1. NEOGENE NANNOFOSSIL BIOSTRATIGRAPHY OF SITES 723 THROUGH 730, OMAN CONTINENTAL MARGIN, NORTHWESTERN ARABIAN SEA[1]

Stacia Spaulding[2]

ABSTRACT

Calcareous nannofossils were studied in 574 Neogene samples recovered from eight sites drilled in block-faulted basins on the continental margin of Oman. This portion of the Arabian Sea experiences seasonal upwelling associated with the southwest monsoon. Not surprisingly, some of the more typical Neogene warm-water nannoplankton are either missing entirely or are extremely rare in these sediments. *Coccolithus pelagicus*, a typical cold-water indicator, is extremely abundant in many samples of late Pliocene to early Pleistocene age. These intervals correspond to periods of Northern Hemisphere glaciation. Reworked Late Cretaceous and Cenozoic nannofossils are found in a majority of the samples. They were probably carried from the Arabian Peninsula or the continent of Africa on strong southwest summer winds.

Ages for the various nannofossil events were calculated by projecting the nannofossil datums onto the magnetostratigraphic scale for Sites 724, 727, and 728. These are the first ages for the various nannofossil datums derived from Oman Margin sediments. The following ages have been calculated for these nannofossil events: FAD *Emiliania huxleyi*, 0.23 Ma; LAD *Pseudoemiliania lacunosa*, 0.38 Ma; FAD *Helicosphaera inversa*, 0.42 Ma; top of acme of *Reticulofenestra* sp. A, 0.70 Ma; FAD *Gephyrocapsa parallela*, 0.85 Ma; LAD *Gephyrocapsa* spp. (large), 1.07 Ma; LAD *Helicosphaera sellii*, 1.34 Ma; LAD *Calcidiscus macintyrei*, 1.47 Ma; FAD *Gephyrocapsa oceanica*, 1.53 Ma; FAD *Gephyrocapsa caribbeanica*, 1.80 Ma; LAD *Discoaster brouweri*, 2.03 Ma; LAD *Discoaster pentaradiatus*, 2.31 Ma; LAD *Discoaster surculus*, 2.42; LAD *Discoaster tamalis*, 2.77 Ma; LAD *Sphenolithus abies*, 3.44 Ma; and LAD *Reticulofenestra pseudoumbilica*, 3.44 Ma.

INTRODUCTION

Leg 117 of the Ocean Drilling Program commenced on 23 August 1987 from Colombo, Sri Lanka, and ended on 18 October 1987 at Port Louis, Mauritius. The primary goal of this leg was to recover continuous sedimentary sections from the Arabian Sea that have been deposited in areas of high biological productivity and high sedimentation rates since the Miocene. The upwelling associated with the summer monsoon makes this region one of the most fertile areas in the world. In order to achieve the objective, 25 holes were drilled at 12 sites and over 4300 m of sediment was recovered. This report deals with the nannofossil biostratigraphy of the eight Oman Margin sites (Sites 723–730; Fig. 1). Three additional sites (721, 722, and 731) were located on the Owen Ridge and a solitary site (720) was located on the Indus Fan. The nannofossil biostratigraphy of these four sites is presented elsewhere in this volume (Sato et al.).

The oxygen-minimum zone (OMZ) in the Arabian Sea extends from 200 m to about 1500 m in the water column. The high primary productivity and the salinity stratification of the waters are responsible for the formation, extent, and maintenance of this intense OMZ (Slater and Kroopnick, 1984). A high proportion of the primary productivity is a direct result of the upwelling which occurs along the Arabian coast during the months coincident with the summer monsoon (May or June to September) (Wyrtiki, 1971; Prell and Streeter, 1982).

Two separate oxygen minimum layers have been reported at depths between 100 and 400 m and 800 and 1500 m. The shallower OMZ is due to the decomposition of organics in oxygen-poor water coming in from the Persian Gulf. The deeper oxygen minimum has its origins in the water in the Gulf of Oman. This water mixes with water masses with similar compositions flowing in from the southern Arabian Sea (Qasim, 1982).

METHODS

Five hundred and seventy-four slides were examined from Holes 723A, 724A, and 724B (composite section), 725C, 726A, 727A, 728A, 729A, and 730A in order to study the calcareous nannoplankton. Smear slides were made from raw sediment for analysis under the light microscope. These tables show the preservational state of the nannofossils, their overall abundance, the abundance of each taxon, and the distribution of the taxa. In addition, the appropriate biostratigraphic zones are listed next to the core samples. The relative abundance of each taxon and the preservation was estimated following Hay (1970) with modifications by Watkins and Bowdler (1984). The abundances for each taxon in the tables are as follows:

A, abundant (1–10 specimens per field of view at 1500×);
C, common (1 specimen per 2–10 fields of view at 1500×);
F, few (1 specimen per 11–100 fields of view at 1500×);
R, rare (1 specimen per 101–1000 fields of view at 1500×);
?, questionable presence of the taxon.

The method for estimating the abundance of nannofossils as a component of the sediment is the same as that used in Watkins and Bowdler (1984). The following symbols are utilized in the tables:

A, abundant (nannofossils comprise more than 15% of the sediment);
C, common (nannofossils comprise 5%–15% of the sediment);
F, few (nannofossils comprise 1%–5% of the sediment);
R, rare (nannofossils comprise less than 1% of the sediment);
B, barren (no nannofossils observed in 100 fields of view at 1500×).

[1] Prell, W. L., Niitsuma, N., et al., 1991. *Proc. ODP, Sci. Results*, 117: College Station, TX (Ocean Drilling Program).
[2] Department of Geology, University of Nebraska, Lincoln, NE 68588-0340, U.S.A. Current address: 760 Magazine Street, New Orleans, LA 70130, U.S.A.

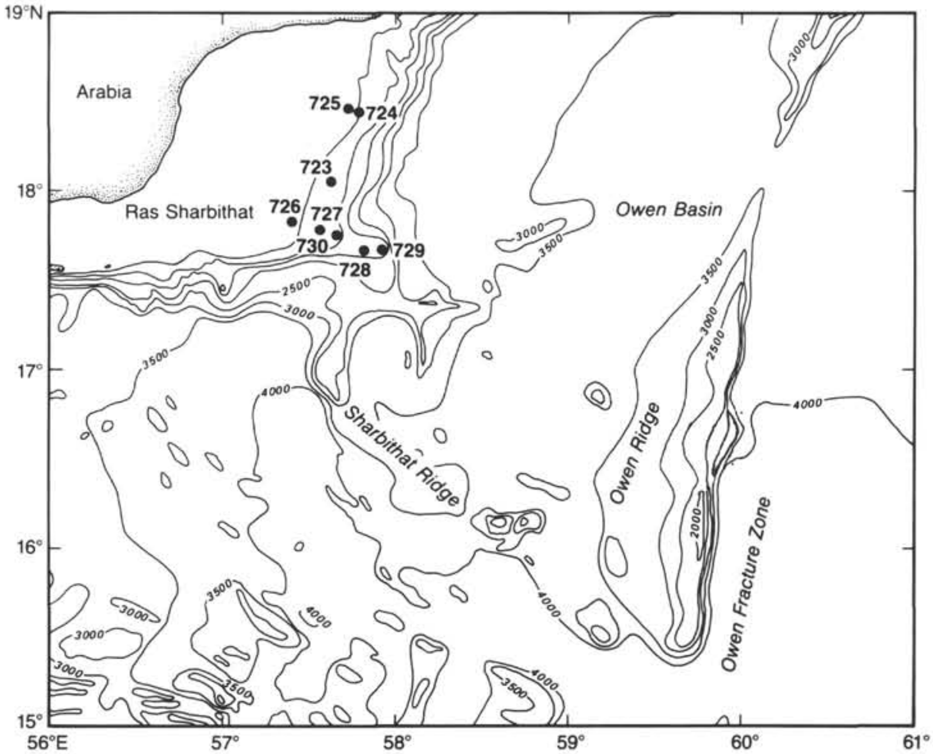

Figure 1. Locations of Sites 723 through 730, ODP Leg 117.

The "average" state of preservation of the assemblage was also determined. Certain taxa are more susceptible to dissolution or overgrowth than others. The preservation of the nannofossil assemblage was denoted by one of the following letter designations:

G, good (fossils lack evidence of dissolution or overgrowth);
M, moderate (fossils exhibit some evidence of dissolution or overgrowth but the identification of them is not impaired);
P, poor (fossils exhibit profound dissolution or overgrowth, but identification of some species is still possible).

Because the material is all Neogene in age, the standard biostratigraphic zonation of Martini (1971) was employed during this leg. This scheme worked quite well, with the exception of some zonal marker species which were not present or were extremely rare (e.g., amauroliths and ceratoliths). For Pleistocene sediments, the zonal scheme of Sato and Takayama (1988) was used. Ideally, this scheme allows for the recognition of 10 zones in the Pleistocene. The nannofossil zones used are shown in Figure 2.

NANNOFOSSIL BIOSTRATIGRAPHY

Site 723

Site 723 is located in approximately 800 m of water at 18°03.079′N and 57°36.561′E. The seafloor at this site is in the center of the OMZ (Fig. 3). This site is part of a transect of sites which cross the continental margin of Oman.

Site 723 is in the center of a basin that is one in a series of linear sedimentary basins which lie along the upper portion of the continental slope. The basins lie in waters 500–1500 m deep and thus collect sediments deposited in the intermediate water masses of the Arabian Sea.

Three holes were drilled at this site. Hole 723A penetrated to 432.3 meters below seafloor (mbsf). The overall recovery of sediments from this hole was 69%. Hole 723B was located 10 m south of Hole 723A and reached a sub-bottom depth of 429.0 m. The average recovery for Hole 723B was 73.8%. This value exceeds the amount of sediment recovered because of gas expansion. Hole 723C was APC-cored to a depth of 76.8 mbsf. Recovery at this hole was 107%. The oldest sediments from Holes 723A and 723B are upper Pliocene and the oldest sediments from Hole 723C are Pleistocene. Sediments from Site 723 are assigned to a single lithologic unit with three facies (Prell, Niitsuma, et al., 1989).

Hole 723A (Table 1)

The sediments from Sample 117-723A-1H-1, 120 cm, down through 117-723A-6H-1, 120 cm (1.20–47.60 mbsf), contain few to common specimens of *Emiliania huxleyi* and can be assigned to Zone NN21 (*Emiliania huxleyi* Zone). Gephyrocapsids and *Neosphaera coccolithomorpha* are the dominant constituents of the nannofossil assemblage throughout this zone. Nannofossils are abundant with moderate to good preservation in this zone.

Sample 117-723A-6H-3, 120 cm, down through Sample 117-723A-8H-5, 120 cm (50.60–73.00 mbsf), contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and, therefore, are assigned to Zone NN20 (*Gephyrocapsa oceanica* Zone). Nannofossils are few in Sample 117-723A-6H-3, 120 cm, but are abundant with moderate preservation throughout the rest of this zone.

Zone NN19 (*Pseudoemiliania lacunosa* Zone) is recognized from Sample 117-723A-8H-CC, to 117-723A-36X-3, 127 cm (75.40–330.36 mbsf). *Pseudoemiliania lacunosa* is few to common throughout this zone, but is not recognized in a few samples. Nannofossils exhibit moderate or good preservation and are abundant in all samples in this zone with the exception of Samples 117-723A-15X-5, 130 cm, 117-723A-20X-5, 129 cm, and 117-723A-22X-1, 120 cm, where they are few. Several datums can be recognized within this zone. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) is recognized between Samples 117-723A-15X-CC, and 117-723A-17X-1,

AGE	ZONE	DATUM
Pleistocene	*Emiliania huxleyi* (NN21)	
		FAD *E. huxleyi*
	Gephyrocapsa oceanica (NN20)	
		LAD *P. lacunosa*
	Pseudoemiliania lacunosa (NN19)	Top acme *Reticulofenestra* sp. A
		FAD *G. parallela*
		LAD *G.* (large)
		LAD *H. sellii*
		LAD *C. macintyrei*
		FAD *G. oceanica*
		FAD *G. caribbeanica*
late Pliocene		LAD *D. brouweri*
	Discoaster brouweri (NN18)	
		LAD *D. pentaradiatus*
	Discoaster pentaradiatus (NN17)	
		LAD *D. surculus*
	Discoaster surculus (NN16)	
		LAD *R. pseudoumbilica*
early Pliocene	*Reticulofenestra pseudoumbilica* (NN 15)	
		LAD *A. tricorniculatus*
	Discoaster asymmetricus (NN14)	
		FAD *D. asymmetricus*
	Ceratolithus rugosus (NN13)	
		FAD *C. rugosus*
	Amaurolithus tricorniculatus (NN12)	
		LAD *D. quinqueramus*
late Miocene	*Discoaster quinqueramus* (NN11)	
		FAD *D. quinqueramus*
	Discoaster calcaris (NN10)	
		LAD *D. hamatus*
middle Miocene	*Discoaster hamatus* (NN 9)	
		FAD *D. hamatus*
	Catinaster coalitus (NN8)	
		FAD *C. coalitus*
	Discoaster kugleri (NN7)	
		FAD *D. kugleri*
	Discoaster exilis (NN6)	
		LAD *S. heteromorphus*
	Sphenolithus heteromorphus (NN5)	
		LAD *H. ampliaperta*
early Miocene	*Helicosphaera ampliaperta* (NN4)	
		LAD *S. belemnos*
	Sphenolithus belemnos (NN3)	
		LAD *T. carinatus*
	Discoaster druggii (NN2)	
		FAD *D. druggii*
	Triquetrorhabdulus carinatus (NN1)	
		LAD *H. recta* and/or *S. ciperoens*

Figure 2. Calcareous nannofossil zonation used in this report. Duration of zones not to scale.

90 cm. The first appearance datum (FAD) of *Gephyrocapsa parallela* occurs between Samples 117-723A-17X-CC, and 117-723A-19X-1, 120 cm. The last appearance datum (LAD) of *Gephyrocapsa* spp. (large) is between Samples 117-723A-20X-CC, and 117-723A-21X-1, 134 cm. The LAD of *Helicosphaera sellii* occurs between Samples 117-723A-24X-5, 118 cm, and 117-723A-25X-1, 117 cm. The LAD of *Calcidiscus macintyrei* is recognized between Samples 117-723A-26X-5, 7 cm, and 117-723A-26X-CC. The FAD of *Gephyrocapsa oceanica*, which is recognizable at levels nearly synchronous with the LAD of *C. macintyrei* in the North Atlantic (Takayama and Sato, 1987), is not recognized in this hole because the bridges which span the central areas of gephyrocapsids are consistently dissolved. This makes the differentiation of *G. oceanica* and *G. caribbeanica* impossible. The bridges of gephyrocapsids are dissolved in Samples 117-723A-27X-5, 120 cm, down through 117-723A-30X-1, 72 cm (256.60–279.02 mbsf). This dissolution is also present in Samples 117-723A-19X-1, 120 cm, down to 117-723A-20X-CC (173.30–191.40 mbsf), but this does not hinder the biostratigraphic classification of the sediments.

Based upon the re-examination of calcareous nannofossils from the Pliocene-Pleistocene boundary stratotype at Le Castella, Italy (T. Takayama, 1988, pers. comm.), the FAD of *Gephyrocapsa caribbeanica* is used as a micropaleontological approximation of the Pliocene-Pleistocene boundary for this leg. The FAD of *G. caribbeanica* occurs in this hole between Samples 117-723A-30X-5, 89 cm, and 117-723A-30X-CC.

The LAD of *Discoaster brouweri* occurs between Samples 117-723A-36X-3, 127 cm, and 117-723A-36X-5, 144 cm, and is the only discoaster species present down through Sample 117-723A-41X-5, 120 cm (333.53–381.50 mbsf). These sediments are assigned to the late Pliocene to early Pleistocene Zone NN18 (*Discoaster brouweri* Zone). *Discoaster pentaradiatus* is present in the lowest sample from this hole, Sample 117-723A-42X-1,

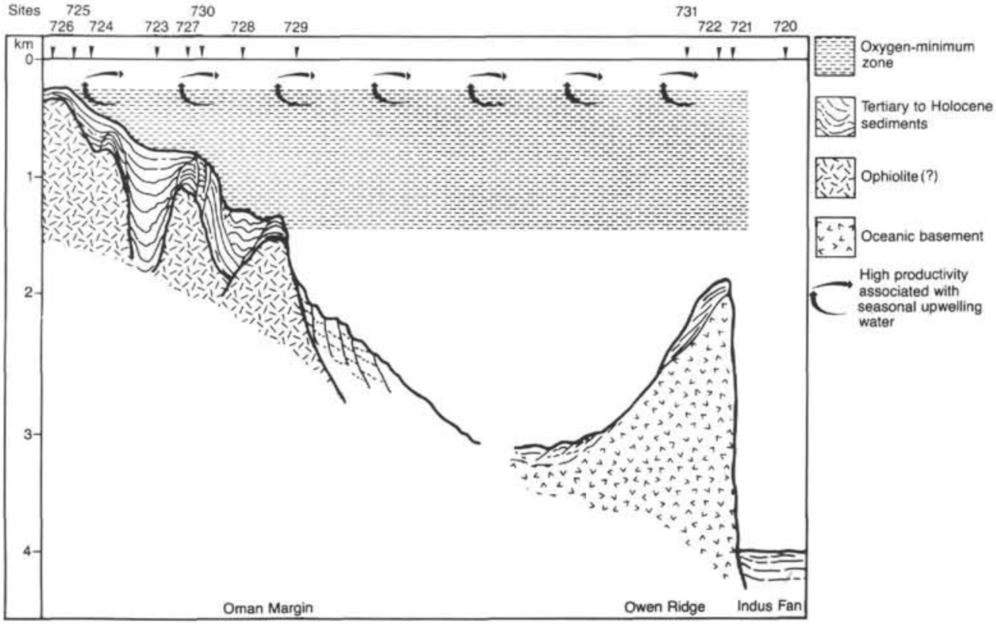

Figure 3. Locations of sites drilled on Oman Margin relative to the position of the oxygen-minimum zone (OMZ).

68 cm, and it, can be assigned to the *Discoaster pentaradiatus* Zone (NN17).

Coccolithus pelagicus and *C. crassipons* are present (rare to few) in a few scattered samples in Zones NN21 down to just below the LAD of *Calcidiscus macintyrei*. The species of *Coccolithus* increase in abundance in Sample 117-723A-27X-5, 120 cm. They are common to abundant in each sample down to the bottom of this hole. They are especially abundant in Samples 117-723A-35X-1, 120 cm, and 117-723A-35X-2, 126 cm. A smear slide of one of the light-colored laminae (Sample 117-723A-35X-3, 46 cm) contained a bloom of *Coccolithus pelagicus*.

Site 724

Site 724 is situated at 18°27.713′N and 57°47.147′E at a water depth of approximately 600 m. Hole 724B penetrated the deepest of the three holes drilled at this site and reached a sub-bottom depth of 257.7 m. This site, like Site 723, is situated in the center of the OMZ (Fig. 3) and was drilled in order to provide an additional record of high-resolution sedimentation, variation of the monsoonal intensity and the OMZ during the Pliocene and Pleistocene (Prell, Niitsuma, et al., 1989).

Three holes were drilled at this site. Hole 724A reached a sub-bottom depth of 44.8 m with 100.7% recovery. The oldest sediments recovered were Pleistocene. A mechanical failure caused the abandonment of Hole 724A. Hole 724B was commenced without offsetting the rig. Hole 724B terminated at 257.7 mbsf when the target depth had been achieved. The oldest sediments at this hole are early Pliocene and the overall recovery was 82.9%. Hole 725C is located 10 m southwest of Holes 724A and 724B. This hole was terminated at 252.4 mbsf and had 96.2% recovery. Like Hole 724B, the oldest sediments from Hole 724C are early Pliocene (Prell, Niitsuma, et al., 1989). Because of the premature termination of Hole 724A and the subsequent drilling of Hole 724B without offset, Samples 117-724A-1H-1, 105 cm, down to 117-724A-4H-CC, are taken from Hole 724A. Samples 117-724B-5H-1, 105 cm, down to 117-724B-27X-5, 74 cm, are taken from Hole 724B.

The sediments at Site 724 are assigned to a single lithologic unit which has two facies. The dominant facies is calcareous clayey silt. Beds of laminated diatomaceous clayey silt are found in the lower cores of Holes 724B and 724C.

