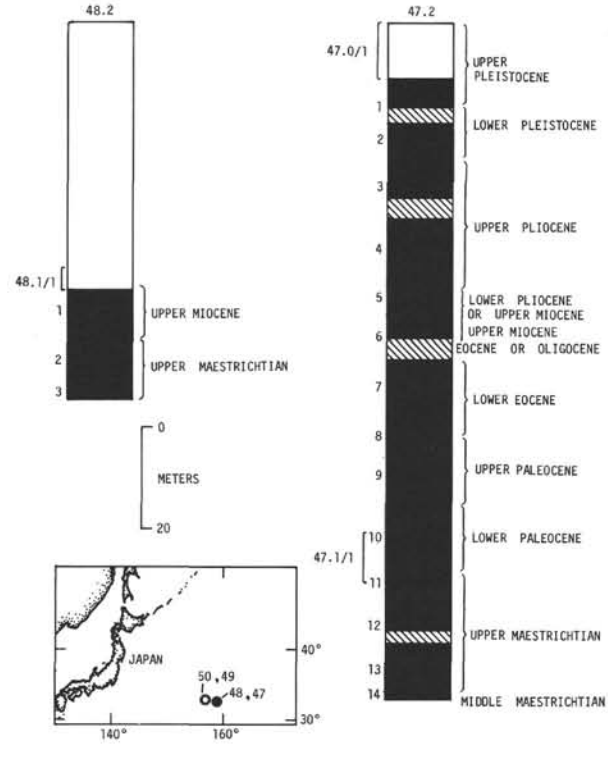

Figure 3. *Series and stages represented in cores of holes at the crest of the Shatsky Plateau based on coccolith assemblages.*

6-47.2-10-Core catcher (101 m):
Coccolithus cavus, C. tenuis, Markalius astroporus, Z. sigmoides; Reworked Cretaceous–*Arkhangeleskiella cymbiformis, Eiffellithus turriseiffeli, Microrhabdulus decoratus, Prediscosphaera cretacea cretacea, Tetralithus murus, Watznaueria barnesae.*

6-47.2-11-2, 145-150 cm (104 m):
Coccolithus sp. [small], *C. tenuis;* Reworked Cretaceous–*A. cymbiformis, E. turriseiffeli, M. decoratus, P. cretacea cretacea, P. cretacea lata, T. murus, W. barnesae.*

Upper Cretaceous
(*Tetralithus murus* Zone)

6-47.2-11-3, 145-150 cm (105 m):
Cribrosphaera ehrenbergi, Cylindralithus gallicus, E. turriseiffeli, M. decoratus, P. cretacea cretacea, T. murus, W. barnesae.

6-47.2-11-4, 145-150 cm (107 m):
A. cymbiformis, C. gallicus, E. turriseiffeli, P. cretacea cretacea, T. murus, W. barnesae.

6-47.2-12-2, 66-67 cm (112 m):
C. ehrenbergi, M. decoratus, P. cretacea lata, T. murus, Zygodiscus megamarginatus.

6-47.2-13-3, 80-81 cm (123 m):
A. cymbiformis, C. ehrenbergi, C. gallicus, P. cretacea lata, T. sp. cf. *T. murus.*

Upper Cretaceous
(*Lithraphidites quadratus* Zone)

6-47.2-14-6, 145-150 cm (129 m):
Apertapetra gronosa, A. cymbiformis, Cretarhabdus? anthophorus, C. gallicus, Micula decussata, Tetralithus pyramidus.

HOLES 58.0, 48.1, 48.2
(lat 32°24.5′N., long 158°01.3′E., depth 2619 meters)

Summary of Coccolith Stratigraphy

A slurry of coccoliths was the only recovery made from the first hole at this site–Hole 48.0. The coccoliths represent both Upper Maestrichtian and Upper Tertiary assemblages. Cores from subsequent holes confirmed this.

Coring at the second hole–Hole 48.1–yielded only a short length of calcareous ooze from the Upper Miocene *Ceratolithus tricorniculatus* Zone.

In the first core of Hole 48.2, a badly disturbed section of Pliocene sediment overlies Upper Miocene, mixed upper Miocene and Maestrichtian, and Maestrichtian sediment. The various lithologies of the upper part of the core yield assemblages of the *Discoaster brouweri* Zone, *Reticulofenestra pseudoumbilica* Zone and *Ceratolithus rugosus* Zone. The middle part of the core contains the Upper Miocene *Ceratolithus tricorniculatus* Zone above the Upper Cretaceous *Tetralithus murus* Zone, with the interface represented by a mixed assemblage of these zones in the lower part of Section 5. Only the lower part of the Upper Maestrichtian *Tetralithus murus* Zone is present. The top of Core 2 contains an assemblage of the next older, Lower or Middle Maestrichtian *Lithraphidites quadratus* Zone; the rest of Core 2 and Core 3 contain similar assemblages.

Coccoliths in Selected Samples, Hole 48.0

Upper Tertiary and Upper Cretaceous, Mixed

6-48.0-1-Core catcher (fluid outwash) (84 m):
Upper Tertiary: *Coccolithus pelagicus, Cyclococcolithus leptoporus, Discoaster brouweri, Helicopontosphaera kamptneri;* Upper Cretaceous: *Apertapetra gronosa, Cylindralithus gallicus, Microrhabdulus decoratus, Prediscosphaera cretacea cretacea, Tetralithus murus, Watznaueria barnesae.*

Coccoliths in Selected Samples, Hole 48.1

Upper Miocene
(*Ceratolithus tricorniculatus* Zone)

6-48.1-1-1, 6-7 cm (48 m):
Ceratolithus tricorniculatus, Cyclococcolithus leptoporus, Discoaster challengeri, D. surculus, Triquetrorhabdulus rugosus.

6-48.1-1-Core catcher (49 m):
C. tricorniculatus, C. leptoporus, D. challengeri, Discoaster quintatus, D. surculus, Reticulofenestra pseudoumbilica.

Coccoliths in Selected Samples, Hole 48.2

Lower Pliocene
(Upper *Reticulofenestra pseudoumbilica* Zone)

6-48.2-1-1, 118-119 cm (52 m):
C. leptoporus, Cyclococcolithus macintyrei, Discoaster brouweri, D. surculus, D. sp. (asymmetric), *R. pseudoumbilica.*

Upper Pliocene
(Upper *Discoaster brouweri* Zone)

6-48.2-1-2, 19-20 cm (53 m):
Coccolithus sp. cf. *C. doronicoides, C. leptoporus, C. macintyrei, D. brouweri, D.* sp. cf. *D. surculus, Helicopontosphaera kamptneri, H. sellii.*

Upper Miocene or Lower Pliocene
(*Ceratolithus rugosus* Zone)

6-48.2-1-3, 72-73 cm (55 m):
Ceratolithus rugosus, C. tricorniculatus, C. leptoporus, C. macintyrei, D. brouweri, D. pentaradiatus, D. quintatus, D. surculus, D. variabilis, R. pseudoumbilica.

Upper Miocene
(*Ceratolithus tricorniculatus* **Zone)**

6-48.2-1-3, 108-109 cm (55 m):
C. tricorniculatus, C. macintyrei, D. brouweri, D. challengeri, D. pentaradiatus, D. surculus, R. pseudoumbilica.

Upper Miocene and Upper Cretaceous, Mixed
(*Ceratolithus tricorniculatus* **and Lower** *Tetralithus murus* **Zones)**

6-48.2-1-5, 118-119 cm (58 m):
Upper Miocene: *C. tricorniculatus, D. brouweri, D. challengeri, D. pentaradiatus, R. pseudoumbilica;* Upper Cretaceous: *Cretarhabdus? anthophorus, Microrhabdulus decoratus, Prediscosphaera cretacea cretacea, Tetralithus murus, Watznaueria barnesae.*

Upper Cretaceous
(*Tetralithus murus* **Zone)**

6-48.2-1-6, 31-32 cm (59 m):
Apertapetra gronosa, Cretarhabdus, crenulatus, Cylindralithus gallicus, P. cretacea cretacea (short stem), *T. murus.*

Upper Cretaceous
(*Lithraphidites quadratus* **Zone)**

6-48.2-2-1, 145-150 cm (62 m):
A. gronosa, Arkhangelskiella cymbiformis, C. gallicus, P. cretacea cretacea (short stem).

6.48.2-2-6, 73-74 cm (68 m):
A. gronosa, A. cymbiformis, C. gallicus, M. decoratus, P. cretacea cretacea, P. cretacea lata.

6-48.2-3-3, 111-112 cm (73 m):
A. gronosa, A. cymbiformis, Cribrosphaera ehrenbergi, C. gallicus, P. cretacea cretacea, P. cretacea lata.

HOLES 49.0, 49.1
(lat 32°24.1'N., long 156°35.0'E., depth 4282 meters)

Summary of Coccolith Stratigraphy

Assemblages of Pleistocene coccoliths are most common in Core 1 of Hole 49.0, but reworked late Tertiary species, such as, *Discoaster brouweri* and *Ceratolithus rugosus,* are sporadically present. Some samples lack all small coccolith species or are barren brown clays.

A coccolith ooze in Core 2 is Upper Jurassic or Lower Cretaceous. Absence of the genus *Nannoconus* makes definite correlation difficult. The assemblage is similar to that assigned to the Tithonian and Valanginian from Sites 4 and 5 in the western Atlantic Ocean. (Several undescribed species in these oldest Mesozoic cores from DSDP Sites 4 and 5 are also present in the oldest cores from DSDP Sites 49 and 50. See Bukry, in press.)

A similar sequence is present in the two cores from Hole 49.1. In Core 1 there are Pleistocene assemblages in the upper core-section and sparse Upper Jurassic to Lower Cretaceous assemblages, representing redeposition in deep-sea clay, through the bottom sections. In contrast, Core 2 is a coccolith ooze of Late Jurassic to Early Cretaceous age.

Coccoliths in Selected Samples, Hole 49.0

Pleistocene with Mixed Pliocene

6-49.0-1-1, 51 cm (1 m):
Ceratolithus cristatus, Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithus leptoporus, Umbilicosphaera mirabilis.*

6-49.0-1-3, 100-101 cm (4 m):
C. cristatus, C. pelagicus, C. leptoporus, Discoaster brouweri. (Small forms not present.)

6-49.0-1-6, 77-79 cm (8 m):
C. sp. cf. *C. doronicoides, C. pelagicus, C. leptoporus, Gephyrocapsa oceanica.*

Upper Jurassic or Lower Cretaceous

6-49.0-2-1, 88-89 cm (18 m):
Diazomatolithus lehmani, Discolithina rugosa, Parhabdolithus embergi, Rhabdolithus sp. cf. *R. sceptrum, Stephanolithion laffittei, Watznaueria barnesae, W. coronata, Zygodiscus* sp. cf. *Z. theta,* and several undescribed species.

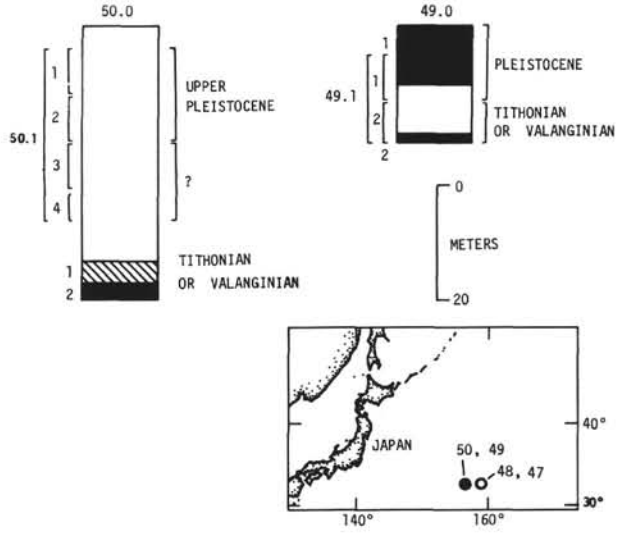

Figure 4. *Series and stages represented in cores of holes at the western flank of the Shatsky Plateau based on the coccolith assemblages.*

Coccoliths in Selected Samples, Hole 49.1

Pleistocene
(*Gephyrocapsa oceanica* **Zone)**

6-49.1-1-1, 67-68 cm (6 m):
Ceratolithus cristatus, Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithus leptoporus, Gephyrocapsa oceanica, Umbilicosphaera mirabilis.*

Upper Jurassic or Lower Cretaceous

6-49.1-2-1, 145-150 cm (13 m):
Diazomatolithus lehmani, Parhabdolithus embergi, Rhabdolithus sp. cf. *R. sceptrum, Stephanolithion* sp. aff. *S. bigoti, S. laffittei, Watznaueria barnesae.*

HOLES 50.0, 50.1
(lat 32°24.2′N., long 156°36.0′E., depth 4487 meters)

Summary of Coccolith Stratigraphy

Material recovered in the two cores from Hole 50.0 is an Upper Jurassic or possibly Lower Cretaceous coccolith ooze. The lack of species of *Nannoconus* precludes precise correlation, but the common occurrence of such species as: *Diazomatolithus lehmani, Rhabdolithus* sp. cf. *R. sceptrum, Stephanolithion* sp. aff. *S. bigoti* and *Watznaueria britannica* in these cores favors the Upper Jurassic assignment.

In Hole 50.1, a higher section near the sea floor was cored. Coccoliths are sparsely present in the upper two cores and absent in the lower two. Uncontaminated assemblages of the Pleistocene *Gephyrocapsa oceanica* Zone in a deep-sea clay occur in both upper cores along with mixed assemblages that incorporate Eocene and Cretaceous species.

