

## 7. NEOGENE AND QUATERNARY CALCAREOUS NANNOPLANKTON FROM DSDP SITE 397 (NORTHWEST AFRICAN MARGIN)

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### INTRODUCTION

DSDP Leg 47A recovered Tertiary sediments from two holes (397, 397A) from the eastern Atlantic Ocean adjacent to Cape Bojador (26°50.7'N, 15°10.8'W). This site is northwest and downslope of DSDP Site 369 (Leg 41). Upper Cenozoic sediments were recovered in 102 cores from Hole 397, and down to the mid-point of Section 397A-34-1. The bathymetric and geographic location of Site 397 is shown in Figure 1. The ages, nannoplankton zonal assignment, and nannoplankton abundance and preservation in recovered cores are shown in Figure 2. Ages of the samples examined range from early Miocene (*Discoaster druggi* Zone - NN 2) through the top of the Quaternary (*Emiliania huxleyi* Zone - NN 21). Neogene and reworked Paleogene and Cretaceous species considered in this report are listed in Table 1.

The relative abundance of species in samples from late Pliocene through Quaternary is presented in Table 2. The method utilized to express abundance is a modification of the technique outlined in Hay (1970), Gartner (1972), and Čepék (1978). When viewed on a light microscope at a magnification of  $\times 1560$ , a species represented by between 1 and 10 specimens per field of view of a standard smear slide is recorded as abundant (A); 1 specimen in 10 fields of view, common (C); 1 specimen in 50 fields of view, few (F); 1 specimen in 200 fields of view, rare (R).

Zonal placement, quality of preservation, and abundance as recorded in Table 2 are based primarily upon light microscope examination of smear slides of ultrasonicated samples. Several well-preserved samples were studied with the scanning electron microscope, which was used to delineate the boundary between the *Gephyrocapsa oceanica* (NN 20) and *Emiliania huxleyi* (NN 21) zones. All scanning electron micrographs were taken on the AUTOSCAN of the Federal Institute for Geosciences and Natural Resources, Hannover, West Germany.

### CALCAREOUS NANNOPLANKTON BIOSTRATIGRAPHY AND ZONATION OF SITE 397

Biostratigraphic zonations for the Pliocene and Quaternary have been proposed by Hay et al. (1967), Gartner (1969), Martini and Worsley (1970), Bukry and Bramlette (1970), Bukry (1971), Martini (1971), and Gartner (1977). The zonation used in this study is a combination of those proposed by Martini (1971) and Gartner (1977).

The discussion of nannoplankton biostratigraphy of the Neogene section at Site 397 is presented in two parts. Lower Miocene through lower Pliocene sediments are briefly surveyed. The reader is directed to Mazzell et al. (this volume) and Salvatorini and Cita (this volume) for more extensive analysis of the biostratigraphy of this interval, and in the latter reference, for a discussion of nannoplankton-planktonic foraminiferal biostratigraphy. The interval from the top of the lower Pliocene to the top of the Quaternary is discussed at greater length. The abundance, distribution, and quality of preservation of coccoliths in this younger portion of the recovered section is presented in Table 2.

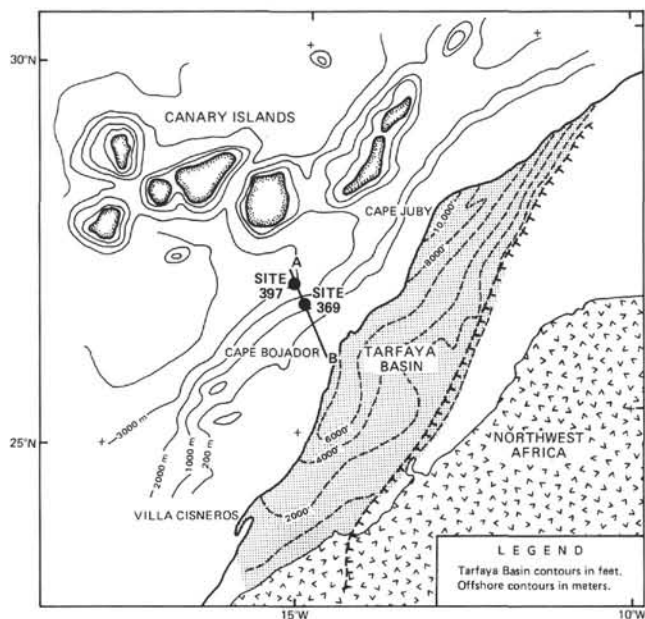


Figure 1. Topography near Site 397, showing location of Site 369 and sediment isopachs for onshore portion of the Tarfaya Basin.

<sup>1</sup>Present Address: Texaco Inc., Los Angeles, California.

Age		Calcareous Nannoplankton Zones	Top	Base	Depth of Base (m)	Nannoplankton Abundance	Preservation
QUATERNARY		<i>Emiliana huxleyi</i>	1-1, 0 cm	2-5, 41 cm	15.41	Abundant	Good
		<i>Gephyrocapsa oceanica</i>	2-6, 47 cm	4-2, 41 cm	29.91		
		<i>Pseudoemiliana lacunosa</i>	4-3, 41 cm	10-2, 41 cm	86.90		
		<i>Helicopontosphaera sellii</i>	11-1, 36 cm	15-3, 100 cm	136.50		
PLIOCENE	LATE	<i>Discoaster brouweri</i>	15-4, 41 cm	19-3, 120 cm	174.70		
		<i>Discoaster pentaradiatus</i>	19-4, 15 cm	19, CC	180.00		
		<i>Discoaster surculus</i>	20-1, 10 cm	23-3, 35 cm	211.85		
	EARLY	<i>Reticulofenestra pseudumbilica</i>	23-4, 41 cm	23, CC	218.00		
		<i>Discoaster asymmetricus</i>	24, CC	35, CC	332.00		
		<i>Ceratolithus rugosus</i>	36-1, 41 cm				
MIOCENE	LATE	<i>Ceratolithus tricorniculatus</i>		42, CC	398.50		
		<i>Discoaster quinquaramus</i>	43-2, 20 cm	56, CC	541.00		
		<i>Discoaster calcaris</i>	57-1, 35 cm	60-2, 21 cm	571.21		
	MIDDLE	<i>Discoaster hamatus</i>	61-2, 42 cm	72, CC	693.00		
		<i>Catinaster coalitus</i>				-	-
		<i>Discoaster kugleri</i>	73-1, 83 cm	75-2, 34 cm	713.84	Common to abundant	Moderate
		<i>Discoaster exilis</i>	75, CC	77-3, 20 cm	734.20		
		<i>Sphenolithus heteromorphus</i>	77, CC	80-1, 141 cm	760.91		
	EARLY	<i>Helicopontosphaera amphiaperta</i>	80-2, 41 cm	16A-5, 31 cm	1074.30	Rare to common	Moderate to good
		<i>Sphenolithus belemnos</i>	16A, CC	21A-3, 47 cm	1118.97	Few	Moderate
		<i>Discoaster druggi</i>	21A, CC	34A-1, 70 cm	1296.72		
		<i>Triquetrorhabdulus carinatus</i>				-	-

Figure 2. Age determinations, zonal assignment, nannoplankton abundance and preservation for the Quaternary and Neogene of Site 397.

TABLE 1  
Nannofossil Species Considered in This Report  
Listed Alphabetically According to Species Name

## Cretaceous

*Corollithion achylosum* (Stover)  
*Tetralithus aculeus* (Stradner)  
*Hayesites albianus* Manivit  
*Chiastozygus amphipons* (Bramlette and Martini)  
*Parahbdolithus angustus* (Stradner)  
*Parahbdolithus asper* (Stradner)  
*Watznaueria barnesae* (Black)  
*Lithraphidites carniolensis* Deflandre  
*Lucianorhabdus cayeuxi* Deflandre  
*Nannoconus colomi* (de Lapparent)  
*Prediscosphaera cretacea* (Arkhangelsky)  
*Arkhangelskiella cymbiformis* Vekshina  
*Micula decussata* Vekshina  
*Zygodiscus diplogrammus* (Deflandre and Fert)  
*Cribrosphaerella ehrenbergi* (Arkhangelsky)  
*Corollithion exiguum* Stradner  
*Eiffellithus eximius* (Stover)  
*Reinhardtites fenestratus* (Worsley)  
*Lithastrinus floralis* Stradner  
*Marthasterites furcatus* Deflandre  
*Parahbdolithus infinitus* (Worsley)  
*Lucianorhabdus maleformis* Reinhardt  
*Vagalapilla matalosa* (Stover)  
*Gartnerago obliquum* (Stradner)  
*Phanulithus obscurus* (Deflandre)  
*Ahmuelerella octoradiata* (Gorka)  
*Corollithion signum* Stradner  
*Vagalapilla stradneri* (Rood, Hay, and Barnard)  
*Eiffellithus trabeculatus* (Gorka)  
*Eiffellithus turriseiffeli* (Deflandre and Fert)

## Cenozoic

*Sphenolithus abies* Deflandre  
*Pontosphaera alboranensis* Bartolini  
*Helicopontosphaera ampliaptera* (Bramlette and Wilcoxon)  
*Discolithina anisoternia* Kamptner  
*Cyclolithella annulus* (Cohen)  
*Scyphosphaera apsteinii* Lohmann  
*Discoaster asymmetricus* Gartner  
*Discoaster barbadiensis* Tan Sin Hok  
*Sphenolithus belemnus* Bramlette and Wilcoxon  
*Reticulofenestra bisecta* (Hay, Mohler, and Wade)  
*Discoaster bollii* Martini and Bramlette  
*Discoaster brouweri* Tan Sin Hok  
*Discoaster calcaris* Gartner  
*Gephyrocapsa californiensis* Kamptner  
*Triquetrorhabdulus carinatus* Martini  
*Discoaster challengerii* Bramlette and Riedel  
*Rhabdosphaera clavigera* Murray and Blackman  
*Cretarhabdus* sp.  
*Ceratolithus cristatus* Kamptner  
*Chiasmolithus danicus* (Brotzen)  
*Discoaster deflandrei* Bramlette and Riedel  
*Dictyococcites dictyodus* (Deflandre and Fert)  
*Discoaster div.* sp.  
*Pontosphaera discopora* Schiller  
*Sphenolithus distentus* (Martini)  
*Coccolithus doronicoides* Black and Barnes  
*Discoaster druggi* Bramlette and Wilcoxon  
*Discoaster exilis* Martini and Bramlette  
*Cyclococcolithus formosus* Kamptner  
*Scapholithus fossilis* Deflandre  
*Oolithotus fragilis* (Lohmann)  
*Discoaster hamatus* Martini and Bramlette  
*Thoracosphaera heimi* (Lohmann)  
*Sphenolithus belemnus* Bramlette and Wilcoxon  
*Emiliana huxleyi* (Lohmann)  
*Pontosphaera indoceanica* Čeppek