Holes 724A/B (Table 2)

The sediments from Hole 724B have been described as a calcareous clayey silt with a sequence of laminated diatomaceous clayey silts present from 180 to 219 mbsf. The sediments down to 117-724A-2H-CC (0–15.90 mbsf), possess few to common specimens of *Emiliania huxleyi* as well as abundant *Gephyrocapsa caribbeanica* and *Gephyrocapsa oceanica* and are assigned to Pleistocene to Holocene Zone NN21 (*Emiliania huxleyi* Zone). Samples 117-724A-3H-1, 105 cm, to Sample 117-724A-4H-5, 105 cm (16.95–32.45 mbsf), contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and are, therefore, assigned to Pleistocene Zone NN20 (*Gephyrocapsa oceanica* Zone).

The LAD of *P. lacunosa* (between Samples 117-724A-4H-5, 105 cm, and 117-724A-4H-CC) marks the top of Zone NN19 (*Pseudoemiliania lacunosa* Zone). As in Hole 723A, these sediments record continuous deposition during the Pleistocene and allow the recognition of several datums within Zone NN19. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) is found between Samples 117-724B-7X-4, 105 cm, and 117-724B-8X-1, 110 cm (60.25–65.50 mbsf). The FAD of *Gephyrocapsa parallela* occurs between Samples 117-724B-8X-3, 110 cm, and 117-724B-8X-5, 100 cm (68.50–71.40 mbsf). The LAD of large *Gephyrocapsa* spp. is recognized between 117-724B-9X-CC, and 117-724B-10X-1, 105 cm (81.05–83.70 mbsf). The LAD of *Helicosphaera sellii* occurs between Samples 117-724B-12X-1, 135 cm, and 117-724B-12X-3, 105 cm (104.35–107.05 mbsf). The LAD of *Calcidiscus macintyrei* is recognized between 117-724B-12X-5, 100 cm, and 117-724B-12X-CC (110.0–112.70 mbsf). The FAD of *Gephyrocapsa oceanica* was recognized between Samples 117-724B-14X-1, 110 cm, and 117-724B-14X-3, 104 cm (123.50–126.44 mbsf). This datum was not detected in Hole 723A due to dissolution. The FAD of *Gephyrocapsa caribbeanica*, which corresponds to the Pliocene-Pleistocene boundary, is recognized between 117-724B-14X-CC, and 117-724B-15X-1, 103 cm (132.00–133.03 mbsf). Sediments down to 117-724B-18X-3, 121 cm (165.21 mbsf), are also assigned to

Zone NN19. The sediments which are assigned to Zones NN19-NN21 contain abundant nannofossils with good or moderate preservation.

Few nannofossils are found in Sample 117-724B-18X-5, 105 cm (168.05 mbsf), which contains very large amounts of organic material as well as large amounts of clastic quartz. This sample is the uppermost sample which contains *Discoaster brouweri*, marking the top of Zone NN18 (*Discoaster brouweri* Zone). In this hole, the LAD of *Discoaster pentaradiatus* is not easily recognizable because only a few scattered specimens are present. Therefore, I have combined Zone NN18 with Zone NN17 (*Discoaster pentaradiatus* Zone). Rare specimens of *D. pentaradiatus* were noted in Sample 117-724B-20X-1, 105 cm, and questionable specimens were observed in Sample 117-724B-20X-5, 105 cm. Samples from 117-724B-18X-5, 105 cm, down to 117-724B-21X-1, 105 cm (187.45–191.05 mbsf), contain *D. brouweri*, sporadic to rare *D. pentaradiatus*, but no *Discoaster surculus*, and are thus assigned to Zones NN17-NN18.

Specimens of *Discoaster surculus* are found only in two samples, (117-724B-21X-3, 105 cm, and 117-724B-21X-CC). However, sediments from Samples 117-724B-21X-3, 105 cm, to 117-724B-26X-1, 104 cm (194.05–239.44 mbsf), are included in the *Discoaster surculus* Zone (NN16) because they do not contain *Reticulofenestra pseudoumbilica*. Within Zone NN16, the LAD of *Sphenolithus abies* occurs between Samples 117-724B-25X-1, 135 cm, and 117-724B-25X-3, 135 cm. Nannofossils are rare in Sample 117-724B-23X-1, 90 cm. Samples 117-724B-22X-1, 74 cm, 117-724B-23X-3, 90 cm, 117-724B-23X-5, 90 cm, and 117-724B-24X-5, 105 cm, are barren of nannofossils. The barren samples are composed of varying amounts of biogenic siliceous material, organic matter, inorganic carbonate, and quartz.

The LAD of *R. pseudoumbilica*, which denotes the top of Zone NN15 (*Reticulofenestra pseudoumbilica* Zone), occurs between Samples 117-724B-26X-1, 104 cm, and 117-724B-26X-3, 114 cm (239.44–242.54 mbsf). Few nannofossils are present in Sample 117-724B-27X-3, 74 cm, which contains large amounts of siliceous material, organic material, inorganic carbonate, and quartz. Nannofossils are abundant in other samples in this zone.

Like Hole 723A, *Coccolithus pelagicus* is present (rare to common, but most often few) in scattered samples down to a level between the FAD of *Gephyrocapsa oceanica* and the FAD of *G. caribbeanica*. *Coccolithus crassipons* is present only in Sample 117-724A-2H-3, 105 cm, where few specimens were observed. *C. pelagicus* is present more consistently at Site 724 than it was at Site 723, and conversely, *C. crassipons* is present less consistently than it was at Site 723. Samples 117-724B-14X-CC, through 117-724B-21X-CC, have few to abundant specimens of *Coccolithus*. Samples 117-724B-16X-1, 103 cm, 117-724B-19X-3, 105 cm, 117-724B-20X-1, 105 cm, and 117-724B-21X-CC, have especially large numbers of *C. pelagicus*. Throughout the rest of Hole 724B no specimens of *Coccolithus* were encountered with the exception of Samples 117-724B-23X-1, 90 cm, and 117-724B-27X-1, 74 cm, where few to common specimens are present. Samples 117-724B-18X-5, 105 cm, down to 117-724B-20X-5, 105 cm, contain, in relative terms, few to very few specimens of discoasters.

Site 725

Site 725 is located at 18°29.210′N and 57°42.080′E in 300 m of water on the continental margin of Oman. This site is the most landward site in a transect that crosses the margin (Fig. 3). Three holes were drilled at this site. Because the recovery of core was poor at Holes 725A and 725B, the calcareous nannofossils were studied only from Hole 725C which penetrated to 162.8 mbsf. Recovery from Hole 725C was 60.9% and all recovered sediments are Pleistocene. The dominant lithology at this site is calcitic marly nannofossil ooze with minor amounts of laminated diatomaceous mud (Prell, Niitsuma, et al., 1989).

Hole 725C (Table 3)

Nannofossils are abundant throughout the entire section. Preservation is good in the four uppermost samples (117-725C-1H-1, 118 cm, through 117-725C-2H-1, 118 cm) and preservation is moderate in the rest of the section. Samples 117-725C-1H-1, 118 cm, down to 117-725C-3H-5, 118 cm (1.18–25.78 mbsf), contain *Emiliania huxleyi* and are assigned to Zone NN21. Samples (117-725C-3H-CC, down to 117-725C-6X-2, 118 cm), which contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* are assigned to Zone NN20 (*Gephyrocapsa oceanica* Zone). Samples 117-725C-6X-3, 118 cm, down to the bottom of the hole can all be assigned to the *Pseudoemiliania lacunosa* Zone (Zone NN19). The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) is located between Samples 117-725C-11X-3, 118 cm, and 117-725C-11X-5, 93 cm. The FAD of *Gephyrocapsa parallela* occurs between Samples 117-725C-11X-5, 93 cm, and 117-725C-11X-CC. The LAD of large gephyrocapsids is located between 117-725C-13X-CC, and 117-725C-14X-1, 118 cm. The LAD of *Helicosphaera sellii* occurs between 117-725C-16X-1, 139 cm, and 117-725C-16X-CC.

Few specimens of *Coccolithus pelagicus* are found in several samples from this hole. The oldest sediments from this hole are too young to show the increase in abundance of *C. pelagicus* in the lower part of Zone NN19 that was observed at Sites 723 and 724.

Site 726 (Table 4)

This site is located in 340 m of water at 17°48.942′N and 57°22.285′E. Only one hole was drilled at this site which was assumed to be located on a basement high (pre-Neogene). Hole 726A reached a sub-bottom depth of 186.3 meters with 59.1% recovery. Two lithologic units are recognized at this hole. Lithologic Unit I consists of calcareous silty clay, organic-rich silty clay, to marly nannofossil ooze to chalk and is present down to 131.10 mbsf. Lithologic Unit II is a partly dolomitized shallow-water limestone present from 121.40 to 186.30 mbsf (Prell, Niitsuma, et al., 1989).

Calcareous nannofossils are present throughout Lithologic Unit I. They range from rare to abundant and exhibit moderate preservation. Lithologic Unit II is barren of nannofossils. Preliminary examination of larger foraminifers suggests an age of Eocene for these limestones (J. Hermelin, pers. comm., 1987).

Samples 117-726A-1H-1, 118 cm, to 117-726A-2H-3, 118 cm (1.18–11.08 mbsf), contain few to abundant *Emiliania huxleyi* and are assigned to the latest Pleistocene to Holocene Zone NN21 (*Emiliania huxleyi* Zone). Samples 117-726A-2H-5, 118 cm, to 117-726A-3H-3, 118 cm (14.08–20.48 mbsf), contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and can be assigned to the *Gephyrocapsa oceanica* Zone (NN20).

Zone NN19 contains sediments from the LAD of *P. lacunosa* down to the LAD of *Discoaster brouweri* (Samples 117-726A-3H-5, 118 cm, to 117-726A-7X-CC; 23.48–63.60 mbsf). In this hole, the top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) and the FAD of *Gephyrocapsa parallela* are found within the same interval (117-726A-4H-5, 118 cm, to 117-726A-4H-CC). The LAD of *Gephyrocapsa* spp. (large) occurs between Samples 117-726A-5H-5, 118 cm, and 117-726A-5H-CC. Sample 117-726A-6H-3, 118 cm, contains rare nannofossils. The LAD of *Helicosphaera sellii* occurs between Samples 117-726A-6H-5, 118 cm, and 117-726A-6H-CC. The LAD of *Calcidiscus macintyrei* is recognized between Samples 117-726A-6H-CC, and 117-726A-7X-1, 118 cm. The FAD of *Gephyrocapsa caribbeanica* (approximation of the Pliocene-Pleistocene boundary) oc-

Table 1. Distribution of calcareous nannofossils, Hole 723A.

Age	Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Ceratolithus cristatus*	*Coccolithus crassipons*	*Coccolithus pelagicus*	*Discoaster asymmetricus*	*Discoaster brouweri*	*Discoaster pentaradiatus*	*Emiliania huxleyi*	*Gephyrocapsa* (large)	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*	*Gephyrocapsa protohuxleyi*	*Helicosphaera carteri*	*Helicosphaera inversa*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera indooceanica*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pseudoemiliania lacunosa*	*Reticulofenestra* sp. A	*Reticulofenestra* sp. B	*Rhabdosphaera clavigera*	*Rhabdosphaera stylifera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Syracosphaera pulchra*	*Thoracosphaera albatrosiana*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
		1H-1, 120	A	G	.	A	.	.	.	.	.	.	.	C	.	A	A	C	F	C	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	C	F
		1H-3, 120	A	M	.	C	.	.	.	R	.	.	.	C	.	C	C	F	.	F	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	F
		1H-5, 120	A	M	.	A	.	.	.	R	.	.	.	F	.	C	C	F	.	C	.	.	C	.	A	.	.	.	R	.	.	.	.	.	.	.	.	.	.	.	F	.
		2H-1, 120	A	M	.	A	.	.	.	.	.	.	.	F	.	C	C	F	.	C	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		2H-3, 120	A	M	.	C	.	.	.	R	.	.	.	C	.	A	A	F	.	C	.	.	F	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		2H-5, 120	A	M	.	C	.	.	.	.	.	.	.	C	.	C	C	C	.	C	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.
		3H-1, 120	A	M	.	C	.	.	.	.	.	.	.	F	.	C	C	F	.	C	.	.	F	.	A	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	F	.
		3H-3, 120	A	G	.	A	.	.	.	.	.	.	.	C	.	A	A	.	.	C	.	.	F	.	A	.	.	.	.	.	.	.	.	.	.	.	C	.	F	.	C	.
	NN21	3H-5, 120	A	M	.	A	.	.	.	F	.	.	.	C	.	A	A	F	.	C	.	.	F	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		3H-CC	A	G	.	C	.	R	.	.	.	.	.	C	.	A	A	F	.	C	F	.	F	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	F	.	F	.
		4H-1, 120	A	M	.	C	.	.	.	F	.	.	.	C	.	C	C	F	.	C	.	.	F	.	A	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		4H-3, 120	A	M	.	A	.	.	.	.	.	.	.	F	.	A	C	F	.	C	.	.	F	.	A	.	.	.	.	.	.	.	.	.	.	.	F	.	C	.	C	.
		4H-5, 120	A	M	.	A	.	.	.	.	.	.	.	C	.	A	A	F	.	C	.	.	.	.	A	F	F	.	.	.	.	.	.	.	.	.	F	.	C	.	F	.
		4H-CC	A	G	.	C	.	.	.	.	.	.	.	F	.	A	A	F	.	C	F	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	F	F	C	.
		5H-1, 124	A	M	.	C	.	.	.	.	.	.	.	F	.	A	A	C	.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		5H-3, 120	A	M	.	C	.	.	.	.	.	.	.	F	.	A	A	C	.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.	F	.
		5H-5, 120	A	M	.	C	.	.	.	.	.	.	.	F	.	A	A	F	C	C	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		6H-1, 120	A	M	.	C	.	R	.	.	.	.	.	F	.	A	A	F	.	C	.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.
		6H-3, 120	F	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.	F	.
		6H-5, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	.
		7H-2, 125	A	M	R	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
	NN20	7H-4, 121	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	F	.	.	.	C	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	.
		7H-6, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	R	.	.	.	C	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	.
		8H-1, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		8H-3, 120	A	M	.	C	.	.	.	F	.	.	.	.	.	A	A	.	.	C	F	.	F	.	A	.	.	.	.	F	.	.	.	.	.	.	F	.	F	.	F	.
		8H-5, 120	A	M	.	A	.	.	.	.	.	.	.	.	.	A	A	.	.	C	.	.	F	.	A	.	F	.	.	F	.	.	.	.	.	F	.	.	F	.	F	.
		8H-CC	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	F	.	F	.	A	.	F	.	F	.	F	F	.	.	.	.	F	.	F	.	.	.
		9H-1, 126	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.
		9H-3, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	F	.	F	.	.	.
		9H-5, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
		11X-1, 120	A	G	.	F	.	.	.	F	.	.	.	.	.	A	A	F	.	C	F	.	C	.	A	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
		13X-1, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	.	.	.	F	.	F	.	.	.	.	F	F	.	.	F	.
		13X-3, 120	A	M	.	A	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	F	.	.	.	.	.	C	F	.	F	.
		13X-5, 54	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	F	C	.	F	.	.	.	.	F	.	.	.	.	.	F	.	.	F	.
		14X-1, 100	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	F	.	.	.	.	.	F	.	.	.	.
		14X-3, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	F	.	.	.	.	F	F	.	.	.	.
		14X-5, 5	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	F	.	.	.	.	.	F	F	.	F	.
		15X-1, 122	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	F	.	C	.	.	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
Quaternary		15X-3, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	C	.	.	.	.	F	.	.	.	F	.
		15X-5, 130	F	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	C	.	.	.	.	C	.	F	.	.	F	.	F	.	.	.	.	.	.	.	.	.	.
		15X-CC	A	M	.	C	.	.	.	R	.	.	.	.	.	A	A	F	.	F	.	.	.	.	A	.	C	.	.	F	.	F	R	.	.	.	.	F	F	.	.	.
		17X-1, 90	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	F	.	F	.	.	.	.	C	.	F	.	.	F	.	C	A	.	.	.	F	.	F	.	.	.
		17X-CC	A	M	R	C	.	.	R	.	.	.	.	.	.	A	A	F	.	F	.	.	.	.	.	.	.	.	.	.	F	.	C	.	.	.	.	.	.	.	.	.
		19X-1, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	F	.	.	F	.	F	C	F	.	.	.	F	F	.	.	.
		19X-3, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	A	.	.	F	.	C	.	F	.	F	F	.	C	A	.	.	.	.	F	F	.	F	F
		19X-5, 120	A	M	.	C	.	.	.	F	.	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	F	.	.	.	.	F	C	.	.	.	.	F	.	.	.	.
		20X-1, 129	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	F	.	.	.	.	F	C	.	.	.	.	F	F	.	F	.
		20X-3, 129	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	F	.	.	F	.	F	C	.	.	.	.	F	F	.	F	.
		20X-5, 129	F	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	.	.	.	.	.	F	C	.	.	.	.	.	.	.	.	.