Coccoliths in Selected Samples, Hole 50.0

Upper Jurassic or Lower Cretaceous

6-50.0-1-Core Catcher (38 m):
Diazomatolithus lehmani, Discolithina asper, Parhabdolithus embergi, Rhabdolithus sp. cf. *R. sceptrum, Stephanolithion* sp. aff. *S. bigoti, S. laffittei, Watznaueria barnesae, W. britannica, W.* sp. cf. *W. coronata, Zygodiscus fibulus,* and several undescribed species.

6.50.0-2-6, 150 cm (45 m):
Same as above.

Coccoliths in Selected Samples, Hole 50.1

Pleistocene
(*Gephyrocapsa oceanica* **Zone**)

6-50.1-1-1, 95-96 cm (6 m):
Ceratolithus cristatus, Coccolithus pelagicus, Cyclococcolithus leptoporus, Gephyrocapsa oceanica, Helicopontosphaera sellii.

Pliocene Mixed with Eocene and Cretaceous

6-50.1-2-1, 117-118 cm (14 m):
Pliocene: *Ceratolithus rugosus, Cyclococcolithus macintyrei;* Eocene: *Campylosphaera dela, Cyclococcolithus formosus, Discoaster* sp. aff. *D. lodoensis;* Cretaceous: *Watznaueria barnesae, Stephanolithion laffittei.*

Pleistocene
(*Gephyrocapsa oceanica* **Zone**)

6-50.1-2-Core catcher (21 m):
C. cristatus, C. pelagicus, Cyclolithella? annula, G. oceanica, Helicopontosphaera kamptneri.

HOLES 51.0, 51.1
(lat 33°28.5′N., long 153°24.3′E., depth 5980 meters)

Summary of Coccolith Stratigraphy

From the five cores recovered at Site 51, the only sample containing coccoliths is a small amount of foraminiferal ooze from the core-catcher sample of Core 3, Hole 51.0. The Late Cretaceous assemblage of coccoliths appears to be no older than late Turonian, on the basis of *Micula* sp. cf. *M. decussata,* and no younger than early Santonian, on the basis of the absence of any common diagnostic species of the interval from late Santonian through late Maestrichtian.

Coccoliths in Selected Samples, Hole 51.0

Upper Cretaceous
(Upper Turonian to Lower Santonian)

6-51.0-3-Core catcher (125 m):
Apertapetra gronosa, Chiastozygus disgregatus, Cretarhabdus crenulatus, Cribrosphaera ehrenbergi, Cylindralithus sp., *Eiffellithus augustus, E. eximius, E. turriseiffeli, Gartnerago concavum, Microrhabdulus decoratus, Micula* sp. cf. *M. decussata, Prediscosphaera cretacea cretacea. Rucinolithus hayi, Vagalapilla octoradiata, Watznaueria actinosa, W. barnesae, W. coronata,* and *Zygodiscus phacelosus.*

HOLE 52.0
(lat 27°46.3′N., long 147°07.8′E., depth 5744 meters)

Summary of Coccolith Stratigraphy

All samples examined from the ten cores taken here were barren of coccoliths.

HOLES 53.0, 53.1, 53.2
(lat 18°02.0′N., long 141°11.5′E., depth 4690 meters)

Summary of Coccolith Stratigraphy

All eight cores from Hole 53.0 contain coccoliths. Whereas the assemblages from the upper four cores, which contain layers of gray volcanic ash, have fairly common Middle to Lower Miocene species, the assemblages of the lower four cores, in pink limestone and marl, are sparse, poorly preserved and dominated by two species that are relatively resistant to degradation—*Cyclococcolithus neogammation* and *Discoaster deflandrei.* In well-preserved samples, these species are

abundant from the Lower Oligocene to Lower Miocene. Their total range is Middle Eocene to Middle Miocene, but other resistant species, such as, *Discoaster barbadiensis,* ought to be present if these lower four cores are Eocene. As basal Middle Miocene strata were sampled higher in the hole, Cores 5, 6, 7 and 8 are considered to be early Oligocene to early Miocene in age.

Selective sampling of marl and limestone from these lower cores indicates that the species present and their state of preservation is identical in the two lithologies. The "marl" may in some cases represent an artifact of drilling of the soft limestone.

Three cores were cut in Hole 53.1 to determine the nature of the upper strata at this site. Coccoliths are absent in Core 1, which consists of brown clay from 0 to 9 meters subbottom. In the gray ash of Cores 2 and 3, small assemblages of poorly preserved discoasters (with central structures dissolved) suggest Upper Miocene.

A single core was cut at Hole 53.2 (12 to 21 meters subbottom) to supplement stratigraphic information obtained from Holes 53.0 and 52.1. The only coccoliths present are poorly preserved Upper Miocene discoasters.

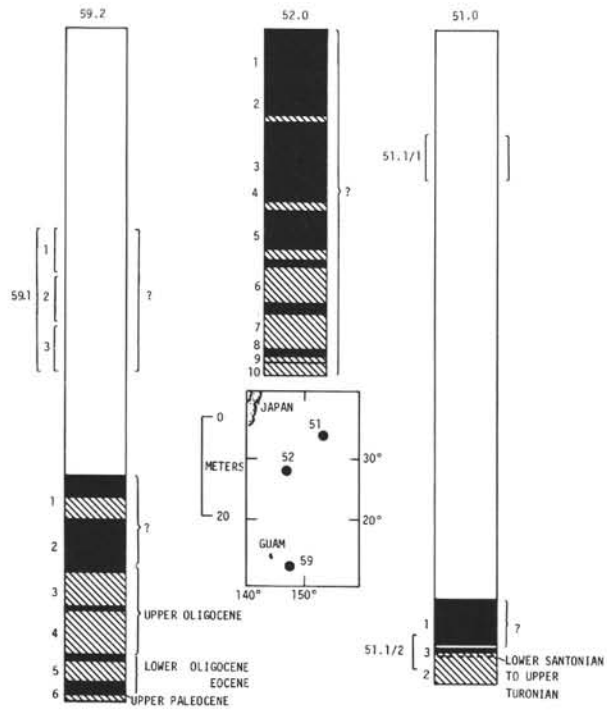

Figure 5. *Series and stages represented in cores of holes in the abyssal northwestern Pacific based on coccolith assemblages.*

Coccoliths in Selected Samples, Hole 53.0

Middle Miocene
(*Discoaster kugleri* **Zone)**

6-53.0-1-1, 1 cm (99 m):
Cyclococcolithus leptoporus, Discoaster aulakos, D. brouweri s.l., D. challengeri, D. deflandrei, D. exilis, D. kugleri, Reticulofenestra pseudoumbilica.

6.53.0-1-2, 27-28 cm (101 m):
Cyclococcolithus neogammation, D. aulakos, D. sp. aff. *D. exilis, D. variabilis, R. pseudoumbilica.*

6-53.0-1-3, 71-72 cm (104 m):
C. leptoporus, C. neogammation, D. variabilis, Sphenolithus heteromorphus.

6-53.0-1-Core catcher (104 m):
C. leptoporus, C. neogammation, D. brouweri,s.l., D. deflandrei, D. dilatus, D. sp. aff. *D. exilis, D. kugleri, D. variabilis.*

Middle Miocene
(?*Sphenolithus heteromorphus* **Zone)**

6-53.0-2-Unoriented (104 m to 113 m):
C. leptoporus, C. neogammation, D. challengeri, D. deflandrei, D. sp. aff. *D. exilis, D. variabilis, S. heteromorphus.*

6-53.0-2-Core catcher (113 m):
C. neogammation, D. brouweri s.l., D. challengeri, D. deflandrei, D. variabilis, S. heteromorphus.

Lower or Middle Miocene

6-53.0-3-1, 1 cm (137 m):
C. leptoporus, C. neogammation, D. aulakos, D. brouweri s.l., D. deflandrei, D. druggi, D. sp. aff. *D. exilis, S. heteromorphus.*

6-53.0-3-Core catcher (138 m):
C. neogammation, D. brouweri s.l., D. deflandrei, Orthorhabdus sp.

6-53.0-4-Core catcher (167 m):
C. neogammation, D. brouweri s.l., D. deflandrei, Helicopontosphaera kamptneri, S. heteromorphus, ?Triquetrorhabdulus carinatus.

Lower Oligocene to Lower Miocene

6-53.0-5-Core catcher (193 m):
Coccolithus sp. cf. *C. pelagicus, C. neogammation, D. deflandrei.*

6-53.0-6-Core catcher (195 m):
C. neogammation, D. deflandrei.

6-53.0-7-Core catcher (196 m):
C. neogammation.

6-53.0-8-Core catcher (198 m):
Coccolithus eopelagicus, C. neogammation, D. deflandrei.

Coccoliths in Selected Samples, Hole 53.1

Upper Miocene

6-53.1-2-1, 145-150 cm (23 m):
Cyclococcolithus leptoporus, Discoaster brouweri s.l., D. sp. cf. *D. challengeri, D. exilis, D. pentaradiatus, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica.*

Middle or Upper Miocene

6-53.1-3-5, 75-76 cm (60 m):
C. leptoporus, D. challengeri, D. sp. aff. *D. exilis, D. variabilis, R. pseudoumbilica, Triquetrorhabdulus rugosus.*

Coccoliths in Selected Samples, Hole 53.2

Upper Miocene

6-53.2-1-4, 75-76 cm (18 m):
Discoaster brouweri s.l., D. sp. cf. *D. quintatus, D. variabilis.*

HOLE 54.0
(lat 15°36.6′N., long 140°18.1′E., depth 4990 meters)

Summary of Coccolith Stratigraphy

All sediment samples examined from Hole 54.0, excepting Cores 8 and 9, contain remarkably similar assemblages of coccoliths that are well-preserved; all are assigned to a single zone in the lower Middle Miocene.

Coccoliths in Selected Samples, Hole 54.0

Middle Miocene
(*Sphenolithus heteromorphus* **Zone)**

(Every sample examined from the ash-rich sediment of the upper seven cores contains a similar assemblage of coccoliths. A composite assemblage of the most representative species in the 39 samples examined from these cores is listed below. Cores 8 and 9 recovered basalt that is barren of coccoliths.)

6-54.0-1 through 6-54.0-7 (83 m to 265 m):
Cyclococcolithus leptoporus, C. neogammation, Discoaster aulakos, D. brouweri s.l., D. deflandrei, D. sp. aff. *D. exilis, D. variabilis, Helicopontosphaera kamptneri,* and *Sphenolithus heteromorphus.*

HOLE 55.0
(lat 09°18.1′N., long 142°32.9′E., depth 2850 meters)

Summary of Coccolith Stratigraphy

This hole on the Caroline Ridge was continuously cored from 0 to 113 meters; Pleistocene through Upper Oligocene ooze was recovered. A single major stratigraphic break occurs between the bottom of Core 3, the Upper Pliocene *Discoaster brouweri* Zone, and the top of Core 4, the Upper Miocene *Discoaster neohamatus* Zone.

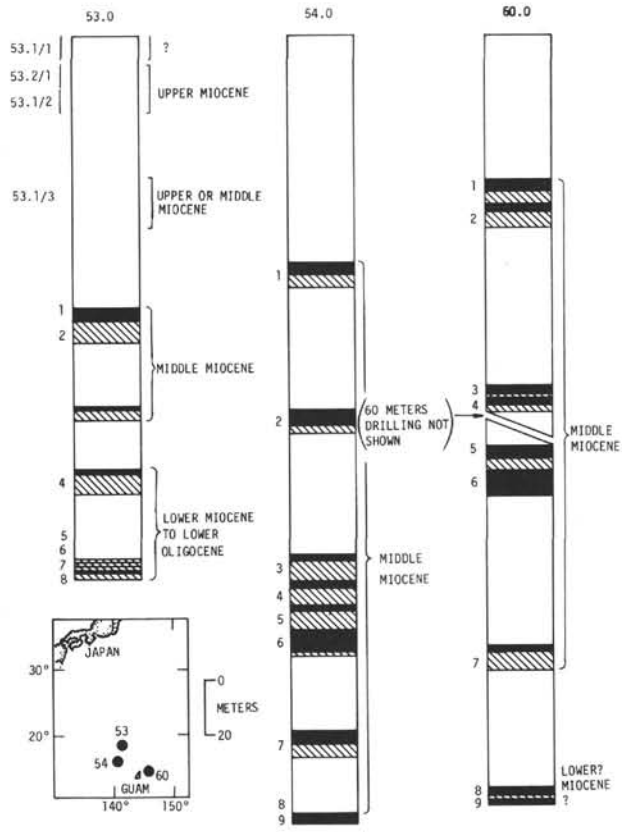

Figure 6. *Series represented in cores of holes in the Philippine Basin (Sites 53, 54) and west of the Marianas Trench (Site 60) based on coccolith assemblages.*

Middle Miocene assemblages are present in Cores 6, 7 and 8, and Lower Miocene in Cores 9, 10 and 11, with transitional Miocene or Oligocene assemblages in Core 12. The lower two cores, 13 and 14, contain the lower *Triquetrorhabdulus carinatus* Zone, or uppermost Oligocene.

Coccoliths in Selected Samples, Hole 55.0

Pleistocene
(*Gephyrocapsa oceanica* **Zone)**

6-55.0-1-1, 105-106 cm (1 m):
Ceratolithus cristatus, Gephyrocapsa oceanica, Helicopontosphaera kamptneri.

Pleistocene
(*Coccolithus doronicoides* **Zone)**

6-55.0-1-5, 110-111 cm (7 m):
C. cristatus, Coccolithus sp. cf. *C. doronicoides, Cyclococcolithus leptoporus, Cyclolithella? annula, H. kamptneri, Rhabdosphaera clavigera.*

Upper Pliocene
(Upper *Discoaster brouweri* **Zone)**

6-55.0-1-Core catcher (9 m):
C. cristatus, Ceratolithus rugosus, C. leptoporus, Cyclo-

coccolithus macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, H. kamptneri.

