23. CALCAREOUS NANNOFOSSILS FROM THE NORTHWESTERN INDIAN OCEAN, LEG 24, DEEP SEA DRILLING PROJECT

Peter H. Roth, Scripps Institution of Oceanography, La Jolla, California

INTRODUCTION

On Leg 24 of the Deep Sea Drilling Project, May to June 1972, through the Gulf of Aden and northwestern Indian Ocean from Djibouti (F.T.A.I.) to Mauritius, 349 cores at eight drilling sites (Figure 1) were recovered. Light microscope techniques were used to study the coccoliths in samples from these cores. Extensive sections of upper Neogene sediments were recovered in the Gulf of Aden (Sites 231 to 233). Fairly good Neogene and Paleogene sections were cored at Sites 236 to 238. Braarudosphaerids were found in the Paleocene, Eocene, and Oligocene of open-ocean sites (236 to 238). The annotated index and bibliography of the calcareous nannoplankton (Loeblich and Tappan, 1966, 1968, 1969, 1970a, 1970b, 1973) provides bibliographic references from previously described species.

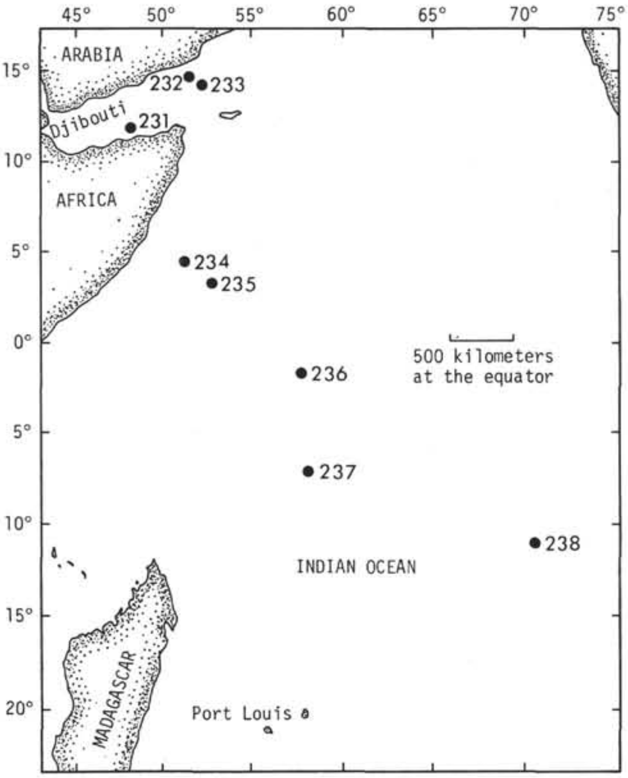

Figure 1. *Location of sites cored during Deep Sea Drilling Project Leg 24 (same map as in D. Bukry's chapter).*

CENOZOIC NANNOFOSSIL ZONATION

Tertiary nannofossil zonations were first established in land sections, mainly in California, southwestern France, Trinidad, and in marine sediment cores from the Atlantic and central Pacific. Detailed studies of many land sections and marine cores from the Atlantic, the Pacific, the Indian Ocean, the Mediterranean, the Gulf of Mexico, and the Caribbean revealed that the same low-latitude zonation can be used in all these areas. Only minor modifications and refinements of existing zonations might be necessary in certain areas. High-latitude assemblages are generally impoverished and can be the basis for only regional zonations (see Wise, 1973). Near-shore assemblages show considerable differences from open-ocean assemblages. They contain a large number of braarudosphaerids and holococcoliths which rarely occur or are generally not preserved in open-ocean environments. Regional zonations have been based on near-shore assemblages by Gartner (1971) for sections from the Blake Plateau; by Roth, Baumann, and Bertolino (1971) for the Priabonian of northern Italy; and by Edwards (1971) for sections in New Zealand. The "Paleogene Standard Nannoplankton Zonation" of Martini (1970, 1971) is based on middle to high latitude near-shore assemblages and cannot be used in its present form for low-latitude, open-ocean sections. For example, *Isthmolithus recurvus*, the marker for the base of Martini's Zone NP19, is a cold water form which also seems to prefer a near-shore environment. It is common in Northern and Central Europe, the North Atlantic north of 40°N (Perch-Nielsen, 1972), the southern Indian Ocean south of 25°S (Thierstein, personal communication), in New Zealand, and the southwest Pacific southeast of New Zealand (Edwards, personal communication), but it has not been observed in the tropical Pacific, Atlantic, or Indian oceans. The marker for the next higher Zone NP20, *Sphenolithus pseudoradians* together with *S. predistentus*, has a much longer range at low latitudes and first occurs in the middle Eocene (in the lower part of the *Chiasmolithus solitus* Zone).

Preferential dissolution is also an important factor which can change assemblages considerably. Delicate species belonging to the genera *Pontosphaera, Scyphosphaera*, some species of *Helicopontosphaera*, and especially the holococcoliths, are unsuitable biostratigraphic markers. *Ellipsolithus macellus* might be absent from some Paleocene sections because of dissolution, which makes it impossible to recognize the *Ellipsolithus macellus* Zone in deep-water sections. It is not clear whether *Helicopontosphaera ampliaperta* is missing from most open-ocean sections due to its low resistance to solution or whether it is regionally restricted to the Gulf Coast-Caribbean area, California coastal waters, and the Mediterranean.

The zonation applied in this report and summarized in Table 1 is almost identical to the one discussed in Roth (1973). It incorporates zones first proposed by Bramlette and Sullivan (1961), Bramlette and Wilcoxon (1967), Boudreaux and Hay (1967), Bukry and Bramlette (1970), Bukry (1971, 1973), Gartner (1969), Hay (1964, 1967), Martini and Worsley (1970), Milow (1970), Mohler and Hay (1967), and Roth and Hay (1967). Some minor differences from the original definition of the zones are discussed here. The base of the *Gephyrocapsa oceanica* Zone is defined as in the original description of this zone by the first occurrence of *Gephyrocapsa oceanica* s.str. This species can be distinguished from *Gephyrocapsa caribbeanica* in the light microscope as well by its large central opening and the bridge more closely aligned to the short axis of the placolith. The last occurrence of *Pseudoemiliania lacunosa* which was used by Gartner (1969) to define the base of the *Gephyrocapsa oceanica* Zone lies in the upper part of the *Gephyrocapsa oceanica* Zone as used here (see Table 2). The *Gephyrocapsa caribbeanica* Zone is defined here using the same criteria as Bukry (1973) and the *Pseudoemiliania lacunosa* Zone is based on the same paleontological events as the *Emiliania annula* Subzone of Bukry (1973a) although a different name is used for the name-giving species. It represents a much shorter interval than Gartner's original zone.

The Pliocene zonation used here is very similar to the one proposed by Bukry (1971, 1973a). The *Reticulofenestra pseudoumbilica* Zone is not further subdivided. No use is made of *Discoaster asymmetricus* for biostratigraphy because of its sporadic occurrence and its considerably longer range than indicated by Gartner (1969). It first occurs in the upper Miocene well below the first occurrence of *Ceratolithus*. The base of the Miocene is drawn at the base of the *Ceratolithus acutus* Zone which seems to agree with the latest results in the Mediterranean area (see Bukry, 1973a). The *Ceratolithus tricorniculatus* Zone covers the uppermost part of the Miocene below the first occurrence of *Ceratolithus acutus* and is equivalent with the *Triquetrorhabdulus rugosus* Subzone of Bukry's much longer *Ceratolithus tricorniculatus* Zone. Both the *Ceratolithus rugosus* Zone and the *Ceratolithus tricorniculatus* Zone are of short duration and often missed if the samples are taken at large intervals.

The zonal subdivision of the upper Miocene follows Bukry (1971, 1973c) rather closely. Typical *Discoaster neorectus* was not found at any of the sections studied for this report. A somewhat smaller form with a similar morphology referred to as *Discoaster* sp. cf. *D. neorectus* occurs at Sites 231, 237, and 238 and can be used to distinguish the *Discoaster neohamatus* Zone from the underlying *Discoaster bellus* Zone. In the Indian Ocean this interval with *Discoaster* cf. *neorectus* is quite short as compared to the underlying *Discoaster bellus* Zone. The *Catinaster coalitus* Zone is a very short interval and was not found at any of the sites. The zonation used for the middle and lower Miocene and the Oligocene is very similar to the original zonation of that interval by Bramlette and Wilcoxon (1967). As in most open-ocean environments outside the Caribbean-Gulf of Mexico region *Helicopontosphaera ampliaperta* was not found and the top of the *Helicopontosphaera ampliaperta* Zone was drawn at the level where a reduction in the dominance of *Discoaster deflandrei* occurs and where long-rayed discoasters like *D. exilis* and *D. variabilis* become dominant. Some difficulties were found in locating the Oligocene/Miocene boundary which is usually drawn at the extinction level of *Reticulofenestra abisecta* because this species is quite rare and smaller than usual in the uppermost part of its range at Sites 234 and 238. The Oligocene is well represented at Sites 236 and 238, but it is incomplete at Site 237. The Eocene is rather poorly represented at Site 237. The upper Eocene is quite thin; the middle Eocene is better developed and contains diversified assemblages. Overgrowth and dissolution produced in impoverished assemblages of early Eocene and Paleocene age at Site 237. Parts of the lower Eocene and upper Paleocene are absent.

Table 3 summarizes the zonal assignment and age of the cores studied for this report. Table 4 contains the most important datum levels as found at each site listed by core and section.

PRESERVATION

Calcareous nannofossils provide not only information on biostratigraphy and paleoecology but, as small sediment particles of distinctive and often involved morphology, they are delicate indicators of dissolution and reprecipitation processes at the sediment/water interface and in the sediment after burial. Therefore, the state of preservation of each sample is listed in Tables 5A to 12B using the preservation scale proposed by Roth and Thierstein (1972) and Roth (1973). The following categories were distinguished:

X: Excellent preservation, no signs of etching or overgrowth.

E-1: Slight etching. Coccoliths have serrate outlines and often enlarged central holes. Delicate forms (*Pontosphaera, Scyphosphaera, Rhabdosphaera*, etc.) generally preserved.

E-2: Moderate etching. More delicate species dissolved. *Helicopontosphaera* and *Sphenolithus* preserved. Few isolated shields of placoliths.

E-3: Strong etching. Only solution-resistant species left. Discoasters relatively enriched; placoliths mostly as isolated shields.

O-1: Slight overgrowth. Thickening of arms of ortholithids. Some secondary calçite deposits on elements of coccoliths.

O-2: Moderate overgrowth. Arms of discoasters strongly thickened. Delicate ornamentation on discoasters and most central structures of placoliths obscured.

O-3: Strong overgrowth. Discoasters often overgrown beyond specific recognition, other species difficult to identify.

A combination of slight to moderate etching and slight to moderate overgrowth is often observed in the same sample. Experiments by Adelseck et al. (1973) indicate that large nannofossils grow at the expense of small ones during diagenesis. This explains why overgrowth is fairly heavy on discoasters but placoliths are etched in the same samples. Some of the calcite deposited on nannofossils is probably

TABLE 1
Nannofossil Zones, Boundary Species and Estimated Time Relations

Series or Subseries	Zones	Boundary Species	Age (m.y.)
Holocene	*Emiliania huxleyi*		
		*E. huxleyi**	0.2
Pleistocene	*Gephyrocapsa oceanica*		
		*G. oceanica**	0.9
	Gephyrocapsa caribbeanica		
		*G. caribbeanica**	1.6
	Pseudoemiliania lacunosa		
		D. brouweri †	1.8
Upper Pliocene	*Cyclococcolithina macintyrei*		
		D. pentaradiatus†	2.1
	Discoaster pentaradiatus		
		D. tamalis†	2.5
	Discoaster tamalis		
		R. pseudoumbilica†	3.0
Lower Pliocene	*Reticulofenestra pseudoumbilica*		
		C. tricorniculatus†, *C. primus*†	4.0
	Ceratolithus rugosus		
		*C. rugosus**, *C. acutus*†	4.3
	Ceratolithus acutus		
		*C. acutus**	5.1
Upper Miocene	*Ceratolithus tricorniculatus*		
		D. quinqueramus†	5.2
	Ceratolithus primus		
		*C. primus**	6.0
	Discoaster berggrenii		
		*D. berggrenii**	6.8
	Discoaster neohamatus		
		*D. neorectus**	7.3
	Discoaster bellus		
		D. hamatus†	11.0
Middle Miocene	*Discoaster hamatus*		
		*D. hamatus**	13.0
	Catinaster coalitus		
		*C. coalitus**	13.2
	Discoaster kugleri		
		*D. kugleri**	13.4
	Discoaster exilis		
		S. heteromorphus†	14.0
	Sphenolithus heteromorphus		
		H. ampliaperta†	15.0
Lower Miocene	*Helicopontosphaera ampliaperta*		
		*S. heteromorphus**	17.0
	Sphenolithus belemnos		
		T. carinatus†	18.0
	Discoaster druggii		
		*D. druggii**	21.0
	Triquetrorhabdulus carinatus		
		R. abisecta†	23.0
Upper Oligocene	*Reticulofenestra abisecta*		
		S. ciperoensis†	24.0
	Sphenolithus ciperoensis		
		S. distentus†	26.5
	Sphenolithus distentus		
		*S. ciperoensis**	30.0
Lower Oligocene	*Sphenolithus predistentus*		
		R. umbilica†	34.0
	Helicopontosphaera reticulata		
		C. formosa†	35.0
	Ericsonia subdisticha		
		D. saipanensis	38.0
Upper Eocene	*Discoaster barbadiensis*		
		C. grandis†	42.0
Middle Eocene	*Chiasmolithus grandis*		
		C. solitus†	43.5
	Chiasmolithus solitus		
		*R. umbilica**	45.0
	Nannotetrina fulgens		
		C. gigas†	46.0
	Chiasmolithus gigas		
		*N. fulgens**	48.0

TABLE 1 – *Continued*

Series or Subseries	Zones	Boundary Species	Age (m.y.)
Lower Eocene		*N. fulgens**	48.0
	Discoaster sublodoensis		
		*D. sublodoensis**	49.5
	Discoaster lodoensis		
		T. orthostylus†	51.0
	Tribrachiatus orthostylus		
		*D. lodoensis**	52.0
	Discoaster diastypus		
		*D. diastypus**	53.0
Upper Paleocene	*Discoaster multiradiatus*		
		*D. multiradiatus**	55.0
	Discoaster nobilis		
		*D. nobilis**	56.0
	Discoaster mohleri		
		*D. mohleri**	57.0
	Heliolithus kleinpellii		
		*H. kleinpellii**	58.0
	Fasciculithus tympaniformis		
		*F. tympaniformis**	60.0
Lower Paleocene	*Cruciplacolithus tenuis*		
		A. cymbiformis†	63.0
Upper Maestrichtian	*Micula mura*		
		*M. mura**	66.0

Note: Ages are from Bukry (1973b).
* = appearance † = disappearance.

TABLE 2
Quaternary Nannofossil Zonations

<table>
<tr><th>Zonation Used in this Paper</th><th>Zonation of Boudreaux and Hay (1971)</th><th>Zonation of Gartner (1969)</th><th colspan="2">Zonation of Bukry (1971, 1973b)</th></tr>
<tr><td>Emiliania huxleyi</td><td>Emiliania huxleyi</td><td>Emiliania huxleyi</td><td colspan="2">Emiliania huxleyi</td></tr>
<tr><td>Gephyrocapsa oceanica</td><td>Gephyrocapsa oceanica</td><td>G. oceanica</td><td colspan="2">Gephyrocapsa oceanica</td></tr>
<tr><td>Gephyrocapsa caribbeanica</td><td rowspan="2">Gephyrocapsa caribbeanica</td><td rowspan="2">Pseudoemiliania lacunosa</td><td rowspan="2">Gephyrocapsa doronicoides</td><td>Gephyrocapsa caribbeanica</td></tr>
<tr><td>Pseudoemiliania lacunosa</td><td>Emiliania annula</td></tr>
</table>

derived from planktonic foraminifera in the sediment (see Schlanger et al., 1973). The lithology of the sediments, the rate of sedimentation, and the age of the sediment seem to be important factors influencing the rate of alteration of the assemblages. High content in organic matter seems to result in the production of CO_2 in the bottom water which leads to dissolution of nannofossils in relatively shallow water. This was observed at all the Gulf of Aden sites. High clay content seems to protect coccoliths from overgrowth formation which is also quite obvious in all the Gulf of Aden holes. Even an overburden of over 500 meters does not lead to overgrowth formation in the hemipelagic sediments at Site 231, whereas assemblages of the same age from pure calcareous ooze with an overburden of 120 meters at Site 237 show moderate overgrowth. The age of the sediments seems to be an important factor too. Slight overgrowth was observed in sediments of Quaternary age, but moderate overgrowth usually starts in sediments of late Miocene age or older. Careful evaluation of the state of preservation of a sample is necessary before conclusions about the biostratigraphy or paleoecology can be drawn because they rely on the composition of whole assemblages. The preservation of the assemblages is discussed together with the biostratigraphy at each site.

