26. COCCOLITH STRATIGRAPHY, EASTERN EQUATORIAL PACIFIC, LEG 16 DEEP SEA DRILLING PROJECT[1]

David Bukry, U.S. Geological Survey, La Jolla, California

INTRODUCTION

Deep Sea Drilling Project Leg 16, February-March 1971, through the eastern equatorial Pacific Ocean from Panama to Hawaii, recovered 210 cores at nine drilling sites (Figure 1). Light-microscope techniques were used to study the coccoliths of 1800 samples from these cores. Stratigraphic assignments of the cores are summarized in Tables 1 and 2. The biostratigraphic zonal system used for Leg 16 is similar to that previously suggested for the Pacific (Bukry, 1971b); new subdivisions of the *Reticulofenestra umbilica* Zone and *Helicopontosphaera reticulata* Zone are presented. Following some remarks on stratigraphic zonation and on new evolutionary stages in oceanic coccolith assemblages are sections on recognition of preservation states and on paleoecology. The systematic paleontology includes two new genera—*Angulolithina*, *Minylitha*—and eight new species—*Angulolithina arca*, *Ceratolithus bizzarus*, *C. dentatus*, *Emiliania ovata*, *Gephyrocapsa lumina*, *G. omega*, *Minylitha convallis*, *Sphenolithus delphix*. Species in selected samples from drill sites are given by age and zone and representative species are illustrated.

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

STRATIGRAPHY

Biostratigraphic Zones

Significant evolutionary changes have affected the form and crystal orientation of coccolith skeletons during the Mesozoic and Cenozoic. In open-ocean strata, the abundance of these minute calcite skeletons, produced by planktonic, golden brown algae, makes them useful for recognizing a sequence of worldwide evolutionary stages and zones. Zones defined for open-ocean assemblages are identified mainly by cosmopolitan, solution-resistant species. These coccolith zones are, therefore, basic biostratigraphic units that characterize fossil assemblages that accumulated over a wide range of geographic locations

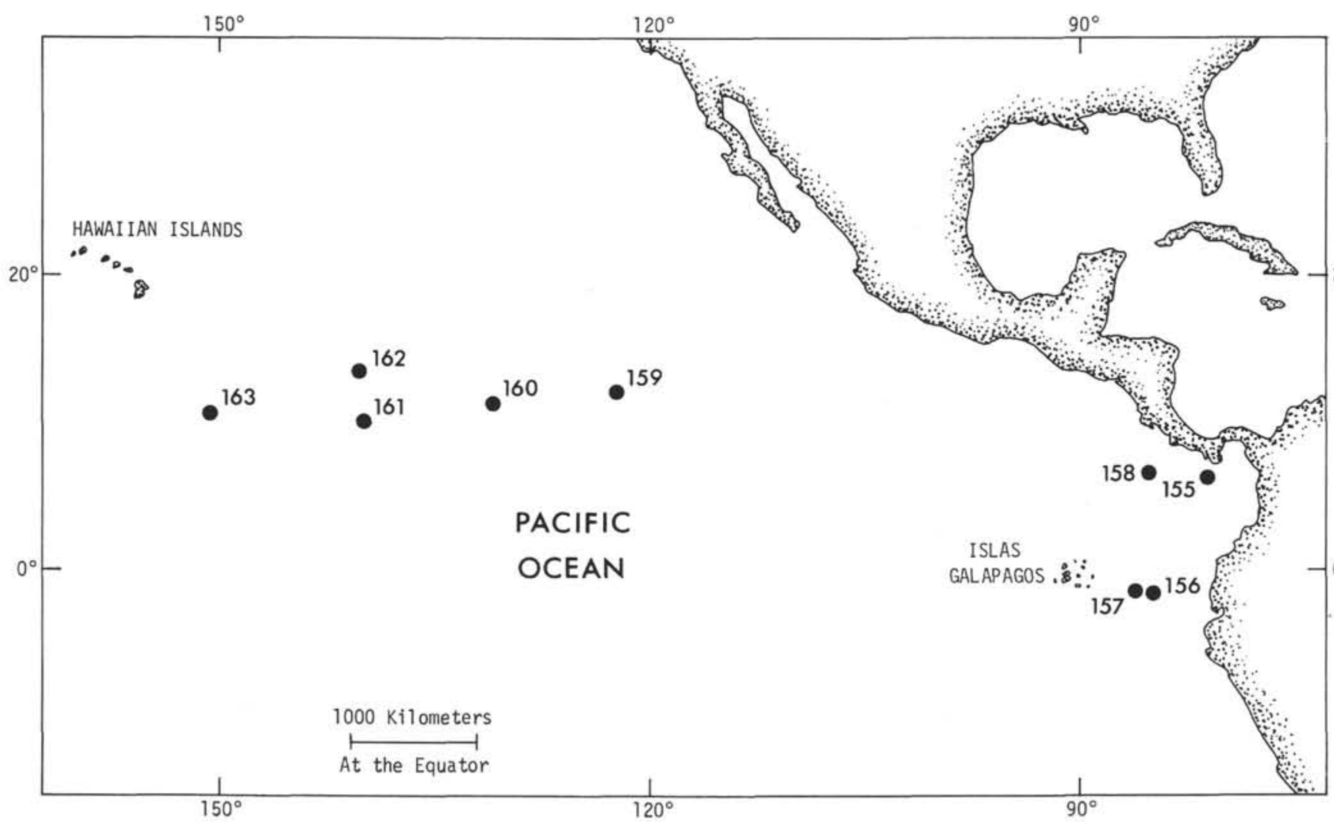


Figure 1. *Location of sites cored during Deep Sea Drilling Project Leg 16.*

TABLE 1
Zonal and Geologic Age Assignments of Leg 16 Cores From The Panama Basin. Numbers Are Core Designations and Typically Represent Nine Meters of Sediment Cored, Although Recovery May Be Less

<table>
<tr><th>Age</th><th>Zone or Subzone</th><th>DSDP 155</th><th>DSDP 156</th><th colspan="2">DSDP 157</th><th colspan="2">DSDP 157A</th><th>DSDP 158</th></tr>
<tr><td rowspan="4">Holocene and Pleistocene</td><td>E. huxleyi</td><td></td><td></td><td colspan="2"></td><td></td><td rowspan="2">1A</td><td>1?</td></tr>
<tr><td>G. oceanica</td><td>bit</td><td>1</td><td colspan="2">1-5</td><td>2A-3A</td><td>1-3</td></tr>
<tr><td>G. caribbeanica</td><td></td><td></td><td colspan="2">5-8</td><td colspan="2"></td><td>4</td></tr>
<tr><td>E. annula</td><td></td><td></td><td colspan="2">8-9</td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="7">Pliocene</td><td>C. macintyrei</td><td></td><td></td><td colspan="2">9-14</td><td colspan="2"></td><td>4</td></tr>
<tr><td>D. pentaradiatus</td><td></td><td></td><td colspan="2">14-16</td><td colspan="2"></td><td>4</td></tr>
<tr><td>D. tamalis</td><td>15</td><td></td><td>16-21</td><td rowspan="2">21-24</td><td colspan="2"></td><td>4-5</td></tr>
<tr><td>D. asymmetricus</td><td>15</td><td></td><td></td><td colspan="2"></td><td>5</td></tr>
<tr><td>S. neoabies</td><td></td><td></td><td colspan="2">25-28</td><td colspan="2"></td><td>5-7</td></tr>
<tr><td>C. rugosus</td><td></td><td></td><td colspan="2">28-29</td><td colspan="2"></td><td>7-8</td></tr>
<tr><td>C. amplificus</td><td>14</td><td></td><td colspan="2">29-35</td><td colspan="2"></td><td>8-9</td></tr>
<tr><td rowspan="5">Late Miocene</td><td>T. rugosus</td><td></td><td></td><td colspan="2">36?</td><td colspan="2"></td><td>9?</td></tr>
<tr><td>C. primus</td><td>13</td><td></td><td colspan="2" rowspan="2">36-43</td><td colspan="2"></td><td>10-17</td></tr>
<tr><td>D. berggrenii</td><td>1</td><td></td><td colspan="2"></td><td>17-19</td></tr>
<tr><td>D. neorectus</td><td rowspan="2">1-4</td><td></td><td></td><td rowspan="2">44-46</td><td colspan="2"></td><td>19</td></tr>
<tr><td>D. bellus</td><td></td><td>48</td><td colspan="2"></td><td>20-23</td></tr>
<tr><td rowspan="5">Middle Miocene</td><td>D. hamatus</td><td>5</td><td></td><td colspan="2"></td><td colspan="2"></td><td>24-28</td></tr>
<tr><td>C. coalitus</td><td>5</td><td></td><td colspan="2"></td><td colspan="2"></td><td>28</td></tr>
<tr><td>D. kugleri</td><td rowspan="2">6-7</td><td></td><td colspan="2"></td><td colspan="2"></td><td rowspan="2">28-36</td></tr>
<tr><td>C. miopelagicus</td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>S. heteromorphus</td><td>7-11</td><td></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

and under varied conditions of calcite supersaturation or undersaturation. In areas favorable to the preservation of richly diversified assemblages, such as warm-water regions and regions where the water column is saturated or only slightly undersaturated, zones can be further divided into subzones by the occurrence of more solution-prone, paleoecologically restricted, short-ranged species. A system of widely recognizable zones and local, regional, or specialized subzones permits realistic flexibility both in providing universal correlation and in highlighting special local conditions. Subzones based on sporadically occurring species may also indicate a preliminary or tenuous refinement within the scope of the zone.

The conventional zonal definition, based on the first and last occurrences of species, has been codified by some investigators (Hay et al., 1967; Martini and Worsley, 1971) into the concept of the "datum" (chronostratigraphic surface). The implied philosophy is that there are no temporally significant barriers to the dispersal of oceanic plankton. Geographic or ecologic barriers are presumed to be overcome in a geologically short time, and a nearly uniform paleogeographic and geologic distribution results. But differential preservation, paleoecology, and barriers to dispersal cause aberrations in this model. For example, *E. huxleyi* appeared in the ocean about 200,000 years ago but in the Black Sea only about 3000 years ago, when communication over the sill of the Bosporus permitted high enough salinities and the biotic access required to establish a population. Moreover, large areas of the North Pacific are so deep that differential solution of calcite has removed *E. huxleyi.* The highly solution-resistant fossils of *Coccolithus pelagicus* are commonly all that remain in the sediment of the original coccolithophycean population. Planktonologists have shown modern *E. huxleyi* to be a tolerant and cosmopolitan species, able to thrive within a wide range of temperature and salinity. Species less adaptable than *E. huxleyi* would provide even more unreliable datums. For instance, warm-water and cool-water plankton are known to be transferred by current systems such as the Gulf Stream to latitudes beyond their usual range (Tolderlund and Bé, 1971; Hulburt, 1967). Datums based on such taxa could have mixed ages in different areas because the true ranges are locally altered first by biogeographic control and secondly by selective solution. In general, zones based on low-latitude taxa that had been displaced would be shorter at high latitudes because the natural species ranges would be incompletely represented.

Ecologic control of one stratigraphic "datum" has been demonstrated clearly by high-latitude deep-sea drilling, where Perch-Nielsen (1972) has shown that the widely recognized extinction of discoasters, usually occurring approximately at the Pliocene-Pleistocene boundary (Olduvai normal polarity event), occurred in the mid-Pliocene (Gauss normal polarity epoch). The earlier onset of late Cenozoic glacial regimes at high latitude evidently affected the range of these warm-water taxa.

Selection of species used for identifying zones requires continuing reappraisal, and zonations of a regional nature, although possibly effective in a particular environment, may not be readily recognized in a different setting (for example, phytoplankton from the area of equatorial upwelling contrast with those of the central water mass). A fundamental zonation based on deep-ocean assemblages

TABLE 2
Zonal and Geologic Age Assignments of Leg 16 Cores from the East Pacific Rise. Numbers are Core Designations and Typically Represent Nine Meters of Sediment Cored, Although Actual Recovery May be Less

Age	Zone or Subzone	DSDP 159	DSDP 160	DSDP 161	DSDP 161A	DSDP 162	DSDP 163	DSDP 163A
Middle Miocene	*D. kugleri*	3						
	C. miopelagicus	3-4						
	S. heteromorphus	4						
Early Miocene	*H. ampliaperta*	5						
	S. belemnos							
	D. druggii	5-9	4	1-2				
	D. deflandrei	9-12	5	2-3				
Late Oligocene	*D. abisectus*	12-13		3				
	S. ciperoensis		5-8	3-9	1A			
	S. distentus		9-10	9-13	1A			
Early Oligocene	*S. predistentus*		10-12	13-14	2A-7A	1-2		
	R. hillae		13		7A-8A	3		
	C. formosa				8A-9A	3-4		
	C. subdistichus							
Late Eocene	*D. barbadiensis*				10A-11A	5		
Middle Eocene	*D. saipanensis*				12A-14A	6-9		
	D. bifax					10		
	C. staurion					10-13		
	C. gigas					13-14		
	D. mirus					15		
	D. sublodoensis					16		
Early Eocene	*D. kuepperi*					17		
	D. lodoensis							
	T. orthostylus							
	D. diastypus							
Paleocene	*C. eodela*							
	C. bidens							
	D. nobilis							
	D. mohleri							
	H. kleinpellii							
	F. tympaniformis							
	C. tenuis							
Late Cretaceous: Maestrichtian	*M. mura*							1A
	L. quadratus						15	
Late Cretaceous: Campanian	*T. trifidus*						15-22	
	B. parca						22-23	
	E. augustus						24-27	

that can be widely recognized in all oceans must necessarily be characterized by cosmopolitan solution-resistant species that are reasonably abundant and easily identified.

A critical factor probably limiting the species diversity of oceanic assemblages is the selective solution of taxa that would be preserved in coeval sediment of warmer, shallower, and less undersaturated areas. Therefore, the use of regional subzones is expedient for paleoecologic and biostratigraphic correlation and helps to eliminate some types of mistaken interpretation. For example, application of a finely divided standard zonation from a temperate nearshore section to an equatorial deep-ocean section might seem to show several hiatuses if some of the marker species from the nearshore section were missing, when, in fact, the equatorial section was complete. Preservational and ecologic controls dictate that attempts to increase stratigraphic resolution not produce such false hiatuses. Zonation based on assemblages of species, many of which are cosmopolitan, is empirically sound and allows discrimination of ecologic and preservational effects. A greater number of sections can be compared on a coeval basis using cosmoplitan species, and the larger the assemblages the more the control for stratigraphic interpretation.

Light-microscope identification of coccolith assemblages provides the means to divide the Quaternary into two widely recognizable zones and, in places, a third. The guide species of the third, or youngest, *Emiliania huxleyi* Zone can be identified consistently only by electron microscopy. The precise appearance of *E. huxleyi* in the late Quaternary is difficult to determine because of the presence of closely similar precursor species. Other indicators, however, are helpful in recognizing the *E. huxleyi* Zone in some areas, such as the occurrence of unusually large *Ceratolithus cristatus* or of the first *Gephyrocapsa ericsonii*.

The lowest coccolith zone assigned to the Quaternary is the *Coccolithus doronicoides* Zone. Assemblages of this zone are characterized by the absence of *Gephyrocapsa oceanica* and certain common species of the underlying *Discoaster brouweri* Zone. Within this zonal interval, the appearance of *Gephyrocapsa caribbeanica* can be used in places to divide the zone into a *Gephyrocapsa caribbeanica* Subzone above and an *Emiliania annula* Subzone below. Paleoecologically induced changes in the abundance of *Coccolithus pelagicus* and the ratio of *Helicopontosphaera kamptneri* to *H. sellii* occur in many areas in this interval. Along with the general elimination of typical Pliocene taxa such as *Ceratolithus rugosus, Cyclococcolithina macintyrei,* and *Discoaster brouweri,* these changes indicate a widespread alteration of the character of coccolith assemblages from those of previous intervals.

Zonation of Miocene-Pliocene boundary sequences has been based largely on the morphologic and crystallographic characters of ceratoliths (Bukry and Bramlette, 1968, 1970; Gartner, 1969). With the availability of thick tropical deep-ocean sections and sections from the Mediterranean Sea obtained by DSDP (Legs 8, 9, 13, 16), new study of the ceratolith sequence verifies that *Ceratolithus amplificus* and *C. rugosus* provide guides to the two basal subzones of the Pliocene.

Changes in the character of ortholithid assemblages of warm-water areas permit regional subdivision of some upper Miocene zones. Owing to the relatively long duration indicated for the *Discoaster quinqueramus* Zone, and especially the *Discoaster neohamatus* Zone (Table 3), further subdivision can be anticipated as detailed studies are undertaken. At present, in eastern equatorial Pacific assemblages, two subzones are recognized for each of these zones. The *D. quinqueramus* Zone, which is characterized by *Discoaster quinqueramus* and *D. surculus,* can be divided into a *Ceratolithus primus* Subzone above and a *Discoaster berggrenii* Subzone below. The *C. primus* Subzone is distinguished by the sporadic occurrence of *Ceratolithus primus* and *C. dentatus,* the earliest occurrence of *Scyphosphaera globulata,* and the dominance of *D. quinqueramus* over *D. berggrenii.* An absence of ceratoliths and the common occurrence of *D. berggrenii* indicate the *D. berggrenii* Subzone. Within the *D. neohamatus* Zone of the eastern equatorial Pacific, a short *Discoaster neorectus* Subzone at the top is characterized by the occurrence of *Discoaster neorectus, D. loeblichii,* and *D. neohamatus.* The *Discoaster bellus* Subzone below is typified by *Discoaster bellus, D. neohamatus,* and the latest *D. pseudovariabilis,* in the absence of *D. neorectus* and *D. hamatus.* In other ocean areas, the full ranges of many upper Miocene species recently described are not as well known.

The *Triquetrorhabdulus carinatus* Zone of early Miocene and late(?) Oligocene age has been divided into a *Discoaster druggii* Subzone above and a *Dictyococcites abisectus* Subzone below (Bukry, 1971a). A transitional interval seemed to exist between these subzones at some sites in the western Pacific. This interval has also been recognized in the Caribbean (DSDP Leg 15) and eastern Pacific (DSDP Leg 16) and has been designated the *Discoaster deflandrei* Subzone. At low latitudes, low-diversity assemblages dominated by *Discoaster deflandrei, Cyclicargolithus floridanus,* and *Triquetrorhabdulus carinatus,* and generally lacking *Dictyococcites abisectus, Discoaster druggii,* or *Orthorhabdus serratus,* characterize this subzone.

The lower Oligocene *Helicopontosphaera reticulata* Zone has been widely recognized in deep-ocean sediment by the disappearance of the rosette discoasters *D. saipanensis* and *D. barbadiensis* at its base, and the nearly coincident disappearance of the large placoliths *Cyclococcolithina formosa* and *Reticulofenestra umbilica* at its top. A subdivision of this interval in nearshore sections has been indicated by the last occurrence of *Coccolithus subdistichus* (see Hay et al., 1967; Martini, 1970). However, owing to its poor preservation and its close resemblance to *Coccolithus fenestratus* and *C. obrutus,* this species is difficult to identify in oceanic assemblages, if it is indeed present. A later redefinition of this zonal unit (Martini, 1971) alters its definition to coincide with the *Helicopontosphaera reticulata* Zone of Bramlette and Wilcoxon (1967). A very short interval between the last occurrences of *Cyclococcolithina formosa* and *Reticulofenestra hillae* or *R. umbilica,* called an emended *Helicopontosphaera reticulata* Zone by Martini (1971), is herein designated the *Reticulofenestra hillae* Subzone. Within the broadly defined original *Helicopontosphaera reticulata* Zone, three subzones may potentially be identified. The basal *Coccolithus subdistichus* Subzone is keyed to an acme of a form resembling *C. subdistichus, C. obrutus,* and *C. fenestratus.* The *Cyclococcolithina formosa* Subzone in the middle represents the interval above this acme and below the last *C. formosa.* The *Reticulofenestra hillae* Subzone at the top, generally not evident in oceanic sections, includes the interval above the last *C. formosa* and below the last *R. umbilica* or *R. hillae.* This subzone is probably present at DSDP 161A in a short interval near the top of Core 8A and the core catcher of Core 7A, but minor Eocene admixtures makes identification uncertain. Subdivision of the *H. reticulata* Zone in oceanic sections is still tentative.

Owing to richly diversified lower and middle Eocene assemblages, often greatly enriched by nearshore or solution-prone components, a variety of zonal systems is available to divide the Eocene in land sections. Recent zonations by Gartner (1971), Martini (1971), and Roth et al. (1971) are useful for deposits that formed in nearshore basins or on shallow oceanic rises, but they are somewhat less effective in deep-ocean areas. For example, although the upper Eocene *Sphenolithus pseudoradians* Zone (Martini, 1970) is useful in sections from northern Europe (Roth, P.H., personal communication, 1972), it is not applicable to the cored sections from the Pacific Ocean or Gulf of Mexico, where *Spenolithus pseudoradians* first appears in the middle Eocene (see Sites DSDP 44, 64, and 94). Division of the Eocene in oceanic assemblages can be indicated by the sequential appearance as *Discoaster diastypus* (coeval *D. binodosus* is typically restricted to nearshore assemblages), *Tribrachiatus orthostylus, Discoaster lodoensis, D. ? mirus, D. sublodoensis, Nannotetrina* spp., *Reticulofenestra umbilica, Dictyococcites bisectus,* and *Discoaster tani.* Diappearances can also provide helpful guides in continuous sections. For example, the sequential extinctions in middle Eocene of *Chiasmolithus gigas,* then *C. solitus,* followed by *C. grandis,* are utilized in a variety of zonal systems.

TABLE 3
Coccolith Zones and Subzones with Estimated Time Relations. Ages Modified from Perch-Nielsen (1972)

Series or Subseries	Zone	Subzone	Duration my	Boundary my
Holocene	*Emiliania huxleyi*		0.2	0.2
Pleistocene	*Gephyrocapsa oceanica*		0.7	0.9
	Coccolithus doronicoides	*Gephyrocapsa caribbeanica*	0.7	1.6
		Emiliania annula	0.2	1.8
Upper Pliocene	*Discoaster brouweri*	*Cyclococcolithina macintyrei*	0.3	2.1
		Discoaster pentaradiatus	0.4	2.5
		Discoaster tamalis	0.5	3.0
Lower Pliocene	*Reticulofenestra pseudoumbilica*	*Discoaster asymmetricus*	0.4	3.4
		Sphenolithus neoabies	0.6	4.0
	Ceratolithus tricorniculatus	*Ceratolithus rugosus*	0.3	4.3
		Ceratolithus amplificus	0.8	5.1
		Triquetrorhabdulus rugosus	0.1	5.2
Upper Miocene	*Discoaster quinqueramus*	*Ceratolithus primus*	0.8	6.0
		Discoaster berggrenii	0.8	6.8
	Discoaster neohamatus	*Discoaster neorectus*	0.5	7.3
		Discoaster bellus	3.7	11.0
Middle Miocene	*Discoaster hamatus*		2.0	13.0
	Catinaster coalitus		0.2	13.2
	Discoaster exilis	*Discoaster kugleri*	0.2	13.4
		Coccolithus miopelagicus	0.6	14.
	Sphenolithus heteromorphus		1.0	15.
Lower Miocene	*Helicopontosphaera ampliaperta*		2.0	17.
	Sphenolithus belemnos		1.0	18.
	Triquetrorhabdulus carinatus	*Discoaster druggii*	3.0	21.
		Discoaster deflandrei	2.0	23.
Oligocene		*Dictyococcites abisectus*	1.0	24.
	Sphenolithus ciperoensis		2.5	27.
	Sphenolithus distentus		3.5	30.
	Sphenolithus predistentus		4.0	34.
	Helicopontosphaera reticulata	*Reticulofenestra hillae*	0.5	35.
		Cyclococcolithina formosa	2.5	37.
		Coccolithus subdistichus	1.0	38.
Upper Eocene	*Discoaster barbadiensis*		4.0	42.
Middle Eocene	*Reticulofenestra umbilica*	*Discoaster saipanensis*	2.0	44.
		Discoaster bifax	1.0	45.
	Nannotetrina quadrata	*Coccolithus staurion*	1.5	46.
		Chiasmolithus gigas	0.5	47.
		Discoaster mirus	1.0	48.
	Discoaster sublodoensis		1.0	49.
Lower Eocene	*Discoasteroides kuepperi*		0.5	50.
	Discoaster lodoensis		0.5	51.
	Tribrachiatus orthostylus		2.0	52.
	Discoaster diastypus		1.5	53.
Paleocene	*Discoaster multiradiatus*	*Campylosphaera eodela*	0.5	54.
		Chiasmolithus bidens	1.0	55.
	Discoaster nobilis		0.5	56.
	Discoaster mohleri		1.5	57.
	Heliolithus kleinpellii		1.0	58.
	Fasciculithus tympaniformis		2.0	60.
	Cruciplacolithus tenuis		3.0	63.
Upper Cretaceous	*Micula mura*		3.0	66.
	Lithraphidites quadratus		4.0	70.
	Tetralithus trifidus		5.0	75.
	Broinsonia parca		1.0	76.
	Eiffellithus augustus		4.0	80.

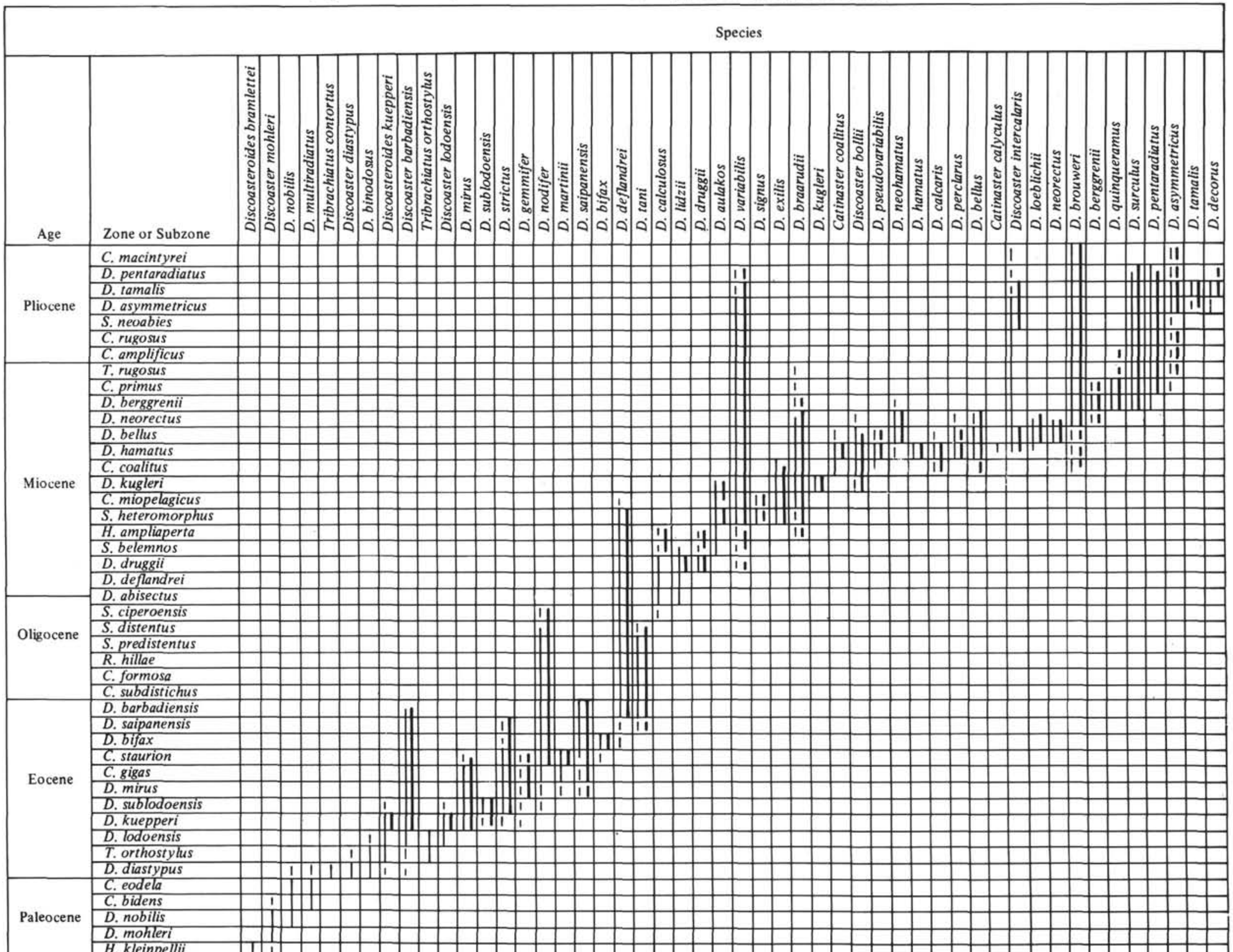
Middle Eocene oceanic assemblages are typically less dissolved and better diversified than those of the upper Eocene. Of three widely recognized middle Eocene zones, the upper two can be subdivided into five subzones in equatorial Pacific assemblages. Within the *Reticulofenestra umbilica* Zone, a *Discoaster saipanensis* Subzone above and a *Discoaster bifax* Subzone below can be distinguished by the typically restricted ranges of *Dictyococcites scrippsae* and rare *D. bisectus* (first occurring in the upper unit) and *Chiasmolithus solitus* and *Discoaster bifax* (last occurring in the lower unit). The *Nannotetrina quadrata* Zone can be recognized by a variety of *Nannotetrina* species below the first occurrence of *Reticulofenestra umbilica.* This zone is divided into three intervals by the restricted occurrence of the large, distinctive species *Chiasmolithus gigas* in the middle interval, the *Chiasmolithus gigas* Subzone; *Discoaster martinii* occurs last in the upper interval, *Coccolithus staurion* Subzone; and *Discoaster gemmifer, D. mirus, D. nonaradiatus,* and *Triquetrorhabdulus inversus* are most common in the *Discoaster mirus* Subzone below, which is the culmination of lower to middle Eocene bifid multiray discoasters in the eastern Pacific. The middle Eocene *Discoaster sublodoensis* Zone has been broadly interpreted to include most of the range of the name-giving species. However, reexamination of reports on this stratigraphic interval (Bramlette and Sullivan, 1961; Bouché, 1962; Sullivan, 1965; Hay et al., 1967; Bukry and Kennedy, 1969; Martini, 1971) and comparisons of newly cored DSDP sections at Sites DSDP 94 and DSDP 162 has prompted reinstitution of Bramlette and Sullivan's (1961) Units 4 and 5 as separate zones instead of a single *Discoaster sublodoensis* Zone. The Unit 4 equivalent is the *Discoasteroides kuepperi* Zone and that of Unit 5, the *Discoaster sublodoensis* Zone. Although the *D. kuepperi* Zone is correlated (DSDP Legs 10 and 16) with the lower Eocene *Acarinina densa* Zone of foraminifera, the *D. sublodoensis* Zone, characterized by *D. sublodoensis* and *Rhabdosphaera inflata,* is at least in part middle Eocene (Bouché, 1962; Worzel et al., in preparation). The *D. kuepperi* Zone assemblage was distinguished by Bramlette and Sullivan (1961) in the following terms: "Although species restricted to the zone are not yet known it seems clearly recognizable by the distinctive association of many species which have their earliest or latest occurrences in Unit 4." The lastest occurrences of *Chiasmolithus consuetus, Coccolithus crassus, C. cribellum, Discoaster lodoensis, Discoasteroides kuepperi, Lophodolithus nascens,* and the earliest occurrences of *Chiasmolithus solitus, Coccolithus staurion, Discoaster sublodoensis, Helicopontosphaera lophota,* and *Lophodolithus mochlophorus* are indicated for the zone in the Lodo Formation of California. At DSDP 94, in the Gulf of Mexico, *Cyclococcolithina gammation* and *Discoasteroides kuepperi* do not range above this zone.

Within the Upper Cretaceous, only Campanian and Maestrichtian assemblages have been recovered at sufficient localities to establish a zonation for open-ocean assemblages. The most extensive sections recovered are from Site DSDP 10 near Bermuda, Site DSDP 47 on the Shatsky Rise, and Site DSDP 163 near Hawaii. The zonal sequence is rather broadly defined in comparison with that of the Cenozoic, as it is mainly based on total ranges of a few species. These zone markers, such as *Broinsonia parca, Eiffellithus augustus, Micula mura, Tetralithus trifidus,* and auxiliary markers, *Arkhangelskiella cymbiformis, Cylindralithus gallicus, Tetralithus aculeus, T. pyramidus,* and *Zygodiscus meudini,* are highly solution-resistant, cosmopolitan, and distinctively shaped, aiding identification. The lowest zone of the sequence that is commonly recognized, the *Eiffellithus augustus* Zone, is typically identified as the interval between the first *B. parca* and the last *E. augustus.* Typical assemblages of the zone have been reported for Sites DSDP 10, Cores 17-18; DSDP 21, Cores 6-8; DSDP 163, Cores 24-27. The next higher, *Broinsonia parca* Zone occurs in thick continuous sections at DSDP 10, Cores 15-16, and DSDP 163, Cores 22-23, and is a minor unit within the range of *B. parca* but above that of *E. augustus* and below that of *T. trifidus.* The range of *T. trifidus* helps define the *Tetralithus trifidus* Zone, which on the basis of foraminiferal correlation, ranges from upper Campanian to lower Maestrichtian. Typically, the common occurrence of *C. gallicus, Z. meudini,* and large *A. cymbiformis* is first noted within this zone. The lower Maestrichtian *Lithraphidites quadratus* Zone of the Atlantic is characterized by the appearance of *Lithraphidites quadratus* and the disappearance of *T. trifidus* and *B. parca.* Owing to the absence of *L. quadratus* in Pacific cores, however, this zone is recognized by assemblages between the last *T. trifidus* and first *M. mura.* At Hole DSDP 47.2, an early, less digitate variety of *M. mura* allows recognition of the lower part of the highest Maestrichtian *Micula mura* Zone. Cretaceous assemblages above the appearance of *M. mura* are assigned to this zone.

Probably the single most useful group of coccoliths for Tertiary stratigraphy is the star-shaped discoasters (Discoasteraceae). From their initial appearance in the Paleocene to their extinction at the end of the Pliocene, they provide excellent guides to zonal assemblages. They attain their largest diversity in the late Paleocene through middle Eocene and in the middle Miocene through middle Pliocene. During the late Pliocene, sequential extinctions of discoasters are stratigraphically useful. The stratigraphic ranges of selected discoasters in DSDP Leg 16 cores are compared with typical ranges compiled from previous Pacific DSDP legs in Table 4.

Owing to their high resistance to solution, their distinctive shapes that aid in species identification, and their relatively short age ranges, discoasters are a key group in identifying oceanic biostratigraphic zones. They tend to retain their identity in adverse diagenetic environments such as deep-ocean clays and volcanic or biogenic siliceous sediments. In carbonate ooze, however, discoasters are susceptible to secondary calcite overgrowths, which, if excessively thick, can obscure specific characters and reduce their stratigraphic usefulness.The stratigraphic interval of most uniform carbonate-rich ooze is the Oligocene to lower Miocene. Coring in both the Pacific and Atlantic has shown the Oligocene to be characteristically rich in carbonate. This high-carbonate content indicates a very deep calcite compensation depth (Hay, 1970b). The rate of production clearly overbalanced the rate of solution, as most carbonate percentages in both Atlantic and Pacific sediments are 70-100 per cent. Some solution was

TABLE 4
Stratigraphic Ranges of Some Discoasteraceae from Leg 16 (Heavy Lines at Right) Compared With Presently Known Total Life Ranges of Stratigraphically Useful Pacific Species (Light Lines at Left). Consistent Occurrence Solid; Sporadic Occurrence Dashed.



still operative, however, because foraminifera assemblages of the Oligocene are usually decimated (Kaneps, this volume). Discoasters from Oligocene deep-ocean carbonate ooze have significant overgrowths. The wrench-shaped tips and rounded interray margins of the dominant species, *Discoaster deflandrei*, are typically obscured (compare Hay et al., 1967; Bukry, 1971a; Wise and Hsü, 1971). In some unusual specimens, one ray may be a morphologically pristine, biologically patterned crystallite, whereas rays directly oppositely show only as massive, crystal-faced remnants.