6-55.0-2-1, 66-67 cm (10 m):
C. rugosus, C. sp. cf. *C. doronicoides, Coccolithus pelagicus* (large), *C. leptoporus, C. macintyrei, D. brouweri* (3- and 6-rayed).

Upper Pliocene
(Lower *Discoaster brouweri* Zone)

6-55.0-2-6, 82-84 cm (17 m):
C. rugosus, C. sp. cf. *C. doronicoides, C. pelagicus, C. macintyrei, D. brouweri, D. pentaradiatus, D. surculus.*

6-55.0-3-Core catcher (27 m):
C. rugosus, C. macintyrei, D. brouweri, Discoaster challengeri, D. pentaradiatus, D. surculus, D. sp. cf. *D. variabilis, Helicopontosphaera sellii.*

Upper Miocene
(*Discoaster neohamatus* Zone)

6-55.0-4-1, 1 cm (27 m):
C. leptoporus, C. macintyrei, D. challengeri, Discoaster neohamatus, D. pentaradiatus, D. quintatus, Sphenolithus abies, Triquetrorhabdulus rugosus.

6-55.0-4-5, 31-32 cm (34 m):
C. leptoporus, C. macintyrei, D. brouweri s.l., D. challengeri, D. neohamatus, D. pentaradiatus, T. rugosus.

6-55.0-5-5, 30-31 cm (43 m):
Catinaster calyculus, C. leptoporus, C. macintyrei, D. brouweri s.l., Discoaster calcaris, D. challengeri, D. neohamatus, D. pentaradiatus, Reticulofenestra pseudoumbilica.

Middle Miocene
(*Discoaster hamatus* Zone)

6-55.0-5-6, 130-131 cm (45 m):
C. calyculus, C. leptoporus, C. macintyrei, D. challengeri, Discoaster hamatus, T. rugosus.

Middle Miocene
(*Catinaster coalitus* Zone)

6-55.0-6-1, 1 cm (46 m):
Catinaster coalitus, C. leptoporus, C. macintyeri, D. brouweri s.l., D. challengeri, Discoaster exilis, R. pseudoumbilica. T. rugosus.

Middle Miocene
(? Zone)

6-55.0-6-1, 30 cm (46 m):
C. leptoporus, D. brouweri s.l., D. challengeri, D. sp. cf. *D. variabilis, R. pseudoumbilica, T. rugosus.*

6-55.0-7-3, 130-131 cm (59 m):
Coccolithus eopelagicus, Cyclococcolithus neogammation, D. brouweri s.l., D. sp. aff. *D. exilis, R. pseudoumbilica, Sphenolithus heteromorphus* (small).

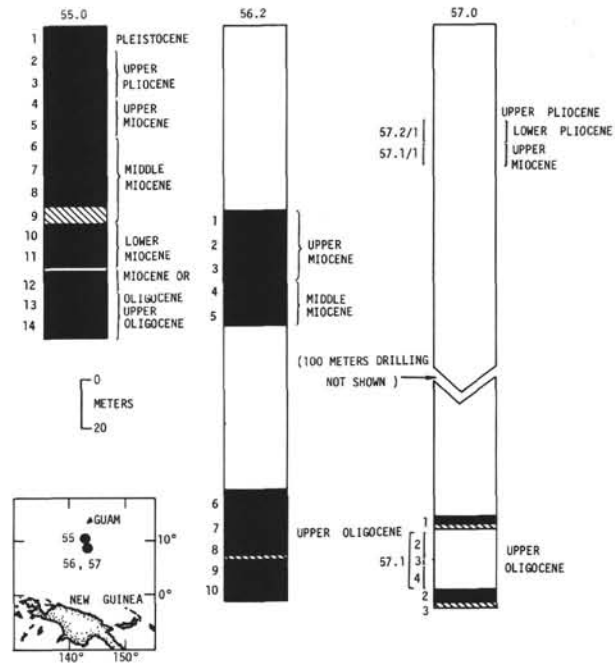

Figure 7. *Series represented in cores from holes on the Caroline Ridge based on coccolith assemblages.*

Middle Miocene
(*Sphenolithus heteromorphus* Zone)

6-55.0-7-5, 121-122 cm (62 m):
C. eopelagicus, C. neogammation, D. brouweri s.l., Discoaster deflandrei, D. sp. cf. *D. variabilis, S. heteromorphus.*

6-55.0-8-5, 120-121 cm (71 m):
C. leptoporus (small), *C. neogammation, D. brouweri a.l., D. challengeri s.l., D. deflandrei, S. heteromorphus.*

Lower Miocene
(*Helicopontosphaera ampliaperta* Zone)

6-55.0-10-2, 120-121 cm (85 m):
C. neogammation, D. brouweri s.l., D. deflandrei, D. perplexus, Sphenolithus belemnos, S. heteromorphus,

6-55.0-11-1, 120-121 cm (93 m):
C. neogammation, D. deflandrei, Discoaster sp. cf. *D. druggi, Helicopontosphaera parallela, S. heteromorphus, Sphenolithus moriformis, Triquetrorhabdulus* sp. cf. *T. carinatus.*

Lower Miocene
(*Triquetrorhabdulus carinatus* Zone,
***Discoaster druggi* Subzone)**

6-55.0-11-3, 120-121 cm (96 m):
Coccolithus sp. aff. *C. bisectus, C. neogammation, D. deflandrei, D.* sp. cf. *D. druggi, Orthorhabdus serratus, S. moriformis.*

6-55.0-11-Core catcher (101 m):
C. eopelagicus, C. neogammation, D. deflandrei, O. serratus, Sphenolithus sp. aff. *S. belemnos.*

Upper Oligocene or Lower Miocene
(*Triquetrorhabdulus carinatus* **Zone)**

6-55.0-12-2, 130-131 cm (106 m):
C. sp. aff. *C. bisectus, C. eopelagicus, C. neogammation, D. deflandrei, S.* sp. aff. *S. belemnos, T.* sp. cf. *T. carinatus.*

Upper Oligocene
(*Triquetrorhabdulus carinatus* **Zone,**
Coccolithus **sp. aff.** *C. bisectus* **Subzone)**

6-55.0-13-1, 63-64 cm (113 m):
C. sp. aff. *C. bisectus* (abundant), *C. neogammation, D. deflandrei, H. parallela, S.* sp. aff. *S. belemnos, S. moriformis.*

6-55.0-14-1, 145-150 cm (123 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, S.* sp. aff. *S. belemnos, T. carinatus.*

6-55.0-14-Core catcher (131 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, S.* sp. aff. *S. belemnos.*

HOLE 56.2
(lat 08°22.4'N., long 143°33.6'E., depth 2508 meters)

Summary of Coccolith Stratigraphy

Ten cores were cut in the same Miocene-Oligocene section as at Site 55, 170 kilometers distant. The preservation of coccoliths is poorer than at Site 55. These cores, however, add to the stratigraphic section in that they include the upper Miocene *Ceratolithus tricorniculatus* Zone at the top and the Upper Oligocene *Sphenolithus ciperoensis* Zone at the bottom (from a center-bit sample).

A continued attempt to obtain basalt and to complete the stratigraphic record on the Caroline Ridge was carried out in three holes at nearby Site 56, described in a succeeding paragraph.

Coccoliths in Selected Samples, Hole 56.2

Upper Miocene
(*Ceratolithus tricorniculatus* **Zone)**

6-56.2-1-1, 0-3 cm (73 m):
Ceratolithus tricorniculatus, Cyclococcolithus leptoporus, C. macintyrei, Discoaster challengeri, D. quintatus, D. surculus, Sphenolithus abies, Triquetrorhabdulus rugosus.

Upper Miocene
(*Discoaster neohamatus* **Zone)**

6-56.2-1-6, 77-78 cm (81 m):
C. macintyrei, Discoaster neohamatus, D. quintatus, D. surculus, T. rugosus.

6-56.2-2-6, 32-33 cm (90 m):
C. leptoporus, C. macintyrei, D. challengeri, D. quintatus, D. neohamatus, S. abies, T. rugosus.

6-56.2-3-3, 0-3 cm (94 m):
C. leptoporus, D. challengeri, D. neohamatus, D. pentaradiatus, Reticulofenestra pseudoumbilica. T. rugosus.

Middle Miocene
(*Discoaster hamatus* **Zone)**

6-56.2-3-Core catcher (101 m):
Catinaster sp. cf. *C. calyculus, C. leptoporus, C. macintyrei, D. challengeri, Discoaster hamatus, D. neohamatus, D. pentaradiatus, R. pseudoumbilica. T. rugosus.*

Middle Miocene
(? Zone)

6-56.2-4-Core catcher (110 m):
C. leptoporus, Discoaster brouweri s.l., D. challengeri s.l., D. perplexus, T. rugosus.

6-56.2-5-Core catcher (119 m):
C. leptoporus, D. brouweri s.l., D. challengeri s.l., T. rugosus.

Upper Oligocene
(*Triquetrorhabdulus carinatus* **Zone,**
Coccolithus **sp. aff.** *C. bisectus* **Subzone)**

6-56.2-6-Core catcher (196 m):
Coccolithus sp. aff. *C. bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Sphenolithus* sp. aff. *S. belemnos.*

6-56.2-10-Core catcher (234 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, Helicopontosphaera parallela, Sphenolithus moriformis, Triquetrorhabdulus carinatus.*

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

6-56.2-10/11-Center-bit sample (270 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, H. parallela, Sphenolithus ciperoensis, S. moriformis, T. carinatus.*

HOLES 57.0, 57.1, 57.2
(lat 08°40.9′N., long 143°32.0′E., depth 3310 meters)

Summary of Coccolith Stratigraphy

Core 1 in Hole 57.0 recovered coccolith ooze of the Upper Oligocene *Sphenolithus ciperoensis* Zone. The center-bit sample from between Cores 1 and 2 contains uncontaminated sediment of the same zone, presumably the oldest sediment above basalt. Cores 2 and 3 contain basalt.

At Hole 57.1, Core 1 containing the Upper Miocene *Ceratolithus tricorniculatus* Zone was taken to help complete the stratigraphic sequence already cored at Hole 55.0 (in the same geologic province—the step-faulted Caroline Ridge), and to allow a lithologic correlation of Site 57 with Site 55 for an interpretation of well-logging done at 57.0. Cores 2, 3 and 4 contain Upper Oligocene assemblages of the *S. ciperoensis* Zone. The sediment directly above basalt in this hole contains well-preserved coccoliths.

Finally, Core 1 of Hole 57.2 was taken to check for the presence of Lower Pliocene sediment, which was missing in the continuously cored Hole 55.0. The Upper Pliocene *Discoaster brouweri* Zone and Lower Pliocene *Reticulofenestra pseudoumbilica* Zone are present, suggesting that the unconformity on the Caroline Ridge is local.

Coccoliths in Selected Samples, Hole 57.0

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

6-57.0-1-1, 86-87 cm (298 m):
Coccolithus sp. aff. *C. bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Helicopontosphaera parallela, Sphenolithus* sp. aff. *S. belemnos, S. ciperoensis, S. moriformis, T. carinatus.*

6-57.0-1-Core catcher (301 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, Helicopontosphaera obliqua, H. parallela, S.* sp. aff. *S. belemnos, S. ciperoensis, S. moriformis, T. carinatus.*

6-57.0-1/2 Center-bit sample (327 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, H. parallela, S.* sp. aff. *S. belemnos, S. ciperoensis, S. moriformis, T. carinatus.*

Coccoliths in Selected Samples, Hole 57.1

Upper Miocene
(*Ceratolithus tricorniculatus* Zone)

6-57.1-1-1, 121-122 cm (45 m):
Ceratolithus tricorniculatus, Cyclococcolithus leptoporus, C. macintyrei, Discoaster brouweri, D. challengeri, D. pentaradiatus, D. quintatus, D. surculus, Reticulofenestra pseudoumbilica, Scyphosphaera sp. cf. *S. apsteinii, Triquetrorhabdulus rugosus.*

6-57.1-1-6, 120-121 cm (53 m):
C. tricorniculatus, D. challengeri, D. pentaradiatus, D. quintatus, D. surculus, R. pseudoumbilica.

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

6-57.1-2-1, 107-108 cm (308 m):
Coccolithus sp. aff. *C. bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Helicopontosphaera parallela, Sphenolithus* sp. aff. *S. belemnos, S. ciperoensis, S. moriformis, Triquetrorhabdulus carinatus.*

6-57.1-4-5, 0-3 cm (327 m):
Coccolithus bisectus, C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, H. parallela, S.* sp. aff. *S. belemnos, S. ciperoensis, S. moriformis, T. carinatus.*

Coccoliths in Selected Samples, Hole 57.2

Upper Pliocene
(Lower *Discoaster brouweri* Zone)

6-57.2-1-1, 81-82 cm (36 m):
Ceratolithus rugosus, Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithus leptoporus, C. macintyrei, Discoaster brouweri, D. challengeri, D. pentaradiatus, D. surculus, Helicopontosphaera sellii.*

Lower Pliocene
(*Reticulofenestra pseudoumbilica* Zone)

6-57.2-1-2, 0-3 cm (37 m):
C. rugosus, C. leptoporus, C. macintyrei, D. brouweri, D. challengeri, D. pentaradiatus, Reticulofenestra pseudoumbilica, Scyphosphaera sp. cf. *S. apsteinii.*

HOLES 58.0, 58.1, 58.2
(lat 90°14.1′N., long 144°25.1′E., depth 4496 meters)

Summary of Coccolith Stratigraphy

The sediment recovered here is mainly redeposited sandy gravel of shallow-water origin. Mixed assemblages of Miocene, Pliocene and Pleistocene coccoliths occur: the mixing probably is the result of the difficulty in drilling this coarse sediment.