TABLE 1 – Continued

*Discolithina japonica* Takayama  
*Helicopontosphaera kamptneri* Hay and Mohler  
*Discoaster kugleri* Martini and Bramlette  
*Pseudoemiliana lacunosa* (Kamptner)  
*Cyclococcolithus leptoporus* (Murray and Blackman)  
*Ellipsolithus macellus* (Bramlette and Sullivan)  
*Cyclococcolithus macintyeri* Bukry and Bramlette  
*Umbilicosphaera mirabilis* Lohmann  
*Sphenolithus moriformis* (Brönnimann and Stradner)  
*Gephyrocapsa oceanica* Kamptner  
*Coccolithus pelagicus* (Wallich)  
*Discoaster pentaradiatus* Tan Sin Hok  
*Reticulofenestra pseudumbilica* (Gartner)  
*Syracosphaera pulchra* Lohmann  
*Discoaster quinqueramus* Gartner  
*Coccolithus scissurus* (Hay, Mohler, and Wade)  
*Scyphosphaera* sp.  
*Helicopontosphaera sellii* Bukry and Bramlette  
*Sphenolithus* sp.  
*Aspidorhabdus stylifer* (Lohmann)  
*Discoaster surculus* Martini and Bramlette  
*Syracosphaera* sp.  
*Thoracosphaera* sp.  
*Amaurolithus tricorniculatus* (Gartner)  
*Reticulofenestra umbilica* (Levin)  
*Discoaster variabilis* Martini and Bramlette

## Miocene

The deepest Tertiary recovery at Site 397 is Sample 397A-34-1, 70 cm, which is placed in the lower Miocene *Discoaster druggi* Zone (NN 2). This sample, as do many in immediately overlying cores, contains some reworked Cretaceous taxa, primarily species of *Watznaueria*. Sample 397A-34-1, 102 cm is the highest sample containing *in-situ* Early Cretaceous (Hauterivian) specimens. The 100 to 105 m.y. hiatus between these two samples represents nondeposition or erosion of post-Hauterivian Mesozoic strata, Paleogene sediments, and those of the lowermost Miocene zone, the *Triquetrorhabdulus carinatus* Zone (NN 1).

*Discoaster druggi* Zone (NN 2)

**Authors:** Martini and Worsley (1970).

**Definition:** Interval from the first occurrence of *Discoaster druggi* Bramlette and Wilcoxon to the last occurrence of *Triquetrorhabdulus carinatus* Martini.

**Age:** Early Miocene.

**Important common species:** *Triquetrorhabdulus carinatus*, *Discoaster druggi*, and *Helicopontosphaera kamptneri*.

**Remarks:** This, the oldest Tertiary zone encountered at Site 397, is present in Samples 397A-34-1, 70 cm through 397A-21, CC.

*Sphenolithus belemnus* Zone (NN 3)

**Authors:** Bramlette and Wilcoxon (1967).

**Definition:** Interval from the last occurrence of *Triquetrorhabdulus carinatus* Martini to the last occurrence of *Sphenolithus belemnus* Bramlette and Wilcoxon.

**Age:** Early Miocene.

**Important common species:** *Helicopontosphaera ampliaptera*, *H. kamptneri*, *Discoaster druggi*, *Sphenolithus heteromorphus*, *S. belemnus* (less common).

TABLE 2

Preservation  
G = Good  
M = Moderate  
P = Poor

[illegible]

**Remarks:** This zone is represented by Samples 397A-21-3, 47 cm through 397A-16, CC.

#### *Helicopontosphaera ampliaptera* Zone (NN 4)

**Authors:** Bramlette and Wilcoxon (1967).

**Definition:** Interval from the last occurrence of *Sphenolithus belemnus* Bramlette and Wilcoxon to the last occurrence of *Helicopontosphaera ampliaptera* (Bramlette and Wilcoxon).

**Age:** Late early Miocene to early Middle Miocene.

**Important common species:** *Helicopontosphaera ampliaptera*, *H. kamptneri*, *Sphenolithus heteromorphus*.

**Remarks:** This zone is represented by the interval between Samples 397A-16-5, 31 cm and 397A-4, CC, and Samples 397-103, CC through 397-80-2, 41 cm. Precise placement of the boundary between this zone and the preceding *Sphenolithus belemnus* Zone is subject to a degree of error due to the inherent inaccuracy in basing a zonal boundary on the last recorded occurrence of a poorly represented species.

#### *Sphenolithus heteromorphus* Zone (NN 5)

**Authors:** Bramlette and Wilcoxon (1967).

**Definition:** Interval from the last occurrence of *Helicopontosphaera ampliaptera* (Bramlette and Wilcoxon) to the last occurrence of *Sphenolithus heteromorphus* Deflandre.

**Age:** Middle Miocene.

**Important common species:** *Sphenolithus heteromorphus*, *Discoaster exilis* (less common).

**Remarks:** This zone is represented by the interval from Samples 397-80-1, 141 cm to 397-77, CC.

#### *Discoaster exilis* Zone (NN 6)

**Authors:** Martini and Worsley (1970).

**Definition:** Interval from the last occurrence of *Sphenolithus heteromorphus* Deflandre to the first occurrence of *Discoaster kugleri* Martini and Bramlette.

**Age:** Middle Miocene.

**Important common species:** *Discoaster exilis*.

**Remarks:** The *Discoaster exilis* Zone is represented by Samples 397-77-3, 20 cm to 397-75, CC.

#### *Discoaster kugleri* Zone (NN 7)

**Authors:** Bramlette and Wilcoxon (1967).

**Definition:** Interval from the first occurrence of *Discoaster kugleri* Martini and Bramlette to the first occurrence of *Catinaster coalitus* Martini and Bramlette.

**Age:** Middle Miocene.

**Important common species:** *Discoaster kugleri*.

**Remarks:** The interval from Samples 397-75-2, 34 cm to 397-73-1, 83 cm is placed in this zone. The absence of the *Catinaster coalitus* Zone in overlying sediments prevents us from determining whether all or only part of the *Discoaster kugleri* Zone is present at this site.

The absence of nannofloras representing the *Catinaster coalitus* Zone (NN 8) and the early part of the *Discoaster hamatus* (NN 9) between Cores 72 and 73 indicates the presence of a hiatus at approximately 693

meters sub-bottom depth. This hiatus represents the nondeposition or erosion of approximately 0.7 m.y. of sedimentary history.

#### *Discoaster hamatus* Zone (NN 9)

**Authors:** Bramlette and Wilcoxon (1967).

**Definition:** Interval from the first to last occurrence of *Discoaster hamatus* Martini and Bramlette.

**Age:** Late middle Miocene to early late Miocene.

**Important common species:** *Discoaster hamatus*, *D. bollii*, *D. pentaradiatus*.

**Remarks:** The oldest samples from Hole 397 placed in this zone contain *Discoaster bollii*. This species has its first occurrence in the upper part of the *Discoaster hamatus* Zone, and its presence in the entire interval assigned to this zone suggests that the early part of this zone is missing from the Site 397 section. The upper portion of the *Discoaster hamatus* Zone is present in Samples 397-72, CC through 397-61-2, 42 cm.

#### *Discoaster calcaris* Zone (NN 10)

**Author:** Martini (1969).

**Definition:** Interval from the last occurrence of *Discoaster hamatus* Martini and Bramlette to the first occurrence of *Discoaster quinqueramus* Gartner.

**Age:** Late Miocene.

**Important common species:** *Discoaster calcaris*, *D. pentaradiatus*.

**Remarks:** Many samples (397-60-2, 21 cm through 397-57-1, 35 cm) are typified by nannofloras of the *Discoaster calcaris* Zone. This interval is characterized by a series of slumped sections, with clasts and several seemingly undisturbed layers containing earlier Miocene and Late/Early Cretaceous nannofloras.

#### *Discoaster quinqueramus* (Zone NN 11)

**Author:** Gartner (1969).

**Definition:** Interval from the first to last occurrences of *Discoaster quinqueramus* Gartner.

**Age:** Late Miocene.

**Important common species:** *Discoaster quinqueramus*, *D. pentaradiatus*, *D. calcaris*, *D. challengerii*.

**Remarks:** This zone is present in Samples 397-56, CC through 397-43-2, 20 cm.

### Pliocene

#### *Ceratolithus tricorniculatus* and *Ceratolithus rugosus* Zones (NN 12-13)

These two zones represent the interval from the last occurrence of *Discoaster quinqueramus* Gartner to the first occurrence of *Discoaster asymmetricus* Gartner.

**Age:** Latest late Miocene to early Pliocene.

**Important common species:** *Reticulofenestra pseudumbilica*, *Discoaster surculus*, *D. challengerii*.

**Remarks:** Gartner (1969) proposed the first occurrence of *Ceratolithus rugosus* as the intervening datum for these two zones. Unfortunately, specimens of *Ceratolithus* and related genera are exceedingly rare in

Site 397 samples and no specimens of *C. rugosus* were observed. These two zones are present in the interval from Samples 397-42, CC to 397-36-1, 41 cm.

#### ***Discoaster asymmetricus* Zone (NN 14)**

**Author:** Gartner (1969).

**Definition:** Interval from the first occurrence of *Discoaster asymmetricus* Gartner to the last occurrence of *Amaurolithus tricorniculatus* (Gartner).

**Age:** Early Pliocene.

**Important common species:** *Discoaster asymmetricus*, *D. surculus*, *Reticulofenestra pseudumbilica*.

**Remarks:** *Amaurolithus tricorniculatus* is a rare nanofloral component. This zone is represented by Samples 397-35, CC through 397-24, CC.

#### ***Reticulofenestra pseudumbilica* Zone (NN 15)**

**Author:** Gartner (1969).

**Definition:** Interval from the last occurrence of *Amaurolithus tricorniculatus* (Gartner) to the last occurrence of *Reticulofenestra pseudumbilica* (Gartner).

**Age:** Late early Pliocene to earliest late Pliocene.

**Important common species:** *Reticulofenestra pseudumbilica*, *Discoaster asymmetricus*, *D. surculus*, *D. pentaradiatus*.

**Remarks:** Two forms of *Reticulofenestra pseudumbilica* are present in the Pliocene of Site 397. We place the top of this zone at the highest occurrence of large specimens of this species (generally 12  $\mu$ m diameter). Smaller forms, generally less than 8  $\mu$ m in diameter, persist higher in the section.

Coccoliths in the *Reticulofenestra pseudumbilica* Zone (Samples 397-23, CC to 397-23-4, 41 cm) are abundant and well preserved. Common species include *Reticulofenestra pseudumbilica*, *Cyclcoccolithus macintyreii*, *Coccolithus daronicoides*, *C. pelagicus*, *Helicopontosphaera kamptneri*, and *Cyclcoccolithus leptoporus*.

#### ***Discoaster surculus* Zone (NN 16)**

**Authors:** Hay and Schmidt (1968) emend. Gartner (1969).

**Definition:** Interval from the last occurrence of *Reticulofenestra pseudumbilica* (Gartner) to the last occurrence of *Discoaster surculus* Martini and Bramlette.

**Age:** Late Pliocene.

**Important common species:** *Discoaster surculus*.

**Remarks:** The base of this zone is placed at the last occurrence of large specimens of *Reticulofenestra pseudumbilica*. Smaller specimens are present at the base of this zone in Samples 397-23-3, 34-35 cm; 397-23-2, 40-41 cm; and 397-23-1, 40-41 cm. Coccoliths in the *Discoaster surculus* Zone (Samples 397-23-3, 34-35 cm through 397-20-1, 70-71 cm) are abundant and well preserved. Common species include *Discoaster surculus* (which is present in all samples placed in this zone), *Helicopontosphaera kamptneri*, *H. sellii* (which is more common than in the preceding zone), *Cyclcoccolithus macintyreii*, *Coccolithus daronicoides*, *C. pelagicus*, *Cyclcoccolithus leptoporus*, and *Discolithi-*

*na anisoternia*. *Rhabdosphaera clavigera* has its first occurrence in the lower part of this zone.