Discoasters are most abundant at low latitude and are therefore considered to have thrived in warm-water conditions. Oligocene discoaster species diversity is remarkably low in comparison with Eocene and Miocene. Oxygen-isotope paleotemperatures determined from Oligocene foraminiferal tests are lower than those for the Eocene or Miocene (Douglas and Savin, 1971; Douglas, R.G., personal communication, 1972), and similar paleotemperature relations are indicated from analyses of terrestrial floras (Wolfe and Hopkins, 1967). Although discoaster specimens are abundant in equatorial assemblages, they are few or absent at high latitude (DSDP Leg 12). The apparent slower rate of speciation in *Discoaster* during the Oligocene and late Eocene has resulted in fairly long zones of about 3 my each, whereas zones and subzones of the Eocene and Miocene average less than 2 my each.

Discoaster assemblages may be influenced by oceanographic circulation patterns. Fossil assemblages representing relatively cool, nutrient-, and silica-enriched waters of late Miocene age associated with upwelling tend to have discoaster populations enriched with *Discoaster variabilis* and *D. intercalaris.* In warm-water assemblages not associated with areas of strong upwelling, these are numerically less important, and species such as *D. brouweri, D. neohamatus, D. quinqueramus, D. pentaradiatus,* and *D. surculus* are most prominent (compare DSDP Legs 6 and 7 with DSDP Legs 5 and 16).

Stages

Closely related to the developmental succession of discoasters are changes in other coccolith groups. A sequence of stages based on evolution within the Coccolithophyceae can be recognized in deep-ocean strata. Whereas zones and subzones represent the basic working units of biostratigraphy, stages or groups of zones (Am. Comm. Stratig. Nomen., 1961) provide a means to identify major evolutionary changes in the character of a particular fossil group. Stages based on the character of Neogene coccolith assemblages have been proposed (Bukry, 1972). These are reviewed and briefly discussed below along with new stages based on Late Cretaceous and Paleogene coccoliths (see Table 5).

BERMUDAN STAGE

The Bermudan Stage, based on Upper Cretaceous calcareous nannoplankton zones, is here named and defined as the interval extending from the base of the *Eiffellithus augustus* Zone to the top of the *Micula mura* Zone. The type section is at Deep Sea Drilling Project Site 10 (lat. 32°51.7'N, long. 52°12.9'W, water depth 4712 m) and includes the interval in Hole DSDP 10 from Core 10, Section 1 (subbottom depth 292 m) to Core 19, Section 1, (subbottom depth 457 m). The stage name is taken from the nearby island of Bermuda.

The development of distinctive species in the genera *Arkhangelskiella, Broinsonia, Micula,* and *Tetralithus* contributes to the unique aspect of Bermudan Stage assemblages. These assemblages contrast with the assemblages of the next younger Shatskyan Stage by the presence of many stem-bearing species of *Amphizygus, Chiastozygus, Cretarhabdus, Eiffellithus, Podorhabdus, Prediscosphaera, Vagalapilla,* and *Zygodiscus,* and of multiperforate non-stemmed species of *Angulofenestrelithus, Cribrosphaera,* and *Nephrolithus.* Only *Zygodiscus* is recognized in the Shatskyan, emphasizing a distinct change in the character of oceanic coccolith assemblages between these two stages. The stem-bearing coccolith taxa characterize the Bermudan, whereas simple nonestemmed placoliths characterize the Shatskyan. The majority of complexly constructed species became extinct near the end of the Bermudan.

SHATSKYAN STAGE

The Shatskyan Stage, based on Paleocene coccolith zones, is here named and defined as the interval extending from the base of the *Cruciplacolithus tenuis* Zone to the top of the *Heliolithus kleinpellii* Zone. A type section is at Deep Sea Drilling Project Site 47 (lat. 32°26.9'N, long. 157°42.7'E, water depth 2689 m) and includes the interval in Hole DSDP 47.2 from Core 9, Section 2 (subbottom depth 84 m) to Core 11, Section 2 (subbottom depth 104 m). The stage name is taken from the Shatsky Rise of the northwestern Pacific Ocean.

Following the elimination of most coccolith species and genera in the late Bermudan, a sequence of poorly diversified assemblages is present in the early Shatskyan. Placoliths dominate oceanic assemblages and, in nearshore basin deposits, pentaliths are also prominent. Assemblages gradually become more diverse upward as new genera such as *Fasciculithus, Ellipsolithus, Chiasmolithus,* and *Neochiastozygus* appear and develop. The assemblages are characteristically smaller and less diversified than those of the following Cantabrian Stage. The large rosette genus *Heliolithus* appears near the top of the Shatskyan and presages the important development of *Discoaster* in the Cantabrian above.

CANTABRIAN STAGE

The Cantabrian Stage, based on Paleocene coccolith zones, is here named and defined as the interval extending from the base of the *Discoaster mohleri* Zone to the top of *Discoaster multiradiatus* Zone. A type section is at Deep Sea Drilling Project Site 119 (lat. 45°02.3'N, long. 7°58.8'W, water depth 4447 m) and includes the interval in Hole DSDP 119 from Core 25 (subbottom depth 410 m) to Core 30 (subbottom depth 502 m). The stage name is taken from Cantabria Seamount off the coast of Spain.

Assemblages of the Cantabrian Stage are typified by a high species diversity. Most of the new species represent variation within genera that appeared in the Shatskyan

TABLE 5
Approximate Correlation of Calcareous Nannoplankton Zones and Stages With Universal Series and Subseries. Ages of Series and Subseries Modified From Berggren et al. (1972).

Zone	Stage	Age MY	Series or Subseries
Emiliania huxleyi		0.01	Holocene
Gephyrocapsa oceanica	Pintan		Pleistocene
Coccolithus doronicoides		1.8	
Discoaster brouweri	Marchenan	3.0	Upper Pliocene
Reticulofenestra pseudoumbilica	Genovesan		Lower Pliocene
Ceratolithus tricorniculatus		5.1	
Discoaster quinqueramus			Upper Miocene
Discoaster neohamatus	Sorolian		
Discoaster hamatus		11	
Catinaster coalitus	Faisian		Middle Miocene
Discoaster exilis			
Sphenolithus heteromorphus			
Helicopontosphaera ampliaperta		15	Lower Miocene
Sphenolithus belemnos	Aruban		
Triquetrorhabdulus carinatus		22.5	
Sphenolithus ciperoensis			
Sphenolithus distentus	Clippertonian		Oligocene
Sphenolithus predistentus			
Helicopontosphaera reticulata	Oan	38	
Discoaster barbadiensis		42	Upper Eocene
Reticulofenestra umbilica			
Nannotetrina quadrata	Palmyran		Middle Eocene
Discoaster sublodoensis			
Discoasteroides kuepperi		49	
Discoaster lodoensis	Campechean		Lower Eocene
Tribrachiatus orthostylus			
Discoaster diastypus		53.5	
Discoaster multiradiatus			
Discoaster nobilis	Cantabrian		
Discoaster mohleri			Paleocene
Heliolithus kleinpellii			
Fasciculithus tympaniformis	Shatskyan		
Cruciplacolithus tenuis		63	
Micula mura			
Lithraphidites quadratus			
Tetralithus trifidus	Bermudan		Upper Cretaceous
Broinsonia parca			
Eiffellithus augustus			

Stage below, such as *Chiasmolithus, Fasciculithus,* and *Neochiastozygus.* The variety of species is well illustrated in Bramlette and Sullivan (1961), Hay and Mohler (1967), and Perch-Nielsen (1971a, b). Several new genera appeared, including *Discoaster, Discoasteroides, Sphenolithus, Campylosphaera,* and *Toweius.* Of these, only *Discoaster* and *Sphenolithus* proved to be highly successful and long-ranged. Speciation in these two genera has provided the basis for most Tertiary zonations of oceanic coccolith assemblages. Both groups are constructed of relatively few crystallites. Cantabrian assemblages have a unique appearance owing to the occurrence of large, circular rosette skeletons of *Discoaster, Discoasteroides,* and *Heliolithus* and to the great diversity of associated smaller forms.

CAMPECHEAN STAGE

The Campechean Stage, based on coccolith zones, is here named and defined as the interval extending from the base of the *Discoaster diastypus* Zone to the top of the *Discoasteroides kuepperi* Zone. A type section is at Deep Sea Drilling Project Site 94 (lat. 24°31.64'N, long. 88°28.16'W, water depth 1793 m) and includes the interval in Hole DSDP 94 from Core 26 (subbottom depth 505 m) to Core 32 (subbottom depth 612 m). The stage name is taken from adjacent Campeche Bank in the Gulf of Mexico.

Campechean Stage assemblages are distinguished from Cantabrian assemblages below by many changes at the genus and species level. Cantabrian genera that disappear at or near the base of the Campechean include *Fasciculithus, Rhomboaster,* and *Toweius.* Genera that appear for the first time in the Campechean include *Chiphragmalithus, Helicopontosphaera, Rhabdosphaera,* and *Striatococcolithus.* At the species level numerous changes occur near the base of the Campechean. For example, in the family Discoasteraceae, the large rosette discoasters, *Discoaster lenticularis, D. multiradiatus,* and *D. nobilis,* dwindle and become extinct. New rosette forms include *D. diastypus, D. barbadiensis,* and *Discoasteroides kuepperi,* but more diagnostic is the development of the first open-ocean and marginal-marine populations of non-rosette discoasters represented by *D. binodosus (marginal-marine), D. distinctus, D. lodoensis, D. septemradiatus, Imperiaster obscurus* (marginal-marine), *Tribrachiatus contortus,* and *T. orthostylus.* Evolutionary experimentation in the number of discoaster rays is evident in several species and led to a reduction of the number of rays in these and succeeding discoaster populations. Bifurcation of the rays of some discoasters is another distinctive morphologic feature that appeared and became established during the Campechean. Other new and distinctive species include *Campylosphaera dela, Coccolithus crassus, C. magnicrassus, Chiasmolithus eograndis, C. grandis,* and *Cyclococcolithina gammation.*

PALMYRAN STAGE

The Palmyran Stage, based on Eocene coccolith zones, is here named and defined as the interval extending from the base of the *Discoaster sublodoensis* Zone to the top of the *Reticulofenestra umbilica* Zone. The type section is at Deep Sea Drilling Project Site 162 (lat. 14°52.19'N, long. 140°02.61'W, water depth 4854 m) and includes the interval in Hole DSDP 162 from Core 6, Section 2, 120, cm (subbottom depth 48 m) to Core 16, Section 1, 143-145 cm (subbottom depth 136 m). The stage name is taken from nearby Palmyra Island in the central Pacific.

Palmyran Stage assemblages are characterized by a great evolutionary explosion of Coccolithophyceae, rivalling that of the earlier Cantabrian Stage. Some of the new species that persist as important elements into later stages include *Bramletteius serraculoides, Coccolithus eopelagicus, Cyclococcolithina formosa, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. saipanensis, D. tani, Helicopontosphaera compacta, Lanternithus minutus* (marginal-marine), *Reticulofenestra umbilica, Rhabdosphaera tenuis, Sphenolithus predistentus,* and *S. pseudoradians.* Other species appearing at the base of the Palmyran or top of the Campechean that rise to prominence and then become extinct within the Palmyran include *Chiasmolithus gigas, C. solitus, Discoaster bifax, D. martinii, D. strictus, D. sublodoensis, D. wemmelensis, Nannotetrina* spp., *Rhabdosphaera inflata, Sphenolithus furcatolithoides, Thoracosphaera prolata,* and *Triquetrorhabdulus inversus.* Species that originated in earlier stages and that became extinct during the Palmyran include *Campylosphaera dela, Chiasmolithus grandis, Coccolithus cribellum, Discoaster lodoensis, Ellipsolithus lajollaensis, Helicopontosphaera lophota, H. seminulum, Sphenolithus radians, Zygolithus dubius,* and the multirayed bifid discoasters such as *D. gemmifer, D. mirus,* and *D. nonaradiatus.* The generally high diversity in this stage is evident not only in oceanic sections such as DSDP 162 and DSDP 94, but also in more marginal-marine settings, where a great variety of discolith, pentalith, rhabdosphaerid, and syracosphaerid coccoliths occurs. The underlying Campechean is distinguished from the Palmyran by a smaller number of new species, many of which occurred in the early part of the stage, and by a greater degree of evolutionary experimentation exhibited within Discoasteraceae.

OAN STAGE

The Oan Stage, based on coccolith zones, is here named and defined as the interval extending from the base of the *Discoaster barbadiensis* Zone to the top of the *Helicopontosphaera reticulata* Zone. A type section is at Deep Sea Drilling Project Site 72 (lat. 0°26.49'N, long. 138°52.02'W, water depth 4326 m) and includes the interval in Hole DSDP 72 from Core 9, Section 2, 63 cm, (subbottom depth 332 m) to Core 11, Section 1, 42-43 cm, (subbottom depth 344 m). The stage name is taken from nearby Hiva Oa in the Archipel de Tuamotu in the central Pacific.

Oan Stage assemblages are characterized by extinctions of several prominent lineages of coccoliths and by relatively few new occurrences. The Oan interval is believed to correspond to a significant decline in paleotemperature. Disappearance of the last rosette discoaster, *Discoaster barbadiensis* and *D. saipanensis,* the last large *Chiasmolithus* species, *C. expansus* and *C. oamaruensis,* the last *Cyclococcolithina formosa, Reticulofenestra umbilica, Syracosphaera labrosa,* and the last thick-stemmed *Rhabdosphaera* species, *R. spinula* and *R. tenuis,* tend to reduce the diversity from prior stages. New forms that appeared and became extinct within the Oan, such as *Cyclicargolithus reticulatus* [large], *Isthmolithus recurvus,* and *Coccolithus subdistichus,* failed to become dominant. Only a few species such as *Chiasmolithus altus* that appeared in Oan assemblages persisted higher. The diversity of the stratigraphically useful assemblage is not significantly increased during the stage, in sharp contrast with the underlying Palmyran, where a great many new distinctive species that persist through the Oan and Clippertonian Stages first appeared. A study of smaller species within the Oan (Roth, 1970) suggests that speciation among the smaller placoliths, especially *Reticulofenestra,* proceeded at a reasonable rate. During the Oan and the much later Marchenan Stage, both characterized by lowered paleotemperature, coccolith diversity is reduced because extinctions exceed new appearances, at least among the larger coccolith species.

CLIPPERTONIAN STAGE

The Clippertonian Stage, based on coccolith zones, is here named and defined as the interval extending from the base of the *Sphenolithus predistentus* Zone to the top of the *Sphenolithus distentus* Zone. A type section is at Deep Sea Drilling Project Site 78 (lat. 7°57.00'N, long. 127°21.35'W, water depth 4378 m) and includes the interval in Hole DSDP 78 from Core 23, Section 4, 64-65 cm (subbottom depth 206 m) to Core 32, Section 6, 65-66 cm (subbottom depth 292 m). The stage name is taken from nearby Isla Clipperton in the eastern Pacific.

Clippertonian Stage assemblages are relatively stable and continuous with the placoliths *Coccolithus, Cyclicargolithus, Dictyococcites,* and *Reticulofenestra* predominant; *Sphenolithus* is also important in tropical areas. Discoaster diversity is limited to only three species, *Discoaster deflandrei, D. nodifer,* and *D. tani,* of which *D. deflandrei* is the most abundant. *D. tani* becomes extinct during this stage, whereas *D. nodifer* may range into the overlying Aruban Stage. The Clippertonian is distinguished from the Aruban by its low diversity. Taxa that typically become extinct within the Clippertonian include *Bramletteius serraculoides, Helicopontosphaera compacta, Sphenolithus predistentus,* and *S. pseudoradians.* The only important new forms, in addition to *Sphenolithus distentus,* occur near the top of the Clippertonian or the base of the Aruban and include early forms of *Dictyococcites abisectus,* *Sphenolithus ciperoensis*, and *Triquetrorhabdulus carinatus*. A general increase in diversity helps to distinguish the Aruban. The base of the Clippertonian is determined by the highest occurrence of two of the most prominent Oan placoliths, *Cyclococcolithina formosa* and *Reticulofenestra umbilica*. Dominance also commonly shifts to the small species *Cyclicargolithus floridanus* in the Clippertonian from larger species in the Oan. This shift tends to reduce the average size of the placolith population—an effect not unlike that characterizing the Pintan Stage of the Quaternary. Generally lowered paleotemperatures for the preceding stage are indicated in both these parallel cases with continued reduction of discoaster diversity, leading in fact to total extinction in the case of the Pintan.

ARUBAN STAGE

The Aruban Stage, including the interval from the base of the *Sphenolithus ciperoensis* Zone to the top of the *Helicopontosphaera ampliaperta* Zone, has its type section at Deep Sea Drilling Project Site 149 near the island of Aruba in the Caribbean Sea (Bukry, 1973). *Discoaster* species of the Aruban are dominated by the moderately thick-rayed taxon *D. deflandrei;* other less abundant taxa of similar structure include *D. calculosus, D. druggii,* and *D. lidzii.* The dominant placolith is *Cyclicargolithus floridanus;* other less abundant but larger placoliths include *Coccolithus eopelagicus* and *Dictyococcites abisectus.* A sequence of species of *Helicopontosphaera* and *Sphenolithus* develops and disappears during the Aruban; this contrasts with the fewer number of new species in these genera in later stages. Through the Aruban, the appearance of *Sphenolithus ciperoensis* is followed by *S. dissimilis, S. belemnos,* and *S. heteromorphus.* In the genus *Helicopontosphaera, H. recta* gives way to *H. intermedia* and *H. euphratis,* followed by *H. ampliaperta, H. granulata,* and *H. kamptneri* near the end of this stage.

FAISIAN STAGE

The Faisian Stage, extending from the base of the *Sphenolithus heteromorphus* Zone to the top of the *Catinaster coalitus* Zone, has its type section at Deep Sea Drilling Project Site 55 near Fais Island in the Caroline Islands (Bukry, 1973). The transition from the Aurban to the Faisian Stage in the Miocene involves major changes in several genera, including a dramatic diversification in the *Discoaster* lineage. Rare progenitors of long slender-rayed *Discoaster* species in the late Aruban displace *D. deflandrei* entirely in the early Faisian. These early slender-rayed species of *Discoaster* are overwhelmingly six-rayed. Typical Faisian species include *D. braarudii, D. exilis, D. signus, D. moorei, D. variabilis,* and in the late Faisian, *D. bollii* and *D. kugleri.* With the disappearance of *Sphenolithus heteromorphus* and the development of *S. abies* and *S. neoabies* in the early Faisian, no further speciation is recognized before the genus becomes extinct at the top of the Genovesan Stage. *Helicopontosphaera kamptneri* dominates the Faisian. Among placoliths, *Cyclicargolithus floridanus* is joined by rare *Cyclococcolithina leptopora* in the late Aruban, but in the early Faisian *C. leptopora* and *C. macintyrei* replace *Cyclicargolithus floridanus. Triquetrorhabdulus rugosus* and large *Reticulofenestra pseudoumbilica* first appear in the early Faisian. The transition from the Aruban to the Faisian is distinctive because the change affects the structural character of the two dominant forms, placoliths and discoasters, as well as initiating a plateau in the development of *Helicopontosphaera* and *Sphenolithus.* This transition establishes much of the character of later stages up to the Pintan.

SOROLIAN STAGE

The Sorolian Stage, extending from the base of the *Discoaster hamatus* Zone to the top of the *Discoaster quinqueramus* Zone, *Ceratolithus primus* Subzone, has its type section at Deep Sea Drilling Project Site 56 near Sorol Island in the Caroline Islands (Bukry, 1973).

The Sorolian Stage is characterized by changes mainly at the species level. Extinctions of *Coccolithus miopelagicus* and *Discoaster kugleri* in the late Faisian are followed by the development and acmes, through the Sorolian, of a series of five-rayed *Discoaster* species: *D. hamatus, D. bellus, D. prepentaradiatus, D. pentaradiatus, D. berggrenii,* and *D. quinqueramus.* Only *D. pentaradiatus* persists above the Sorolian. Both five-rayed and six-rayed *Discoaster* species begin to develop significant bending of the rays, for the first time in their evolution. *Helicopontosphaera* species and the placoliths—*Coccolithus, Cyclococcolithina, Reticulofenestra*—show little change. Zonation of the Sorolian is based largely on the development of *Discoaster,* especially the five-rayed forms. The top of the Sorolian occurs at the end of a major diversification of five-rayed *Discoaster* species, just after the initial appearance of *Ceratolithus* and just before the disappearance of *Triquetrorhabdulus.*

GENOVESAN STAGE

The Genovesan Stage, extending from the base of the *Ceratolithus tricorniculatus* Zone, *Triquetrorhabdulus rugosus* Subzone, to the top of the *Reticulofenestra pseudoumbilica* Zone, *Discoaster asymmetricus* Subzone, has its type section at Deep Sea Drilling Project Site 83 near Isla Genovesa, one of the northern Islas Galápagos (Bukry, 1973). The Genovesan Stage is characterized by the development and presence throughout of *Ceratolithus* species that show strong birefringence, *C. amplificus* and *C. rugosus. Discoaster* does not diversify until the upper Genovesan, when the last new species, *D. asymmetricus, D. tamalis,* and *D. decorus,* first appear or have significant acmes. A single new *Helicopontosphaera* species *H. sellii s.s.* appears in this stage. Except for the *Ceratolithus* development at the Sorolian-Genovesan transition and the *Discoaster* development in the upper Genovesan, other genera show little speciation. Extinctions of long-ranging genera *Reticulofenestra* and *Sphenolithus* mark the top of the stage.

MARCHENAN STAGE

The Marchenan Stage, extending from the base of the *Discoaster brouweri* Zone, *Discoaster tamalis* Subzone, to the top of the *Discoaster brouweri* Zone, *Cyclococcolithina macintyrei* Subzone, has its type section at Deep Sea Drilling Project Site 83 and was named for nearby Isla Marchena, one of the northern Islas Galápagos (Bukry, 1973).

The transition from the Genovesan to the Marchenan Stage is recognized by the disappearance together of large *Reticulofenestra pseudoumbilica* specimens and of *Sphenolithus* species and by the assemblage of three new *Discoaster* species that acme at this level. Through the Marchenan, *Discoaster* species show a sequential extinction: *D. decorus, D. tamalis, D. asymmetricus, D. surculus, D. pentaradiatus, D. triradiatus,* and finally *D. brouweri.*

PINTAN STAGE

The Pintan Stage, extending upward from the base of the *Coccolithus doronicoides* Zone, *Emiliania annula* Subzone, through the *Emiliania huxleyi* Zone to the present day flora, has its type section at Deep Sea Drilling Project Site 83 and was named for Isla Pinta, one of the northern Islas Galápagos (Bukry, 1973).

In addition to the extinction of *Discoaster,* several other significant changes occur near the top of the Marchenan or base of the Pintan Stage. *Cyclococcolithina macintyrei* becomes extinct, but the smaller *C. leptopora* persists into present oceans. *Ceratolithus rugosus* is completely replaced by the thinner *C. cristatus. Helicopontosphaera sellii* becomes more abundant with respect to *H. kamptneri;* also *Coccolithus pelagicus* and *Emiliania annula* become especially common for a short interval. *Rhabdosphaera sytlifera* and *R. clavigera* likewise become conspicuous members of the coccolith assemblage. These changes are followed shortly by the disappearance of *C. pelagicus* at low latitude, then by the first appearance of barred species of *Gephyrocapsa* in the lower part of the Pintan. The composite effect of these changes is to produce Pintan assemblages that are distinctly more dominated by small placolith-type coccolith species than those of earlier stages.

Panama Basin Sites

Coccolith assemblages ranging in age from middle Miocene to late Pleistocene or Holocene have been identified at five Deep Sea Drilling Project coring sites, DSDP 84 and and 155 to 158. Although the sites are relatively shallow, 1900-3100 meters, many assemblages show the effects of solution. Species diversity of the assemblages is generally poorer than that of assemblages of comparable age and depth from the Caribbean or western equatorial Pacific (DSDP Leg 7). Strong upwelling in the southern part of the Panama Basin and the resultant rain of siliceous plankton provide the main contrast between this and the other regions. Sediment thickness of various zones reflects generally rapid sedimentation (Table 6). Only at DSDP 158 on Cocos Ridge is part of the section greatly shortened. The upper Pliocene and lower Pleistocene section there could contain some sedimentary discontinuities, but drilling disturbance prevents their recognition.

DSDP 155

Site DSDP 155 is on the eastern flank of Coiba Ridge and is the most landward of the sites drilled in the Panama Basin. It is located near the foot of the continental slope in the Gulf of Panama. Coccolith assemblages recovered at DSDP 155 range in age from Pleistocene to middle Miocene (approximately 15 my) and are generally poorly diversified and solution etched. Many typical guide species are rare or absent. The youngest coccolith assemblage, *Gephyrocapsa oceanica* Zone, was obtained from diatomaceous sediment adhering to the bit. The level of this sediment in the hole is uncertain, 0 to 285 meters. The assemblage lacks the usual number of species present in coeval ooze reported from other tropical areas. Three samples from triple side-wall Core 15 at 285 meters contain coccoliths assigned to the *Discoaster tamalis* Subzone of late Pliocene age and to the *Discoaster asymmetricus* Subzone of early Pliocene age. The younger sample is differentiated from the older pair by the occurrence of common diatoms and *Thoracosphaera* sp. cf. *T. saxea,* by the absence of *Reticulofenestra pseudoumbilica,* and by the rare occurrence of *S. neoabies. Discoaster decorus,* a short-ranging tropical mid-Pliocene species, occurs in all three samples.

Side-wall Core 13 (371 m) recovered poorly preserved coccoliths of late Miocene or early Pliocene age. The few guide fossils generally helpful in zonation of such Genovesan Stage assemblages—*Ceratolithus amplificus, C. rugosus, C. tricorniculatus,* and *Triquetrorhabdulus rugosus*—are absent. *Sphenolithus abies* and *S. neoabies* are especially abundant, suggesting warm water. This abundance is characteristic in much of the lower cored section. Strong etching of coccoliths and variation in abundance are most notable in the late Miocene section in Cores 13 and 1-5 (384 to 477 m). Some samples are barren; others contain concentrations of solution-resistant taxa such as *Discoaster bellus, D. variabilis, Cyclococcolithina leptopora,* and *Reticulofenestra pseudoumbilica.*

The upper Miocene coccolith sequence, although it seems to be generally complete, is represented by poor assemblages and occasional barren intervals. Diagnostic assemblages of the *Ceratolithus primus* Subzone are indicated by the occurrence together of *Ceratolithus dentatus, C. primus, Discoaster quinqueramus,* and *D. surculus* in Core 13. *Discoaster berggrenii, D. quinqueramus,* and *D. surculus* characterize the *Discoaster berggrenii* Subzone of Cores 2 to 3. Minor drilling contamination is indicated in the Core 2 core-catcher sample by the rare presence of younger Miocene and Pliocene taxa: *Ceratolithus rugosus* and *C. tricorniculatus.* (A. Kaneps noted younger Miocene foraminifera contamination in this sample also.)

The *Catinaster coalitus* Zone, a typically short interval, is represented by only about a meter of section (479 to 480 m) at the bottom of Core 5. Poorly preserved but abundant Faisian Stage assemblages assigned to the *Discoaster exilis* Zone and *Sphenolithus heteromorphus* Zone are present in the remaining cores above basalt (480 to 521 m). No deterioration in preservation occurs near the basalt-sediment contact (Core 11), but an isolated chalk within the basalt (Core 12) is barren of identifiable coccoliths.

DSDP 156

Site DSDP 156 is located atop a manganese oxide encrusted basalt(?) pinnacle on the southern flank of the Carnegie Ridge between the Islas Galápagos and Ecuador. A single sediment core containing only 49 cm of material was obtained before termination of drilling. Coccoliths

TABLE 6
Approximate Thickness in Meters of Coccolith Zones at Panama Basin Sites and at a Nearby Site, DSDP 83, on the Eastern Flank of the East Pacific Rise. All Sites Were Cored to Basalt at the Base of the Sediment Section. The Upper Part of DSDP 155 Was Insufficiently Cored to Permit Estimates of Zone Thickness.

<table>
<tr><th colspan="2">Age</th><th>Zone</th><th>DSDP 155</th><th>DSDP 84</th><th>DSDP 158</th><th>DSDP 157</th><th>DSDP 83</th></tr>
<tr><td colspan="2" rowspan="2">Pleistocene</td><td>Gephyrocapsa oceanica</td><td rowspan="5">?(384)</td><td>48</td><td>25</td><td>42</td><td>31</td></tr>
<tr><td>Coccolithus doronicoides</td><td>39</td><td>2</td><td>37</td><td>4</td></tr>
<tr><td rowspan="5">Pliocene</td><td>Late</td><td>Discoaster brouweri</td><td>60</td><td>8</td><td>122</td><td>28</td></tr>
<tr><td rowspan="2">Early</td><td>Reticulofenestra pseudoumbilica</td><td>35</td><td>16</td><td>44</td><td>20</td></tr>
<tr><td>Ceratolithus tricorniculatus</td><td>22</td><td>24</td><td>66</td><td>27</td></tr>
<tr><td rowspan="2">Late</td><td>Discoaster quinqueramus</td><td>57</td><td>47</td><td>86</td><td>56</td><td>83</td></tr>
<tr><td>Discoaster neohamatus</td><td>29</td><td></td><td>37</td><td>41</td><td>13</td></tr>
<tr><td rowspan="4">Miocene</td><td rowspan="4">Middle</td><td>Discoaster hamatus</td><td>8</td><td></td><td>37</td><td></td><td></td></tr>
<tr><td>Catinaster coalitus</td><td>1</td><td></td><td>5</td><td></td><td></td></tr>
<tr><td>Discoaster exilis</td><td>11</td><td></td><td>65</td><td></td><td></td></tr>
<tr><td>Sphenolithus heteromorphus</td><td>30</td><td></td><td></td><td></td><td></td></tr>
</table>

and siliceous phytoplankton are abundant. A late Pleistocene age is indicated by the abundance of *Gephyrocapsa oceanica.* The warm-water aspect of the coccolith assemblage is also indicated by *G. oceanica* (optimum temperature range 18°C to 23°C according to McIntyre and Bé, 1967) and the related taxon *G. omega,* which is presently known only from low-latitude areas. All assemblages examined have been augmented by a few reworked Tertiary taxa. Absence or rare occurrence of *Discolithina, Pontosphaera, Rhabdosphaera, Scapholithus, Scyphosphaera, and Syracosphaera* could be, in part, ecologically controlled, but differential solution seems a more likely cause, in view of the warm, nutrient-rich conditions indicated by those calcareous and siliceous phytoplankton that are present. The small number of species preserved in Pintan Stage assemblages of the Panama Basin sites contrasts with other coeval tropical assemblages.

DSDP 157

Coccoliths are abundant in all forty-eight sediment cores from Site DSDP 157 on the southern flank of Carnegie Ridge. The rapidly accumulated biogenic sediment (423 m in about 9 my = 47 bubnoffs) represents an apparently complete section of upper Miocene to upper Pleistocene or Holocene. Species diversity is low and preservation state deteriorates progressively in deeper sediment levels. Upper Miocene coccolith assemblages are equally poor above and below a chert horizon in Core 38 (342 to 345 m); diatoms and silicoflagellates are absent in all deeper levels. The most striking feature of the upper Miocene (Sorolian Stage) coccolith assemblages at DSDP 157 is the excessively thick, irregular secondary overgrowth on discoasters, which makes identification of most specimens difficult and limits recognition of subzonal units.

The Pliocene section of Cores 10 to 33 is remarkable for its thickness, 232 meters in about 3.4 my = 68 bubnoffs. Unfortunately, species diversity is generally low and minor reworking in the middle and upper Pliocene is indicated by rare occurrences of lower Pliocene taxa such as *Reticulofenestra pseudoumbilica, Discoaster quinqueramus, Sphenolithus abies,* and *S. neoabies.* Although a short, local extension of the natural ranges of these forms would be possible, their occurrence here continues well above the diagnostic tropical middle Pliocene acmes of *Discoaster asymmetricus, D. decorus,* and *D. tamalis.* This, coupled with their occurrence in the Pleistocene section of Carnegie Ridge and an incised bottom topography, suggests that reworking by bottom-scouring currents is responsible for the extended ranges. But in the immediate vicinity of the upper Pliocene-lower Pliocene coccolith boundary, difficulty in separating the effects of erosional mixing from natural ranges has led to an either/or age assignment of Cores 21 to 24 (193 to 219 m). Pleistocene assemblages at DSDP 157 are dominated sequentially from top to bottom by *Gephyrocapsa oceanica, Emiliania annula,* and *Coccolithus doronicoides.*

DSDP 158

Site DSDP 158 is located in a small basin on the crest of Cocos Ridge. Middle Miocene to Holocene coccolith assemblages were continuously cored for 323 meters to basalt. This site was selected as a northern stratigraphic counterpart to DSDP 157 at the southern margin of the Panama Basin. The contrast between the two sites is apparent in several aspects: (a) coccoliths at DSDP 158 have superior preservation and diversity; (b) Pliocene carbonate percentages are consistently higher; (c) sedimentation rates are lower; (d) silicoflagellates are absent and diatoms are rare and poorly preserved in the Pliocene and Pleistocene. These differences reflect the effect of strong upwelling and resultant high biogenic productivity in the Peru Current in the vicinity of DSDP 157. The thinner Pliocene and Pleistocene section at DSDP 158 lacks abundant biologic silica, and this contributes to the better preservation and greater diversity of coccoliths. The great abundance of organic siliceous material deposited at DSDP 157 tends to dilute the coccoliths in the sediment and associated acids from organic material (indicated also by an H_2S odor) make them more susceptible to post-depositional solution than at DSDP 158. A slightly shallower depth of deposition at DSDP 158, 1953 m as compared with 2591 meters, would also favor better preservation of more coccolith taxa. Reworking of Pliocene or Miocene taxa into the Pleistocene, which was slight at DSDP 157, is more common.

Because of moderately rich species diversity in the thin upper Pliocene of Core 4, assemblages of all three upper Pliocene subzones are identified. But the subzones are out of sequence at some levels because drilling disturbance disrupted sediment layers and produced vertical flowage of sediment within the core. Therefore, any natural hiatuses are undetected. Lower Pliocene assemblages, undisturbed by drilling and stratigraphically complete, occur in Cores 5 to 9 (39 to 79 m). The presence of *Ceratolithus rugosus, Discoaster perplexus, Scyphosphaera globulata, Thoracosphaera* sp., and common species of *Discoaster* indicates a well-preserved, warm-water association.

Upper and middle Miocene sediment has large populations of diatoms as well as coccoliths. Poorer coccolith diversity in the Miocene is indicated by the absence of presumably more soluble forms such as *Discolithina, Rhabdosphaera,* and *Scyphosphaera.* The upper Miocene section extends from Core 9 to Core 23 (80 to 205 m). Coccolith assemblages typical of the Genovesan and Sorolian Stages are apparently continuous and show variation in species composition within single zones. For example, *Coccolithus pelagicus* and *Reticulofenestra pseudoumbilica* exchange abundance positions between the base and top of the *Discoaster quinqueramus* Zone; *Discoaster bellus* is most abundant in the middle of the *Discoaster neohamatus* Zone. Characteristic tropical guide fossils for both upper and middle Miocene zones are present; *Catinaster coalitus, Discoaster bellus, D. berggarenii, D. hamatus, D. neohamatus,* and *D. quinqueramus.* Middle Miocene assemblages of Cores 28 to 36 (249 to 323 m) are well preserved at the top but deteriorate noticeably in the *Discoaster exilis* Zone and closely resemble the coeval assemblages at DSDP 155. Discoasters are rare and distorted by secondary overgrowths, whereas placoliths are abundant and etched. The presence of *Triquetrorhabdulus rugosus* and the lack of *Cyclicargolithus floridanus* and *Sphenolithus heteromorphus* distinguish the middle Miocene basal sediment at DSDP 158 on the Cocos Ridge as younger than the similarly preserved middle Miocene basal sediment at DSDP 155 on the Coiba Ridge.