Core 1, Hole 58.0, contains a small amount of sandy gravel with coccoliths of Middle Miocene to Upper Pliocene age mixed together. Core 1, Hole 58.1, also contains mixed assemblages of Miocene and Pliocene coccoliths, but a light brown clay from the core catcher contains an assemblage with common Pleistocene *Gephyrocapsa oceanica* and *Ceratolithus cristatus.*

Only a trace of material was obtained in Core 2 from 142 meters; the coccoliths represent a uniform assemblage from the lower Miocene *Triquetrorhabdulus carinatus* Zone, *Discoaster druggi* Subzone. Finally, in Core 1, Hole 58.2, from 137 to 143 meters, sediment of the Upper Oligocene, lower *Triquetrorhabdulus carinatus* Zone was encountered.

Coccoliths in Selected Samples, Hole 58.0

Miocene and Pliocene, Mixed

6-58.0-1-Core catcher (15 m):
Middle Miocene: *Cyclococcolithus neogammation, Discaoster deflandrei, Sphenolithus heteromorphus;* Upper Miocene or Pliocene: *Ceratolithus rugosus, Cyclococcolithus macintyrei, Discoaster brouweri, D. challengeri, D. pentaradiatus, D. surculus.*

Coccoliths in Selected Samples, Hole 58.1

Miocene to Pleistocene?, Mixed

6-58.1-1-3, 0-4 cm (3 m):
Ceratolithus rugosus, Coccolithus sp. cf. *C. doronicoides, Cyclococcolithus leptoporus, C. macintyrei, Cyclolithella? annula, Discoaster deflandrei, Helicopontosphaera kamptneri.*

Pleistocene
(*Gephyrocapsa oceanica* **Zone)**

6-58.1-1-Core catcher (5 m):
Ceratolithus cristatus, C. leptoporus, C.? annula, Gephyrocapsa oceanica, H. kamptneri.

Lower Miocene
(*Triquetrorhabdulus carinatus* **Zone)**
Discoaster druggi **Subzone)**

6-58.1-2-Core catcher (142 m):
Coccolithus eopelagicus, Cyclococcolithus neogammation, D. deflandrei, Discoaster druggi, Triquetrorhabdulus carinatus.

Coccoliths in Selected Samples, Hole 58.2

Upper Oligocene
(*Triquetrorhabdulus carinatus* **Zone,**
Coccolithus **sp. aff.** *C. bisectus* **Subzone)**

6-58.2-1-1, 14-15 cm (137 m):
Coccolithus sp. aff. *C. bisectus, Cyclococcolithus neogammation, Discoaster deflandrei, Sphenolithus* sp. aff. *S. belemnos, Triquetrorhabdulus carinatus.*

6-58.2-1-6, 118-119 cm (143 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, Sphenolithus moriformis, T. carinatus.*

HOLES 59.1, 59.2
(lat 11°46.8′N., long 147°34.9′E., depth 5547 meters)

Summary of Coccolith Stratigraphy

No samples were recovered from Hole 59.0, and no coccoliths are present in the single core recovered from Hole 59.1. At Hole 59.2 the first coccoliths encountered belong to the Upper Oligocene *Triquetrorhabdulus carinatus* Zone from Cores 3 and 4.

In Cores 5 and 6, Upper Eocene or Lower Oligocene assemblages are present. Mixed lithologies from the core catcher of Core 6 include a gray clay with an Upper Oligocene to Lower Miocene assemblage and a white clay with an Upper Paleocene assemblage of the *Discoaster multiradiatus* Zone.

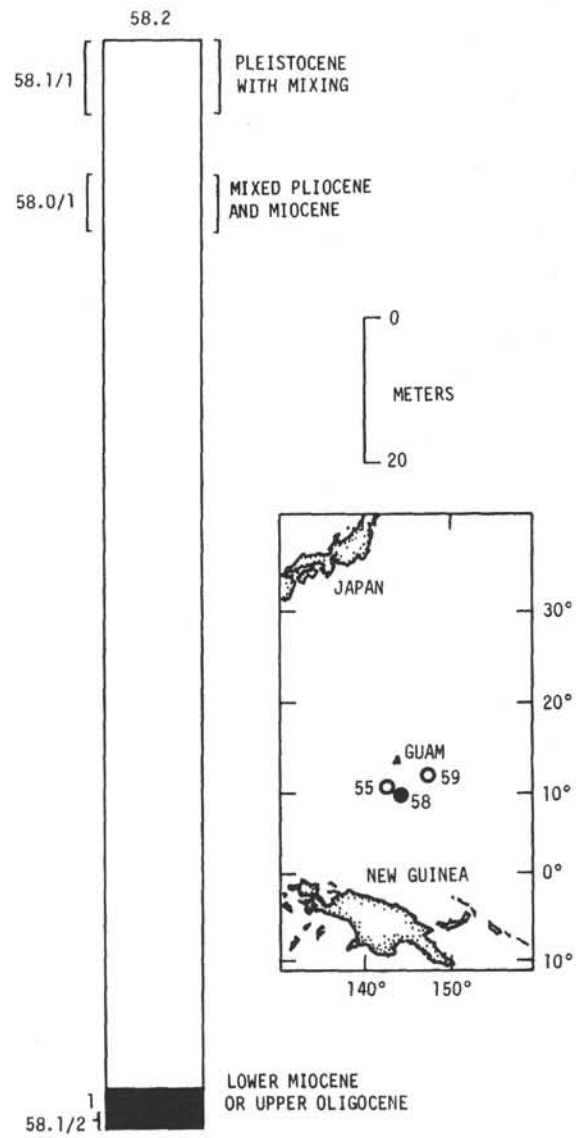

Figure 8. *Series represented in cores of holes on the eastern flank of the Caroline Ridge based on coccolith assemblages.*

Coccoliths in Selected Samples, Hole 59.2

Upper Oligocene
(*Triquetrorhabdulus carinatus* **Zone,**
Coccolithus **sp. aff.** *C. bisectus* **Subzone)**

6-59.2-3-Core catcher (111 m):
Coccolithus sp. aff. *C. bisectus, C. eopelagicus, Cyclococcolithus neogammation, Discoaster deflandrei, Sphenolithus* sp. aff. *S. belemnos, S. moriformis, Triquetrorhabdulus carinatus.*

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

6-59.2-4-Core catcher (118 m):
C. sp. aff. *C. bisectus, C. neogammation, D. deflandrei, S.* sp. aff. *S. belemnos, Sphenolithus ciperoensis, S. moriformis, T. carinatus;* Reworked Lower Oligocene and Eocene: *Bramletteius serraculoides, Coccolithus bisectus, Discoaster barbadiensis, Reticulofenestra umbilica, Sphenolithus distentus, S. predistentus.*

Upper Eocene or Lower Oligocene with Mixing

6-59.2-5-Core catcher (128 m):
B. serraculoides, C. bisectus, Cyclococcolithus formosus, D. barbadiensis, D. deflandrei, D. tani tani, R. umbilica, S. moriformis.

6-59.2-6-2, 0-5 cm (134 m):
B. serraculoides, C. bisectus, C. formosus, C. neogammation, D. barbadiensis, D. deflandrei, D. tani tani, R. umbilica, S. moriformis; Reworked Paleocene: *Cruciplacolithus tenuis, Fasciculithus tympaniformis.*

Upper Paleocene
(*Discoaster multiradiatus* **Zone**)

6-59.2-6-Core catcher (135 m):
Chiasmolithus bidens, Discoaster multiradiatus, Fasciculithus tympaniformis, Toweius eminens; Reworked Cretaceous: *Watznaueria barnesae.*

HOLE 60.0
(lat 13°40.0′N., long 145°41.9′E., depth 3728 meters)

Summary of Coccolith Stratigraphy

Coccoliths including discoasters are abundant in the upper cores and become progressively rare in deeper cores. The Middle Miocene *Discoaster hamatus, Catinaster coalitus* and *Sphenolithus heteromorphus* Zones are recognized in Cores 1 through 7. Rare specimens in Core 8 suggest the Lower Miocene; Core 9 is barren. Discoasters are particularly well-preserved in this ash-rich sediment and show little secondary overgrowth of calcite. The discoaster assemblages can be closely correlated with those present in ash-rich sediment of the Caribbean area, on Trinidad and in cores recovered during Leg 4.

Coccoliths in Selected Samples, Hole 60.0

Middle Miocene
(*Discoaster hamatus* **Zone**)

6-60.0-1-1, 44 cm (52 m):
Catinaster calyculus, C. coalitus, Cyclococcolithus leptoporus, Discoaster brouweri s.l., D. calcaris, D. challengeri, D. hamatus, Triquetrorhabdulus rugosus.

Middle Miocene
(*Catinaster coalitus* **Zone**)

6-60 .0-1-Core catcher (56 m):
C. coalitus, D. brouweri s.l., D. challengeri, T. rugosus.

6-60.0-2-1, 76 cm (62 m):
C. coalitus, Cyclococcolithus macintyrei, C. leptoporus, D. brouweri s.l., D. challengeri, Discoaster exilis, D. sp. aff. *D. variabilis, Reticulofenestra pseudoumbilica, T. rugosus.*

Middle Miocene
(? Zone)

6-60.0-3-1, 100-101 cm (130 m):
D. brouweri s.l., D. challengeri, D. exilis, R. pseudoumbilica.

6-60.0-4-Core catcher (57 m):
Cyclococcolithus neogammation, D. brouweri s.l., D. challengeri, Discoaster deflandrei, D. sp. aff. *D. variabilis, Discolithina* sp., *Helicopontosphaera kamptneri, R. pseudoumbilica.*

Middle Miocene
(*Sphenolithus heteromorphus* **Zone**)

6-60.0-5-1, 100-101 cm (214 m):
C. neogammation, D. sp. aff. *D. challengeri, D. deflandrei, D. exilis, Sphenolithus heteromorphus.*

6-60.0-6-1, 100-101 cm (223 m)
C. neogammation, D. deflandrei, D. sp. aff. *D. exilis, D. variabilis, Helicopontosphaera obliqua, S. heteromorphus.*

6-60.0-7-Core catcher (291 m):
C. neogammation, D. brouweri s.l., D. challengeri, D. deflandrei, D. sp. aff. *D. exilis, Discolithina* sp. (large), *H. kamptneri, S. heteromorphus.*

Miocene
(? Zone)

6.60.0-8-Core catcher (346 m):
C. neogammation, D. deflandrei, D. variabilis, Discolithina sp.

ACKNOWLEDGMENT

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PLATE 1

Coccolith replica electronmicrographs
Pleistocene, Shatsky Plateau, Hole 47.0, Core 1, Section 4
77-78 cm (5 meters subbottom)

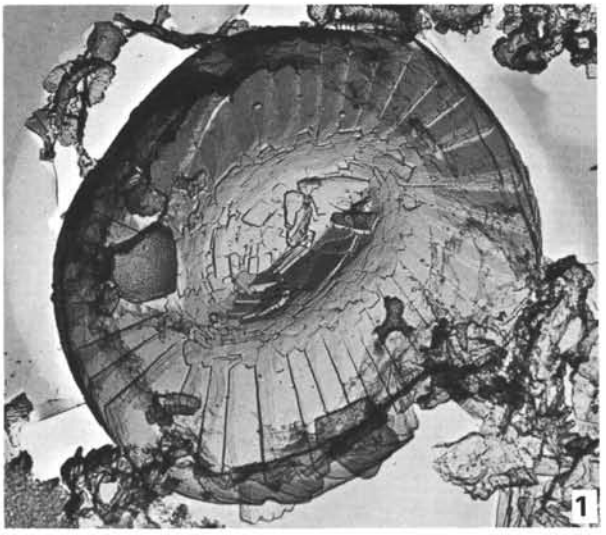
Figures 1, 2 — *Coccolithus pelagicus* (Wallich); 1: 6500 X, 2: 9200 X.

Figure 3 — *Cyclococcolithus leptoporus* (Murray and Blackman); 9000 X.

Figure 4 — *Discolithina* sp.; 8500 X.

Figure 5 — *Gephyrocapsa aperta* Kamptner; 24,000 X.