Martini (1971) indicates that the first occurrence of *Pseudoemiliana lacunosa* is in the lower part of the *Discoaster surculus* Zone (NN 16). At Site 397, however, rare to few specimens of *P. lacunosa* are present in samples as old as the upper part of the *Reticulofenestra pseudumbilica* Zone (NN 15). *Pseudoemiliana lacunosa* becomes common to abundant in the middle portion of the *Discoaster surculus* Zone, and remains a dominant nanofloral component through the two succeeding Pliocene zones and the *P. lacunosa* Zone.

#### ***Discoaster pentaradiatus* Zone (NN 17)**

**Authors:** Martini and Worsley (1970).

**Definition:** Interval from the last occurrence of *Discoaster surculus* Martini and Bramlette to the last occurrence of *Discoaster surculus* Martini and Bramlette to the last occurrence of *Discoaster pentaradiatus* Tan Sin Hok.

**Age:** Late Pliocene.

**Important common species:** *Helicopontosphaera sellii*, *Cyclcoccolithus macintyreii*, *Discoaster brouweri*, *D. pentaradiatus* (less common).

**Remarks:** Single fragmented specimens of *Discoaster surculus* were found in the two lowest samples placed in this zone (Samples 397-19, CC and 397-19-5, 35-36 cm). The presence of these specimens in these samples is viewed as the result of reworking or bioturbation. The coccoliths of this zone are abundant and generally well preserved. Common species include *Helicopontosphaera sellii*, *H. kamptneri*, *Cyclcoccolithus macintyreii*, *Pseudoemiliana lacunosa*, *Coccolithus daronicoides*, *C. pelagicus*, and *Cyclcoccolithus leptoporus*. This zone is represented by Samples 397-19, CC to 397-19-4, 59-60 cm.

#### ***Discoaster brouweri* Zone (NN 18)**

**Authors:** Hay and Schmidt (1968) emend. Martini and Worsley (1970).

**Definition:** Interval from the last occurrence of *Discoaster pentaradiatus* Tan Sin Hok to the last occurrence of *Discoaster brouweri* Tan Sin Hok.

**Age:** Late Pliocene.

**Important common species:** *Discoaster brouweri*.

**Remarks:** The top of this zone is placed above the highest "few" or "common" occurrence of *Discoaster brouweri*, which is not accompanied by other species of *Discoaster*. Rare specimens of *D. brouweri* are present in several Quaternary samples, occasionally accompanied by other reworked specimens, most noticeably, specimens of *Discoaster surculus*. The sharp difference in the abundance of *D. brouweri* between Samples 397-15-4, 40-41 cm and 397-15-3, 40-41 cm suggests that the shallower sample postdates the time of extinction of the discoasters, and the presence of *D. brouweri* in the latter sample is due to reworking. Coccoliths in the *D. brouweri* Zone (Samples 397-19-3, 120 cm through 397-15-4, 40-41 cm) are abundant and well preserved. Common species include *Helicopontosphaera kampt-*

*neri*, *H. sellii*, *Cyclococcolithus macintyreii*, *Pseudoemiliana lacunosa*, *Coccolithus daronicoides*, *C. pelagicus*, and *Cyclococcolithus leptoporus*.

### Quaternary

The zonation used for the Quaternary of Site 397 is a combination of the zonations proposed by Martini (1971) and Gartner (1977) (see Figure 3).

#### *Helicopontosphaera sellii* Zone

This zone is defined as the interval from the last occurrence of *Helicopontosphaera sellii* Bukry and Bramlette.

Bramlette.

**Age:** Early Quaternary.

**Important common species:** *Helicopontosphaera sellii* and *Cyclococcolithus macintyreii*.

**Remarks:** This zone is equivalent to the lower part of the Martini (1971) *Pseudoemiliana lacunosa* Zone (NN 19). Gartner (1977) divides the interval between the datums recognized here into two zones (*Cyclococcolithus macintyreii* and *Helicopontosphaera sellii*) which are separated by the last occurrence of *Cyclococcolithus macintyreii*. It is not possible to use this twofold division for this interval at Site 397, as both *C. macintyreii* and *Helicopontosphaera sellii* have their last occurrence in the same sample. The presence of a few specimens of *Discoaster brouweri* in the deepest sample placed in this zone is interpreted as the result of reworking.

Coccoliths of this zone are abundant and well preserved. *Helicopontosphaera sellii* and *Cyclococcolithus macintyreii* are abundant in the lower samples of this zone, but their abundance decreases in younger

Age	m.y. B.P.	Martini (1971)		this paper Nannofossil Zones	Gartner (1977)		m.y. B.P.
		Datums	Nannofossil Zones		Nannofossil Zones	Datums	
QUATERNARY	0.2	First occurrence of <i>Emiliana huxleyi</i>	<i>Emiliana huxleyi</i>	<i>Emiliana huxleyi</i>	<i>E. huxleyi</i> Acme	Dominant <i>Emiliana huxleyi</i>	-0.07
					<i>Emiliana huxleyi</i>		
			<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa oceanica</i>	<i>Gephyrocapsa oceanica</i>	First occurrence of <i>Emiliana huxleyi</i>	-0.27
					Last occurrence of <i>Pseudoemiliana lacunosa</i>	-0.44	
	0.6	Last occurrence of <i>Pseudoemiliana lacunosa</i>		<i>Pseudoemiliana lacunosa</i>			
						Last dominant small <i>Gephyrocapsa</i>	-0.9
			<i>Pseudoemiliana lacunosa</i>		Small <i>Gephyrocapsa</i>		
		Last occurrence of <i>Helicopontosphaera sellii</i>			-1.22		
	1.8	Last occurrence of <i>Discoaster brouweri</i>		<i>Helicopontosphaera sellii</i>	<i>Helicopontosphaera sellii</i>		
<i>Cyclococcolithina macintyreii</i>					Last occurrence of <i>Cyclococcolithina macintyreii</i>	-1.51	
		<i>Discoaster brouweri</i>	<i>Discoaster brouweri</i>		Last occurrence of <i>Discoaster brouweri</i>	-1.65	
PLIOCENE							

Figure 3. Upper Pliocene and Quaternary calcareous nannoplankton zonation.

material. *Coccolithus pelagicus* also decreases in abundance up-section, but persists as an important nanofloral component. *Gephyrocapsa oceanica* has its first occurrence within this zone, in Sample 397-11-4, 40-41 cm. *Pseudoemiliana lacunosa*, *Coccolithus daronicoides*, *Helicopontosphaera kamptneri*, and *Cyclococcolithus leptoporus* are also common in samples from this zone, which is represented by the interval from Samples 397-15-3, 40-41 cm through 397-11-1, 35-36 cm.

#### *Pseudoemiliana lacunosa* Zone

This zone is defined as the interval from the last occurrence of *Helicopontosphaera sellii* Bukry and Bramlette and *Cyclococcolithus macintyreii* Bukry and Bramlette to the last occurrence of *Pseudoemiliana lacunosa* (Kamptner).

**Age:** Early Quaternary.

**Important common species:** *Pseudoemiliana lacunosa*, *Gephyrocapsa oceanica*, *G. californiensis*.

**Remarks:** Coccoliths of this zone are abundant and generally well preserved. *Pseudoemiliana lacunosa* is abundant in the lower part of this zone, but becomes rare in higher samples. The first occurrence of *Gephyrocapsa californiensis* falls within this zone, while *G. oceanica* is a continuous common element of the nanoflora. Additional common species include *Coccolithus daronicoides*, *Helicopontosphaera kamptneri*, *Cyclococcolithus leptoporus*, *Syracosphaera pulchra*, and *Coccolithus pelagicus*. The *Pseudoemiliana lacunosa* Zone is represented by the interval from Samples 397-10-2, 40-41 cm through 397-4-3, 40-41 cm.

#### *Gephyrocapsa oceanica* Zone

**Authors:** Boudreaux and Hay (1967), emend. Gartner (1969).

**Definition:** Interval from the last occurrence of *Pseudoemiliana lacunosa* (Kamptner) to the first occurrence of *Emiliana huxleyi* (Lohmann).

**Age:** Late Quaternary.

**Important common species:** *Gephyrocapsa oceanica* and *G. californiensis*.

**Remarks:** The abundant and well-preserved coccolith assemblage of this zone is characterized by large numbers of *Coccolithus daronicoides*, *C. pelagicus*, *Helicopontosphaera kamptneri*, *Cyclococcolithus leptoporus*, *Gephyrocapsa oceanica*, and *G. californiensis*. This zone is represented in Hole 397 by Samples 397-4-2, 40-41 cm through 397-2-6, 46-47 cm.

#### *Emiliana huxleyi* Zone (NN 21)

**Authors:** Boudreaux and Hay (1967).

**Definition:** Interval above the first occurrence of *Emiliana huxleyi* (Lohmann).

**Age:** Latest Quaternary.

**Important common species:** *Emiliana huxleyi*.

**Remarks:** The stratigraphic distribution and relative abundance of *Emiliana huxleyi* as presented in Table 2 is based upon scanning electron microscope analysis. *Emiliana huxleyi* is initially rare, but becomes more common in the youngest samples. *Coccolithus pelagicus*

is generally more abundant in samples of this zone than in any previous Quaternary zone. The well-preserved nanoflora includes common to abundant specimens of *Coccolithus pelagicus*, *Helicopontosphaera kamptneri*, *Cyclococcolithus leptoporus*, *Cyclolithella annulus*, *Gephyrocapsa oceanica*, and *Thoracosphaera heimi*. The deepest sample placed in this zone is 397-2-5, 40-41 cm.

### NANNOPLANKTON ABUNDANCE AND PRESERVATION

Nannoplankton are generally well preserved and fairly abundant throughout most of the Neogene section recovered at Site 397 (see Figure 2). The lower Miocene sediments from Hole 397A often contain sparse and moderately well preserved nanofloras. As with most of the lower and middle Miocene populations from Holes 397 and 397A, discoasters appear to have been the forms most affected by the minor dissolution and reprecipitation evident in the majority of the samples. Nanofloras of the *Helicopontosphaera ampliaperata* Zone vary greatly in terms of population abundance and preservation because of the multiple bathymetric origin of sediment clasts and reworked nannoplankton. Similar variation in abundance and preservation typifies the intervals of slumps and debris flows in Core 397-57 through 397-61. The section above the slump sequence, from upper Miocene through the Quaternary, is consistently highly fossiliferous, with a diverse and well-preserved calcareous nanoflora.

### SEDIMENTATION RATES FOR THE NEOGENE AT SITE 397

The rate of sediment accumulation for the Neogene at Site 397 is exceptionally high for a hemipelagic environment, averaging approximately 65 m/m.y. A detailed sedimentation rate curve based upon the positions of nannoplankton zonal boundaries is presented in Figure 4. Absolute age corresponding to the biostratigraphic datums recognized at Site 397 are from Martini (1976, table 1).