East Pacific Rise Sites

During Leg 16, five sites (DSDP 159 to 163) were drilled across the western flank of the East Pacific Rise. These sites contribute to a latitudinal traverse at about 10°N and to a longitudinal traverse at about 140°W composed of many drilling sites from DSDP Legs 5, 8, 9, and 16. Coccolith zones ranging in age from Late Cretaceous to middle Miocene are present along the 10°N traverse. Coccolith zones ranging in age from early Eocene to late Pleistocene or Holocene in various paleoclimatic settings are present along the 140°W traverse. Relatively complete coccolith-rich sections are present only at the southern equatorial sites of the traverse. This relation is illustrated in the section on preservation (Figure 4). The most striking feature of the 10°N traverse sites is the absence of any coccolith assemblages younger than middle Miocene. Thin sections of brown clay dated by radiolarian assemblages at DSDP 159 and DSDP 160, closest to the axis, indicate differential solution of carbonate in younger sediment. At DSDP 161 and DSDP 162, strongly etched upper Oligocene and lower Miocene coccolith ooze is at the surface, indicating submarine erosion as well as solution. The absence of any middle Miocene to Holocene sediment such as highly insoluble red clay, which is deposited at a rate of about 1 bubnoff (1 m per my) in deep-ocean areas, suggests removal of young surficial sediment at these sites by physical erosion. Because these sites are presently below the calcite compensation depth, the uppermost coccolith sediment now exposed at the surface is subject to modern solution. At DSDP 163, brown clay containing radiolarians of Oligocene age is at the surface and the first significant coccolith assemblages are Late Cretaceous at about 162 meters below the sea floor (Figure 2).

DSDP 159

Site DSDP 159 is about 2000 km west of the East Pacific Rise crest, midway between the Clarion and Clipperton fracture zones. Early and middle Miocene coccolith assemblages are abundant in Cores 3 to 13 (18 to 109 m). Only in Core 3 are coccolith-rich layers interlayered with barren brown clay. The concentrations of discoasters and resistant placoliths have few species represented and probably indicate periods of high productivity as the site passed below the middle Miocene calcite compensation depth. Higher samples from Cores 1 and 2 (0 to 18 m) are barren of coccoliths.

Preservation and diversity are variable from sample to sample within a given core. The most commonly occurring species are *Coccolithus miopelagicus, Coronocyclus* spp., *Cyclicargolithus floridanus, Discoaster deflandrei, D. exilis, Sphenolithus moriformis,* and *Triquetrorhabdulus carinatus.* Although *Triquetrorhabdulus milowii* ranges upward into the *Helicopontosphaera ampliaperta* Zone or *Sphenolithus belemnos* Zone, *T. carinatus* is restricted to the *Triquetrorhabdulus carinatus* Zone of Cores 8 to 13. This lowest Miocene zone contains three subzones here. The basal *Dictyococcites abisectus* Subzone has a few specimens of *Coccolithus* sp. cf. *C. fenestratus, Dictyococcites abisectus,* and *Discolithina segmenta,* suggesting affinity with Oligocene assemblages. The *Discoaster deflandrei* Subzone is a low-diversity interval dominated by *D.*

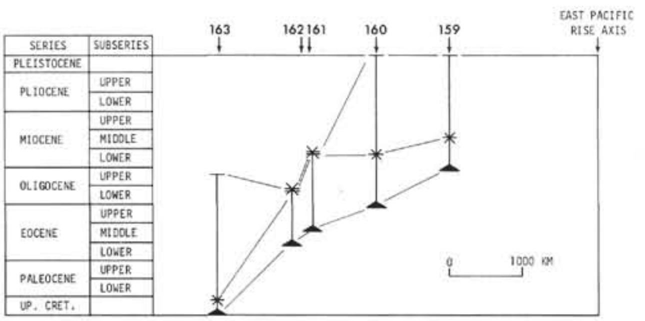


Figure 2. *Stratigraphic relations of youngest coccolith occurrences to overlying sediment and basalt basement at East Pacific Rise DSDP sites. Sea floor (–), shallowest coccolith occurrence (*), basalt (Δ).*

deflandrei, Cyclicargolithus floridanus, and *Triquetrorhabdulus carinatus.* Rare *Sphenolithus ciperoensis,* possibly reworked, was noted in only one sample near the bottom of the sediment section. An abundance of *Discoaster* and *Sphenolithus* in moderate brown ferruginous coccolith ooze of Cores 3 to 13 indicates deposition under tropical conditions. Some dissolution of calcite throughout the section has resulted in the preservation of only a few etched specimens of the readily dissolved genera *Helicopontosphaera* and *Discolithina* and no *Scyphosphaera.*

DSDP 160

Site DSDP 160 is located on the western flank of the East Pacific Rise about 1000 km farther west than DSDP 159. The sediment thickness and composition is similar to that of DSDP 159 but the section is older, ranging from early Oligocene at the basalt contact to early Miocene at the top of the carbonate section. Coccoliths are absent in the brown clay of Cores 1 to 3 (surface to 27 m), but rare specimens indicating the Miocene occur in the Core 3 core-catcher sample.

Early Oligocene to early Miocene coccoliths are abundant throughout Cores 4 to 13 (36 to 109 m). Preservation state of assemblages is moderate to poor; *Helicopontosphaera* species are preserved only in Cores 6 and 10 to 13. Abundant *Discoaster* and *Sphenolithus* throughout indicate tropical deposition. The early Miocene *Triquetrorhabdulus carinatus* Zone of Cores 4 and 5 lacks the basal *Dictyococcites abisectus* Subzone, as the *Discoaster deflandrei* Subzone directly overlies the late Oligocene *Sphenolithus ciperoensis* Zone. The Oligocene section appears to be continuous. *Sphenolithus predistentus* Zone assemblages contain common *Discoaster tani* and *Helicopontosphaera compacta.* In the lower part of the zone (Core 12), *Dictyococcites bisectus* is especially large and abundant. Cuttings of basalt and mixed sediment in Core 13 include a few dark brown sediment specks that contain *Reticulofenestra hillae* and *R. umbilica* with rare *Cyclococcolithina formosa,* indicating that the upper part of the lower Oligocene *Helicopontosphaera reticulata* Zone (approximately 34-35 my) is present within the iron-rich sediment above basalt. White clay in Core 13 is drilling contamination from the *Sphenolithus ciperoensis* Zone; tan clay is from the *Sphenolithus predistentus* Zone. Although the Oligocene section at DSDP 160 is thin in comparison with other DSDP sites, no hiatuses are noted. On the basis of coccolith assemblages, this site passed below the calcite compensation depth about 20 my ago.

DSDP 161

Site DSDP 161 was continuously cored at a location low on the western flank of the East Pacific Rise about 4000 km from the crest. Middle Eocene to early Miocene coccoliths are common to abundant in the fourteen sediment cores of Hole DSDP 161 and in the fourteen sediment cores of Hole DSDP 161A, which terminated in basalt at Core 15A (244 to 245 m). Coccolith preservation within this continuously cored section ranges from moderate to poor. The top of the section (Cores 1 and 2) and the bottom (Cores 10A to 14A) are dominated respectively by *Discoaster deflandrei* and *D. barbadiensis,* indicating strong dissolution acting on tropical assemblages. The section is stratigraphically complete except for a possible late Eocene hiatus in the upper part of Core 13A. Species diversity is low, but the boundary between the *Reticulofenestra umbilica* Zone and the overlying *Discoaster barbadiensis* Zone is marked by a decrease in total calcium carbonate from 32-54 per cent to 2-23 per cent above.

Zonal assignments for DSDP 161 are based on cosmopolitan, solution-resistant species, as easily soluble taxa such as *Rhabdosphaera, Helicopontosphaera,* and holococcoliths are absent or rare. Reworking is indicated at certain intervals within the middle Oligocene *Sphenolithus predistentus* Zone, which contains elements of the early Oligocene *Helicopontosphaera reticulata* Zone in Core 4A and elements of the late Eocene *Discoaster barbadiensis* Zone in Core 6A.

Core 1A was cut at a depth equivalent to Core 8 but recovered coccolith assemblages equivalent to those of Core 9, where the *Sphenolithus ciperoensis* Zone-*Sphenolithus distentus* Zone boundary is indicated (Table 2).

DSDP 162

Site DSDP 162 is about 4000 km west of the East Pacific Rise crest on the 140°W traverse just south of the Clarion Fracture Zone. Late early Eocene to early Oligocene coccolith assemblages are present in the 153-meter section cored above basalt. Although coccolith ooze is present in Cores 1 to 3 and in Core 17, the intermediate cores contain radiolarian ooze in which coccoliths are absent or rare to common and are poorly preserved owing to intensive calcite dissolution. Intervals completely barren of coccoliths occur in Cores 5, 6, 7, and 16. Blocks of Oligocene coccolith ooze, representing in-hole slumping, occur in the Eocene radiolarian ooze in Sample 162-6-2(38-39 cm), 162-7-1(2-3 cm) and 162-10-2(33-34 cm). White sediment surrounding a manganese nodule at 162-15-4(52-53 cm) contains the same middle middle Eocene coccolith assemblage as the adjacent darker sediments and therefore indicates in situ origin of this nodule.

The lower Oligocene *Helicopontosphaera reticulata* Zone and upper Eocene *Discoaster barbadiensis* Zone show low species diversity in Cores 4 and 5, with the top of the Eocene provisionally determined by the highest occurrence of *Discoaster barbadiensis* at 162-5-1(120-121 cm). The upper Eocene to middle Eocene boundary is within an interval of minimal coccolith preservation, and the top of the upper middle Eocene is provisionally indicated at Sample 162-6-2(120-121 cm) by a rare occurrence of *Chiasmolithus grandis.* Cores 10 to 15 contain the middle middle Eocene *Nannotetrina quadrata* Zone, which can be divided into three local-range subzones based on *Discoaster mirus, D. gemmifer,* and *Chiasmolithus gigas. C. gigas* is noted only in Cores 13 and 14; *Discoaster mirus* and *D. gemmifer* mainly in Cores 13 to 17.

Lower middle Eocene *Discoaster sublodoensis* Zone assemblages are possibly present at the top of Core 16. Best preservation and diversity at this site are noted in the core-catcher sample of Core 17. The occurrence of species of *Discolithina, Ellipsolithus, Helicopontosphaera, Lophodolithus, Rhabdosphaera,* and *Syracosphaera* indicates that the assemblage has been only slightly affected by calcite dissolution (also confirmed by high foraminiferal diversity). The assemblage, assigned to the *Discoasteroides kuepperi* Zone or to Unit 4 of Bramlette and Sullivan (1961), includes: *Campylosphaera dela, Chiasmolithus solitus, Coccolithus crassus, Cyclococcolithina gammation, Discoaster barbadiensis, D. lodoensis, D. sublodoensis, Discoasteroides kuepperi, Discolithina plana, Ellipsolithus lajollaensis, Helicopontosphaera lophota, H. seminulum, Lophodolithus mochlophorus, L. rotundus, Sphenolithus radians, Syracosphaera formosa, Triquetrorhabdulus inversus, Zygolithus dubius,* and *Zygrhablithus* sp. cf. *Z. bijugatus.*

This assemblage, the oldest above basalt, represents the top of the lower Eocene, about 49-50 my. The youngest coccolith assemblage at the sea floor is early Oligocene, about 32-33 my.

DSDP 163

Site DSDP 163 is located in an area of abyssal hills at the lower flank of the East Pacific Rise about 5100 km west of the rise crest. Continuous coring in Hole DSDP 163 from the sea floor to 111 meters and from 162 to 294 meters total depth shows the upper interval, above chert, to be a radiolarian ooze of middle Eocene to late Oligocene age. Calcium carbonate ranges from 0 to 2 per cent in this sediment, and only trace amounts of coccoliths are present in Cores 6 and 10. The lower interval is a Late Cretaceous, strongly etched coccolith ooze with a high calcium carbonate content of 23 to 95 per cent, most determinations exceeding 70 per cent. The discontinuous coring between 111 meters and 162 meters resulted from an attempt to penetrate, without coring, the chert layers that had been encountered in Cores 13 and 14 (100 to 111 m). Coring in part of this missing interval was attempted in Hole DSDP 163A. Core 1A (140 to 144 m) contains a zeolitic brown clay that is barren of coccoliths or contains rare, probably reworked coccoliths of the *Tetralithus trifidus* Zone. The reworked origin of the rare calcite in this sediment, lying above early Maestrichtian coccolith ooze at 162 meters (Core 15), suggests that the site passed below the calcite-compensation depth prior to Tertiary time. Ages of the top and bottom of the Cretaceous coccolith-ooze section of Cores 15 to 28 are estimated on the basis of dates by Izett et al. (1971) to be 68 and 78 my.

The Late Cretaceous sequence of stratigraphic assemblages and zones at DSDP 163 is similar to that described for the Atlantic Ocean at DSDP 10 and DSDP 21 and for the Caribbean at DSDP 146 and DSDP 152 (Bukry, 1970; Bukry and Bramlette, 1970; Bukry, in preparation; Peterson et al. 1970; Cita and Gartner, 1971). The uppermost Cretaceous zone, *Micula mura* Zone (= *Tetralithus murus* Zone), identified by the range of solution-resistant *Micula mura* or by the probably more readily soluble *Nephrolithus frequens* is missing from DSDP 163, although it has been identified in the Pacific at DSDP 47.2 and DSDP 48.2. The early Maestrichtian *Lithraphidites quadratus* Zone identified at the Atlantic sites contains the name-giving species, whereas at the Pacific sites and at DSDP 163 (Core 15) this species is missing. The late Campanian to early Maestrichtian *Tetralithus trifidus* Zone is recognized at DSDP 163 in Cores 15 to 22 (162 to 229 m) by the ranges of *Tetralithus trifidus* and *Zygodiscus meudini.* The lower part of Core 22 to 23 (230 to 243 m) contains the *Broinsonia parca* Zone, a short interval indicated between the youngest specimens of *Eiffellithus augustus* and the earliest of *T. trifidus.* As both these guide fossils are solution resistant, their disconcurrent range at DSDP 163 reflects an "expanded" Campanian section here. The oldest stratigraphic zone sampled during DSDP Leg 16 is the *Eiffellithus augustus* Zone in Cores 24 to 27 (243 to 272 m). The cooccurrence of *E. augustus* and *Broinsonia parca* is a guide to these assemblages. The basal chalk above basalt is strongly dissolved and only the most resistant taxa occur. *B. parca* and *Tetralithus acuelus* provide the keys to a Campanian assignment.

Perhaps the most intriguing paleontologic aspect of the Campanian to Maestrichtian section is the report that Cenomanian to Albian and Aptian planktonic foraminifera occur throughout the section and numerically dominate the Campanian to Maestrichtian taxa (Pessagno and Longoria, this volume; Douglas, R.G., personal communication, 1972). Such an occurrence is considered unusual because of the homogeneity of the coccolith assemblages, which show no evidence of older reworking for the 114 meters of section which represents deposition for a period of about 10 my. In an effort to confirm the reworked origin of the presumed older foraminifera, individual species were crushed to examine coccoliths contained within the formainifera shells.The use of coccoliths to distinguish naturally occurring and reworked foraminifera is based on the premise that the contained coccolith taxa are most likely to represent the fine matrix of the original deposit and that reworked foraminifera will carry these "tracers" internally as they are reworked into younger deposits (Bramlette and Riedel, 1954; Gartner and Lidz, in press). Examination of coccoliths from foraminiferal specimens selected by E.A. Pessagno and by P.J. Worstell revealed no specimens diagnostic of strata older than Campanian. The specimens selected by E.A. Pessagno from 163-16-1, 163-19-4, and 163-20-2 all contained *Broinsonia parca* and *Tetralithus acuelus* or *T. trifidus,* which are diagnostic of Campanian or younger strata. Specimens selected by P.J. Worstell from deeper strata were prepared for individual foraminiferal taxa. Coccoliths from foraminiferal specimens similar to *Hedbergella pacifica* were examined from core-catcher samples of Cores 23 to 26. Rare, long-ranging coccoliths are typical, although *Micula decussata, Broinsonia parca,* and *Eiffellithus augustus* from Cores 25 and 26 have restricted Upper Cretaceous ranges. Minute heterohelicids and *Globigerinelloides* from the same samples contained only rare small coccolith specimens of long-ranging taxa such as *Prediscosphaera* or *Watznaueria.* Therefore no definitive evidence for an Aptian to Cenomanian source for the majority of foraminifers at DSDP 163 is provided by the coccolith assemblages. If the foraminifera are truly as old as suggested, then they must have been deposited free of any internal sediment matrix. A strongly winnowed and subsequently current-transported source of the foraminifera would be required to eliminate coccoliths. But this situation is improbable in view of the abundant coccoliths in Quaternary winnowed foraminiferal sands and the better solution resistance of coccoliths. A consistent input of reworked, cleaned foraminifera with no trace of the expected associated coccoliths over a period of up to 10 my seems unlikely, as both groups would be carried by the same current which would have to maintain its unusual sorting process for an unreasonable length of geologic time. It is more likely that a few reworked foraminifera occur but that the bulk of the compared species are indigenous Campanian taxa.

PRESERVATION AND REWORKING

The two dominant types of Cenozoic coccoliths, discoasters and placoliths, have different preservation characteristics, making generalizations about preservation of the class difficult. The differing preservation characteristics (Bukry et al., 1971) are well illustrated by some upper Miocene assemblages containing almost pure discoaster ooze. The discoasters are pristine or only slightly etched, whereas rare placoliths are represented only by rim fragments. Large size and crystallite orientation help to account for the superior solution resistance of discoasters. In early phases of marine diagenesis and lithification of coccolith-rich sediment, as at DSDP 158, discoasters acquire much thicker secondary overgrowths than do placoliths, even though placoliths do begin to show clumping or solution welding (see Wise and Hsü, 1971). The excess calcite deposited on discoasters probably derives from more solution-prone foraminifera and smaller coccoliths. Because structural features of discoasters are much more readily obscured by calcite overgrowth than those of placoliths, discoaster species may be barely recognizable in a sample where placoliths are easily identified (Figure 3). This contrasts with the condition of partially dissolved assemblages where discoasters retain their structural identity better than placoliths. Typically, the rim margins of placoliths become raggedly incised by etching, central-area structures are removed, and central-area openings are irregularly enlarged at the expense of the inner part of the rim cycles and their connecting tube. Distal and proximal shields become disconnected, and the large distal shields tend to survive the smaller proximal shields. Placoliths characterized by solid central areas, such as *Dictyococcites,* show thinning and irregular removal of central-area crystallites followed by total removal, which results in a ragged-margined central opening. Terminal placolith etching is seen in the form of isolated fragments of single rims, where either a few crystallites remain together or are totally disaggregated into individual crystallites, as in *Coccolithus* or *Reticulofenestra.* In the sturdy genus *Cyclicargolithus,* isolated individual crystallites are approximately U-shaped because they form part of both shields and the central tube.

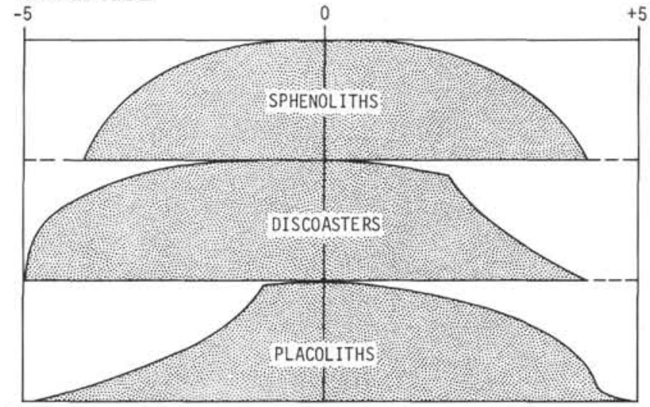


Figure 3. *Relative identifiability of species in major coccolith groups at different preservation stages* (-5, *dissolved;* 0, *pristine;* +5, *overgrown*).

Discoasters can also show evidence of intense solution. They are constructed as radial arrays of crystallites with solid centers that commonly have a central knob. First evidence of solution is seen in the removal of this knob creating a central opening through the discoaster and in the disappearance of small spines and spurs on the rays. The central opening can become enlarged, and eventually the resultant shortening of the intercrystallite connection areas leads to disaggregation into individual ray crystallites.

A general solution sequence of genera of calcareous plankton can be determined empirically from study of a large number of samples (Berger and Parker, 1970; Bukry, 1971b; Douglas, 1971), by experimental laboratory procedures (Hart, 1972), or by field experiments (Berger, 1967). The relation of overgrowth and diagenesis to dissolving needs considerable study, as stratigraphic and paleoecologic determinations are dependent upon the nature and identity of whole assemblages. Differential alteration of various components in an assemblage indicates the need for a preservation classification that can be applied not only to the whole assemblage but also to any part of the assemblage.

The variety of taxa preserved, that is the diversity, is a convenient rule-of-thumb guide to the preservation state of an assemblage, because both overgrowth and etching can lead to nonrecognition of taxa. A possible paradox exists in slightly etched or slightly overgrown assemblages that for some workers show a seemingly higher diversity through morphologic alterations that qualify as primary taxonomic characters. Although a preservation classification system for whole coccolith assemblages is a simplification, it might yield an initial understanding of the complex factors influencing their character. If a system is devised that can be applied to subsections of an assemblage, greater precision in preservation descriptions can be achieved while still retaining a convenient basis for comparison between a variety of assemblages.

A preservation key designed for whole assemblages by P.H. Roth (personal communication, 1970) uses three stages of overgrowth (O−1, −2, −3) and three of etching (E−1, −2, −3). This keying system is useful in providing brief statements about preservation of assemblages. Below is a new qualitative system elaborating on Roth's and intended for use both with individual coccolith specimens as well as with assemblages. It is based on a numerical scale from −5 to +5 in which a value of 0 is assigned to pristine coccoliths lacking both etching and overgrowth.

Qualitative Preservation Key

PRESERVATION CATEGORIES

−5: Noncalcareous, barren of coccoliths

−4: All specimens strongly etched. Almost all specimens fragmented. (−4.5: Only rare specimens present; sediment almost noncalcareous.)

−3: Majority of specimens strongly etched. Many major structures removed. Many centerless specimens and fragmented specimens of questionable identity; low-diversity assemblages. (−3.5: One or two species dominant with an abundance of disaggregated crystallites.)

−2: Majority of specimens moderately etched. Fine, weakly-resistant structures attacked. More than half the specimens are readily identified but some solution-prone genera are absent.

−1: Majority of specimens slightly etched. Fine, weakly-resistant structures discernible. Normal taxonomic diversity and easy identification.

O: Pristine stage, a generally unattained ideal for fossils, yielded only in nannoplankton tows containing living coccolithophycean populations.

+1: Majority of specimens have slight overgrowth. Fine structures discernible. Rich taxonomic diversity and easy identification.

+2: Majority of specimens show moderate overgrowth. Fine structures obscured. More than half of specimens are readily identified.

+3: Majority of specimens have heavy overgrowth. Many major structures obscured. Many questionably identifiable specimens; low-diversity assemblage. (+3.5: One or two species dominant.)

+4: All specimens have heavy, irregular overgrowth. Almost all evidence of coccolith presence obliterated. (+4.5: All species rare.)

+5: Limestone or irregular calcareous debris, barren of identifiable coccoliths.

OVERGROWTH STAGES

+1: As in the initial stage of etching, alteration in first-stage overgrowth is minor. At the assemblage level, a few specimens may have observable overgrowth but the majority show little evidence of secondary thickening. Diversity is typically high. Although discoasters show overgrowth thickening much more readily than placoliths, almost all specimens can be assigned to species. Their nearly pristine shape, though slightly thickened, is not obscured. This preservation stage, like other overgrowth stages, is found mainly in assemblages from marine carbonate ooze.

+2: In the second stage of overgrowth, smaller structures become obscured. Reticulate central-area structures of some placoliths begin to coalesce. Some rims are moderately thick, appearing yellowish white in cross-polarized light instead of white and slightly translucent. The +2 stage for discoasters is indicated by increased thickening and development of crystal faces on rays. Taper, camber, and relative proportions of rays and the distinct sharp outlines of spurs, bifurcations, and central knobs are at least partially obscured on as many as half of the specimens.

+3; In the third or thick-overgrowth stage, many major morphologic structures used for taxonomy are obscured. This is particularly true for discoasters, distinguishing bifurcate from single-tipped rays is difficult on many specimens. Original character of central-area knobs is obscured. A rare moderately obscured specimen may allow an estimate of species diversity, but commonly only the number of rays can be discerned. Placoliths are greatly thickened, generally in an irregular manner providing a key to early diagenesis of carbonate sediment. In cross-polarized light, extinction bands are irregular, and specimens are yellowish indicating uneven thickening. Some crystallites seem more overgrown than others. Many specimens are identified only questionably and fairly low diversity is typical. Discoasters suffer more loss of identity than placoliths in third-stage overgrowth (+3); this relation is reversed in third-stage etching (−3).

+4: Practically all evidence of coccolith presence is obliterated as the fourth stage of overgrowth is approached.One or two questionably identifiable species may be common (+3.5), or a rarely occurring specimen or two may occur in a matrix of indeterminant irregular calcareous particles (+4.5). The fourth stage occurs in marine carbonates that have undergone advanced diagenesis or lithification, as for example at DSDP 53 (Pimm et al., 1971). At DSDP 158, Core 36, placoliths are largely indistinguishable and occur in microscopic clumps probably resulting from solution welding. Discoasters, though possibly present in this sample, are unrecognizable.

+5: This category is designated for carbonate-rich rock with no trace of coccoliths under light-microscope examination, although electron-microscope examination may reveal relict coccolith structures (Fischer et al., 1967).

ETCHING STAGES

−1: The initial stage of slight etching is characterized by only minor changes on coccolith surfaces. No diagnostic changes of form are seen in light microscopy. In transmission electron microscopy, slight etching along growth lamellae of crystallites can be seen. Discoasters appear pristine or only slightly thinned; no overgrowth species occur. Placoliths are not noticeably thinned, but no thickened specimens occur. Thin reticulate structures are usually intact. Some fossil holococcoliths may occur intact. Clay-enriched and only slightly calcite-undersaturated environments often exhibit this preservation state (Gartner and Bukry, 1969). Deep-ocean sediment is usually more strongly etched. Sediment deposited in oceanic environments enriched in silicic particles such as volcanic ash, diatoms, and radiolarians may contain −1 discoaster assemblages, but commonly the low carbonate content of such sediment has fostered moderate to strong differential solution of placoliths (−2 or −3).

−2: Many weakly-resistant structures and taxa are removed at this moderate stage of etching. Some breakage is noted as a result of solution thinning that weakens structures. A majority of the specimens present can be identified, but diversity is lower than for −1. A few discoaster specimens have their central knobs dissolved out, and a few disaggregated discoaster rays occur. Placoliths at stage −2 have central structures such as reticulate nets and crosses partially or wholly removed on as many as half the specimens. Initial incisement of some placolith rim margins occurs. Only the most massive holococcolith, *Zygrhablithus,* occurs.

−3: The majority of specimens show the effects of strong solution. Placoliths, owing to solution thinning of all structures, are very susceptible to breakage; pieces of rims are often broken out. Rim margins are often deeply indented by etching. The smaller and thinner proximal shields of many placoliths are dissolved, leaving only isolated distal shields. Central-area openings are enlarged on most specimens at the expense of the rim. Incomplete placolith rims and isolated discoaster rays are typical in strongly etched assemblages. The form and ornamentation of intact discoasters persists better than in placoliths, although a high proportion of discoasters have the central knob dissolved and the resultant opening enlarged.This leads to disaggregation of many specimens. Placolith diversity is generally low, although that of discoasters is usually less affected. Assemblages of resistant species of *Discoaster, Reticulofenestra, Dictyococcites, Cyclicargolithus, Coccolithus, Sphenolithus,* and some ortholithids such as *Triquetrorhabdulus* show the effects of solution at this stage, whereas at lesser stages they are not significantly altered. The combination of common, directly visible, fragmented and etched specimens with low species diversity is typical of the −3 stage.

−4: Strong solution is evidenced by the presence of only a few of the most resistant taxa, and even these are etched and fragmented. Two degrees of strong solution can be recognized. One or two strongly resistant taxa showing intensive etching may be associated with a background of nonspecific common rim fragments and isolated crystallites (−3.5). For example, upper Eocene oceanic assemblages are often represented by large, centerless *Discoaster barbadiensis* with a few rims of one or two resistant placoliths such as *Coccolithus eopelagicus, Dictyococcites bisectus,* or *Reticulofenestra umbilica.* Fragments of placoliths completely dominate intact specimens. Near-terminal solution may also be represented by the occurrence of only rare specimens of etched resistant species in an almost noncalcareous sediment (−4.5). This is a stage which could overlap with −5, the noncalcareous stage, when there is contamination or extreme specimen rarity in the sediment.

−5: No trace of coccoliths or other carbonate remains in oceanic sediment, for example, the Eocene radiolarian clay at DSDP 163.

PANAMA BASIN COCCOLITH PRESERVATION

The oldest sediment recovered at Panama Basin drill sites is middle Miocene at both the Coiba Ridge (DSDP 155) and the Cocos Ridge (DSDP 158). Coccolith preservation of the basal carbonate ooze is similarly overgrown at +3 to +4 for discoasters and +2 to +3 for placoliths. DSDP 158, Core 36, exhibits rare or obliterated discoasters and clumping of placoliths (and discoasters?), probably resulting from solution welding. The poor preservation state of discoasters, in particular, leads to many compared (cf.) species determinations for the middle Miocene. The section is thickest at DSDP 158 (approximately 107 m). In the higher part of this section (Cores 25-27), solution is evident in etched placoliths and some centerless discoasters (−2) with some levels having isolated distal shields of *Cyclococcolithina macintyrei* and large amounts of fragmented specimens (−3). The middle part of the section shows mixed preservation. Discoasters range from slightly overgrown (+1) to thickly and irregularly overgrown (+3) distorted forms, but associated placoliths are etched (−2).

Upper Miocene sediment is present at the Carnegie Ridge, Site DSDP 157, in addition to the sections at the Coiba and Cocos ridges. Discoasters are overgrown through almost all of the upper Miocene at all three sites. At many levels they are thickly overgrown and distorted (+3). Only in the upper cores at DSDP 155 are etched and broken specimens (−2) present; these specimens tend to be small and sparse. A distinct preservation change from etched to overgrown discoasters occurs in Core 5 at DSDP 155.

Upper Miocene overgrowth of discoasters is typically less severe through the section at DSDP 158 (+1 to +2); only in the lower cores (17 to 24) is overgrowth significant. Placolith margins are etched (−2) in the short section at DSDP 157. Etching is less intense (−1 to −2) at DSDP 158, but is more evident at DSDP 155 (−2 to −3), where carbonate rhombs and pyrite occur through the section. Diversity and abundance is generally low at DSDP 155, where small and broken specimens are characteristic.

Pliocene and Pleistocene sections were recovered at DSDP 157 (0 to 316 m) and DSDP 158 (0 to 79 m). Minor solution is fairly uniform through the shorter section at DSDP 158. Broken discoasters or isolated rays and placoliths with solution-etched margins are typical throughout (−2). At DSDP 157, preservation typical of the upper Miocene for this site (overgrown discoasters and etched placoliths) persists into the upper Pliocene, where, from about Core 20 upward, both discoasters and placoliths are etched. The degree of solution is highest in Cores 9 and 10 just below the Pliocene-Pleistocene boundary; broken

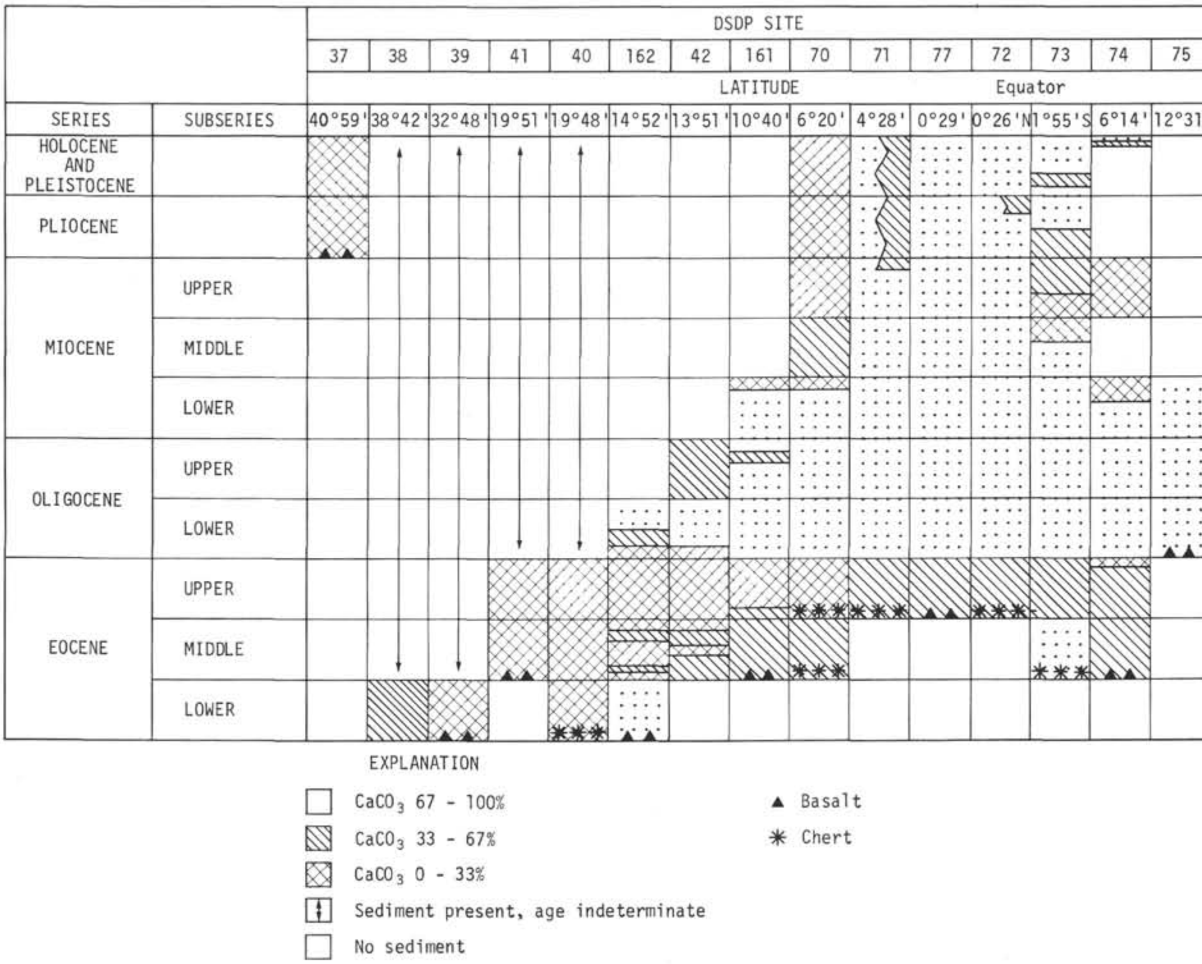


Figure 4. *Calcium carbonate content of sediment cored on or near the 140°W meridian. Sites arrayed from north (DSDP 37) to south (DSDP 75). Note prominent change at the beginning of the Oligocene.*

and centerless *Cyclococcolithina* occur (−2 to −3). A fairly strong H_2S odor from the upper Pliocene cores (9 to 21) at DSDP 157 and the strong etching observed there probably resulted from chemical activity of decomposing organic material in this rapidly accumulated sediment. Shipboard geochemical measurements indicate pH levels of 7.0 to 7.5 for the Pliocene and Pleistocene, somewhat lower than the 7.8 value characteristic of subsurface seawater. Although diversity of Pleistocene assemblages at DSDP 157 is lower than that of coeval, tropical carbonate ooze, little direct evidence of etching is discernible on the small placoliths by light microscopy. The relative dilution of carbonate particles by the abundant biogenic silica deposited here probably contributes to removal of solution-prone coccolith taxa. Low carbonate percentages (less than 50%) in Cores 9 and 10 at the Pliocene-Pleistocene boundary increase to a range of 60 to 80 per cent through the Pleistocene. Other equatorial Pacific Pliocene-Pleistocene sections, such as DSDP 62.1, show comparable carbonate distributions of about 50 per cent near the boundary, increasing to a range of 60 to 80 per cent through the Pleistocene. Even thicknesses are comparable, yet the diversity is lower at DSDP 157. The presence of organic material associated with much greater abundance of biogenic silica, such as silicoflagellate and diatom skeletons, provides the contrasting elements to account for the solution effects observed in the Panama Basin.

Only minor reworking generally exists at DSDP 157, but the basal Pleistocene, DSDP 157-8, and upper Pliocene, DSDP 157-9, have considerable reworking. This, together with the poor, etched preservation in this interval could be a result of reduced sedimentation or increased bottom-current activity. The short Pleistocene section at DSDP 158 has low diversity and generally good preservation but has significant reworking of Miocene or Pliocene discoasters throughout. The basal Pleistocene at both DSDP 158 and DSDP 157 contains common fine calcareous debris, which may be derived from disaggregated foraminifera or placoliths.