DIVERSITY OF CALCAREOUS NANNOPLANKTON IN THE INDIAN OCEAN AND COMPARISON WITH THE PACIFIC

The total number of species (excluding obviously reworked forms) versus age was plotted for selected samples from Sites 231, 237, and 238. The paleotemperature curve based on planktonic foraminiferal assemblages from Site 167, Magellan Rise, central Pacific by Douglas and Savin (1973) is superimposed on these diversity values (Figure 3). The two curves are almost parallel from 15 m.y. to 40 m.y., but the highest peak in temperature and the highest diversity values are offset by about 7 m.y. This might be explained as a certain lag effect. High temperatures in the middle Miocene started a diversification process which culminated in the late Miocene. Effects of overgrowth lead

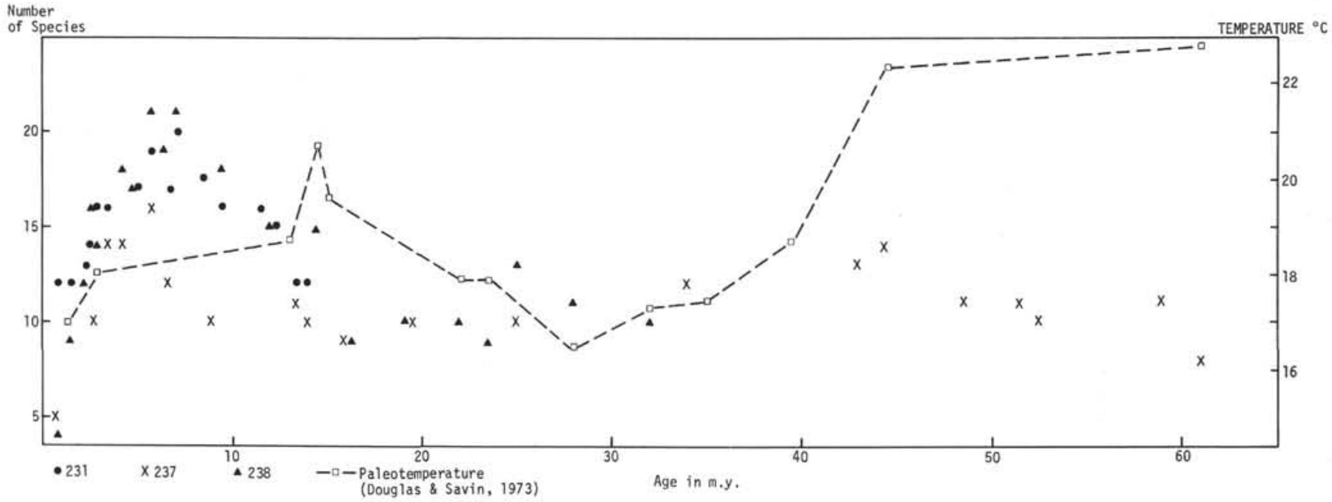

Figure 2. *Diversity of nannofossils during the Cenozoic at Sites 231, 237, and 238 compared to the paleotemperature (paleotemperature curve based on planktonic foraminifera from the central Pacific, Douglas and Savin, 1973).*

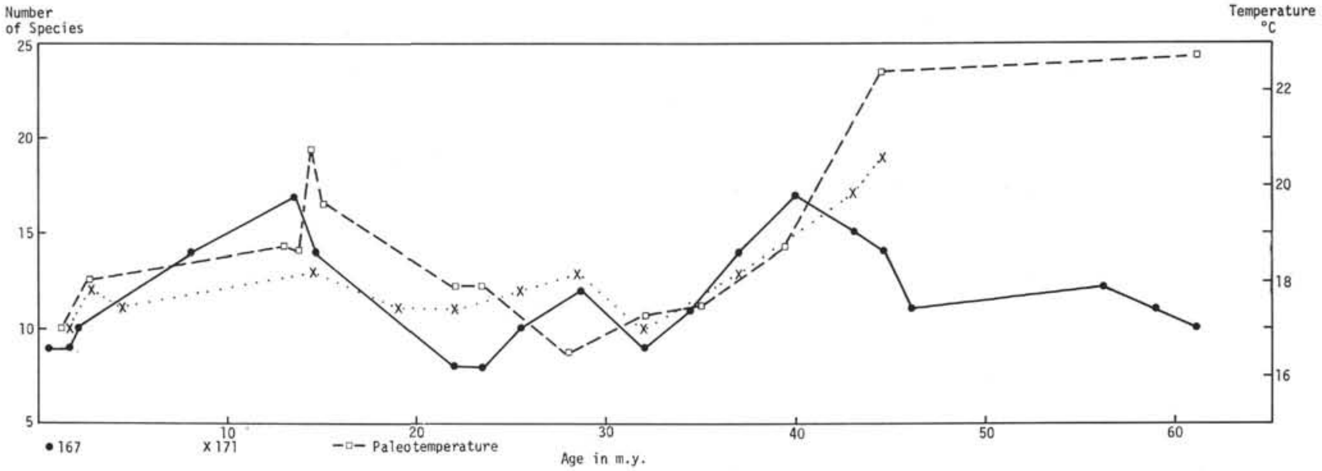

Figure 3. *Diversity of nannofossils during the Cenozoic at Sites 167 and 171, central Pacific compared to the paleotemperature (paleotemperatures by Douglas and Savin, 1973).*

TABLE 3
Zonal Assignment and Age of Leg 24 Cores Based on Nannofossils

	Site (Cores)							
Zone	231	232	233	234	235	236	237	238
Emiliania huxleyi	1?						1	1
Gephyrocapsa oceanica	2-9	1-5	1-2		1	1	2	2
Gephyrocapsa caribbeanica	10	6-7	4-5		3-4	3		
Pseudoemiliania lacunosa	11-12	8-9	7-9		5	3		3
Cyclococcolithina macintyrei	13-16	10	10-14					5,6
Discoaster pentaradiatus	17-19	11-14	15-19 1A-4A					4,7-8
Discoaster tamalis	20	15-16	5A-7A		7		4-5	4,9-10

TABLE 3 – *Continued*

Zone	Site (Cores)							
	231	232	233	234	235	236	237	238
Reticulofenestra pseudoumbilica	21-27	17-19 1A-8A		1	8	4	6-8	5, 11
Ceratolithus rugosus		9A			9	4-5	9	12-13
Ceratolithus acutus	28	10A-11A						14-15
Ceratolithus tricorniculatus	29	13A-19A				6		
Ceratolithus primus	30-42	20A-26A			10-11	7-12	10-12	16-20
Discoaster berggrenii	43-46					13		21-23
Discoaster neohamatus	47-48						13	24
Discoaster bellus	49-52			1	12	14	14	25-28
Discoaster hamatus	53-56				13	15		29-30
Catinaster coalitus								
Discoaster kugleri	57-60				14		15	
Discoaster exilis	61-62						16	
Sphenolithus heteromorphus	?62-63			5	15	17	17	32-39
Helicopontosphaera ampliaperta						?18	18-19	40-41
Sphenolithus belemnos								
Discoaster druggii				6		18-19	20	42
Triquetrorhabdulus carinatus				9				43
Reticulofenestra abisecta				10		20		44-49
Sphenolithus ciperoensis				12		21	21-22	50-51
Sphenolithus distentus				?13		22-23		52-53
Sphenolithus predistentus						23-24		54
Helicopontosphaera reticulata						25	23	
Ericsonia subdisticha						26-27		
Discoaster barbadiensis						28		
Chiasmolithus grandis							24	
Chiasmolithus solitus							25-26	
Nannotetrina fulgens								
Chiasmolithus gigas							27-32	
Discoaster sublodoensis						29	36?	
Discoaster lodoensis						30,31		
Tribrachiatus orthostylus							37	
Discoaster diastypus							38	
Discoaster multiradiatus						32	41	
Discoaster nobilis								
Discoaster mohleri						33		
Heliolithus kleinpellii							43-44	
Fasciculithus tympaniformis							45-51	
Cruciplacolithus tenuis							52-54	
Micula mura					?17-20?			

to reduced diversity before about 45 m.y. which explains the slow reduction in diversity during a time when the temperature slightly increased. For comparison, the total nannofossil diversity and the paleotemperature based on planktonic foraminifera (Douglas and Savin, 1973) are also plotted for Sites 167 and 171 in the central Pacific. The agreement between the diversity and paleotemperature curves is even better for these sites where diversity and paleotemperatures were determined in the same section. This suggests that diversity of nannofossils was highest

TABLE 4
Important Nannofossil Events

Events[a]	Sites (Core-Section or CC)							
	231	232	233	234	235	236	237	238
B *Emiliania huxleyi*	?1-1?						?1-1?	?1-6?
T *Pseudoemiliania lacunosa*	4-1	3-6	2-4		2-2	2-1		3-6
B *Gephyrocapsa oceanica*	9-1	5-3	2-4		1-1	1-1	2-1	2-6
B *Gephyrocapsa caribbeanica*	10-3	7-4	5-6		2-2	2-1		
T *Cyclococcolithina macintyrei*	7-3	9-2	10-6		5-6	3-3	4-1	4-1
T *Ceratolithus rugosus*	12-1	11-5	16-6		5-6	3-3	4-1	4-1
T *Discoaster brouweri*	13-2	10-2	10-6		5-6	3-3	4-1	4-1
T *Discoaster pentaradiatus*	17-1	11-5	15-6		7-4	4-1	4-1	4-1
T *Discoaster surculus*	19-2	12-5	16-6		7-4	4-1	4-1	4-1
T *Discoaster tamalis*	20-1	15-5	18-5		7-4	5-1	4-1	4-6
T *Reticulofenestra pseudoumbilica*	21-1	17-3		1-1	8-1	4-1	6-1	5-2
T *Sphenolithus abies*	18-2	12-5		1-6	9-1	4-5	6-1	10-6
B *Discoaster tamalis*	31-5	16-3			8-1	5-1	5-4	10-6
T *Ceratolithus tricorniculatus*	29-6	9A-1			9-1	4-5	9-1	12-6
B *Ceratolithus rugosus*	27-6	9A-1			9-1	5-1	9-1	13-5
T *Ceratolithus acutus*	28-6	10A-1						14-5
B *Ceratolithus acutus*	28-6	11A-1						15-6
T *Discoaster quinqueramus*	30-6	20A-1			10-1	7-1	10-1	16-6
B *Ceratolithus primus*	42-6	26A, CC			11-5	12-6	12-1	20-6
B *Discoaster quinqueramus*	46, CC				11-5	13-6	12-1	22-6
B *Discoaster berggrenii*	46, CC				11-5	13-6	12-1	23-6
B *Discoaster surculus*	46, CC				11-5	13-6	12-1	23-6
T *Discoaster* cf. *neorectus*	47-6						13-1	22-6
B *Discoaster* cf. *neorectus*	48-1						13-1	24-6
T *Discoaster hamatus*	53-6				13-1	15-6		29-6
B *Discoaster bellus*	55-1				12-1	14-3		28-6
B *Discoaster hamatus*	56-2				13-1	15-6		30-6
T *Coccolithus eopelagicus*	57-1			9-2	15-4	17-6	15-1	32-1
T *Discoaster kugleri*	57-1				14-2	17-6	15-1	
T *Discoaster exilis*	57-1			5-3	14-2	17-6	15-1	32-1
B *Discoaster kugleri*	60-2				14-2		15-1	
T *Sphenolithus heteromorphus*				5-3	15-4	17-6	17-1	32-1
B *Discoaster exilis*	62-1			5-3	15, CC	17-6	17-1	40-1
T *Sphenolithus belemnos*				9-2		18-1	19-1	41-6
B *Sphenolithus heteromorphus*				5-3		18-1	19-1	41-6
T *Triquetrorhabdulus carinatus*				9-2		18-6	20-1	42-4
T *Discoaster druggii*				9-2		18-6	20-1	42-4
T *Reticulofenestra abisecta*				10-3		20-5	21-1	44-1
B *Sphenolithus belemnos*				11-1		21-6	20-1	49-2
T *Sphenolithus ciperoensis*						21-6	21-1	47-4
T *Reticulofenestra bisecta*				12-1		21-6	21-1	48-1
B *Triquetrorhabdulus carinatus*				12-1		21-6	22-1	51-2
B *Sphenolithus ciperoensis*				12-1		22-1	22-1	53-5
B *Reticulofenestra abisecta*						23-1	22-1	53-5
B *Sphenolithus distentus*						24-6		53-5
T *Reticulofenestra umbilica*						25-6	23-1	
T *Cyclococcolithina formosa*						26-6	24-1	
T *Discoaster saipanensis*						28-1	25-1	
T *Discoaster barbadiensis*						28-1	24-1	
T *Chiasmolithus grandis*							24-1	
T *Chiasmolithus solitus*							25-1	
B *Reticulofenestra umbilica*						28-1	26-1	
T *Nannotetrina fulgens*							31-1	
T *Chiasmolithus gigas*							27-1	
B *Chiasmolithus gigas*							32-2	
B *Nannotetrina fulgens*							31-1	
T *Discoaster sublodoensis*							36-1	
B *Discoaster sublodoensis*							36-1	
T *Tribrachiatus orthostylus*							37-1	
B *Tribrachiatus orthostylus*							37-1	
B *Discoaster diastypus*							38-1	
B *Discoaster multiradiatus*							41-1	
B *Discoaster nobilis*						32-3		
B *Discoaster mohleri*						33-3	41-1	
B *Heliolithus kleinpellii*							44-1	
B *Fasciculithus tympaniformis*							51-2	
B *Cruciplacolithus tenuis*							54-1	
T *Micula mura*					18-1			
B *Micula mura*					18-1			

[a]B = bottom; T = top.

TABLE 5A
Calcareous Nannofossils, Site 231

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Ceratolithus acutus*	*Ceratolithus amplificus*	*Ceratolithus cristatus*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus pelagicus*	*Coccolithus* cf. *pelagicus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster berggrenii*	*Discoaster brouweri*	*Discoaster deflandrei*	*Discoaster intercalaris*	*Discoaster pentaradiatus*	*Discoaster quadramus*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*
Quaternary	*E. huxleyi?*	1-1, 145	C	G	E-1											C													
	Gephyrocapsa oceanica	2-2, 49	C	G	E-1										R	C													
		3-4, 53	C	G	E-1											C													
		4-1, 50	C	G	E-1											C													
		5-1, 49	C	G	E-1											C													
		6-1, 50	C	G	E-1											C													
		7-5, 130	C	G	E-1							F				C	F												
		8-6, 110	C	G	E-1											C	F												
		9-1, 49	C	G	E-1											C													
	G. caribbeanica	10-3, 29	C	G	E-1									C		C	R			R	R								
	P. lacunosa	11-2, 50	C	G	E-1							C		C		C	F			R									R
		12-1, 50	C	G	E-1			R		R		C		C		C	C			R									
Late Pliocene	*C. macintyrei*	13-2, 30	C	G	E-1					R		C		C		C	F			C								R	
		14-5, 118	C	G	E-1					R		C		C		C	C			C								R	
		15-2, 19	C	G	E-1					R		C		C		C	C			C									
		16-2, 19	C	G	E-1					R		C		C		C	C	R		C								R	
	D. pentaradiatus	17-1, 58	C	G	E-1					R		C		C		C	C			C			F						R
		18-2, 29	C	G	E-1					R		F		C		C	C		R	C			F	R					
		19-2, 29	C	G	E-1					R		F		C	R	C	C	R	R	C			F			F			
	D. tamalis	20-1, 44	C	G	E-1					R				C		C	C	R		C	R		C			R	F	R	R
Early Pliocene	*Reticulofenestra pseudoumbilica*	21-1, 59	C	G	E-1					R				C		C	C			C			F			F			R
		22-1, 54	F	G	E-1					R				C		F	F			R			R			R			
		23-6, 19	C	G	E-1					R		F		C		C	C	R		C			F		R	F		R	F
		24-5, 119	C	G	E-1					R		F		C		C	C		R	C			C		R	F			
		25-6, 120	C	G	E-1					R		F		C		C	C		R	C		R	C			C		R	F
		26-6, 110	C	G	E-1					R		F		C	R	C	C			C			C			C			R
		27-6, 110	C	G	E-1					R		F		C	R	C	C			C			C			C		R	
	C. acutus	28-6, 110	C	G	E-1	R					R	F		C	R	C	C	R	R	F			F			F			R
Late Miocene	*C. tricorn.*	29-6, 110	C	G	E-1				R		R		C	C		C	C	R		C		R	C			C			F
	Ceratolithus primus	30-6, 110	C	G	E-1				R				F	C		C	C		F	C			C		C	C			
		31-5, 110	C	G	E-1				R				C	C		C	C		F	C			C		C	C	R		C
		32-6, 110	C	G	E-1				R				C	C		C	C		F	C			C		C	C		R	F
		33-5, 110	C	G	E-1				R				C	C		C	C		C	C	R	R	F		C	C		R	F
		34-6, 110	C	G	E-1		R		R				C	C		C	C		C	C		R	F		C	C		R	F
		35-2, 50	C	G	E-1		R		R				F	C		C	C		F	F		R	F		C	C		R	F
		36-6, 100	C	G	E-1		R		R				F	C		C	C		C	F		R	F		C	C			F
		37-5, 100	C	G	E-1		R		R				F	C		C	C		C	C		R	F		C	C		R	C
		38-4, 60	C	G	E-1		R		R				C	C		C	C		C	C			F		C	C			F