The *Sphenolithus belemnus* and *Helicopontosphaera ampliaperata* zones (NN 3 and NN 4) of the upper Miocene are characterized by a sedimentation rate of approximately 180 m/m.y. These two zones are treated as a single unit because of the generally rare occurrence of *Sphenolithus belemnus* and the resulting poor reliability of its last occurrence datum as an accurate age indicator. Although both the top and base of the *Helicopontosphaera ampliaperata* Zone were not observed in a single hole at the site, the 313.4 meters of strata placed in this zone is probably an accurate representation of what would be recovered from a single hole, as Holes 397 and 397A were only 60 meters apart.

During the latter part of the early Miocene to the middle part of the middle Miocene (*Sphenolithus heteromorphus* Zone to *Discoaster kugleri* Zone) (Sections 397-81-1 to 397-73-1), the rate of deposition slowed to 15 m/m.y. The hiatus in the middle Miocene between Zones NN 7 and NN 9 is of approximately one m.y. duration.

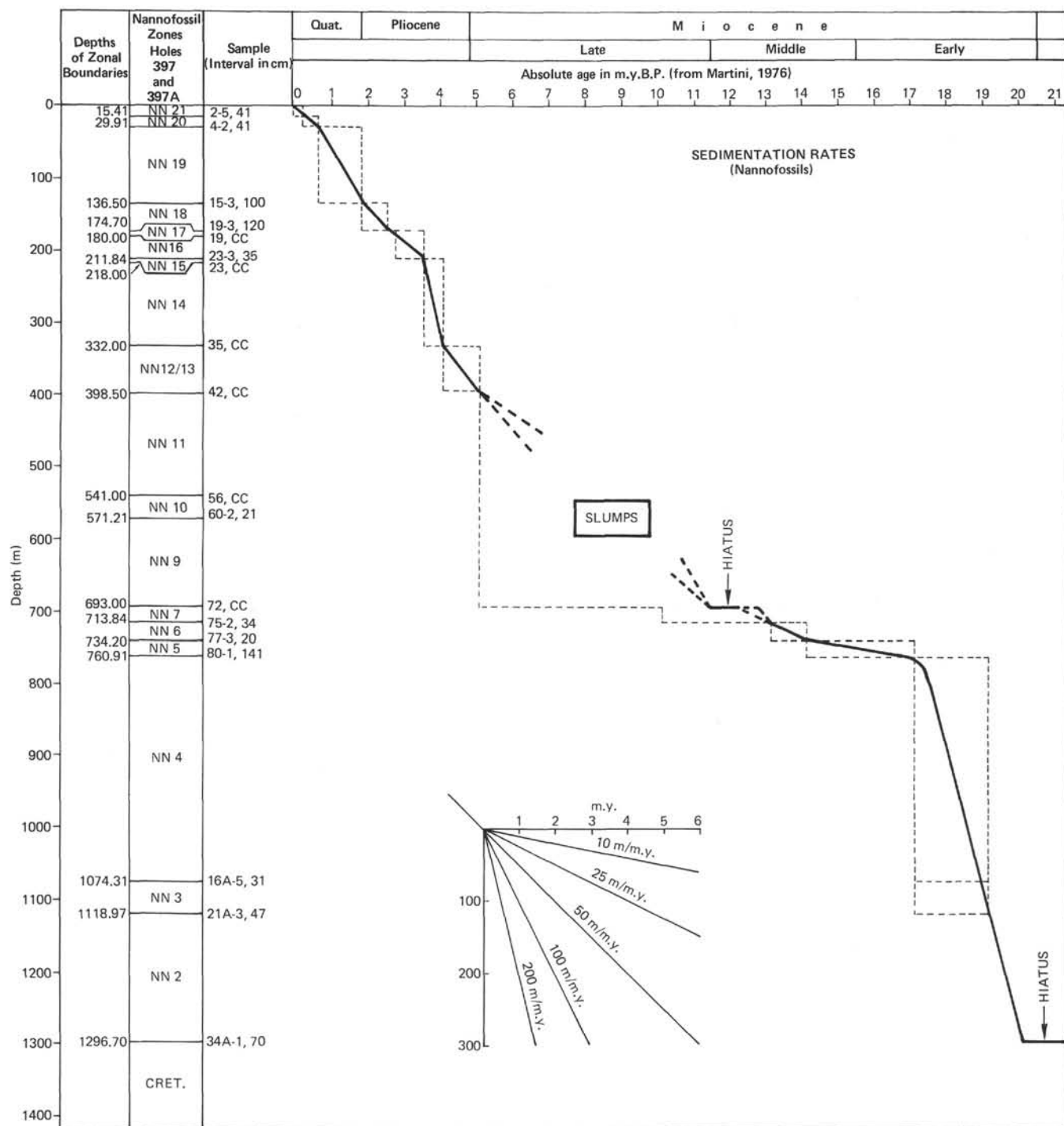


Figure 4. Rates of deposition for Site 397 based upon calcareous nannoplankton datums. Absolute ages are from Martini (1976).

Much of the sediment in the upper Miocene section (Cores 397-72 to 397-43), from the *Discoaster hamatus* Zone to the *Discoaster quinqueringus* Zone, consists of slumped sediments. Therefore, an accurate determination of the depositional rate for autochthonous sediments is difficult. Inclusion of the slumped portions generate a sedimentation rate of approximately 50 m/m.y.

Pliocene hemipelagic sediments accumulated at this site at an average rate of 83 m/m.y. A similar depositional rate persisted early in the Quaternary, but in the last 600,000 years, the rate slowed to approximately 50 m/m.y.

### REWORKED NANNOPLANKTON

One feature of sedimentation in the region of Site 397 during the Neogene was the almost continual rain of reworked earlier Tertiary and Cretaceous nannoplankton. Reworked Cretaceous specimens are often well preserved, as illustrated by the Cretaceous specimens shown in Plates 4 and 7. Although clearly detectable when taxa are reworked into sediments of an age outside their documented stratigraphic range, redeposition of nearly contemporaneous sediments at Site 397 may help explain the great thickness of Neogene sediments observed in the region of Cape Bojador. Redeposition of nannoplankton continued into the Quaternary, as extended examination of samples from the youngest cores from this site occasionally reveals discoasters and Mesozoic species. Reworked species, their recognized range, and the cores in which they have been observed are listed in Figure 5. The occurrences listed only record those instances in which specimens were redeposited as discrete sedimentary particles rather than as part of a lithic clast in debris flows or slumps.

The lower and lower/middle Miocene at Site 397 is interpreted as a rapidly deposited, mostly allochthonous sequence of debris flows, turbid layer sediments, and slumped masses which were deposited following the erosion of post-Hauterivian Mesozoic and Paleogene sediments. Much of the lower Miocene at Site 397 consists of pebbly mudstones. The matrix in Cores 397A-33 through 397A-16 is dated as NN 2 to NN 3, but contains common reworked specimens from the Oligocene and rarer Cretaceous specimens. Clasts from Cores 397A-16 and 397A-20 contain moderately well preserved upper Albian to Cenomanian nannofloras.

Cores 397-89 and 397-87 are chaotic breccia conglomerates consisting of dark brown, dark green, black, and tan pebbles in a dark olive-green matrix which is dated as the *Helicopontosphaera ampliapertura* Zone (NN 4). Clasts from Core 397-89 are either the same age as the matrix, or Cretaceous. A flaggy dark gray-green mudstone clast in Sample 397-89-2, 12-13 cm contains a well-preserved, diverse nannoflora which is dated as Coniacian to early Santonian based on the presence of *Marthasterites furcatus*, *Eiffellithus eximius*, *Lithastrinus floralis*, *Corollithion exiguum*, and *C. signum*. A tan limestone chip in Sample 397-89-2, 20 cm contains a poorly preserved nannoflora which can only

be dated as no older than Turonian, based on the presence of *Micula decussata* and *Cribrosphaerella ehrenbergi*.

Core 397-87 contains a chaotic breccia conglomerate with nearly all clasts containing essentially contemporaneous nannofloras. However, one thin tan mudstone chip in Sample 397-87-3, 137 cm contains a moderately well-preserved nannoflora which, based on the concurrence of *Corollithion achylosum*, *C. exiguum*, *Eiffellithus eximius*, and *Lithastrinus floralis*, is dated as Turonian.

Core 397-57 also contains evidence of large-scale sediment reworking, but here, in the form of slumped intervals which are lithic clast-bearing marly nannofossil chalks and mudstones. Many clasts within these slumps contain Cretaceous nannofloras which are as abundant and well preserved as the richest samples from the Hauterivian section recovered in Hole 397A. Three dark gray-green mudstones from Sections 57-4 and 57-5 are approximately the same age; the presence of *Lithastrinus floralis*, *Corollithion achylosum*, *Hayesites albianus*, *Parhabdolithus infinitus*, *P. asper*, *Reinhardtites fenestratus*, and *Eiffellithus trabeculatus* indicates an Albian age. Slight differences in the populations of the individual clasts suggest that one clast is early Albian, while the others are probably late Albian.