East Pacific Rise Coccolith Preservation

Coring at five sites on the western flank of the East Pacific Rise during DSDP Leg 16 recovered coccolith-bearing sediment of Late Cretaceous to middle Miocene age. Preservation of Late Cretaceous (Campanian and Maestrichtian) coccoliths is generally poor throughout the 114 meter carbonate ooze section recovered at DSDP 163. Etching and breakage (−2 to −3) of placoliths and rhabdoliths is typical. Diversity is variable through the section, depending upon the extent of solution, but most assemblages are composed entirely of solution-resistant taxa, and these show evidence of etching and breakage. The basal chalk above basalt, recovered at 276 meters, is a low-diversity solution residue composed chiefly of *Cretarhabdus crenulatus* lacking central structures, *Micula decussata, Watznaueria barnesae,* and an abundance of rim fragments; this near-terminal preservation is classified −3.5. Through the remainder of the section, solution-prone genera are rare; only a single specimen of *Kamptnerius* was observed. Genera possessing central-area stem or tube structures generally lack these. Rare etched specimens of resistant Cretaceous taxa that occur in a zeolitic brown clay above the Maestrichtian carbonate ooze probably represent minor reworking.

The only sediment assigned to the early Eocene is a coccolith-foraminiferal marl at the bottom of Hole DSDP 162, directly above basalt. Diversity and preservation in this short section (145 to 147 m) is best near the bottom, becoming poorer upward. Moderately solution-prone genera, *Discolithina, Helicopontosphaera, Lophodolithus,* and *Syracosphaera* occur. Placoliths consistently show moderate and somewhat uneven overgrowth (+2), whereas discoasters are more thickly overgown (+2 to +3). *Discoaster lodoensis* is especially overgrown, the curving ridges of each ray being completely obscured. *Discoaster barbadiensis* shows less overgrowth.

Middle Eocene sections were sampled at DSDP 161A, DSDP 162, and DSDP 163. Only rare moderately etched specimens of a few resistant taxa occur in the radiolarian brown clay of DSDP 163. Except for these occurrences at Core 6 (37 to 46 m) and Core 10 (73 to 82 m), the remainder of this section is barren. Only the uppermost part of the middle Eocene was sampled at DSDP 161A (220 to 237 m), whereas a relatively complete section was sampled at DSDP 162 (48 to 136 m). All the middle Eocene assemblages are etched to varying degrees. Most of the sediment is described as yellowish brown radiolarian-coccolith marl ooze. Carbonate content is low, ranging from 0 to 61 per cent and mainly less than 30 per cent. Except for totally barren, noncalcareous intervals (−5), the most intense solution is indicated in DSDP 162, Core 16 (135 to 144 m, *?Discoaster sublodoensis* Zone), where coccoliths are rare. The only common element is highly resistant *Discoaster barbadiensis,* which is etched and centerless. This interval is classified −4.5. Some intervals such as DSDP 162, Cores 12 and 13 (99 to 117 m, *Nannotetrina quadrata* Zone) are dominated by ortholithid genera such as *Discoaster* and *Nannotetrina,* which appear to have been initially overgrown and subsequently etched. Placoliths are rare, represented mainly by rims and fragments. Diversity of this and most other assemblages is low in comparison with coeval assemblages from the Gulf of Mexico (DSDP 94) and the Blake Plateau, which were preserved under more nearly calcite-saturated conditions. Taxa such as *Braarudosphaera bigelowi, B. discula, B. rosa, Discolithina oamaruensis, D. plana, Helicopontosphaera seminulum, Markalius inversus, Micrantholithus aequalis, M. procera,* and *Thoracosphaera prolata* are absent from the East Pacific Rise section. Other solution-prone taxa such as *Lanternithus, Rhabdosphaera, Syracosphaera,* and *Transversopontis* are also missing.

Samples with common placoliths and placolith fragments have relatively high diversity, and the cross structures of *Chiasmolithus* are more commonly preserved. Even in these less etched samples (−2 to −3), however, resistant species, typical of deep-ocean settings, are dominant. Moderately resistant taxa such as *Sphenolithus* and *Zygrhablithus* are rare. The upper part of the middle Eocene section at DSDP 162, Cores 6 to 9 (45 to 81 m, *Reticulofenestra umbilica* Zone), ranges from barren to intervals containing selective concentrations of thinned and etched, resistant placolith rims (*Reticulofenestra* and *Coccolithus)* and resistant discoasters (*D. barbadiensis* and *D. saipanensis).*

Etching of upper Eocene assemblages is equal to, or greater than, that in the middle Eocene. Carbonate percentages are extremely low: 0 to 1 per cent at DSDP 163, 0 to 13 per cent at DSDP 162, and 2 to 32 per cent at DSDP 161A. Only at DSDP 163 and DSDP 162 do assemblages rank above minimum levels of preservation. Upper Eocene assemblages are essentially solution residues of resistant species; diversity is low. Broken placolith rim fragments and centerless discoasters (−3) are common in the interval. In some samples where carbonate is common (162-5-3, 39 m; 162-5-6, 44 m), the assemblage is a hash, and the taxonomic source of much of the carbonate can no longer be determined.

A dramatic increase in carbonate abundance on the East Pacific Rise is characteristic of lower Oligocene sediment. This is true not only at DSDP Leg 16 sites, but also those at DSDP Legs 5, 8, and 9 (Figure 4). Carbonate percentages of lower Oligocene sediment range from 84 to 92 per cent at DSDP 160, 86 to 96 per cent at DSDP 161, 57 to 95 per cent at DSDP 161A, and 1 to 87 per cent at DSDP 162. The preservation state of early Oligocene assemblages is fairly uniform; placoliths show slight to moderate etching (mostly −1, in places −2), whereas discoasters are consistently overgrown (at least +1, typically +2, rarely +3). Well-preserved *Helicopontosphaera* is common only near the top of the lower Oligocene section at DSDP 160, although rare specimens or rims from the genus are recorded at most localities. *Cyclicargolithus* specimens show some solution enlargement of the central opening. Intact specimens and isolated rims of *Coccolithus* occur together.

Upper Oligocene sediment sections are dominated by coccoliths and therefore have high carbonate percentages: 70 to 92 per cent at DSDP 160, 30 to 94 per cent at DSDP 161 (less than 70% levels occur only in the upper 36 m of the 90-m section), and 81 to 90 per cent at DSDP 161A. The decreasing carbonate percentage at DSDP 161 is reflected in the preservation state and diversity of the coccolith assemblages. Discoasters are overgrown (+2) throughout, but solution of placoliths becomes significant and increases toward the top of the section. Centerless placoliths and specimens with ragged, etched margins (−2) occur in the low-diversity assemblages. In the other fairly long section at DSDP 160, solution of placoliths is generally evident throughout, with centerless rims, etched margins, and enlarged central openings. Diversity is fairly high but decreases upward. Upper samples contain abundant, overgrown discoasters, some of which are centerless, suggesting strong subsequent solution.

The trend toward increased solution seen through the upper Oligocene is continued into lower Miocene sediment at the same sites. Carbonate percentages of sediments, somewhat reduced from Oligocene levels, are 27 to 72 per cent at DSDP 159, 0 to 74 per cent at DSDP 160, and 1 to 82 per cent at DSDP 161. The most drastic reduction is at DSDP 160 where basal lower Miocene sediment is reduced from 55 to 70 per cent carbonate levels to levels of 0 to 2 per cent at about 27 meters below bottom between Cores 3 and 4. No coccoliths are preserved above this solution boundary at DSDP 160. At DSDP 161, the only lower Miocene sediment with drastically reduced carbonate, 1 to 3 per cent, lies 3 meters or less below the sea floor. Solution of placoliths (−2) and overgrowth of discoasters (+2 to +3) characterize the remainder of the lower Miocene here. In strongly etched intervals, however, such as the upper 3 meters, discoasters show subsequent solution of centers and breakage of rays.

Diversity is similarly low at the three sites, but *Helicopontosphaera* is noted only at DSDP 159, and *Sphenolithus* diversity is greatest there also. Of the three, this site is closest to the East Pacific Rise axis and therefore should have been slightly higher with respect to the calcite compensation depth at the other sites. The intense solution of the upper 3 meters at DSDP 161 could be a Miocene preservational relict, but it probably reflects more recent solution following erosional stripping of a thin veneer of younger brown clay. The coccolith assemblage at the downslope sites, DSDP 160 and DSDP 161, differs from DSDP 159 in the greater dominance of solution resistant *Discoaster* and *Triquetrorhabdulus*. Levels of intensive solution have centerless discoasters.

The only middle Miocene coccoliths recovered, at DSDP 159, are associated with a moderate brown calcareous clay with palagonite in Core 3 (18 to 27 m). Carbonate content in coccolithic layers is variable, 5 to 14 per cent, and the coccolith-rich layers are interlayered with barren and nearly barren clay. These coccolith concentrations are believed to have resulted from periods of high productivity that locally depressed the middle Miocene calcite compensation depth as the water depth at the site gradually deepened beyond that of the average compensation depth. Discoasters with subordinate numbers of placolith rims, indicating strong solution (−3), dominate. Species diversity is low, as only the most resistant taxa are present.

All sediment younger than middle Miocene from East Pacific Rise sites is barren of coccoliths. A coupling of reduced productivity and calcite-undersaturated bottom-water currents would account for this situation. Present water depth at the sites ranges from 4484 meters at DSDP 159 to 5320 meters at DSDP 163. Bramlette (1961) indicated the calcite-compensation depth in the Pacific to be at about 4500 meters. If crustal motion away from the rise axis is downslope as well as translational (Fischer and Gealy, 1969), then markedly shallower calcite-compensation levels are indicated for the post-middle Miocene of this region.

PALEOECOLOGY

Interpretation of paleoecologic conditions from fossil coccolith assemblages is limited by two important factors: (a) Most Cretaceous and even many Tertiary genera of Coccolithophyceae failed to survive to the present, making direct ecologic inference from environmental requirements of living relatives difficult. (b) Selective solution can so severly alter the taxonomic composition of preserved assemblages that they no longer reflect the original biotic population. At present, no unambiguous criteria are available to assess the paleoecologic significance of coccolith assemblages.

The cool-water association (6° to 15°C) of living *Coccolithus pelagicus* (McIntyre and Bé, 1967) and late Tertiary abundance variation of that species stratigraphically and geographically (Martini and Worsley, 1971; McIntyre et al., 1970) are probably significant because it is resistant to solution. Living populations are reported only in cold-temperate waters of the North Atlantic and North Pacific (McIntyre et al., 1970). The geologic record of this species at tropical Panama Basin Sites DSDP 157 and DSDP 158 shows that it disappeared locally in the early Pleistocene perhaps as a result of a regional warming or interspecific competition from newly developing abundant populations of *Gephyrocapsa* that dominate Pleistocene assemblages. Pliocene abundances of *C. pelagicus*, specially those of the late Pliocene, are much greater at the Carnegie Ridge site (DSDP 157) than at the Cocos Ridge site (DSDP 158). This could indicate the more optimum 9°C to 12°C growth conditions then at the Carnegie Ridge site as a result of a northward shift of the intense upwelling associated with the Peru Current. Very high sedimentation rates in the late Pliocene at DSDP 157 also reflect greater productivity and intensified upwelling. The association of fossil *C. pelagicus* with tropical diatom assemblages leads to the conclusion that the presently observed oceanic temperature gradient of 12°C to 27°C for the photic zone (0 to 200 m) in this region (Beers and Stewart, 1971) was probably closely approximated during the Pliocene. Such a gradient could provide stratified cool and warm niches simultaneously. However, the length of time for which *C. pelagicus* can be assumed to have had a low-temperature preference is uncertain.

The Panama Basin record of *Coccolithus pelagicus* prior to the late Pliocene is similar at DSDP 157 and DSDP 158. Specimen counts in the early Pliocene upper *Ceratolithus tricorniculatus* Zone are low. A minor peak occurs in the late Miocene upper *Discoaster quinqueramus* Zone, and a major peak is noted at both sites just below the base of the *Discoaster quinqueramus* Zone. This last peak corresponds to an important reduction in preservation state and taxonomic diversity of diatom populations at DSDP 158 (Core 19). It also corresponds to a reversal in the dominance of the silicoflagellates *Dictyocha fibula* and *D. aspera*. This major peak of *C. pelagicus* could therefore be interpreted to be the climax of an important period of cooling and upwelling in the Basin. The diminishing *C. pelagicus* abundance through the *Discoaster quinqueramus* Zone and into the *Ceratolithus tricorniculatus* Zone would then signify a warming interval when upwelling was less intense. But an observed dominance of the silicoflagellate genus *Dictyocha* over *Distephanus* in the interval of the *C. pelagicus* peak at DSDP 158 (Bukry and Foster, this volume) indicates warm paleotemperatures. Both of these paleotemperature indicators agree in the late Pliocene of DSDP 157, where a general increase in *C. pelagicus* abundance coincides with a relative increase of *Distephanus* versus *Dictyocha*. Because both measures are based on distributions of living descendants, the late Pliocene convergence is accepted as significant. The Miocene divergence may suggest a changing paleotemperature response in which the relation to living counterparts is less direct.

Problems in the use of an extinct group to interpret paleoenvironmental significance is best illustrated by *Discoaster*. This genus, the last few species of which became extinct through the late Pliocene, is known only from fossil skeletal elements that are not clearly related to those of any living Coccolithophyceae. Owing to similarities of size, composition, and geographic and stratigraphic distribution, they are treated as coccoliths, although they are technically one of several genera incertae sedis-*Catinaster, Discoaster,* and *Discoasteroides*. Because they are resistant to solution and commonly are a major constituent in Tertiary coccolith assembalges, discoasters have been used to provide empirical evidence on paleoecology. On a coeval basis, low-latitude localities yield more abundant and diversified discoaster assemblages than do those from high latitude. For example, compare the rarity of Atlantic Oligocene to Pliocene discoasters in DSDP Leg 12 (45°N to 59°N) with their abundance in DSDP Leg 14 (3°N to 35°N). The contrast in the Pacific is equally distinct between the western equatorial sites of DSDP Leg 6 and 7 (1°S to 12°N) and the recently completed DSDP Leg 18 in the North Pacific (31°N to 57°N), where discoasters are virtually absent (Wise, S.W., personal communication, 1971). The distribution of discoasters is, of course, determined by both solution and paleoenvironmental factors. The Shatsky Rise, at 32°N in the Pacific, is rich in discoasters and is a shallow area beneath the warm Kuroshio Current. Use of discoaster diversity and abundance to suggest paleolatitude may therefore be subject to local abberations. The much lower abundance of discoasters in eastern Pacific DSDP Leg 5 sites of latitudes comparable to the Shatsky Rise is clearly related to the strong solution (preservation state -2 to -3) and dilution of discoasters in turbidite-like deposits. Calcium carbonate content of the compared Leg 5 assemblages rarely exceeds 40 per cent, whereas that of the Shatsky Rise assemblages is consistently 80 per cent or greater. Paradoxically, discoasters, as highly solution-resistant forms, can be selectively concentrated by solution, thus greatly increasing their abundance in an assemblage and possibly seeming to imply a warm-water deposit at a relatively high latitude. Are so-called warm-water taxa of discoasters missing at high latitude because of paleoenvironmental controls, or has solution largely determined their observed distribution? Except for situations where discoasters have clearly suffered strong solution, extreme overgrowth, or sediment dilution, they are common throughout the Tertiary section of DSDP Leg 16, and, subject to the uncertainties outlined above, seem to indicate generally continuous tropical conditions for the Tertiary of this area.

SYSTEMATIC PALEONTOLOGY

The annotated index and bibliography of the calcareous nannoplankton (Loeblich and Tappan, 1966, 1968, 1969, 1970a, 1970b) provides bibliographic references for previously described species. Comments on some selected coccolith taxa are included in the following section in addition to new species descriptions and recombinations.

Genus ANGULOLITHINA n. gen.

Description: Two thick calcite limbs joined in the form of a V and making an angle of less than 90 degrees. In plan view, shows birefringence in cross-polarized light, acting as a single optical unit.

Type species: *Angulolithina arca* n. sp.

Remarks: *Angulolithina* is distinguished from *Ceratolithus* by a continuous opening of the angle formed by two equant limbs. Specimens of *Ceratolithus* have either inequant limbs or limbs that bend together distally. When viewed with a single polarizer in light microscopy, *Angulolithina* shows highest relief in the orientation where *Ceratolithus (C. rugosus, C. cristatus)* shows lowest relief (90° and 270°). In the opposite case, birefringent *Ceratolithus* is at highest relief and *Angulolithina* at low relief (0° and 180°). Both genera are bright in cross-polarized light at the intermediate positions (45°, 135°, 225°, 315°). Fragments of *Discoaster* species with two adjacent rays remaining intact may resemble *Angulolithina* in outline. In cross-polarized light, however, only slight birefringence from tilted specimens is shown. Relief remains constant in bright field with a single polarizer.

Angulolithina Arca n. sp.
(Plate 1, Figures 1-5)

Description: Two straight calcite limbs meeting at a common point to form a single angle that ranges from 20 degrees to 50 degrees. The limbs taper distally, and the common point may be rounded in thickly calcified forms. In light microscopy, this form is at minimum relief above the mounting medium ($n = 1.5$) when the bisectrix of the angle is aligned parallel with the vibration direction of the lower polarizer.

Remarks: No surface ornamentation has been observed on the limbs of *Angulolithina arca*. Whereas the outer margin is slightly convex in overgrown forms, the inner margin remains straight. *Angulolithina arca* is distinguished from *Ceratolithus rugosus* by its straight limbs that form a constant angle and by having minimum relief in the orientation where *C. rugosus* has maximum relief when viewed with a single polarizer.

Occurrence: *Angulolithina arca* occurs mainly in upper Miocene and lower Pliocene sediment cores from DSDP Leg 16. It is typically a low-abundance member of coccolith assemblages.

Size: 12 to 25 microns.

Holotype: USNM 183514 (Plate 1, Figure 2-3).

Paratypes: USNM 183513 and 183515.

Type locality: Cocos Ridge, Pacific Ocean, DSDP 158-16-6(70-71 cm).

Genus CERATOLITHUS Kamptner, 1950

Remarks: A variety of horeshoe-shaped skeletal elements are classified in this genus. Features common to the various species are pointed arm-tips and a slightly thickened and curved arch. Distinctive morphologic and crystallographic features allow division of ceratoliths into several species which are stratigraphically restricted and therefore represent evolutionary development. Earliest species from the late Miocene have skeletons that act as a single crystallographic unit, with the optic axis oriented approximately perpendicular to the plane of the arms. Latest species have the axis parallel with the plane of the arms. A transitional species with an intermediate orientation occurred in the early Pliocene. Species with tooth-like ornamentation (appearing as dots in usual plan-view orientations used in descriptions) on one or both arms occur in several species. Taxa with a horn or rod at the arch occur at the Miocene-Pliocene boundary interval.

The stratigraphic sequence of species is generally as follows: *Ceratolithus primus,* the first ceratolith, is a simple, smooth form that shows no birefringence in plan view and has short to moderately long arms. The arch is often thickened. A combination of simple unornamented form and constant optical character in plan view distinguish it from other species. *Ceratolithus dentatus* is commonly associated with the early specimens of *C. primus* but has a shorter range. One arm, bearing teeth, is larger than the other. The arch is broad and planar in appearance. *C. dentatus* also shows no birefringence in plan view. *Ceratolithus tricorniculatus* has been employed as a general category for all ceratolithus that fail to show birefringence in plan view (Bukry and Bramlette, 1968). In the restricted sense of the type specimens, however, *C. tricorniculatus* is a smooth ceratolith with a horned arch. It typically occurs in latest Miocene and early Pliocene.

The earliest species of ceratolith that shows birefringence, *Ceratolithus amplificus*, is also horned and could be of polyphyletic origin; most forms resemble *C. tricorniculatus* morphologically but a few approach *C. dentatus*. The partial birefringence in cross-polarized light plus the pointed horn structure on the arch distinguish *C. amplificus*. *Ceratolithus bizzarus* is a rare form with one or two non-birefringent ceratolith structures attached to a long rod. It has been observed only in early Pliocene sediment. The earliest ceratolith that is fully birefringent in plan view is *Ceratolithus rugosus* from the early Pliocene. This species is typically robust, having thick arch and arms. The unornamented arch is not as smoothly curved as that of the second birefringent species, *Ceratolithus cristatus*. Whereas *C. rugosus* is characteristic of the Pliocene, *C. cristatus* characterizes the Pleistocene and is reported from living plankton (Norris, 1965). In some areas such as the Gulf of Mexico (DSDP 93 and DSDP 97), the most recent fossil forms of *C. cristatus* are considerably larger than the typical forms of the Pleistocene.

Ceratolithus amplificus Burry and Percival

Ceratolithus amplificus Bukry and Percival, 1971. Tulane Studies Geology Paleontology. 8, p. 125, pl. 1, figs. 9-11.

Ceratolithus bizzarus n. sp.
(Plate 1, Figures 6-10)

Ceratolithus tricorniculatus Gartner, Bukry and Bramlette, 1968 (in part). Tulane Studies Geology. 6, p. 152, pl. 2, figs. 2 and 4.

Description: This species has one or two horseshoe-shaped ceratolith structures attached to a long rod. The multiple structure shows no birefringence in plan view.

Remarks: *Ceratolithus bizzarus* is distinguished from other species by its multiple structure, typically having two horseshoe-shaped structures attached together along a rod. Broken specimens may lack part of one of the three elements. The horseshoe-shaped portions of *C. bizzarus* are most similar to *C. tricorniculatus*.

Occurrence: This rare species has been observed in greatest numbers in Lamont cores V3-153 and V16-21 from the Atlantic Ocean in sediment of early Pliocene age. It also occurs in Italy and in cores from the eastern equatorial Pacific.

Size: 40 to 50 microns, total length intact; 7 to 12 microns, width.

Holotype: USNM 183517 (Pl. 1, figs. 7-8).

Paratype: USNM 183516 and 183518.

Type locality: V3-153, 210 cm, lat 28°14'N, long 77°56'W.

Ceratolithus cristatus Kamptner

Ceratolithus cristatus Kamptner, 1954. Archiv Protistenk. 100, p. 43, text-figs. 44-45. ________, Bukry and Bramlette, 1968. Tulane Studies Geology. 6, p. 150, pl. 1, figs. 1-4.

Ceratolithus dentatus n. sp.
(Plate 2, Figures 1-3)

Description: This species has a relatively broad planar arch connecting two arms. One of the two is larger than the second and has a row of stout teeth. The ceratolith shows no birefringence in cross-polarized light in plan view.

Remarks: *Ceratolithus dentatus* is distinguished from other ceratoliths that show no birefringence by its robust, inequant arms and by a prominent row of teeth on one arm. Specimens with thick secondary overgrowth of calcite show the asymmetry of the arms, but the tooth structures are obscured. The need to distinguish this species from *C. primus* and *C. tricorniculatus* was suggested by Stefan Gartner, Jr. (personal communication, 1972).

Occurrence: *C. dentatus* occurs commonly in upper Miocene sediment from the tropical Atlantic and Pacific Oceans.

Size: 12 to 18 microns.

Holotype: USNM 183519 (Plate 2, Figure 1-3).

Type locality: Cocos Ridge, DSDP 158-10-6(120-121 cm).

Ceratolithus primus Bukry and Percival, 1971
(Plate 1, Figure 11)

Ceratolithus primus Bukry and Percival, 1971. Tulane Studies Geology Paleontology. 8, p. 126, pl. 1, figs. 12-14.

Ceratolithus tricorniculatus Gartner, Bukry and Bramlette, 1968 (in part). Tulane Studies Geology. 6, p. 152, pl. 2, fig. 1.

Ceratolithus rugosus Bukry and Bramlette, 1968

Ceratolithus rugosus Bukry and Bramlette, 1968. Tulane Studies Geology. 6, p. 152, pl. 1, figs. 5-9.

Ceratolithus tricorniculatus Gartner, 1967

Ceratolithus tricorniculatus Gartner, 1967. Kansas Univ. Paleont. Contr., Paper. 29, p. 5, pl. 10, figs. 4-6. ________, Bukry and Bramlette, 1968 (in part). Tulane Studies Geology. 6, p. 152, pl. 2, fig. 1. ________, Bukry and Bramlette, 1969. Initial Reports, Deep Sea Drilling Project, Volume I. p. 385, pl. 7, fig. A.

Genus COCCOLITHUS Schwarz, 1894

Remarks: This genus was formerly broadly applied to most circular and elliptical coccoliths constructed of two shields and a central connecting tube. Following the designation of *Coccolithus pelagicus* as the type species of the genus (Braarud et al., 1964), most species have been transferred to new genera. In many cases, the distinctions are clearly based on important differences in general shape, ultrastructure, crystallography, and stratigraphic range. For example, *Chiasmolithus* (Deflandre) Hay, Mohler, and Wade and *Cyclococcolithina leptopora* (Murray and Blackman) Wilcoxon are distinctly different by all four criteria. The only similarity between these two species and *Coccolithus pelagicus* is in stratigraphic range. The restricted characters of the type species of *Coccolithus*, which have allowed taxonomic splitting, include elliptical shape, single distal rim cycle, simple central-area domain, and perpendicular c-axis orientation of distal-rim crystallites (Hay et al., 1966). Of these, the most restricting character is the c-axis orientation. This crystallographic distinction, accepted as a qualifying character of the genus *Coccolithus*, greatly reduces the number of species that can be properly assigned to it. Only three large and widespread species constitute the bulk of the genus-*Coccolithus eopelagicus* (Bramlette and Riedel), *C. miopelagicus* Bukry, and *C. pelagicus* (Wallich).

Some workers consider any cross structure in the central opening of specimens that by form, ultrastructure, and crystallography are identical with *Coccolithus pelagicus* should require assignment to the genus *Cruciplacolithus* (see Clocchiatti and Jerkovic, 1970). This author considers such central-area variation to represent specific or intraspecific variability. Rim structure, form, and crystallography are considered the fundamental characteristics of genera. For example, *Chiasmolithus* can be identified as to genus (and in some cases to species) by specimens lacking any central-area crosses.

One genus, *Ericsonia*, is potentially a junior synonym of *Coccolithus*, even in the restricted sense. It was established using ultrastructural detail revealed by electron microscopy (Black, 1964). All of the new species assigned to the genus were illustrated in proximal view; three cycles of crystallites compose the holotype specimen in proximal view-the inner cycle is probably part of the central-area collar, the outer cycle is the larger distal rim cycle seen from the proximal side, and the third cycle is the proximal rim cycle (see the holotype of *E. occidentalis*). Proximal views of *Coccolithus pelagicus* show the same three concentric cycles, although the relative proportions differ. No distinction between *Ericsonia* and *Coccolithus* was suggested by Black. And unfortunately all specimens assigned to *Coccolithus* in his 1964 paper are illustrated in distal view. This could lead to the suspicion that *Ericsonia* is merely the proximal view of *Coccolithus*. If it is not, then the distinction is still ambiguous, because distal electron-microscope views and light-microscocpe illustrations fail to discriminate the two genera. Because among the original species of *Ericsonia* other species were described that show a complex proximal rim of three or four cycles including the central collar (for example, *Ericsonia ovalis)*, an emended *Ericsonia* may be distinguished in proximal views of proximal shields in electronmicrographs. As no clear-cut distinction of this character is possible in light microscopy, a taxonomic conflict would probably develop in practical usage.

On the basis of historic usage of *Coccolithus* and because of the identification ambiguity of *Ericsonia*, *Coccolithus* should be retained for a lineage of related Cenozoic placoliths and should not be restricted to a virtually monospecific position. But recognition of the structural difference of *Ericsonia* emended may be retained. Within the genus *Coccolithus*, *Ericsonia* should be recognized as a subgenus, *Coccolithus (Ericsonia)*. Such an arrangement would accommodate practical usage and detailed studies by allowing use of *Coccolithus* for ambiguous cases and *Coccolithus (Ericsonia)* where the identifying character could be discriminated. Workers who do not accept this convention should use question marks in most citations of *Ericsonia* or *Coccolithus*.

Studies by Black (1964) and by Hay et al. (1966) have shown variation of the number of rim crystallites in species of *Coccolithus*. The species are structurally nearly identical, being distinguished mainly by rim count. Whether such variation represents evolutionary development or merely intraspecific ecophenotypic response has not been clearly demonstrated. There is at present little stratigraphic utility in species distinguished only by rim counts.

Some species at present assigned to *Coccolithus*, such as *Coccolithus doronicoides* Black and Barnes, fail to meet the restricted character of *Coccolithus*. *C. doronicoides* seems more closely related to *Gephyrocapsa* by its structure and crystallography, but lacks the diagonal central-area bar that is generally considered diagnostic of that genus. Even without the bar, however, this species should be assigned to *Gephyrocapsa* rather than retained in *Coccolithus*.

Coccolithus orbutus (Perch-Nielsen) N. Comb.

Ericsonia obruta Perch-Nielsen, 1971. K. Danske Videnskabernes Selskab, Biol. Skrifter. 18 (3), p. 14, pl. 4, figs. 4-7.

Genus CRETARHABDUS Bramlette and Martini, 1964, emended, Bukry, 1969

Remarks: The structure of *Heterorhabdus* Noël and *Polypodorhabdus* Noël duplicates that of *Cretarhabdus;* they are therefore considered junior synonyms.

Cretarhabdus crenulatus Bramlette and Martini

Cretarhabdus crenulatus Bramlette and Martini, 1964. Micropaleontology. 10, p. 300, pl. 2, figs. 21-24.

Coccolithus actinosus Stover, 1966. Micropaleontology. 12, p. 138, pl. 1, figs. 15-16; pl. 8, fig. 7.

Cretarhabdus crenulatus Bramlette and Martini, Gartner, 1968. Kansas Univ. Paleont. Contr., Protista. 1, p. 21, pl. 1, figs. 1-9; pl. 16, figs. 12-14; pl. 17, figs. 10a-10d; pl. 25, figs. 3-4.

Cretarhabdus crenulatus crenulatus Bramlette and Martini, Bukry, 1969 (in part). Kansas Univ. Paleont. Contr., Protista. 2, p. 35, pl. 14, figs. 1-3.

Cretarhabdus crenulatus hansmanii Bukry, 1969. Kansas Univ. Paleont. Contr., Protista. 2, p. 35, pl. 14, figs. 7-9.

Cretarhabdus surirellus (Deflandre and Fert), Reinhardt, 1970. Freiberger Forschungsh. C265, p. 50, pl. 1, figs. 6-8; pl. 2, figs. 1-6.

Cretarhabdus surirellus (Deflandre), Thierstein, 1971. Ecologae Geol. Helvetiae. 64, p. 477, pl. 6, figs. 1-6.

Remarks: Many ambiguously described and vaguely drawn taxa published prior to *Cretarhabdus crenulatus* have been associated with this species by Reinhardt (1970). All of the first six entries in his synonymy either lack stems or cannot be demonstrated to belong to *Cretarhabdus* by rim structure. The first taxa on the list readily recognized by light microscopy is *C. crenulatus*. The distinctive rim structure of this species in electron microscopy (Bukry, 1969) helps to further define members of the genus *Cretarhabdus*.

As it cannot be demonstrated from the poor direct-transmission electronmicrographs that figure the holotype and paratype of *Discolithus surirella* Deflandre and Fert whether they are *Pontilithus obliquicancellatus* Gartner, *C. crenulatus*, or even an etched specimen of *C. lorei* Gartner, the name *C. crenulatus* is maintained in this report.

A suggestion that *C. crenulatus* be emended to include forms having only eight struts (Thierstein, 1971) seems inappropriate because, even though not stated in the text description, the type specimen has more than eight struts. Usage of the taxon *C. crenulatus* in this report includes specimens of *Cretarhabdus* having more than eight struts and a single cycle of openings between the rim and stem. Forms with eight struts that were illustrated as *C. crenulatus* by Thierstein (1971) and as *C. crenulatus crenulatus* by Bukry (1969) have been shown to be long-ranging and an important stratigraphic marker at the beginning of their range by Thierstein. Several forms described by Noël and Black define the eight-strut species concept.

Cretarhabdus angustiforatus (Black), N. Comb.
(Plate 2, Figures 4-7)

Cretarhabdus crenulatus crenulatus Bramlette and Martini, Bukry, 1969 (in part). Kansas Univ. Paleont. Cont., Protista. 2, p. 35, pl. 14, figs. 4-6, 12.

Cretarhabdus crenulatus Bramlette and Martini, emend., Thierstein, 1971. Eclogae Geol. Helvetiae. 64, p. 476, pl. 5, figs. 10-14.

Retecapsa angustiforata Black, 1971. Yorkshire Geol. Soc. Proc. 38, p. 409, pl. 33, fig. 4.

Remarks: This elliptic species has struts aligned with the major and minor axis that arise from the distal shield and support a solid central stem. Four auxilary struts connect the major-axis struts to the distal rim and help form a single cycle of eight perforations between the rim and stem.

Cretarhabdus angustiforatus is distinguished from similarly constructed *C. crenulatus* by having only eight struts in the central-area structure. The size of the central area is smaller in Late Cretaceous specimens than in those of the Early Cretaceous.

Occurrence: *C. angustiforatus* is first reported from the Lower Cretaceous, basal Valanginian, *Cretarhabdus angustiforatus* Zone [= *Cretarhabdus crenulatus* Zone] in southeastern France and at Sites DSDP 4 and DSDP 5 in the western North Atlantic (Thierstein, 1971). It occurs at least as high as the lower Campanian in Texas.

Size: 6 to 10 microns.

Paratypes: USNM 183520 and 183521.

Genus CYCLICARGOLITHUS Bukry, 1971

Remarks: Both the distal and proximal shields of the type species *Cyclicargolithus floridanus* (Roth and Hay) are bright in cross-polarized light. Owing to relative thickness, the distal shield is brighter. This relation is well demonstrated in the *Sphenolithus heteromorphus* Zone at DSDP 54.0, where specimens with partially broken distal and proximal shields are present.

CYCLICARGOLITHUS PSEUDOGAMMATION (BOUCHE) N. COMB.

Coccolithus(?) *pseudogammation* Bouché, 1962. Rev. Micropaléontologie 5, p. 84, pl. 1, figs. 19, 20, ?23; text-fig. 6.

Genus DISCOASTER Tan, 1927

Remarks: This group of star-shaped fossils appear dark in cross-polarized light unless they are greatly thickened by secondary overgrowth, where they are dim, or tilted from plan view, where they exhibit near normal birefringence. Varieties of the type species *Discoaster pentaradiatus*, which have strongly bowed rays resembling umbrella ribs, do show slight birefringence in plan view because the natural curvature tilts the rays when viewed parallel with the central stem. *D. pentaradiatus* is a member of the last group of discoasters characterized by few rays, three to six. The rays are bowed and very long with respect to the size of the central area. They are blade-like in form, being thinnest in plan view. Prior to the middle Miocene, discoasters were mainly planar with rays broader and shorter with respect to central-area size. The earliest group of discoasters were multirayed, planar rosettes with rays in contact through most of their length.

Because of limited crystallographic criteria for discoaster taxonomy (for example, no complex birefringence patterns), subtle changes in form and proportion are important. Whether rays terminate in simple points or bifurcations can mean a species distinction. Breakage, etching, and solution can lead to incorrect species determinations, or at least make definite identification of part of a fossil population difficult.

The combination of finely drawn species distinctions and secondary alteration of specimens has probably contributed to multiple recognition of some species. But the process of recognizing and naming discoaster taxa on the basis of minor structural distinctions can be useful. For example, recognition of two forms in the *Discoaster variabilis* group-*D. pseudovariabilis* and *D. decorus*-has proved to be stratigraphically helpful in recognizing subzones in cores from the tropical Pacific. Some *Discoaster* specimens from DSDP Leg 16 samples are illustrated in Plates 2, 4, and 5.

Discoaster decorus (Bukry) n. comb.
(Plate 2, Figures 8-9; Plate 4, Figure 11)

Discoaster variabilis decorus Bukry, 1971. Micropaleontology. 17, p. 48, pl. 3, figs. 5-6.