			20X-CC	A	M	.	A	.	.	.	F	.	.	.	.	.	.	.	.	.	A	.	.	.	.	A	.	C	.	F	.	F	C	C	.	F	.	F	C	F	.	C	.
			21X-1, 134	A	M	.	A	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	.	F	.	A	.	F	.	F	.	.	C	.	.	.	.	F	F	F	.	F	.
			21X-3, 110	A	M	.	A	.	.	.	.	.	.	.	.	C	.	.	.	.	C	.	.	F	.	A	.	F	.	.	.	.	C	.	.	.	.	.	F	F	.	C	.
			21X-5, 120	A	M	.	C	.	.	.	.	.	.	.	.	C	C	C	.	.	C	.	.	.	.	C	.	.	.	.	.	.	F	C	.	.	.	.	F	.	.	F	.
			22X-1, 120	F	M	.	C	.	.	.	.	.	.	.	.	F	C	C	.	.	F	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
			22X-3, 120	A	M	.	C	.	.	.	R	.	.	.	.	F	C	C	.	.	C	.	.	.	.	F	.	F	.	.	.	.	F	.	.	.	.	.	F	.	F	.	.
			22X-5, 120	A	M	.	C	.	.	.	F	.	.	.	.	F	A	A	.	.	C	.	.	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
			23X-1, 72	A	M	.	C	.	.	.	.	.	.	.	.	C	A	A	.	.	C	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	.	F	F	.	F	.
			23X-2, 41	A	M	.	C	.	.	.	.	.	.	.	.	F	A	A	.	.	C	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
			24X-1, 120	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	.	.	F	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	F	.
			24X-3, 120	A	M	.	C	.	.	.	.	.	.	.	.	F	C	C	.	.	F	.	.	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	C	.	.	F	.
		NN19	24X-5, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	C	C	.	.	F	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	.	.	.	F	F	.
			25X-1, 117	A	M	.	C	.	.	.	.	.	.	.	.	C	C	C	.	.	C	.	F	F	.	C	.	F	.	.	F	.	F	.	.	.	F	.	.	.	.	F	F
			25X-3, 5	A	M	.	C	.	.	.	.	.	.	.	.	C	A	.	.	.	C	.	F	.	.	C	.	F	.	.	F	.	.	.	.	.	.	F	.	F	.	F	F
			25X-5, 125	A	M	.	C	.	.	.	.	.	.	.	.	.	A	A	.	.	C	.	F	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
			26X-1, 110	A	M	.	C	.	.	.	F	.	.	.	.	.	C	C	.	.	A	.	F	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
			26X-3, 87	A	M	.	C	.	.	F	F	.	.	.	.	.	C	.	.	.	C	.	C	F	.	C	.	F	.	.	C	.	C	.	.	.	.	.	F	.	.	.	.
			26X-5, 7	A	M	.	A	.	.	.	.	.	.	.	.	.	C	C	.	.	A	.	C	F	.	C	.	F	.	F	F	.	F	.	.	.	.	.	F	F	.	F	.
			26X-CC	A	M	.	A	F	.	.	.	.	.	.	.	.	F	F	.	.	A	.	F	.	.	C	.	F	.	.	.	.	C	F	.	.	.	.	.	.	F	F	.
			27X-1, 81	A	M	.	F	C	.	.	F	.	.	.	.	.	C	C	.	.	C	.	F	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			27X-3, 95	A	M	.	C	A	.	.	F	.	.	.	.	.	F	.	.	.	A	.	C	F	.	C	.	.	.	.	F	.	F	F	.	.	.	.	.	F	.	.	.
			27X-5, 120	A	M	.	C	F	.	R	F	.	.	.	.	.	.	.	.	.	C	.	F	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			28X-1, 120	A	M	.	C	F	.	C	F	.	.	.	.	.	.	.	.	.	C	.	F	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	F	.	.
			28X-2, 121	C	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			29X-1, 120	C	M	.	C	C	.	C	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			29X-2, 100	A	M	.	C	C	.	C	F	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			29X-6, 115	A	M	.	C	F	.	C	C	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
			30X-1, 72	A	M	.	C	F	.	C	C	.	.	.	.	.	.	.	.	.	C	.	C	.	.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	F
			30X-3, 37	A	M	.	C	C	.	C	C	.	.	.	.	.	F	.	.	.	A	.	C	F	.	C	.	.	.	F	.	.	C	.	.	.	.	.	.	F	.	F	.
			30X-5, 89	A	M	.	C	C	.	C	C	.	.	.	.	.	F	.	.	.	A	.	F	F	.	C	.	.	.	F	.	F	.	.	.	.	.	.	.	F	.	.	F
			30X-CC	A	M	.	A	F	.	C	A	.	.	.	.	.	.	.	.	.	A	.	C	.	.	C	.	.	.	.	.	.	F	F	.	F	.	F	.	.	.	.	.
			31X-1, 59	A	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	A	.	C	.	.	C	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.
			31X-3, 119	A	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	F	F	.	.	.	.	.	.	.	F	.	.
			31X-5, 100	A	M	.	F	.	.	C	C	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	.	.	.	.	.	F	F	.	.	F	.	.	.	.	.	.	.
			32X-1, 120	A	M	.	.	F	.	C	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			32X-3, 114	A	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	C	.	.	.	.
			32X-6, 2	A	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	C	.	C	.	.	.	.	F	.	.	.	C	F	.	.	.	.	.	F	.	.	.	.
			33X-1, 59	A	M	.	C	F	.	C	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			33X-3 75	A	M	.	C	F	.	F	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	F	F	.	.	.	F	.	.	.	.	.	.
			33X-5, 88	A	M	.	C	.	.	F	C	.	.	.	.	.	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	F	F	.	.	.	.	.	.	.	.	.	.
			33X-7, 34	C	M	.	C	.	.	F	C	.	.	.	.	.	.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			34X-1, 3	A	M	.	F	F	.	C	C	.	.	.	.	.	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			35X-1, 120	A	M	.	F	F	.	A	A	.	.	.	.	.	.	.	.	.	A	.	F	F	.	.	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			35X-2, 126	A	M	.	F	F	.	A	A	.	.	.	.	.	.	.	.	.	F	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			35X-3, 129	A	M	.	F	.	.	C	C	.	.	.	.	.	.	.	.	.	F	.	.	F	.	.	.	.	.	.	.	F	F	.	.	.	.	.	.	.	.	F	.
Pliocene	late		36X-1, 125	A	M	.	F	F	.	C	C	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			36X-3, 127	A	M	.	C	.	.	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	.	F	.	.
			36X-5, 144	A	M	.	C	F	.	C	C	.	F	.	.	.	.	.	.	.	C	.	C	.	.	.	.	.	R	F	.	.	F	.	.	.	.	F	.	F	.	F	.
			37X-1, 100	A	M	.	F	.	.	C	C	.	F	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			39X-1, 64	C	M	.	F	F	.	C	C	.	F	.	.	.	.	.	.	.	F	.	C	.	.	.	.	F	.	.	.	C	.	C	.	.	.	.	.	.	.	F	.
			39X-3, 80	A	M	.	.	C	.	C	C	.	F	.	.	.	.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.
			39X-5, 63	A	M	.	F	F	.	C	C	.	C	.	.	.	.	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
		NN18	40X-1, 121	A	M	.	F	C	.	C	C	.	.	.	.	.	.	.	.	.	C	.	C	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.	F	.	.	F	.
			40X-3, 87	A	M	.	F	C	.	C	C	.	F	.	.	.	.	.	.	.	F	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			40X-5, 120	A	M	.	F	.	.	C	C	.	F	.	.	.	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	F	F	.	.	.	.	.	.	.	.	.
			41X-1, 16	A	M	.	F	.	.	.	C	.	C	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			41X-2, 117	A	M	.	C	C	.	F	C	.	C	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	F	.	.	F	.	.	.	.	.	F	F	.	F	.
			41X-5, 120	A	M	.	C	.	.	F	C	F	C	.	.	.	.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	.	.	F	.
		NN17	42X-1, 68	A	M	.	F	C	.	F	C	.	F	F	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	F	.	.	.	.

Note: B = barren; R = rare; F = few; C = common; A = abundant; G = good; M = moderate; P = poor; ? = questionably present. Same for Tables 2-9.

Table 2. Distribution of calcareous nannofossils, Site 724.

Age	Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Ceratolithus cristatus*	*Coccolithus crassipons*	*Coccolithus pelagicus*	*Discoaster asymmetricus*	*Discoaster brouweri*	*Discoaster intercalaris*	*Discoaster pansus*	*Discoaster pentaradiatus*	*Discoaster surculus*	*Emiliania huxleyi*	*Gephyrocapsa* (large)	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*
Quaternary	NN21	1H-1, 105	A	M	C	.	.	.	.	.	.	.	.	.	.	C	.	A	A	F
		1H-3, 105	A	M	C	.	.	.	R	.	.	.	.	.	.	C	.	A	A	F
		2H-1, 105	A	M	A	.	.	.	F	.	.	.	.	.	.	F	.	A	A	F
		2H-3, 105	A	G	A	.	.	F	C	.	.	.	.	.	.	F	.	A	A	C
		2H-5, 105	A	G	A	.	.	.	.	.	.	.	.	.	.	F	.	A	A	F
		2H-CC	A	G	A	.	.	.	.	.	.	.	.	.	.	C	.	A	A	.
	NN20	3H-1, 105	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		3H-3, 105	A	G	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	.
		3H-5, 105	A	M	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		4H-1, 105	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		4H-3, 105	A	G	A	.	.	.	.	.	.	.	.	.	.	.	.	A	A	F
		4H-5, 105	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
	NN19	4H-CC	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	.
		5H-1, 105	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	A	A	F
		5H-3, 105	A	G	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	C
		5H-5, 105	A	G	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	C
		6X-1, 105	A	G	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	C
		6X-3, 105	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		6X-4, 105	A	G	A	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		7X-1, 105	A	G	A	.	.	.	.	.	.	.	.	.	.	.	.	A	A	F
		7X-3, 105	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		7X-4, 105	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		8X-1, 110	A	M	F	.	.	.	F	.	.	.	.	.	.	.	.	A	A	C
		8X-3, 110	A	G	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	F
		8X-5, 100	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	A	.
		8X-CC	A	M	A	.	.	.	.	.	.	.	.	.	.	.	.	A	A	F
		9X-1, 105	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.
		9X-3, 105	A	M	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		9X-5, 105	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		9X-CC	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		10X-1, 105	A	M	A	.	.	.	F	.	.	.	.	.	.	.	C	C	C	.
		10X-3, 52	A	P	C	.	.	.	F	.	.	.	.	.	.	.	A	C	C	.
		11X-1, 105	A	M	C	.	.	.	.	.	.	.	.	.	.	.	C	C	C	.
		11X-3, 105	A	M	C	.	.	.	F	.	.	.	.	.	.	.	C	A	C	.
		11X-5, 105	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	C	.
		12X-1, 135	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	C	.
		12X-3, 105	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	A	C	.
		12X-5, 100	A	M	C	.	.	.	F	.	.	.	.	.	.	.	.	A	F	.
		12X-CC	A	M	C	F	.	.	.	.	.	.	.	.	.	.	.	A	A	.
		14X-1, 110	A	M	C	F	.	F	F	.	.	.	.	.	.	.	.	F	F	.
		14X-3, 104	A	M	F	F	.	F	F	.	.	.	.	.	.	.	.	F	.	.
		14X-5, 110	A	M	C	.	.	F	C	.	.	.	.	.	.	.	.	C	.	.
		14X-CC	A	M	C	F	.	C	C	.	.	.	.	.	.	.	.	F	.	.
Pliocene, late		15X-1, 103	A	M	C	F	.	F	C	.	.	.	.	.	.	.	.	.	.	.
		15X-CC, 6	A	M	C	.	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		16X-1, 103	A	M	F	.	.	A	A	.	.	.	.	.	.	.	.	.	.	.
		16X-3, 104	A	M	C	F	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		16X-5, 110	A	M	F	F	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		17X-1, 125	A	M	C	.	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		17X-3, 121	A	M	C	.	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		17X-5, 107	A	M	C	F	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		18X-1, 105	A	M	C	F	.	C	C	.	.	.	.	.	.	.	.	.	.	.
		18X-3, 121	A	M	F	F	.	C	C	.	.	.	.	.	.	.	.	.	.	.
	NN18–NN17	18X-5, 105	F	M	F	F	.	C	C	.	F	.	.	.	.	.	.	.	.	.
		19X-1, 103	A	M	F	F	.	C	C	.	F	.	.	.	.	.	.	.	.	.
		19X-3, 105	A	M	C	.	.	A	A	.	F	.	.	.	.	.	.	.	.	.
		19X-5, 89	A	M	F	F	.	C	A	.	F	.	.	.	.	.	.	.	.	.
		20X-1, 105	A	M	F	F	.	A	A	.	F	.	.	R	.	.	.	.	.	.
		20X-3, 105	A	M	F	C	.	A	C	.	F	.	.	.	.	.	.	.	.	.
		20X-5, 105	A	M	F	F	.	C	C	.	F	.	.	?	.	.	.	.	.	.
		21X-1, 105	B	M	F	F	.	C	C	.	F	.	.	.	.	.	.	.	.	.
	NN16	21X-3, 105	A	M	F	F	.	C	C	.	C	.	.	.	R	.	.	.	.	.
		21X-CC	A	M	F	.	.	A	A	.	F	.	.	F	F	.	.	.	.	.
		22X-1, 74	B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		23X-1, 90	R	M	F	F	.	.	F	F	.	?	.	?	.	.	.	.	.	.
		23X-3, 90	B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		23X-5, 90	B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		24X-1, 98	A	M	F	C	.	.	.	.	F	.	.	F	.	.	.	.	.	.
		24X-3, 105	A	M	F	C	.	.	.	.	F	.	.	?	.	.	.	.	.	.
		24X-5, 105	B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		25X-1, 135	A	M	F	C	.	.	.	F	F	.	.	F	.	.	.	.	.	.
		25X-3, 135	A	M	C	C	.	.	.	F	F	.	.	F	.	.	.	.	.	.
		25X-5, 135	A	M	C	C	R	.	.	.	F	.	.	.	.	.	.	.	.	.
		25X-CC	A	M	A	C	.	.	.	.	F	.	.	F	.	.	.	.	.	.
		26X-1, 104	A	M	C	C	.	.	.	?	F	.	R	F	.	.	.	.	.	.
Pliocene, early	NN15–NN12	26X-3, 114	A	M	F	C	.	.	.	.	F	.	.	.	.	.	.	.	.	.
		26X-5, 114	A	M	C	C	.	.	.	.	F	.	.	F	.	.	.	.	.	.
		27X-1, 74	A	M	C	C	.	C	F	.	F	R	.	?	.	.	.	.	.	.
		27X-3, 74	F	M	C	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
		27X-5, 74	A	M	F	C	.	.	.	.	F	.	.	F	.	.	.	.	.	.

Table 2 (continued).

Gephyrocapsa protohuxleyi	*Helicosphaera carteri*	*Helicosphaera inversa*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pseudoemiliania lacunosa*	*Reticulofenestra gelida*	*Reticulofenestra pseudoumbilica*	*Reticulofenestra* sp. A	*Reticulofenestra* sp. B	*Rhabdosphaera clavigera*	*Rhabdosphaera stylifera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Sphenolithus abies*	*Syracosphaera pulchra*	*Thoracosphaera albatrosiana*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
F	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	F	.	F	.	.	F	.	F	F
.	C	.	.	.	.	A	.	.	.	.	.	.	.	.	.	.	F	.	F	.	.	F	.	F	.
.	C	.	.	F	.	A	F	.	.	.	.	.	.	.	.	.	.	.	C	.	.	C	.	C	.
F	C	.	.	F	.	A	C	F	.	.	.	.	.	.	.	.	.	.	F	.	.	F	.	F	.
.	F	.	.	C	.	A	C	F	.	.	.	.	.	.	.	.	.	.	C	.	.	F	.	F	.
F	C	.	.	F	.	A	.	F	.	.	.	.	.	.	.	.	F	.	F	.	.	F	.	F	.
.	C	.	.	F	.	A	F	.	.	.	.	.	.	.	.	.	F	.	F	.	.	C	.	F	F
.	C	.	.	.	.	C	C	.	.	.	.	.	.	.	.	.	.	.	C	.	.	C	.	C	F
.	C	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
.	C	F	.	.	.	A	F	.	.	F	.	.	.	.	.	.	.	.	F	.	.	C	.	F	.
.	A	.	.	.	.	A	F	.	F	C	.	.	.	.	.	.	.	.	F	.	.	C	.	F	.
.	A	.	.	.	.	A	C	F	.	F	.	.	.	.	.	.	.	F	C	.	.	C	.	F	.
.	C	.	.	.	.	A	F	F	.	.	.	F	.	.	.	.	.	.	.	F	.	.	.	F	.
.	A	.	.	.	.	A	C	F	.	.	.	C	.	.	.	.	.	.	F	.	.	C	.	F	.
.	C	.	.	.	.	A	C	.	.	F	.	C	.	.	.	.	.	.	F	.	.	C	.	C	.
.	C	.	.	F	.	A	F	.	.	F	.	C	.	.	.	.	.	.	.	.	.	F	.	F	.
.	C	.	.	.	.	C	F	F	.	.	.	F	.	.	.	.	.	.	.	.	.	C	.	F	.
.	A	.	.	.	.	A	F	F	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.
.	A	.	.	.	.	A	.	F	.	.	.	F	.	.	.	.	.	.	F	.	.	F	.	F	.
.	C	.	.	.	.	A	.	C	.	F	.	F	.	.	.	.	.	.	F	F	.	F	.	C	.
.	C	.	.	F	.	C	C	F	.	F	.	F	.	.	.	.	.	.	F	F	.	F	.	.	.
.	C	.	.	F	.	A	F	F	.	F	F	F	.	.	.	.	.	.	F	F	.	F	.	F	.
.	F	.	.	.	.	C	F	F	F	.	F	F	.	.	C	.	.	.	.	F	.	F	.	F	.
.	F	.	.	F	.	A	F	F	.	.	.	F	.	.	C	R	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	C	.	F	.	.	.	C	.	.	C	.	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	A	.	F	.	.	.	F	.	.	C	F	.	F	F	.	.	F	.	F	.
.	F	.	.	.	.	A	.	.	.	.	.	C	.	.	A	F	.	.	F	.	.	F	.	.	.
.	A	.	.	.	.	A	C	C	.	F	.	A	.	.	A	.	.	.	.	.	.	F	.	F	.
.	C	.	.	.	.	C	.	F	.	F	F	C	.	.	C	.	.	.	.	F	.	.	.	F	.
.	C	.	.	.	F	.	.	F	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.
.	A	.	.	.	.	A	C	C	F	.	.	C	.	.	.	.	R	.	F	.	.	C	.	.	.
.	A	.	.	.	.	A	.	C	.	.	F	C	.	.	.	.	.	.	.	.	.	.	.	F	F
.	A	.	.	.	.	A	F	.	.	C	.	C	.	.	.	.	.	.	.	F	.	.	.	F	.
.	C	.	.	.	.	A	.	.	.	.	.	F	.	.	.	.	.	.	.	F	.	F	.	F	.
.	C	.	.	.	.	A	F	F	.	.	C	F	.	.	.	.	.	.	.	F	.	F	.	F	.
.	C	.	.	.	.	A	.	F	.	F	.	C	.	.	.	.	.	.	.	F	.	F	.	F	.
.	A	.	F	F	.	A	F	F	.	F	.	C	.	.	.	.	F	.	.	F	.	F	.	F	F
.	C	.	.	.	.	A	.	F	.	.	.	F	.	.	F	.	.	.	.	F	.	.	.	C	.
.	C	.	F	.	.	A	.	F	F	.	.	F	.	.	C	.	.	.	.	F	.	F	F	F	.
.	C	.	C	F	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	C	.	.	.	.	.	F	.	.	C	.	.	.	.	.	.	F	.	.	F	.	.	.
.	C	.	C	F	.	A	.	F	.	.	F	F	.	.	.	.	.	.	.	.	.	C	.	.	.
.	C	.	C	.	.	A	.	.	.	F	F	F	.	.	F	.	F	.	F	F	.	.	F	F	.
.	C	.	C	F	.	C	.	F	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	.	F
.	C	.	C	.	.	C	.	.	F	.	F	F	.	.	.	.	.	.	.	.	.	.	.	.	F
.	C	.	C	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	F	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.
.	C	.	C	.	.	C	.	.	.	F	.	F	.	.	.	.	.	.	.	F	.	.	.	.	.
.	C	.	C	.	.	C	.	F	.	.	F	.	.	.	.	.	.	.	F	.	.	F	.	F	F
.	C	.	C	.	.	C	.	F	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.
.	C	.	C	.	.	C	.	F	.	.	F	C	.	.	.	.	.	.	.	.	.	F	.	.	.
.	C	.	F	.	.	.	.	F	.	.	.	C	.	.	.	.	.	.	F	.	.	.	.	.	.
.	C	.	F	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.
.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	F	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	.	.	F	.	.	.	C	.	.	.	.	.	.	.	F	.	.	.	.	.
.	C	.	F	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	C	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.
.	C	.	F	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	F	.	.	.	.	.
.	F	.	.	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	F	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	F	F	.	F	.	F	.
.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.
.	F	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	C	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	F	.	.	.	.	.
.	C	.	F	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	C	.	.	.	.
.	C	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	C	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	.
.	C	.	.	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	F	A	.	.	F	.
.	C	.	.	.	.	.	.	F	.	.	.	.	.	F	.	.	.	.	.	.	A	.	.	F	.
.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	A	.	.	.	.
.	C	.	.	.	.	.	.	F	.	.	.	F	F	F	.	.	.	.	.	F	C	.	.	.	.
.	C	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	C	.	.	.	.
.	C	.	.	.	.	.	.	F	.	.	.	.	F	F	.	.	.	.	F	.	C	.	.	.	.

Table 3. Distribution of calcareous nannofossils, Hole 725C.