### ACKNOWLEDGMENTS

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SPECIES NAME	KNOWN RANGE	HOLE 397 Core No.	HOLE 397A Core No.
<i>Tetralithus aculeus</i> (Stradner)	Late Campanian — Late Maestrichtian	4	
<i>Chiastozygus amphipons</i> (Bramlette and Martini)	Turonian — Late Maestrichtian	4	
<i>Parhabdololithus angustus</i> (Stradner)	Late Aptian — Campanian	4	19
<i>Parhabdololithus asper</i> (Stradner)	Early Berriasian — Late Turonian		15
<i>Discoaster asymmetricus</i> Gartner	Early Pliocene — Late Pliocene	2, 13	
<i>Discoaster barbadiensis</i> Tan Sin Hok	Early Eocene — Late Eocene	33	
<i>Watznaueria barnesae</i> (Black)	Oxfordian — Danian	4, 87, 89, 95, 102	10, 19, 20, 32, 33
<i>Sphenolithus belemnus</i> Bramlette and Wilcoxon	Early Miocene	75	
<i>Reticulofenestra bisecta</i> (Hay, Mohler, and Wade)	Eocene — Oligocene		32
<i>Discoaster bollii</i> Martini and Bramlette	Middle Miocene — Late Miocene	34	
<i>Discoaster brouweri</i> Tan Sin Hok	Middle Miocene — Late Pliocene	2, 12, 13, 15	
<i>Discoaster calcaris</i> Gartner	Middle Miocene — Late Miocene	10, 11, 12	
<i>Triquetrorhabdulus carinatus</i> Martini	Late Oligocene — Early Miocene	74	
<i>Lithraphidites carniolensis</i> Deflandre	Early Berriasian — Late Maestrichtian	4	
<i>Lucianorhabdus cayeuxi</i> Deflandre	Early Turonian — Late Maestrichtian	4	
<i>Discoaster challengerii</i> Bramlette and Riedel	Middle Miocene — Late Pliocene	16, 19	
<i>Nannoconus colomi</i> (de Lapparent)	Late Tithonian — Early Barremian	83	
<i>Prediscosphaera cretacea</i> (Arkhangelsky)	Middle Cenomanian — Late Maestrichtian	2, 4, 10, 19, 20, 21	
<i>Arkhangelskiella cymbiformis</i> Vekshina	Campanian — Maestrichtian	4	
<i>Micula decussata</i> Vekshina	Late Cretaceous	87	6
<i>Dictyococcites dictyodus</i> (Deflandre and Fert)	Middle Eocene — Early Miocene	71, 76	16
<i>Zygodiscus diplogrammus</i> (Deflandre and Fert)	Late Valanginian — Maestrichtian	4, 10, 87	10, 16
<i>Sphenolithus distentus</i> (Martini)	Middle Oligocene — Late Oligocene		16
<i>Discoaster druggi</i> Bramlette and Wilcoxon	Early Miocene — Middle Miocene	34	
<i>Cribrosphaerella ehrenbergi</i> (Arkhangelsky)	Late Albian — Maestrichtian	4	7
<i>Eiffellithus</i> sp.	Cretaceous	97	
<i>Discoaster exilis</i> Martini and Bramlette	Early Miocene — Middle Miocene	1, 9	
<i>Eiffellithus eximius</i> (Stover)	Cenomanian — Maestrichtian	4, 87, 89	
<i>Lithastrinus floralis</i> Stradner	Late Aptian — Early Santonian	4	19
<i>Marthasterites furcatus</i> Deflandre	Early Coniacian — Early Campanian	38, 53	
<i>Ellipsolithus macellus</i> (Bramlette and Sullivan)	Early Paleocene — Early Eocene	34	
<i>Lucianorhalodus maleformis</i> Reinhardt	Late Turonian — Early Campanian	4	
<i>Vagalapilla matalosa</i> (Stover)	Middle Aptian — Early Turonian	2, 19	
<i>Micula</i> sp.	Late Cretaceous	4	
<i>Nannoconus</i> sp.	Tithonian — Cretaceous	80, 87	
<i>Gartnerago obliquum</i> (Stradner)	Cenomanian — Maestrichtian	4	
<i>Phanulithus obscurus</i> (Deflandre)	Early Coniacian — Late Maestrichtian		19
<i>Ahmuelerella octoradiata</i> (Gorka)	Middle Turonian — Maestrichtian	4, 87	
<i>Parhabdololithus</i> sp.	Cretaceous		33
<i>Helicopontosphaera parallela</i> (Bramlette and Wilcoxon)	Oligocene — Early Miocene	72	
<i>Discoaster pentaradiatus</i> Tan Sin Hok	Middle Miocene — Late Pliocene	2, 11, 15, 16	
<i>Sphenolithus predistentus</i> Bramlette and Wilcoxon	Late Eocene — Oligocene		16
<i>Reticulogenestra pseudoubilica</i> (Gartner)	Late Miocene — Early Pliocene	2, 11, 15, 19	
<i>Discoaster saipanensis</i> Bramlette and Riedel	Middle Eocene — Late Eocene	33	
<i>Helicopontosphaera seminulum</i> (Bramlette and Sullivan)	Early Eocene — Middle Eocene		16
<i>Discoaster surculus</i> Martini and Bramlette	Late Miocene — Late Pliocene	10, 11, 12, 19	
<i>Vagalapilla stradneri</i> (Rood, Hay, and Barnard)	Late Oxfordian — Maestrichtian	4	20
<i>Tetralithus</i> sp.	Cretaceous		6
<i>Eiffellithus trabeculatus</i> (Gorka)	Middle Albian — Maestrichtian	19	
<i>Tetralithus</i> sp.	Cretaceous		6
<i>Marthasterites tribrachiatus</i> (Bramlette and Riedel)	Early Eocene	33, 42, 61, 62	
<i>Eiffellithus turriseiffeli</i> (Deflandre and Fert)	Late Albian — Late Maestrichtian	4, 5, 13, 16, 19, 80, 83, 87, 89	16
<i>Discoaster variabilis</i> Martini and Bramlette	Early Miocene — Late Pliocene	13	
<i>Zygodiscus</i> sp.	Cretaceous		33

Figure 5. Reworked calcareous nannoplankton at Site 397.

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PLATE 1

All specimens approximately  $\times 2800$ .

- Figure 1 *Umbilicosphaera mirabilis* Lohmann. Distal side. Sample 397-2-1, 55-56 cm.  
1a. Phase contrast.  
1b. Cross-polarized light.
- Figure 2 *Pseudoemiliana lacunosa* (Kamptner). Distal side. Sample 397-11-1, 35-36 cm.  
2a. Phase contrast.  
2b. Cross-polarized light.
- Figure 3 *Coccolithus daronicoides* Black and Barnes. Distal side. Sample 397-2-6, 46-47 cm.  
3a. Phase contrast.  
3b. Cross-polarized light.  
3c. Cross-polarized  $+45^\circ$ .
- Figure 4 *Scapholithus fossilis* Deflandre. Sample 397-4-4, 46-47 cm.  
4a. Phase contrast.  
4b. Cross-polarized light.  
4c. Cross-polarized light  $+45^\circ$ .
- Figure 5 *Cyclolithella annula* (Cohen). Distal side. Sample 397-2-6, 46-47 cm.  
5a. Phase contrast.  
5b. Cross-polarized light.
- Figure 6 *Syracosphaera pulchra* Lohmann. Distal side. Sample 397-2-1, 55-56 cm.  
6a. Phase contrast.  
6b. Cross-polarized light.  
6c. Cross-polarized light  $+45^\circ$ .
- Figure 7 *Gephyrocapsa oceanica* Kamptner. Distal side. Sample 397-2-1, 55-56 cm.  
7a. Phase contrast.  
7b. Cross-polarized light.  
7c. Cross-polarized light  $+45^\circ$ .
- Figure 8 *Helicopontosphaera sellii* Bukry and Bramlette. Distal side. Sample 397-19-5, 35-36 cm.  
8a. Phase contrast.  
8b. Cross-polarized light.  
8c. Cross-polarized light  $+45^\circ$ .
- Figure 9 *Helicopontosphaera kamptneri* Hay and Mohler. Distal side. Sample 397-2-4, 80-81 cm.  
9a. Phase contrast.  
9b. Cross-polarized light.  
9c. Cross-polarized light  $+45^\circ$ .
- Figure 10 *Cyclococcolithus macintyreii* Bukry and Bramlette. Distal side of the distal shield. Sample 397-20-2, 70 cm.  
10a. Phase contrast.  
10b. Cross-polarized light.

PLATE 1

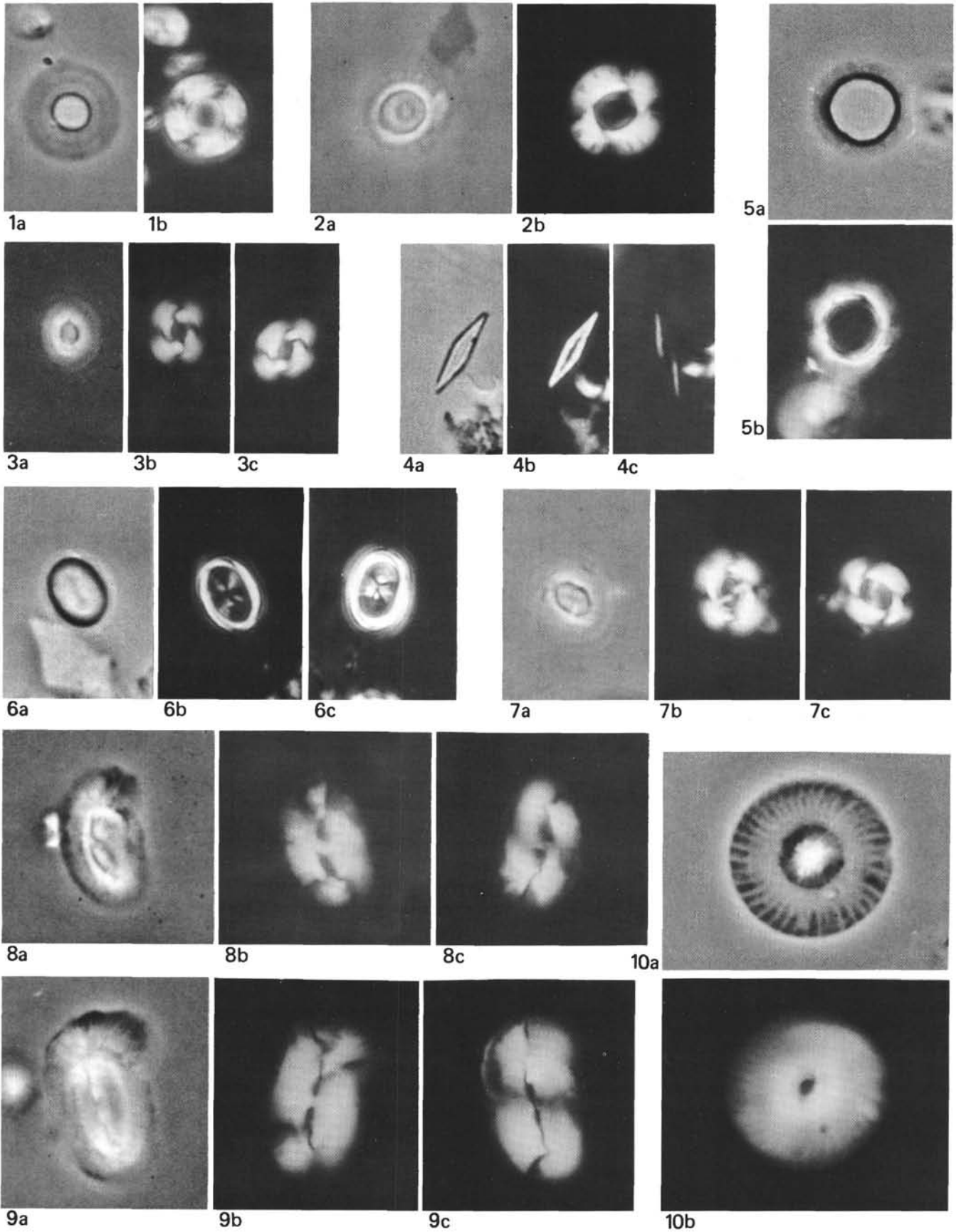
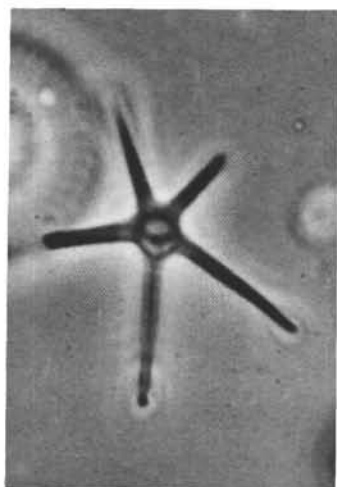


PLATE 2

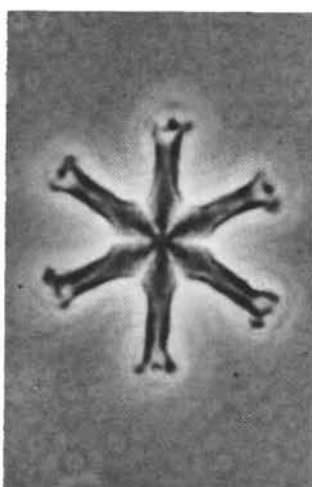
All specimens approximately  $\times 2800$ .