Core, Section, Interval (cm)	*Emiliania huxleyi*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Helicopontosphaera sellii*	*Helicopontosphaera wallichii*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera scutellum*	*Pontosphaera syracusana*	*Pseudoemiliania lacunosa*	*Reticulofenestra pseudoumbilica*	*Rhabdosphaera clavigera*	*Scyphosphaera apsteinii*	*Scyphosphaera globulata*	*Scyphosphaera pulcherrima*	*Syracosphaera* cf. *histrica*	*Syracosphaera* cf. *pulchra*	*Sphenolithus abies*	*Triquetrorhabdulus rugosus*	*Umbilicosphaera sibogae*
1-1, 145	C?		C	C		C															C
2-2, 49		F	C	C		F	F														C
3-4, 53		F	C	C		F	F											F			C
4-1, 50		C	C	C			F				R							F			C
5-1, 49		C	C	C			F				F						R				F
6-1, 50		F	C	C			F			F	F			R				F			C
7-5, 130		C	C	F				R			F	R				R		F			F
8-6, 110		F	C	C			F				C	R									C
9-1, 49		C	C	C			R		R	R	F										F
10-3, 29		C		C			F				C	R									C
11-2, 50				C			F				C		F								F
12-1, 50				C			F				C		R								F
13-2, 30				F				R			F										
14-5, 118				C			F				F	R									
15-2, 19				C			R	R			F										
16-2, 19				C	F			R			F	R									
17-1, 58				C				R			F										
18-2, 29				C				R			F	R							R		
19-2, 29				C				R			F										
20-1, 44				C				R			F								R		
21-1, 59				C							F	F							C		
22-1, 54				F								F							F		
23-6, 19				C				R				C							F		
24-5, 119				F								C							C		
25-6, 120				F								C		R					C		
26-6, 110				F				R				C			R				C		
27-6, 110				F				F				C							C		
28-6, 110				F				F				C		R					C		
29-6, 110				C				F				C							C	F	
30-6, 110				F								C							C	C	
31-5, 110				F				R				C							C	C	
32-6, 110				R				R				C				R			C	C	
33-5, 110				F				R				C							C	C	
34-6, 110				F								C							C	C	
35-2, 50				F				R				C							C	C	
36-6, 100				C				R				C							C	C	
37-5, 100				F								C							C	C	
38-4, 60				F				R				C							C	F	

during warm temperatures and lowest during times of low temperatures.

GULF OF ADEN SITES

All the holes drilled in the Gulf of Aden penetrated quite similar sections of upper Neogene hemipelagic mud. Reworked older fossils occur throughout the studied sections. Some reworked forms are older than the oldest sediments recovered and could be windblown from land sediments. The nannofossil assemblages from all the sites in the Gulf of Aden have a characteristic aspect and differ somewhat from assemblages recovered at the other sites in the northwest Indian Ocean. The genus *Ceratolithus* is quite poorly represented in the sediments from the Gulf of Aden. *Ceratolithus cristatus* was not observed in the Quaternary samples except for rare specimens in one sample at the base of the *Pseudoemiliania lacunosa* Zone. The Pliocene *Ceratolithus rugosus, C. acutus,* and *C. tricorniculatus* and the Miocene *C. primus* and *C. amplificus* are very rare in all samples and a lot of searching is necessary to find a few specimens. *Coccolithus pelagicus* becomes increasingly abundant in the late Pliocene but disappears abruptly at the Pliocene/Pleistocene boundary. This change in the abundance is less pronounced at the other sites in the northwest Indian Ocean. *Discoaster intercaris*, a cooler water form, seems to occur only in the Gulf of Aden sediments.

SITE 231
(lat 11°53.41′N, long 48°14.71′E, water depth 2161 m)

This site is located in the Gulf of Aden about 70 km north of the Somalia coast. The section consists of about

TABLE 5B
Calcareous Nannofossils, Site 231

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Catinaster coalitus*	*Catinaster mexicanus*	*Ceratolithus amplificus*	*Ceratolithus primus*	*Coccolithus eopelagicus*	*Coccolithus* cf. *pelagicus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster bollii*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster calcaris*	*Discoaster challengeri*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster exilis*	*Discoaster hamatus*	*Discoaster intercalaris*	*Discoaster kugleri*	*Discoaster neohamatus*	*Discoaster* cf. *neorectus*	*Discoaster pentaradiatus*	*Discoaster prepentaradiatus*	*Discoaster pseudovariabilis*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster triradiatus*	*Discoaster variabilis*	*Helicopontosphaera kamptneri*	*Pontosphaera* cf. *anisotrema*	*Pontosphaera* cf. *discopora*	*Pontosphaera* cf. *sparsiforata*	*Reticulofenestra pseudoumbilica*	*Sphenolithus abies*	*Sphenolithus moriformis*	*Triquetrorhabdulus rugosus*
Late Miocene	*Ceratolithus primus*	39-4, 100	C	G	E-1			R	R		C	C	R	C	C			C			C											F			C	C		C	F				F	C		F
		40-5, 104	C	G	E-1						F	C		C	C			C			C							F				F			C	C		C	F				F	C		F
		41-5, 120	C	G	E-1			R	R		F	C		C	C			F			C											F			C	C	F	C	F				F	C		F
		42-6, 120	C	G	E-1				F		C	C		C	C			C			C							R				F			C	C		C	F				F	C		F
	Discoaster berggrenii	43-6, 120	C	G	E-1						F	C		C	C			C			C											F			F	C	R	C	F		R		F	C		F
		44-2, 110	C	G	E-1						F			C	C	R		C			C							R				F			F	C		C	F				C	C		F
		45-6, 119	C	G	E-1						F			C	C			C		F	C							R				F			R	F	R	C	F		R		C	C		F
		46, CC	C	G	E-1						F			C	C	R		F		F	C		F									F			R	F		C	C				C	C		F
	D. neohamatus	47-6, 120	C	G	E-1						F			C	C	R	R			C	F		F	R				F		C	R	F		F				C	C			R	C	C		F
		48-1, 119	C	G	E-1	R					F			C	F		F			C	F			R				R		C	R	R		F				C	C				C	C		F
	Discoaster bellus	49-2, 40	C	G	E-1						F			F	F	R	R			C	F							F		C		R		F				C	F				C	C		F
		50-6, 110	C	G	E-1						F			F	F	R	C			C	F							F		C		F	F	F			R	C	F				C	C		F
		51-6, 120	C	G	E-1						F			F	F		C			C	F	C						F		C			F	C			R	C	F				C	C		F
		52-5, 130	C	G	E-1		R				F			F	F	F	C			C	F	F								C							F	C	F				C	F		F
Middle Miocene	*Discoaster hamatus*	53-6, 120	C	G	E-1		R				C			F	F		F		R	C	R	F					C			C								C	F				C	F		F
		54-2, 56	C	G	E-1	F					F			F	F		F			F	F	F					F			F								F	F				C	F		F
		55-1, 70	C	G	E-1	R					F			F	F		F			F	R	F		R			F			F								F	F				C	F		F
		56-2, 30	C	G	E-1	R					F			F	F				R	C	F	F					C			C				R				C	F				C			F
	Discoaster kugleri	57-1, 107	C	G	E-1					R	C			F	F											F			F									F	R				C			F
		58-6, 50	C	G	E-1					R	F			F	F											F			F									F	F				C		C	F
		59-6, 102	C	G	E-1					R	C			C	C								F			F			F									C	F				C		F	F
		60-2, 70	C	G	E-1					R	C			F	F				R	R				F		F			F									R	F				C		F	
	D. exilis	61-6, 117	C	G	E-1					R	F		F	F	F										F	F												F	F	R			C		F	
		62-1, 58	C	M	O-2					F			C		F									F		F													R				C		F	
	?*D. exilis*	62-1, 130	C	M	O-3					F	F		C		F									F															R				C		F	
	S. hetero.	63-1, 90	C	P	O-3					F	F		C		F									F															F				C		C	

566 meters of olive-gray hemipelagic mud with sand layers in the upper 220 meters. The upper 102 meters are of Quaternary age, the underlying Pliocene is 152 meters thick and the hole bottoms in basalt with slightly altered nannofossil chalk inclusions of middle Miocene age. Nannofossils are common throughout the sedimentary section.

Core 1 contains an assemblage consisting of *Gephyrocapsa oceanica* and many small placoliths which belong most probably to *Emiliania huxleyi*. This core is tentatively assigned to the *Emiliania huxleyi* Zone but only electron microscopy could give definitive proof of this age assignment. Cores 2 through 9 recovered the *Gephyrocapsa oceanica* Zone with common *G. oceanica* and *G. caribbeanica*. The last occurrence of *Pseudoemiliania lacunosa* in Core 4 could be used to further subdivide this interval. The *Gephyrocapsa caribbeanica* Zone is thin and was recovered only in Core 10. *Crenalithus doronicoides* and *Gephyrocapsa caribbeanica* overlap in that interval. The *Pseudoemiliania lacunosa* Zone is present in Cores 11 and 12 with assemblages including common *Crenalithus doronicoides* and *Pseudoemiliania lacunosa*. *Ceratolithus cristatus* and *C. rugosus* occur in the lower part of this zone and *Cyclococcolithina macintyrei* ranges throughout this interval. Reworked *Discoaster brouweri* is present in small numbers throughout this zone. The upper Pliocene *Cyclococcolithina macintyrei* Zone was found in Cores 13 through 16 with assemblages including *Cyclococcolithina macintyrei* and *Discoaster brouweri*. Cores 17 through 19 yield assemblages belonging to the *Discoaster pentaradiatus* Zone with *Discoaster brouweri, D. pentaradiatus*, and, in the lower part, *D. surculus*. The *Discoaster tamalis* Zone occurs in Core 20 only. The *Reticulofenestra pseudoumbilica* Zone was recovered in Cores 21 through 27 with assemblages including common *Reticulofenestra pseudoumbilica* and *Sphenolithus abies*. Cores 23 through 27 contain reworked Miocene discoasters and placoliths in small numbers. Core 28 yielded *Ceratolithus acutus* together with rare *C. tricorniculatus* which indicates the basal Pliocene *Ceratolithus acutus* Zone. The *Ceratolithus rugosus* Zone was not found in any of the samples studied.

The Pliocene/Miocene boundary based on calcareous nannofossils would fall between Cores 28 and 29. Core 29 belongs to the upper Miocene *Ceratolithus tricorniculatus* Zone and contains an assemblage including *Ceratolithus tricorniculatus* and *C. primus*. The *Ceratolithus primus*

TABLE 6
Calcareous Nannofossils, Site 232

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Angulolithina arca*	*Arkhangelskiella cymbiformis*	*Braarudosphaera bigelowii*	*Ceratolithus acutus*	*Ceratolithus amplificus*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus pelagicus*	*Coccolithus* cf *pelagicus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster barbadiensis*	*Discoaster berggrenii*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster deflandrei*	*Discoaster intercalaris*	*Discoaster pentaradiatus*	*Discoaster quinqueramus*	*Discoaster saipanensis*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Helicopontosphaera sellii*	*Pontosphaera discopora*	*Pontosphaera* cf *discopora*	*Pontosphaera japonica*	*Pontosphaera scutellum*	*Pseudoemiliania lacunosa*	*Reticulofenestra pseudoumbilica*	*Rhabdosphaera clavigera*	*Scyphosphaera apsteinii*	*Syracosphaera* cf *pulchra*	*Sphenolithus abies*	*Triquetrorhabdulus rugosus*	*Umbellosphaera irregularis*	*Umbilicosphaera sibogae*	*Watznaueria barnesae*
Pleistocene	*Gephyrocapsa*	1-2, 20	C	G	E-1												R	C																F	C	C		F			F									F	
		2-6, 120	C	G	E-1													C																F	C	C		F			F			F						F	
		3-6, 110	C	G	E-1													C																F	C	C		C				R								C	
		4-6, 121	C	G	E-1													C																C	C	F		F			F	R	R							C	
		5-3, 110	C	G	E-1									C				C																C	F	C					F	F								F	
	G. caribbeanica oceanica	6-4, 99	C	G	E-1									C		C		C																C		C					R	F				F				F	
		7-4, 119	C	G	E-1									C		C		C																C		C					F	F									
	P. lacunosa	8-3, 119	C	G	E-1									C		C		C																		C	F					F				F			F		
		9-2, 112	C	G	E-1									C		C		C	R																	C					F	C									R
Late Pliocene	*Discoaster pentaradiatus*	10-2, 69	C	G	E-1									C		C		C	C		R			F					R							C						F									
		11-5, 119	C	G	E-1		R					R		C		C		C	C					C			R									C				R		R									
		12-5, 100	C	G	E-1									C		C		C	C					C			R			R		R				C				R		R					R				
		13-1, 82	C	G	E-1							R		F		C	R	C	F					C			R			R						C				R		R									
		14-3, 122	C	G	E-1							R		C		C		C	C	R				F			F			F						F			F	R		F	R								
	D. tamalis	15-5, 91	C	G	E-1									F		C		C	C		R			F			F			F	R					C			F	F											
		16-3, 100	C	G	E-1									F		C	R	C	F					F			R			R	F		F			C				R											
Early Pliocene	*Reticulofenestra pseudoumbilica*	17-3, 115	C	G	E-1			R				R		F		C		C	F	R				F			R			R						C	F			R			F				C				
		18-3, 99	C	G	E-1							R		F		C		F	F					F			R			R						F							F				C				
		19-6, 120	C	G	E-1									F		C		C	F	R				F			R			R						F							C				C				
		1A-2, 12	C	G	E-1									F		C		C	F	R				C			F			F						C				R			F				R				
		2A-1, 50	C	G	E-1							R		F		C		C	F					F			R			R						F							R				C				
		3A-1, 84	C	G	E-1							R		F		C		C	F					C			F			F						C				F			C				C				
		4A-2, 42	C	G	E-1							R		F		C		C	F					F			F			F						F							C				C				
		5A-1, 59	C	G	E-1							R		F		C		F	F					C			F			F						C			R				C				C				
		6A-1, 50	C	G	E-1							R		F		C		F	F					F			F			F						C							C				C				
		7A-1, 49	C	G	E-1							F		C		C	F	C	C					C			F			F			F			F				R			C				C				
		8A-1, 50	C	G	E-1									F		C		C	F			R		F			F			F			F			F				R			C				C				
	C. rugosus	9A-1, 50	C	G	E-1						R	R	R	F		C	R	F	F	R				F			F			F			F			F				R			C				C				
	C. acutus	10A-1, 60	C	G	E-1				R		R		R	F		C		C	F			R		F			F			F			F			F				R			C				C				
		11A-1, 60	C	G	E-1				R		R		R	F	F	C		F	F					F			F			R			F			F							C				C	R			
Late Miocene	*Ceratolithus tricorniculatus*	13A-1, 110	R	G	E-1										R	F		R	R					R																			R				R	R			
		14A-1, 51	R	G	E-1						R		R		R			R	R					R						R			R										C					R			
		15A-2, 50	R	G	F-1						R		R		R			R						R			R			R			R			R							R		R		R	R			
		18A-2, 28	C	G	E-1						R		R		F	C		F	F					F			F			F			F			F			R	R			C		R		C	F			
		19A-1, 60	C	G	E-1						R		R		F	C		F	F					F			F			F			F			F							C				C	F			
	Ceratolithus primus	20A-1, 50	C	G	E-1	R					R				F	F		F	F			R	F	F		R		F		F			F			F							C				C	R			
		21A-2, 30	C	G	E-1						R				F	C		F	F			C	C	C		R		C		C			C			F							C				C	R			
		22A-2, 26	F	M	E-1										F	C		F	F				R	R		R		R		R			R			F							F				C	R			
		23A-1, 50	C	M	E-1					R	R				F	C		C	F			F	F	F		R		F		R		R	F			C							C				C	R			
		26A, CC									R				F	C		F	F			F	F	F		R	R	F		F			F			F							C				C	R			