Figure 6 — *Gephyrocapsa protohuxleyi* McIntyre; 19,000 X.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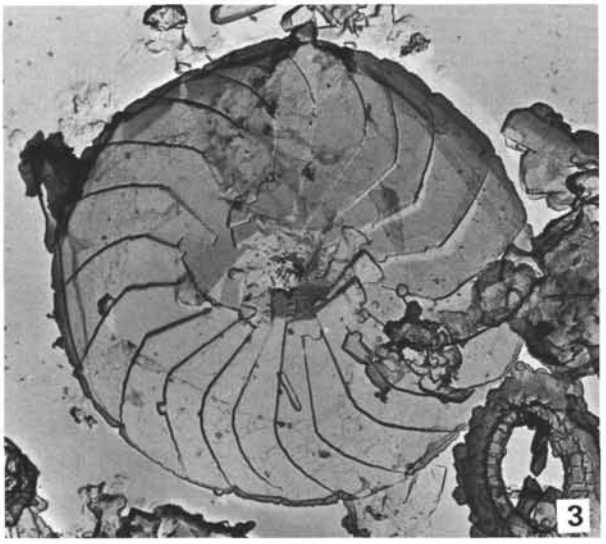
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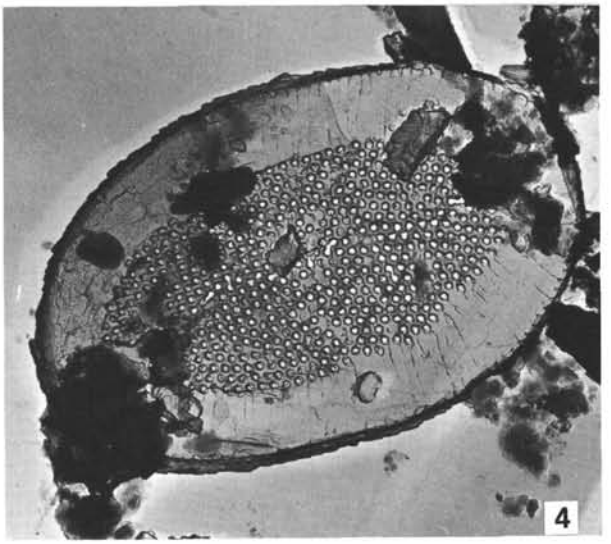
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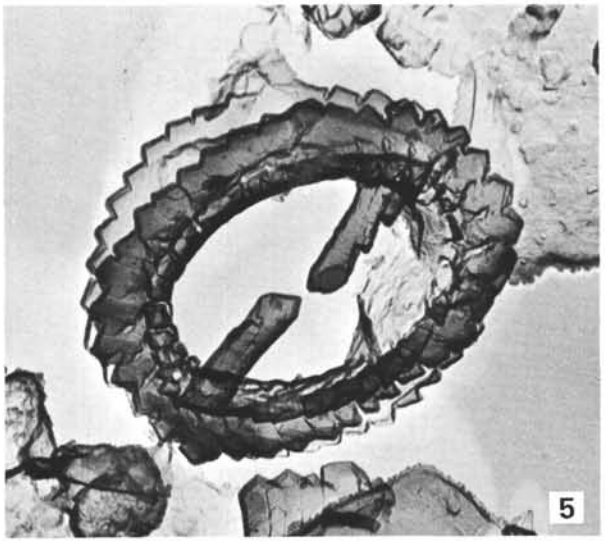
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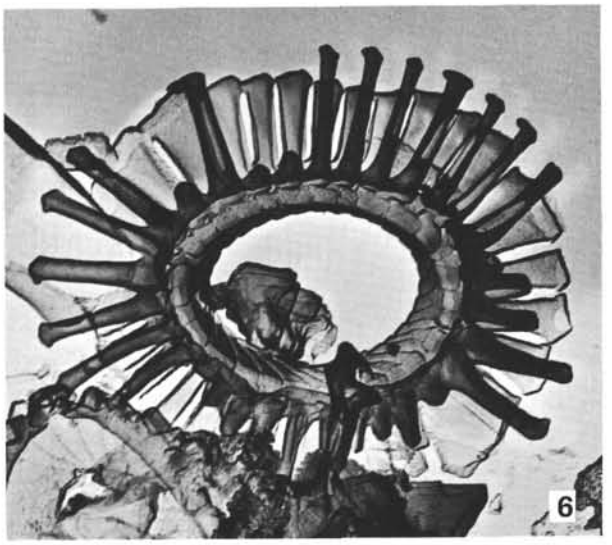
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PLATE 2

Coccolith replica electronmicrographs
Pleistocene, Shatsky Plateau, Hole 47.0, Core 1, Section 4
77-78 cm (5 meters subbottom)

Figure 1 — *Gephyrocapsa oceanica* Kamptner; 12,000 X

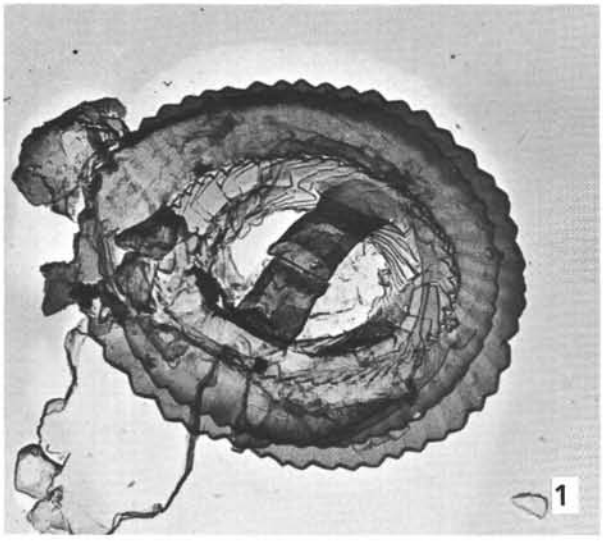
Figure 2 — *Gephyrocapsa producta* (Kamptner); 21,000 X.

Figure 3 — *Helicopontosphaera sillii* Bukry and Bramlette; 11,700 X.

Figure 4 — *Rhabdosphaera clavigera* Murray and Blackman; 11,500 X.

Figure 5 — *Syracosphaera pulchra* Lohmann; 7,500 X.

Figure 6 — *Umbilicosphaera mirabilis* Lohmann; 10,700 X.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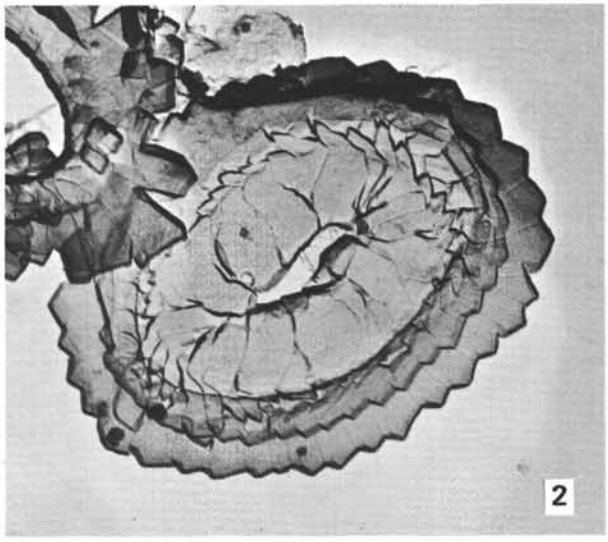
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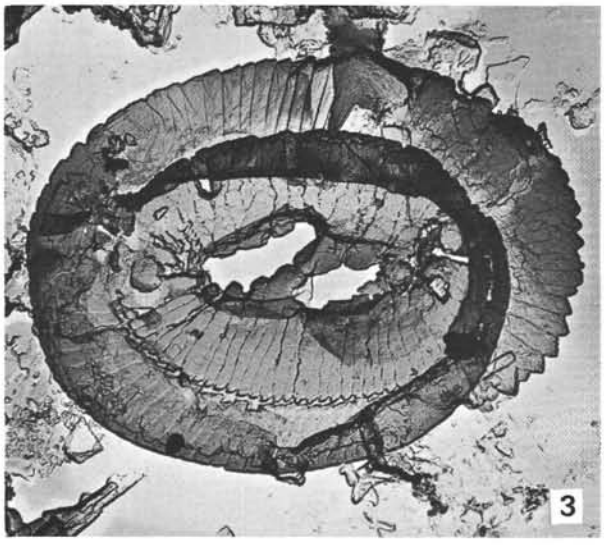
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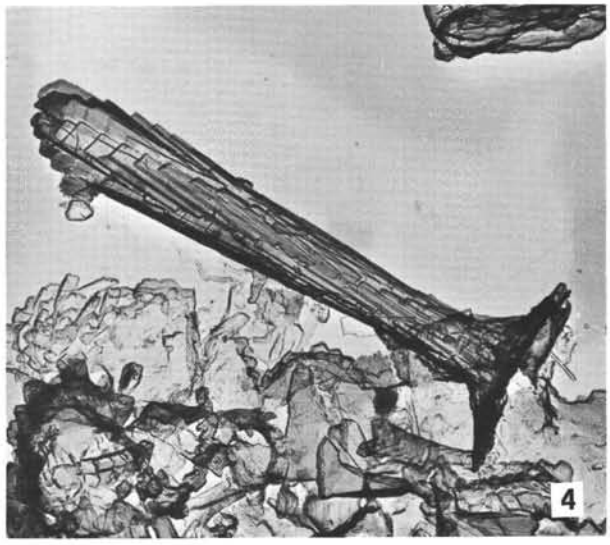
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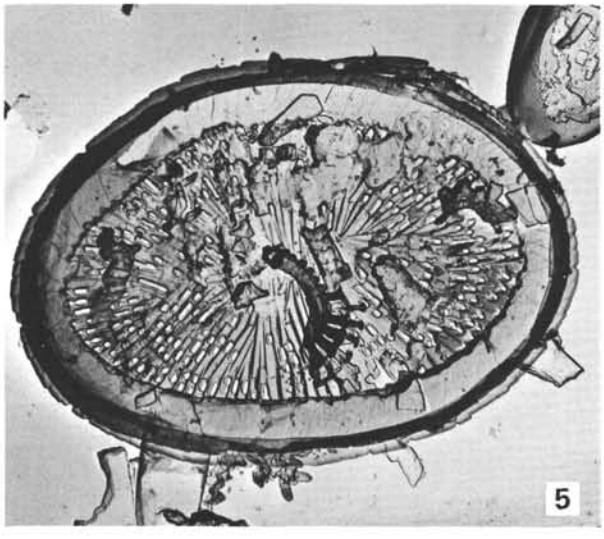
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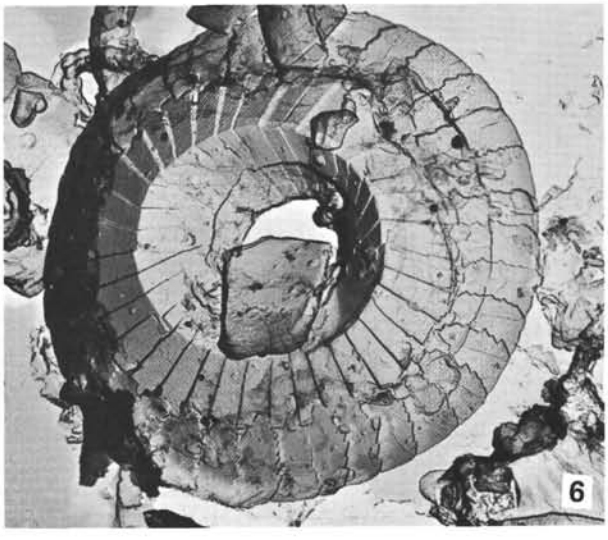
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PLATE 3

Coccolith replica electronmicrographs
Pliocene, Caroline Rise, Hole 57.2, Core 1, Section 6, 0-3 cm
(43 meters subbottom)

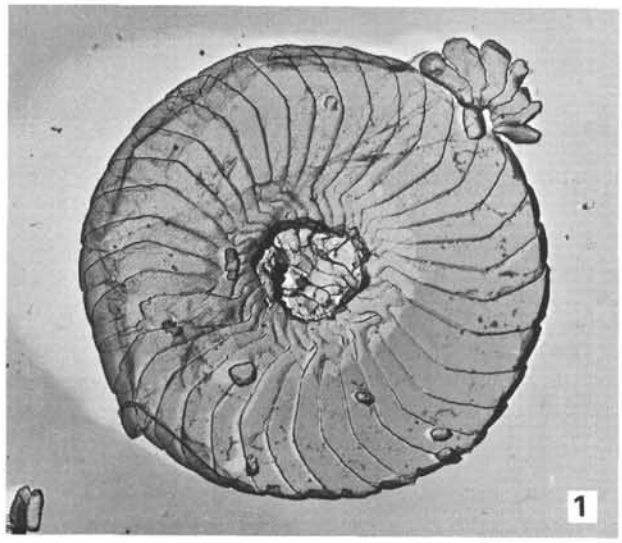
Figure 1 — *Cyclococcolithus macintyrei* Bukry and Bramlette; 6200 X.

Figure 2 — *Discoaster brouweri* Tan; 7500 X.

Figure 3 — *Discoaster surculus* Martini and Bramlette; 5600 X.

Figures 4, 5 — *Reticulofenestra pseudoumbilica* (Gartner); 4: 8600 X.