Age	Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Calcidiscus leptoporus*	*Coccolithus crassipons*	*Coccolithus pelagicus*	*Emiliania huxleyi*	*Gephyrocapsa* (large)	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*	*Helicosphaera carteri*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*
Quaternary	NN21	1H-1, 118	A	G	F	.	.	C	.	A	A	F	F	.	F	.	C
		1H-3, 118	A	G	A	.	F	A	.	A	A	C	C	.	F	.	.
		1H-5, 118	A	G	F	.	.	F	.	A	A	.	F	.	.	.	C
		2H-1, 118	A	G	G	.	F	C	.	A	A	.	C	.	.	.	C
		2H-3, 118	A	M	C	.	.	F	.	A	A	.	C	.	.	.	C
		2H-5, 118	A	M	C	.	F	F	.	A	A	F	C	.	.	.	C
		3H-1, 118	C	M	C	.	F	.	.	A	A	.	C	.	.	.	C
		3H-3, 118	C	M	C	.	.	C	.	A	A	C	F	.	F	.	C
		3H-5, 118	A	M	C	.	.	A	.	A	A	C	F	.	F	.	.
	NN20	3H-CC	A	M	C	.	.	.	.	A	A	F	C	.	.	.	A
		4X-1, 118	A	M	C	.	.	.	.	A	A	.	C	.	.	.	C
		6X-1, 118	A	M	C	F	.	.	.	A	A	.	F	.	.	.	F
		6X-2, 118	A	M	C	.	.	.	.	A	A	.	F	.	.	.	C
	NN19	6X-3, 118	A	M	A	.	.	.	.	A	A	F	C	.	.	.	C
		8X-1, 118	A	M	C	.	.	.	.	A	A	F	C	.	.	.	F
		8X-2, 118	C	M	F	F	.	.	.	C	C	.	F	.	.	.	C
		8X-3, 69	A	M	C	.	F	.	.	A	A	.	F	.	.	.	C
		9X-1, 118	A	M	C	.	F	.	.	A	A	.	C	.	.	.	C
		9X-3, 118	A	M	C	.	F	.	.	A	A	F	C	.	.	.	C
		9X-5, 58	A	M	C	.	.	.	.	A	A	.	C	.	.	.	C
		11X-1, 118	A	M	C	.	.	.	.	A	A	.	C	.	.	.	C
		11X-3, 118	A	M	C	.	.	.	.	A	A	F	F	.	F	.	.
		11X-5, 93	A	M	C	.	.	.	.	C	C	F	C	.	.	.	C
		11X-CC	A	M	C	.	.	.	.	F	F	.	C	.	.	.	C
		12X-1, 118	A	M	C	.	.	.	.	F	F	.	A	.	.	.	C
		12X-3, 118	A	M	C	.	.	.	.	F	F	.	C	.	.	.	C
		13X-1, 118	A	M	C	.	F	.	.	F	F	.	A	.	.	F	C
		13X-3, 59	A	M	C	.	.	.	.	F	F	.	A	.	.	.	C
		13X-CC	A	M	C	.	.	.	.	F	F	.	C	.	.	.	.
		14X-1, 118	C	M	C	.	F	.	C	.	C	.	F	.	.	.	C
		14X-3, 118	C	M	F	.	F	.	C	C	C	.	C	.	.	.	C
		14X-5, 118	A	M	C	.	.	.	F	A	A	.	C	.	.	F	C
		15X-1, 119	A	M	A	.	.	.	A	A	A	.	C	.	.	F	C
		15X-3, 118	A	M	C	.	.	.	F	A	A	.	C	.	.	F	C
		15X-5, 118	A	M	C	.	F	.	C	A	A	.	C	.	.	.	C
		16X-1, 139	C	M	F	.	.	.	.	A	A	.	F	.	.	.	F
		16X-CC,	A	M	C	.	.	.	C	A	A	.	C	F	.	.	A
		17X-1, 129	A	M	C	F	.	.	.	C	C	.	A	.	.	.	C
		17X-3, 118	A	M	F	C	.	.	.	.	.	.	C	C	.	.	.
		17X-5, 113	C	M	F	.	F	.	F	C	C	.	F	.	.	.	F

Core, section, interval (cm)	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pseudoemiliania lacunosa*	*Reticulofenestra* sp. A	*Reticulofenestra* sp. B	*Rhabdosphaera clavigera*	*Rhabdosphaera stylifera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Syracosphaera pulchra*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
1H-1, 118	F	.	.	.	.	.	.	.	.	.	F	F	C	.	.
1H-3, 118	F	F	.	.	.	.	.	.	.	.	F	.	F	F	F
1H-5, 118	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
2H-1, 118	.	.	.	.	.	.	.	.	.	.	.	.	F	F	.
2H-3, 118	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
2H-5, 118	F	.	.	.	.	.	.	.	.	.	.	.	.	F	.
3H-1, 118	.	.	F	.	.	.	.	.	.	.	F	.	F	F	.
3H-3, 118	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.
3H-5, 118	F	.	.	.	.	.	.	.	.	.	F	.	F	.	.
3H-CC	.	.	.	A	.	.	.	.	.	.	F	.	F	.	.
4X-1, 118	.	.	F	.	.	.	.	.	.	.	.	.	F	F	.
6X-1, 118	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
6X-2, 118	C	.	F	.	.	.	.	.	.	.	F	.	.	.	.
6X-3, 118	C	.	.	F	.	F	.	.	.	.	F	F	.	.	.
8X-1, 118	.	F	.	.	.	.	.	.	.	.	F	.	.	F	.
8X-2, 118	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.
8X-3, 69	.	F	.	.	.	.	.	.	.	.	.	F	.	F	.
9X-1, 118	.	F	.	F	.	.	.	.	.	.	.	.	.	F	.
9X-3, 118	.	F	.	.	.	F	.	.	.	.	F	F	.	F	.
9X-5, 58	C	.	.	.	.	F	.	.	.	.	F	.	F	F	.
11X-1, 118	C	F	.	.	.	.	R	.	.	.	.	F	.	.	.
11X-3, 118	F	F	.	.	.	F	.	.	.	.	F	.	F	.	.
11X-5, 93	.	F	.	.	F	F	C	F	.	.	.	F	F	.	.
11X-CC	F	F	.	.	F	F	C	.	F	.	F	.	.	F	.
12X-1, 118	.	F	.	.	.	F	F	.	F	.	.	.	.	F	.
12X-3, 118	F	F	.	.	.	F	C	.	.	.	.	F	.	F	.
13X-1, 118	F	F	.	.	.	C	C	.	.	.	.	.	.	.	.
13X-3, 59	.	F	.	.	.	F	.	.	.	.	.	F	.	F	.
13X-CC	.	F	.	F	.	F	.	.	.	.	F	F	.	F	.
14X-1, 118	.	.	.	.	.	F	.	.	.	.	.	F	.	.	.
14X-3, 118	.	F	.	.	C	C	.	.	.	.	.	F	.	.	.
14X-5, 118	.	F	.	.	F	C	C	.	.	.	.	F	.	F	.
15X-1, 119	.	F	.	.	.	F	.	.	.	.	.	C	.	F	.
15X-3, 118	.	F	F	.	.	C	F	.	.	.	.	F	.	F	.
15X-5, 118	.	F	F	.	.	F	F	.	.	.	.	F	F	F	.
16X-1, 139	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
16X-CC,	.	F	.	.	.	F	F	.	.	.	.	F	.	F	.
17X-1, 129	.	F	.	.	.	F	.	.	.	F	.	.	F	F	.
17X-3, 118	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
17X-5, 113	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.

curs between Samples 177-726A-7X-5, 118 cm, and 117-726A-7X-CC. The central bridges of *Gephyrocapsa* spp. are frequently dissolved making the FAD of *Gephyrocapsa caribbeanica* somewhat dubious, and making the accurate recognition of the FAD of *Gephyrocapsa oceanica* impossible.

Late Pliocene Zone NN18 (*Discoaster brouweri* Zone) is represented from Sample 117-726A-8X-1, 118 cm, down to Sample 117-726A-8X-5, 103 cm (64.78–70.63 mbsf). This zone is recognized by the presence of *D. brouweri* as the sole representative of the genus.

The LAD of *Discoaster pentaradiatus* (top of Zone NN17) is recognized between Samples 117-726A-8X-5, 103 cm, and 117-726A-8X-CC, but the LAD of *Discoaster surculus* is not recognizable. Therefore, it is not possible to separate Zones NN16 and NN17 in this hole. The LAD of *Sphenolithus abies* occurs between Samples 117-726A-8X-CC, and 117-726A-9X-1, 118 cm.

The LAD of *Reticulofenestra pseudoumbilica*, which marks the top of Zone NN15, is in the interval between 117-726A-9X-3, 92 cm, and 117-726A-9X-4, 15 cm. The LAD of *Amaurolithus tricorniculatus*, the FAD of *Discoaster asymmetricus*, and the FAD of *Ceratolithus rugosus* are not recognized. These datums mark the tops of Zones NN14, NN13, and NN12, respectively. Therefore, Zones NN12 through NN15 have been combined.

The LAD of *Discoaster quinqueramus* (and *Discoaster berggrenii*) occurs between Samples 117-726A-11X-1, 118 cm, and 117-726A-11X-3, 118 cm. The total range of *D. quinqueramus* was used by Martini (1971) to define the *Discoaster quinqueramus* Zone (Zone NN11). The FAD of *D. quinqueramus* (and *D. berggrenii*) occurs between Samples 117-726A-11X-4, 120 cm, and 117-726A-12X-CC (98.10–102.10 mbsf).

Zone NN10 (*Discoaster calcaris* Zone) is defined by the absence of both *D. quinqueramus* and *Discoaster hamatus*. Sediments from 102.10 to 116.24 mbsf fit these requirements and can therefore, be assigned to this zone. A questionable specimen of *D. hamatus* was encountered in Sample 117-726A-13X-5, 144 cm. Whether this is a reworked specimen is unknown, but I have assigned this sample to the *Discoaster hamatus* Zone (NN9). Calcareous nannofossils are completely absent from the rest of the sedimentary sequence recovered from Hole 726A.

Rare to few specimens of *Coccolithus pelagicus* are found in three samples assigned to Zones NN21 down through the middle part of Zone NN19. Again, this species becomes more abundant and is common just above the LAD of *Calcidiscus macintyrei* down through the uppermost part of Zone NN18. *C. pelagicus* is absent from Samples 117-726A-8X-CC, through 117-726A-9X-4, 15 cm, but appears again in Samples 117-726A-10X-1, 18 cm, through 117-726A-13X-5, 144 cm (Zones NN12-NN15 down to the upper part of Zone NN9), where it is few to common. Samples 117-726A-9X-1, 118 cm, through 117-726A-11X-3, 118 cm, contain very few discoasters, in relative terms.

Site 727

Site 727 is located on the continental margin of Oman in approximately 925 m of water at 17°40.096′N and 57°35.261′E. This site together with Site 723 were targeted to drill where the central part of the OMZ impinges on the bottom (Fig. 3). Two holes were drilled at this site. Hole 727A penetrated to a depth of 182.20 mbsf with 103% recovery, and the oldest sediments recovered are late Pliocene. Hole 727B was drilled solely to recover the mud line and was completed after retrieving three APC cores. Hole 727B also had 103% recovery with a sub-bottom depth of 27.10 m. All of the sediments recovered from Site 727 can be assigned to a single lithologic unit (Prell, Niitsuma, et al., 1989).

Hole 727A (Table 5)

With one exception (Sample 117-727A-17X-1, 100 cm), calcareous nannofossils are abundant in all samples studied from Hole 727A. Preservation of the nannofossils ranges from moderate to good.

Samples 117-727A-1H-1, 118 cm, down through 117-727A-3H-3, 118 cm (11.18–23.28 mbsf), contain few to abundant specimens of *Emiliania huxleyi* with the abundance decreasing downsection. These sediments are assigned to the late Pleistocene to Holocene Zone NN21 (*Emiliania huxleyi* Zone). Sediments from 26.08 to 37.80 mbsf contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and are assigned to Zone NN20 (*Gephyrocapsa oceanica* Zone).

The LAD of *Pseudoemiliania lacunosa* (between Samples 117-727A-4H-CC, and 117-727A-5H-1, 118 cm) marks the top of Zone NN19 (*P. lacunosa* Zone). Compared to Zones NN21 and NN20, this is a zone of relatively long duration and at this site, most of the recovered sediments (37.80–179.90 mbsf) are assigned to it. Several nannofossil datums are recognizable within this zone. The FAD of *Helicosphaera inversa* occurs between Samples 117-727A-5H-3, 118 cm, and 117-727A-5H-5, 118 cm. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) is recognized between Samples 117-727A-9H-CC, and 117-727A-10H-3, 118 cm. The FAD of *Gephyrocapsa parallela* occurs between Samples 117-727A-10H-5, 118 cm, and 117-727A-10H-7, 118 cm. The LAD of large gephyrocapsids is between Samples 117-727A-12X-3, 118 cm, and 117-727A-12X-CC. The LAD of *Helicosphaera sellii* is between Samples 117-727A-14X-1, 118 cm, and 117-727A-14X-3, 114 cm. The LAD of *Calcidiscus macintyrei* occurs between Samples 117-727A-15X-1, 106 cm, and 117-727A-15X-3, 116 cm. The FAD of *Gephyrocapsa oceanica* is observed between Samples 117-727A-15X-CC, and 117-727A-16X-1, 118 cm. The FAD of *Gephyrocapsa caribbeanica*, which also marks the approximate position of the Pliocene-Pleistocene boundary, occurs at 147.78–150.74 mbsf (between Samples 117-727A-16X-3, 118 cm, and 117-727A-16X-5, 118 cm).

The LAD of *Discoaster brouweri*, which marks the top of late Pliocene Zone NN18 (*Discoaster brouweri* Zone), occurs between Samples 117-727A-19X-5, 120 cm, and 117-727A-19X-CC. Therefore, the lowermost sediments recovered from this hole can be assigned to Zone NN18.

Coccolithus pelagicus is few to common in scattered samples in Zones NN21 down through most of Zone NN19. *C. pelagicus* and *C. crassipons* increase in number just below the FAD of *Gephyrocapsa caribbeanica*. These species are few to abundant in Sample 117-727A-17X-1, 100 cm, down to the bottom of the hole and is especially abundant in Sample 117-727A-19X-5, 120 cm.

Site 728

Site 728 is located in approximately 1425 m of water at 17°40.700′N and 59°49.553′E. This site was selected because the sediment-water interface is presumed to lie in the lowermost part of the OMZ. Site 728 lies approximately in the center of the deeper of two slope basins (Fig. 3). The deeper basin is approximately 8 km wide and is smaller in areal extent than the upper (and shallower) slope basin where Sites 723, 724, and 727 are located. Two holes were drilled at this site with both of them reaching approximately 347 mbsf. Recovery from Hole 728A is 99% and 100% for Hole 728B. This site provides the longest continuous section recovered on the Oman Margin. The oldest sediments recovered are late Miocene in age (Prell, Niitsuma, et al., 1989).

Hole 728A (Table 6, Back pocket)

The sediments recovered at Hole 728A can be described as one lithologic unit which is divided into three subunits based on minor biogenic components. Calcareous nannofossils are abundant throughout the recovered section. Their preservation ranges from moderate to good. The sequence appears to record continuous sedimentation at Hole 728A from the late Miocene to the

Table 4. Distribution of calcareous nannofossils, Hole 726A.

Age		Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Braarudosphaera bigelowii*	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Coccolithus crassipons*	*Coccolithus pelagicus*	*Discoaster adamanteus*	*Discoaster berggrenii*	*Discoaster brouweri*	*Discoaster calcaris*	*Discoaster hamatus*	*Discoaster intercalaris*	*Discoaster neohamatus*	*Discoaster pentaradiatus*	*Discoaster quinqueramus*	*Discoaster surculus*	*Discoaster variabilis*	*Emiliania huxleyi*	*Gephyrocapsa* (large)
Quaternary		NN21	1H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.
			1H-3, 118	A	M	.	C	.	.	R	.	.	.	.	.	.	.	.	.	.	.	A	.
			1H-5, 70	A	M	.	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.
			2H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
			2H-3, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.
		NN20	2H-5, 118	A	M	.	C	.	R	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			3H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			3H-3, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		NN19	3H-5, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			3H-CC	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			4H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			4H-3, 118	A	M	.	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
			4H-5, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			4H-CC	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			5H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			5H-3, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			5H-5, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
			5H-CC	A	M	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C
			6H-1, 118	A	M	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C
			6H-3, 118	R	M	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F
			6H-5, 118	A	M	.	C	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	A
			6H-CC	A	M	F	C	.	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.
			7X-1, 118	A	M	.	C	F	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.
			7X-3, 118	A	M	.	C	F	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.
			7X-5, 118	A	M	.	F	F	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.
			7X-CC	A	M	.	C	F	C	C	.	.	.	.	.	.	.	.	.	.	.	.	.
Pliocene	late	NN18	8X-1, 118	A	M	.	F	C	C	C	.	.	C	.	.	.	.	.	.	.	.	.	.
			8X-3, 118	A	M	.	F	F	F	F	.	.	F	.	.	.	.	.	.	.	.	.	.
			8X-5, 103	A	M	.	F	C	F	F	.	.	.	.	.	.	.	.	.	.	.	.	.
		NN17–NN16	8X-CC	A	M	.	C	F	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.
			9X-1, 118	F	M	.	F	F	.	.	.	.	F	.	.	.	.	?	.	.	.	.	.
			9X-3, 92	A	M	.	F	C	.	.	.	.	F	.	.	.	.	F	.	.	.	.	.
	early	NN15–NN12	9X-4, 15	A	M	.	F	C	F	.	.	.	F	.	.	.	.	.	.	.	.	.	.
			10X-1, 118	A	M	.	F	C	C	C	.	.	C	.	.	.	.	C	.	F	F	.	.
			10X-3, 118	A	M	.	F	C	C	C	.	.	F	.	.	.	.	C	.	.	.	.	.
			10X-5, 108	A	M	.	C	F	.	F	.	.	F	.	.	.	.	.	.	.	.	.	.
			11X-1, 118	A	M	.	.	.	.	C	.	.	F	.	.	.	.	F	.	F	.	.	.
Miocene	late	NN11	11X-3, 118	A	M	.	F	.	.	C	.	F	F	.	.	.	.	F	F	.	F	.	.
			11X-4, 120	A	M	.	A	.	.	F	.	F	F	.	.	.	.	F	F	F	.	.	.
		NN10	13X-1, 144	A	M	.	C	C	.	C	.	.	F	.	.	.	.	F	.	.	.	.	.
			13X-3, 144	A	M	.	F	C	F	C	R	.	F	F	.	F	F	F	.	F	.	.	.
	middle	NN9	13X-5, 144	A	M	.	F	F	.	F	.	.	F	.	?	.	.	.	.	.	.	.	.

Recent. Sediments from 1.18 mbsf down to 10.78 mbsf (Samples 117-728A-1H-1, 118 cm, to 117-728A-2H-1, 118 cm) contain common to abundant *Emiliania huxleyi* and are referred to the late Pleistocene to Holocene *Emiliania huxleyi* Zone (NN21). Samples 117-728A-2H-3, 118 cm, down to 117-728A-2H-CC (13.78–19.10 mbsf), contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and are therefore assigned to the *Gephyrocapsa oceanica* Zone (NN20). The LAD of *P. lacunosa*, which marks the top of Zone NN19 (*Pseudoemiliania lacunosa* Zone), occurs between Samples 117-728A-2H-CC, and 117-728A-3H-1, 118 cm. This zone extends down to the LAD of *Discoaster brouweri* which occurs between Samples 117-728A-7H-3, 125 cm, and 117-728A-7H-5, 125 cm. Several nannofossil datums can be recognized within Zone NN19. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) occurs between Samples 117-728A-4H-1, 118 cm, and 117-728A-4H-3, 118 cm. The FAD of *Gephyrocapsa parallela* is recognized between Samples 117-728A-4H-5, 118 cm, and 117-728A-4H-CC. The LAD of large gephyrocapsids occurs between Samples 117-728A-5H-3, 118 cm, and 117-728A-5H-5, 118 cm. The LAD of *Helicosphaera sellii* is recognized between Samples 117-728A-6H-1, 118 cm, and 117-728A-6H-3, 118 cm. The LAD of *Calcidiscus macintyrei* and the FAD of *Gephyrocapsa oceanica* are recognized within the interval between Samples 117-728A-6H-3, 118 cm, and 117-728A-6H-5, 118 cm. This is not to imply that these two events are synchronous, but is more likely a reflection of the sampling interval in combination with the lower sedimentation rate at this site. These two datums are however, very close in their temporal occurrences (Takayama and Sato, 1987).

The *Discoaster brouweri* Zone (NN18) extends from the LAD of *D. brouweri* to the LAD of *Discoaster pentaradiatus* (Samples 117-728A-7H-5, 125 cm, to 117-728A-8H-1, 118 cm; 64.25–

Table 4 (continued).