Zone is quite thick at this site and occurs in Cores 30 through 42. *Ceratolithus primus, C. amplificus,* and *Discoaster quinqueramus* are characteristic of this interval. Cores 43 through 46 are assigned to the *Discoaster berggrenii* Zone based on assemblages including *Discoaster berggrenii, D. quinqueramus,* and *D. surculus.* Cores 47 and 48 contain *Discoaster* sp. cf. *D. neorectus* (somewhat smaller), *D. bellus, D. neohamatus,* and *D. pseudovariabilis* and are thus assigned to the *Discoaster neohamatus* Zone. Cores 49 through 52 yield assemblages typical of the *Discoaster bellus* Zone including *Discoaster neohamatus, D. bellus, D. calcaris,* and *D. pseudovariabilis.* The boundary between the upper and the middle Miocene based on nannofossils lies between Cores 52 and 53. Cores 53 through 56 contain rich assemblages characteristic of the *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus, D. calcaris,* rare *Discoaster bollii, Catinaster coalitus,* and *C. mexicanus.* The next lower zone present at this site is the *Discoaster kugleri* Zone recovered in Cores 57 through 60 with assemblages including *Discoaster kugleri, D. exilis,* and *Coccolithus eopelagicus.* Core 61 and the top of Core 62 contain impoverished assemblages with *Discoaster exilis* and *Coccolithus eopelagicus* which are assigned to the *Discoaster exilis* Zone. Nannoplankton chalk layers interbedded with basalt in Cores 62 and 63 yield moderately recrystallized assemblages including early forms of *Cyclococcolithina macintyrei* (slightly elliptical), *Coccolithus eopelagicus, Cyclicargolithus floridanus,*

TABLE 7
Calcareous Nannofossils, Site 233

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Ceratolithus cristatus*	*Ceratolithus rugosus*	*Coccolithus pelagicus*	*Crenalithus doronicoides*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster brouweri*	*Discoaster divaricatus*	*Discoaster pentaradiatus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera scutellum*	*Pseudoemiliania lacunosa*	*Reticulofenestra pseudoumbilica*	*Sphenolithus abies*	*Umbilicosphaera sibogae*
Pleistocene	*G. oceanica*	1-4, 130	C	G	E-1					F										F	C	F			R				F
		2-4, 120	C	G	E-1			F		F										C	F	F			R	F			F
	G. caribbeanica	4-3, 130	C	G	E-1				C	C										C		C			R	F			
		5-6, 120	C	G	E-1				C	C										F		C				F	R	R	
	P. lacunosa	7-5, 110	C	G	E-1			C	C	C												F			R	F			
		8-4, 109	C	G	E-1			C	C	C												F			F	F			
		9-6, 108	C	G	E-1			C	C	C			R									F				F			
Late Pliocene	*C. macintyrei*	10-6, 110	C	G	E-1			C	C	C	F		F									C	R			F			
		11-6, 118	C	G	E-1			C	C	F	F		F									C			R	F			
		12-6, 110	C	G	E-1			C	C	F	F		C									C			R	F			
		13-6, 119	C	G	E-1			C	C	F	F		C									F				F	R		
		14-1, 50	C	G	E-1	R		C	C	C	F		C									F				R			
	Discoaster pentaradiatus	15-6, 109	C	G	E-1			F	C	C	F		C		F							F							
		16-6, 108	C	G	E-1		R	F	C	C	F		F	R	F	F			F			F							
		18-5, 110	C	G	E-1		R	F	C	C	F		C		F	F	R		F			F		R					
		19-5, 107	C	G	E-1		R	F	C	F	F		C		F	R		R				F		R					
		1A-4, 119	C	G	E-1		R	F	C	F	F		F		R	R			R			F							
		2A-2, 60	C	G	E-1		R	F	C	F	F		F		R	R			R			F		R					
		3A-6, 110	C	G	E-1			F	C	F	F	R	F		R	R	R		R			F							
		4A-4, 100	C	G	E-1			F	C	F	F		F		R	R			R			F		R					
	D. tamalis	5A-4, 106	F	M	E-1			F	C	F	R		R	R	R	R	R		R			F							
		6A-2, 19	F	M	E-1			F	C	C	R		R	R	R	R	R		R			C							
		7A-5, 60	F	P	E-1				C	F	R		R																

Discoaster deflandrei, and *Reticulofenestra pseudoumbilica* (with covered central areas). This assemblage is typical of the *Discoaster exilis* to *Sphenolithus heteromorphus* Zone.

Preservation: All the assemblages recovered from soft sediments at this site show slight etching resulting in serrate margins of coccoliths and sometimes destruction of central area elements. Delicate forms like *Pontosphaera* and *Scyphosphaera* are preserved. The sediment interbedded with basalt contains highly overgrown nannofossils with almost unrecognizable discoasters and considerably altered placoliths. *Reticulofenestra pseudoumbilica* has a strongly overgrown central area giving it an appearance similar to *Reticulofenestra bisecta*.

SITE 232
(lat 14°28.93′N, long 51°54.87′E, water depth 1758 m)

Two holes were drilled at this site which is located on the lip of the western flank of the Alula-Fartak Trench at the eastern entrance to the Gulf of Aden. The section is Quaternary to late Miocene in age and consists of gray hemipelagic mud with occasional thin sand layers throughout the section and a layer of siltstone and sandstone in the uppermost Miocene. Basaltic basement was not reached. Nannoplankton assemblages are rich and diversified and reworked forms occur throughout a larger part of the section.

TABLE 8
Calcareous Nannofossils, Site 234

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Coccolithus* cf. *pelagicus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster calcaris*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster druggii*	*Discoaster exilis*	*Discoaster* cf. *lidzii*	*Discoaster neohamatus*	*Discoaster pentaradiatus*	*Discoaster signus*	*Discoaster surculus*	*Discoaster variabilis*	*Helicopontosphaera kamptneri*	*Reticulofenestra abisecta*	*Reticulofenestra bisecta*	*Reticulofenestra pseudoumbilica*	*Sphenolithus abies*	*Sphenolithus belemnos*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Triquetrorhabdulus carinatus*
E. Plio.	*R. pseudoumb.*	1-1, 45	C	P	E-3		F		C		C	F	F			C								C		F	C				F					
Late Mio.	*D. bellus*	1-6, 100	C	P	E-3			F			F		F	C	C	C	F						C				C	R			F	C				
		2-2, 45	B																																	
		3-2, 50	B																																	
		4-2, 37	B																																	
Mid. Mio.	*S. heteromorphus*	5-3, 70	C	P	E-3					C	C	F			F			F			C				F		C							F		
Early Miocene	*D. druggii*	6-2, 27	C	P	E-3					C								F	F	R																R
		6-6, 100	B																																	
		7-1, 50	B																																	
		7-6, 100	B																																	
		8-2, 75	B																																	
		9-1, 49	B																																	
	T. carinatus	9-2, 104	C	P	E-3	F				C								C															F		C	C
Late Oligocene	*R. abisecta*	10-3, 49	C	P	E-3	F				C								F											C				F		C	C
		10-4, 99	B																																	
		11-1, 98	C	P	E-3	F				C								F				R							F				R		F	F
		11-3, 99	B																																	
	S. ciperoensis ?	12-1, 85	C	P	E-3	F				C								F				R							F	R					F	R
		12-5, 106	B																																	
	?	13-1, 48	C	P	E-3					C								R	F										F	R						
		13-5, 39	R	P	E-3					C									R										R							
?		14-2, 68	B																																	
		15-2, 48	B																																	
		15-3, 63	R	P	E-3					F																										

Cores 1 to 5 are assigned to the *Gephyrocapsa oceanica* Zone. They contain common *Gephyrocapsa oceanica, G. caribbeanica, Umbilicosphaera sibogae,* and *Pontosphaera discopora. Pseudoemiliania lacunosa* is present in the lower part of this zone (Cores 3 to 5). The *Gephyrocapsa caribbeanica* Zone with *Gephyrocapsa caribbeanica, Crenalithus doronicoides,* and *Coccolithus pelagicus* occurs in Cores 6 and 7. This high range of *Coccolithus pelagicus* in fairly large numbers which are thus probably not reworked is unusual and suggests cool water. The *Pseudoemiliania lacunosa* Zone was recovered in Cores 8 and 9 with an assemblage including *Pseudoemiliania lacunosa* and *Crenalithus doronicoides.* The Pliocene/Pleistocene boundary based on nannofossils lies between Cores 9 and 10. Core 10 belongs to the *Cyclococcolithina macintyrei* Zone and contains *Cyclococcolithina macintyrei, Discoaster brouweri,* and rare specimens of the Eocene *Discoaster barbadiensis.* The *Discoaster pentaradiatus* Zone is present in Cores 11 through 14 with *Discoaster brouweri, D. pentaradiatus, D. surculus,* and *Ceratolithus rugosus.* The *Discoaster tamalis* Zone was recovered in Cores 15 and 16.

The *Reticulofenestra pseudoumbilica* Zone is quite thick and includes Cores 17 and 19 and 1A to 3A. There might be some overlap between the two holes so that this interval seems thicker than it is. Assemblages contain common *Reticulofenestra pseudoumbilica, Sphenolithus abies,* and *Ceratolithus rugosus.* The *Ceratolithus rugosus* Zone with both *Ceratolithus rugosus* and *C. tricorniculatus* present was found in Core 9A and the *Ceratolithus acutus* Zone with *C. acutus* and *C. tricorniculatus* in Cores 10A and 11A. Reworked Miocene discoasters occur in Cores 8A, 10A, and 11A. The Pliocene/Miocene boundary based on calcareous nannofossils lies between Cores 11A and 13A. The *Ceratolithus tricorniculatus* Zone of late Miocene age was recovered in Cores 13A through 19. Assemblages include *Ceratolithus tricorniculatus, C. primus,* and *Triquetrorhabdulus rugosus.* The assemblages above and below the indurated siltstone and sandstone bed are almost identical. Cores 20A through 26 belong to the *Ceratolithus primus* Zone with an assemblage including *Ceratolithus primus, Discoaster quinqueramus, D. berggrenii,* and *D. intercalaris.*

TABLE 9A
Calcareous Nannofossils, Site 235

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section Interval (cm)	Abundance	Preservation			*Ceratolithus cristatus*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Coccolithus* cf. *pelagicus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Cyclolithella annula*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster blackstockae*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster deflandrei*	*Discoaster exilis*	*Discoaster hamatus*	*Discoaster kugleri*	*Discoaster neohamatus*	*Discoaster pentaradiatus*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera scutellum*	*Pontosphaera* cf. *syracusana*	*Pseudoemiliania lacunosa*	*Reticulofenestra pseudoumbilica*	*Reticulofenestra reticulata*	*Reticulofenestra umbilica*	*Rhabdosphaera clavigera*	*Scyphosphaera apsteinii*	*Scyphosphaera globulata*	*Scyphosphaera pulcherima*	*Sphenolithus abies*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Triquetrorhabdus rugosus*	*Umbilicosphaera sibogae*
	G. oceanica	1-1, 100	A	G	E-1	O-1										C		R																			C	F			R						F								C
Quaternary	*G. caribbeanica*	2-2, 34	A	G	E-1	O-1	F					R		C		C																			R	C		F	F		F		F		R	R									C
	P. lacunosa	3-4, 100	A	G	E-1	O-1								C		C																						F			F		F												F
		4-4,.106	A	G	E-1	O-1	F							C		C																						F			F		F												F
Late Pliocene	*C. macintyrei*	5-6, 99	A	G	E-1	O-1			F			F		C		F	F							C										R				C		F															
	D. tamalis	7-4, 90	A	G	E-1	O-1			F		R			C		C	F							C						C		F	F	R				C	F	R															
Early Pliocene	*R. pseudoumb.*	8-1, 96	A	G	E-1	O-1								C		F	F		R					C						F		F	R		C			F	R					F											
	C. rugosus	9-1, 57	A	G	E-1	O-1			F	F		F		C		F	F							C						F		C			C			F		R				C				R	R	R	F				
Late Miocene	*C. primus*	10-1, 46	C	M	E-1	O-1		F					F	C		F	F				R		F	C							C	C		R	C			C						C							C			F	
		11-5, 99	C	M	E-1	O-1		F					C	C		F	F				F		C	F							C	C			C			F				R		C							C				
	D. bellus	12-1, 98	C	M	E-1	O-1							F			F	F			F			C	F					C						C			C						C							F			F	
Middle Miocene	*D. hamatus*	13-1, 49	C	M	E-1	O-1							F			F	F					R	C	F			C		F						C			C						C							R				
		13-3, 109	B																																																					
	D. kugleri	14-2, 34	C	M	E-1	O-1							F			F	F						F			C		F							C			C		R				C										F	
		15-4, 108	C	M	E-1	O-1					C				C										F	C									C			F				R											C	C	F	
	S. heteromorphus	15, CC	C	M	E-1	O-1					C				C											F									C			C															F	F		
		16-1, 136	B																																																				

TABLE 9B
Calcareous Nannofossils, Site 235

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see test for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Cretarhabdus crenalatus*	*Markalius inversus*	*Micula decussata*	*Micula mura*	*Prediscosphaera cretacea*	*Watznaueria barnesae*
L. Maastr.	?*Micula mura*	17, CC	R	P	0-3			R			R
		18-1, piece 5	F	P	0-3	R		F	R	R	F
		20-1, 3	R	P	0-3		R	R			R
		20-1, 85	R	P	0-3			R			R

Preservation: The state of preservation is similar as at Site 231. Slight etching of coccoliths leading to serrate margins was observed. Since the present water depth is quite shallow, the high organic content in the sediment must be responsible for this etching. *Pontosphaera* is present in many samples throughout the entire section, *Scyphosphaera* occurs only rarely in the Upper Miocene.

SITE 233
(lat 14°19.68′N, long 52°08.11′E, water depth 1860 m)

This site is located on the eastern flank of the Alula Fartak Trench. Two holes were drilled and a total of 271 meters of sediment was penetrated. The section consists of gray hemipelagic nannofossil muds resting on diabase. Nannofossils are common throughout the section, and there are fewer reworked forms than in other sites in the Gulf of Aden. Cores 1 and 2 recovered the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa oceanica, G. caribbeanica,* and *Umbilicosphaera sibogae. Pseudoemiliania lacunosa* only occurs in Core 2. Cores 4 and 5 belong to the *Gephyrocapsa caribbeanica* Zone and contain assemblages including *Gephyrocapsa caribbeanica, Crenalithus doronicoides* and *Pseudoemiliania lacunosa.* Assemblages typical of the *Pseudoemiliania lacunosa* Zone were found in Cores 7 through 9. The Pliocene/Pleistocene boundary based on calcareous nannofossils lies between Cores 9 and 10. Cores 10 through 14 are assigned to the *Cyclococcolithina macintyrei* Zone based on the presence of *Discoaster brouweri* and *Cyclococcolithina macintyrei.* The *Discoaster pentaradiatus* Zone is present in Cores 15 through 19 and Cores 1A through 4A and probably appears thicker due to some overlap of the two holes drilled at this site. The assemblages include *Discoaster brouweri, D. pentaradiatus, D. surculus,* the last mentioned species disappears below the top of this zone, i.e., in Core 16. Cores 5A through 7A recovered the *Discoaster tamalis* Zone with *Discoaster tamalis, D. pentaradiatus, D. surculus,* and *D. brouweri.*

Preservation: As at all the other Gulf of Aden sites slight etching was observed in all the assemblages. The margin of placoliths is often serrate, sometimes central areas are enlarged or central structures dissolved. *Pontosphaera* was observed throughout the section but *Scyphosphaera* which is another delicate form was not found.

NORTHWEST INDIAN OCEAN SITES (SOMALI BASIN, MASCARENE PLATEAU, CENTRAL INDIAN RIDGE, CHAGOS-LACCADIVE RIDGE)

Nannofossil assemblages from all these open-ocean sites far removed from large land masses differ from the assemblages encountered at the Gulf of Aden sites. Due to the greater water depth at some of the sites and to the greater age of parts of the section, dissolution (etching) and reprecipitation (overgrowth) play a larger part in determining the observed composition of the assemblages. Other differences are explained by different paleoecological conditions. In general the genus *Ceratolithus* is more common in these open-ocean sites and *Ceratolithus cristatus* is commonly observed in the Quaternary. It is possible that the increased salinity in the Gulf creates unfavorable conditions for this group. *Coccolithus pelagicus* is less common and there is not such a distinctive increase in abundance in the upper Pliocene. *Discoaster intercalaris* was only observed at the Gulf of Aden sites.