Remarks: Narrow rays, narrow bifurcations, and large size make this an easily distinguished form. Its short middle Pliocene range is again indicated in the Panama Basin. At continuously cored DSDP 157, *Discoaster decorus* occurs consistently in Cores 17 to 21 of the *Discoaster tamalis* Subzone, with only rare occurrences in adjacent subzones. At DSDP 158, it is consistently present in the *D. tamalis* Subzone and occurs elsewhere only in the adjacent upper *Discoaster asymmetricus* Subzone.

Discoaster nodifer (Bramlette and Riedel) n. comb.

(Plate 4, Figure 24)

Discoaster tani nodifer Bramlette and Riedel, 1954. J. Paleontology. 28, p. 397, pl. 39, fig. 2.

Remarks: This species ranges from middle Eocene to late Oligocene. It usually has six or seven rays but specimens with eight rays occur in the middle Eocene.

Discoaster pansus (Bukry and Percival) n. comb.

(Plate 4, Figure 25)

Discoaster variabilis pansus Bukry and Percival, 1971. Tulane Studies Geology Paleontology. 8, p. 129, pl. 3, figs. 8-9.

Genus EMILIANIA Hay and Mohler, 1967
Synonym: *Pseudoemiliania* Gartner, 1969)

Remarks: The original diagnosis of the genus includes any species of placolith-bearing coccolithophyceans producing placoliths with at least one shield (distal) constructed of segments that are I-shaped in plan view. The proximal shield may or may not be constructed of I-shaped segments. Such a definition allows the recognition of ecophenotypic and evolutionary variation within the genus (for example, McIntyre, 1970; McIntyre et al., 1970).

The stratigraphic range of species that can be assigned to *Emiliania* is upper Pliocene and higher. Several taxa that are here considered to belong to *Emilania* have previously been placed in other genera such as *Coccolithus, Cyclolithella,* and *Pseudoemiliania.* This last genus has recently been judged invalid (Loeblich and Tappan, 1970b).

Emiliania annula (Cohen) Bukry

Coccolithites annulus Cohen, 1964. Micropaleontology. 10, p. 237, pl. 3, figs. la-le.

Coccolithus doronicoides Black and Barnes, McIntyre, Bé, and Preikstas, 1967 (in part). Prog. Oceanography. 4, p. 8, pl. 3, fig. A.

Pseudoemiliania lacunosa (Kamptner) Gartner, 1969. Gulf Coast Assoc. Geol. Soc. Trans. 19, p. 598, pl. 2, figs. 9-10.

Emiliania annula (Cohen) Bukry, 1971. Deep Sea Drilling Proj. Initial Repts. 7, p. 1514.

Pseudoemiliania lacunosa (Kamptner), Geitzenauer, 1972. Deep Sea Research. 19, p. 51, fig. 2-1.

Remarks: This essentially circular taxon has at least one cycle of I-shaped rim crystallites and therefore meets the definition of *Emiliania.* In cross-polarized light microscopy, a narrow collar around the central opening is bright and a "feathery" or "fringed" rim cycle more faint. *E. annula* is often abundant at low latitudes. Stratigraphically, it becomes larger from late Pliocene to early Pleistocene but ranges through the Pleistocene. Hay (1970a), in tabulating circular and elliptical varieties of *P. lacunosa,* found that elliptical varieties appeared slightly earlier and became extinct slightly earlier.

Emiliania ovata n. sp.

(Plate 2, Figures 10-12)

Description: Elliptical placoliths with at least one rim cycle of I-shaped crystallites. Moderate to large central opening surrounded by a narrow collar cycle that is bright in cross-polarized light. Rim cycle is faint.

Remarks: *Emiliania ovata* is structurally similar to *E. annula.* It is distinguished by its elliptical shape. It is distinguished from *E. huxleyi* by its much larger size.

Occurrence: *E. ovata* ranges from late Pliocene to late Pleistocene in oceanic sediment.

Size: 4 to 8 microns.

Holotype: USNM 183522 (Plate 2, Figure 10).

Paratypes: USNM 183523 and 183524.

Type locality: Eauripik Ridge, DSDP 62.1-4-4(80-81 cm).

Genus GEPHYROCAPSA Kamptner, 1943

Remarks: These small placoliths are characterized, in light microscope, by bright distal shields in cross-polarized light and usually by a bright diagonal bar in the central area. Under the electron microscope they all show a distinctive serrate rim margin. Variation in central area to rim proportions, bar angles, and size are used to differentiate fossil species. Earliest forms, appearing in the early Quaternary, have proportionally small central-area openings; the diagonal bar tends to fill the central area. Such forms include *Gephyrocapsa caribbeanica, G. lumina,* and a special case, *G.producta,* that has almost no central opening but also lacks a diagonal bar. A second type of *Gephyrocapsa* appearing later in the Quaternary is characterized by large central area openings and by diagonal bars that are more closely aligned to the short axis of the placoliths. The average size of this group is larger. These open-centered forms include *G. aperta, G. oceanica,* and *G. omega.* A species that appeared very late in the Quaternary, *G. ericsonii,* has a diagonal bar, the center point of which is elevated well above the plane of the distal rim. Variation in the angle that the diagonal bar makes with the major axis appears to be temperature controlled in these species, as forms from high latitudes have bars that make small angles with the major axis, whereas those at low latitude make large angles with the major axis.

A small early Quaternary placolith called *Coccolithus doronicoides* (see Black and Barnes, 1961, pl. 25, fig. 3; McIntyre et al., 1967, pl. 2, figs. A-B) has the same construction and crystallographic arrangement as *Gephyrocapsa* but lacks a diagonal bar in the open central area. The rim structures are so similar that some *C. doronicoides* specimens possibly could be *Gephyrocapsa* specimens with diagonal bars broken away. But *C. doronicoides* is usually most prominent in early Quaternary assemblages prior to the appearance of bar-bearing *Gephyrocapsa* species and well before the appearance of *Gephyrocapsa* species with large central openings. This species, although previously recorded as *Coccolithus,* should be classified as a member of *Gephyrocapsa,* because it has the same serration of the rim margin and the same rim crystallography.

Gephyrocapsa caribbeanica Boudreaux and Hay

Gephyrocapsa caribbeanica Boudreaux and Hay, in Hay et al., 1967. Gulf Coast Assoc. Geol. Soc. Trans. 17, p. 447, pl.12, figs. 1-4; pl. 13, figs. 1-4.

Remarks: This small species appears early in the Quaternary and is the first gephyrocapsid type of placolith with a diagonal crossbar. It is distinguished by a very small central-area opening. The high angle of the diagonal bar, cited in the original description, is less distinctive than the central-area proportions. In light microscopy the bar usually seems to make an angle of 45 degrees, or slightly greater, with the long axis of the placolith. This species ranges through the Quaternary and is considered eurythermal (McIntyre et al., 1970).

Gephyrocapsa doronicoides (Black and Barnes) n. comb.

Coccolithus doronicoides Black and Barnes, 1961. Royal Microscop. Soc. Jour. 80, p. 142, pl. 25, fig. 3.

Remarks: Bright distal shield, elliptic shape, small size, and serrate rim margin are characters of *Gephyrocapsa.* If rim structure, form, and crystallography are considered primary characters, then *Gephyrocapsa doronicoides* should be considered as part of the *Gephyrocapsa* lineage, even though it lacks a diagonal bar. Although it has been universally classified as *Coccolithus, G. doronicoides* does not have the proper rim crystallography nor the central-area structure characteristic of *Coccolithus.* Because the need for this recombination was determined after completion of the species lists and tables for this report, the old name, *C. doronicoides,* appears in the text.

Gephyrocapsa lumina n. sp.

(Plate 3, Figures 1-4)

Description: This large species has a proportionally small central opening and a large distal rim. The central opening is surrounded by a narrow collar that is much brighter than the rim in cross-polarized light. A narrow diagonal bar across the center is also bright when aligned parallel to a polarization direction. This bar makes an angle of about 45 degrees with the long axis of the placolith but is variable and can be larger or smaller within the same population. Extinction bands are narrow in the bright area around the central opening but curve sharply and are broad in the rim.

Remarks: *Gephyrocapsa lumina* is distinguished from the smaller *G. caribbeanica* and other species by the greater width of the rim with respect to the central area. It is distinguished from comparably sized *G. oceanica* by its much smaller central opening.

Occurrence: *G. lumina* occurs in the lower Quaternary of tropical Pacific Site DSDP 157.

Size: 5 to 7 microns.

Holotype: USNM 183525 (Plate 3, Figures 1-2).

Paratypes: USNM 183526 and 183527.

Type locality: Carnegie Ridge, DSDP 157-7-2(119-120 cm).

Gephyrocapsa oceanica Kamptner

Gephyrocapsa oceanica Kamptner, 1943. Osterr. Akad. Wiss. Math.-Naturw. Kl. Anz. 80, p. 45.

Gephyrocapsa oceanica var. *typica* Kamptner, 1956. Archiv Protistenk. 101, pl. 16, figs. 4-5.

Gephyrocapsa oceanica Kamptner, Hay et al., 1967 (in part). Gulf Coast Assoc. Geol. Soc. Trans. 17, pl. 12, fig. 5; pl. 13, fig. 5. ———, McIntyre and Bé, 1967. Deep Sea Research. 14, p. 570, pl. 9, figs. A-B. ———, Bukry, 1971. Deep Sea Drilling Proj. Initial Repts. 6, pl. 2, fig. 1.

Remarks: This species has a moderately large central opening that is approximately equal to the rim width when measured along the short axis of the placolith. The diagonal bar is generally robust, and the angle between it and the long axis of the placolith is variable. In specimens from tropical localities, the angle with the long axis tends to be large, approaching that of *G. omega.* The first appearance of *G. oceanica* in the middle Quaternary serves as a general stratigraphic indicator; temporal and paleobiogeographic data are still sketchy owing to a limited number of studies and to varying criteria of species identification. *G. oceanica* is distinguished from *G. caribbeanica* and *G. lumina* by the larger central opening, narrower rim, and more robust diagonal bar. Living *G. oceanica* is restricted to tropical and warm subtropical waters of 23°C to 30°C in the Pacific (McIntyre et al., 1970). At DSDP 157 it first appears during a middle Quaternary warming trend (Bukry and Foster, this volume).

Gephyrocapsa omega n. sp.
(Plate 3, Figures 5-11)

Gephyrocapsa oceanica Kamptner, Hay et al., 1967 (in part). Gulf Coast Assoc. Geol. Soc. Trans. 17, pl. 12, fig. 6; pl. 13, fig. 6.

Descriptions: This species has a large central opening and a narrow rim that is less wide than the central opening along both principal axes of the placolith. The narrow diagonal crossbar is nearly aligned with the short axis of the placolith.

Remarks: *Gephyrocapsa omega* is distinguised from tropical *G. oceanica,* which also has crossbar angles approaching those of *G. omega,* by the large size of the central opening and narrower rim. It is distinguished from *G. aperta* by its larger size and different crossbar alignment.

Occurrence: *G. omega* occurs in the middle Quaternary of tropical Pacific Sites DSDP 62.1, DSDP 79, DSDP 156, and DSDP 157. It has not been observed in any high-latitude assemblages, and its occurrence probably reflects tropical conditions.

Size: 4 to 7 microns.

Holotype: USNM 183531 (Plate 3, Figures 10-11).

Paratypes: USNM 183528 to 183530.

Type locality: Cariaco Trench, DSDP 147-5-2(78-80 cm).

Genus MICULA Vekshina

Micula mura (Martini) n. comb.

Tetralithus murus Martini, 1961. Senckenb. Leth. 42, p. 4, pl. 1, fig. 6; pl. 4, fig. 42. ———, Bramlette and Martini, 1964. Micropaleontology. 10, p. 320, pl. 6, figs. 18-21.

Micula staurophora concava (Stradner), Clocchiatti, 1971. Muséum Nat. Hist. Natur., Mem. 23, p. 109, pl. 22, figs. 1a-1c.

Remarks: Early forms of *Micula mura* lack long extensions and resemble *Micula decussata* in their compactness. Later varieties have longer extensions and resemble *Tetralithus.* Scanning electron microscope illustrations by Clocchiatti show the geometry of *M. mura* as part of cubical structure, suggesting the new generic assignment.

Genus MINYLITHA n. gen

Description: Thick plate-like individual calcite elements with polygonal outline, depressed central area, and raised rim. Only moderately bright in cross-polarized light, with slight birefringence when rotated with respect to polarization directions.

Type species: *Minylitha convallis* n. sp.

Remarks: *Minylitha* is distinguished by its polygonal plate-like form from other ortholithid genera that act as single optic units, such as *Ceratolithus, Triquetrorhabdulus,* and *Orthorhabdus.* Fragments of ortholithid taxa, such as *Braarduosphaera, Micrantholithus,* and *Discoaster perplexus* have similar polygonal outlines but different crystallography, lack element rims, and are not associated as common intact specimens in oceanic upper Miocene assemblages where *Minylitha* is abundant. The possibility of an inorganic origin is not likely because of the restricted stratigraphic occurrence of *Minylitha* and the ridged margin with central depression.

Minylitha convallis n. sp.
(Plate 3, Figures 12-18)

Description: Thick, polygonal, plate-like elements with central depression and raised rim. Mainly four-sided with two adjacent sides long and the other two short. Moderately bright to dim in cross-polarized light; slight birefringence with four faint positions alternating with four moderately bright positions in a revolution of the microscope stage.

Remarks: Some specimens have a fifth side developed, but these represent a minor part of the population of *Minylitha convallis.* On four-sided specimens, the angle formed by the two long sides ranges from 55 degrees to 80 degrees. *M. convallis* most closely resembles the form of isolated crystallites from the pentaliths of *Braarudosphaera bigelowi,* which are four-side plates having an angle of 72 degrees between the two long sides. This resemblance is so suggestive that extensive search of open-ocean core samples, where *M. convallis* occurs, was carried out in an effort to locate an intact specimen. None was found, nor were any *Braarudosphaera,* which are generally absent in oceanic assemblages. The marginal rim, central depression, and lowering on some specimens of the short-side rims out of the plane of the long-side rims help distinguish *M. convallis* from *B. bigelowi* crystallites, which are flat and planar.

Occurrence: *M. convallis* occurs most abundantly in upper Miocene sediment from DSDP 15 in the South Atlantic. It is also present at equatorial Pacific Sites DSDP 62.1, DSDP 155, and DSDP 158 in the lower *Discoaster quinqueramus* Zone and *Discoaster neohamatus* Zone of late Miocene age.

Size: 5 to 7 microns.

Holotype: USNM 183535 (Plate 3, Figures 14-15).

Paratypes: USNM 183532 to 183534, and 183536 to 183537.

Type locality: South Atlantic Ocean, DSDP 15-5-1(70-80 cm).

Genus PREDISCOSPHAERA Vekshina, 1959

Prediscosphaera lata (Bukry) n. comb.

Prediscosphaera cretacea lata Bukry 1969. Kansas Univ. Paleont. Contr., Protista. 2, p. 39, pl. 17, figs. 7-9.

Genus SPHENOLITHUS Deflandre, 1952

Sphenolithus delphix n. sp.
(Plate 3, Figures 19-22)

Description: The apical spine and two of the basal spines are slender and elongate, resulting in a triradiate outline. The remaining spines are small and compact. In cross-polarized light, the apical spine is bright and the basal spines faint at 90 degrees and 270 degrees. The reverse is true at 0 degrees and 180 degrees.

Remarks: *Sphenolithus delphix* is distinguished from other species of *Sphenolithus* by its pronounced triradiate outline, instead of the usual wedge or triangular outline. The structure of some specimens suggests that the two long basal spines are secondary elongations. Because of the regular position of these spines and the low abundance of *S. delphix* in populations of fossil coccoliths, however, these structures are probably biologic in origin. Secondary overgrowth would have affected most sphenoliths equally.

Occurrence: *S. delphix* occurs in assemblages of the upper Oligocene *Sphenoliths ciperoensis* Zone and the upper Oligocene or lower Miocene *Dictyococcites abisectus* Subzone. It occurs in DSDP 14 from the South Atlantic in a placolith-rich assemblage and in DSDP 159 from the eastern Pacific in a sphenolith-rich assemblage. In both instances, it occurs in small numbers.

Size: 8 to 12 microns, height.

Holotype: USNM 183538 (Plate 3, Figures 19-21).

Paratype: USNM 183539.

Type locality: East Pacific Rise, DSDP 159-10-4(120-121 cm).

Genus TETRALITHUS Gardet, 1955

Tetralithus aculeus (Stradner) Gartner

Zygrhablithus aculeus Stradner, 1961. Erdöl Zeitschr. 77, p. 81, figs. 53-57.

Tetralithus sp. aff. *Tetralithus aculeus* (Stradner) Gartner, 1968. Kansas Univ. Paleont. Contr., Protista. 1, p. 43, pl. 9, fig. 5; pl. 13, figs. 5a-5c.

Tetralithus aculeus (Stradner), Bukry and Kennedy, 1969. California

Div. Mines Geology Spec. Rept. 100, p. 35, fig. 2 (11-12).

Remarks: This small arrowhead-shaped taxon is not clearly related to other members of *Tetralithus.* It is bilaterally symmetric in plan view, but in cross-polarized light only the thicker, flaring portion is bright. It apparently ranges through most of the Campanian.

Tetralithus trifidus (Stradner) n. comb.

Tetralithus gothicus trifidus Stradner, in Stradner and Papp, 1961. österr. Geol. Bundesanst. Jahrb. Sonderband. 7, p. 124, fig. 23 (3a-3b).

Tetralithus nitidus Martini, Gartner, 1968 (in part). Kansas Univ. Paleont. Contr., Protista. 1, p. 42, pl. 9, fig. 14; pl. 13, fig. 4.

Tetralithus nitidus trifidus (Stradner), Bukry and Kennedy, 1969. California Div. Mines Geology Spec. Rept. 100, p. 35, fig. 2 (13-14).

Remarks: These three-rayed rosettes show sequential extinction of the three crystallites in cross-polarized light as the microscope stage is rotated. Forms with short crystallites are triangular in outline.

Genus ZYGODISCUS Bramlette and Sullivan, 1961

Zygodiscus bicrescenticus (Stover) n. comb.

Discolithus bicrescenticus Stover, 1966. Micropaleontology. 12, p. 142, pl. 2, figs. 5-7; pl. 8, fig. 11.

SPECIES IN SELECTED SAMPLES

SITE DSDP 155
(lat. 06°07.38′N, long. 81°02.62′W, depth 2752 m)

Pleistocene
(*Gephyrocapsa oceanica* Zone)

155-Bit sample (0 to 285 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Gephyrocapsa caribbeanica, G. oceanica (common), *Helicopontosphaera kamptneri.* Reworked ?Pliocene taxa, etched and rare: *Coccolithus pelagicus, Discoaster brouweri, Sphenolithus abies.* Associated siliceous phytoplankton: *Actinoptychus senarius, Coscinodiscus excentricus, C. nodulifer, Dictyocha fibula, Ethmodiscus rex* s. 1., *Hemidiscus cuneiformis* [rims], *Thalassiosira oestrupii s. l.*

Upper Pliocene
(*Discoaster brouweri* Zone,
***Discoaster tamalis* Subzone)**

155-15-Side-wall core (approx. 285 m):
Ceratolithus rugosus s. 1., *Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. intercalaris, D. pentaradiatus, Helicopontosphaera kamptneri, D. sellii, Spenolithus neoabies* [rare], *Thoracosphaera* sp. cf. *T. saxea.* Siliceous phytoplankton, rare: *Ethomodiscus rex s. l.*

Lower Pliocene
(*Reticulofenestra pseudoumbilica* Zone,
***Discoaster asymmetricus* Subzone)**

155-15-Side-wall core (approx. 285 m):
Ceratolithus rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. pentaradiatus, D. variabilis, Helicopontosphaera kamptneri, D. sellii, Reticulofenestra pseudoumbilica, Scyphosphaera sp. [rare], *Sphenolithus abies, S. neoabies.* Siliceous phytoplankton, rare: *Ethmodiscus rex s. l., Thalassiothrix* sp.

Lower Pliocene or Upper Miocene
(?*Ceratolithus tricorniculatus* Zone)

155-14-Side-wall core (371 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus [rare], *D. brouweri, D. challengeri* [rare], *D. pentaradiatus, D.* sp. cf. *D. phyllodus* [rare], *D. variabilis, Discolithina* sp. cf. *D. japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Scyphosphaera* sp., *Sphenolithus abies, Sphenolithus neoabies* [abundant], *Triquetrorhabdulus* sp. cf. *T. rugosus* [small].

Upper Miocene
(*Discoaster quinqueramus* Zone,
***Ceratolithus primus* Zone)**

155-13-Side-wall core (384 m):
Ceratolithus dentatus, C. primus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. quinqueramus [abundant], *D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H.* sp. cf. *H. sellii* [small pores], *Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies* [myriad], *Triquetrorhabdulus rugosus.*

Upper Miocene
(*Discoaster quinqueramus* Zone,
***Discoaster berggrenii* Subzone)**

155-1-Top (434m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster berggrenii (rare] *D. braarudii, D.* sp. cf. *D. loeblichii* [rare], *D. quinqueramus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [rare], *Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus* [common].

155-1-4(120-121 cm) (439 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster berggrenii, D. braarudii, D. obtusus, D. sp. cf. *D. quinqueramus* [small knobbed], *D. variabilis, Helicopontosphaera kamptneri, Minylitha convallis, Reticulofenestra pseudombilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

Upper Miocene
(*Discoaster neohamatus* Zone)

155-1-5(121-122 cm) (441 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. berggrenii, D. braarudii, D. challengeri, D. loeblichii, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudombilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.

155-1-6(120-121 cm) 442 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. sp. cf. *D. berggrenii* [rare], *D.braarudii, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

155-2-3(120-121 mc) (447 m):
Discoaster sp. cf. *D. bellus, D. braarudii, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.* all specimens rare.

155-2-6(110-111 cm) (452 m):
Coccolithus pelagicus [large-centered, common], *Cyclococcolithina macintyrei, Discoaster bellus* [abundant], *D.* sp. cf. *D. berggrenii, D. braarudii, D.* sp. cf. *D. neohamatus, D. variabilis, Helicopontosphaera kamptneri, Minylitha convallis, Reticulofenestra pseudoumbilica* [meager], *Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

155-3-1(120-121 cm) (453 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus [small, common], *D.* sp. cf. *D. bollii* [rare], *D. braarudii, D. variabilis, Helicopontosphaera kamptneri, Lithostromation perdurum, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

155-3-3(121-122 cm) (456 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discaster bellus, D. braarudii, D. variabilis, Discolithina multipora, Helicopontosphaera sp. aff. *H. intermedia, H. kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

155-4-3(118-119 cm) (465 m):
Coccolithus pelagicus, Discoaster bellus, D. bollii, D. sp. cf. *D. intercalaris, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

155-4(CC) (470 m):
Discoaster bellus, D. braarudii, D. intercalaris, D. variabilis, Minylitha convallis, Reticulofenestra pseudoumbilica [small], *Sphenolithus abies.*

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

155-5-1(7-8 cm) (470 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. cf. *D. bellus, D.* sp. cf. *D. bollii, ?D. hamatus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica.* Reworked Middle Miocene taxa: *Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster* sp. cf. *D. deflandrei, Scyphosphaera* sp. cf. *S. amphora, Sphenolithus heteromorphus.*

Middle Miocene
(*Discoaster hamatus* Zone)

155-5-3(110-111 cm) (474 m):
Catinaster coalitus, Coccolithus pelagicus, Discoaster bellus, D. sp. cf. *D. bollii, D. braarudii, D.* sp. cf. *D. hamatus* [large, unspurred], *D. obtusus, D. perclarus, D. variabilis, Reticulofenestra pseudoumbilica.*

155-5-4(119-120 cm) (476 m):
Catinaster coalitus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. hamatus, D. pseudovariabilis, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica [abundant], *Sphenolithus neoabies.*

155-5-5(55-56 cm) (477 m):
Catinaster sp., *Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus, D. hamatus, D. pseudovariabilis, D. variabilis, Helicopontosphaera kamptneri, Lithostromation perdurum* [rare], *Reticulofenestra pseudoumbilica, Triquetrorhabdulus rugosus.*

Middle Miocene
(*Catinaster coalitus* Zone)

155-5-6(119-120 cm) (479 m):
Catinaster coalitus, Coccolithus miopelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. bollii, D. braarudii, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica.*

155-5(CC) (479 m):
Catinaster coalitus, Coccolithus miopelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. cf. *D. bellus* [rare], *D.* sp. cf. *D. braarudii, D.* sp. cf. *D. exilis, D.* sp. cf. *D. moorei, D. perplexus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

Middle Miocene
(*Discoaster exilis* Zone)

155-6-1(119-120 cm) (480 m):
Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. aulakos, D. braarudii, D. exilis, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Triquetrorhabdulus rugosus.*

155-6-4(119-120 cm) (485 m):
Coccolithus miopelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. exilis, D.* sp. cf. *D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

155-7-2(121-122 cm) (491 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus [meager], ?*Discoaster deflandrei, D. variabilis, Helicopontosphaera kamptneri.*

Middle Miocene
(*Sphenolithus heteromorphus* Zone)

155-7(CC) (491 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina leptopora, Discoaster sp. cf. *D. deflandrei, D.* sp. cf. *D. exilis, Helicopontosphaera granulata, Reticulofenestra pseudoumbilica, Sphenolithus heteromorphus.*

155-8(CC) (500 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Cyclococcolithina leptopora, Coronocyclus sp., *Discoaster* sp. cf. *D. aulakos, D.* sp. cf. *D. exilis, D. exilis, Helicopontosphaera granulata, H. kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus heteromorphus, S. neoabies, Triquetrorhabdulus rugosus.*

155-11-Basal limestone (521 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina leptopora, Discoaster deflandrei, D. sp. cf. *D. exilis, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [abundant], *Sphenolithus heteromorphus, S.* sp. cf. *S. moriformis.*

SITE DSDP 156
(lat. 01°40.80'S, long. 85°24.06'W, depth 2369 m)

Upper Pleistocene
(*Gephyrocapsa oceanica* Zone)

156-1-1(111-112 cm) (0 to 4 m):
Ceratolithus cristatus [rare], *Cyclococcolithina leptopora, Gephyrocapsa oceanica* [abundant], *Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera claviger, Syracosphaera* sp. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Discoaster berggrenii, D. brouweri, D. surculus, Reticulofenestra pseudoumbilica, Sphenolithus abies.* Associated siliceous phytoplankton: *Asteromphalus imbricatus, Dictyocha fibula, Hemidiscus cuneiformis* [rims], *Rhizosolenia bergonii, Thalassionema nitzschoides* s. 1., *Thalassiothrix* sp.

156-1-1(135 cm) (0 to 4 m):
Ceratolithus cristatus, Cyclococcolithina leptopora, ?Emiliania huxleyi, Gephyrocapsa caribbeanica, G. oceanica, Helicopontosphaera kamptneri [late], *H.sellii.* Reworked Miocene or Pliocene taxa: *Cyclococcolithina macintyrei, Discoaster berggrenii, D. brouweri, D. surculus, D. variabilis.* Associated siliceous phytoplankton: *Asteromphalus imbricatus, Coscinodiscus africanus, Coscinodiscus nodulifer, Dictyocha fibula, Ethmodiscus rex* s. 1., *Hemidiscus cuneiformis, Pseudoeunotia doliolus, Thalassionema nitzchioides s. l., Thalassiothrix* sp., *Triceratium cinnamomeum.*

156-1(CC) (0 to 4 m):
Ceratolithus cristatus [rare], *Cyclococcolithina leptopora, Discolithina japonica* [rare], *Gephyrocapsa oceanica, Helicopontosphaera kamptneri, H. sellii, Thoracosphaera saxea, T.* sp. Reworked Miocene or Pliocene taxa: *Cyclococcolithina macintyrei, Discoaster brouweri, Reticulofenestra pseudoumbilica.* Associated siliceous phytoplankton: *Actinoptychus senarius, Asteromphalus imbricatus, Coscinodiscus excentricus, C. nodulifer, Dictyocha fibula, Ethmodiscus rex s. l., Hemidiscus cuneiformis, Pseudoeunotia doliolus, Rhizosolenia bergonii, R. styliformis, Roperia tessellata, Thalassionema nitzchioides s. l., Thalassiosira oestrupii, Thalassiothrix* sp., *Triceratium cinnamomeum.*

SITE DSDP 157 (Holes DSDP 157 and DSDP 157A)
(lat. 01°45.70'S, long. 85°54.17'W, depth 259 m)

Upper Pleistocene or Holocene
(*Gephyrocapsa oceanica* Zone or *Emiliania huxleyi* Zone)

157-1A-2(119-120 cm) (2 m):
Ceratolithus cristatus [rare], *Cycococcolithina leptopora, ?Emiliania huxleyi, Gephyrocapsa caribbeanica* [abundant], *G. oceanica, Helicopontosphaera kamptneri, H.* sp. cf. *H. sellii* [small pores], *Thoracosphaera* sp.

157A-1A-4(119-120 cm) (5 m):
Cyclococcolithina leptopora, ?Emiliania huxleyi, Gephyrocapsa oceanica [abundant], *Helicopontosphaera kamptneri, H. sellii, Pontosphaera discopora, Thoracosphaera* sp. Reworked Miocene or Pliocene taxa: *Cyclococcolithina macintyrei, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

Upper Pleistocene
(*Gephyrocapsa oceanica* Zone)

157-1-Top (10 m):
Ceratolithus cristatus, Cyclococcolithina leptopora, Emiliania annula, ?E. huxleyi, Gephyrocapsa oceanica [abundant, large and small], *Helicopontosphaera kamptneri, H. sellii,* Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Discoaster asymmetricus, D. brouweri, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

157A-2A(CC) (11 m):
Cyclococcolithina leptopora, Gephyrocapsa caribbeanica [abundant, small], *G. oceanica, Helicopontosphaera kamptneri, Rhabdosphaera claviger, Syracosphaera* sp., *Thoracosphaera saxea* [fragments].

157-2-1(119-120 cm) (20 m):
Cyclococcolithina leptopora, Gephyrocapsa caribbeanica, G. oceanica [rare], *?G. producta, Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera claviger.*

157A-3A-2(119-120 cm) (21 m):
Cyclococcolithina leptopora, Emiliania annula, Gephyrocapsa oceanica [small], *?G. producta, Helicopontosphaera kamptneri, Pontosphaera discopora, Thoracosphaera saxea* [fragments]. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Sphenolithus abies.*

157A-3A (CC) (27 m):
Cyclococcolithina leptopora, Gephyrocapsa oceanica [large and small], *?G. producta, Helicopontosphaera kamptneri, Pontosphaera discopora, Thoracosphaera saxea* [fragments].

157-2-6(120-121 cm) (28 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Emiliania annula, Gephyrocapsa caribbeanica, G. oceanica, ?G.producta, Helicopontosphaera kamptneri.

157-4-2(122-123 cm) (40 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Emiliania annula, Gephyrocapsa oceanica, ?G. producta, Helicopontosphaera kamptneri, Pontosphaera discopora.

157-5-1(50-51 cm) (46 m):
Cyclococcolithina leptopora, Emiliania annula, Gephyrocapsa oceanica, Helicopontosphaera kamptneri.

Lower Pleistocene
(*Coccolithus doronicoides* Zone, *Gephyrocapsa caribbeanica* Subzone)

157-5-1(119-120 cm) (47 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Emiliania annula [rare], *Gephyrocapsa caribbeanica, ?G. producta, Helicopontosphaera kampneri.*

157-5-2(119-120 cm) (49 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Emiliania annula [large, common], *Gephyrocapsa caribbeanica, Helicopontosphaera kamptneri.*

157-5(CC) (55 m):
Ceratolithus cristatus [rare], *Coccolithus doronicoides, Cyclococcolithina leptopora, Discolithina japonica, Emiliania*

annula [abundant], *Gephyrocapsa caribbeanica, Helicopontosphaera kamptneri.*

157-7-2(50-51 cm) (65 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Discolithina japonica, Emiliania annula, Gephyrocapsa caribbeanica [large, common], *Helicopontosphaera kamptneri* [common], *Thoracosphaera saxea* [fragments]. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster surculus, Reticulofenestra pseudoumbilica.*

157-8-2(117-118 cm) (76 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Gephyrocapsa caribbeanica [large, abundant], *Helicopontosphaera kamptneri* [large, common], *Pontosphaera discopora, Thoracosphaera* sp. [fragments]. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

157-8-4(120-121 cm) (79 m):
Ceratolithus cristatus [rare], *Coccolithus doronicoides, D. pelagicus* [common], *Cyclococcolithina leptopora, Gephyrocapsa caribbeanica, ?G. producta, Helicopontosphaera kamptneri* [common].

Lower Pleistocene
(*Coccolithus doronicoides* Zone, *Emiliania annula* Subzone)

157-8(CC) (79 m):
Ceratolithus cristatus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, Discolithina japonica, ? Gephyrocapsa producta, Helicopontosphaera kamptneri, H. sellii, Scyphosphaera sp. [rare], *Thoracosphaera saxea* [fragments]. Reworked Miocene or Pliocene taxa: *Discoaster surculus, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

157-9-1(110-111 cm) (82 m):
Coccolithus doronicoides, C.pelagicus, Cyclococcolithina leptopora, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii [common]. Reworked Miocene or Pliocene taxa: *Ceratolithus tricorniculatus, Cyclococcolithina macintyrei, Discoaster asymmetricus. D. quinqueramus, D. variabilis, Sphenolithus abies.*

157-9-2(120-121 cm) (84 m):
Ceratolithus rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discolithina japonica [rare], *Helicopontosphaera kamptneri, H. sellii* [rare]. Reworked Miocene or Pliocene taxa: *Ceratolithus tricorniculatus, Discoaster asymmetricus, D. brouweri, D. surculus, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

Upper Pliocene
(*Discoaster brouweri* Zone, *Cyclococcolithina macintyrei* Subzone)

157-9-3(0-1 cm) (84 m):
Ceratolithus cristatus, C. rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei [common], *Discoaster brouweri* [rare], *Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Scyphosphaera pulcherrima* [rare], *Thoracosphaera saxea* [fragments]. Reworked Miocene or Pliocene taxon: *Discoaster surculus.*

157-9-3(84-85 cm)(85 m):
Ceratolithus rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei [large, abundant], *Discoaster brouweri* [rare], *Helicopontosphaera kamptneri, H. sellii* [common], *Thoracosphaera saxea.* Reworked Miocene or Pliocene taxa: *Discoaster variabilis, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

157-10-4(121-122 cm) (97 m):
Ceratolithus rugosus, Coccolithus sp. cf. *C. doronicoides, C pelagicus, Cyclococcolithina leptopora, C. macintyrei* [centerless], *Discoaster brouweri, D. triradiatus, Helicopontosphaera sellii.* Reworked Miocene or Pliocene taxa: *Discoaster quinqueramus, D. variabilis, Reticulofenestra pseudoumbilica.*

157-11-3(87-88 cm) (103 m):
Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithina macintyrei* [large, abundant], *Discoaster brouweri* [rare], *Discolithina japonica* [rare], *Helicopontosphaera sellii* [common].

157-13-1(60-61 cm) (118 m):
Coccolithus rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, Discoaster asymmetricus, D. brouweri [common], *Helicopontosphaera kamptneri, H. sellii.*

157-14-2(119-120 cm) (128 m):
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, Helicopontosphaera kamptneri, H. sellii. Reworked Miocene or Pliocene taxa: *Discoaster berggrenii, D. intercalaris, D. variabilis, Reticulofenestra pseudoumbilica.*

157-14-5(119-120 cm) (133 m):
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei [meager], *Discoaster asymmetricus* [rare], *D. brouweri, D. perplexus, Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera procera* [rare]. Reworked Miocene or Pliocene taxa: *Discoaster intercalaris, D. surculus, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

Upper Pliocene
(*Discoaster brouweri* Zone, *Discoaster pentaradiatus* Subzone)

157-14-6(120-121 cm) (134 m):
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei [rare], *Discoaster asymmetricus, D. brouweri, D.* sp. cf. *D. surculus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera procera* [rare]. Reworked Miocene or Pliocene taxa: *Discoaster* sp. cf. *D. berggrenii, D. intercalaris, Reticulofenestra pseudoumbilica, Sphenoliths abies, S. neoabies.*

157-15-1(119-120 cm) (136 m):
Ceratolithus rugosus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. perplexus [rare], *D.* sp. cf. *D. surculus, D. triradiatus, D. japonica, Helicopontosphaera kamptneri, H. sellii.* Reworked Miocene or Pliocene taxa: *Discoaster*

berggrenii, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.