Gephyrocapsa caribbeanica	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*	*Gephyrocapsa protohuxleyi*	*Helicosphaera carteri*	*Helicosphaera intermedia*	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pseudoemiliania lacunosa*	*Reticulofenestra gelida*	*Reticulofenestra pseudoumbilica*	*Reticulofenestra* sp. A	*Reticulofenestra* sp. B	*Rhabdosphaera clavigera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Sphenolithus abies*	*Sphenolithus moriformis*	*Syracosphaera pulchra*	*Thoracosphaera albatrosiana*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
A	A	.	.	F	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	F	F	.	.	.	F	.	F	.
A	A	.	.	F	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.
A	A	.	.	C	.	.	.	.	C	C	F	F	.	.	.	.	.	.	.	.	F	F	.	.	.	.	F	.
A	A	.	.	C	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.
A	A	.	F	F	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.
A	A	.	.	C	.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.	F	.
A	A	.	.	C	.	.	.	.	C	F	F	.	.	.	.	.	.	.	.	.	.	F	.	.	F	.	F	.
A	A	.	.	F	.	.	.	.	C	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.	F	.	F	.
A	A	F	.	F	.	.	.	.	A	C	F	.	.	.	R	.	.	.	.	.	F	F	.	.	.	.	F	.
A	A	F	.	C	.	.	.	.	.	F	F	F	.	.	F	.	.	.	.	.	F	F	.	.	.	.	F	.
A	A	C	.	C	.	.	.	.	A	C	.	.	.	.	F	.	.	.	.	.	F	.	.	.	F	.	F	.
A	A	C	.	C	.	.	.	.	A	C	C	.	F	.	C	.	.	.	.	F	F	F	.	.	F	.	.	.
A	A	C	.	F	.	.	.	.	A	C	.	.	.	.	F	.	.	.	.	.	F	F	.	.	F	.	.	.
A	A	.	F	C	.	.	.	.	C	F	.	.	.	.	C	.	.	C	F	.	F	.	.	.	F	.	F	.
.	.	.	.	C	.	.	.	.	A	C	F	.	.	.	F	.	.	C	.	.	.	F	.	.	.	.	F	.
.	.	.	.	C	.	.	.	.	C	C	F	.	.	.	C	.	.	C	.	.	F	F	.	.	F	.	F	.
.	.	.	.	A	.	.	.	.	C	F	F	.	.	.	F	.	.	F	.	.	.	.	.	.	.	.	F	.
A	A	.	.	C	.	.	.	.	C	.	F	.	.	F	F	.	.	.	.	.	.	F	.	.	.	.	F	.
.	.	.	.	F	.	.	.	.	C	C	F	.	.	.	F	.	.	.	.	.	.	F	.	.	.	.	F	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	.
A	C	.	.	C	.	.	.	.	A	C	F	.	.	F	F	.	.	F	.	.	F	F	.	.	F	.	F	.
.	.	.	.	C	.	C	.	F	A	C	F	.	.	.	C	.	.	.	.	F	F	.	.	.	F	.	.	.
A	.	.	.	C	.	C	F	.	A	C	.	.	.	F	C	.	.	F	.	.	.	.	.	.	C	.	.	.
.	.	.	.	C	.	.	.	.	C	C	F	.	F	.	F	.	.	.	.	.	F	F	.	.	F	.	F	F
C	.	.	.	C	.	F	F	.	A	.	.	.	.	F	C	.	.	.	.	.	.	.	.	.	F	.	.	.
.	.	.	.	C	.	C	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.
.	.	.	.	C	.	.	.	.	.	F	F	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	F	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	F	F	.
.	.	.	.	C	.	.	.	.	.	.	F	.	.	.	F	.	.	.	.	.	.	.	.	.	F	.	.	.
.	.	.	.	C	.	F	.	.	C	.	F	.	.	.	.	.	.	C	.	.	.	.	.	.	.	F	.	.
.	.	.	.	F	.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	.	F	.
.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	C	.	.	F	F	.
.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	F	.	.	.	.	.	C	.	.	.	.	.
.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	C	A	.	.	.	.	.	A	.	.	.	.	.
.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	A	.	.	.	.	.	C	.	.	.	.	.
.	.	.	.	C	.	.	.	.	F	.	F	.	.	.	.	C	A	.	.	F	.	.	A	.	.	.	.	.
.	.	.	.	F	.	.	.	.	F	.	F	.	.	.	.	C	A	.	.	.	.	.	C	.	.	.	.	F
.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	F	A	.	.	.	.	F	C	C	.	.	F	.
.	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	C	.	.	.	.	.	A	A	.	.	.	.
.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	.	C	C	.	.	.	.	.	C	C	.	.	.	.
.	.	.	.	F	.	.	.	.	.	F	.	.	.	.	.	A	A	.	.	.	.	.	C	.	.	.	.	F
.	.	.	.	.	F	.	.	.	.	.	.	.	.	.	.	A	F	.	.	.	.	.	F	F	.	.	.	F

67.68 mbsf). The LAD of *Discoaster surculus* delimits the top of Zone NN16 (*Discoaster surculus* Zone). Unfortunately, this datum was not recognized at this site, so Zones NN16 and NN17 have been combined. The LAD of *Discoaster tamalis* occurs between Samples 117-728A-8H-CC, and 117-728A-9H-1, 118 cm, in Zones NN16-17.

The LAD of *Reticulofenestra pseudoumbilica* marks the top of Zone NN15 (*Reticulofenestra pseudoumbilica* Zone). The LAD of *Sphenolithus* spp. also occurs within the same interval (117-728A-10X-CC, to 117-728A-11X-1, 118 cm). The absence of warm water index species hinders the ability to zone these sediments more precisely. The zonal markers for Zones NN13 and NN14, *Ceratolithus rugosus* and *Amaurolithus tricorniculatus*, are absent making it necessary to combine latest Miocene and early Pliocene Zones NN12 through NN15.

The LAD of *Discoaster quinqueramus*, which marks the top of Zone NN11 (*Discoaster quinqueramus* zone), occurs between Samples 117-728A-24X-1, 121 cm, and 117-728A-24X-3, 120 cm. Therefore, sediments from 117-728A-11X-1, 118 cm, to 117-728A-24X-1, 120 cm (96.48–222.01 mbsf), are assigned to Zones NN12-NN15. Sediments from the LAD of *D. quinqueramus* down to the bottom of this hole can be assigned to Zone NN11.

Coccolithus pelagicus is more ubiquitous at Hole 728A than at the other holes examined thus far. A few specimens of *C. pelagicus* are present in all samples from Zones NN21 and NN20 and in most samples from Zone NN19 down to the LAD of large gephyrocapsids. An increase in the numbers of *C. pelagicus* occurs at the level of the LAD of *Helicosphaera sellii*. *C. pelagicus* is common to abundant in Samples 117-728A-6H-3, 118 cm, through 117-728A-9H-1, 118 cm (lower part of Zone

Table 5. Distribution of calcareous nannofossils, Hole 727A.

Age	Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Calcidiscus leptoporus*	*Calcidiscus macintyrei*	*Ceratolithus cristatus*	*Ceratolithus telesmus*	*Coccolithus crassipons*	*Coccolithus pelagicus*	*Discoaster brouweri*	*Emiliania huxleyi*	*Gephyrocapsa* (large)	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*	*Gephyrocapsa protohuxleyi*	*Helicosphaera carteri*
Quaternary	NN21	1H-1, 118	A	G	A	.	.	.	.	.	.	A	.	A	A	C	.	A
		1H-3, 118	A	M	C	.	.	.	.	R	.	C	.	A	A	F	.	C
		1H-5, 118	A	G	A	.	.	R	.	.	.	C	.	A	A	C	.	C
		2H-1, 118	A	M	C	.	.	.	.	R	.	C	.	A	A	F	.	C
		2H-3, 118	A	M	A	.	.	.	F	.	.	C	.	A	A	C	.	C
		2H-5, 118	A	M	C	.	.	.	.	F	.	C	.	C	C	F	C	C
		3H-1, 118	A	M	A	.	.	.	.	F	.	C	.	A	A	C	.	C
		3H-3, 118	A	M	C	.	.	.	.	.	.	F	.	A	A	.	.	C
	NN20	3H-5, 118	A	M	C	.	.	.	.	.	.	.	.	F	F	F	.	C
		4H-1, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	F	.	F
		4H-3, 118	A	M	A	.	.	.	.	.	.	.	.	A	A	F	.	F
		4H-5, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	C	.	A
		4H-CC	A	M	A	.	.	.	.	.	.	.	.	A	A	C	.	A
	NN19	5H-1, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	C	.	C
		5H-3, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	.	.	C
		5H-5, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	C	F	C
		6H-1, 118	A	M	C	.	.	.	.	R	.	.	.	A	A	F	.	C
		6H-3, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	C	.	C
		6H-5, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	F	.	C
		7H-1, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	F	.	F
		7H-3, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	C	.	F
		7H-5, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	C	.	C
		8H-1, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	C	.	C
		8H-3, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	C	.	C
		8H-5, 118	A	M	A	.	.	.	.	F	.	.	.	A	A	A	.	A
		9H-1, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	A	.	C
		9H-3, 118	A	M	C	.	R	.	.	F	.	.	.	C	C	F	.	F
		9H-5, 118	A	M	C	.	.	.	.	.	.	.	.	C	C	C	.	C
		9H-CC	A	M	C	.	.	.	.	F	.	.	.	A	A	C	.	C
		10H-3, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	.	.	C
		10H-5, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	C	.	F
		10H-7, 118	A	M	C	.	.	.	.	F	.	.	.	A	A	.	.	C
		10H-CC	A	M	C	.	.	.	.	F	.	.	.	C	C	.	.	C
		11X-1, 118	A	M	C	.	.	.	.	.	.	.	.	.	.	.	C	C
		11X-3, 118	A	M	C	.	.	.	.	.	.	.	.	A	A	.	.	C
		11X-5, 118	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	C
		12X-1, 115	A	M	C	.	.	.	.	.	.	.	.	.	.	.	.	C
		12X-3, 118	A	M	A	.	.	.	.	.	.	.	.	.	.	.	.	A
		12X-5, 115	A	M	C	.	.	.	.	.	.	.	.	C	C	.	.	C
		12X-CC	A	M	C	.	.	.	.	F	.	.	F	.	.	.	.	C
		13X-1, 118	A	M	A	.	.	.	.	.	.	.	A	C	C	.	.	A
		13X-3, 120	A	M	C	.	.	.	.	.	.	.	C	C	C	.	.	C
		14X-1, 118	A	M	C	.	.	.	.	F	.	.	C	C	C	.	.	C
		14X-3, 114	A	M	C	.	.	.	.	.	.	.	A	A	A	.	.	A
		14X-5, 118	A	M	C	.	.	.	.	.	.	.	F	A	A	.	.	C
		15X-1, 106	A	M	C	.	.	.	.	.	.	.	F	A	A	.	.	C
		15X-3, 116	A	M	C	R	.	.	.	F	.	.	.	A	A	.	.	A
		15X-5, 115	A	M	C	.	.	.	F	.	.	.	.	C	C	.	.	C
		15X-CC	A	M	C	F	.	.	.	.	.	.	.	C	F	.	.	A
		16X-1, 118	A	M	C	F	.	.	.	F	.	.	.	F	.	.	.	A
		16X-3, 118	A	M	C	C	.	.	C	C	.	.	.	F	.	.	.	C
Pliocene		16X-5, 114	A	M	C	C	.	.	C	C	.	.	.	.	.	.	.	C
		17X-1, 100	C	M	C	F	.	.	C	C	.	.	.	.	.	.	.	C
		17X-3, 114	A	P	F	F	.	.	C	C	.	.	.	.	.	.	.	A
		17X-5, 114	A	M	C	C	.	.	F	F	.	.	.	.	.	.	.	C
		18X-1, 140	A	M	C	.	.	.	C	C	.	.	.	.	.	.	.	C
		18X-3, 94	A	M	C	F	.	.	C	C	.	.	.	.	.	.	.	A
		18X-5, 118	A	M	F	F	.	.	F	F	.	.	.	.	.	.	.	F
		19X-1, 118	A	M	C	F	.	.	C	C	.	.	.	.	.	.	.	C
		19X-3, 118	A	M	C	F	.	.	C	C	.	.	.	.	.	.	.	C
		19X-5, 120	A	M	C	F	.	.	A	A	.	.	.	.	.	.	.	C
	NN18	19X-CC	A	M	C	F	.	.	C	C	F	.	.	.	.	.	.	C

Table 5 (continued).

Helicosphaera inversa	*Helicosphaera sellii*	*Helicosphaera wallichii*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera indooceanica*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pontosphaera* sp. C	*Pseudoemiliania lacunosa*	*Reticulofenestra* sp. A	*Reticulofenestra* sp. B	*Rhabdosphaera clavigera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Syracosphaera pulchra*	*Thoracosphaera albatrosiana*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
.	.	C	.	A	.	F	R	F	F	.	.	.	.	.	F	C	F	C	.	C	.
.	.	.	.	A	.	.	.	.	.	.	F	.	.	.	F	F	.	F	.	F	.
.	.	.	.	A	F	.	.	.	.	F	.	.	F	.	.	F	.	F	.	C	.
.	.	.	.	A	.	F	.	.	.	.	F	.	.	.	.	F	.	F	.	F	F
.	.	F	.	A	.	F	.	.	.	.	.	.	.	.	.	C	.	F	.	F	.
.	.	F	.	A	.	F	.	.	F	.	.	.	.	.	.	F	.	C	.	C	C
.	.	.	.	A	.	F	.	F	F	.	.	.	.	.	.	C	.	F	F	C	F
F	.	.	.	A	F	F	.	.	F	.	.	.	.	.	F	F	F	C	.	C	F
F	.	F	.	A	.	F	.	F	.	.	.	.	.	.	.	C	F	C	.	F	.
F	.	F	.	A	.	F	.	.	.	.	F	.	.	.	.	C	.	F	.	F	.
.	.	F	.	A	.	F	.	.	.	.	F	.	.	.	.	F	.	F	.	C	F
F	.	F	.	A	.	.	.	.	F	.	.	.	.	.	F	F	.	C	.	C	.
F	.	.	.	A	.	F	.	.	.	.	.	.	.	.	.	.	.	F	.	F	.
.	.	F	.	C	.	.	.	.	.	.	.	F	.	.	.	.	.	C	.	C	F
F	.	.	.	C	.	.	.	.	.	.	.	.	.	.	.	F	.	C	.	C	.
.	.	.	.	A	.	F	.	.	F	.	.	C	.	.	.	C	F	C	.	C	.
.	.	F	.	A	.	F	.	.	F	.	.	C	.	.	.	F	.	F	.	F	.
.	.	.	.	C	.	F	.	.	.	.	.	C	.	.	.	.	F	F	.	C	.
.	.	.	.	C	.	F	.	.	F	.	.	C	.	.	.	F	F	F	.	F	.
.	.	.	.	C	F	.	.	.	.	.	.	.	.	.	.	.	F	.	.	F	.
.	.	F	.	A	F	C	.	.	.	F	.	F	.	.	.	F	.	F	.	F	F
.	.	F	.	C	.	F	.	.	.	.	.	F	.	.	.	.	F	F	.	F	.
.	.	.	.	C	.	F	.	.	F	.	.	F	.	.	.	F	F	F	.	F	.
.	.	.	.	C	.	F	.	.	F	.	.	F	.	.	.	F	F	.	.	F	F
.	.	.	.	C	.	F	.	F	.	.	.	F	.	.	.	F	F	F	.	F	.
.	.	.	.	C	.	C	.	.	.	.	.	F	.	.	.	F	F	F	.	F	.
.	.	.	.	A	.	F	.	.	F	F	.	A	.	.	.	.	.	F	.	F	F
.	.	F	.	A	.	F	.	.	.	.	.	F	R	.	.	F	.	F	.	.	.
.	.	.	.	C	.	C	.	.	.	.	.	F	.	F	F	F	F	.	.	.	.
.	.	.	.	C	.	F	.	F	F	.	.	C	F	F	.	.	F	.	.	.	.
.	.	.	.	A	.	F	.	.	F	.	.	C	A	.	.	F	F	F	.	F	.
.	.	.	.	A	.	F	.	.	.	F	.	F	C	.	.	.	F	F	.	F	.
.	.	.	.	C	.	C	.	.	F	.	.	F	.	.	F	F	.	.	.	F	.
.	.	F	.	A	.	F	.	.	C	F	F	F	F	.	.	F	F	F	.	F	.
.	.	.	.	C	.	.	.	.	F	F	.	C	.	.	.	.	F	F	.	F	.
.	.	F	.	A	.	F	.	.	.	.	.	F	.	.	.	.	F	.	.	F	.
.	.	F	.	A	.	F	.	.	F	.	.	F	F	.	.	F	F	F	.	F	.
.	.	.	F	A	.	C	.	F	.	C	.	C	.	.	.	.	C	.	.	C	.
.	.	.	.	C	.	C	.	.	.	.	.	C	.	.	.	F	F	.	.	F	.
.	.	.	F	C	.	.	.	.	.	.	.	F	.	.	.	.	F	F	.	F	.
.	.	.	.	A	.	F	.	F	.	F	.	F	.	.	.	.	F	.	.	C	F
.	.	.	.	A	.	F	.	.	.	F	.	F	.	.	.	.	F	F	.	C	.
.	.	.	.	C	.	F	.	.	.	F	.	C	.	.	.	.	F	.	.	F	.
.	F	.	F	A	.	C	.	.	F	F	.	C	.	.	.	.	F	F	.	F	F
.	.	.	.	C	.	F	.	.	.	.	.	F	.	.	.	.	.	F	.	F	.
.	.	.	.	C	.	F	.	.	.	.	.	F	.	.	.	.	.	F	.	F	.
.	C	.	.	A	.	F	.	.	.	F	.	C	.	.	.	F	.	F	.	C	.
.	F	F	.	.	.	F	.	.	.	.	.	F	.	.	.	.	F	.	.	.	.
.	F	.	.	C	.	F	.	.	.	.	.	F	.	.	.	.	F	.	.	.	.
.	F	.	.	A	.	F	.	.	.	.	.	C	C	.	.	.	.	.	F	.	.
.	C	.	.	A	.	F	.	.	.	.	.	C	.	.	.	.	.	.	.	F	F
.	C	.	.	A	.	F	.	F	.	.	.	C	C	.	.	F	.	.	.	.	.
.	C	F	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.
.	C	.	.	C	F	F	.	F	.	.	.	C	.	.	.	.	.	.	.	.	F
.	F	F	.	.	.	F	.	.	.	.	.	F	.	.	.	.	.	F	.	.	.
.	F	F	.	.	.	.	.	.	.	.	.	C	.	.	.	.	.	.	.	.	.
.	C	.	F	C	.	F	.	.	.	.	.	C	.	.	.	F	F	F	.	.	.
.	F	F	.	.	.	F	.	.	.	F	.	C	.	.	.	.	.	.	.	.	.
.	F	F	.	.	.	F	.	.	F	F	.	F	.	.	.	.	F	.	.	.	.
.	C	.	.	.	.	F	.	.	.	.	.	C	.	.	.	.	F	F	.	.	F
.	C	.	.	A	.	F	.	.	.	.	.	C	.	.	.	.	.	F	.	F	F
.	C	.	.	.	.	F	.	.	.	.	.	F	.	.	.	.	F	.	.	F	.

NN19 through the upper part of Zones NN16-NN17). Most of the rest of the samples in this hole have few to common specimens of *C. pelagicus.* Samples 117-728A-23X-1, 118 cm, and 117-728A-34X-3, 118 cm, have abundant *C. pelagicus.* The relative abundance of discoasters fluctuates throughout the sedimentary sequence. Discoasters are abundant in Samples 117-728A-16X-1, 118 cm, and 117-728A-30X-3, 118 cm, suggesting warmer surface waters at those times. Conversely, relatively few discoasters are present in Samples 117-728A-11X-1, 118 cm, 117-728A-11X-3, 118 cm, 117-728A-13X-3, 118 cm, through 117-728A-14X-1, 118 cm, 117-728A-20X-3, 118 cm, 117-728A-30X-1, 118 cm, and 117-728A-32X-5, 118 cm.

Both *Reticulofenestra pseudoumbilica* and *R. gelida* are present in samples from Hole 728A. In a few samples (i.e., 117-728A-25X-1, 118 cm, through 117-728A-25X-5, 118 cm), *R. gelida* is more abundant than *R. pseudoumbilica.* In most other samples, *R. pseudoumbilica* is more abundant than *R. gelida.* In some samples (i.e., 117-728A-31X-1, 118 cm, and 117-728A-32X-5, 118 cm) the ratio of *R. gelida:R. pseudoumbilica* is very close to 1:1.

Sphenolithus, like *Discoaster*, is a warm water genus. Sphenoliths are abundant in most samples, but are common in others. There does not seem to be a correlation of high numbers of (warm water) sphenoliths with low numbers (also warm water) of *C. pelagicus* (Table 6).

Site 729 (Table 7)

A single hole was drilled at this site situated at 17°38.715′N and 57°57.221′E in 1400 m of water. The drilling target was a presumably ophiolitic basement block. This block forms the seaward boundary of the lower slope basin which contains Site 728 (Fig. 3) (Prell, Niitsuma, et al., 1989).

Hole 729A reached a depth of 109.10 mbsf with only 31.72 m of recovered material. Two lithologic units are recognized at this hole. Unit I extends from 0 to 28.35 mbsf and is an olive nannofossil-foraminifer-rich mud to marly nannofossil ooze. Recovery of this unit was 119.4%. Nannofossils are abundant throughout this unit with moderate to good preservation (Table 7). Lithologic Unit II (28.35–109.10 mbsf) is a larger foraminifer and algae-bearing carbonate sequence. This unit is highly porous and weakly cemented. A relatively sharp contact separates these two lithologies (Prell, Niitsuma, et al., 1989). Samples of this lithology were ground in a mortar and pestle and examined as smear slide material but were barren of nannofossils. *Emiliania huxleyi* are common to abundant in Samples 117-729A-1R-1, 105 cm, to 117-729A-2R-3, 105 cm, and therefore, these sediments are assigned to the latest Pleistocene to Holocene Zone NN21 (*Emiliania huxleyi* Zone). Samples 117-729A-2R-5, 105 cm, and 117-729A-3R-1, 105 cm, contain neither *E. huxleyi* nor *Pseudoemiliania lacunosa* and can be referred to the *Gephyrocapsa oceanica* Zone (NN20). The remainder of the nannofossil-bearing sediments in this hole are assigned to Zone NN19 (*Pseudoemiliania lacunosa* Zone) based on the presence of *P. lacunosa* and the absence of *Discoaster brouweri.* Three Pleistocene datums can be identified within Zone NN19. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) occurs between Samples 117-729A-3R-3, 105 cm, and 117-729A-3R-5, 105 cm. The FAD of *Gephyrocapsa parallela* is between Samples 117-729A-3R-CC, and 117-729A-4R-1, 105 cm. Lastly, the LAD of large gephyrocapsids is in the interval between 23.35 and 26.35 mbsf (between Samples 117-729A-4R-1, 105 cm, and 117-729A-4R-3, 105 cm).