BRAARUDOSPHAERIDS IN THE INDIAN OCEAN

Pentaliths belonging to the genera *Braarudosphaera, Micrantholithus,* and *Pemma* occur commonly in the upper Paleocene, the lower and middle Eocene, the lower and upper Oligocene, and rare specimens occur in the uppermost Miocene (at Site 238 only). These pentaliths occur over a fairly wide area at Sites 236, 237, 238, and at several sites cored during other Indian Ocean legs (H. R. Thierstein and D. Bukry, personal communication). Similar sediments containing even larger numbers of *Braarudosphaera* occur in the southern Atlantic (Maxwell et al., 1970). They are of early to late Oligocene age and are thus equivalent in age to the youngest *Braarudosphaera*

TABLE 10A
Calcareous Nannofossils, Site 236

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation			*Ceratolithus cristatus*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Coccolithus* cf. *pelagicus*	*Coronocyclus serratus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster calcaris*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster druggii*	*Discoaster exilis*	*Discoaster hamatus*	*Discoaster neohamatus*	*Discoaster pentaradiatus*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Pontosphaera japonica*	*Pontosphaera* cf. *multipora*	*Pontosphaera scutellum*	*Pseudoemiliania lacunosa*	*Reticulofenestra abisecta*	*Reticulofenestra bisecta*	*Reticulofenestra pseudoumbilica*	*Scyphosphaera apsteinii*	*Scyphosphaera conica*	*Scyphosphaera globulata*	*Scyphosphaera intermedia*	*Sphenolithus abies*	*Sphenolithus belemnos*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus rugosus*
Quart.	*G. oceanica*	1-1, 122	A	G	E-1		F									R	C																				C	C	C					R												
	G. caribbeanica	2-1, 99	A	G	E-1		C										C																				C		C			R	F													
	P. lacunosa	3-1, 48	A	G	E-1		F								C		C						R																F				F		R											
	C. macintyrei	3-3, 99	A	G	E-1	O-1			F			F			C		C	C					C																C						R											
Early Pliocene	*R. pseudoumbilica*	4-1, 55	A	M	E-2	O-1			F			F			C		F	F	R				C								C		F		F				F							F										
	C. rugosus	4-5, 91	A	G	E-1	O-1		R	F	R		F			C		C	C					C								C		F			F			F							F					F					
		5-1, 137	A	G	E-1	O-1		R	F	R		F			C		C	C	F				C								C		F	F	R	C			F	R						C		R		F	C					
Late Miocene	*C. tricorniculatus*	6-1, 84	A	G	E-1	O-1		R		F			F				F	F	R				C								C		C			C			C							C					C					F
	Ceratolithus primus	7-1, 49	A	G	E-1	O-1		F					F				F	F					C								C	C	C			C			F							C					C					F
		8-6, 107	A	G	E-1	O-1		F					F				C	C	R			F	C								C	C	C			C			C							C					C					C
		9-5, 99	A	M	E-1	O-2		F					F				F	F				F	C								F	C	C			C			C							C					C					F
		10-5, 97	A	G	E-1	O-1		F					F				F	F	R			F	C								F	C	C			C			C	R						C	R		R	R	C					F
		11-2, 99	A	G	E-1	O-1		F					F				F	F				F	C								F	C	C			F			F							F					C					F
		12-6, 98	A	G	E-1	O-1		R					F				F	F				F	C			R					F	C	C			C			F							F					C					F
	D. berggrenii	13-6, 123	A	G	E-1	O-1							F				F	F			C	F	C									F	F			C			F		R					C					C					F
	D. bellus	14-3, 109	A	G	E-1	O-1							F				F	F		C		C								C						C										C	C				C			C		F
Middle Miocene	*D. hamatus*	15-6, 94	A	G	E-1	O-1							F				F	F				C		F					C	F						C										C								C		F
		16-1, 58	B																																																					
		16-6, 102	B																									C																												
	S. heteromorphus	17-6, 98	C	M	E-2						F					C	F	F				F				F										C																	F	F		
Early Miocene	*?H. ampliaperta*	18-1, 45	F	P	E-2						F					C									F	F																										F	R	C		
	D. druggii	18-6, 11	A	M	E-1	O-2					F					C									C	C	F																			F						F		C	F	
		19-3, 95	A	M	E-1	O-2					F			F		C									C		C																									R		C	C	

TABLE 10B
Calcareous Nannofossils, Site 236

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation			*Braarudosphaera bigelowii*	*Bramletteius serraculoides*	*Campylosphaera dela*	*Chiasmolithus consuetus*	*Chiasmolithus danicus*	*Chiasmolithus grandis*	*Chiasmolithus solitus*	*Coccolithus cavus*	*Coccolithus crassus*	*Coccolithus cribellum*	*Coccolithus eopelagicus*	*Coccolithus* cf. *pelagicus*	*Cyclicargolithus floridanus*	*Cyclicargolithus pseudogammation*	*Cyclococcolithina formosa*	*Discoaster barbadiensis*	*Discoaster deflandrei*	*Discoaster lodoensis*	*Discoaster* cf. *mirus*	*Discoaster mohleri*	*Discoaster multiradiatus*	*Discoaster nobilis*	*Discoaster nodifer*	*Discoaster saipanensis*	*Discoaster sublodoensis*	*Discoasteroides kuepperi*
Late Oligocene	*R. abisecta*	20-5, 98	A	M	E-1	0-2											F		C				C									
	S. ciperoensis	21-6, 99	A	M	E-1	0-1											C		C				C									
	S. distentus	22-1, 115	A	M	E-1	0-1											C		C				C									
		23-1, 73	A	M	E-1	0-1	R										C		C				C									
Early Oligocene	*S. predistentus*	23-6, 110	A	M	E-1	0-2											C		C				C									
		24-6, 117	A	M	E-1	0-2		F									C		C				C						F			
	H. reticulata	25-6, 99	A	M	E-1	0-2	F										C		C			R	F						F	R		
	E. subdisticha	26-6, 102	A	M	E-1	0-2	F	C									C		C		F		F									
		27-2, 33	A	M	E-1	0-2		F									C		C		F	R	F						F			
L. Eocene	*D. barbadiensis*	28-1, 127	A	M	E-1	0-2		R									C		C		F	C							F	C		
M. Eocene	*D. sublodoensis*	29, CC	C	M	E-1	0-2			R			F	F		F	R		C		C	C	C		F	F						C	C
E. Eocene	*D. lodoensis*	30, CC	R	P		0-3																F		F	F							
		31, CC	C	M	E-1	0-2				F		F			F			C		F	F	C										F
L. Paleocene	*D. multiradiatus*	32-3, 47	F	M	E-1	0-2								F										F	F		F	F				
	D. mohleri	33-3, 68	C	M	E-1	0-2					F			C												F						

Core, Section, Interval (cm)	*Ellipsolithus macellus*	*Ericsonia subdisticha*	*Fasciculithus involutus*	*Fasciculithus tympaniformis*	*Helicopontosphaera compacta*	*Helicopontosphaera reticulata*	*Micrantholithus flos*	*Pemma* cf. *rotunda*	*Reticulofenestra abisecta*	*Reticulofenestra bisecta*	*Reticulofenestra reticulata*	*Reticulofenestra scrippsae*	*Reticulofenestra umbilica*	*Sphenolithus anarrhopus*	*Sphenolithus belemnos*	*Sphenolithus ciperoensis*	*Sphenolithus distentus*	*Sphenolithus moriformis*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Sphenolithus radians*	*Towenus craticulus*	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus inversus*	*Zygodiscus plectopons*
20-5, 98									C						R			C					C		
21-6, 99									C	C						F	R	C					F		
22-1, 115									C	C						R	C	C	F						
23-1, 73									F	C							C	C	F	R					
23-6, 110		F			R					C							R	C	C	F					
24-6, 117		F			R					C							R	C	C	F					
25-6, 99		F			R	R				C			F					C	C						
26-6, 102		F						F		C			F					C	C	F					
27-2, 33		F				R	R	R		C			F					C	F						
28-1, 127										F	C	C	C					C							
29, CC																		C			C			F	
30, CC																		C							
31, CC	R																				F				
32-3, 47																									
33-3, 68			F	C										F				C				C			C

TABLE 11A
Calcareous Nannofossils, Site 237

Legend:
Abundance/distribution:
- A – abundant
- C – common
- F – few
- R – rare
- B – barren

Preservation
- G – good
- M – moderate
- P – poor

(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation			*Braarudosphaera bigelowii*	*Bramletteius serraculoides*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Coccolithus* cf. *pelagicus*	*Coronocyclus serratus*	*Crenalithus doronicoides*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster druggii*	*Discoaster exilis*	*Discoaster kugleri*	*Discoaster neohamatus*	*Discoaster* cf. *neorectus*	*Discoaster nodifer*	*Discoaster pentaradiatus*	*Discoaster prepentaradiatus*	*Discoaster quinqueramus*
Quaternary	*E. huxleyi*	1-1, 108	A	G		X												C																	
	G. oceanica	2-1, 58	A	G		X												C																	
Late Pliocene	*D. tamalis*	4-1, 49	A	G		X				F			F			C		C	C					C										C		
		5-1, 49	A	G		0-1				F			C			C		C	C					C										C		
	R. pseudoumbilica	6-1, 49	A	G		X				F			C			C		C	C	F				C										C		
		7-2, 48	A	G		0-1				F			C					C	C					C										C		
		8-1, 50	A	G		0-1				F			C					C	C					C										C		
E. Pliocene	*C. rugosus*	9-1, 49	A	G		0-1			F	F	F		C					C	C					C										C		
Late Miocene	*C. primus*	10-1, 97	A	G	E-1	0-1			F					C				C	C			R		C										C		F
		11-1, 48	A	G	E-1	0-1			F					F				C	C			F	C	C										F		C
		12-1, 49	A	M	E-1	0-2			F					C				F	F			F	C	F												C
	D. neohamatus	13-1, 49	A	M	E-1	0-2								C				F	F		F									C	F			F	
	D. bellus	14-1, 49	A	M	E-1	0-2								C				C	C		C					F				C					
Middle Miocene	*D. kugleri*	15-1, 129	A	M	E-1	0-2						F		C				C	C							C		F	F						
	D. exilis	16-1, 50	A	M	E-1	0-2						C					C	F	R							C		C							
	S. heteromorphus	17-1, 49	A	M	E-1	0-2						C					C	F	R							C		C							
E. Miocene	*H. ampliaperta*	18-1, 133	A	M	E-1	0-2						F					C								C	C									
		19-1, 48	A	M	E-1	0-2						F			F		C								C	C									
	D. druggii	20-1, 48	A	M	E-1	0-2						F					C								C		F								
L. Oligocene	*S. ciperoensis*	21-1, 50	A	M	E-1	0-2						C					C								C										
		22-1, 100	A	M	E-1	0-1						F					C								C										
E. Oligocene	*H. reticulata*	23-1, 45	A	M	E-1	0-1	R	F				C					C															F			

Core, Section, Interval (cm)	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster variabilis*	*Discoaster woodringii*	*Emiliania huxleyi* (?)	*Ericsonia subdisticha*	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Pontosphaera japonica*	*Reticulofenestra abisecta*	*Reticulofenestra bisecta*	*Reticulofenestra pseudoumbilica*	*Reticulofenestra scrippsae*	*Reticulofenestra umbilica*	*Rhabdosphaera clavigera*	*Scyphosphaera apsteinii*	*Scyphosphaera intermedia*	*Scyphosphaera pulcherima*	*Sphenolithus abies*	*Sphenolithus belemnos*	*Sphenolithus ciperoensis*	*Sphenolithus dissimilis*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus rugosus*
1-1, 108					C			C	F																				
2-1, 58							C	F	F							F													
4-1, 49	F	F							F																				
5-1, 49	F	F							F																				
6-1, 49	C		F						F				F				R			C									
7-2, 48	C		F						F				C				F			C									
8-1, 50	C		F						F				C				F			C									
9-1, 49	C		F						C				C				F			C									F
10-1, 97	C		F						F	R			C				F			C									F
11-1, 48	C		F						C				C					R		C									F
12-1, 49	F		F						F				C							C									F
13-1, 49									C				C						R	C									F
14-1, 49									F				C							C									F
15-1, 129									F				C												C				F
16-1, 50									F																C				F
17-1, 49									F										R					C	C				F
18-1, 133				C					F															C	C				
19-1, 48				C					F			R												C	C				
20-1, 48				C					R						R						F		C		C			C	
21-1, 50				C		F					C	F										F			C			C	
22-1, 100				F							C	F										F	C		C			C	
23-1, 45						F						C		C	C											C	F	F	

TABLE 11B
Calcareous Nannofossils, Site 237

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B – barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation			*Biantholithus sparsus*	*Bomolithus elegans*	*Braarudosphaera bigelowii*	*Braarudosphaera discula*	*Bramletteius serraculoides*	*Chiasmolithus bidens*	*Chiasmolithus californicus*	*Chiasmolithus consuetus*	*Chiasmolithus danicus*	*Chiasmolithus gigas*	*Chiasmolithus grandis*	*Chiasmolithus solitus*	*Coccolithus cavus*	*Coccolithus eopelagicus*	*Cruciplacolithus tenuis*	*Cyclicargolithus cf floridanus*	*Cyclococcolithina formosa*	*Discoaster barbadiensis*	*Discoaster collettii*	*Discoaster diastypus*	*Discoaster hillii*	*Discoaster mohleri*	*Discoaster multiradiatus*	*Discoaster saipanensis*	*Discoaster sublodoensis*	*Discoaster tanii*	*Discoaster wemmelensis*	*Discoaster woodringii*	*Ellipsolithus macellus*	*Ericsonia subdisticha*	*Fasciculithus pileatus*	*Fasciculithus tympaniformis*	*Fasciculithus cf ulii*	*Heliolithus kleinpellii*	*Micrantholithus flos*	*Micrantholithus obscurus*	*Nannotetrina cristata*	*Nannotetrina fulgens*	*Neochiastozygus concinnus*	*Prinsius bisulcus*	*Reticulofenestra bisecta*	*Reticulofenestra reticulata*	*Reticulofenestra scrippsae*	*Reticulofenestra umbilica*	*Sphenolithus anarrhopus*	*Sphenolithus furcatolithoides*	*Sphenolithus moriformis*	*Sphenolithus predistentus*	*Sphenolithus radians*	*Thoracosphaera prolata*	*Toweius craticulus*	*Tribrachiatus orthostylus*	*Triquetrorhabdulus inversus*	*Zygodiscus plectopons*	*Zygodiscus sigmoides*	*Zygodiscus simplex*	*Zygodiscus* sp	*Zygolithus protenus*	*Zygolithus* sp
Middle Eocene	*C. grandis*	24-1, 39	C	M	E-1	0-1					F						C			C		C	C	C								F																			F	F	C	C			C												
	C. solitus	25-1, 48	C	M	E-1	0-1					F						C	F		C		C	C	C			F			F																								C			C	R	F	F									
		26-1, 98	C	M	E-1	0-2					F						C	F		C		C	C	C			C																											F		F	C		C	F									
	Chiasmolithus gigas	27-1, 80	C	M	E-1	0-2					F					F	C	F		C		C	C	C	F								F																							F	C		F	F									
		28-1, 49	C	M	E-1	0-2					F					F	C	R		C		C	C	C												F																					C		F				C						
		29-1, 49	C	M	E-1	0-2										F	F	R		C		C	C	C																																	C		F	F			C						
		30-1, 50	C	M	E-1	0-2										F	C	F		C		C		C														F				R	R													C		F	F			C						
		31-1, 108	C	M	E-1	0-2										F	C			C		C		C						C													F	F												C		F				C						
		32-2, 48	C	M	E-1	0-2			F							F	F			C		C		F	F																														F	F		F	F			C						
	?D. sublodoensis	36-1, 130	C	M	E-1	0-2			C								F			C				F							F			R	F						C														F	C		C										
Late Eocene	*T. orthostylus*	37-1, 133	C	P	E-1	0-2			F	F							F			F				C		C															F														F	C		C			R							
	D. diastypus	38-1, 90	C	P	E-1	0-2			F					F			F			C				F		F							F		F																					C		C										
Late Paleocene	*D. multiradiatus*	41-1, 70	C	P	E-1	0-2		F					F	F					C									F	F						F			F															C				C								
	H. kleinpellii	43-2, 105	C	P	E-1	0-2							F	F					C																R			R	R	F																	C						F		
		44-1, 85	C	P	E-1	0-2			F				F	F					C																			F		F					F								F				C						F		
	Fasciculithus tympaniformis	45-1, 68	C	M	E-1	0-2			F					F					C																F			F			F				F	F					F		F				C								
		46-2, 75	C	P	E-1	0-2				R		F		F					C																F			F			R				F												C			F		F			
		47-2, 66	C	P	E-1	0-2								F					C																			F							F	C											C			F					
		48-1, 98	C	P	E-1	0-2						F	F	F					C																		F	F							F	F											C			F					
		49-2, 90	C	P	E-1	0-2									F				C																		F	F	F						F	C											C			F					
		50-1, 70	C	P	E-1	0-2									F				C		R																F	F	F							C							C				C						F		F
		51-2, 53	C	P	E-1	0-2									F				C		F																F	F	F							C											C					F	F	R	
Early Paleocene	*C. tenuis*	52-1, 105	C	P	E-1	0-2	R								F				C		F																									C											C			F			F		
		53-2, 82	R	P	E-1	0-2									F				F		F																									F											F						F		
		54-1, 120	F	P	E-1	0-2									F				C		F																									C											F			F					