157-15-4(119-120 cm) (141 m):
Coccolithus sp. cf. *C. doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, D. brouweri, D.* sp. cf. *D. decorus, D. pentaradiatus, D. surculus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Scyphosphaera pulcherrima* [rare].

157-16-1(50-51 cm) (144 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [rare, ?reworked].

Upper Pliocene
(*Discoaster brouweri* Zone, *Discoaster tamalis* Subzone)

157-16-1(139-140 cm) (145 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora [abundant], *C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. surculus, D. tamalis, D. triradiatus, D. variabilis, Helicopontosphaera kamptneri* [abundant], *H. sellii.* ?Reworked Miocene or Pliocene taxa: *Discoaster* sp. cf. *D. quinqueramus, Reticulofenestra pseudoumbilica.*

157-16-6(120-121 cm) (152 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. surculus, D. tamalis, Discolithina japonica, Helicopontosphaera kamptneri [abundant], *H. sellii, Reticulofenestra pseudoumbilica* [small, ?reworked], *Sphenolithus neoabies* [rare].

157-17-5(119-120 cm) (160 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. sp. cf. *D. intercalaris, D. surculus, D. tamalis, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica* [small, ?reworked], *Sphenolithus abies* [rare].

157-18-4(118-119 cm) (168 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [small, ?reworked].

157-19-6(119-120 cm) (180 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. surculus, D. tamalis, D. triradiatus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [large and small, meager], *Sphenolithus neoabies* [rare].

157-21-1(119-120 cm) (190 m):
Ceratolithus rugosus, Coccolithus pelagicus [abundant], *Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. surculus, D. tamalis, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [small].

Lower or Upper Pliocene
(*Reticulofenestra pseudoumbilica* Zone or *Discoaster brouweri* Zone)

157-21-3(119-120 cm) (193 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. sp. cf. *D. surculus, D. tamalis, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii* [rare], *Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-22-4(119-120 cm) (204 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster asymmetricus, D. sp. cf. *D. berggrenii* [rare], *D. brouweri, D. intercalaris, D. surculus, D. tamalis, D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Sphenolithus neoabies* [rare].

157-23-2(119-120 cm) (210 m):
Ceratolithus rugosus, Coccolithus pelagicus [common], *Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri* [abundant], *D. surculus, D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica* [small], *Sphenolithus abies, Thoracosphaera* sp. cf. *T. saxea.*

157-23-4(119-120 cm) (213 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster asymmetricus [common], *D. decorus* [rare], *D. perplexus, D. surculus, D. tamalis* [common], *D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-24-3(119-120 cm) (219 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster asymmetricus, D. brouweri, D. sp. [overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S.* sp. cf. *S. apsteinii, Sphenolithus abies, S. neoabies.*

Lower Pliocene
(*Reticulofenestra pseudoumbilica* Zone, *Sphenolithus neoabies* Subzone)

157-25-2(119-120 cm) (228 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. intercalaris, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.

157-25-4(121-122 cm) (231 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei [abundant], *Discoaster* sp. cf. *D. berggrenii, D.* sp. cf. *D. brouweri, D.* sp. cf. *D. surculus, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Sphenolithus abies* [abundant], *S. neoabies* [abundant].

157-26-4(119-120 cm) (240 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. perplexus, D. sp. cf. *D. surculus, Helicopontosphaera kamptneri, Reticulofenestra*

pseudoumbilica [abundant], *Scyphosphaera globulata, Sphenolithus abies* [abundant], *S. neoabies* [abundant].

157-28-5(119-120 cm) (259 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. brouweri, D.* sp. cf. *D. surculus, Reticulofenestra pseudoumbilica* [abundant], *Sphenolithus abies* [abundant], *S. neoabies* [abundant].

Lower Pliocene
(*Ceratolithus tricorniculatus* Zone, *Ceratolithus rugosus* Subzone)

157-28-6(0-1 cm) (259 cm) (259 m):
Ceratolithus rugosus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. [six-rayed, overgrown], *Heliconpontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-29-2(119-120 cm) (263 m):
Ceratolithus rugosus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. brouweri, D.* sp. cf. *D. surculus, D.* sp. cf. *D. variabilis, Helicopontosphaera kamptneri, H.* sp. cf. *H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

Lower Pliocene
(*Ceratolithus tricorniculatus* Zone, *Ceratolithus amplificus* Subzone)

157-29(CC) (265 m):
Ceratolithus amplificus, C. rugosus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. cf. *D. berggrenii* [?reworked], *D. brouweri, D.* sp. cf. *D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Sphenolithus abies, S. neoabies.*

157-30-2(119-120 cm) (273 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. sp. cf. *D. surculus, D.* sp. cf. *D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-31-5(0-1 cm) (284 m):
Ceratolithus tricorniculatus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster sp. cf. *D. surculus, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-32-4(119-120 cm) (294 m):
Ceratolithus amplificus, ?C. rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp., *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [small], *Scyphosphaera globulata* [rare], *Sphenolithus abies, S. neoabies, Thoracosphaera* sp. [fragments].

157-33-5(119-120 cm) (304 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp., *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-35-1(119-120 cm) (316 m):
Ceratolithus amplificus [common, overgrown], *Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. surculus, D. variabilis, Helicopontosphaera kamptneri, Sphenolithus abies.*

Upper Miocene
(*Ceratolithus tricorniculatus* Zone, ?*Triquetrorhabdulus rugosus* Subzone)

157-36-2(40-41 cm) (325 m):
Ceratolithus primus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. surculus, D. variabilis, Helicopontosphaera kamptneri, H. sp. cf. *H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

Upper Miocene
(*Discoaster quinqueramus* Zone)

157-36-2(95-96 cm) (326 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. quinqueramus, D. surculus, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.

157-37(CC) (333 m):
Ceratolithus primus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. quinqueramus, D. surculus, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus abies.

157-38(CC) (343 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. quinqueramus, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.

157-39(CC) (346 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. quinqueramus, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.

157-40(CC) (350 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. cf. *D. quinqueramus, D.* sp. cf. *D. surculus, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-41(CC) (360 m):
Cyclococcolithina leptopora, Discoaster sp. [five- and six-rayed, overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-42(CC) (370 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. [five- and six-rayed, overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies.*

157-43(CC) (378 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. cf. *D. berggrenii* [common, large-knobbed, short-rayed], *D.* sp. [five- and six-rayed, overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

Upper Miocene
(?*Discoaster neohamatus* Zone)

157-44(CC) (386 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. [six-rayed, large, common], *D.* sp. [five-rayed, small, rare], *Helicopontosphaera kamptneri Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

157-45(CC) (395 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. [six-rayed, large], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [small], *Sphenolithus abies.*

157-46(CC) (405 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster sp. [six-rayed], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, Triquetrorhabdulus rugosus.*

Upper Miocene
(*Discoaster neohamatus* Zone,
***Discoaster bellus* Subzone)**

157-48(CC) (423 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei [abundant], *Discoaster bellus* [abundant], *D.* sp. cf. *D. brouweri, D.* sp. cf. *D. perclarus, D.* sp. cf. *D. variabilis, Helicopontosphaera kamptneri, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

SITE DSDP 158
(lat. 06°37.36′N, long. 85°14.16′W, depth 1953 m)

Upper Pleistocene or Holocene
(?*Emiliania huxleyi* Zone)

158-1-1(0-1 cm) (0 m):
Ceratolithus cristatus [large], *Cyclococcolithina leptopora, ?Emiliania huxleyi* [abundant], *Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Thoracosphaera saxea, T.* sp. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Discoaster brouweri, D. pentaradiatus, D. surculus, Helicopontosphaera sellii, Reticulofenestra pseudoumbilica, Sphenolithus abies.* Associated small siliceous phytoplankton: *Hemidiscus cuneiformis, Pseudoeunotia doliolus, Thalassiosira oestrupii.*

Upper Pleistocene
(*Gephyrocapsa oceanica* Zone)

158-1-1(128-129 cm) (1 m):
Ceratolithus cristatus, Cyclococcolithina leptopora, Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Thoracosphaera sp. Reworked Miocene or Pliocene taxa: *Coccolithus pelagicus, Discoaster berggrenii, D. neorectus, D. surculus, Helicopontosphaera sellii, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

158-2-4(122-123 cm) (14 m):
Cyclococcolithina leptopora, Gephyrocapsa oceanica, Helicopontosphaera kamptneri, Rhabdosphaera claviger, Thoracosphaera saxea [common]. Reworked Miocene or Pliocene taxa: *Ceratolithus rugosus, Coccolithus pelagicus, Discoaster intercalaris, Discolithina japonica.*

158-3-3(49-50 cm) (21 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Emiliania annula [rare], *Gephyrocapsa* sp. cf. *G. oceanica* [small], *?G. producta, Helicopontosphaera kamptneri, Pontosphaera scutellum* [rare]. Reworked Miocene or Pliocene taxa: *Discoaster brouweri, D. variabilis, Sphenolithus abies.*

158-3-6(80-81 cm) (26 m):
Coccolithus doronicoides, Cyclococcolithina leptopora, Discolithina japonica, Emiliania annula, Gephyrocapsa caribbeanica, G. sp. cf. *G. oceanica, Helicopontosphaera kamptneri, Rhabdosphaera stylifer, Syracosphaera* sp. Reworked Miocene or Pliocene taxa: *Reticulofenestra pseudoumbilica, Sphenolithus abies.*

Lower Pleistocene
(*Coccolithus doronicoides* Zone,
***Gephyrocapsa caribbeanica* Subzone)**

158-4-1(10-11 cm) (27 m):
Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, Discolithina japonica, Gephyrocapsa caribbeanica, Helicopontosphaera kamptneri [abundant], *H. sellii, Syracosphaera* sp., *Thoracosphaera saxea.* Reworked Miocene or Pliocene taxa: *Discoaster brouweri, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

158-4-2(20-21 cm) (28 m):
Ceratolithus cristatus, Coccolithus doronicoides, Cyclococcolithina leptopora, Discolithina sp. cf. *D. japonica, Emiliania annula, Gephyrocapsa caribbeanica, G.* sp. cf. *G. caribbeanica* [large-center, high-angle bar], *Helicopontosphaera kamptneri, H. sellii, Rhabdosphaera stylifer, Thoracosphaera saxea.* Reworked Miocene or Pliocene taxa: *Discoaster brouweri, D. loebilichii, Reticulofenestra pseudoumbilica.*

Upper Pliocene
(*Discoaster brouweri* Zone,
***Cyclococcolithina macintyrei* Zone)**

158-4-2(60-61 cm) (29 m):
Coccolithus doronicoides, C. pelagicus [abundant], *Cyclococcolithina leptopora, C. macintyrei* [rare], *Discoaster brouweri* [abundant], *Helicopontosphaera kamptneri.*

158-4-2(111-112 cm) (29 m):
Ceratolithus rugosus, Coccolithus doronicoides, C. pelagicus [abundant], *Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri* [abundant], *Helicopontosphaera kamptneri.*

Upper Pliocene
(*Discoaster brouweri* Zone,
***Discoaster tamalis* Subzone)**

158-4-3(119-120 cm) (31 m);
Coccolithus doronicoides, C. pelagicus [rare], *Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. pentaradiatus, D. perplexus, D. surculus, D. tamalis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Thoracosphaera saxea.*

Upper Pliocene
(*Discoaster brouweri* Zone, *Cyclococcolithina macintyrei* Subzone)

158-4-4(1-2 cm) (31 m):
Ceratolithus cristatus, Coccolithus doronicoides, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Thoracosphaera saxea. ?Reworked Miocene taxa: *Discoaster pentaradiatus, D. surculus, D. variabilis, Scyphosphaera pulcherrima.*

Upper Pliocene
(*Discoaster brouweri* Zone, *Discoaster pentaradiatus* Subzone)

158-4-4(42-43 cm) (32 m);
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Scyphosphaera pulcherrima, Thoracosphaera saxea.

158-4-4(70-71 cm) (32 m):
Ceratolithus cristatus, C. rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster asymmetricus, D. brouweri [abundant], *D. pentaradiatus, D. triradiatus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Scyposphaera pulcherrima, Thoracosphaera saxea.*

Upper Pliocene
(*Discoaster brouweri* Zone, *Discoaster tamalis* Subzone)

158-5-1(40-41 cm) (36 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus [abundant], *D. pentaradiatus, Discolithina japonica, Helicopontosphaera kamptneri, Scyphosphaera pulcherrima, S.* sp., *Thoracosphaera saxea.* Reworked Miocene taxa: *Angulolithina arca, Discoaster* sp. cf. *D. bollii, D. neohamatus.*

158-5-1(83-84 cm) (37 m):
Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. pentaradiatus, D. tamalis, Discolithina japonica, Helicopontosphaera kamptneri, Thoracosphaera saxea.

158-5-1(124-125 cm) (37 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus [common], *D. pentaradiatus, D. tamalis, Helicopontosphaera kamptneri, Thoracosphaera saxea.*

Lower Pliocene
(*Reticulofenestra pseudoumbilica* Zone, *Discoaster asymmetricus* Subzone)

158-5-2(126-127 cm) (39 m):
Ceratolithus rugosus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. decorus, D. pentaradiatus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus neoabies [rare], *Thoracosphaera saxea.*

158-5-3(121-122 cm) (40 m):
Ceratolithus rugosus [common], *Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. perplexus* [rare], *D. surculus, D. tamalis* [rare], *D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Thoracosphaera saxea.*

158-5-4(120-121 cm) (42 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. challengeri, D. pentaradiatus, D. perplexus, D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [rare], *Scyphosphaera pulcherrima, Sphenolithus abies, S. neoabies, Thoracosphaera saxea.* Reworked Miocene or Pliocene taxa: *Ceratolithus primus, ?Discoaster quinqueramus, Scyphosphaera globulata, Triquetrorhabdulus rugosus.*

158-5-5(121-122 cm) (43 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster asymmetricus, D. brouweri, D. pansus, D. pentaradiatus, D. triradiatus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [meager], *Spenolithus neoabies.*

Lower Pliocene
(*Reticulofenestra pseudoumbilica* Zone, *Sphenolithus neoabies* Subzone)

158-5-6(120-121 cm) (45 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. sp. cf. *D. challengeri, D. pentaradiatus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [common], *Spenolithus neoabies.*

158-6-1(120-121 cm) (46 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, D. variabilis, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica [abundant], *Scyphosphaera globulata, S. recurvata, Sphenolithus abies, S. neoabies, Thoracosphaera saxea.*

158-7-1(140-141 cm) (55 m):
Ceratolithus rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. pentaradiatus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, Sphenolithus abies, S. neoabies.

Lower Pliocene
(*Ceratolithus tricorniculatus* Zone, *Ceratolithus amplificus* Subzone)

158-7-2(83-84 cm) (56 m):
Ceratolithus rugosus, C. tricorniculatus s. s., Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. pentaradiatus [large, abundant], *D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii* [small], *Reticulofenestra pseudoumbilica, Scyphosphaera* sp. aff. *S. intermedia, Sphenolithus abies, S. neoabies, Thoracosphaera saxea.*

158-7-5(120-121 cm) (61 m):
Ceratolithus rugosus, C. tricorniculatus s. s., Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.

158-8-2(83-84 cm) (65 m):
Ceratolithus rugosus, C. sp. cf. *C. tricorniculatus, Coccolithus pelagicus* [rare], *Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri* [abundant], *D. pentaradiatus, D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

158-8-2(120-121 cm) (65 m):
Ceratolithus amplificus s. s. [rare], *C. rugosus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri* [abundant], *D. pentaradiatus, D. surculus, D. triradiatus, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S. pulcherrima, S. recurvata, Sphenolithus abies.*

158-8-3(120-121 cm) (67 m):
Ceratolithus amplificus, C. bizzaurs, C. rugosus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus, D. brouweri, D. pentaradiatus, D. perplexus, D. surculus, Discolithina japonica, Helicopontosphaera kamptneri, H. sellii, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S. pulcherrima, Sphenolithus abies.

Lower Pliocene
(*Ceratolithus tricorniculatus* Zone,
Ceratolithus amplificus **Subzone)**

158-8-5(120-121 cm) (70 m):
Ceratolithus amplificus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. pentaradiatus, D. surculus, D. variabilis, Discolithina japonica, D. sp., *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [small], *Scyphosphaera globulata, S. pulcherrima, Sphenolithus abies.*

158-8-6(120-121 cm) (71 m):
Angulolithina arca, Ceratolithus amplificus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. challengeri, D. pentaradiatus, D. surculus, D. variabilis, Discolithina sp. cf. *D. japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [small], *Scyphosphaera globulata, Sphenolithus abies.*

158-9-5(120-121 cm) (79 m):
Angulolithina arca, Ceratolithus sp. cf. *C. amplificus, Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. pentaradiatus, D. quinqueramus* [rare], *D. surculus, D. variabilis, Discolithina* sp. cf. *D. multipora, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S. sp., Sphenolithus abies.*

Upper Miocene
(*Ceratolithus tricorniculatus* Zone,
?*Triquetrorhabdulus rugosus* Subzone)

158-9-6(120-121 cm) (80 m):
Angulolithina arca, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. pentaradiatus, D. quinqueramus [rare], *D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Rhabdosphaera procera* [rare], *Scyphosphaera globulata, S. pulcherrima, S.* sp., *Sphenolithus abies, Thoracosphaera saxea, Triquetrorhabdulus rugosus.*

Upper Miocene
(*Discoaster quinqueramus* Zone,
Ceratolithus primus Subzone)

158-10-1(70-71 cm) (81 m):
Ceratolithus primus, Coccolithus pelagicus [common], *Cyclococcolithina leptopora, Discoaster brouweri, D. pentaradiatus, D.* sp. cf. *D. quinqueramus, D. surculus, Disclothina multipora, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S. pulcherrima, Sphenolithus abies.*

158-11-1(110-111 cm) (91 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. quinqueramus, D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Scyphosphaera globulata, S. sp. cf. *S. apsteinii, Sphenolithus abies.*

158-11-6(120-121 cm) (99 m):
Ceratolithus primus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. quinqueramus [abundant], *D. surculus, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

158-12-6(110-111 cm) (108 m):
Ceratolithus dentatus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster brouweri, D. perplexus, D. quinqueramus, D. surculus, D. variabilis, Discolithina japonica, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies [abundant], *Triquetrorhabdulus rugosus.*

158-14-3(70-71 cm) (121 m):
Ceratolithus dentatus, C. primus, Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster sp. cf. *D. berggrenii, D. brouweri, D. pentaradiatus, D. quinqueramus, D. surculus, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus abies, Triquetrorhabdulus rugosus.*

158-16-1(30-31 cm) (135 m):
Ceratolithus primus, C. tricorniculatus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster brouweri, D. quinqueramus, D. surculus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies, Triquetrorhabdulus rugosus.

158-17-1(70-71 cm) (145 m):
Ceratolithus primus [rare], *Coccolithus pelagicus* [common], *Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri, D. quinqueramus, D. surculus,*

Helicopontosphaera kamptneri, Sphenolithus abies, Triquetrorhabdulus rugosus.

158-17-5(70-71 cm) (151 m):
?Ceratolithus primus, Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster berggrenii, D. brouweri, D. quinqueramus, D. surculus, D. variabilis, Sphenolithus abies [abundant], *Triquetrorhabdulus rugosus.*

Upper Miocene

(*Discoaster quinqueramus* Zone, *Discoaster berggrenii* Subzone)

158-17-6(126-127 cm) (153 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster asymmetricus [rare], *D. berggrenii, S. brouweri s. l., D. surculus, D. variabilis, Helicopontos phaera kamptneri, Reticulofenestra pseudoumbilica* [rare], *Triquetrorhabdulus rugosus.*

158-18-4(70-71 cm) (158 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster berggrenii [common], *D. brouweri s. l., D. quinqueramus* [rare], *D. surculus, D. variabilis, Sphenolithus abies, Triquetrorhabdulus rugosus.*

158-19-1(70-71 cm) (163 m):
Coccolithus pelagicus [abundat], *Cyclococcolithina macintyrei, Discoaster brouweri s. l., D. berggrenii, D. quinqueramus, D. surculus, D. variabilis, Helicopontosphaera kamptneri, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

158-19-3(70-71 cm) (166 m):
Coccolithus pelagicus [abundant], *Cyclococcolithina macintyrei, Discoaster berggrenii, D. brouweri s. l.* [abundant], *D. loeblichii, D. variabilis, Helicopontosphaera kamptneri, H.* sp. aff. *H. sellii, Reticulofenestra pseudoumbilica* [rare], *Sphenolithus neoabies.*

158-19-4(20-21 cm)(167 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster brouweri s. l., D. loebilichii, D. neorectus [rare], *D. quinqueramus, D. surculus, D. variabilis, Helicopontosphaera kamptneri, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

Upper Miocene

(*Discoaster neohamatus* Zone, *Discoaster neorectus* Subzone)

158-19-4(120-121 cm) (168 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus [rare], *D. berggrenii, D. brouweri s. l., D. loeblichii, D. neorectus* [common], *D. quinqueramus, D. variabilis, Helicopontosphaera kamptneri, H.* sp. aff. *H. sellii, Reticulofenestra pseudoumbilica* [rare], *Sphenolithus abies, S. neoabies.*

158-19-5(120-121 cm) (169 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus, D. brouweri, D. sp. cf. *D. loeblichii, D.* sp. cf. *D. neohamatus, D. neorectus, D. quinqueramus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [rare], *Sphenolithus abies, S. neoabies* [abundant], *Triquetrorhabdulus rugosus.*

158-19-6(120-121 cm) (171 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus, D. brouweri, D. sp. cf. *D. loeblichii, D. neohamatus, D. neorectus* [rare], *D.* sp. cf. *D. variabilis, Helicopontosphaera kamptneri, Sphenolithus abies, S. neoabies* [abundant], *Triquetrorhabdulus rugosus.*

Upper Miocene

(*Discoaster neohamatus* Zone, *Discoaster bellus* Subzone)

158-20-1(70-71 cm) (172 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, Discoaster bellus, D. brouweri s. l., D. neohamatus [meager], *D. variabilis, Helicopontosphaera kamptneri, Sphenolithus abies, S. neoabies* [abundant], *Triquetrorhabdulus rugosus.*

158-20-6(120-121 cm) (180 m):
Coccolithus pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus [rare], *D. brouweri s. l., D. intercalaris* [common], *D. variabilis, Helicopontosphaera* sp. aff. *H. sellii, Minylitha convallis, Reticulofenestra pseudoumbilica, Sphenolithus abies, S. neoabies, Triquetrorhabdulus rugosus.*

158-21-4(120-121 cm) (186 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus [abundant], *D. brouweri s. l., D. neohamatus, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [large], *Sphenolithus abies, S. neoabies.*

158-22-6(120-121 cm) (197 m):
Coccolithus pelagicus [small], *Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus* [rare], *D. braarudii, D. brouweri s. l., D.* sp. cf. *D. pseudovariabilis* [rare], *D. variabilis* [abundant], *Helicopontosphaera kamptneri, Minylitha convallis* [abundant], *Reticulofenestra pseudoumbilica* [large], *Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

158-23-5(120-121 cm) (205 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. braarudii, D. brouweri s. l., D. pansus, D. variabilis [abundant], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* [abundant], *Sphenolithus neoabies, Triquetrorhabdulus rugosus* [rare].

Middle Miocene

(*Discoaster hamatus* Zone)

158-24-1(94-96 cm) (207 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. sp. cf. *D. bolli, D. brouweri, s. 1., D. challengeri, D. hamatus, D. variabilis* [abundant], *Reticulofenestra pseudoumbilica* [abundant], *Triquetrorhabdulus rugosus.*

128-25-4(101-102 cm) (220 m):
Coccolithus pelagicus, Cyclococcolithina macintyrei, Discoaster bellus, D. hamatus, D. obtusus, D. sp. cf. *D. pseudovariabilis, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

158-26-5(130-131 cm) (232 m):
Catinaster coalitus, Cyclococcolithina macintyrei, Discoaster bellus, D. hamatus, D. variabilis, Discolithina multipora [rare], *Reticulofenestra pseudoumbilica,*

Sphenolithus neoabies [meager], ?*Triquetrorhabdulus rugosus.*

158-27-6(140-141 cm) (243 m):
Catinaster coalitus, Coccolithus pelagicus, Discoaster bellus, D. hamatus, D. pseudovariabilis, D. variabilis, Reticulofenestra pseudoumbilica.

158-28-2(45-46 cm) (244 m):
Catinaster coalitus, Coccolithus miopelagicus [rare], *C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus* [rare], *D.* sp. cf. *D. bollii, D. braarudii, D. calcaris, D. hamatus* [rare], *D. variabilis, Helicopontosphaera kamptneri* [rare], *Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

Middle Miocene
(*Catinaster coalitus* Zone)

158-28-2(80 cm) (245 m):
Catinaster coalitus, Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster bellus [rare], *D.braarudii, D. calcaris, D. challengeri, D. variabilis, Reticulofenestra pseudoumbilica, Triquetrorhabdulus rugosus.*

158-28-5(7-8 cm) (246 m):
Catinaster coalitus, Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina macintyrei, Discoaster braarudii, D. challengeri, D. sp. cf. *D. exilis, D. moorei. D. variabilis, Helicopontosphaera kamptneri* [rare], *Reticulofenestra pseudoumbilica, Sphenolithus neoabies* [rare], *Triquetrorhabdulus rugosus.*

Middle Miocene
(*Discoaster exilis* Zone)

158-28-5(120-121 cm) (249 m):
Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster exilis, D. variabilis, Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.

158-30-2(116-117 cm) (264 m):
Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster exilis, D. moorei, D. perplexus, D. sp. [overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies, Triquetrorhabdulus rugosus.*

158-32-2(95-96 cm) (281 m):
Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina leptopora, C. macintyrei, Discoaster braarudii, D. perplexus, D. sp. [overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus neoabies.*

158-34-1(70-71 cm) (296 m):
Coccolithus miopelagicus, C. pelagicus, Cyclococcolithina macintyrei, Discoaster bollii, D. sp. cf. *D. exilis, D.* sp. [overgrown], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus abies.*

158-36-1(97-98 cm) (314 m):
Coccolithus miopelagicus, C. pelagicus, Coronocyclus sp., *Cyclococcolithina macintyrei, Discoaster braarudii, D.* sp. cf. *D. variabilis, D.* sp. [overgrown], *Discolithina* sp. [large], *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica, Sphenolithus* sp. cf. *S. abies.*

SITE DSDP 159
(lat. 12°19.92-086N, long. 122°17.27'W, depth 4484 meters)

Series Unknown
[Barren]

159-1-Top (0 m)
159-1-1(5-6 cm) (0 m)
159-1-5(145 cm)(6 m)
159-1(CC) (6 m)
159-2-1(40 cm) (9 m)
159-2-3(112 cm) (13 m)
159-2-4(71 cm) (14 m)
159-2-5(80 cm) (16 m)
159-2-5(125 cm) (16 m)
159-2-6(80 cm) (17 m)
159-2(CC) (18 m)

Middle Miocene
(*Discoaster exilis* Zone,
Discoaster kugleri Subzone)

159-3-1(5 cm) (18 m):
Coccolithus miopelagicus, Cyclococcolithina macintyrei, Discoaster braarudii, D. exilis, D. sp. cf. *D. kugleri, D. moorei, D. variabilis.*

159-3-2(5 cm) (19 m):
Coccolithus miopelagicus [rims], *Cyclococcolithina macintyrei, Discoaster bollii, D. braarudii, D. variabilis.*

159-3-3(80 cm) (22 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster bollii, D. braarudii, D. exilis [abundant].

Middle Miocene
(*Discoaster exilis* Zone,
***Coccolithus miopelagicus* Subzone)**

159-3-5(70 cm) (25 m):
Coccolithus miopelagicus, Coronocyclus sp., *Cyclococcolithina macintyrei, Discoaster exilis, D. moorei, D. variabilis.*

159-4-1(120-121 cm) (28 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster braarudii, D. exilis.

159-4-2(120-121 cm) (29 m):
Coccolithus miopelagicus, Coronocylus sp., *Cyclicargolithus floridanus, Cyclococcolithina leptopora, Discoaster braarudii, D. exilis, D. signus, D. variabilis, Sphenolithus moriformis.*

Middle Miocene
(*Sphenolithus heteromorphus* Zone)

159-4-3(60-61 cm) (30 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster aulakos, D. challengeri, D. deflandrei, D. exilis, D. moorei, D. variabilis, Sphenolithus heteromorphus.

159-4-6(120-121 cm) (35 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, D. exilis, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus heteromorphus.

Lower Miocene
(*Helicopontosphaera ampliaperta* Zone or *Sphenolithus belemnos* Zone)

159-5-1(110-111 cm) (37 m):
Coccolithus miopelagicus, Coronocyclus sp., *Cyclicargolithus floridanus, Discoaster deflandrei, Reticulofenestra* sp., *Sphenolithus moriformis.*

159-5-2(120-121 cm) (39 m):
Coccolithus miopelagicus [abundant rims], *Coronocyclus* sp. cf. *C. nitescens* [large], *Cyclicargolithus floridanus, Discoaster braarudii, D. deflandrei* [abundant], *D. variabilis, Reticulofenestra* sp. cf. *R. gartneri, Sphenolithus heteromorphus, S. moriformis, Triquetrorhabdulus milowii.*

159-5-3(70-71 cm) (40 m):
Coccolithus miopelagicus, Coronocyclus sp. cf. *C. nitescens, Cyclicargolithus floridanus, Cyclococcolithina leptopora, Discoaster deflandrei, D. moorei, D. signus, D. variabilis, Helicopontosphaera* sp. [centerless], *Reticulofenestra* sp. cf. *R. gartneri, Sphenolithus heteromorphus, S. moriformis, Triquetrorhabdulus milowii.*

159-5-5(50-51 cm) (43 m):
Coccolithus miopelagicus, Coronocyclus sp. cf. *C. nitescens* [large], *Cyclicargolithus floridanus, Discoaster calculosus, D. deflandrei, D. druggii, D. exilis, D.* sp. cf. *D. moorei, D. variabilis, Sphenolithus moriformis, Triquetrorhabdulus milowii.*

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

159-5-5(120-121 cm) (43 m):
Coccolithus miopelagicus, Coronocyclus sp. cf. *C. nitescens, Cyclicargolithus floridanus, Discoaster deflandrei, D.* sp. aff. *D. exilis, D. lidzii, D. moorei, D. variabilis, Orthorhabdus serratus s. l., Sphenolithus moriformis, Triquetrorhabdulus carinatus.*

159-5-6(50-51 cm) (44 m):
Coccolithus miopelagicus, Coronocyclus sp. cf. *C. nitescens, Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, D.* sp. cf. *D. moorei, D.* sp. cf. *D. variabilis, Orthorhabdus serratus s. l., Reticulofenestra gartneri, Sphenolithus moriformis.*

159-6-1(105-106 cm) (46 m):
Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Orthorhabdus serratus s. l., Reticulofenestra sp., *Sphenolithus moriformis, Triquetrorhabdulus carinatus, T. milowii.*

159-8-5(120-121 cm) (70 m):
Coccolithus miopelagicus, Coronocyclus sp. cf. *C. nitescens, Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Sphenolithus moriformis, Triquetrorhabdulus milowii.*

159-8-6(120-121 cm) (72 m):
Coccolithus eopelagicus, C. miopelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Reticulofenestra gartneri, Sphenolithus dissimilis* [late variety], *S. moriformis, Triquetrorhabdulus carinatus, T. milowii.*

159-9-1(1-2 cm) (72 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Helicopontosphaera sp. cf. *H. euphratis* [centers partly dissolved], *Reticulofenestra gartneri, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus* [abundant].

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

159-9-1(120-121 cm) (73 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, Helicopontosphaera sp. cf. *H. euphratis, Reticulofenestra gartneri, Sphenolithus moriformis, Triquetrorhabdulus carinatus* [abundant].

159-10-2(120-121 cm) (84 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, Reticulofenestra gartneri, Spenolithus conicus, S. delphix, S. dissimilis, S. moriformis, Triquetrorhabdulus carinatus.

159-12-5(120-121 cm) (106 m):
Coccolithus eopelagicus, C. sp. cf. *C. fenestratus, C. miopelagicus, C.? orangensis, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, Discolithina segmenta* [rare], *Helicopontosphaera euphratis, Sphenolithus conicus, S. dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

Lower Miocene or upper Oligocene
(*Triquetrorhabdulus carinatus* Zone, *Dictyococcites abisectus* Subzone)

159-12(C) (107 m):
Coccolithus eopelagicus, C. sp. cf. *C. fenestratus, C. miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus* [meager], *Discoaster deflandrei, Discolithina segmenta, Helicopontosphaera euphratis, Reticulofenestra gartneri, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

159-13-5(38-39 cm) (108 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, Discoaster deflandrei, Discolithina segmenta, Helicopontosphaera sp. [centerless], *Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

159-13-6(90-91 cm) (108 m):
Coccolithus eopelagicus, C. fenestratus, C. miopelagicus, C. pelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Dictyococcites abisectus, Discoaster deflandrei, Helicocpontosphaera intermedia, H.* sp. [centerless], *Reticulofenestra gartneri, Sphenolithus ciperoensis* [?reworked], *S. dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

159-13(C), dark brown clay (108 m):
Coccolithus eopelagicus, C. fenestratus, C. miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, Discoaster deflandrei, Discolithina segmenta, Helicopontosphaera sp. [centerless], *Reticulofenestra gartneri, Sphenolithus conicus, S. moriformis, S. dissimilis, Triquetrorhabdulus carinatus.*

159-13(C), light tan clay (108 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus [abundant], *Dictyococcites abisectus, Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus conicus, S. dissimilis, S. moriformis, Triquetrorhabdulus* sp. cf. *T. carinatus* [rare].

SITE DSDP 160

(lat. 11°42.27'N, long. 130°52.81'W., depth 4940 meters)

Series Unknown
[Barren]

160-1-2(135-136 cm) (3 m)
160-1(CC) (4 m)
160-2-2, (83-85 cm) (11 m)
160-2-3, (65-67 cm) (12 m)
160-2-5, (35-38 cm) (15 m)
160-2(CC) (16 m)
160-3-1, (56-58 cm) (18 m)
160-3-2, (57-60 cm) (20 m)
160-3-3, (43-46 cm) (21 m)
160-3-4, (127-130 cm) (23 m)
160-3-5, 130-133 cm) (25 m)
160-3-6, (37-40 cm) (25 m)

Miocene

160-3(C) (27 m):
Cyclicargolithus floridanus, ? Cyclococcolithina macintyrei, Discoaster sp. cf. *D. variabilis, D.* sp.

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

160-4-1(82-83 cm) (27 m):
Coccolithus miopelagicus, C. pelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Sphenolithus moriformis, Triquetrorhabdulus carinatus, T. milowii* [abundant].

160-4-5(130-131 cm) (34 m):
Coccolithus miopelagicus, C. pelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Reticulofenestra gartneri, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus* [abundant], *T. milowii.*

160-4(C) (34 m):
Coccolithus miopelagicus, C. pelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

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

160-5-1(134-135 cm) (37 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus [rare], *Discoaster deflandrei, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

160-5-5(110-111 cm) (43 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

160-5-6(50-51 cm) cm) (44 m):
Coccolithus pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, D. scrippsae, Discoaster deflandrei, Sphenolithus ciperoensis, S. dissimilis, S. moriformis, Triquetrorhabdulus carinatus.

160-6-3(120-121 cm) (49 m):
Coccolithus eopelagicus s. s., C. fenestratus, C. miopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, Discolithina segmenta, Helicopontosphaera sp. [rims], *Reticulofenestra gartneri, Sphenolithus ciperoensis, Triquetrorhabdulus carinatus.*

160-8-5(121-122 cm) (70 m):
Coccolithus eopelagicus, C. fenestratus, C. miopelagicus, C. ? orangensis, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, D. scrippsae, D. deflandrei, Reticulofenestra gartneri, Sphenolithus ciperoensis, S. dissimilis, S. moriformis.

160-8(C) (70 m):
Coccolithus eopelagicus, C. fenestratus, C. miopelagicus, C. pelagicus, Coronocyclus sp., *Cyclicargolithus floridanus, Dictyococcites* sp. cf. *D. abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, Reticulofenestra gartneri, Sphenolithus ciperoensis, S. distentus, S. moriformis, S. pseudoradians.*

Upper Oligocene
(*Sphenolithus distentus* Zone)

160-9-1(125-126 cm) (73 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, D. nodifer, Reticulofenestra gartneri, Sphenolithus distentus, S. moriformis [small].