Site 730 (Table 8, Backpocket)

Hole 730A was drilled on the continental margin of Oman in approximately 1065 m of water at 17°43.885′N and 57°41.519′E. Like Sites 723 and 727, this site is located in an area where the bottom of the OMZ impinges on the seafloor (Fig. 3). Hole 730A reached a sub-bottom depth of 403.90 m. The sediments can be divided into three lithologic units (Prell, Niitsuma, et al., 1989).

Nannofossils are abundant in all of the samples examined from this hole (Table 8). The preservation is moderate to good throughout most of the hole. Poor preservation, represented by extremely heavy overgrowths of asteroliths, sphenoliths, and *Cyclicargolithus floridanus*, was encountered in core catcher samples 117-730A-27X-CC, through 117-730A-33X-CC, 117-730A-35X-CC, 117-730A-36X-CC, and 117-730A-39X-CC.

Samples 117-730A-1H-1, 105 cm, and 117-730A-1H-3, 105 cm, contain abundant and common specimens of *Emiliania huxleyi* respectively, and are assigned to Zone NN21 (*Emiliania huxleyi* Zone). Samples 117-730A-1H-5, 105 cm, down through 117-730A-2H-3, 105 cm, are assigned to Zone NN19 (*Pseudoemiliania lacunosa* Zone) based on the presence of nominant taxon in these sediments. It is unknown whether the *Gephyrocapsa oceanica* zone (NN20) is present and was not recognized due to the sampling interval, or if a hiatus is present between Samples 117-730A-1H-3, 105 cm, and 117-730A-1H-5, 105 cm. The top of the acme of *Reticulofenestra* sp. A of Takayama and Sato (1987) occurs between Samples 8 117-730A-2H-2, 146 cm, and 117-730A-2H-3, 61 cm. An extensive hiatus occurs between Samples 117-730A-2H-3, 105 cm, and 117-730A-2H-5, 60 cm. Sample 117-730A-2H-3, 105 cm, contains *Gephyrocapsa parallela* placing this lowermost Zone NN19 sample above the FAD of *G. parallela.*

Samples 117-730A-4H-5, 105 cm, through 117-730A-9X-5, 105 cm (34.85-82.25 mbsf), contain *Discoaster hamatus*, indicating the late Miocene *D. hamatus* Zone (NN9). Therefore, Samples 117-730A-2H-5, 60 cm, down to 117-730A-4H-3, 105 cm, which contain *Discoaster bellus, D. berggrenii, D. brouweri*, and *D. neohamatus* can be assigned to Zone NN10 (*Discoaster calcaris* Zone). Zone NN8 (*Catinaster coalitus* Zone) is defined as the interval from the FAD of *C. coalitus* to the FAD of *D. hamatus.* The FAD of *C. coalitus* occurs between Samples 117-730A-10X-3, 105 cm, and 117-730A-10X-5, 105 cm. Therefore, sediments between 84.90 and 88.95 mbsf are assigned to Zone NN8. However, data from radiolarians and planktonic foraminifers (Prell, Niitsuma, et al., 1989), together with the relatively short interval of sediments assigned to Zone NN8 when compared to Zone NN9, suggest strongly that the FAD of *C. coalitus* in this hole is too shallow if an age of 10.8 Ma for its FAD (Berggren et al., 1985) is correct.

Samples 117-730A-10X-5, 105 cm, down to 117-730A-24X-1, 105 cm (91.95–221.25 mbsf), contain neither *C. coalitus* nor *Cyclicargolithus floridanus* and therefore, are assigned to Zone NN7 (*Discoaster kugleri* Zone). This zone does contain few specimens of *D. kugleri* in many of its samples.

Zone NN6 (*Discoaster exilis* Zone) is assigned to Samples 117-730A-24X-3, 105 cm, to 117-730A-27X-1, 105 cm (224.25–250.25 mbsf), which contain common to abundant specimens of *C. floridanus*, but no specimens of *Sphenolithus heteromorphus.* Sediments from Sample 117-730A-27X-3, 105 cm, down to the bottom of the hole (117-730A-42X-3, 96 cm; 253.25–403.9 mbsf) contain *S. heteromorphus.* The LAD of *Helicosphaera ampliaperta* marks the Zone NN4/Zone NN5 boundary. This species was not recognized in samples from this leg so it is not known whether these sediments belong to Zone NN4 or Zone NN5.

Because of the extensive hiatus at Hole 730A, the sediments which correspond to the interval where *Coccolithus pelagicus* increases in number as was observed at some other sites (i.e., 723, 724, 726, 727, and 728) are missing. Few specimens of *C. pelagicus* are found in only two samples from Zones NN19 through NN21. *Coccolithus pelagicus* is few to abundant in each

Table 7. Distribution of calcareous nannofossils, Hole 729A.

Age	Nannofossil zone	Core, section, interval (cm)	Abundance	Preservation	*Calcidiscus leptoporus*	*Emiliania huxleyi*	*Gephyrocapsa* (large)	*Gephyrocapsa caribbeanica*	*Gephyrocapsa oceanica*	*Gephyrocapsa parallela*	*Gephyrocapsa protohuxleyi*	*Helicosphaera carteri*	*Helicosphaera inversa*	*Holodiscolithus* spp.	*Neosphaera coccolithomorpha*	*Oolithotus fragilis*	*Pontosphaera discopora*	*Pontosphaera japonica*	*Pontosphaera* sp. A	*Pontosphaera* sp. B	*Pseudoemiliania lacunosa*	*Reticulofenestra* sp. A	*Rhabdosphaera clavigera*	*Scapholithus fossilis*	*Scyphosphaera* spp.	*Syracosphaera pulchra*	*Thoracosphaera heimi*	*Thoracosphaera operculata*
Quaternary	NN21	1R-1, 105	A	G	A	C	.	A	A	F	.	C	.	.	A	A	.	.	.	F	.	.	.	C	.	C	A	.
		1R-2, 105	A	G	A	A	.	A	A	F	F	C	.	.	A	.	F	.	F	F	.	.	.	C	F	C	F	.
		2R-1, 105	A	G	A	C	.	A	A	F	.	C	.	.	A	.	.	.	.	.	.	.	.	.	.	.	.	.
		2R-3, 105	A	G	A	C	.	A	A	F	.	C	.	.	A	.	.	.	.	F	.	.	.	C	F	.	.	.
	NN20	2R-5, 105	A	M	F	.	.	A	A	F	.	C	.	.	C	.	F	.	.	.	.	.	.	.	.	F	.	F
		3R-1, 105	A	M	A	.	.	A	A	F	.	A	F	F	A	.	.	.	.	.	.	.	F	C	.	C	.	F
	NN19	3R-3, 105	A	G	C	.	.	A	A	F	.	C	.	.	A	.	F	F	F	.	F	.	.	F	.	F	.	F
		3R-5, 105	A	M	C	.	.	A	A	.	.	C	.	.	A	.	F	F	F	.	C	F	.	F	F	F	C	F
		3R-CC	A	M	C	.	.	A	A	F	.	C	.	.	C	.	F	.	.	.	C	F	.	F	F	F	F	.
		4R-1, 105	A	M	C	.	.	.	.	.	.	C	.	.	A	.	C	.	C	.	C	C	.	F	F	F	.	F
		4R-3, 105	A	M	C	.	A	A	A	.	.	A	.	.	A	.	.	F	.	F	C	C	F	.	F	F	.	.
? ? ?		4R-5, 105	B	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

sample from 117-730A-2H-5, 105 cm, down to the bottom of the hole. It is abundant in Samples 117-730A-2H-5, 105 cm, 117-730A-3H-1, 105 cm (especially abundant), 117-730A-3H-3, 105 cm, 117-730A-18X-5, 105 cm, through 117-730A-19X-3, 105 cm, 117-730A-20X-1, 105 cm, 117-730A-21X-5, 105 cm, and 117-730A-24X-CC.

Reticulofenestra pseudoumbilica and *R. gelida* occur together in nearly every sample. Samples 117-730A-5H-1, 105 cm, through 117-730A-6X-1, 105 cm, possess assemblages dominated by the genus *Reticulofenestra* (medium-sized). It is estimated that reticulofenestrids comprise approximately 95% of the placolith fraction.

Discoasters are very abundant in Samples 117-730A-4H-3, 105 cm, abundant in 117-730A-18X-5, 105 cm, and 117-730A-19X-5, 105 cm, and few in 117-730A-12X-1, 105 cm, and 117-730A-12X-3, 105 cm. There appears to be no relationship between abundances of *Coccolithus pelagicus* and the discoasters. Table 9 shows the depths of the nannofossil datums at Sites 723 through 730.

PALEOECOLOGICAL IMPLICATIONS

An investigation of the Neogene nannofossils recovered from previous DSDP sites in the Arabian Sea (Boudreaux, 1974) reveal an interesting pattern. The sediments from holes drilled in areas removed from the region of upwelling (e.g., Sites 219, 220, and 221) contain no to common specimens of *Ceratolithus cristatus, C. rugosus*, and *Amaurolithus tricorniculatus*. *Coccolithus pelagicus* is absent to common, but never abundant. Discoasters such as *D. brouweri, D. pentaradiatus*, and *D. surculus* are each rare to abundant with many samples containing abundant specimens. *Sphenolithus abies* is abundant in nearly all of the appropriate samples.

Conversely, sediments from Site 223, which is probably located in waters which are affected by the upwelling which occurs off the coast of Oman, contain no specimens of *Ceratolithus rugosus* (Boudreaux, 1974). Rare specimens of *C. cristatus* and *Amaurolithus tricorniculatus* are found, and are much less consistent in their distribution. *Coccolithus pelagicus* is rare to common in every sample from the top of Zone NN18 down through the middle part of Zone NN11 where it becomes abundant. *Discoaster brouweri* is absent to abundant, but is common in most of the samples. *D. pentaradiatus* is absent to rare, and *D. surculus* is absent to common. *Sphenolithus abies* also exhibits a reduction in numbers, but is common in most of the samples. Some noticeable differences exist between Arabian Sea nannofossil assemblages deposited in areas affected by upwelling and those from areas not affected by upwelling. Ceratoliths, amauroliths, discoasters, and sphenoliths are less abundant in sediments deposited in upwelling regions, while *Coccolithus pelagicus* is a more dominant component of the same assemblages.

This is the same pattern seen in nannofossils from sediments from DSDP Leg 24 at sites in the Gulf of Aden (Roth, 1974). Sites 231, 232, and 233 are located in an area which probably experiences the influence of cool waters from both the north (upwelling off Oman) and the south (upwelling off Somalia). Ceratoliths and amauroliths are quite poorly represented in these sediments. *C. pelagicus* is common at these sites from the upper or middle part of Zone NN19 down into varying depths in the Pliocene and Miocene.

A similarity exists between the nannofossil assemblages in sediments from the Oman Margin and the sediments described above from DSDP Leg 24. This suggests that cold water related to upwelling along the western edge of the Arabian Sea most likely accounts for the general scarcity of ceratoliths and amauroliths in sediments from Sites 723 through 730.

Coccolithus pelagicus becomes more abundant during the late Pliocene and disappears quite abruptly in the early Pleistocene with scattered later appearances in the upper Pleistocene sediments in DSDP Sites 231 through 233 in the Gulf of Aden (Roth, 1974). This change in abundance is not as evident in other sites in the Indian Ocean. However, Martini and Worsley (1971) reported several peaks in the abundance of *C. pelagicus* in DSDP Leg 7 sediments from the upper part of Zone NN16 through NN18 in the western equatorial Pacific. They related these peaks to a probable lowering of the temperatures of waters in the region during the late Pliocene. Also, wide fluctuations in the abundance of *C. pelagicus* were recognized by Raffi and Rio (1981) in upper Pliocene sediments from DSDP Site 132 in the Mediterranean Sea. An exceptionally high peak of *C. pelagicus* in the middle part of Zone NN16 corresponds to a strong cool-

Table 9. Depths (mbsf) for nannofossil events at selected holes.

Datum	723A	724	725C	726A	727A	728A	729A	730A
LAD *Helicosphaera inversa*	24.70/27.10							
FAD *Emiliania huxleyi*	47.60/50.60	15.90/16.95	25.78/28.50	11.08/14.08	23.08/26.08	10.78/13.78	7.25/10.25	4.05/7.05
LAD *Pseudoemiliania lacunosa*	73.00/75.40	32.45/34.90	50.18/51.68	20.48/23.48	37.80/38.98	19.10/20.28	13.75/16.75	4.05/7.05
FAD *Helicosphaera inversa*					41.98/44.98			
Top acme *Reticulofenestra* sp. A	143.10/153.70	60.25/65.50	99.48/102.23	32.98/35.30	85.80/88.70	29.68/32.68	16.75/19.75	11.91/12.31
FAD *Gephyrocapsa parallela*	162.40/173.30	68.50/71.40	102.23/104.90	32.98/35.30	91.70/94.70	35.68/38.00	22.30/23.35	
LAD *Gephyrocapsa* (large)	191.40/192.74	83.70/84.75	124.10/125.28	42.48/44.70	109.18/112.15	42.18/45.18	23.35/26.35	
LAD *Helicosphaera sellii*	227.58/231.27	104.35/107.05	114.89/153.20	51.88/54.10	125.18/128.14	48.68/51.68		
LAD *Calcidiscus macintyrei*	245.87/249.40	110.00/112.70		54.10/55.28	134.96/138.06	51.68/54.68		
FAD *Gephyrocapsa oceanica*		123.50/126.44			143.06/144.78	51.68/54.68		
FAD *Gephyrocapsa caribbeanica*	285.19/287.90	132.00/133.03		61.28/63.60	147.78/150.74	61.25/64.25		
LAD *Discoaster brouweri*	330.36/333.53	165.21/168.05		63.60/64.78	179.90/182.40	61.25/64.25		
LAD *Discoaster pentaradiatus*	381.50/384.68			70.63/73.20		67.68/70.68		
LAD *Discoaster tamalis*						76.10/77.28		
LAD *Discoaster surculus*		191.05/194.05						
LAD *Sphenolithus abies*		230.05/233.05		73.20/74.38		95.30/96.48		
LAD *Reticulofenestra pseudoumbilica*		238.40/239.44		77.85/83.98		95.30/96.48		
LAD *Discoaster quinqueramus*				93.58/96.58		222.01/225.00		
LAD *Discoaster berggrenii*				93.58/96.58				
FAD *Discoaster quinqueramus*				98.10/113.24				
FAD *Discoaster berggrenii*				98.10/113.24				
LAD *Discoaster hamatus*				116.24/119.24				31.35/34.35
LAD *Catinaster coalitus*								53.35/56.85
FAD *Discoaster hamatus*								82.25/84.90
FAD *Catinaster coalitus*								91.95/95.65
FAD *Discoaster kugleri*								221.25/224.25
LAD *Cyclicargolithus floridanus*								221.25/224.25
LAD *Sphenolithus heteromorphus*								250.25/253.25

ing as indicated from transfer-function-based paleotemperatures. Just below the FAD of *Gephyrocapsa oceanica* the abundance of *C. pelagicus* decreases, and later in the early Pleistocene it disappears completely.

Hay and others (1967) noted the rather abrupt disappearance of *Coccolithus pelagicus* in sediments in the Caribbean Sea, at a level between the LAD of *Discoaster brouweri* and the FAD of *Gephyrocapsa oceanica*. The same pattern is evident in sediments from DSDP Sites 219, 222, and 223 in the Arabian Sea (Boudreaux, 1974). McIntyre and others (1967) noted that *C. pelagicus* is found below the Pliocene/Pleistocene boundary but not above it in seven Atlantic Ocean cores taken between 10°S and 28°N. *Coccolithus pelagicus* decreases rapidly in number just above the Pliocene/Pleistocene boundary at Sites 723, 724, 726, 727, and 728 drilled during this leg.

Shackleton and Opdyke (1977) have determined that between 2.5 and 1.8 Ma glaciations that were at least two-thirds the magnitude of late Pleistocene glacial maxima were occurring. This appears to correspond quite well with the interval of time when *C. pelagicus* is found in sediments from Sites 723, 724, 726, 727, and 728.

Clearly, some global event resulted in the rather rapid reduction in the numbers of *Coccolithus pelagicus* around the Pliocene/Pleistocene boundary in widespread low-latitude regions such as the Gulf of Aden, Arabian Sea, Caribbean and Mediterranean Sea, and Atlantic and Pacific Oceans. An early Pleistocene warming may have caused the migration of *Coccolithus pelagicus* from these lower latitude regions. Thermal barriers may have prevented its return to these regions later in the cooler late Pleistocene.

Presently, *Coccolithus pelagicus* is found only in narrow areas of the North Atlantic and North Pacific where water temperatures range between 6° and 14°C. Interestingly, this species is found in modern surface sediments underlying southern hemisphere subpolar water masses, but is not known to be a member of living plankton assemblages of the southern hemisphere (McIntyre et al., 1970).

Reticulofenestra gelida, the winter morphovariant of *R. pseudoumbilica*, is present in varying proportions in the same samples in which *R. pseudoumbilica* is found. Backman (1980) has suggested that the presence of both of these forms in the same samples suggests that there was sufficient seasonality to allow the growth of both of these ecophenotypes. The colder water associated with the annual upwelling is probably responsible for the presence of *R. gelida* in samples from Hole 728A.

In some samples there appears to be a correlation between higher numbers of *Coccolithus pelagicus* and lower numbers of sphenoliths and/or discoasters (i.e., Hole 726A). In other cases, there appears to be no correlation between *C. pelagicus* and discoasters and/or sphenoliths (i.e., Hole 728A). Table 10 shows the summary of paleoecological preferences for selected Neogene nannofossils.

What is a plausible explanation for the mixing of seemingly warm-water and cold-water taxa (Table 11)? The sediments studied seem to have been extensively bioturbated, thereby eradicating any laminations and combining nannofossils which may have been produced during the separate summer and winter monsoons. This seems to be a reasonable explanation, as an examination of two samples from the few laminated intervals which were recovered shows assemblages which are dominated by one taxon (i.e., *Coccolithus pelagicus* with a few specimens of *Discoaster brouweri*).

Sixty percent of the samples examined contain reworked specimens. These specimens may be rare to common, but are most often few. The most common reworked specimens are Late Cretaceous (Campanian to Maestrichtian) and Tertiary in age. The oldest sediments recovered on this leg are Miocene, so the Cretaceous and Paleogene specimens are not the result of contamination of the samples. Instead, it seems more likely that these reworked nannofossils are transported by the same eolian processes (southwest monsoon winds) that are known to supply quite significant amounts of clays to the region. This would account for the consistent supply of reworked forms. Possible source areas which are known to possess marine rocks of the appropriate ages to have supplied these reworked nannoplankton include Africa (Furon, 1963) and the Arabian Peninsula (Al Naqib, 1966; Beydoun, 1966; Geukens, 1966; Greenwood and Bleackley, 1966; Powers et al., 1966). The most common reworked specimens are *Arkhangelskiella* spp., *Chiastozygus litterarius, Cretarhabdus conicus, C. loriei, Cribrosphaerella ehrenbergii, Eiffelithus eximius, E. turriseiffeli, Microrhabdulus decoratus, Micula decussata, Prediscosphaera intercisa, Prediscosphaera* spp., *Quadrum gothicum, Retecapsa angustiforata, Tranolithus phacelosus*, and *Watznaueria barnesae* from the Cretaceous. The most frequently encountered reworked Cenozoic taxa are *Coccolithus miopelagicus, Cyclicargolithus floridanus, Discoaster brouweri, D. deflandrei, Reticulofenestra gelida, R. pseudoumbilica, R. umbilica, Sphenolithus abies, S. heteromorphus, S. moriformis*, and *Sphenolithus* spp. Most of these species are quite robust and could probably survive transportation by winds.

Table 10. Paleoecological preference of selected Neogene calcareous nannofossils.