TABLE 12A
Calcareous Nannofossils, Site 238

Legend:
Abundance/distribution:
- A – abundant
- C – common
- F – few
- R – rare
- B – barren

Preservation:
- G – good
- M – moderate
- P – poor

(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation		*Braarudosphaera bigelowii*	*Ceratolithus amplificus*	*Ceratolithus acutus*	*Ceratolithus cristatus*	*Ceratolithus primus*	*Ceratolithus rugosus*	*Ceratolithus tricorniculatus*	*Coccolithus eopelagicus*	*Coccolithus pelagicus*	*Coccolithus* cf *pelagicus*	*Crenalithus doronicoides*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster asymmetricus*	*Discoaster bellus*	*Discoaster berggrenii*	*Discoaster braarudii*	*Discoaster brouweri*	*Discoaster calcaris*	*Discoaster challengeri*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster hamatus*	*Discoaster neohamatus*	*Discoaster* cf *neorectus*	*Discoaster pentaradiatus*	*Discoaster prepentaradiatus*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster tamalis*	*Discoaster triradiatus*	*Discoaster variabilis*	*Emiliania huxleyi* (?)	*Gephyrocapsa oceanica*	*Helicopontosphaera kamptneri*	*Pontosphaera japonica*	*Pontosphaera scutellum*	*Pseudoemiliania lacunosa*	*Reticulofenestra bisecta*	*Reticulofenestra pseudoumbilica*	*Rhabdosphaera clavigera*	*Scyphosphaera apsteinii*	*Scyphosphaera cantharella*	*Scyphosphaera globulata*	*Scyphosphaera intermedia*	*Scyphosphaera pulcherima*	*Sphenolithus abies*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Syracosphaera* cf *pulchra*	*Triquetrorhabdulus rugosus*	*Umbilicosphaera sibogae*
Quaternary	*E. huxleyi ?*	1-6, 98	A	G	X									C			C						F				F											C	C	C							F										
	G. oceanica	2-6, 132	A	G	X				F								F																						C	C																	
	P. lacunosa	3-6, 125	A	G	X				F							C	C																							C		F	F			F					F				R		
Reworked or Mixed	*D. pentaradiatus*	4-1, 49	A	G	X						F					C	C	F					F				R		R		F			F			F			C	R		F								F						
	D. tamalis	4-6, 97	A	G	X						F			F		C	C	F	F				C								F			C			C			C			F				R										
	R. pseudoumbilica	5-2, 88	C	G	X						F			F		C	C	C					C								F			F			F			C	F				F							F					
Late Pliocene	*C. macintyrei*	5-4, 98	C	G	X						F			F		C	C	C					F																	C		F	C				F				F						C
		6-4, 98	C	G	X						F			F		C	C	C					F																	C	R	F															
	D. pentaradiatus	7-6, 99	C	G	E-1	0-1					F			C		C	C	C	R				C								F			C			F			C																	
		8-2, 48	A	G	E-1	0-1					F			F		C	C	C					C								F			C		F	F			C							R				R				F		
	D. tamalis	9-1, 45	A	G	E-1	0-1					F			F		C	C	C	F				C								C			C	F	F	C			C	R						F										
		10-6, 98	A	G	E-1	0-1					F			C		C	C	F	F				C								C			C	F	F	C			C							F				R	R					
Early Pliocene	*R. pseudoumbilica*	11-1, 48	A	G	E-1	0-1					F			C			C	C	F				C								C			C		F	C			C					C		F		F		F	C					
	C. rugosus	12-6, 98	A	G	E-1	0-1				F	F	F			C		C	C	F				C								C			C		F	C			C					C		R				R	C				R	
		13-5, 108	A	G	E-1	0-1				F	F	F			C		C	C					C								C			C		F	C			C					C		F		F		F	C				R	
	C. acutus	14-5, 98	A	G	E-1	0-1			F		F		F			C		C	C					C								C			C		F	C			C					C		F				F	C				F	
		15-6, 99	A	G	E-1	0-1			F		F		F			C		C	C					C								C			C		F	C			C	R				C		F				F	C				F	
Late Miocene	*Ceratolithus primus*	16-6, 100	A	G	E-1	0-1		R			F					C		C	C	R		F		C								C		C	C		F	C			C	R				C		F		F		F	C				C	
		17-6, 98	A	G	E-1	0-1		R			F					C		C	C			F		C		F						F		C	C		F	C			C	R				C		F				F	C				F	
		18-6, 96	A	G	E-1	0-1		F			F					C		C	C	R		F		C								F		C	C		F	C			C					C		F		F	F	F	C				C	
		19-6, 98	A	G	E-1	0-1	F	F			F					C		C	C			F		C								F		C	C			C			C					C		R				F	C				F	
		20-6, 99	A	G	E-1	0-1					F					C		C	C			C		C		C						F		C	C			C			C					C		F				F	C				C	
	D. berggrenii	21-6, 99	A	G	E-1	0-1										C		C	C			C	F	C		F							F	F	C		F	C			C					C		F		F		R	C				C	
		22-6, 99	A	G	E-1	0-1										C		C	C			C	C	C		C					R		F	F	C		F	C			C					C		F				F	C				C	
		23-6, 98	A	G	E-1	0-1										C		C	C	R		C	C	C		C							F		F		F	C			C					C		F				R	C				F	
	D. neohamatus	24-6, 97	A	G	E-1	0-1								R		C		C	C		C		C	F	F					C	R		C					C			F					C		F		F	F	F	C	R			F	
	D. bellus	25-6, 98	A	G	E-1	0-1										C		C	C		C		C	F	F					C			C					C			F					C		F	F				C				F	
		26-2, 48	A	G	E-1	0-1										C		C	C		C		C	F	F		R			C			C					C			F					C		F					F		C		C	
		27-6, 95	A	G	E-1	0-1										C		C	C		C		C	F						C								C			F					C		F		F		F			F		C	
		28-6, 98	A	G	E-1	0-1										C		C	C		F		C	F						C								C			C					C		F		F					F		C	
Middle Miocene	*D. hamatus*	29-6, 108	A	G	E-1	0-1										C		C	C				C			F			C	C								C			C				R	C									F		C	
		30-6, 98	A	G	E-1	0-1										C		C	C				C		F	F			C	C								C			C					C									F		R	

TABLE 12B
Calcareous Nannofossils, Site 238

Legend:
Abundance/distribution:
A – abundant
C – common
F – few
R – rare
B barren
Preservation:
G – good
M – moderate
P – poor
(see text for explanation of preservation symbols: "X", "E–", and "O–".)

Age	Zone	Core, Section, Interval (cm)	Abundance	Preservation			*Braarudosphaera bigelowii*	*Coccolithus eopelagicus*	*Coccolithus* cf. *pelagicus*	*Coronocyclus serratus*	*Cyclicargolithus floridanus*	*Cyclococcolithina leptopora*	*Cyclococcolithina macintyrei*	*Discoaster challengeri*	*Discoaster deflandrei*	*Discoaster divaricatus*	*Discoaster druggii*	*Discoaster exilis*	*Discoaster variabilis*	*Discoaster woodringii*	*Ericsonia subdisticha*	*Helicopontosphaera bramlettei*	*Helicopontosphaera* cf. *euphratis*	*Helicopontosphaera kamptneri*	*Pontosphaera* cf. *alta*	*Reticulofenestra abisecta*	*Reticulofenestra bisecta*	*Reticulofenestra pseudoumbilica*	*Sphenolithus belemnos*	*Sphenolithus capricornutus*	*Sphenolithus ciperoensis*	*Sphenolithus distentus*	*Sphenolithus heteromorphus*	*Sphenolithus moriformis*	*Sphenolithus predistentus*	*Sphenolithus pseudoradians*	*Sphenolithus* cf. *spiniger*	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus milowii*
Middle Miocene	*Sphenolithus heteromorphus*	32-1, 48	A	M	E-1	0-2		F	C		C	F	F	F	C	C		C	F					F		R	R	F		R			C	C				R	
		33-1, 48	A	M	E-1	0-2		C	C	F	C	F	F	F	F	C		C	F					F				F					C	C					
		34-1, 57	A	M	E-1	0-2		F	C		C	F	F	F	F	C		C	F					F				F					C	C					
		35-1, 105	A	M	E-1	0-2		C	C		C	F	F	F	F	C		C	F					F				F					C	C					
		36-6, 98	A	M	E-1	0-2		C	C		C	F	F	C	F	C		C	C					R				C					C	C					
		37-6, 48	A	M	E-1	0-2		C	C		C	F	F		C	C		C	F					R				F					C	C					
		38-6, 48	A	M	E-1	0-2		C	C	F	C	F	F		C	C		C	F					R				F					C	C					
		39-2, 45	A	M	E-1	0-2		C	C		C	F	F		C	C		C		C				R				F					C	C					
Early Miocene	*H. ampliaperta*	40-1, 109	A	M	E-1	0-2		C		F	C				C	C		F															C	C					
		41-6, 100	A	M	E-1	0-2		C			C				C	F				C					R				F				C	C					
	D. druggii	42-4, 44	A	M	E-1	0-2		C		F	C				C		F			C									F					C				C	F
	T. carinatus	43-1, 70	A	M	E-1	0-2		C		F	C				C					C							R		F		R			C			R	C	
Late Oligocene	*Reticulofenestra abisecta*	44-1, 122	A	M	E-1	0-2		C			C				C					C			R			F	R		F					C				C	F
		45-1, 137	A	M	E-1	0-2		C			C				C					C						C			F					C				C	F
		46-3, 101	A	M	E-1	0-2		C			C				C					C						F			F					C				C	R
		47-4, 99	A	M	E-1	0-2		C			C				C					C			F			F			C	F	R			C				C	
		48-1, 116	A	M	E-1	0-2	F	C			C				C					C						C	R		C	F				C				C	
		49-2, 69	A	M	E-1	0-2		C			C				C					C	F					C	R		F		R			C				C	
	S. ciperoensis	50-4, 114	A	M	E-1	0-2	F	C			C				C					C	F				R	C	C				C	F		C				C	
		51-2, 56	A	M	E-1	0-2		C			C				C					C	F					C	F				C	C		C				F	
	S. distentus	52-2, 48	A	M	E-1	0-2		C			C				C					C	R					C	C				R	C		C					
		53-5, 103	A	M	E-1	0-2	C	C			C				C						R					C	C				R	C		C	F				
E. Oligocene	*S. predistentus*	54-1, 58	A	M	E-1	0-2	C	C			C				C						F	R					C							C	C	C			

containing sediments recovered during Leg 24. The reconstruction of the Indian Ocean and the southern Atlantic during the Paleogene (McKenzie and Sclater, 1971) shows that the south Atlantic and Indian Oceans were linked by a wide connection, whereas the Drake Passage and the sea connection between Australia and Antarctica were either closed or very narrow (see Figure 4). This might suggest that similar oceanographic conditions existed in the two ocean basins and that some water was exchanged. Similar deposits rich in pentaliths are not known from the open Pacific ocean.

The distribution of recent *Braarudosphaera bigelowii* is not too well known but reports by Gran and Braarud (1935), Gaarder (1954), Hulburt (1962), and Borsetti and Cati (1972) indicate that it was observed in coastal waters in large numbers and only rarely encountered in open-ocean plankton. Takayama (1972) shows in a study of sediment samples from Sendai Bay that *Braarudosphaera* is quite abundant in near-shore sediments from depths down to 24 meters, is quite common down to a depth of 100 meters, but becomes rare below 150-200 meters. Martini (1967) shows that *Braarudosphaera* is present in recent sediments from the Persian Gulf but is missing in the Arabian Sea. Ramsay (1971) notes the absence of *Braarudosphaeraceae* from sediments below 1600 meters water depth but thinks ecological control might be important and not just dissolution below that depth. Bramlette and Martini (1964) and Martini (1965) think the lowered salinity and higher

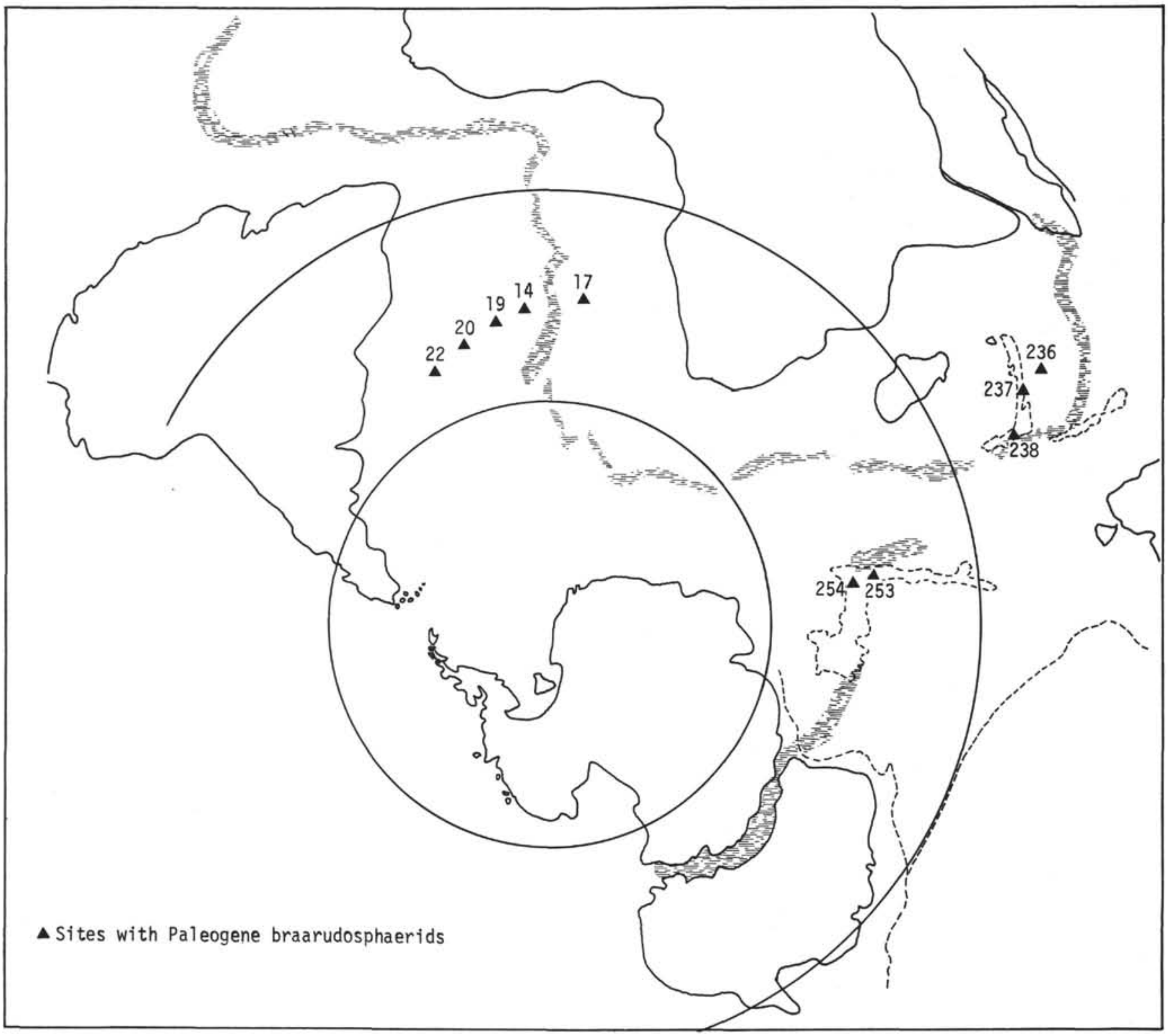

Figure 4. *Reconstruction of the Indian Ocean at 45 m.y. B.P. (McKenzie and Sclater, 1971) and the position of sites with Paleogene braarudosphaerids.*

turbidity of near-shore waters are preferred by this group. Bukry (in press) explains the presence of *Braarudosphaera bigelowii* in the Black Sea and its absence from the Red Sea by the ability of this species to thrive in unusually low salinities. Bukry also speculates that the *Braarudosphaera* chalk recovered from the Oligocene of the south Atlantic might have resulted from a prolonged ecologic effect such as reduced salinities from increased regional rainfall. Saito and Percival (in Maxwell et al., 1970, p. 445) give two possible explanations for the *Braarudosphaera* chalk in the south Atlantic: (1) "Bloom" conditions which lasted several hundred or a thousand years or (2) transportation of shallow-water sediments to deep water over a very wide area. The second explanation can probably be excluded because of an even wider geographic distribution of sediments rich in pentaliths known at the present time. Wise and Hsu (1971) postulate that special environmental conditions related to the Antarctic current system or temporary cooling lead to the exclusion of many tropical or subtropical phytoplankton species and resulted in unusually high production rate of *Braarudosphaera* during the Oligocene in the south Atlantic. Wise and Kelts (1972) give an extensive discussion of the *Braarudosphaera* chalk in the south Atlantic. They think special environmental conditions, perhaps unusual current conditions, triggered high production of *Braarudosphaera* which was also responsible for a lowering of the calcite compensation level and quick burial leading to subsequent preservation of the pentaliths. Not enough is known about the biology and life cycle of *Braarudosphaeraceae*. A benthic phase or a naked motile phase might occur (Bybell and Gartner, 1972) which would only produce pentaliths when conditions are favorable. The fact that *Braarudosphaera bigelowii* occurs in the Black Sea with surface salinities of 17°/₀₀ to 18°/₀₀ but also in the Persian Gulf with surface salinities of 34 to 40 per mil clearly indicates that we are far from understanding all the factors controlling the distribution of the braarudosphaerids. The presence of *Braarudosphaera* in Paleogene deposits of the open Indian and south Atlantic is still not fully understood. Special oceanographic conditions of a temporary nature leading to very high production of braarudosphaerids still seems to be the most likely explanation.