- Figure 1 *Discoaster asymmetricus* Gartner. Distal side. Sample 397-19-19-5, 35-36 cm. Phase contrast.
- Figure 2 *Discoaster surculus* Martini and Bramlette. Proximal side. Sample 397-23-2, 40-41 cm. Phase contrast.
- Figure 3 *Discoaster pentaradiatus* Tan Sin Hok. Proximal side. Sample 397-20-2, 70 cm. Phase contrast.
- Figure 4 *Rhabdosphaera clavigera* Murray and Blackmann. Sample 397-2-1, 55-56 cm.  
4a. Phase contrast.  
4b. Cross-polarized light.
- Figure 5 *Ceratolithus cristatus* Kamptner. Sample 397-23-5, 30-31 cm.  
5a. Phase contrast.  
5b. Cross-polarized light.  
5c. Cross-polarized light  $+45^\circ$ .
- Figure 6 *Discoaster brouweri* Tan Sin Hok. Distal side. Sample 397-19-2, 100 cm. Phase contrast.  
Phase contrast.
- Figure 7 *Coccolithus pelagicus* (Wallich). Distal side. Left - without bridge; right - with bridge. Sample 397-2-1, 40-41 cm.  
7a. Phase contrast.  
7b. Cross-polarized light.  
7c. Cross-polarized light  $+45^\circ$ .

PLATE 2



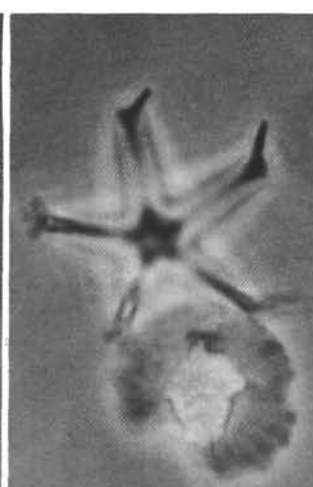
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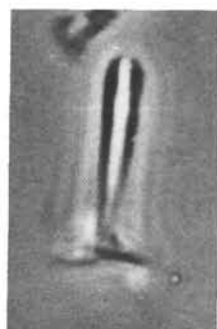
2



3a



3b



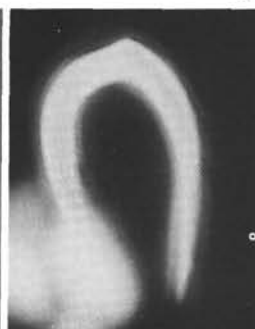
4a



4b



5a



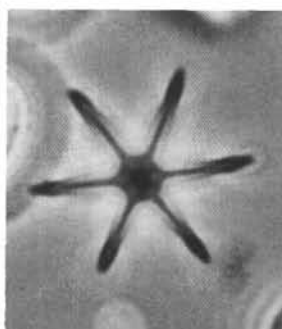
5b



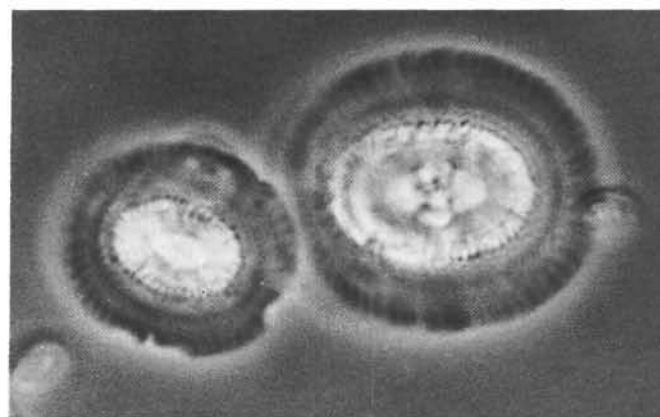
5c



6a



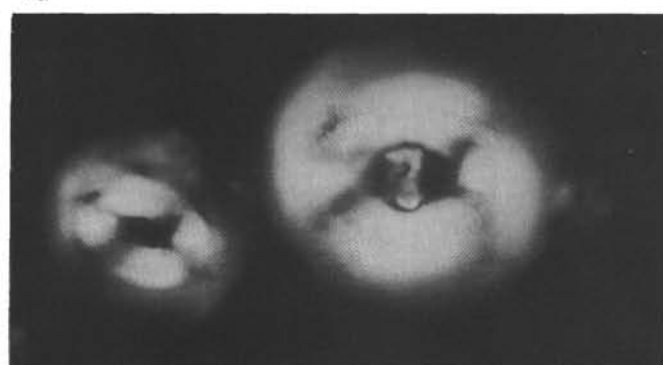
6b



7a



7b



7c

PLATE 3

All specimens approximately  $\times 2800$ .

- Figure 1      *Pontosphaera indooceanica* Čepék. Distal side.  
Sample 397-2-1, 55-56 cm.  
1a. Phase contrast.  
1b. Cross-polarized light.  
1c. Cross-polarized light  $+45^\circ$ .
- Figure 2      *Discolithina anisotrenia* Kamptner. Distal side.  
Sample 397-10-2, 40-41 cm.  
2a. Phase contrast.  
2b. Cross-polarized light.  
2c. Cross-polarized light  $+45^\circ$ .
- Figure 3      *Cyclococcolithus leptoporus* (Murray and Blackmann) Distal side. Sample 397-2-4, 80-81 cm.  
3a. Phase contrast.  
3b. Cross-polarized light.
- Figure 4      *Thoracosphaera heimi* (Lohmann). Sample 397-1-1, 11-12 cm.  
4a. Phase contrast.  
4b. Cross-polarized light.  
4c. Fragment; phase contrast.  
4d. Fragment; cross-polarized light.
- Figure 5      *Reticulofenestra pseudoumbilica* (Gartner). Distal side. Sample 397-8-4, 39-40 cm (reworked).  
5a. Phase contrast.  
5b. Cross-polarized light.  
5c. Cross-polarized light  $+45^\circ$ .

PLATE 3

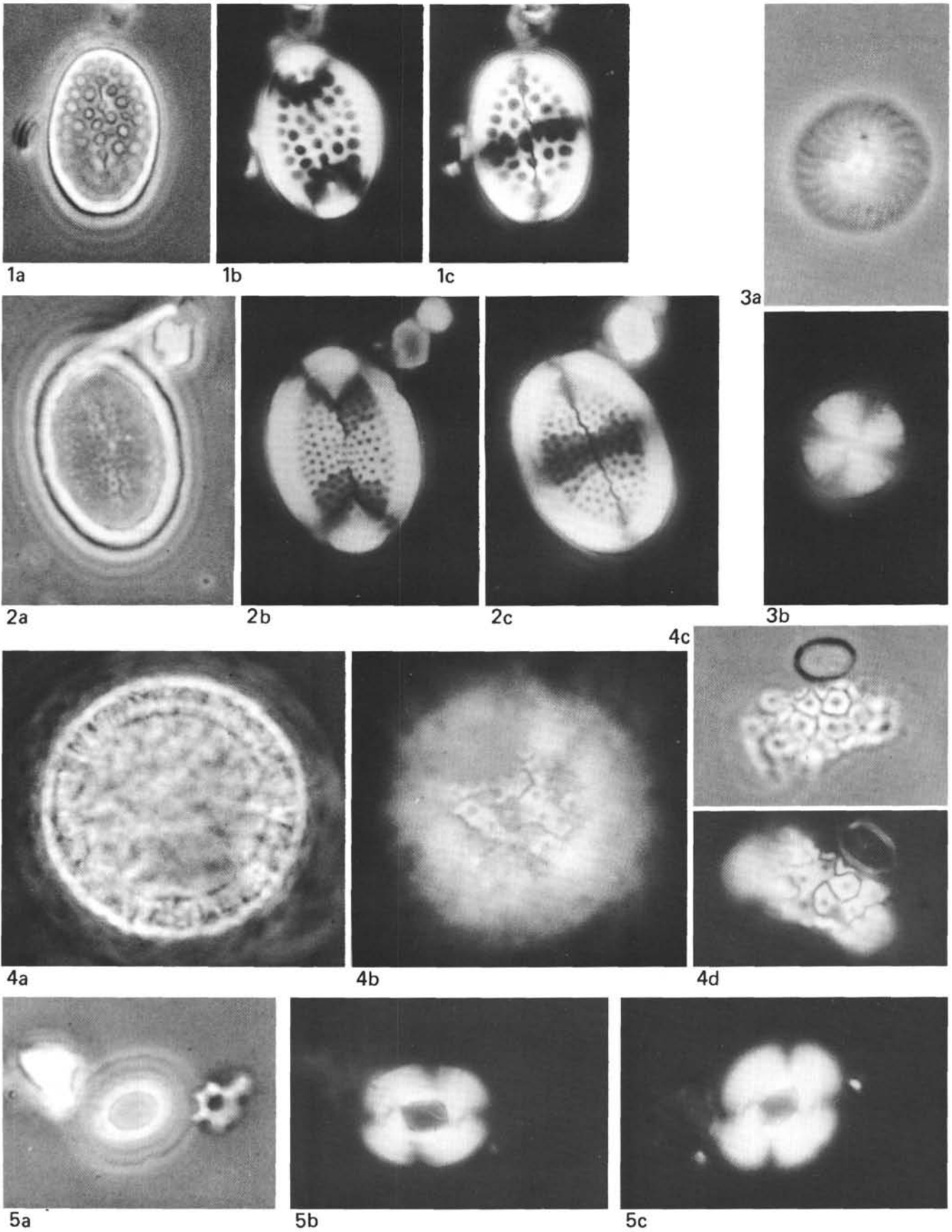


PLATE 4

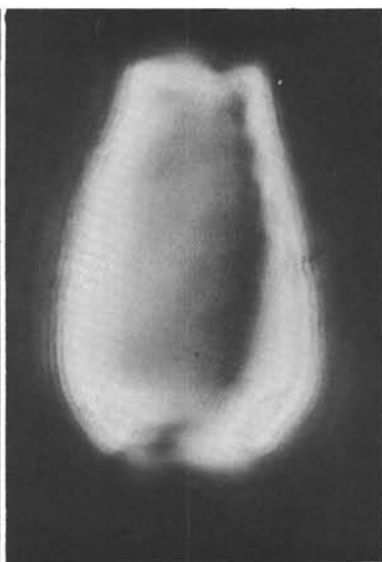
All specimens approximately  $\times 2800$ .

- Figure 1 *Scyphosphaera apsteinii* Lohmann. Side view.  
Sample 397-15-3, 40-41 cm.  
1a. Phase contrast.  
1b. Cross-polarized light.
- Figure 2 *Eiffellithus eximius* (Stover). Distal side. Sample  
397-4-4, 46-47 cm; reworked from Cretaceous.  
2a. Phase contrast.  
2b. Cross-polarized light.  
2c. Cross-polarized light  $+45^\circ$ .
- Figure 3 *Discolithina japonica* Takayama. Distal side.  
Sample 397-2-4, 80-81 cm.  
3a. Phase contrast.  
3b. Cross-polarized light.  
3c. Cross-polarized light  $+45^\circ$ .
- Figure 4 *Eiffellithus turriseiffeli* (Deflandre and Fert).  
Distal side. Sample 397-4-4, 46-47 cm; reworked  
from Cretaceous. Phase contrast.
- Figure 5 *Parhabdolithus angustus* (Stradner). Distal side.  
Sample 397-4-4, 46-47 cm; reworked from Creta-  
ceous.  
5a. Phase contrast.  
5b. Cross-polarized light.
- Figure 6 *Gartnerago obliquum* (Stradner). Distal side.  
Sample 397-4-4, 46-47 cm; reworked from Creta-  
ceous.  
6a. Phase contrast.  
6b. Cross-polarized light.  
6c. Cross-polarized light  $+45^\circ$ .
- Figure 7 *Lucianorhabdus maleformis* Reinhardt. Side view.  
Sample 397-4-4, 46-47 cm; reworked from Creta-  
ceous.  
7a. Phase contrast.  
7b. Cross-polarized light.