Figure 6 — *Scyphosphaera* sp. cf. *S. apsteinii* Lohmann; 5000 X.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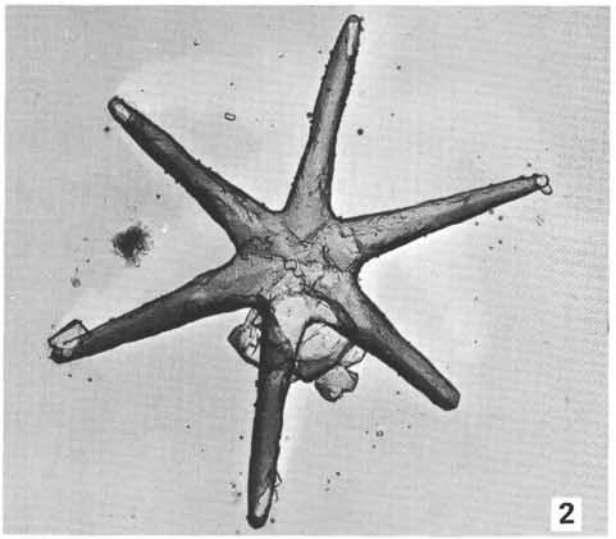
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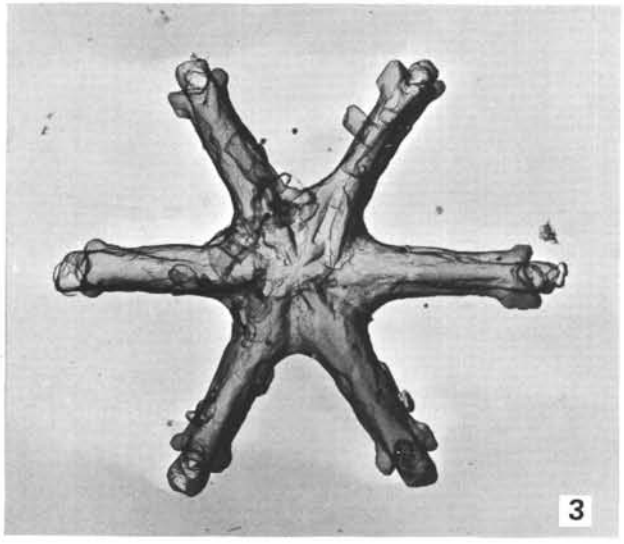
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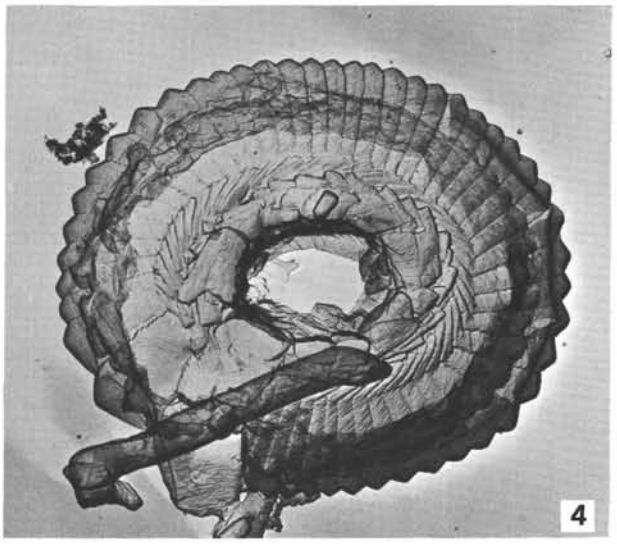
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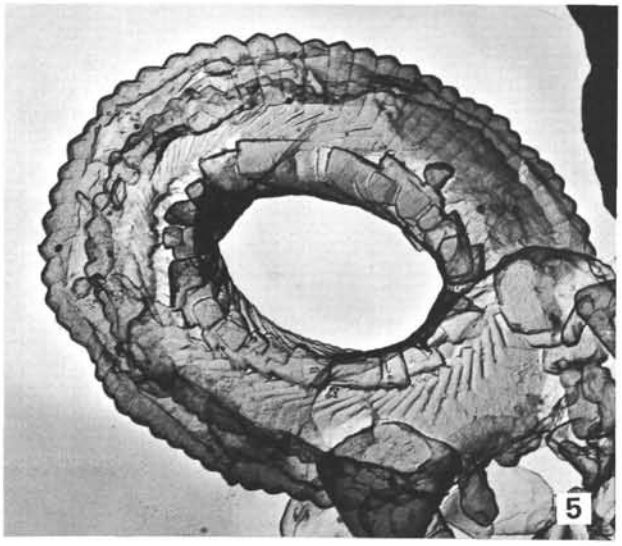
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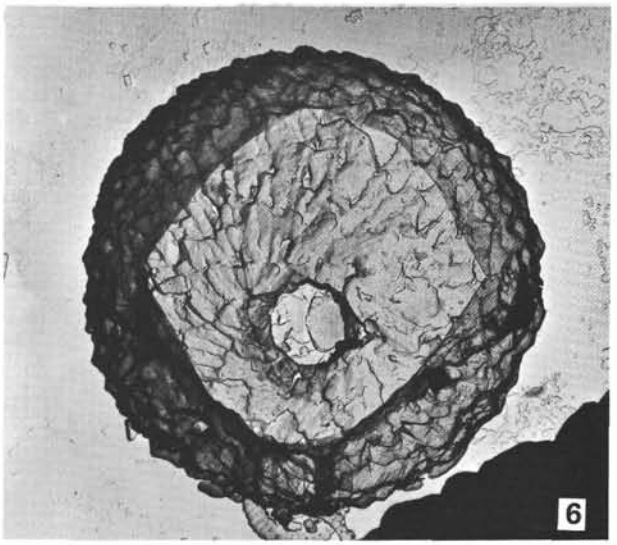
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PLATE 4

Coccolith replica electronmicrographs
Miocene, Caroline Rise, Hole 55, Core 11, Section 5, 78-80 cm
(99 meters subbottom)

Figure 1 — *Coccolithus* sp.; 11,800 X.

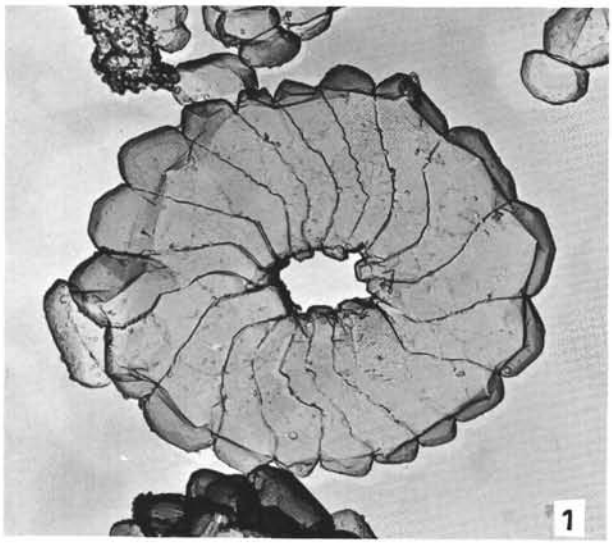
Figure 2 — *Coronocyclus* sp.; 11,300 X.

Figure 3 — *Cyclococcolithus neogammation* Bramlette and Wilcoxon; 7900 X.

Figure 4 — *Discoaster deflandrei* Bramlette and Riedel [showing typical calcite overgrowth surfaces]; 3700 X.

Figure 5 — *Discoaster perplexus* Bramlette and Riedel; 8200 X.

Figure 6 — *Sphenolithus moriformis* (Bronnimann and Stradner); 12,400 X.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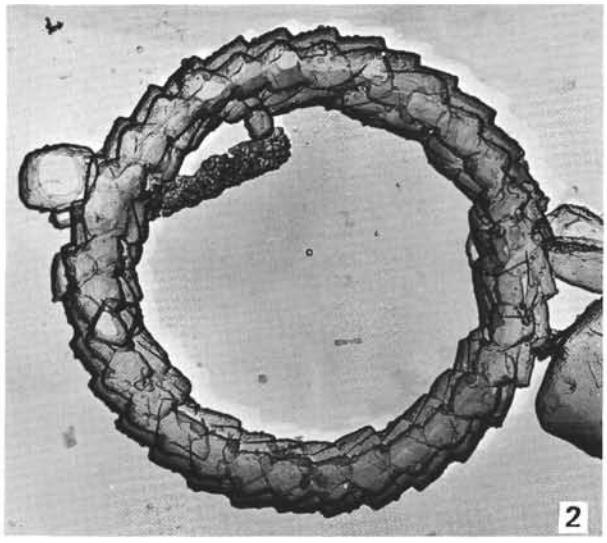
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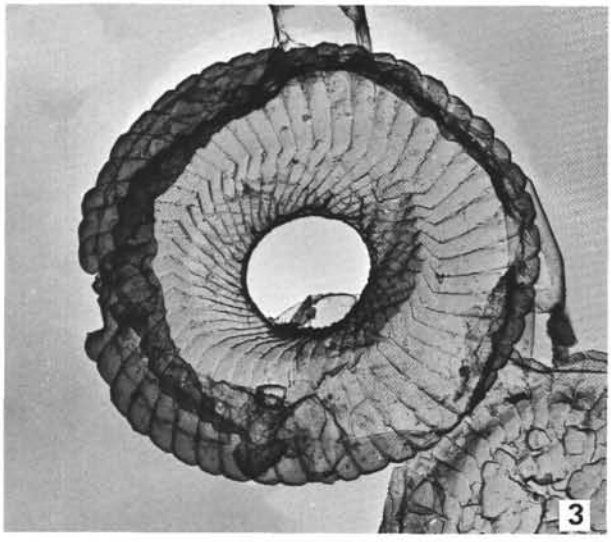
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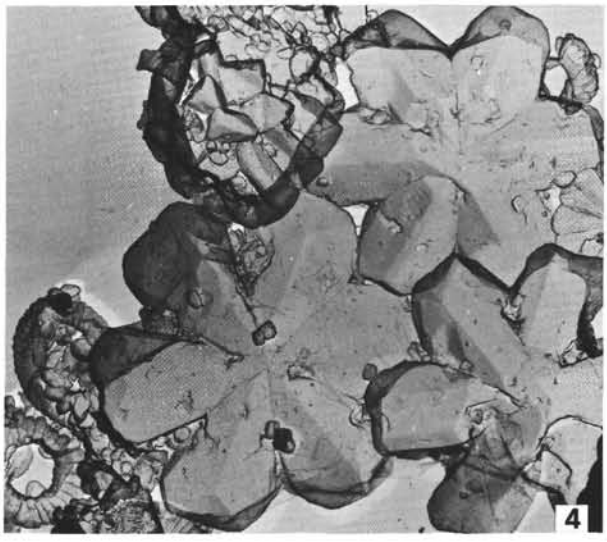
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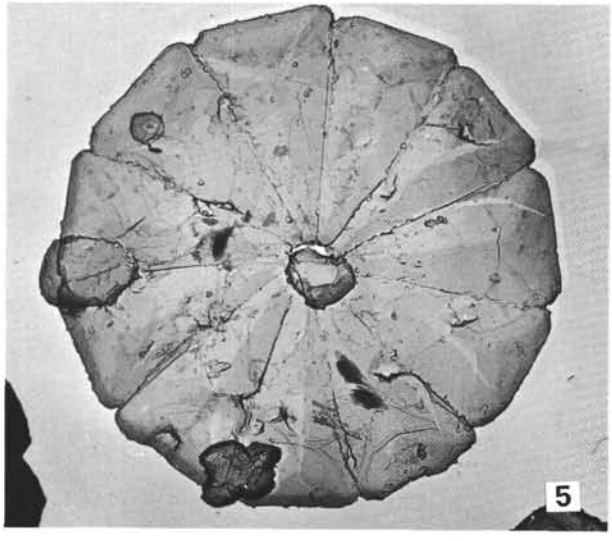
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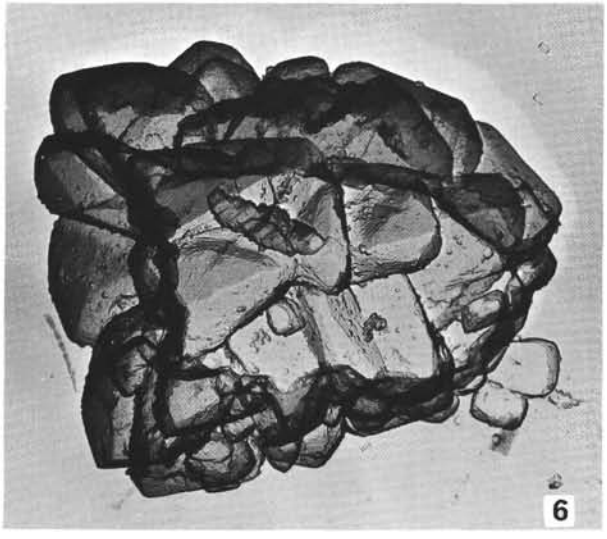
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PLATE 5

Coccolith replica electronmicrographs
Eocene, Horizon Guyot, Hole 44, Core 3, Section 5, 145-150 cm
(63 meters subbottom)

Figure 1 — Assemblage; 950 X.

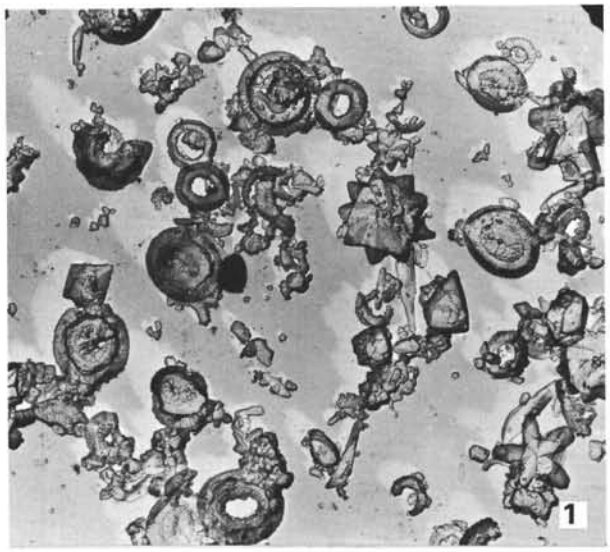
Figure 2 — Group of *Coccolithus bisectus* (Hay, Mohler, and Wade) and *Discoaster barbadiensis* Tan; 4000 X.

Figure 3 — *Bramletteius serraculoides* Gartner and *Coccolithus bisectus* (Hay, Mohler, and Wade); 5800 X.

Figure 4 — *Bramletteius* sp. aff. B. *serraculoides* Gartner; 6100 X.

Figure 5 — *Chiasmolithus grandis* (Bramlette and Riedel); 3700 X.