SITE 234
(lat 04°28.96′N, long 51°13.48′E, water depth 4738 m)

This site lies on a ridge flanking the western margin of the northwestern Somali Basin. The total penetration was 247 meters with nannofossil marl at the top and gray silty clays, some with nannofossils, others completely lacking fossils. Core 1, Section 1 recovered a poor assemblage belonging to the *Reticulofenestra pseudoumbilica* Zone with few specimens of *Reticulofenestra pseudoumbilica* together with *Discoaster brouweri, D. pentaradiatus, D. surculus,* and *D. variabilis.* Section 6 of the same core belongs to the late Miocene *Discoaster bellus* Zone with *Discoaster neohamatus, D. bellus, D. calcaris,* and *D. asymmetricus.* Cores 1, 3, and 5 lack nannofossils. Core 5 is middle Miocene with a poor assemblage of *Sphenolithus heteromorphus, Cyclicargolithus floridanus,* and *Discoaster exilis* which are characteristic of the *Sphenolithus heteromorphus* Zone. Cores 6, 7, and 8 are barren of nannofossils. Core 9 contains a poor assemblage belonging to the early Miocene *Triquetrorhabdulus carinatus* Zone with *Triquetrorhabdulus carinatus, Discoaster deflandrei,* and rare, small *Sphenolithus belemnos.* Cores 10 and 11 yield a similar assemblage which also includes *Reticulofenestra abisecta* and is thus assigned to the upper Oligocene *Reticulofenestra abisecta* Zone. Core 12 recovered the *Sphenolithus ciperoensis* Zone with rare *Triquetrorhabdulus carinatus, Sphenolithus ciperoensis,* and *Reticulofenestra bisecta.* Core 13 contains only long-ranging species like *Reticulofenestra abisecta, R. bisecta,* and *Discoaster deflandrei.* It cannot be assigned to any zone but is of late Oligocene age. Core 15 only yields *Cyclicargolithus floridanus* and cannot be dated.

Preservation: All assemblages are strongly etched and only solution-resistant species are common. This site must have been close to the calcite compensation depth throughout the time of deposition of the sediments recovered.

SITE 235
(lat 03°14.06′N, long 52°41.64′E, water depth 5146 m)

This site is located on the westernmost edge of the abyssal plain bordering the east flank of the Chain Ridge. It was cored discontinuously down to a depth of 684 meters. The sediment section is Quaternary to middle Miocene in age and consists of yellow-green to gray nannofossil mud resting on basalt which contains sediment inclusions of Late Cretaceous age.

Core 1 belongs to the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa oceanica* and *Umbilicosphaera sibogae.* Core 2 recovered the *Gephyrocapsa caribbeanica* Zone with *Gephyrocapsa caribbeanica* and *Crenalithus doronicoides.* Cores 3 and 5 are assigned to the *Pseudoemiliania lacunosa* Zone and yield an assemblage with *Pseudoemiliania lacunosa* and *Crenalithus doronicoides.* The Pliocene/Pleistocene boundary lies between Cores 4 and 5. Core 5 belongs to the Late Miocene *Cyclococcolithina macintyrei* Zone with *Discoaster brouweri* and *Cyclococcolithina macintyrei.* Core 7 recovered the *Discoaster tamalis* Zone with *Discoaster tamalis, D. surculus, D. pentaradiatus,* and *D. variabilis.* The *Reticulofenestra pseudoumbilica* Zone is present in Core 8 with *Reticulofenestra pseudoumbilica* and *Sphenolithus abies.* Core 9 yields an assemblage characteristic of the *Ceratolithus rugosus* Zone with *Ceratolithus rugosus* and *C. tricorniculatus.* The Miocene/Pliocene boundary lies between Cores 9 and 10. Cores 10 and 11 recovered the *Ceratolithus primus* Zone with *Ceratolithus primus* and *Discoaster quinqueramus.* The *Discoaster bellus* Zone with *Discoaster neohamatus* and *D. bellus* occurs in Core 12. Core 13 contains the *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus,* and rare *D. blackstockae.* Core 14 belongs to the *Discoaster kugleri* Zone with *Discoaster kugleri* and *D. exilis.* Core 15 recovered the *Sphenolithus heteromorphus* Zone with *Sphenolithus heteromorphus, Discoaster exilis,* and *Coccolithus eopelagicus.* Core 16 is barren of nannofossils. Sediment inclusions in the basalt in Cores 17, 18, and 20 contain rare nannofossils including *Micula* *decussata, M. mura, Markalius inversus,* and *Prediscosphaera cretacea* which indicate a late Maestrichtian age.

Preservation: Assemblages are moderately to well preserved with slight etching and overgrowth throughout the sedimentary section. The inclusions in the basalt contain strongly overgrown nannofossils.

SITE 236
(lat 1°40.62′S, long 57°38.85′E, water depth 4504 m)

This site is located 270 km northeast of the Seychelles Islands block. The sediment section is 328 meters thick and consists of nannofossil chalk oozes, with foraminiferal sands in the upper 140 meters, above 50 meters of nannofossil-bearing clays and chalk ooze, a 60-meter transition zone of nannofossil chalk ooze to chalk, and about 60 meters of chalk with chert resting on basalt. The section ranges in age from the late Paleocene to the Quaternary with substantial hiatuses in the lower Eocene and probably in the lower and middle Miocene.

Core 1 contains assemblages typical of the *Gephyrocapsa oceanica* Zone with the zonal marker and some reworked Oligocene. Core 2 belongs to the *Gephyrocapsa caribbeanica* Zone with *Gephyrocapsa caribbeanica, Pseudoemiliania lacunosa,* and *Crenalithus doronicoides.* Core 3 yields assemblages indicating the *Pseudoemiliania lacunosa* Zone in the upper part (Section 1) with *Pseudoemiliania lacunosa* and *Crenalithus doronicoides.* Core 3, Section 3 belongs to the late Pliocene *Cyclococcolithina macintyrei* Zone with *Discoaster brouweri* and *Cyclococcolithina macintyrei.* The Pliocene/Pleistocene boundary lies within Core 3. Core 4, Section 1 recovered the Early Pliocene *Reticulofenestra pseudoumbilica* Zone with *Reticulofenestra pseudoumbilica* and *Sphenolithus abies.* The lower part of Core 4 contains *Ceratolithus rugosus* together with *C. tricorniculatus* and *C. primus* indicating the *Ceratolithus rugosus* Zone. Core 6 recovered the *Ceratolithus tricorniculatus* Zone with *Ceratolithus tricorniculatus, C. primus,* and *Triquetrorhabdulus rugosus.* The Miocene/Pliocene boundary based on nannofossils lies between Cores 5 and 6. Cores 7 through 12 belong to the *Ceratolithus primus* Zone with assemblages including *Ceratolithus primus, Discoaster quinqueramus,* and *D. surculus.* Core 13 is assigned to the *Discoaster berggrenii* Zone based on the presence of *Discoaster berggrenii, D. quinqueramus,* and *D. surculus.* Core 14 recovered good *Discoaster bellus* Zone assemblages including *Discoaster neohamatus* and *D. bellus.* Core 15 belongs to the middle Miocene *Discoaster hamatus* Zone with *Discoaster hamatus, D. neohamatus,* and *D. calcaris* as the most important species. Core 16 lacks calcareous nannofossils and Core 17 is already in the lowermost part of middle Miocene, the *Sphenolithus heteromorphus* Zone with *Sphenolithus heteromorphus* and *Discoaster exilis.* Lower Miocene was recovered in Cores 18 and 19. The upper part of Core 18 contains *Sphenolithus belemnos* and *S. heteromorphus* and is probably best assigned to the *Helicopontosphaera ampliaperta* Zone although the marker is absent. The lower part of Core 18 and Core 19 contain *Discoaster druggii* and *Triquetrorhabdulus carinatus* and therefore belong to tthe *Discoaster druggii* Zone. The Oligocene/Miocene boundary based on nannofossils is drawn between Cores 19 and 20. Core 20 yields assemblages typical of the *Reticulofenestra abisecta* Zone with *Triquetrorhabdulus carinatus* and *Reticulofenestra abisecta.* Core 21 recovered the *Sphenolithus ciperoensis* Zone with *Sphenolithus ciperoensis, Triquetrorhabdulus carinatus,* and *Reticulofenestra bisecta.* Core 22 and the upper part of Core 23 belong to the *Sphenolithus distentus* Zone with common *Sphenolithus distentus,* rare *S. ciperoensis, Reticulofenestra abisecta* and in the lower part with rare *Braarudosphaera bigelowii.* Cores 23 and 24 are assigned to the early Oligocene *Sphenolithus predistentus* Zone with assemblages including *Sphenolithus predistentus, S. distentus,* and *Sphenolithus pseudoradians.* Core 25 contains *Reticulofenestra umbilica, Discoaster nodifer, Helicopontosphaera reticulata, Sphenolithus predistentus,* and *Braarudosphaera bigelowii,* together with some reworked Eocene discoasters. It belongs to the *Helicopontosphaera reticulata* Zone. Cores 26 and 27 recovered the *Ericsonia subdisticha* Zone with assemblages including *Cyclococcolithina formosa, Reticulofenestra umbilica, Ericsonia subdisticha,* and *Braarudosphaera bigelowii.* The Eocene/Oligocene boundary based on nannofossils lies between Cores 27 and 28. Core 28 yields assemblages typical of the late Eocene *Discoaster barbadiensis* Zone with *Discoaster saipanensis, D. barbadiensis,* and *Reticulofenestra reticulata.* Core 29 belongs to the *Discoaster sublodoensis* Zone and contains an assemblage including *Discoaster sublodoensis, D. lodoensis,* and *Discoasteroides kuepperi.* Most of the middle Eocene seems to be missing, and we have to assume the presence of an unconformity between Cores 28 and 29. Cores 30 and 31 recovered the *Discoaster lodoensis* Zone with *Discoaster lodoensis, Coccolithus crassus,* and *Chiasmolithus consuetus.* Parts of the lower Eocene are also missing because Core 32 belongs to the late Paleocene *Discoaster multiradiatus* Zone with poor assemblages including *Discoaster multiradiatus* and *D. nobilis.* The Paleocene/Eocene boundary is marked by an unconformity and lies between Cores 31 and 32. Core 33 recovered the *Discoaster mohleri* Zone with *Discoaster mohleri, Sphenolithus anarrhopus, Fasciculithus tympaniformis,* and *Chiasmolithus danicus.*

Preservation: The Quaternary assemblages are slightly etched and the Pliocene to upper middle Miocene assemblages show slight etching and overgrowth. Below a barren interval the lower middle and upper lower Miocene assemblages are moderately etched. The assemblages from the lower part of the lower Miocene, the Oligocene, and the middle and upper Eocene are slightly etched and show moderate overgrowths. Some layers in the lower Eocene contain nannofossils which are considerably altered by overgrowths and only discoasters are preserved. Other parts of the lower Eocene and the upper Paleocene are characterized by assemblages with slight etching and moderate overgrowths.

SITE 237
(lat 07°04.99′S, long 58°07.48′E, water depth 1640 m)

This site is located on the Mascarene Plateau in the saddle between the Seychelles and Saya de Malha bank. The section penetrated is 694 meters thick and consists of 300 meters of Quaternary to middle Eocene nannofossil ooze and about 400 meters of middle Eocene to lower Paleocene chalk with chert and some glauconitic horizons in the upper Paleocene. Nannofossils are common throughout the sediment section. Core 1 recovered an assemblage with many small placoliths, probably *Emiliania huxleyi* and *Gephyrocapsa oceanica.* It probably belongs to the *Emiliania huxleyi* Zone but electron microscope studies would be necessary to confirm this result. Core 2 belongs to the *Gephyrocapsa oceanica* Zone with *Gephyrocapsa oceanica* and *G. caribbeanica.* The lower part of the Quaternary and the uppermost part of the Pliocene were not found and Cores 4 and 5 belong to the *Discoaster tamalis* Zone with assemblages including *Discoaster tamalis, D. pentaradiatus,* and *D. surculus.* The *Reticulofenestra pseudoumbilica* Zone with *Reticulofenestra pseudoumbilica* and *Sphenolithus abies* was recovered in Cores 6 through 8. Core 9 belongs to the *Ceratolithus rugosus* Zone characterized by the joint occurrence of *Ceratolithus rugosus, C. tricorniculatus,* and *C. primus.* The lowermost Pliocene and the uppermost Miocene zones were not found. The Miocene/Pliocene boundary based on nannofossils lies between Cores 9 and 10. Cores 10 through 12 are assigned to the *Ceratolithus primus* Zone based on assemblages including *Ceratolithus primus, Discoaster quinqueramus,* and *D. berggrenii.* Core 13 belongs to the *Discoaster neohamatus* Zone and contains *Discoaster* sp. cf. *D. neorectus, D. neohamatus,* and *D. bellus.* Core 14 recovered the *Discoaster bellus* Zone with *Discoaster neohamatus* and *D. bellus.* The upper part of the middle Miocene was not found. Core 15 yields assemblages typical of the *Discoaster kugleri* Zone with *Discoaster kugleri, D. exilis, D. divaricatus* and *Coccolithus eopelagicus.* The *Discoaster exilis* Zone is present in Core 16 with assemblages including *Discoaster exilis, D. divaricatus,* and *Coccolithus eopelagicus.* Core 17 recovered the *Sphenolithus heteromorphus* Zone with *Sphenolithus heteromorphus* and *Discoaster exilis.* Cores 18 and 19 yielded assemblages typical of the *Helicopontosphaera ampliaperta* Zone with *Sphenolithus heteromorphus, Discoaster deflandrei,* and *Coronocyclus serratus.* The next lower zone recovered was the *Discoaster druggii* Zone in Core 20 with *Triquetrorhabdulus carinatus* and *Discoaster druggi.* The lowermost Miocene and the uppermost Oligocene zones were not found but the Oligocene/Miocene boundary lies somewhere between Cores 20 and 21. Cores 21 and 22 belong to the *Sphenolithus ciperoensis* Zone with *Triquetrorhabdulus carinatus, Sphenolithus ciperoensis,* and *Reticulofenestra bisecta.* The lower part of the upper Oligocene was not observed. Core 23 was assigned to the *Helicopontosphaera reticulata* Zone based on an assemblage including *Reticulofenestra umbilica, Ericsonia subdisticha, Sphenolithus predistentus,* and *Braarudosphaera bigelowii.* The upper Eocene was not found and Core 24 belongs to the middle Eocene *Chiasmolithus grandis* Zone with *Chiasmolithus grandis, Discoaster barbadiensis, D. saipanensis,* and *Reticulofenestra reticulata.* Cores 25 and 26 recovered the *Chiasmolithus solitus* Zone with *Chiasmolithus grandis, C. solitus, Reticulofenestra umbilica,* and *Thoracosphaera prolata.* Cores 27 through 32 contain rich assemblages belonging to the *Chiasmolithus gigas* Zone with *Chiasmolithus gigas, C. grandis, C. solitus, Nannotetrina fulgens, N. cristata,* and *Thoracosphaera prolata.* Core 36 recovered the *Discoaster sublodoensis* Zone with *Discoaster sublodoensis, Micrantholithus flos, Braarudosphaera bigelowii,* and *Sphenolithus furcatolithoides.* Core 37 belongs to the lower Eocene *Tribrachiatus orthostylus* Zone with *Tribrachiatus orthostylus, Discoaster diastypus, Micrantholithus flos,* and some down-mixed middle Eocene forms like *Sphenolithus furcatolithoides.* Core 38 recovered the *Discoaster diastypus* Zone with *Discoaster diastypus, Chiasmolithus consuetus,* and *Braarudosphaera bigelowii.* Cores 39 and 40 had no recovery. Core 41 belongs to the late Paleocene *Discoaster multiradiatus* Zone with *Discoaster multiradiatus, D. mohleri,* and *Fasciculithus tympaniformis.* Cores 43 and 44 recovered the *Heliolithus kleinpellii* Zone with *Heliolithus kleinpelli, Fasciculithus tympaniformis, Chiasmolithus consuetus, Ellipsolithus macellus, Micrantholithus flos,* and *Braarudosphaera bigelowii.* Cores 45 through 51 are assigned to the *Fasciculithus tympaniformis* Zone based on the assemblages which include *Fasciculithus tympaniformis, F. pileatus, F.* sp. cf. *F. ullii, Chiasmolithus consuetus, C. danicus, Neochiastozygus concinnus, Prinsius bisulcus,* and *Zygodiscus plectopons.* Cores 52 through 67 belong to the *Cruciplacolithus tenuis* Zone with poor assemblages including *Chiasmolithus danicus, Cruciplacolithus tenuis, Zygodiscus plectopons,* and *Biantholithus sparsus.*

Preservation: Quaternary and Pilocene assemblages are very well preserved or show slight overgrowth. Slight etching and slight overgrowth prevail in the upper part of the upper Miocene. The lower part of the upper Miocene, the Middle and lower Miocene, the Oligocene, Eocene, and Paleocene show slight etching and moderate overgrowth which becomes more and more pronounced in the lower Paleocene.