160-10-2(120-121 cm) (83 m):
Coccolithus eopelagicus, C. fenestratus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani [rare], *Helicopontosphaera compacta, Reticulofenestra gartneri, Sphenolithus distentus, S. predistentus, S. pseudoradians.*

160-10-6(110-111 cm) (89 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani [common], *Helicopontosphaera compacta, Reticulofenestra gartneri, Sphenolithus distentus, S. moriformis, S. predistentus, S. pseudoradians.*

Lower Oligocene
(*Sphenolithus predistentus* Zone)

160-10(CC) (90 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani [common], *Helicopontosphaera compacta, Reticulofenestra gartneri, Sphenolithus moriformis* [abundant], *S. predistentus.*

160-11-4(120-121 cm) (95 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster

deflandrei, D. nodifer, D. tani, Helicopontosphaera compacta, Pontosphaera vadosa, Sphenolithus moriformis [small], *S. predistentus.*

160-12-6(143-144 cm) (108 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus [abundant], *D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Helicopontosphaera compacta, Pontosphaera vadosa, Reticulofenestra gartneri, Sphenolithus moriformis, S. predistentus.*

Lower Oligocene
(Upper *Helicopontosphaera reticulata* Zone)

160-13-1(120-130 cm) (109 m):
Coccolithus eopelagicus, C. pelagicus, Coronocyclus sp., *Cyclicargolithus floridanus, Cyclococcolithina formosa* [rare], *Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Pontosphaera vadosa, Reticulofenestra hillae, Sphenolithus moriformis, S. predistentus.*
160-13(CC), dark-brown ferruginous clay (109 m):
Coccolithus eopelagicus, C. fenestratus, C. pelagicus, Coronocyclus sp., *Cyclicargolithus floridanus, Cyclococcolithina formosa* [rare], *Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. tani, Helicopontosphaera* sp., *Reticulofenestra gartneri, R. hillae, R. umbilica* [rare], *Sphenolithus moriformis, S. predistentus, S. pseudoradians.* Drilling contaminants: *Dictyococcites abisectus* and *Sphenolithus ciperoensis.*

SITE DSDP 161 (HOLES DSDP 161 AND DSDP 161A)
(lat. 10°50.25'N, long. 139°57.21'W, depth 4939 meters)

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

161-1-0, Top (0 m):
Coccolithus sp. [rim fragments], *Discoaster deflandrei* [abundant], *D.* sp. cf. *D. druggii, Sphenolithus moriformis.*

161-1-1(111-112 cm) (1 m):
Coccolithus pelagicus, Cyclicargolithus floridanus [centerless], *Discoaster deflandrei* [abundant, with overgrowths], ?*D. druggii, Sphenolithus moriformis, Triquetrorhabdulus milowii.*

161-1-5(120-121 cm) (7 m):
Coccolithus eopelagicus [rare], *C. miopelagicus, C. pelagicus, Coronocyclus* sp. [small], *Cyclicargolithus floridanus, Discoaster deflandrei, D. druggii, Sphenolithus* sp. cf. *S. belemnos, S. dissimilis* [late], *S. moriformis, Triquetrorhabdulus carinatus, T. milowii.*

161-2-5(114-115 cm) (15 m):
Coccolithus miopelagicus, C. pelagicus, Cyclicargolithus floridanus [centerless], *Discoaster deflandrei, D. druggii, Sphenolithus moriformis, Triquetrorhabdulus carinatus.*

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

161-2(C) (17 m):
Coccolithus miopelagicus, C. pelagicus [abundant], *Discoaster deflandrei, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

161-3-1(120-121 cm) (19 m):
Coccolithus pelagicus [distal rims], *Cyclicargolithus floridanus* [centerless], *Discoaster deflandrei, Sphenolithus moriformis, Triquetrorhabdulus carinatus.*

Lower Miocene or upper Oligocene
(*Triquetrorhabdulus carinatus* Zone,
***Dictyococcites abisectus* Subzone)**

161-3-2(120-121 cm)(21 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus [abundant], *Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

161-3-4(120-121 cm) (24 m):
Coccolithus eopelagicus, C. pelagicus, Coronocyclus sp. [small], *Cyclicargolithus floridanus, Dictyococcites abisectus, Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus moriformis, Triquetrorhabdulus carinatus.*

Upper Oligocene
(*Sphenolithus ciperoensis* Zone)

161-3-5(38-39 cm) (24 m):
Coccolithus eopelagicus, C. fenestratus [rare], *C. miopelagicus, C. pelagicus, Dictyococcites abisectus, D. scrippsae, Discoaster deflandrei, D.* sp. cf. *D. nodifer, Discolithina segmenta, Reticulofenestra gartneri, Sphenolithus ciperonesis, S. moriformis* [large and small], *Triquetrorhabdulus carinatus.*

161-5-(C) (44 m):
Coccolithus eopelagicus, C. miopelagicus, C. pelagicus [abundant], *Cyclicargolithus floridanus, Dictyococcites abisectus, D. bisectus, Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus ciperoensis, S. dissimilis, S. moriformis, Triquetrorhabdulus carinatus.*

161-7-4(120-121 cm) (59 m):
Coccolithus eopelagicus, C. fenestratus, C. miopelagicus, C ? *orangensis, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus, D. bisectus, Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus ciperoensis, S. distentus, S. moriformis,* ? *Triquetrorhabdulus carinatus* [slender].

161A-1A-3(115-116 cm) (67 m):
Coccolithus eopelagicus, C.? Orangensis, C. pelagicus [abundant], *Coronocyclus* sp., *Cyclicargolithus floridanus, Dictyococcites abisectus, D. bisectus, D. scrippsae, Discoaster deflandrei, Reticulofenestra gartneri, Sphenolithus ciperoensis, S. distentus, S. moriformis* [abundant], ?*Triquetrorhabdulus carinatus* [slender].

161-9-4(50-51 cm) (77 m):
Coccolithus eopelagicus, C. fenestratus, C. ? *orangensis, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites abisectus* [early], *D. scrippsae, Discoaster deflandrei, D. nodifer, Sphenolithus ciperoensis, S. distentus, S. moriformis, S. predistentus.*

Upper Oligocene
(*Sphenolithus distentus* Zone)

161A-1A-5(140-141 cm) (70 m):
Chiasmolithus altus, Coccolithus eopelagicus, C. pelagicus,

Cyclicargolithus floridanus, Dictyococcites abisectus, Discoaster deflandrei, Sphenolithus distentus, S. moriformis.

161-9-5(50-51 cm) (78 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyoccoccites sp. cf. *D. abisectus, D. bisectus, Discoaster deflandrei, D. nodifer, Sphenolithus distentus* [late], *S. moriformis* [small], *S. predistentus, S. pseudoradians, ? Triquetrorhabdulus carinatus* [rare].

161-13-1(50-51 cm) (108 m):
Coccolithus pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Reticulofenestra gartneri, Sphenolithus distentus, S. moriformis, S. predistentus, S. pseudoradians.

Lower Oligocene
(*Sphenolithus predistentus* Zone)

161-13-1(120121 cm)(109 m):
Coccolithus eopelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus [large], *Discoaster tani, Sphenolithus predistentus* [late], *S. pseudoradians.*

161-13(CC) (117 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani [common], *Reticulofenestra gartneri, Sphenolithus moriformis, S. predistentus, S. pseudoradians.*

161A-2A-1(128-129 cm) (129 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. tani, Reticulofenestra gartneri, Sphenolithus moriformis [small].

161A-6A-2(53-54 cm) (166 m): *Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Discoaster deflandrei, D. tani, Reticulofenestra gartneri, Sphenolithus moriformis, S. predistentus.* Reworked Eocene taxa: *Cyclococcolithina formosa, Discoaster barbadiensis, D. saipanensis, Reticulofenestra umbilica.*

161A-7A-4(125-126 cm) (179 m):
Chiasmolithus sp. cf. *C. altus* [rims], *Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Pontosphaera vadosa, Sphenolithus moriformis, S. predistentus.*

Lower Oligocene
(?*Helicopontosphaera reticulata* Zone, *Reticulofenestra hillae* Subzone)

161A-7A(CC) (182 m):
Chiasmolithus altus, Coccolithus pelagicus, C. eopelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Reticulofenestra hillae [?reworked], *Sphenolithus moriformis, S. predistentus.* Reworked Eocene taxon: *Discoaster barbadiensis.*

161A-8A-2(50-51 cm) (183 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei [meager], *D. nodifer, D. tani, Reticulofenestra gartneri, R. hillae* [rare], *R. umbilica* [rare], *Sphenolithus moriformis* [small], *S. predistentus.*

Lower Oligocene
(*Helicopontosphaera reticulata* Zone)

161A-8A-2(120-121 cm) (184 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina formosa [rare], *Dictyococcites bisectus, D. scrippsae* [abundant], *Discoaster tani, Reticulofenestra gartneri, R. hillae, R. umbilica* [common], *Sphenolithus moriformis, S. predistentus.*

161A-9A-3(2-3 cm) (193 m):
Chiasmolithus sp. [rims], *Coccolithus eopelagicus, C.* sp. cf. *C. fenestratus* [rare], *C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Helicopontosphaera compacta* [rare], *Pontosphaera vadosa, Reticulofenestra gartneri, R. hillae, Sphenolithus moriformis, S. predistentus.*

191A-9A(CC) (198 m):
Bramletteis serraculoides [rare], *Coccolithus* sp. cf. *C. fenestratus, C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, D. deflandrei, D. tani, Pontosphaera vadosa, Reticulofenestra hillae, R. umbilica, Sphenolithus moriformis* [small], *S. predistentus.*

Upper Eocene
(*Discoaster barbadiensis* Zone)

161A-10A-Top (200 m):
Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina formosa, Dictyococcites scrippsae, Discoaster saipanensis, D. nodifer, D. tani, Reticulofenestra hillae, R. umbilica.

161A-10A(CC) (208 m):
Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster barbadiensis, D. deflandrei, D. saipanensis, D. nodifer, D. tani, Reticulofenestra umbilica, Sphenolithus predistentus.

161A-11A-5(120-121 cm)(215 m):
Coccolithus eopelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster barbadiensis, D. saipanensis, Reticulofenestra umbilica, Sphenolithus predistentus.

Middle(?) Eocene
(?*Reticulofenestra umbilica* Zone)

161A-12A(CC), yellow clay (220 m):
Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster barbadiensis, D. sp. cf. *D. deflandrei, D. saipanensis, D.* sp. cf. *D. strictus, Reticulofenestra umbilica.*

Middle Eocene
(*Reticulofenestra umbilica* Zone)

161A-13A(CC) (228 m):
Chiasmolithus grandis [rare], *C. solitus, Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina formosa, Discoaster barbadiensis, D. saipanensis, D. strictus, Helicopontosphaera* sp. [rim], *Reticulofenestra samodurovi, R. umbilica.*

161A-14A(CC) (237 m):
Chiasmolithus grandis, C. solitus, Coccolithus eopelagicus, Discoaster barbadiensis, D. sp. cf. *D. mirus* [rare], *D. saipanensis, D. strictus, Reticulofenestra samodurovi, R. umbilica.*

SITE DSDP 162

(lat. 14°52.19'N, long. 140°02.61'W, depth 4854 meters)

Lower Oligocene
(*Sphenolithus predistentus* Zone)

162-1-Top (0 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. nodifer, D. tani, Pontosphaera vadosa, Sphenolithus moriformis, S. pseudoradians.

162-1-5(121-122 cm) (7 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Discoaster deflandrei, D. tani, Helicopontosphaera compacta, Sphenolithus predistentus.

162-2(CC) (18 m):
Coccolithus eopelagicus, C. pelagicus, Coronocyclus sp., *Cyclicargolithus floridanus, Dictyococcites bisectus, Discoaster deflandrei, D. nodifer, D. tani, Helicopontosphaera compacta* [rim], *Sphenolithus moriformis, S. predistentus, S. pseudoradians.*

Lower Oligocene
(*Helicopontosphaera reticulata* Zone, *Reticulofenestra hillae* Subzone)

162-3-1(14-15 cm) (18 m):
Coccolithus eopelagicus, C. pelagicus, Cyclicargolithus sp. cf. *C. floridanus, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. tani, Pontosphaera vadosa, Reticulofenestra hillae, R. umbilica, Sphenolithus moriformis, S. predistentus.*

162-3-1(120-121 cm) cm) (19 m):
Coccolithus eopelagicus, C. sp. cf. *C. fenestratus, C. pelagicus, Cyclicargolithus floridanus, Dictyococcites bisectus, Discoaster tani, D.* sp. [six-rayed], *Reticulofenestra hillae, Sphenolithus moriformis, S. predistentus.*

Lower Oligocene
(*Helicopontosphaera reticulata* Zone, *Cyclococcolithina formosa* Subzone)

162-3-2(30-31 cm)(20 m):
Coccolithus eopelagicus, C. sp. cf. *C. fenestratus, C. pelagicus, Cyclicargolithus floridanus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. tani, Reticulofenestra hillae, R. umbilica, Sphenolithus moriformis, S. predistentus.*

162-4-1(60-61 cm)(28 m):
Bramletteius serraculoides, Coccolithus eopelagicus, C. sp. cf. *C. fenestratus, C. pelagicus, ?Cyclicargolithus floridanus* [small, centerless], *Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster deflandrei, D. tani, Helicopontosphaera* sp. [rims], *Pontosphaera vadosa, Reticulofenestra hillae, R. umbilica, Sphenolithus moriformis, S. predistentus.*

162-4-4(120-121 cm)s (33 m):
Coccolithus pelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster sp. cf. *D. nodifer, Reticulofenestra hillae.*

Upper Eocene
(*Discoaster barbadiensis* Zone)

162-5-1(120-122 cm) (36 m):
Coccolithus eopelagicus, Dictyococcites scrippsae, Discoaster barbadiensis, D. deflandrei.

162-5-3 (40-41 cm) (39 m):
Coccolithus eopelagicus, Discoaster barbadiensis, D. saipanensis.

162-5-6(120-121 cm) (44 m):
Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina formosa, Dictyococcites bisectus, D. scrippsae, Discoaster barbadiensis, D. saipanensis, D. nodifer, D. tani, Reticulofenestra umbilica, Sphenolithus moriformis.

Middle Eocene
(*Reticulofenestra umbilica* Zone, *Discoaster saipanensis* Subzone)

162-6-2(120-121 cm) (48 m):
Chiasmolithus grandis, Coccolithus eopelagicus, Dictyococcites scrippsae, Discoaster barbadiensis, D. saipanensis [common], *D. nodifer, D. tani* [rare], *Reticulofenestra samodurovi, R. umbilica* [abundant].

162-6(CC) (51 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, Dictyococcites sp. cf. *D. bisectus, D. scrippsae, Discoaster barbadiensis, D. saipanensis, D.* sp. cf. *D. nodifer, D. tani* [rare], *Reticulofenestra hillae, R. umbilica, Sphenolithus* sp. [base].

162-8-1(120-121 cm) (64 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, Discoaster barbadiensis, D. saipanensis, Reticulofenestra samodurovi, R. umbilica, Sphenolithus sp.

162-8-6(120 cm) (72 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina sp. cf. *C. formosa, Discoaster barbadiensis, D. saipanensis, D.* sp. cf. *D. strictus, D. nodifer, Reticulofenestra samodurovi, R. umbilica, Sphenolithus sp.*

162-9-5(110-111 cm) (79 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. sp. cf. *C. miopelagicus, C. pelagicus, C.* sp. cf. *C. staurion, Discoaster barbadiensis, D. gemmeus, D. saipanensis, D. nodifer* [7- and 8-rayed], *Reticulofenestra samodurovi, R. umbilica, Sphenolithus* sp. [base].

162-9(CC) (81 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C.*

formosa, Discoaster barbadiensis, D. distinctus, D. saipanensis, D. strictus, D. nodifer, Reticulofenestra samodurovi, R. umbilica.

Middle Eocene
(*Reticulofenestra umbilica* Zone, *Discoaster bifax* Subzone)

162-10-1(8-9 cm)(81 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Dictyococcites scrippsae, Discoaster barbadiensis, D. bifax, D. distinctus, D. saipanensis, D. strictus, Nannotetrina mexicana, Reticulofenestra samodurovi.*

162-10-2(25-26 cm) (81 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. sp. cf. *C. miopelagicus, C. pelagicus, C.* sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. bifax, D. saipanensis, D. strictus, Nannotetrina* sp. cf. *N. alata, N. mexicana, Reticulofenestra samodurovi, R. umbilica.*

162-10-4(120-121 cm) (85 m):
Chiasmolithus grandis, Coccolithus eopelagicus, C. pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. bifax, D. saipanensis, D. strictus, D. nodifer, Nannotetrina mexicana, Reticulofenestra samodurovi, R. umbilica* [rare].

Middle Eocene
(*Nannotetrina quadrata* Zone, *Coccolithus staurion* Subzone)

162-10-5(60-61 cm) (86 m):
Coccolithus eopelagicus, C. sp. cf. *C. staurion, Discoaster barbadiensis, D. saipanensis, D. strictus, D. nodifer, Nannotetrina cristata, N. mexicana, Reticulofenestra samodurovi.*

162-11-2(120-121 cm) (92 m):
Chiasmolithus grandis, Coccolithus pelagicus, Cyclococcolithina sp. cf. *C. formosa, Discoaster barbadiensis, D. martinii, D.* sp. cf. *D. nonaradiatus, D. strictus* [large-knobbed], *Nannotetrina quadrata.*

162-12-2(50-51 cm) (101 m):
Coccolithus sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. gemmeus, D. martinii, D.* sp. cf. *D. mirus, D. strictus, Nannotetrina cristata, N. spinosa.*

162-13-2(40-41 cm)(110 m):
Campylosphaera dela [rare], *Coccolithus pelagicus, C.* sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D.* sp. cf. *D. gemmifer, D. mirus, D. strictus, Nannotetrina mexicana, N. quadrata, N. spinosa, Reticulofenestra samodurovi, Sphenolithus* sp. cf. *S. radians,* ?*Triquetrorhabdulus inversus* [small].

Middle Eocene
(*Nannotetrina quadrata* Zone, *Chiasmolithus gigas* Subzone)

162-13-3(40-41 cm)(111 m):
Chiasmolithus gigas, Coccolithus eopelagicus, C. pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. strictus, Nannotetrina* sp., *Reticulofenestra samodurovi.*

162-13-5(40-41 cm) (114 m):
Chiasmolithus gigas, C. grandis, Coccolithus eopelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. mirus, D.* sp. cf. *D. nonaradiatus, D. strictus, Nannotetrina cristata, N.* sp. cf. *N. alata, Reticulofenestra samodurovi; Sphenolithus* sp. cf. *S. spiniger, Triquetrorhabdulus inversus.*

162-14-1(40-41 cm) (117 m):
Chiasmolithus gigas, C. grandis, Coccolithus eopelagicus, C. pelagicus, Cyclococcolithina sp. cf. *C. formosa, Discoaster barbadiensis, D. gemmifer, D. nonaradiatus, D.* sp. cf. *D. saipanensis, D. strictus, D. wemmelensis, Nannotetrina* sp. cf. *N. mexicana, Reticulofenestra samodurovi.*

162-14-4(40-41 cm) (122 m):
Chiasmolithus expansus, C. gigas, C. grandis, Coccolithus eopelagicus, C. pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D.* sp. cf. *D. gemmifer, D. saipanensis, D. strictus, Nannotetrina* sp. cf. *N. alata, N. mexicana.*

Middle Eocene
(*Nannotetrina quadrata* Zone, *Discoaster mirus* Subzone)

162-15-0, Top (126 m):
Campylosphaera dela, Chiasmolithus grandis, C. solitus, Coccolithus pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. gemmifer, D. mirus, D. nonaradiatus, D. saipanensis, D. strictus, Nannotetrina* sp. cf. *N. cristata, N. mexicana, Reticulofenestra dictyoda, Triquetrorhabdulus inversus.*

162-15-3(40-41 cm) (129 m):
Campylosphaera dela, Chiasmolithus grandis, Coccolithus pelagicus, C. staurion [with crossbars], *Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. gemmifer, D. mirus, D. strictus, Discolithina* sp. cf. *D. rimosa, Nannotetrina mexicana, N. quadrata, Reticulofenestra samodurovi, Sphenolithus* sp. cf. *S. radians, Triquetrorhabdulus inversus.*

162-15-6(40-41 cm) (134 m):
Chiasmolithus grandis, Coccolithus pelagicus, C. sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. gemmifer, D. mirus, D.* sp. cf. *D. saipanensis, D. strictus, Nannotetrina* sp., *Reticulofenestra dictyoda, R. samodurovi, Sphenolithus radians, Triquetrorhabdulus inversus.*

162-15(CC) (135 m):
Chiasmolithus grandis, Coccolithus sp. cf. *C. miopelagicus, C. pelagicus, C.* sp. cf. *C. staurion, Cyclococcolithina* sp. cf. *C. formosa, Discoaster barbadiensis, D. mirus* [common], *D. nonaradiatus, D.* sp. cf. *D. saipanensis, D. stictus, Nannotetrina mexicana, Reticulofenestra dictyoda, Sphenolithus radians, Triquetrorhabdulus inversus.*

Middle Eocene
(?*Discoaster sublodoensis* Zone)

162-16-1 (143-145 cm) (136 m):
Discoaster barbadiensis [centerless], *D. mirus, D. strictus, ?D. sublodoensis.*

Middle Eocene
(*Discoasteroides kuepperi* Zone)

162-17-1(77-78 cm)(145 m):
Coccolithus crassus, C. pelagicus, Cyclococcolithina sp. cf. *C. formosa, Discoaster barbadiensis, D. cruciformis, D. lodoensis, D. mirus, D. sublodoensis, Discoasteroides kuepperi, Sphenolithus radians.*

162-17-2(2-3 cm) (145 m):
Campylosphaera dela, Chiasmolithus solitus, Coccolithus crassus, C. pelagicus, Cyclococcolithina gammation, Discoaster barbadiensis, D. cruciformis, D. lodoensis, D. mirus, D. sublodoensis, Discoasteroides kuepperi, Ellipsolithus lajollaensis, Helicopontosphaera lophota, H. seminulum, Sphenolithus radians, Triquetrorhabdulus inversus [early], *Zygrhablithus* sp. cf. *Z. bijugatus.*

162-17-3(15-16 cm) (146 m):
Campylosphaera dela, Chiasmolithus solitus, Coccolithus crassus, C. cribellum, Cyclococcolithina formosa, C. gammation, Discoaster barbadiensis, D. cruciformis, D. lodoensis [3- to 8-rayed], *D. sublodoensis, Discoasteroides kuepperi, Ellipsolithus* sp. cf. *E. lajollaensis, Helicopontosphaera lophota, H. seminulum, Sphenolithus radians, Syracosphaera formosa.*

162-17-4(146 cm) (147 m):
Campylosphaera dela, Chiasmolithus consuetus, C. solitus, Coccolithus crassus, Cyclococcolithina formosa, C. gammation, Discoaster barbadiensis, D. sp. cf. *D. lodoensis* [rare, overgrown], *Discoasteroides kuepperi, Discolithina plana, Helicopontosphaera lophota, H. seminulum, Sphenolithus radians, Syracosphaera formosa, Zygolithus dubius.*

162-17(CC) (147 m):
Campylosphaera dela, Chiasmolithus consuetus, C. eograndis, C. solitus, Chiphragmalithus sp. cf. *C. acanthodes, Coccolithus crassus, C. cribellum, C. pelagicus, Cyclococcolithina formosa, C. gammation, Cyclolithella? bramlettei, C. kariana, Discoaster barbadiensis, D. lodoensis, D. sublodoensis, Discoasteroides kuepperi, Discolithina* sp. cf. *D. duocava, D. plana, Ellipsolithus lajollaensis, Helicopontosphaera lophota, H. seminulum, Lophodolithus mochlophorus, L.* sp. cf. *L. rotundus, Sphenolithus radians, Syracosphaera fimbriata, S. formosa, Striatococcolithus pacificanus, Transversopontis pulcher, Zygolithus dubius* [small], *Zygrhablithus* sp. cf. *Z. bijugatus.*

SITE DSDP 163 (HOLES DSDP 163 AND DSDP 163A)
(lat.11°14.66'N, long. 150°17.52'W, depth 5320 meters)

Series Unknown
[Barren]

163-1-Top (0 m)
163-1(CC) (1 m)
163-2-3(43-45 cm) (3 m)
163-2(CC) (6 M)163-3-2(43-45 cm) (11 m)
163-3-3(43-45 cm) (13 m)
163-3-5(43-45 cm) (16 m)
163-3(CC) (18 m)
163-4-1(23-25 cm) (19 m)
163-4-3(132-134 cm) (23 m)
163-4-5(120-123 cm) (26 m)
163-4-6(84-86 cm) (27 m)
163-5(CC) (27 m)
163-5(CC) (35 m)

Middle or Upper Eocene

163-6-3(40-42 cm) (40 m):
Coccolithus eopelagicus, Dictyococcites bisectus, Discoaster barbadiensis, Reticulofenestra samodurovi, R. umbilica.

Series Unknown
[Barren]

163-6-4(43-45 cm) (42 m)
163-6-4(101-102 cm) (43 m)
163-6-5(43-45 cm) (43 m)
163-6(CC) (46 m)
163-7-2(105-107 cm)(49 m)
163-7-4(120-122 cm) (52 m)
163-7(CC) (55 m)
163-8-1(137-139 cm) (55 m)
163-8(CC) (56 m)
163-9(CC) (68 m)
163-101(135-137 cm (74 m)
163-10-3(120-122 cm) (77 m)
163-10-5(120-122 cm) (80 m)

Middle (?) Eocene

163-10(CC) (81 m):
Coccolithus pelagicus, Cyclococcolithina formosa, Dictyococcites scrippsae, Discoaster barbadiensis, Zygrhablithus sp. cf. *Z. bijugatus.*

Series Unknown
[Barren]

163-11-2(42-45 cm) cm) (84 m)
163-11-3(20-22 cm) (85 m)
m)163-11-4(146-148 cm) (88 m)
163-11-5(122-125 cm) (89 m)
163-11(CC) (91 m)
163-12-3(112-114 cm) (95 m)
163-12(CC) (96 m)

Lower Maestrichtian or
Upper Campanian

163A-1A-1(130 cm) (140 m):
All rare: *Tetralithus trifidus, Watznaueria barnesae.*

163A-1A(CC) (144 m):
All rare: *Micula decussata, Prediscosphaera cretaçea, Tetralithus trifidus, Watznaueria barnesae.*

Lower Maestrichtian
(*Lithraphidites quadratus* Zone)

163-15-1(0 cm) (162 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Bidiscus rotatorius, Cretarhabdus conicus, C. crenulatus, Cribrosphaera ehrenbergii, Cylindralithus gallicus,

Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, Watznaueria barnesae, W. biporta, Zygodiscus lacunatus.

163-15-1(10 cm) (162 m):
Apertapetra gronosa, Chiastozygus amphipons, Cretarhabdus conicus, C. crenulatus, Cribrosphaera ehrenbergii, Cylindralithus gallicus, C. sp. cf. *C. serratus, Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, Watznaueria barnesae, W.* sp. cf. *W. biporta, Zygodiscus bicrescenticus, Z. lacunatus.*

163-15-1(44-45 cm) (162 m):
Apertapetra gronosa, Cretarhabdus conicus, C. sp. cf. *C. crenulatus, Cribrosphaera ehrenbergii, Cylindralithus gallicus, C.* sp. cf. *C. serratus, Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, Watznaueria barnesae, Zygodiscus bicrescenticus, Z.* sp. cf. *Z. sigmoides.*

Lower Maestrichtian or Upper Campanian

(*Tetralithus trifidus* Zone)

163-15-2(2-3 cm) (162 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Cylindralithus gallicus, Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, P. lata, Tetralithus gothicus, T. pyramidus, T. trifidus, Watznaueria barnesae, Zygodiscus meudini, Z. sp. cf. *Z. sigmodies.*

163-16-3(128-129 cm) (175 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, Tetralithus pyramidus, T. trifidus, Watznaueria barnesae, Zygodiscus meudini.

163-18(CC) (198 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Broinsonia parca, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, Tetralithus aculeus, T. pyramidus, T. trifidus, Watznaueria barnesae, W.biporta, Zygodiscus meudini.

163-19(CC) (207 m):
Arkhangelskiella cymbiformis, Broinsonia parca, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Eiffellithus turriseiffeli, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, P. lata, Tetralithus aculeus [common], *T. pyramidus, T. trifidus, Watznaueria barnesae, W. biporta, Zygodiscus lacunatus, Z.meudini.*

163-22-4(20-21 cm) (229 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Broinsonia parca, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Eiffellithus turriseiffeli, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, P. lata, Tetralithus trifidus, Watznaueria barnesae, Zygodiscus meudini.

Upper(?) Campanian

(*Broinsonia parca* Zone)

163-22-4(70-71 cm) (230 m):
Apertapetra gronosa, Broinsonia parca, Cylindralithus sp., *Eiffellithus turriseiffeli, Prediscosphaera cretacea, P. lata, Tetralithus gothicus, T. pyramidus, Watznaueria barnesae, Zygodiscus lacunatus.*

163-22-6(13-14 cm) (233 m):
Apertapetra gronosa, Arkhangelskiella cymbiformis, Broinsonia parca, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Eiffellithus turriseiffeli, Micula decussata, Prediscosphaera cretacea, Tetralithus gothicus, T. pyramidus, Watznaueria barnesae.

163-23(CC) (243 m):
Arkhangelskiella cymbiformis [small], *Broinsonia parca, Cylindralithus* sp., *Eiffellithus turriseiffeli, Micula decussata, Tetralithus gothicus, T. pyramidus, Watznaueria barnesae, Zygodiscus lacunatus.*

Middle Campanian

(*Eiffellithus augustus* Zone)

163-24-1(122-123 cm) (243 m):
Apertapetra gronosa, Arkhangelskiella sp. cf. *A. cymbiformis, Bidiscus rotatorius, Chiastozygus* sp. cf. *C. amphipons, Cretarhabdus crenulatus Cribrosphaera ehrenbergii, Cylindralithus* sp., *Eiffellithus augustus, E. turriseiffeli, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, P. lata, Tetralithus pyramidus, Watznaueria barnesae, Zygodiscus bicrescenticus.*

163-25-1(80-81 cm) (252 m):
Arkhangelskiella sp. cf. *A. cymbiformis, Broinsonia parca, Cretarhabdus crenulatus, Cribrosphaera ehrenbergii, Cyclagelosphaera circumradiata* [rare], *Eiffellithus augustus, Micula decussata, Prediscosphaera cretacea, Tetralithus aculeus, Watznaueria barnesae, Zygodiscus* sp. cf. *Z. sigmoides* [rare].

163-26(CC) (263 m):
Apertapetra gronosa, Arkhangelskiella sp. cf. *A. cymbiformis, Broinsonia parca, Cretarhabdus conicus, C. crenulatus, Cribrosphaera ehrenbergii, Cylindralithus* sp., *Effellithus augustus* [common], *E. turriseiffeli, Microrhabdulus decoratus, Micula decussata, Prediscosphaera cretacea, Tetralithus pyramidus, Watznaueria barnesae, W. biporta, Zygodiscus bicrescenticus, Z. lacunatus, Z.* sp. cf. *Z. spiralis, Z.* spp.

163-27(CC) (272 m):
Apertapetra gronosa, Arkhangelskiella sp. cf. *A. cymbiformis, Broinsonia* sp. cf. *B. parca* [rare], *Cretarhabdus crenulatus, Cribrosphaera ehrenbergii* [rare], *Cylindralithus* sp., *Eiffellithus augustus, E. turriseiffeli, Microrhabdulus decoratus* [rare], *Micula decussata, Prediscosphaera cretacea, Tetralithus aculeus, Watznaueria barnesae.*

Campanian

163-28-Top, pale-orange chalk (276 m):
Apertapetra gronosa, Broinsonia parca, Cretarhabdus crenulatus, Micula decussata [abundant], *Tetralithus aculeus, Watznaueria barnesae, W. biporta.*

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REFERENCES

Am. Comm. Stratig. Nomen., 1961. Code of stratigraphic nomenclature. Bull. Am. Assoc. Petrol. Geologists **45,** 645.

Beers, J.R. and Stewart, G.L., 1971. Micro-zooplankters in the plankton communities of the upper waters of the eastern tropical Pacific. Deep-Sea Res. **18,** 861.

Berger, W.H., 1967. Foraminiferal ooze: Solution at depth. Science. **156,** 383.

________, and Parker, F.L., 1970. Diversity of planktonic foraminifera in deep-sea sediment. Science. **168,** 1345.

Berggren, W.A. and others, 1972. Boston Massachusetts to Lisbon, Portugal. *In* Laughton, A.S., Berggren, W.A. et al., 1972. Initial Reports of the Deep Sea Drilling Project, Volume XII. Washington (U.S. Government Printing Office).1.

Black, M., 1964. Cretaceous and Tertiary coccoliths from Atlantic seamounts. Palaeontology. **7,** 306.

________ and Barnes, B., 1961. Coccoliths and discoasters from the floor of the South Atlantic Ocean. J. Roy. Microscop. Soc. **80,** 137.

Bouché, P.M., 1962. Nannofossiles calcaires du Lutétien du bassin de Paris. Rev. Micropaléontologie. **5,** 75.

Braarud, T., Bramlette, M.N., Deflandre, G., Kamptner, E., Loeblich, A.R., Jr., Martini, E. and Tappan, H., 1964. Rhabdosphaera Haeckel, 1894 (Coccolithophorida): proposed validation under the plenary powers and designation of a lectotype for *Coccolithus oceanicus* Schwarz, 1894. Bull. Zool. Nomenclature **21,** 397.

Bramlette, M.N., 1961. Pelagic sediments. *In* M. Sears (Ed.), Oceanography. Am. Assoc. Advan. Sci., Washington, D.C. 345.

________ and Riedel, W.R., 1954. Stratigraphic value of discoasters and some other microfossils related to recent coccolithophores. J. Paleontol. **28,** 403.

________ and Sullivan, F.R., 1961. Coccolithophorids and related nannoplankton of the early Tertiary in California. Micropaleontology. **7,** 129.

________ and Wilcoxon, J.A., 1967. Middle Tertiary calcareous nannoplankton of the Cipero section, Trinidad W.I. Tulane Studies Geol. **5,** 93.

Bukry, D., 1969. Upper Cretaceous coccoliths from Texas and Europe. Kansas Univ. Paleont. Contrib., Protista. **2,** 1.

________, 1970. Coccolith age determinations Leg 2, Deep Sea Drilling Project. *In* Peterson, M.N.A, Edgar, N.T. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume II. Washington (U.S. Government Printing Office). 349.

________, 1971a. Coccolith stratigraphy Leg 6, Deep Sea Drilling Project. *In* Fischer, A.G., Heezen, D.C. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VI. Washington (U.S. Government Printing Office). 965.

________, 1971b. Cenozoic calcareous nannofossils from the Pacific Ocean. Trans. San Diego Soc. Nat. Hist. **16,** 303.

________, 1973. New Miocene to Holocene stages in the ocean basins based on calcareous nannoplankton zones *In* T. Saito and L. H. Burckle (Eds.), *Late Neogene epoch boundaries.* Micropaleontology Press, AMNH, Spec. Publ. no. 1.

________, in preparation. Coccolith stratigraphy Leg 15, Deep Sea Drilling Project. *In* Edgar, N.T., Saunders, J.B. et al. Initial Reports of the Deep Sea Drilling Project, Volume XV. Washington (U.S. Government Printing Office).

________, and Bramlette, M.N., 1968. Stratigraphic significance of two genera of Tertiary calcareous nannofossils. Tulane Studies Geol. **6,** 149.

________, and Bramlette, M.N., 1970. Coccolith age determinations Leg 3, Deep Sea Drilling Project. *In* Maxwell, A.E., von Herzen, R. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume III. Washington (U.S. Government Printing Office). 589.

________, Douglas, R.G., Kling, S.A. and Krasheninnikov, F., 1971. Planktonic microfossil biostatigraphy of the northwestern Pacific Ocean. *In* Fischer, A.G., Heezen, B.C. et al, 1971. Initial Reports of the Deep Sea Drilling Project, Volume VI. Washington (U.S. Government Printing Office). 1253.