Figure 6 — *Cyclolithella?* sp.; 12,600 X.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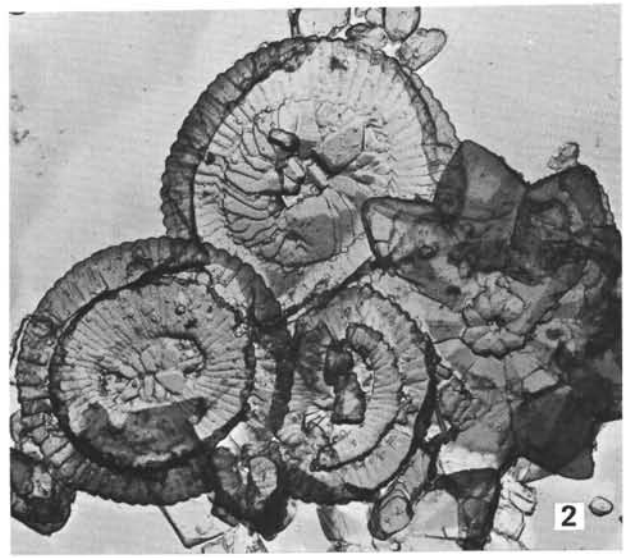
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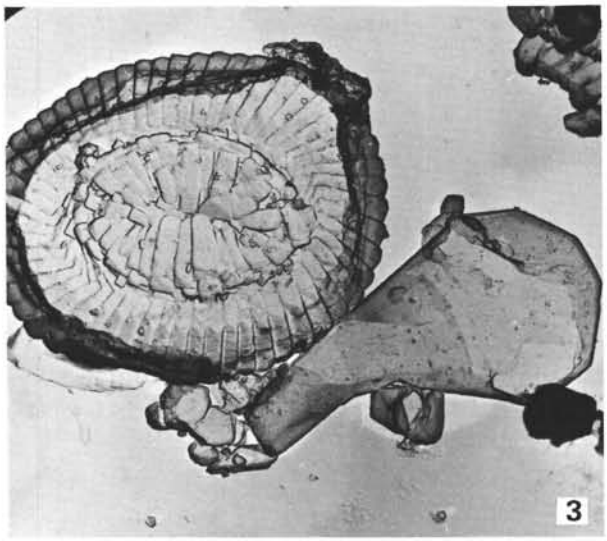
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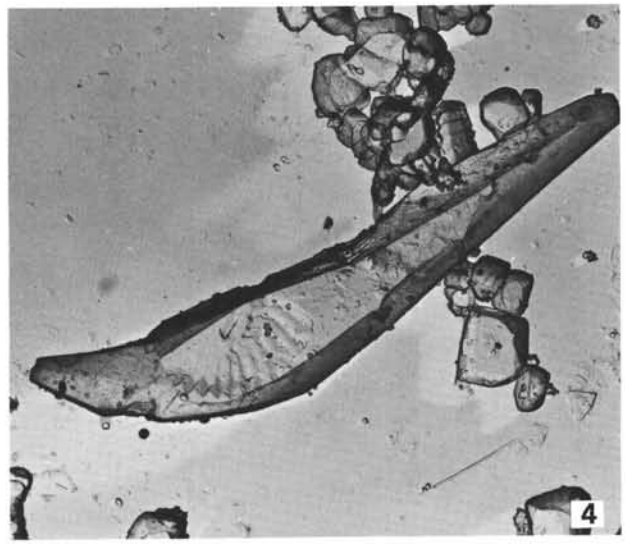
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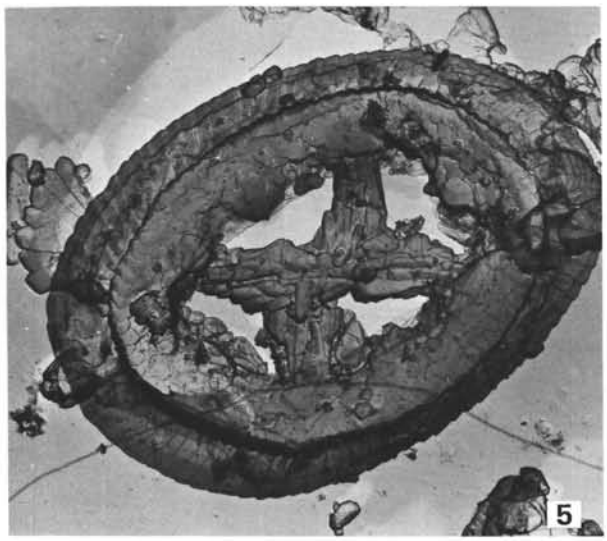
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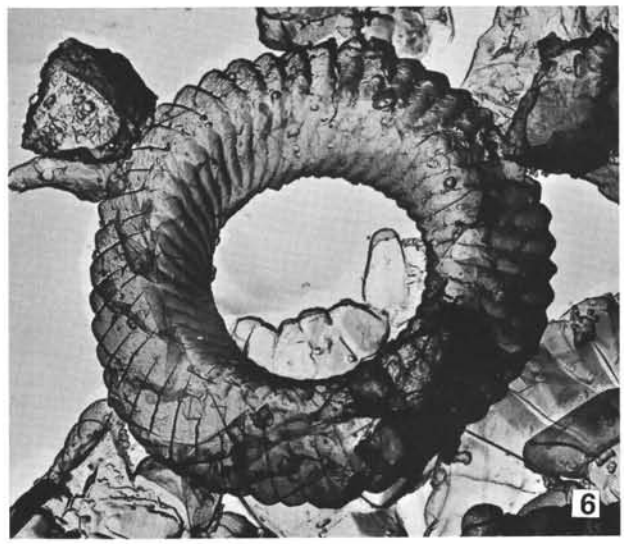
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PLATE 6

Coccolith replica electronmicrographs
Eocene, Horizon Guyot, Hole 44, Core 3, Section 5, 145-150 cm
(63 meters subbottom)

Figure 1 — *Coccolithus bisectus* (Hay, Mohler, and Wade); 7900 X.

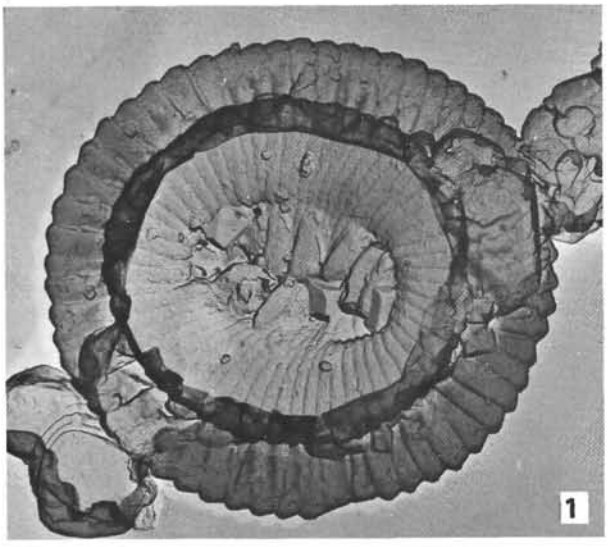
Figure 2 — *Discoaster gemmeus* Stradner; 10,900 X.

Figure 3 — *Discoaster robustus* Haq [47.2-8-1, 71-71 cm]; 12,000 X.

Figure 4 — *Leptodiscus larvalis* Bukry and Bramlette; 5200 X.

Figure 5 — *Pontosphaera vadosa* Hay, Mohler, and Wade; 12,100 X.

Figure 6 — *Reticulofenestra umbilica* (Levin); 4400 X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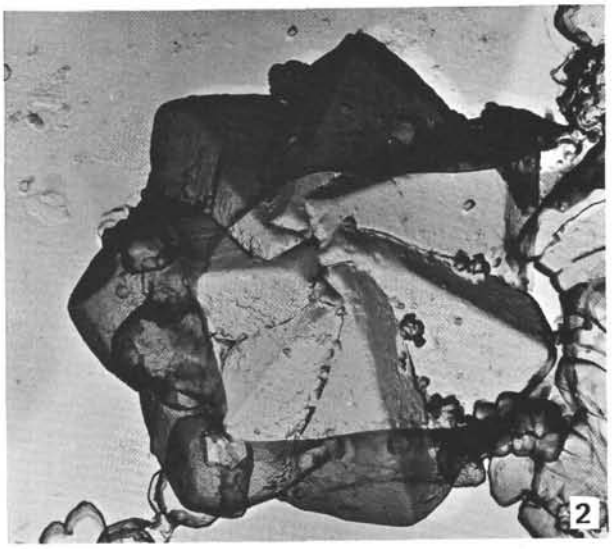
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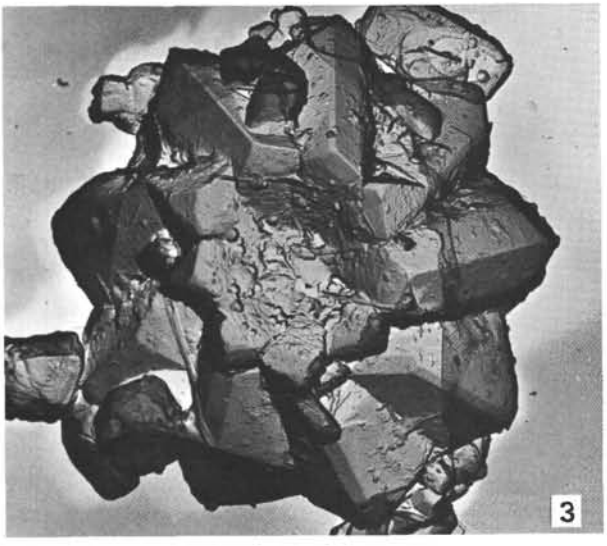
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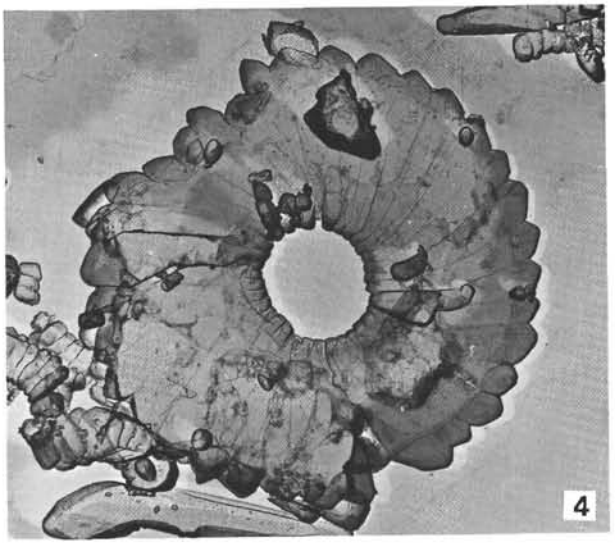
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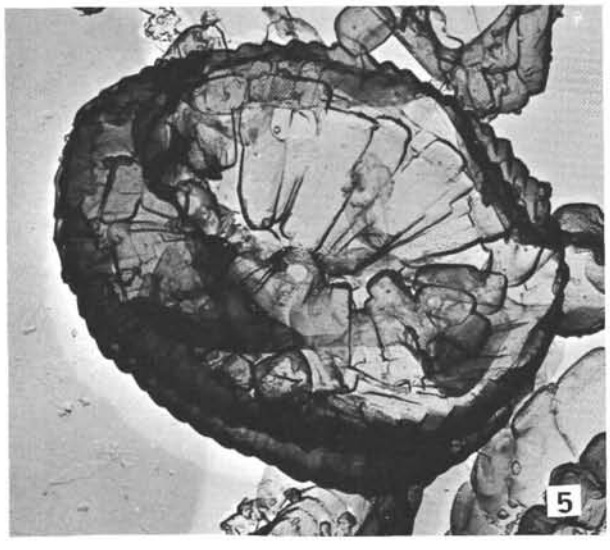
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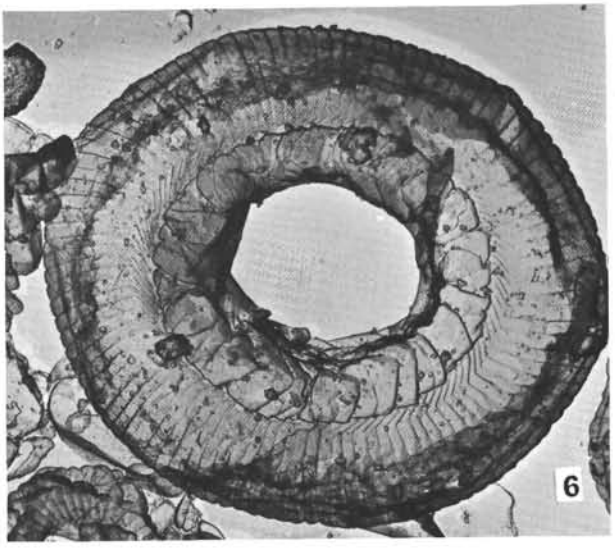
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PLATE 7

Coccolith replica electronmicrographs
Paleocene, Shatsky Plateau, Hole 47.2, Core 8, Section 6
78-80 cm (81 meters subbottom)

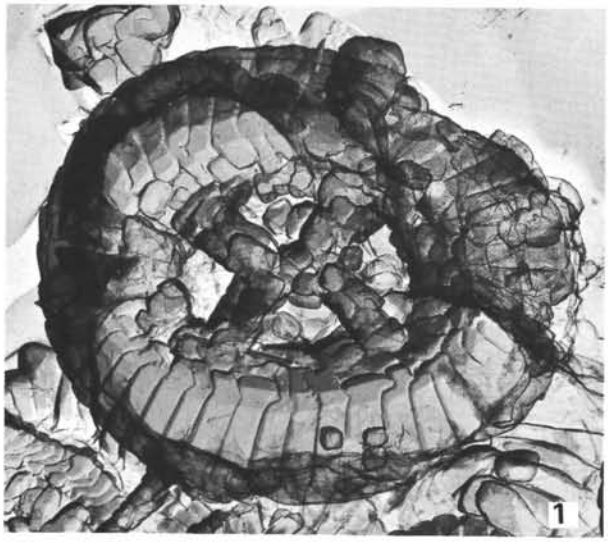
Figure 1 — *Chiasmolithus consuetus* (Bramlette and Sullivan); 7,700 X.