SITE 238
(lat 11°09.21′S, long 70°31.56′E, water depth 2844 m)

This site is located close to the southern end of the Chagos-Laccadive Ridge. The sedimentary section penetrated to a depth of 506 meters and consists of 470 meters of nannofossil ooze of late Oligocene to Quaternary age and of 35 meters of nannofossil chalk and volcanic ash layers of late Oligocene age. Nannofossils are abundant throughout the penetrated section. Core 1 contains common small placoliths, probably *Emiliania huxleyi,* and *Gephyrocapsa oceanica.* It is tentatively assigned to the *Emiliania huxleyi* Zone. Core 2 belongs to the *Gephyrocapsa oceanica* Zone and contains assemblages including *Gephyrocapsa oceanica* and *Ceratolithus cristatus.* Core 3 recovered the *Pseudoemiliania lacunosa* Zone with *Pseudoemiliania lacunosa, Crenalithus doronicoides,* and *Ceratolithus cristatus.* Between Cores 4 and 11 the upper Pliocene and the uppermost part of the lower Pliocene are repeated. Whether this is due to reworking or slumping is difficult to determine. Core 4, Section 1, belongs to the *Discoaster pentaradiatus* Zone and yields assemblages including *Discoaster pentaradiatus, D. surculus,* and *D. brouweri,* with reworked Miocene discoasters like *Discoaster neohamatus* and *D. divaricatus.* Core 4, Section 6 recovered the *Discoaster tamalis* Zone, with *Discoaster tamalis, D. penta-*

radiatus, D. surculus, D. asymmetricus, D. variabilis, and *D. brouweri*. Core 5, Section 2 recovered the *Reticulofenestra pseudoumbilica* Zone with *Reticulofenestra pseudoumbilica* and *S. abies*. Core 5, Section 4 and Core 6 belong to the late Pliocene *Cyclococcolithina macintyrei* Zone with *Discoaster brouweri* and *Cyclococcolithina macintyrei*. Cores 7 and 8 yield assemblages typical of the *Discoaster pentaradiatus* Zone and Cores 9 and 10 are assigned to the *Discoaster tamalis* Zone. Core 11 recovered the *Reticulofenestra pseudoumbilica* Zone. Cores 12 and 13 belong to the *Ceratolithus rugosus* Zone and contain assemblages including *Ceratolithus rugosus, C. tricorniculatus*, and *C. primus. Ceratolithus rugosus* is replaced by *C. acutus* in Cores 14 and 15 which are thus assigned to the earliest Pliocene *Ceratolithus acutus* Zone. The Miocene/Pliocene boundary based on nannofossils lies between Cores 15 and 16. Cores 16 to 20 contain *Discoaster quinqueramus, D. berggrenii*, and *Ceratolithus primus* and therefore belong to the Late Miocene *Ceratolithus primus* Zone. Cores 22 through 21 recovered the *Discoaster berggrenii* Zone with *Discoaster quinqueramus, D. berggrenii*, and *D. surculus*. Rare specimens of *Discoaster* sp. cf. *D. neorectus* and common *D. neohamatus* in Core 24 indicate the presence of the *D. neohamatus* Zone. Cores 25 through 28 belong to the *Discoaster bellus* Zone with assemblages including *Discoaster neohamatus, D. calcaris*, and *D. bellus*. Cores 29 and 30 are assigned to the middle Miocene *Discoaster hamatus* Zone based on assemblages with common *Discoaster hamatus, D. neohamatus*, and *D. calcaris*. Part of the middle Miocene (*Catinaster coalitus, Discoaster kugleri*, and *D. exilis* zones) was not found and might be absent or condensed. Cores 32 through 39 recovered the *Sphenolithus heteromorphus* Zone with assemblages including *Sphenolithus heteromorphus, Discoaster exilis, D. deflandrei*, and *Coccolithus eopelagicus*. Cores 40 and 41 recovered the *Helicopontosphaera ampliaperta* Zone, lacking the marker species, but with an otherwise characteristic assemblage including *Sphenolithus heteromorphus, S. belemnos*, and common *Discoaster deflandrei*. Core 42 recovered the *Discoaster druggii* Zone with *Triquetrorhabdulus carinatus* and *Discoaster druggii*. Core 43 belongs to the *Triquetrorhabdulus carinatus* Zone with *Triquetrorhabdulus carinatus* and some reworked Oligocene forms like *Reticulofenestra bisecta* and *Sphenolithus ciperoensis*. The Oligocene/Miocene boundary based on nannofossils lies between Core 43 and 44. Cores 44 through 49 belong to the late Oligocene *Reticulofenestra abisecta* Zone with assemblages including *Triquetrorhabdulus carinatus, Reticulofenestra abisecta* and *Braarudosphaera bigelowii* (in the lower part only). Cores 50 and 51 are assigned to the *Sphenolithus ciperoensis* Zone based on assemblages including *Sphenolithus ciperoensis, Reticulofenestra bisecta* and *Braarudosphaera bigelowii*. Cores 52 and 53 recovered the *Sphenolithus distentus* Zone with *Sphenolithus distentus*, rare *S. ciperoensis*, and *Reticulofenestra abisecta*. Core 54 belongs to the early Oligocene *Sphenolithus predistentus* Zone with *Sphenolithus predistentus, S. distentus*, and *S. pseudoradians*.

Preservation: Assemblages in the upper part of the section down to the upper Pliocene are well preserved. Most of the Pliocene, the upper Miocene, and the uppermost middle Miocene assemblages show slight etching and overgrowth. The lower part of the middle Miocene, the lower Miocene, and the Oligocene assemblages display slight etching and moderate overgrowth. Braarudosphaerids occur in the Oligocene.

ACKNOWLEDGMENTS

I wish to thank M. N. Bramlette, Scripps Institution of Oceanography; David Bukry, U. S. Geological Survey, and R. G. Douglas, Case Western Reserve University for stimulating discussions on biostratigraphy and paleotemperatures. I am grateful to David Bukry and R. G. Douglas for constructive review of this paper.

REFERENCES

Adelseck, C. A., Geehan, G. W., and Roth, P. H., 1973. Experimental evidence for the selective dissolution and overgrowth of calcareous nannofossils: Geol. Soc. Am. Bull., v. 84, p. 2755.

Borsetti, A. M. and Catti, F., 1972. Il nannoplancton calcareo vivente nel Tirreno centro-meridionale: Gior. Geol., (2) v. 38 12, p. 395.

Boudreaux, J. E. and Hay, W. W., 1967. Zonation of the latest Pliocene-Recent interval: Gulf Coast Assoc. Geol. Soc., Trans., v. 17, p. 443.

Bramlette, M. N. and Martini, E., 1964. The great change in calcareous nannoplankton fossils between the Maastrichtian and Danian: Micropaleontology, v. 10, p. 291.

Bramlette, M. N. and Sullivan, F. R., 1961. Coccolithophorids and related nannoplankton of the early Tertiary in California: Micropaleontology, v. 7, p. 129.

Bramlette, M. N. and Wilcoxon, J. A., 1967. Middle Tertiary calcareous nannoplankton of the Cipero Section. Trinidad W. I.: Tulane Stud. Geol., v. 5, p. 93.

Bukry, D., 1971. Cenozoic calcareous nannofossils from the Pacific Ocean: Trans. San Diego Soc. Nat. Hist. v. 16, p. 303.

_______, 1973a. Coccolith stratigraphy Leg 13, Deep Sea Drilling Project. *In* Ryan, W. B. F., Hsu, K. J., et al., Initial Reports of the Deep Sea Drilling Project, Volume 13: Washington (U. S. Government Printing Office), p. 817.

_______, 1973b. Coccolith stratigraphy, Eastern Equatorial Pacific, Leg 16, Deep Sea Drilling Project. *In* van Ardel, T. H., Heath, G. R., et al., Initial Reports of the Deep Sea Drilling Project, Volume 16: Washington (U. S. Government Printing Office), p. 653.

_______, 1973c, Low-latitude coccolith biostratigraphic zonation. *In* Edgar, T. N., Saunders, S. B., et al., Initial Reports of the Deep Sea Drilling Project, Volume 15: Washington (U. S. Government Printing Office), p. 685.

_______, 1974. Coccoliths as paleosalinity indicators—Evidence from the Black Sea. *In* E. T. Degens and D. A. Ross (Eds.), The Black Sea. Its Geology, Chemistry and Biology: Am. Assoc. Pet. Geol., Mem. 20, p. 353.

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

Bybell, L. and Gartner, S., 1972. Provincialism among mid-Eocene calcareous nannofossils: Micropaleontology, v. 18, p. 319.

Douglas, R. G. and Savin, S. M., 1973. Oxygen and Carbon Isotope analyses of Cretaceous and Tertiary foraminifera from the Central North Pacific. *In* Winterer, E. L., Ewing, J. I., et al., Initial Reports of the Deep Sea Drilling Project, Volume 17: Washington (U. S. Government Printing Office), p. 591.

Edwards, A. R., 1971. A calcareous nannoplankton zonation of the New Zealand Paleogene: Plank. Conf. 2nd, Roma 1970, Proc., Farinacci, A. (Ed.) Roma (Technoscienza) v. 1, p. 381.

Gaarder, K. R., 1954. Coccolithineae, Silicoflagellatae, Pterospermataceae and other forms from the "Michael Sars" North Atlantic Deep-Sea Expedition 1910: Rep. Sci. Results "Michael Sars" North Atlantic Deep-Sea Exped. 1910, v. 2, no. 4.

Gartner, S., Jr., 1969. Correlation of Neogene planktonic foraminifera and calcareous nannofossil zones: Gulf Coast Assoc. Geol. Soc. Trans., v. 19, p. 585.

———, 1971. Calcareous nannofossils from JOIDES Blake Plateau cores and revision of Paleogene nannofossil zonation: Tulane Stud. Geol. Paleont., v. 8, p. 101.

Graan, H. H. and Braarud, T., 1935. A qualitative study of the phytoplankton in the Bay of Fundy and the Gulf of Maine (including observations on hydrography, chemistry and turbidity): J. Biol. Board Canada l, p. 279.

Hay, W. W., 1964. Utilisation stratigraphique des Discoastérides pour la zonation du Paléocéne et de l' Eocene inferieur: Bur. Réch. Geol. Min. Mem. 28, p. 885.

———, 1967. Zonation of the middle-upper Eocene interval: Gulf Coast Assoc. Geol. Soc. Trans., v. 17, p. 438.

Hulburt, E. M., 1962. Phytoplankton in the Southwestern Sargasso Sea and the north Equatorial current, February, 1961: Limonology and Oceanogr. 7, p. 307.

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

———, 1968. Annotated index and bibliography of the calcareous nannoplankton II: J. Paleont. v. 42, p. 584.

———, 1969. Annotated index and bibliography of the calcareous nannoplankton III: J. Paleont., v. 43, p. 568.

———, 1970a. Annotated index and bibliography of the calcareous nannoplankton IV: J. Paleont., v. 44, p. 558.

———, 1970b. Annotated index and bibliography of the calcareous nannoplankton V: Phycologia, v. 9, p. 157.

———, 1971. Annotated index and bibliography of the calcareous nannoplankton VI: Phycologia, v. 10, p. 315.

———, 1973. Annotated index and bibliography of the calcareous nannoplankton VII. J. Paleont. v. 47, p. 715.

Martini, E., 1965. Mid-Tertiary calcareous nannoplankton from Pacific deep-sea cores. *In* Whittard, W. F. and Bradshaw, R. B. (Eds.), Submarine geology and geophysics: (Colston. Res. Soc., 17th Symp. Proc.), London (Butterworths), p. 393-422.

———, 1967. Nannoplankton und Umlagerungserscheinungen im Persischen Golf und in nördlichen Arabischen Meer: Neues Jahrb. Geologie Paläontologie, Monatshefte, no. 10, p. 597-607, 5 figs.

———, 1970. Standard Paleogene calcareous nannoplankton zonation: Nature, v. 226, p. 560.

———, 1971. Standard Tertiary calcareous nannoplankton zonation: Plankt. Conf. 2nd, Roma Proc., Farninacci, A. (Ed.), Rome Tecnoscienza), v. 2, p. 739.

Martini, E. and Worsley, T., 1970. Standard Neogene calcareous nannoplankton zonation: Nature, v. 115, p. 289.

Maxwell, A. E. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume III. Washington (U.S. Government Printing Office).

McKenzie, D. and Sclater, J. G., 1971. The evolution of the Indian Ocean since the Late Cretaceous: Geophys. J. Roy. Astr. Soc., v. 25, p. 437.

Milow, E. D., 1970. Tentative nannofossil zones and subzones and their radiometric age, northeast Pacific. *In* McManus, D. A., Burns, R. E., et al., Initial Reports of the Deep Sea Drilling Project, Volume 5: Washington (U.S. Government Printing Office), p. 8.

Mohler, H. P. and Hay, W. W., 1967. Zonation of the Paleocene-lower Eocene interval: Gulf Coast Assoc. Geol. Soc. Trans. v. 17, p. 432.

Perch-Nielsen, K., 1972. Remarks on Late Cretaceous to Pleistocene coccoliths from the North Atlantic. *In* Laughton, A. S., Berggren, W. A., et al., Initial Reports of the Deep Sea Drilling Project, Volume 12: Washington (U.S. Government Printing Office), p. 1003.

Ramsay, A. T. S., 1971. The investigation of lower Tertiary sediments from the North Atlantic. Planktonic Conf. 2nd, Roma 1970, Proc., Rarinacci A. (Ed.) Roma (Technoscienza), v. 2, p. 1039.

Roth, P. H., 1973. Calcareous nannofossils - Leg 17, Deep Sea Drilling Project. *In* Winterer, E. L., Ewing, J. I., et al., Initial Reports of the Deep Sea Drilling Project, Volume 17: Washington (U.S. Government Printing Office), p. 675-796.

Roth, P. H., Baumann P. and Bertolino, V. 1971. Late Eocene - Oligocene calcareous nannoplankton from Central and Northern Italy: Plank. Conf. 2nd, Roma 1970, Proc., Farinacci, A. (Ed.), Roma (Tecnoscienza) v. 2, p. 1069-1097.

Roth, P. H. and Thierstein, H. R., 1972. Calcareous nannoplankton, Leg 14 of the Deep Sea Drilling Project. *In* Hayes, D. E., Ferman, H. C., Initial Reports of the Deep Sea Drilling Project, Volume 14: Washington (U.S. Government Printing Office), p. 421.

Saito, T. and Percival, S. F., 1970. Mid-Atlantic Ridge sequence. Paleontology. *In* Maxwell, A. E., von Haigen, R., et al., Initial Reports of the Deep Sea Drilling Project, Volume 3: Washington (U. S. Government Printing Office), p. 444.

Schlanger, S. O., Douglas, R. G., Lancelot, V., Moore, T. C., and Roth, P. H., 1973. *In* Winterer, E. L. and Ewing, J. I., et al., Initial Report of the Deep Sea Drilling Project, Volume 17: Washington (U. S. Government Printing Office), p. 407-428.

Takayama, T., 1972. A note on the Distribution of *Braarudosphaera bigelowi* (Graan and Brarrud) Deflandre in the bottom sediments of Sendai Bay, Japan: Paleont. Soc. Japan, Trans. Proc. N. S. No. 87, p. 429.

Wise, S. W., Jr., 1973. Calcareous nannofossils from cores recovered during Leg 18, Deep Sea Drilling Project: Biostratigraphy and observations of diagenesis. *In* Kulm, L. D., van Huene, R., et al., Initial Reports of the Deep Sea Drilling Project, Volume 18: Washington (U.S. Government Printing Office), p. 569.

Wise, S. W., Jr. and Hsu, K. J., 1971. Genesis and lithification of a deep sea chalk: Eclog. Geol. Helv., v. 64, p. 157-163.

Wise, S. W., Jr. and Kelts, K. R., 1972. Inferred diagenetic history of a weakly silicified deep sea chalk: Gulf Coast Assoc. Geol. Soc. Trans., v. 22, p. 177.