________ and Kennedy, M.P., 1969. Cretaceous and Eocene coccoliths at San Diego, California. California Div. Mines Geol. Spec. Rept. 100, 33.

Cita, M.B. and Gartner, S., 1971. Deep sea Upper Cretaceous from the western North Atlantic. Proc. Second Planktonic Conf. 287.

Clocchiatti, M. and Jerkovic, L., 1970. *Cruciplacolithus tenuiforatus,* nouvelle espece de Coccolithophroide du Miocene d'Algerie et de Yougoslavie. Cahiers Micropaleontologie. **2,** 1.

Douglas, R.G., 1971. Cretaceous Foraminifera from the northwestern Pacific Ocean: Leg 6, Deep Sea Drilling Project. *In* Fischer, A.G., Heezen, B.C. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VI. Washington (U.S. Government Printing Office). 1027.

________ and Savin, S.M., 1971. Isotopic analysis of planktonic foraminifera from the Cenozoic of the northwest Pacific, Leg. 6. *In,* Fischer, A.G., Heezen, B.C. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VI. Washington (U.S. Government Printing Office). 1223.

Fischer, A.G. and Gealy, E.L., 1969. Summary and comparison of lithology and sedimentary sequence in northwest Atlantic and northwest Pacific. Geol. Soc. Am. Abs. with Programs for 1969. Pt. 7, 65.

________, Honjo, S. and Garrison, R.E., 1967. Electron micrographs of limestones and their nannofossils. Princeton Monographs Geol. Paleontol. **1,** 1.

Gartner, S., Jr., 1969. Correlation of Neogene planktonic foraminifer and calcareous nannofossil zones. Trans. Gulf Coast Assoc. Geol. Soc. **19,** 585.

________, 1971. Calcareous nannofossils from the JOIDES Blake Plateau cores, and revision of Paleogene nannofossil zonation. Tulane Studies Geol. Paleontol. **8,** 101.

________ and Bukry, D., 1969, Tertiary holococcoliths. J. Paleontol. **43,** 1213.

________ and Lidz, B., in press. Reworking and apparent reworking. Micropaleontology.

Hart, W.G., 1972. Experimental aspects of coccolith species relative abundance (Niobrara Formation, Kansas). Geol. Soc. Am. Abs. with Programs. **4,** 280.

Hay, W.W., 1970a. Calcareous nannofossils from cores recovered on leg 4. *In* Bader, R.G., Gerard, R.D. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume IV. Washington (U.S. Government Printing Office). 455.

———, 1970b. Sedimentation rates. *In* Bader, R.G., Gerard, R.D. et al., 1979. Initial Reports of the Deep Sea Drilling Project, Volume IV. Washington (U.S. Government Printing Office). 668.

——— and Mohler, H.P., 1967. Calcareous nannoplankton from early Tertiary rocks at Pont Labau, France, and Paleocene-early Eocene correlations. J. Paleontol. **41,** 1505.

———, Mohler, H., Roth, P.H., Schmidt, R.R. and Boudreaux, J.E., 1967, Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area, and transoceanic correlation. Trans. Gulf Coast Assoc. Geo. Soc. **17,** 428.

———, Mohler, H. and Wade, M.E., 1966. Calcareous nannofossils from Nal'chik (Northwest Caucasus). Eclogae Geol. Helvetiae. **59,** 379.

Hulburt, E.M., 1967. Some notes on the phytoplankton off the southeastern coast of the United States. Bull. Marine Sci. **17,** 330.

Izett, G.A., Cobban, W.A. and Gill, J.R., 1971. The Pierre Shale near Kremmling, Colorado, and its correlation to the east and the west. U.S. Geol. Surv. Prof. Paper. 684-A, 1.

Loeblich, A.R., Jr. and Tappan, H., 1966. Annotated index and bibliography of the calcareous nannoplankton. Phycologia. **5,** 81.

——— and Tappan, H., 1968. Annotated index and bibliography of the calcareous nannoplankton II. J. Paleontol. **42,** 584.

——— and Tappan, H., 1969. Annotated index and bibliography of the calcareous nannoplankton III. J. Paleontol. **43,** 568.

——— and Tappan, H., 1970a. Annotated index and bibliography of the calcareous nannoplankton IV. J. Paleontol. **44,** 558.

——— and Tappan, H., 1970b. Annotated index and bibliography of the calcareous nannoplankton V. Phycologia. **9,** 157.

Martini, E., 1970. Standard Palaeogene calcareous nannoplankton zonation. Nature. **226,** 560.

———, 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. Proc. Second Planktonic Conf. 739.

——— and Worsley, T.R., 1971. Tertiary calcareous nannoplankton from the western equatorial Pacific. *In* Winterer, E.L., Riedel, W.R. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VII. Washington (U.S. Government Printing Office). 1471.

McIntyre, A., 1970. *Gephyrocapsa protohuxleyi* sp. n. a possible phyletic link and index fossil for the Pleistocene. Deep-sea Res. **17**,187.

——— and Bé, A.W.H., 1967. Modern Coccolithophoridae of the Atlantic Ocean—I. Placoliths and Cyrtoliths. Deep-Sea Res. **14,** 561.

———, Bé, A.W.H. and Preikstas, R., 1967. Coccoliths and the Pliocene-Pleistocene boundary. Prog. Oceanog. **4,** 3.

———, Bé, A.W.H. and Roche, M.B., 1970. Modern Pacific Coccolithophorida: A paleontological thermometer. Trans. New York Acad. Sci. **32,** 720.

Norris, R.E. 1965. Living cells of *Ceratolithus cristatus* (Coccolithophorineae). *Arch. Protistenk.* **108,** 19.

Perch-Nielsen, K., 1971a. Einige neue Coccolithen aus dem Paleozän der Bucht von Biskaya. Bull. Geol. Soc. Denmark **20,** 347.

———, 1971b. Neue Coccolithen aus dem Paleozän von Dänemark, der Bucht von Biskaya und dem Eozän der Labrador See. Bull. Geol. Soc. Denmark. **21,** 55.

———, 1972. Remarks on Late Cretaceous to Pleistocene coccoliths from the North Atlantic. *In* Laughton, A.S., Berggren, W.A. et al., 1972. Initial Reports of the Deep Sea Drilling Project, Volume XII. Washington (U.S. Government Printing Office). 1003.

Peterson, M.N.A. and others, 1970. Site 10. *In* Peterson, M.N.A., Edgar, N.T. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume II. Washington (U.S. Government Printing Office). 117.

Pimm, A.C., Garrison, R.E. and Boyce, R.E., 1971. Sedimentologic synthesis: Lithology, chemistry and physical properties of sediments in the northwestern Pacific Ocean. *In* Fischer, A.G., Heezen, B.C. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VI. Washington (U.S. Government Printing Office). 1131.

Reinhardt, P., 1970. Synopsis der Gattungen und Arten der mesozoischen Coccolithen und anderer kalkiger Nannofossilien, Teil II. Freiberger Forschungshefte. **C265**, 41.

Roth, P.H., 1970. Oligocene calcareous nannoplankton biostratigraphy. Eclogae Geol. Helvetiae. **63**, 799.

———, Baumann, P. and Bertolino, V., 1971. Late Eocene-Oligocene calcareous nannoplankton from Central and Northern Italy. Proc. Second Planktonic Conf. 1069.

Sullivan, F.R., 1965. Lower Tertiary nannoplankton from the California Coast Ranges—Pt. 2, Eocene. California Univ. Pubs. Geol. Sci. **53,** 1.

Thierstein, H.R., 1971. Tentative lower Cretaceous calcareous nannoplankton zonation. Eclogae Geol. Helvetiae. **64,** 459.

Tolderlund, D.S. and Bé, A.W.H., 1971 (1972). Seasonal distribution of planktonic foraminifera in the western North Atlantic. Micropaleontology. **17,** 297.

Wise, S.W. and Hsü, K.J., 1971. Genesis and lithification of a deep-sea chalk. Eclogae Geol. Helvetiae. **64,** 273.

Wolfe, J.A. and Hopkins, D.M., 1967. Climatic changes recorded by Tertiary land floras in northwestern North America. *In* Tertiary correlations and climatic changes in the Pacific, K. Hatai (Ed.). Sendai, Japan (Sasaki Printing and Publishing Co. Ltd.) 67.

Worzel, J.L. and others, in preparation. Galveston, Texas to Miami, Florida. *In* Worzel, J.L., Bryant, W. et al. Initial Reports of the Deep Sea Drilling Project, Volume X. Washington (U.S. Government Printing Office).

PLATE 1

Coccolith Photomicrographs, 2000 ×,
Except Figure 11 Which Is 2500 ×
(BF = Bright-field; PC = Phase-contrast; XN = Cross-polarized)

Figures 1-5	*Angulolithina arca* n. sp. (1) USNM 183513, DSDP 158-16-6(70-71 cm), XN, 45°. (2) Holotype, USNM 183514, DSDP 158-16-6(70-71 cm), BF, 90°. (3) Same, XN, 45°. (4) USNM 183515, DSDP-158-16-6(70-71 cm), BF, 90°. (5) Same, XN, 135°.
Figures 6-10	*Ceratolithus bizzarus n. sp.* (6) USNM 183516, DSDP 158-8-2(83-84 cm), BF. (7) Holotype, USNM 183517, V3-153, 210 cm, BF. (8) Same, PC. (9) USNM 183518, V3-153, 210 cm, BF, high focus. (10) Same, BF, low focus.
Figure 11	*Ceratolithus primus* Bukry and Percival (11) USNM 651136, V16-21, 600 cm, BF, 2500 ×.

PLATE 1

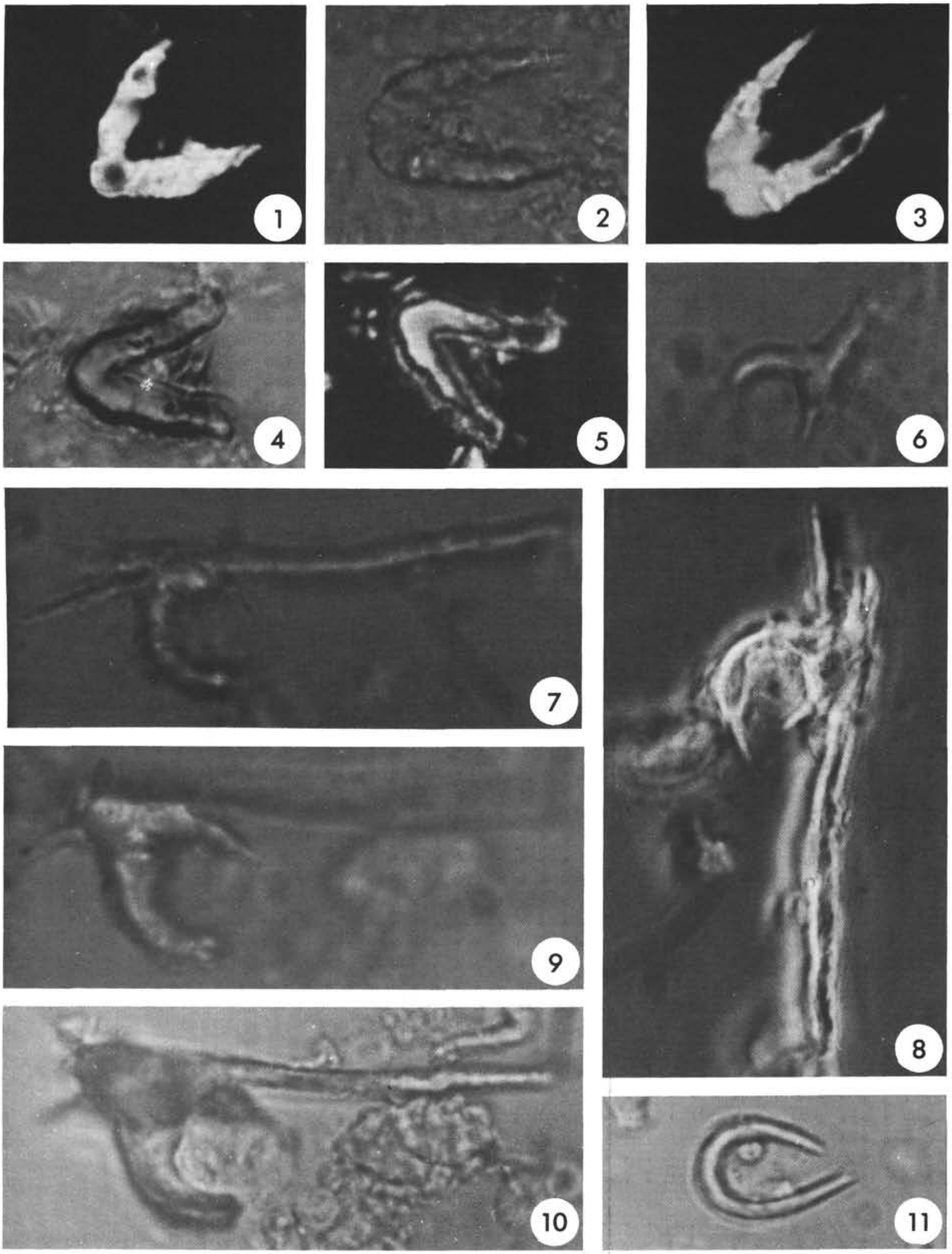

PLATE 2

Coccolith Photomicrographs, 2000 ×,
Except Figure 7 Which Is 9000 ×
(BF = Bright-field; PC = Phase-contrast; XN = Cross-polarized)

Figures 1-3 — *Ceratolithus dentatus* n. sp.
(1) Holotype, USNM 183519, DSDP 158-10-6(120-121 cm), BF, high focus. (2) Same, median focus. (3) Same, PC.

Figures 4-7 — *Cretarhabdus angustiforatus* (Black), n. comb.
(4) USNM 183520, DSDP 4-4-1(77-79 cm), PC. (5) Same, XN, 24°. (6) Same, XN, 90°. (7) USNM 183521, DSDP 5A-7A-Core catcher, transmission electronmicrograph, 9000 ×.

Figures 8-9 — *Discoaster decorus* (Bukry), n. comb.
(8) DSDP 84-19-3(90-91 cm), BF. (9) DSDP 158-5-1(40-41 cm), BF.

Figures 10-12 — *Emiliania ovata* n. sp.
(10) Holotype, USNM 183522, DSDP 62.1-4-1(80-81 cm), PC. (11) USNM 183523-183524, DSDP 17-1-5(75-76 cm), XN. (12) Same, PC.

PLATE 2

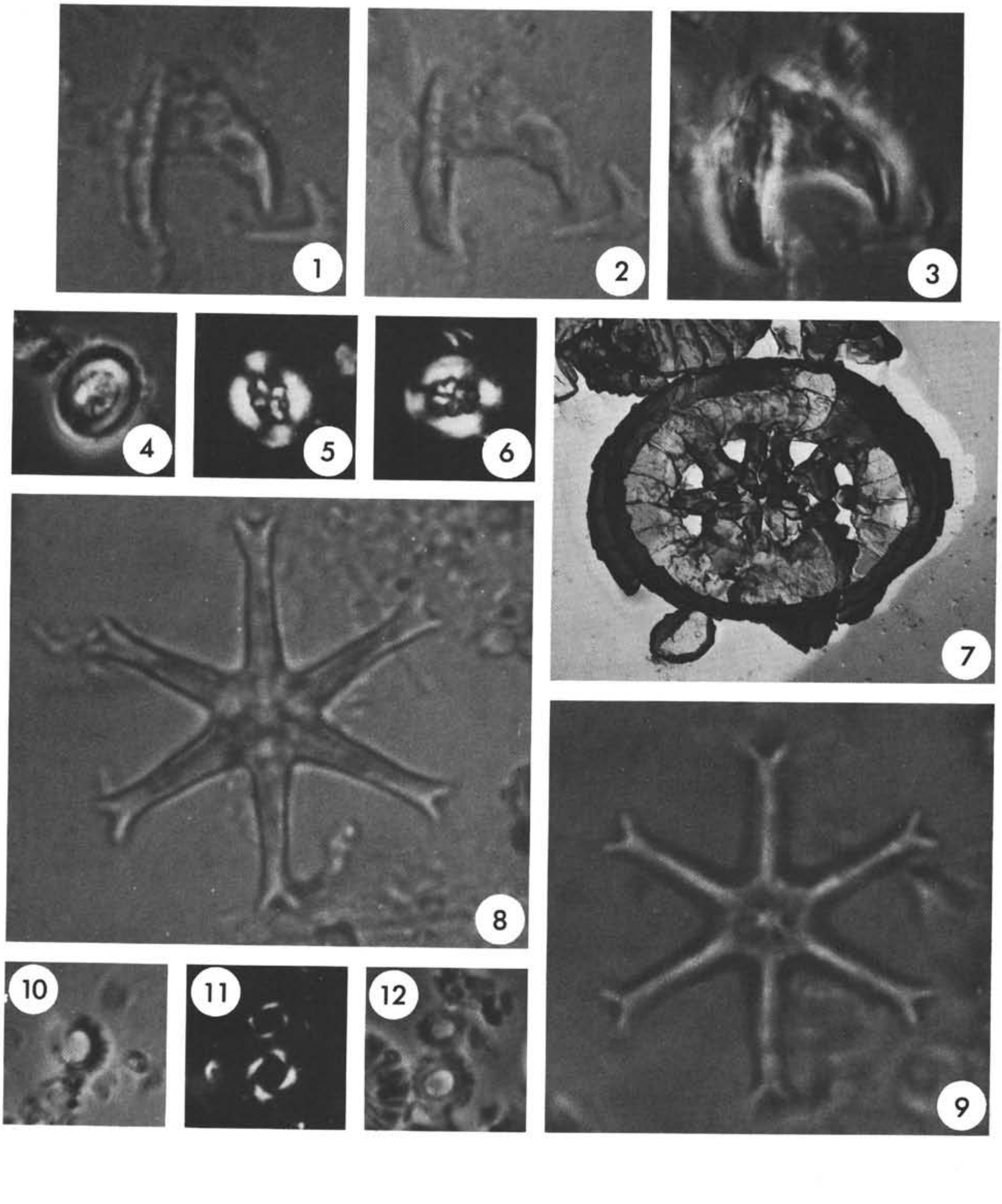

PLATE 3

Coccolith Photomicrographs, 2000 ×
(BF = Bright-field; PC = Phase-contrast; XN = Cross-polarized)

Figures 1-4	*Gephyrocapsa lumina* n. sp. (1) Holotype, USNM 183525, DSDP 157-7-2(119-120 cm), PC. (2) Same, XN. (3) USNM 183526, DSDP 157-7-2(119-120 cm), XN. (4) USNM 183527, DSDP 157-7-2(119-120 cm), XN.
Figures 5-11	*Gephyrocapsa omega* n. sp. (5) USNM 183528, DSDP 156-1(CC), XN. (6) Same, PC. (7) USNM 183529, DSDP 62.1-2-3(80-81 cm), XN. (8) Same, PC. (9) USNM 183530, DSDP 62.1-2-3(80-81 cm), PC. (10) Holotype, USNM 183531, DSDP 147-5-2(78-80 cm), XN. (11) Same, PC.
Figures 12-18	*Minylitha convallis* n. sp. (12) Group of three, USNM 183532-183534, DSDP 15-5-1(79-80 cm), BF. (13) Same, XN. (14) Holotype, USNM 183535, DSDP 15-5-1(79-80 cm), BF. (15) Same, XN. (16) USNM 183536, DSDP 15-5-1(79-80 cm), BF. (17) Same, XN. (18) USNM 183537, DSDP 155-1-4(119-120 cm), PC.
Figures 19-22	*Sphenolithus delphix* n. sp. (19) Holotype, USNM 183538, DSDP 159-10-4(120-121 cm), BF. (20) Same, XN, 0°. (21) Same, XN, 45°. (22) USNM 183539, DSDP 159-10-4(120-121 cm), XN, 45°.

PLATE 3

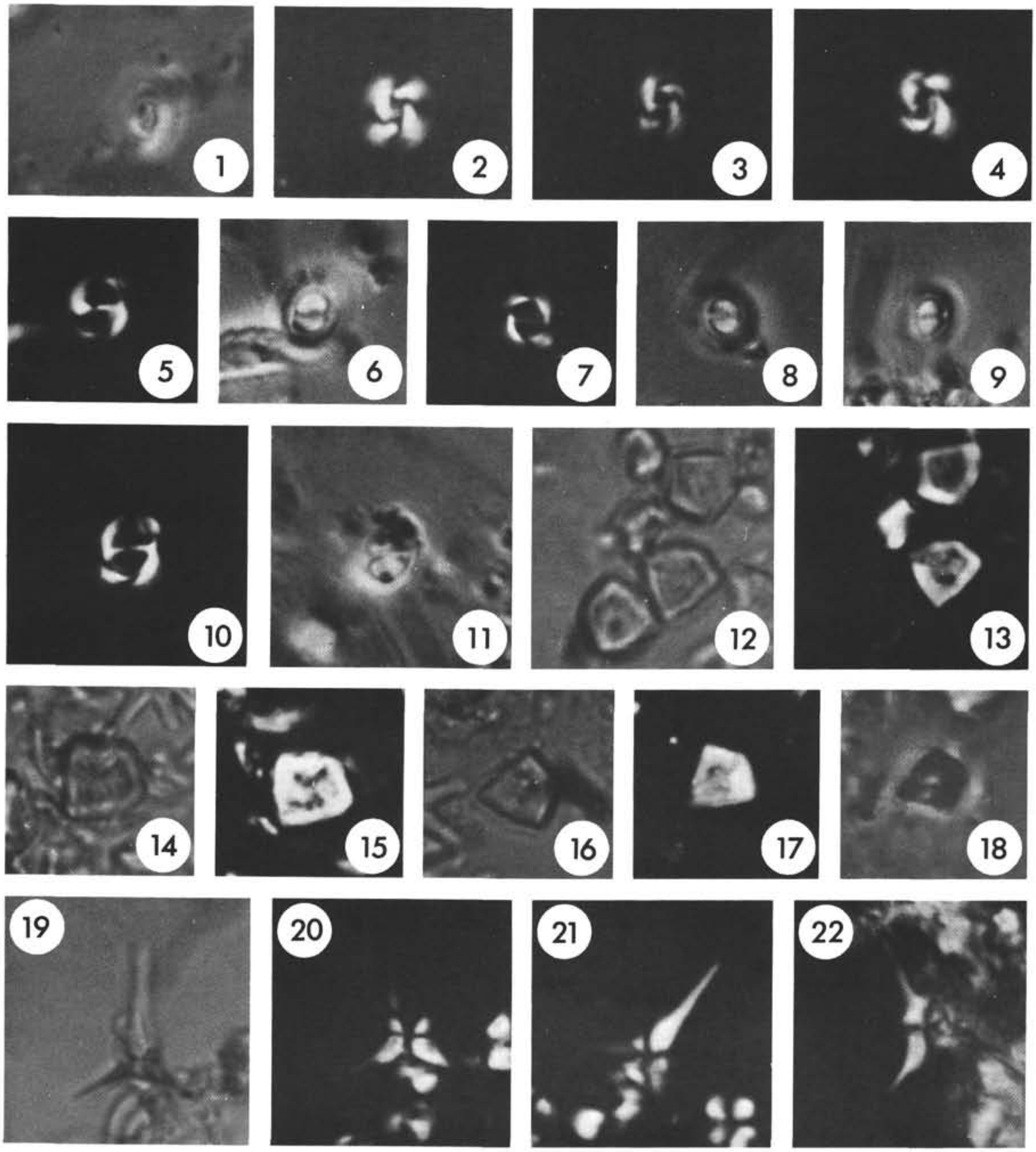

PLATE 4

Discoaster Specimens in DSDP Leg 16 Samples, 1000 ×

Figures 1-2	*Discoaster asymmetricus* Gartner (1) Sample DSDP 158-19-5(20-21 cm) (168 m). (2) Sample DSDP 157-23-5(126-127 cm) (214 m).
Figure 3	*Discoaster aulakos* Gartner Sample DSDP 159-4-3(60-61 cm) (30 m).
Figures 4-5	*Discoaster barbadiensis* Tan (4) Sample DSDP 161-11-2(51-52 cm) (91 m). (5) Sample DSDP 162-17-1(77-78 cm) (145 m).
Figure 6	*Discoaster bellus* Bukry and Percival Sample DSDP 158-22-2(120-121 cm) (191 m).
Figure 7	*Discoaster berggrenii* Bukry Sample DSDP 158-19-5(20-21 cm) (164-m).
Figures 8-9	*Discoaster bifax* Bukry Sample DSDP 162-10-4(120-121 cm) (85 m).
Figure 10	*Discoaster braarudii* Bukry Sample DSDP 158-23-5(120-212 cm) (205 m).
Figure 11	*Discoaster decorus* (Bukry) Sample DSDP 158-4-4(120-121 cm) (33 m).
Figures 12-14	*Discoaster deflandrei* Bramlette and Riedel (12) Sample DSDP 159-5-2(120-121 cm) (39 m). (13) Sample DSDP 162-5(CC) (44 m). (14) Sample DSDP 159-8-6(120-121 cm) (72 m). Both rounded and angular interray outlines because of secondary overgrowth.
Figure 15	*Discoaster* sp. cf. *D. deflandrei* Bramlette and Riedel Sample DSDP 162-9-4(120-121 cm) (78 m).
Figure 16	*Discoaster hamatus* Martini and Bramlette Sample DSDP 158-25-6(120-121 cm) (224 m).
Figure 17	*Discoaster intercalaris* Bukry Sample DSDP 158-20-6(120-121 cm) (180 m).
Figure 18	*Discoaster loeblichii* Bukry Sample DSDP 158-19-4(70-71 cm) (167 m).
Figure 19	*Discoaster lodoensis* Bramlette and Riedel Sample DSDP 162-27-1(77-78 cm) (145 m).
Figure 20	*Discoaster martinii* Stradner Sample DSDP 162-11-2(51-52 cm) (91 m).
Figures 21-22	*Discoaster mirus* Deflandre (21) Sample DSDP 162-11-2(51-52 cm) (91 m). (22) Sample DSDP 162-13-4(40 cm) (113 m).
Figure 23	*Discoaster* sp. cf. *D. mirus* Deflandre Sample DSDP 162-11-2(51-52 cm) (91 m).
Figure 24	*Discoaster nodifer* (Bramlette and Riedel) Sample DSDP 162-5(CC) (44 m).
Figure 25	*Discoaster pansus* (Bukry and Percival) Sample DSDP 158-23-5(120-121 cm) (205 m).
Figure 26	*Discoaster pseudovariabilis* Martini and Worsley Sample DSDP 158-19-5(20-21 cm) (164 m).
Figure 27	*Discoaster quinqueramus* Gartner Sample DSDP 158-11-1(110 cm) (91 m).
Figure 28	*Discoaster saipanensis* Bramlette and Riedel Sample DSDP 162-10-4(120-121 cm) (85 m).
Figure 29	*Discoaster strictus* Stradner Sample DSDP 162-12-2(120-121 cm) (102 m).
Figure 30	*Discoaster* sp. cf. *D. strictus* Stradner Sample DSDP 162-11-2(51-52 cm) (91 m).

PLATE 4

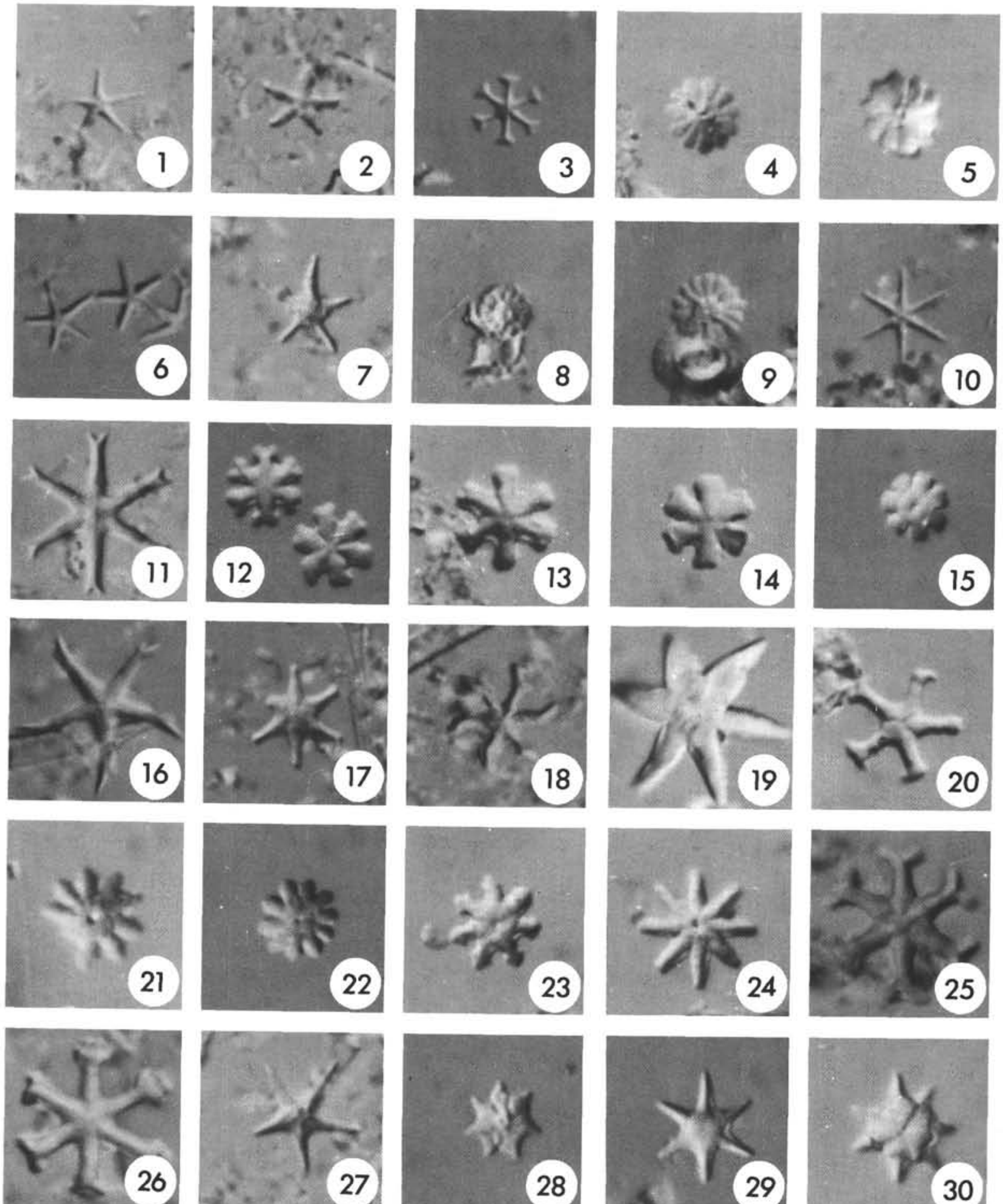
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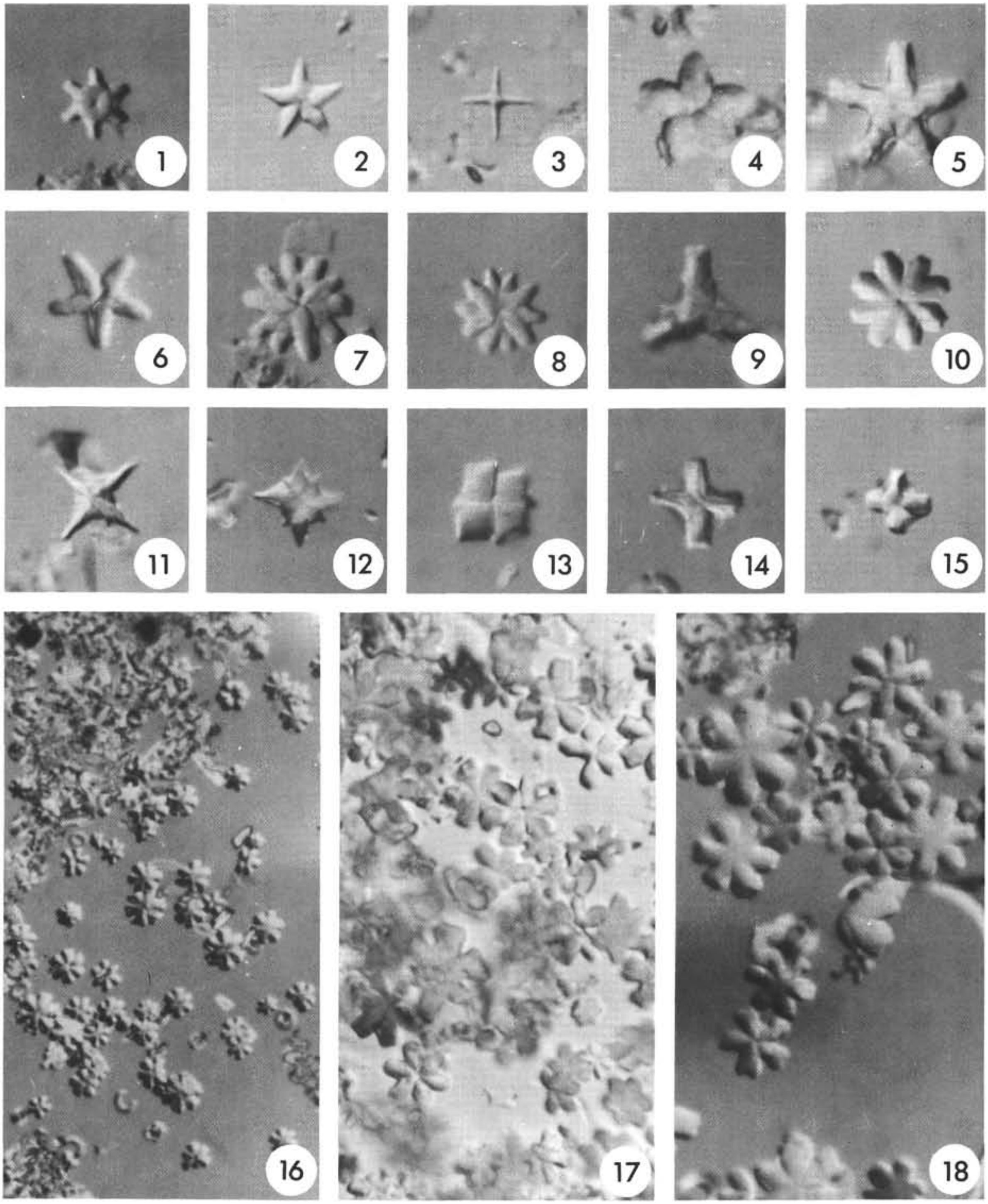
PLATE 5

Discoaster and *Nannotetrina* Specimens in DSDP Leg 16 Samples.
Photomicrographs Magnified 1000 ×, Except Figure 12
Which Is 750 × and Figure 16 Which Is 400 ×.

Figure 1	*Discoaster* sp. cf. *D. strictus* Stradner Sample DSDP 162-13-4(40-41 cm) (113 m).
Figure 2	*Discoaster sublodoensis* Bramlette and Sullivan Sample DSDP 162-17-1(77-78 cm) (145 m).
Figure 3	*Discoaster tamalis* Kamptner Sample DSDP 158-4-3(119-120 cm) (31 m)
Figures 4-6	*Discoaster tani* Bramlette and Riedel (4) Sample DSDP 161A-6A-6(120 cm) (173 m). (5-6) Sample DSDP 162-5 (CC) (44 m).
Figures 7-8	*Discoaster* sp. Sample DSDP 162-13-4 (40 cm) (113 m).
Figure 9	*Discoaster* sp. Sample DSDP 162-5(CC) (44 m).
Figure 10	*Discoaster* sp. Sample DSDP 162-17-1 (77-78 cm) (145 m).
Figures 11-15	*Nannotetrina* spp. (11) Sample DSDP 162-11-2(51-52 cm) (91 m). (12) Sample DSDP 162-12-2(120-121 cm) (102 m). (13) Sample DSDP 162-13-4(40-41 cm) (113 m). (14) Sample DSDP 165-10-4(120-121 cm) (85 m). (15) Sample DSDP 165-14-1(40-41 cm) (117 m).
Figures 16-18	*Discoaster* ooze dominated by *Discoaster deflandrei* Bramlette and Riedel (16, 18) Sample DSDP 160-5-4(120 cm) (41 m). (17) Sample DSDP 161-1-0, top (0 m).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