PLATE 4



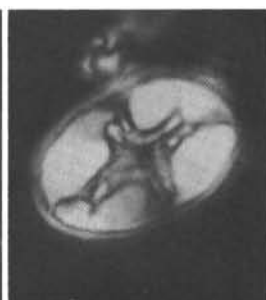
1a



1b



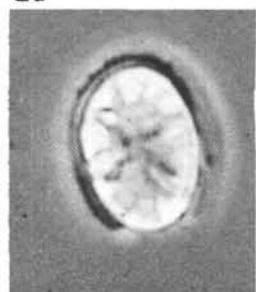
2a



2b



2c



4



5a



5b



6a



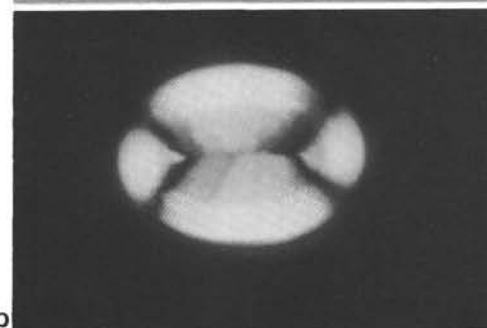
6b



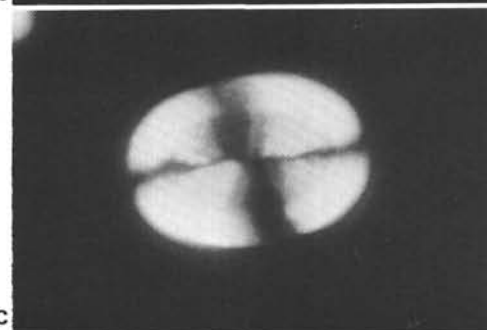
6c



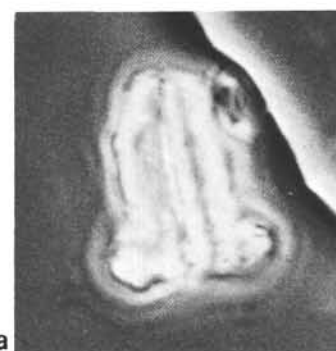
3a



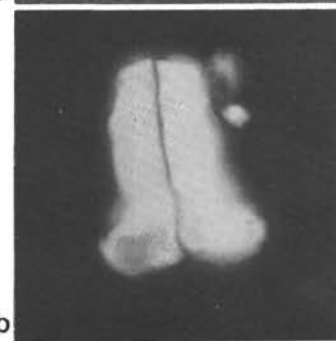
3b



3c



7a



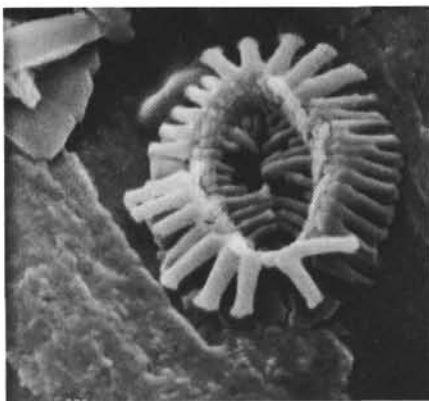
7b

PLATE 5

All specimens scanning electron micrographs.

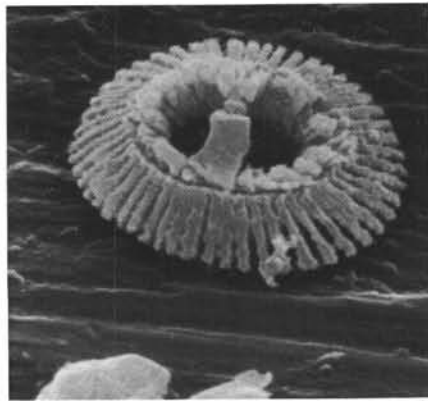
- Figure 1      *Emiliana huxleyi* (Lohmann). Distal side. Sample 397-2-5, 40-41 cm.
- Figure 2      *Gephyrocapsa oceanica* Kamptner. Distal side. Sample 397-1-1, 11-12 cm.
- Figures 3, 6      *Coccolithus* cf. *doronicoides* Black and Barnes. Sample 397-2-6, 46-47 cm.  
3. Distal side  
6. Proximal side.
- Figures 4, 5      *Gephyrocapsa californiensis* Kamptner. Distal side.  
4. Sample 397-4-1, 40-41 cm.  
5. Sample 397-2-2, 40-41 cm.
- Figures 7-9      *Cyclococcolithus* cf. *macintyre*i Bukry and Bramlette. Sample 397-1-1, 11-12 cm.  
7. Distal side.  
8. Proximal side.  
9. Side view.
- Figure 10      *Cyclococcolithus macintyre*i Bukry and Bramlette. Distal side. Sample 397-1-1, 11-12 cm.
- Figure 11      *Reticulofenestra pseudoumbilica* (Gartner). Distal side. Sample 397-23-5, 30-31 cm.
- Figure 12      *Pseudoemiliana lacunosa* (Kamptner). Distal side. Sample 397-21-6, 40-41 cm.

PLATE 5



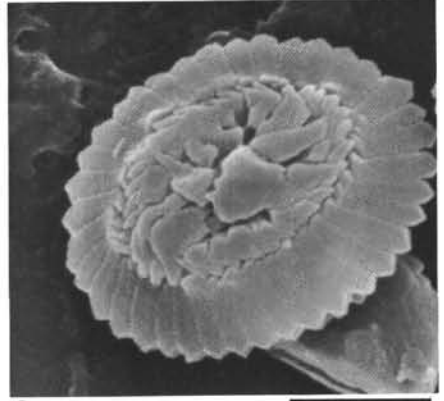
1

1.0 μm



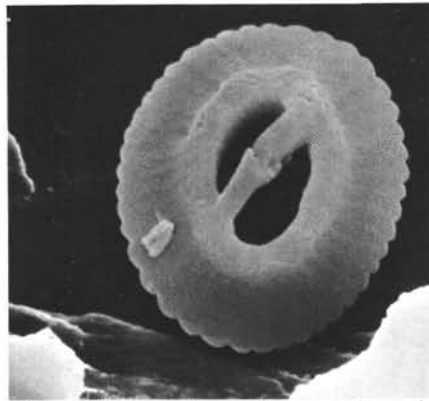
2

2.0 μm



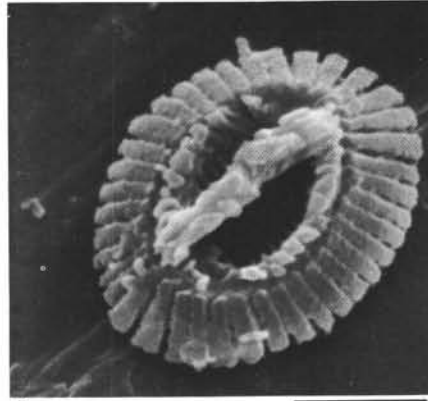
3

1.0 μm



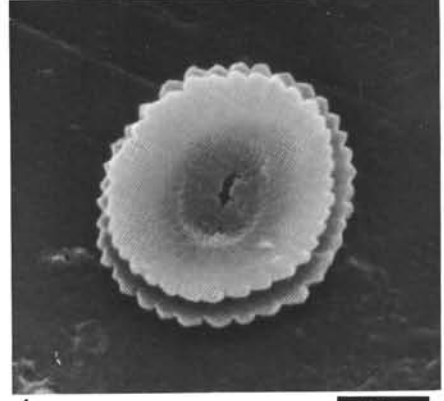
4

2.0 μm



5

1.0 μm



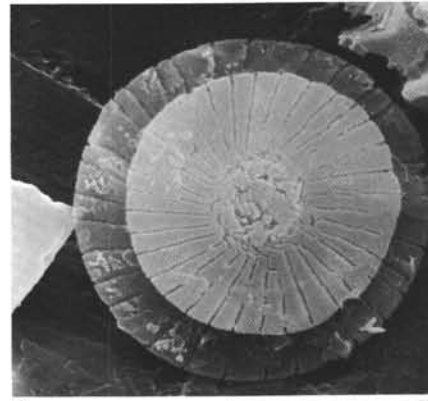
6

1.0 μm



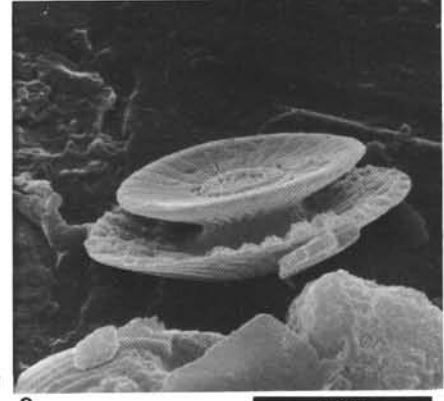
7

5.0 μm



8

5.0 μm



9

5.0 μm



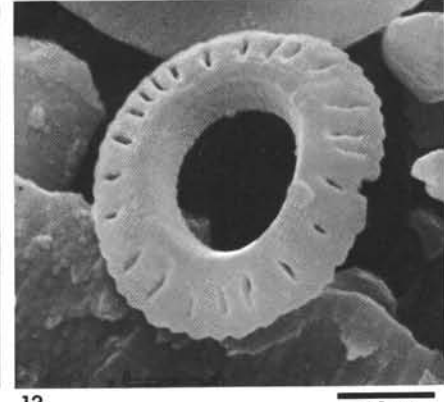
10

5.0 μm



11

2.0 μm



12

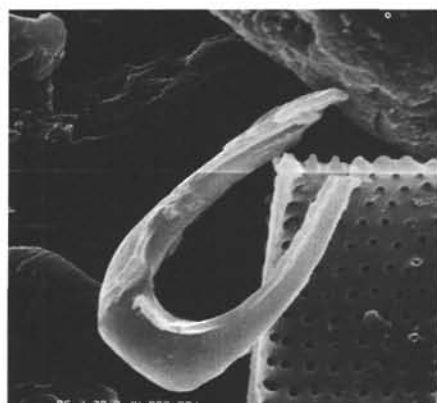
1.0 μm

PLATE 6

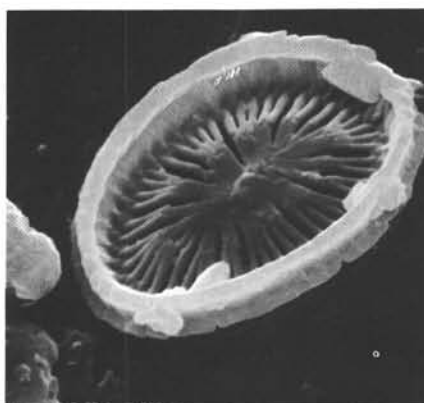
All specimens scanning electron micrographs.