Figure 2 — *Ellipsolithus macellus* (Bramlette and Sullivan); 6,000 X.

Figure 3 — *Fasciculithus tympaniformis* Hay and Mohler; 12,100 X.

Figure 4 — *Sphenolithus anarrhopus* Bukry and Bramlette, 8,500 X.

Figures 5, 6 — *Toweius* sp., 5: 9,200 X, 6: 10,800 X.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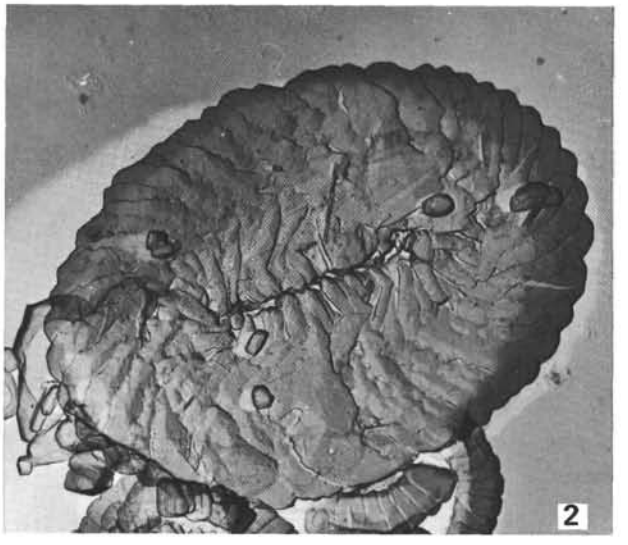
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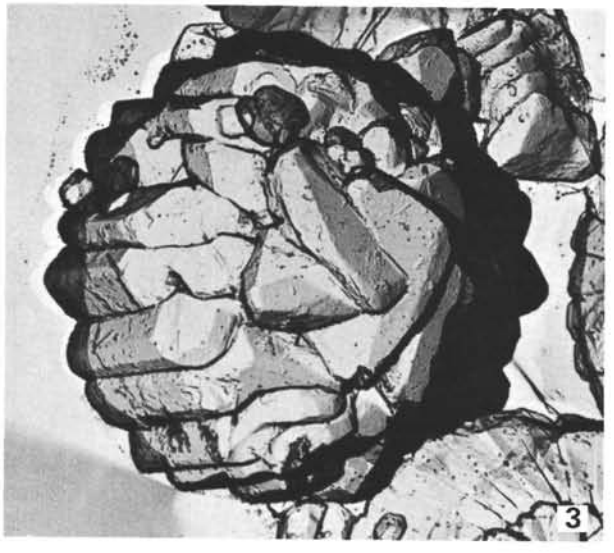
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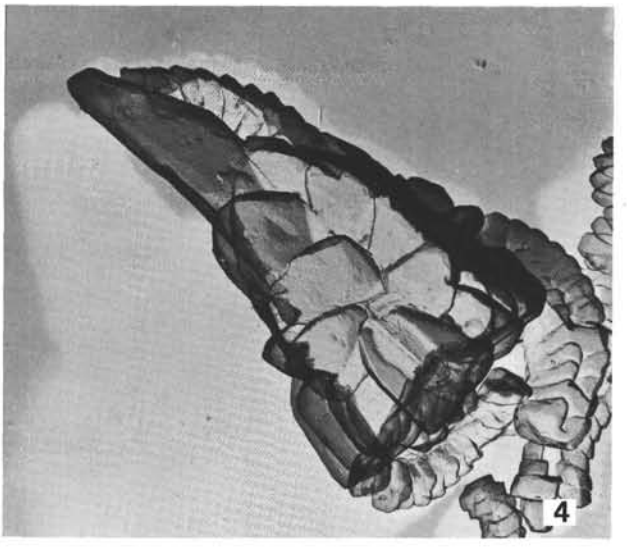
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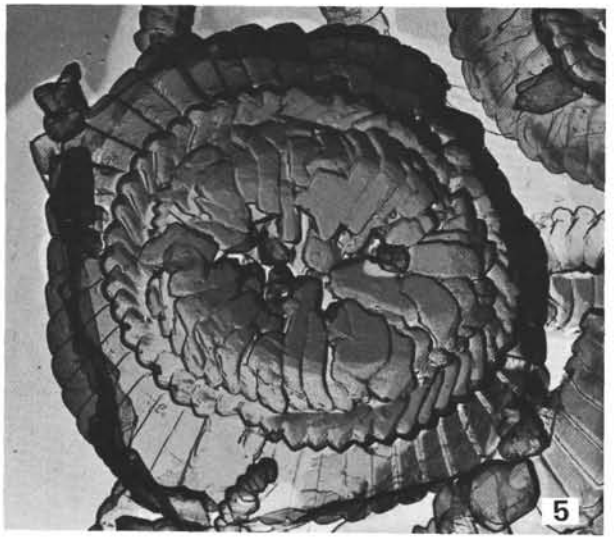
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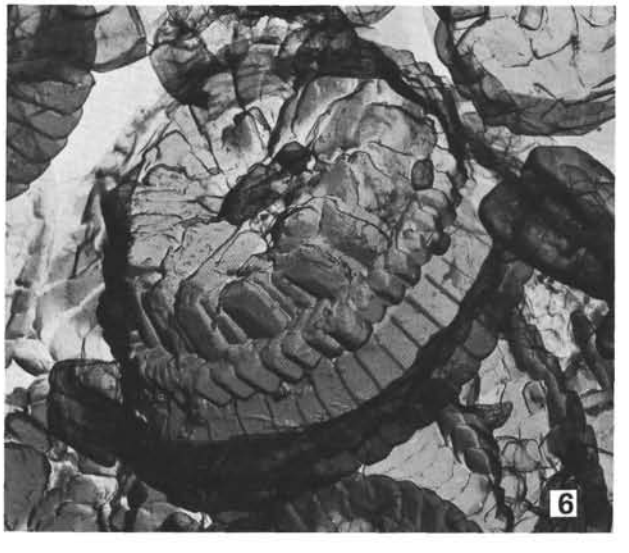
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PLATE 8

Coccolith replica electronmicrographs
Paleocene, Shatsky Plateau, Hole 47.2, Core 9, Section 5
77-78 cm (89 meters subbottom)

Figure 1 Assemblage; 4,000 X.

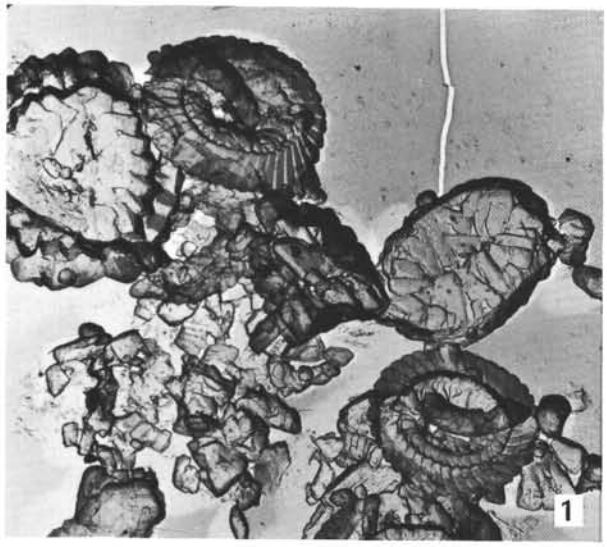
Figure 2 *Chiasmolithus consuetus* (Bramlette and Sullivan); 6,200 X.

Figure 3 *Ericsonia subpertusa* Hay and Mohler; 7,200 X.

Figure 4 *Heliolithus kleinpelli* Sullivan; 5,600 X.

Figure 5 *Heliolithus* sp.; 7,400 X.

Figure 6 *Zygodiscus* sp.; 8,000 X.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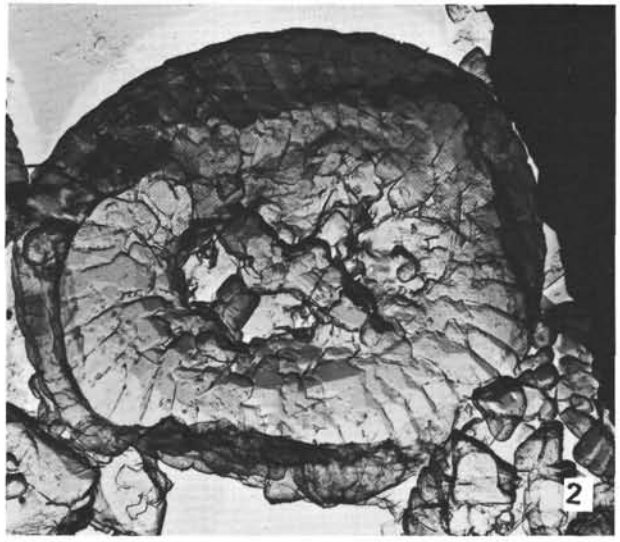
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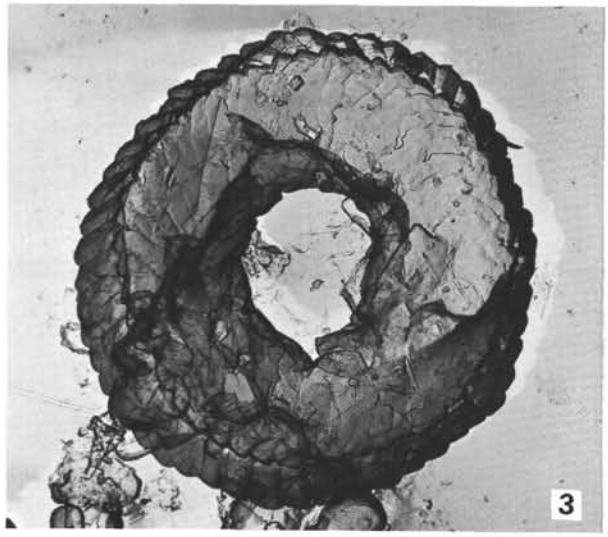
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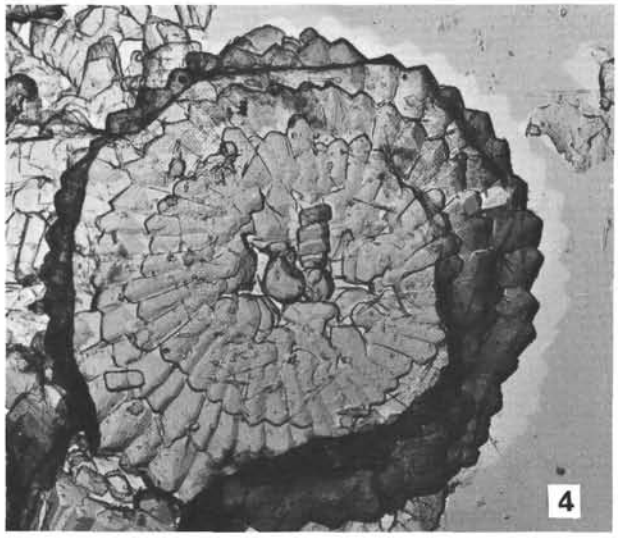
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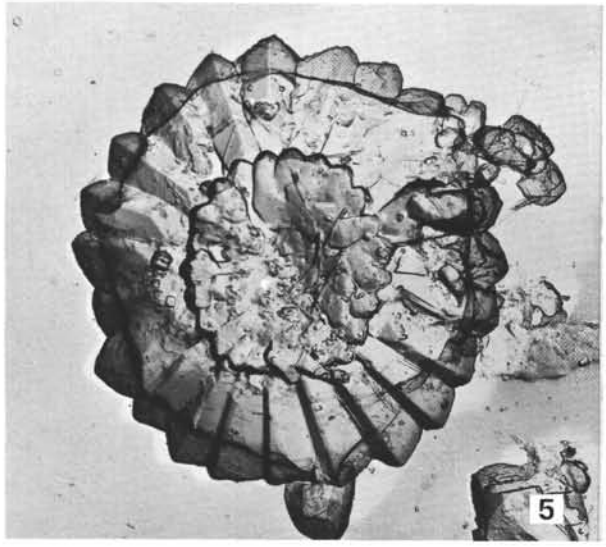
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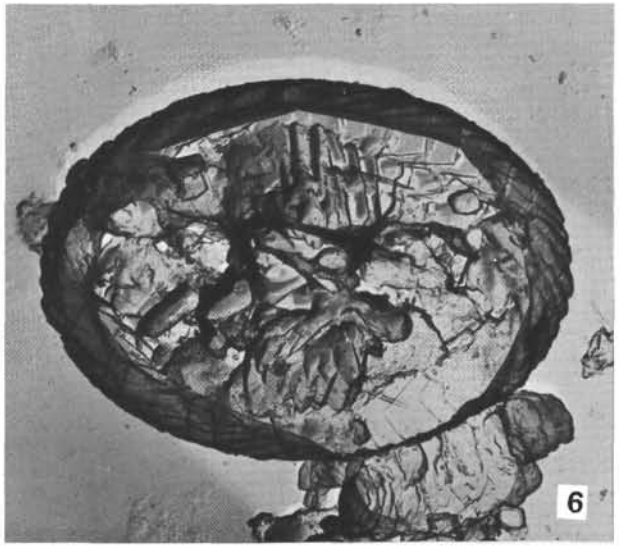
6

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