Warmer surface water	Cooler surface water
C. calyculus	*C. pelagicus*
C. coalitus	*C. floridanus*
C. rugosus	*D. deflandrei*
D. asymmetricus	*D. exilis*
D. bellus	*D. intercalaris*
D. bollii	*D. variabilis*
D. hamatus	*G. caribbeanica* s.s.
D. kugleri	*H. macroporus*
D. neohamatus	*R. gelida*
D. pansus	
D. pentaradiatus	
D. prepentaradiatus	
D. quinqueramus	
relatively common *Scyphosphaera*	
common to abundant *Sphenolithus*	
S. heteromorphus	
T. rugosus	

CALIBRATION OF DATUM PLANES WITH MAGNETOSTRATIGRAPHY

The discussion of the calibration of nannofossil datums to the magnetostratigraphic record will be restricted to Sites 724, 726, 727, and 728 because no paleomagnetic reversals were recorded at Sites 723, 725, 729 and 730.

The top of the acme of *Reticulofenestra* sp. A occurs at 65.50 mbsf at Site 724. At this site, the Brunhes/Matuyama reversal, dated at 0.73 Ma (Berggren et al., 1985), occurs between 65.45 and 66.95 mbsf. At Site 727, however, the top of the acme of *Reticulofenestra* sp. A occurs several meters below the Brunhes/Matuyama reversal (75.80–76.50 mbsf) at 85.70–88.70 mbsf. At Sites 724 and 727, the FAD of *Gephyrocapsa parallela* occurs very near the top of the Jaramillo Subchron, which has been dated at 0.91 Ma (Berggren et al., 1985). In Hole 724B the FAD of *G. parallela* is recorded between 68.50 and 71.40 mbsf, and the top of the Jaramillo Subchron occurs between 71.34 and 74.44 mbsf. In Hole 727A the FAD of *Gephyrocapsa parallela* occurs between 91.70 and 94.70 mbsf, and the top of the Jaramillo Subchron is recorded between 95.40 and 95.83 mbsf.

Table 11. Paleoecology of selected calcareous nannofossil taxa. Sources are as follows: 1 = Cohen, 1964, 2 = McIntyre et al., 1970; 3 = Bukry, 1971; 4 = Bukry, 1972; 5 = Gartner, 1972; 6 = Bukry, 1973; 7 = Wise, 1973; 8 = Bukry, 1974; 9 = Roth, 1974; 10 = Bukry, 1975; 11 = Bukry, 1977; 12 = Backman, 1980; 13 = Roth and Coulbourn, 1982; 14 = Aubry, 1984; 15 = Steinmetz and Anderson, 1984; 16 = Perch-Nielsen, 1985; 17 = Aubry, 1988; 18 = Woellner et al., 1988.

Taxon	Paleoecological implication	Source
C. leptoporus	no relation to temperature	5, 15
C. calyculus	low latitude marker	7
C. coalitus	low latitude marker	7, 11
C. cristatus	no relation to temperature	1
	temperature maxima	5
	increase during interglacial	15
C. rugosus	warm water	17
C. pelagicus	cold water	2
C. floridanus	cool water	7
D. asymmetricus	warm water	4, 7
D. bellus	warm water	10
D. bollii	warm water	14
D. deflandrei	cool water	7
D. exilis	cool water	3, 7
D. hamatus	warm water	7
D. intercalaris	cool water	7, 9
D. kugleri	warm water	7
D. neohamatus	warm water	7, 8
D. pansus	warm water	11
D. pentaradiatus	warm water	6, 8
D. prepentaradiatus	warm water	8
D. quinqueramus	warm water	7, 10
D. variabilis	more abundant in cooler sites	3
G. caribbeanica s.s.	cool water	5, 7
G. oceanica	temperature maxima	1
	no relation to temperature	15
H. perplexus	warm water	7, 11
	temperature minima	1, 5, 15
H. carteri	no relation to temperature	1, 15
H. wallichi	no relation to temperature	1, 15
H. spp.	upwelling areas	16
H. macroporus	temperature minima	1
O. fragilis	no relation to temperature	15
	temperature minima	1, 5
	warm water	13
R. gelida	winter morphovariant of *R. pseudoumbilica*	12
R. clavigera	no relation to temperature	1
	warm water	7, 15
	most abundant in warm, nutrient-poor waters	14
R. stylifera	temperature minima	1
	temperature maxima	15
S. fossilis	no relation to temperature	1, 5, 15
relatively common *Scyphosphaera* spp.	warm water	12
common to abundant *Sphenolithus* spp.	relatively warm water	11
S. heteromorphus	warm water	7
T. heimi	temperature maxima	1
	no relation to temperature	15
T. rugosus	warm water	4
U. sibogae	high salinity	18

The LAD of *Gephyrocapsa* spp. (large) at Site 724 occurs between 83.70 and 84.75 mbsf, just below the bottom of the Jaramillo Subchron, which has a date of 0.98 Ma (Berggren et al., 1985) and occurs between 81.14 and 81.93 mbsf. The LAD of *Gephyrocapsa* spp. (large) occurs between 109.18 and 112.15 mbsf at Site 727, and the bottom of the Jaramillo Subchron occurs between 104.14 and 104.69 mbsf. Finally, at Site 728 the bottom of the Jaramillo Subchron occurs between 40.72 and 42.20 mbsf, and the LAD of large gephyrocapsids occurs between 42.18 and 45.18 mbsf.

At Site 724 the LAD of *Helicosphaera sellii*, the LAD of *Calcidiscus macintyrei*, the FAD of *Gephyrocapsa oceanica*, and the FAD of *G. caribbeanica* occur between the bottom of the Jaramillo Subchron (0.98 Ma) and the top of the Olduvai Subchron (1.66 Ma; Berggren et al., 1985).

At Site 724, the LAD of *Discoaster brouweri* occurs below the base of the Olduvai Subchron. The bottom of the Olduvai is recognized between 148.86 and 149.70 mbsf, and the LAD of *D. brouweri* occurs between 165.21 and 168.05 mbsf.

The LAD of *Discoaster pentaradiatus* at Site 728 occurs above the Matuyama/Gauss reversal, which has been dated at 2.47 Ma (Berggren et al., 1985). These depths are 67.68–70.68 mbsf and 72.20–73.70 mbsf, respectively. The LAD of *Discoaster surculus* at Site 724 occurs between 191.05 and 194.05 mbsf, just above the Matuyama/Gauss reversal which is recognized between 194.23 and 200.36 mbsf.

The LAD of *Discoaster tamalis* (76.10–77.28 mbsf) at Site 728 occurs in the Gauss Chron, slightly above the top of the Kaena Subchron (78.80–79.55 mbsf) which has been dated at 2.92 Ma (Berggren et al., 1985). The LAD of *Sphenolithus abies* at Site 728 is recorded between 95.30 and 96.48 mbsf. This is just below the Gauss/Gilbert reversal which occurs between 92.90 and 93.65 mbsf. Berggren and others (1985) assigned an age of 3.40 Ma to this reversal and recorded the LAD of *S. abies* late in the Gilbert Chron. The LAD of *Reticulofenestra pseudoumbilica* occurs between 95.30 and 96.48 mbsf at Site 728, also late in the Gilbert Chron.

An age for selected nannofossil events has been calculated for Sites 724, 727, and 728. This was accomplished by plotting the magnetostratigraphic events for each of these three sites. A line of correlation was drawn through the points. The nannofossil datums were then projected onto the line of correlation and extended down onto the absolute time scale. The ages calculated by this method are presented in Table 12 along with the overall estimated age for this leg. Table 13 shows the nannofossil events, chron or subchron during which it occurs, the estimated age of each datum (from Table 12), and other published ages for these datums.

The depths and ages of the nannofossil events and paleomagnetic reversals have been plotted for each site (Figs. 4–10). The ages for the nannofossil events are those estimated ages found in Table 12. The ages for the paleomagnetic reversals are taken from Berggren et al. (1985).

SUMMARY AND CONCLUSIONS

Calcareous nannofossils provide good age determinations for Neogene sedimentation on the continental margin of Oman. The upwelling related to the seasonal monsoon appears to have an effect on the nannofossil assemblages. Typical warm water species such as *Amaurolithus tricorniculatus* and *Ceratolithus rugosus* are extremely rare or absent in the studied material of this leg. Other paleoecological conclusions are not easily drawn as many samples appear to have both cold and warm water components. This may be a result of bioturbation as some samples taken from an occasional laminated interval appear to be dominated by one or two species. Abundant specimens of the cold water indicator *Coccolithus pelagicus* (and *C. crassipons*) in upper Pliocene through lower Pleistocene sediments are probably related to Northern Hemisphere glaciation which occurred during the corresponding interval of time. These observations are consistent with the pattern of *C. pelagicus* observed at other low-latitude regions of the Mediterranean and Caribbean Seas, and the Atlantic and Pacific Oceans.

Table 12. Ages (Ma) of selected nannofossil events at Sites 724, 727, and 728 and overall estimated ages for selected nannofossil events on the Oman Margin. The error term in the overall age represents two standard deviations.

Datum	Site 724	Site 727	Site 728	Estimated age (Ma)
FAD *E. huxleyi*	0.18 ± 0.006	0.24 ± 0.015	0.25 ± 0.031	0.23 ± 0.080
LAD *P. lacunosa*	0.37 ± 0.014	0.37 ± 0.006	0.40 ± 0.013	0.38 ± 0.044
FAD *H. inversa*	No data	0.42 ± 0.015	No data	0.42
Top acme *R.* sp. A	0.69 ± 0.029	0.84 ± 0.014	0.64 ± 0.032	0.70 ± 0.186
FAD *G. parallela*	0.82 ± 0.044	0.84 ± 0.014	0.83 ± 0.081	0.85 ± 0.140
LAD *G.* (large)	1.01 ± 0.007	1.07 ± 0.021	1.09 ± 0.072	1.07 ± 0.126
LAD *H. sellii*	1.28 ± 0.019	1.29 ± 0.021	1.40 ± 0.072	1.34 ± 0.170
LAD *C. macintyre*	1.34 ± 0.017	1.43 ± 0.022	1.55 ± 0.072	1.47 ± 0.210
FAD *G. oceanica*	1.51 ± 0.018	1.53 ± 0.012	1.55 ± 0.072	1.53 ± 0.112
FAD *G. caribbeanica*	1.60 ± 0.006	1.61 ± 0.021	2.00 ± 0.072	1.80 ± 0.434
LAD *D. brouweri*	2.10 ± 0.018	No data	2.00 ± 0.072	2.03 ± 0.162
LAD *D. pentaradiatus*	No data	No data	2.31 ± 0.072	2.31
LAD *D. surculus*	2.42 ± 0.019	No data	No data	2.42
LAD *D. tamalis*	No data	No data	2.77 ± 0.044	2.77
LAD *R. pseudoumbilica*	No data	No data	3.44 ± 0.010	3.44
LAD *S. abies*	No data	No data	3.44 ± 0.010	3.44

Table 13. Chrons and ages of nannofossil datum levels. Sources are as follows: a = Takayama and Sato, 1987 — North Atlantic data; b = Thierstein et al., 1977; c = Gartner, 1977 — South Pacific data; d = Berggren et al., 1985; e = Pujos, 1985 — North Atlantic data; f = Rahman and Roth, 1989 — Gulf of Aden data; g = Backman and Shackleton, 1983 — Atlantic, Pacific and Indian Ocean data; h = Monechi et al., 1985 — Northwest Pacific data; i = Hsü et al., 1984 — South Atlantic data; j = Haq and Berggren, 1978 — South Atlantic data; k = Backman and Pestiaux, 1987 — North Atlantic data (DSDP Site 606); l = Berggren et al., 1983 — South Atlantic data (DSDP Site 516); m = Poore et al., 1984 — South Atlantic data; n = Barron et al., 1985 — central equatorial Pacific data; o = Hodell and Kennett, 1986 — Southwest Pacific data (DSDP Site 588); p = Hodell and Kennett, 1986 — Southwest Pacific data (DSDP Site 590); q = Hodell and Kennett — South Atlantic data (Site CH115); r = Hodell and Kennett, 1986 — South Atlantic data (DSDP Hole 516A); s = Hodell and Kennett, 1986 — South Atlantic data (DSDP Site 519); t = Thunnell, 1981.

Datum	Chron or subchron	Age (Ma)	Reported age(s) (Ma)
FAD *E. huxleyi*	Brunhes	0.23	[a]0.24, [b]0.268, [c]0.27, [d]0.275
LAD *P. lacunosa*	Brunhes	0.38	[a]0.39, [c]0.44, [b]0.458, [e]0.46, [d]0.474, [f]0.570
FAD *H. inversa*	Brunhes	0.42	[a]0.48
Top of acme *R.* sp. A	within or just below Brunhes/ Matuyama reversal	0.70	[a]0.83
FAD *G. parallela*	just above Jaramillo Subchron	0.85	[a]0.89
LAD *G.* (large)	just below Jaramillo Subchron	1.07	[a]1.10
LAD *H. sellii*	between Jaramillo and Olduvai Subchrons	1.34	[a]1.19, [e]1.22, [g]1.37, [f]1.524
LAD *C. macintyrei*	between Jaramillo and Olduvai Subchrons	1.47	[g]1.45, [e]1.51, [f]1.55, [a]1.57, [h]1.58
FAD *G. oceanica*	between Jaramillo and Olduvai Subchrons	1.53	[f]1.354, [a]1.57, [d]1.68
FAD *G. caribbeanica*	between Jaramillo and Olduvai Subchrons	1.80	[a]1.66, [f]1.682, [d]1.74
LAD *D. brouweri*	below Olduvai Subchron	2.03	[j]1.65, [i]1.80, [g]1.88, [k]1.89, [d]1.90, [a]1.91, [f]1.951
LAD *D. pentaradiatus*	just above M/G reversal	2.31	[g]2.20, [j]2.20–2.30, [k]2.33–2.43, [f]2.354, [g]2.35, [a]2.37, [d]2.40
LAD *D. surculus*	just above M/G reversal	2.42	[j]2.20–2.30, [d, i]2.40, [g]2.41, [k]2.42–2.46, [a]2.49
LAD *D. tamalis*	Gauss, just above Kaena Subchron	2.77	[d]2.60, [g, k]2.65, [a]2.75, [f]3.02
LAD *S. abies*	late Gilbert	3.44	[g]3.45, [l]3.46, [d]3.47, [f]3.514, [a]3.56
LAD *R. pseudoumbilica*	late Gilbert	3.44	[s]3.43, [m]3.45, [l]3.46, [d, i, n, p, t]3.50, [g]3.56, [f]3.595, [j]3.60, [q]3.61, [r]3.70, [o]3.75

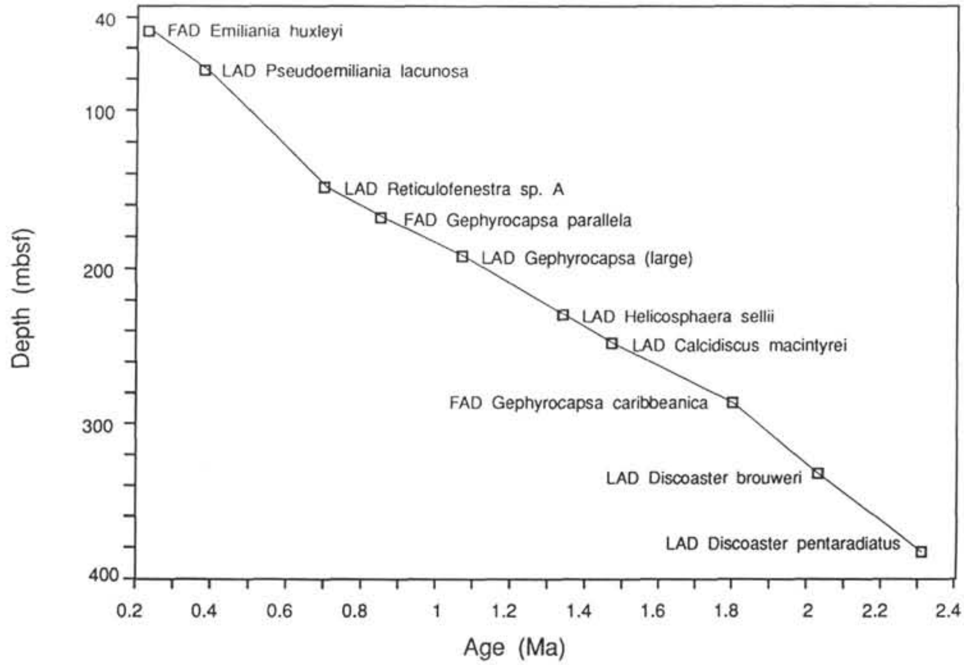

Figure 4. Depths (mbsf) and ages (Ma) of nannofossil events at Site 723.

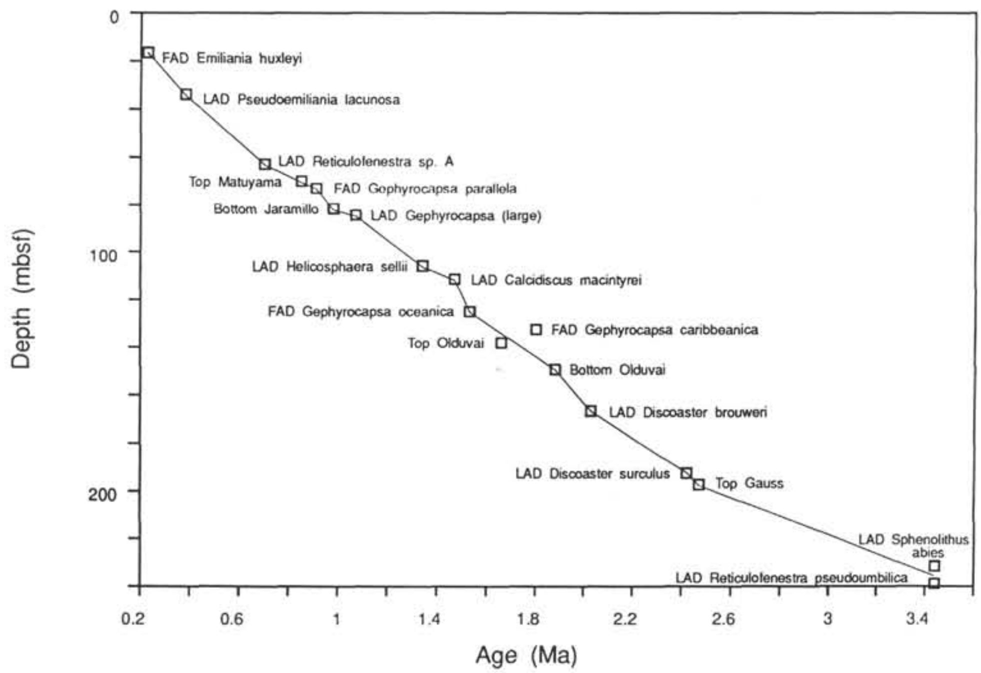

Figure 5. Depths (mbsf) and ages (Ma) of nannofossil events and paleomagnetic reversals at Site 724.

More than 60% of the samples examined have reworked Cretaceous and Cenozoic nannofossils. Monsoonal-related winds originating from the southwest may well have carried nannofossils from the continent of Africa or the Arabian Peninsula along with the clays which they are known to deposit into the Arabian Sea. Three sites (724, 727, and 728) provide good magnetostratigraphic control, and allow, for the first time, the assignment of ages to nannofossil datums observed in Neogene Oman Margin sediments.

TAXONOMIC NOTES

Genus *GEPHYROCAPSA* Kamptner, 1943

Remarks. Those specimens of *Gephyrocapsa* whose length exceeds 6 μm were identified as "*Gephyrocapsa* (large)".