- Figure 1      *Ceratolithus cristatus* Kamptner. Sample 397-23-5, 30-31 cm.
- Figure 2      *Syracosphaera pulchra* Lohmann. Distal side. Sample 397-19, CC.
- Figure 3      *Scyphosphaera apsteinii* Lohmann. Side view. Sample 397-4-1, 40-41 cm.
- Figures 4, 5    *Discolithina discopora* (Schiller). Sample 397-23-5, 30-31 cm.  
                    4. Distal side.  
                    5. Proximal side.
- Figure 6      *Discolithina japonica* Takayama. Distal side. Sample 397-23-5, 30-31 cm.
- Figure 7      *Discolithina anisoternia* Kamptner. Distal side. Sample 397-23-5, 30-31 cm.
- Figure 8      *Umbilicosphaera mirabilis* Lohmann. Proximal side. Sample 397-1-1, 11-12 cm.
- Figures 9-12   *Coccolithus pelagicus* (Wallich).  
                    9. Sample 397-2-6, 46-47 cm, proximal view.  
                    10. Sample 397-21-6, 40-41 cm, distal side.  
                    11. Sample 397-1-1, 11-12 cm, distal side.  
                    12. Sample 397-2-6, 46-47 cm, proximal side.

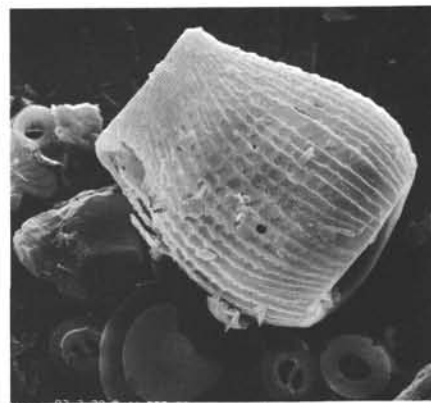
PLATE 6



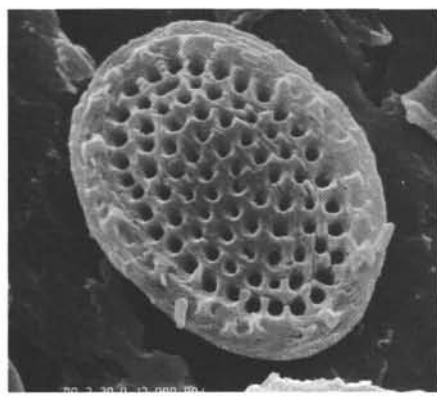
1 10.0 μm



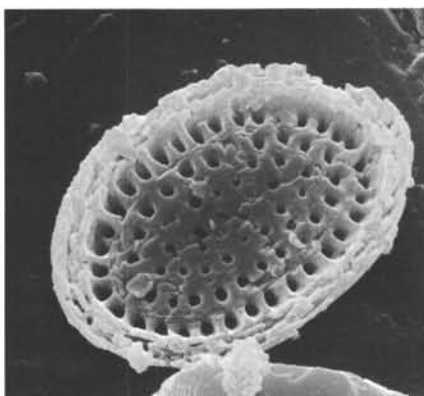
2 2.0 μm



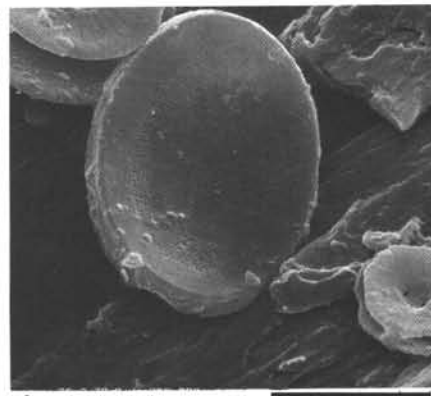
3 10.0 μm



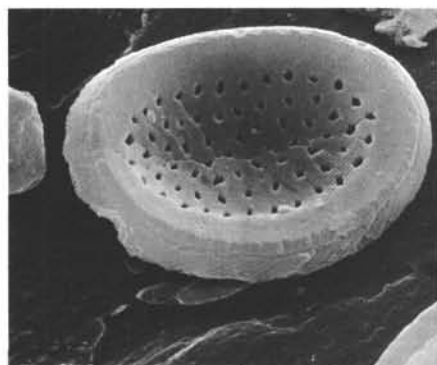
4 5.0 μm



5 5.0 μm



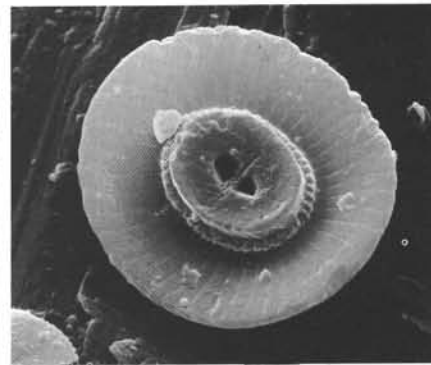
6 5.0 μm



7 5.0 μm



8 5.0 μm



9 5.0 μm



10 5.0 μm



11 10.0 μm



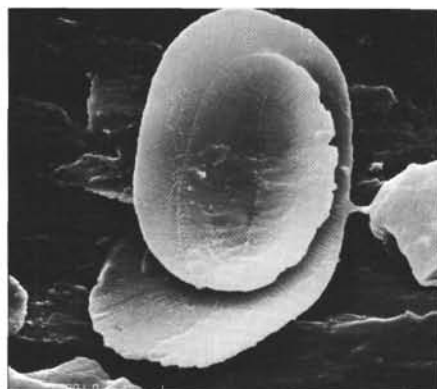
12 10.0 μm

PLATE 7

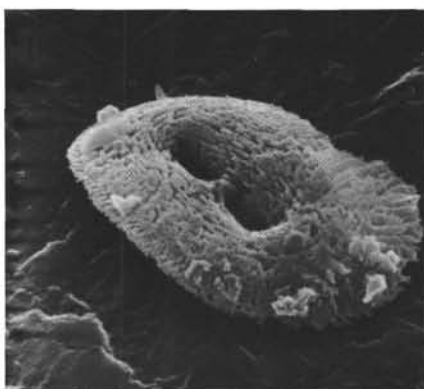
All specimens scanning electron micrographs.

- Figures 1, 2     *Helicopontosphaera kamptneri* Hay and Mohler.  
1. Sample 397-4-1, 40-41 cm, proximal side.  
2. Sample 397-1-1, 11-12 cm, distal side.
- Figure 3        *Helicopontosphaera sellii* Bukry and Bramlette.  
Proximal side. Sample 397-23-5, 30-31 cm.
- Figure 4        *Discoaster* sp. cf. *brouweri* Tan Sin Hok. Distal  
side. Sample 397-21-6, 40-41 cm.
- Figures 5, 6     *Discoaster surculus* Martini and Bramlette.  
5. Sample 397-21-6, 40-41 cm, distal side.  
6. Sample 397-21-6, 40-41 cm, proximal side.
- Figure 7        *Discoaster pentaradiatus* Tan Sin Hok. Proximal  
side. Sample 397-21-6, 40-41 cm.
- Figure 8        *Rhabdosphaera clavigera* Murray and Black-  
mann. Side View. Sample 397-4-1, 40-41 cm.
- Figure 9        *Aspidorhabdus stylifer* (Lohmann). Side view.  
Sample 397-19, CC.
- Figures 10, 11   *Thoracosphaera heimi* (Lohmann). Sample 397-  
1-1, 11-12 cm.
- Figure 12        *Lithastrinus floralis* Stradner. Sample 397-4-1,  
40-41 cm; reworked from Cretaceous.

PLATE 7



1 5.0 μm



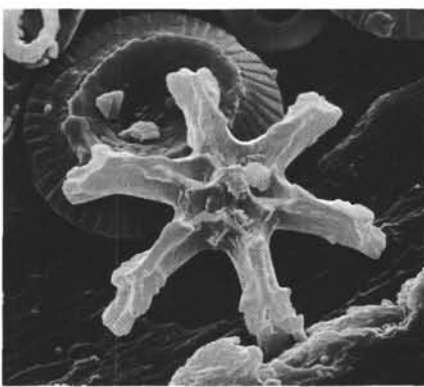
2 5.0 μm



3 5.0 μm



4 10.0 μm



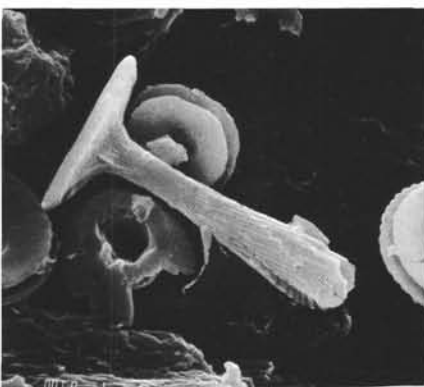
5 10.0 μm



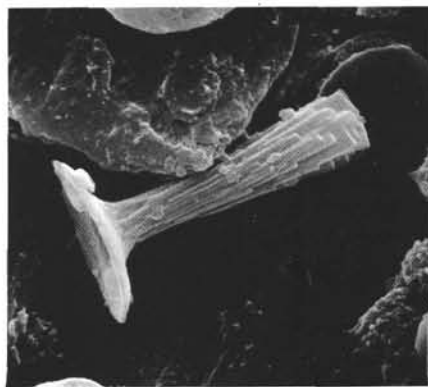
6 10.0 μm



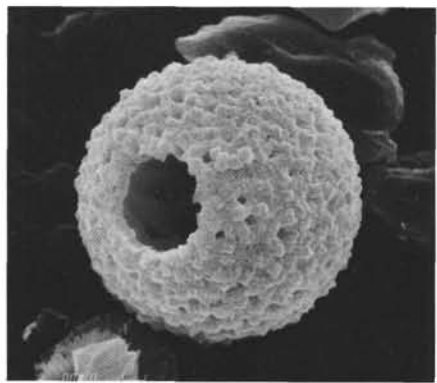
7 10.0 μm



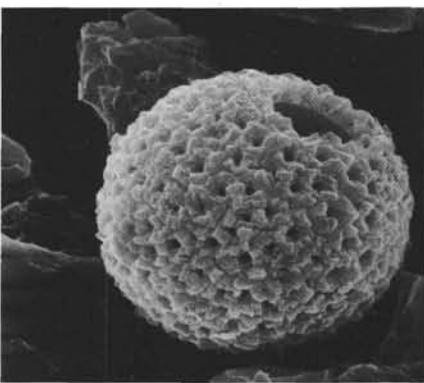
8 5.0 μm



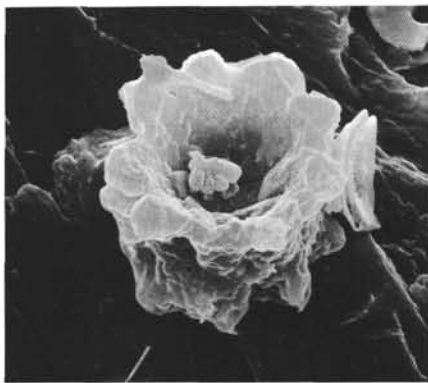
9 5.0 μm



10 10.0 μm



11 10.0 μm



12 10.0 μm