Genus *HOLODISCOLITHUS* Roth, 1970

Remarks. The distinction between the two species of *Holodiscolithus, H. macroporus* and *H. solidus*, is based upon the arrangement

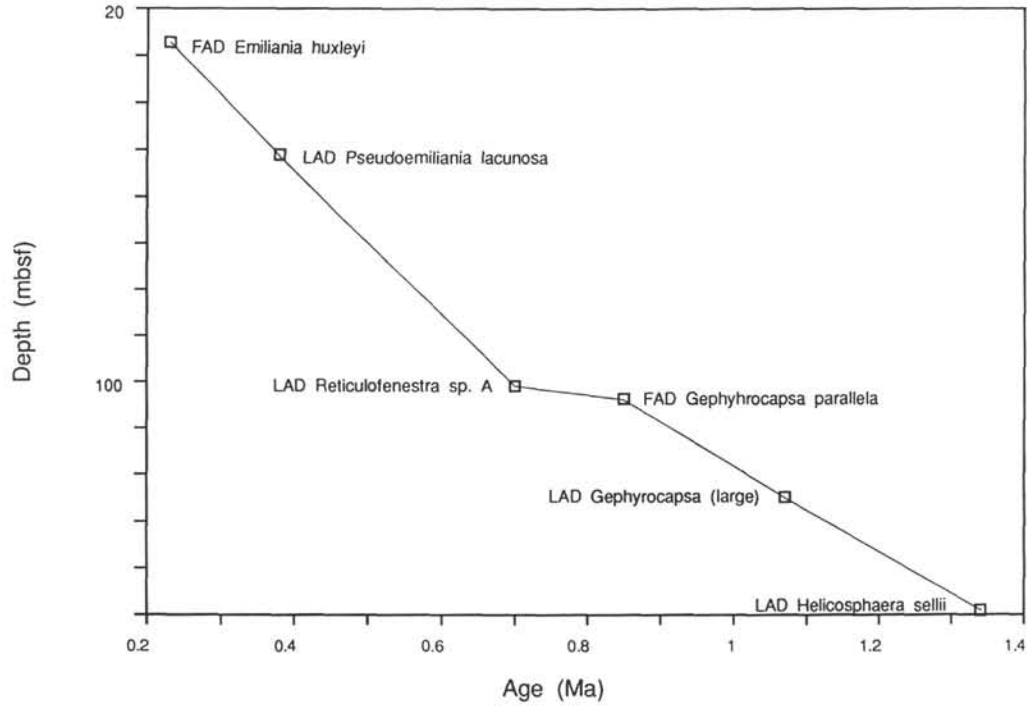

Figure 6. Depths (mbsf) and ages (Ma) of nannofossil events at Site 725.

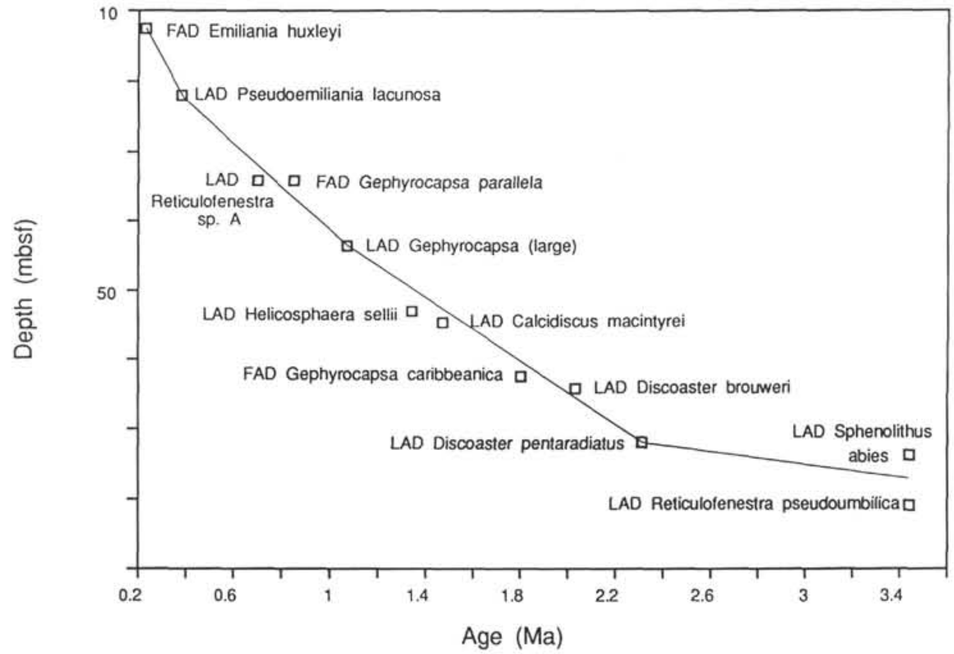

Figure 7. Depths (mbsf) and ages (Ma) of nannofossil events at Site 726.

and size of the crystal cubes. These differences are not visible with a standard light microscope so I have opted to name all specimens as *Holodiscolithus* spp.

Genus *PONTOSPHAERA* Lohmann, 1902
Pontosphaera sp. A

Remarks. *Pontosphaera* sp. A is distinguished from *Pontosphaera discopora* Schiller by the outer cycle of perforations which number approximately 30. This species is few to abundant in scattered samples from Zones NN5 through NN21.

Pontosphaera sp. B

Remarks. This species has a wider rim than other *Pontosphaera* species such as *P. discopora* and has about 20 pores in the outermost cycle. This species ranges from few to common and is present in samples from Zone NN6 through NN21.

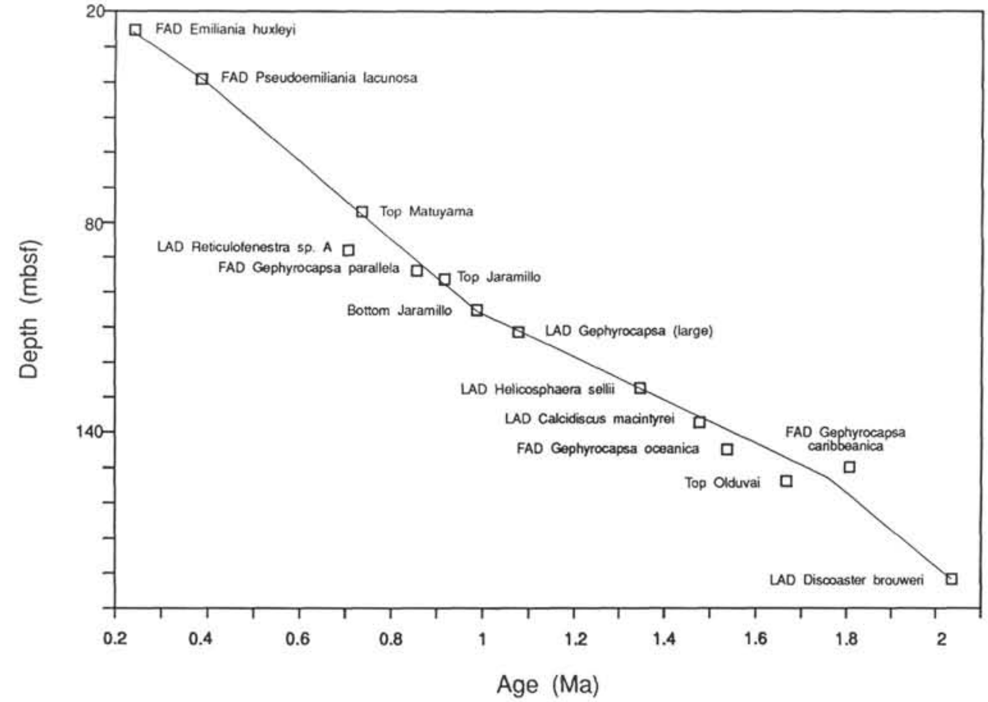

Figure 8. Depths (mbsf) and ages (Ma) of nannofossil events and paleomagnetic reversals at Site 727.

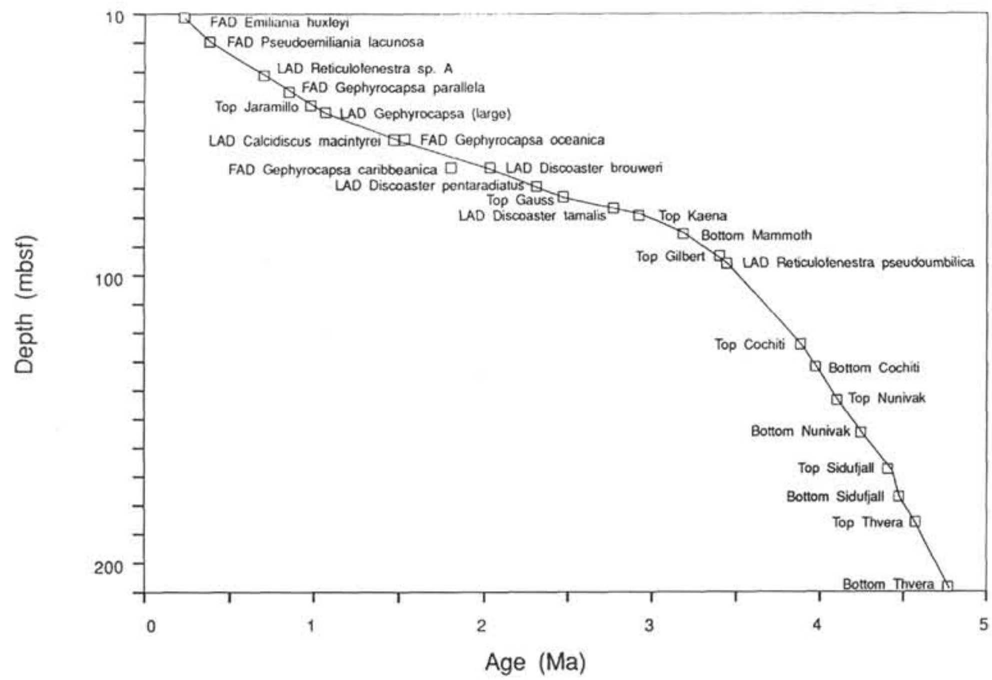

Figure 9. Depths (mbsf) and ages (Ma) of nannofossil events and paleomagnetic reversals at Site 728.

Pontosphaera sp. C

Remarks. This species has a rim which is approximately one-fourth the width of the nannofossil. There are approximately 50–60 relatively small perforations in the outermost cycle. These perforations are not arranged in a linear fashion. It is difficult to accurately count the number of cycles of pores with the light microscope but there appear to be four. This species ranges from few to common and is found from the middle part of Zone NN19 through NN21.

Genus *RETICULOFENESTRA* Hay, Mohler and Wade, 1966
Reticulofenestra sp. A

Remarks. Takayama and Sato (1987) utilized the acme of this species as a datum in the Pleistocene. This species can be distinguished from

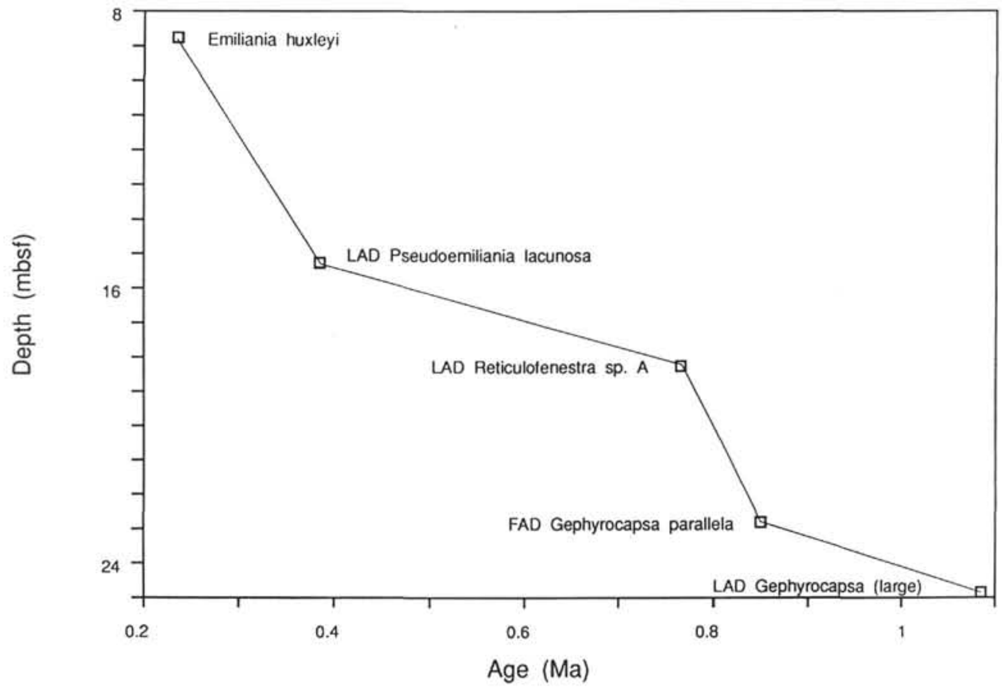

Figure 10. Depths (mbsf) and ages (Ma) of nannofossil events at Site 729.

Crenalithus doronicoides (Black and Barnes) Roth by its larger size (larger than 6 μm).

Reticulofenestra sp. B

Remarks. *Reticulofenestra* sp. B of Takayama and Sato (1987) appears in the same horizon as *Reticulofenestra* sp. A, but is distinguished from it by its circular outline.

ACKNOWLEDGMENTS

I thank Texaco USA in New Orleans for the use of their facilities during the summer of 1988. Purtyasti Resiwati assisted in plate preparation. Jonathan Rice took the SEM photographs and gave many suggestions which were appreciated. Dr. Toshiaki Takayama provided encouragement, friendship, and valuable advice on nannofossil biostratigraphy which made my first leg on board the *JOIDES Resolution* a wonderful experience. Finally, a very special thank you to Dr. David K. Watkins who made many useful suggestions which greatly improved this manuscript. His wisdom and, perhaps even more importantly, his unfaltering patience truly are an inspiration.

REFERENCES

Al Naqib, K. M., 1966. Geology of the Arabian Peninsula: southwestern Iraq. *U.S. Geol. Surv. Prof. Pap.*, 560-G.

Aubry, M.-P., 1984. *Handbook of Cenozoic Calcareous Nannoplankton. Book 1: Ortholithae (Discoasters)*: New York (Micropaleontology Press).

_______, 1988. *Handbook of Calcareous Nannoplankton. Book 2: Ortholithae (Holococcoliths, Ceratoliths and others)*: New York (Micropaleontology Press).

Backman, J., 1980. Miocene-Pliocene nannofossils and sedimentation rates in the Hatton-Rockall Basin, NE Atlantic Ocean. *Stockholm Contrib. Geol.*, 36:1-91.

Backman, J., and Pestiaux, P., 1986. Pliocene *Discoaster* abundance variations, Deep Sea Drilling Project Site 606: biochronology and paleoenvironmental implications. *In* Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94 (Pt. 2): Washington (U.S. Govt. Printing Office), 903-910.

Backman, J., and Shackleton, N. J., 1983. Quantitative biochronology of the Pliocene and early Pleistocene calcareous nannofossils from the Atlantic, Indian and Pacific Oceans. *Mar. Micropaleontol.*, 8: 141-170.

Barron, J. A., Nigrini, C. A., Pujos, A., Saito, T., Theyer, F., Thomas, E., and Weinrich, N., 1985. Synthesis of biostratigraphy, central equatorial Pacific, DSDP Leg 85: refinement of Oligocene to Quaternary biochronology. *In* Mayer, L., Theyer, F., Thomas, E., et al., *Init. Repts. DSDP*, 85: Washington (U.S. Govt. Printing Office), 905-934.

Berggren, W. A., Aubry, M. P., and Hamilton, N., 1983. Neogene magnetostratigraphy of DSDP Site 516 (Rio Grande Rise, South Atlantic). *In* Barker, P. F., Carlson, R. L., Johnson, D. A., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office), 675-713.

Berggren, W. A., Kent, D. V., and Van Couvering, J. A., 1985. The Neogene: Part 2. Neogene geochronology and chronostratigraphy. *In* Snelling, N. J. (Ed.), *The Chronology of the Geological Record*. Geol. Soc. London Mem., 10:211-260.

Beydoun, Z. R., 1966. The geology of the Arabian Peninsula: eastern Aden Protectorate and part of Dhufar. *U.S. Geol. Surv. Prof. Pap.*, 560-H.

Boudreaux, J. E., 1974. Calcareous nannoplankton ranges, DSDP Leg 23. *In* Whitmarsh, R. B., Weser, O. E., Ross, D. A., et al., *Init. Repts. DSDP*, 23: Washington (U.S. Govt. Printing Office), 1073-1090.

Bukry, D., 1971. Coccolith stratigraphy Leg 6, DSDP. *In* Fischer, A. G., Heezen, B. C., et al., *Init. Repts. DSDP*, 6: Washington (U.S. Govt. Printing Office), 965-1004.

_______, 1972. Further comments on coccolith stratigraphy, Leg 12, DSDP. *In* Laughton, A. S., Berggren, W. A., et al., *Init. Repts. DSDP*, 12: Washington (U.S. Govt. Printing Office), 1071-1083.

_______, 1973. Coccolith and silicoflagellate stratigraphy, Tasman Sea and southwestern Pacific Ocean, DSDP Leg 21. *In* Burns, R. E., Andrews, J. E., et al., *Init. Repts. DSDP*, 21: Washington (U.S. Govt. Printing Office), 885-893.

_______, 1974. Phytoplankton stratigraphy offshore East Africa, DSDP Leg 25. *In* Simpson, E.S.W., Schlich, R., et al., *Init. Repts. DSDP*, 25: Washington (U.S. Govt. Printing Office), 635-646.

_______, 1975. Coccolith and silicoflagellate stratigraphy, northwestern Pacific Ocean, Deep Sea Drilling Project Leg 32. *In* Larson,

R. L., Moberly, R., et al., *Init. Repts. DSDP*, 32: Washington (U.S. Govt. Printing Office), 677–701.

———, 1977. Cenozoic coccolith and silicoflagellate stratigraphy, offshore northwest Africa, DSDP Leg 41. *In* Lancelot, Y., Seibold, E., et al., *Init. Repts. DSDP*, 41: Washington (U.S. Govt. Printing Office), 689–719.

Cohen, C.L.D., 1964. Coccolithophorids from two Caribbean deep-sea cores. *Micropaleontology*, 10:231–250.

Furon, R., 1963. *The Geology of Africa*: Edinburgh (Oliver & Boyd).

Gartner, S., 1972. Late Pleistocene calcareous nannofossils in the Caribbean and their interoceanic correlation. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 12:169–191.

Gartner, S., Jr., 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Mar. Micropaleontol.*, 2:1–25.

Geukens, F., 1966. Geology of the Arabian Peninsula: Yemen. *U.S. Geol. Surv. Prof. Pap.*, 560-B.

Greenwood, J.E.G.W., and Bleackley, D., 1966. Geology of the Arabian Peninsula: Aden Protectorate. *U.S. Geol. Surv. Prof. Pap.*, 560-C.

Haq, B. U., and Berggren, W. A., 1978. Late Neogene calcareous nannoplankton biogeography of the Rio Grande Rise (South Atlantic Ocean). *J. Paleontol.*, 52:1167–1194.

Hay, W. W., 1970. Calcareous nannofossils from cores recovered on DSDP Leg 4. *In* Bader, R. G., Gerard, R. D., et al., *Init. Repts. DSDP*, 4: Washington (U.S. Govt. Printing Office), 455–501.

Hay, W. W., Schmidt, R. R., Mohler, H. P., Boudreaux, J. E., and Roth, P. H., 1967. Calcareous nannoplankton zonation of the Cenozoic of the Gulf Coast and Caribbean-Antillean area, and transoceanic correlation. *Trans. Gulf Coast Assoc. Geol. Soc.*, 17:428–480.

Hodell, D. A., and Kennett, J. P., 1986. Late Miocene-early Pliocene stratigraphy and paleoceanography of the South Atlantic and Southwest Pacific Oceans: a synthesis. *Paleoceanography*, 1:285–311.

Hsü, K. J., Percival, S. F., Wright, R. C., and Petersen, N. P., 1984. Numerical ages of magnetostratigraphically calibrated biostratigraphic zones. *In* Hsü, K. J., La Brecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office), 623–635.

Loeblich, A. R., and Tappan, H., 1966. Annotated index and bibliography of the calcareous nannoplankton. *Phycologia*, 5:81–215.

———, 1968. Annotated index and bibliography of the calcareous nannoplankton II. *J. Paleontol.*, 42:584–598.

———, 1969. Annotated index and bibliography of the calcareous nannoplankton III. *J. Paleontol.*, 43:568–588.

———, 1970a. Annotated index and bibliography of the calcareous nannoplankton IV. *J. Paleontol.*, 44:558–574.

———, 1970b. Annotated index and bibliography of the calcareous nannoplankton V. *Phycologia*, 9:157–174.

———, 1971. Annotated index and bibliography of the calcareous nannoplankton VI. *Phycologia*, 10:315–339.

———, 1973. Annotated index and bibliography of the calcareous nannoplankton VII. *J. Paleontol.*, 47:715–759.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In* Farinacci, A. (Ed.), *Proc. 2nd Planktonic Conf. Roma, 1971.* 2:739–785.

Martini, E., and Worsley, T., 1971. Tertiary calcareous nannoplankton from the western equatorial Pacific. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7: Washington (U.S. Govt. Printing Office), 1471–1507.

McIntyre, A., Bé, A.W.H., and Roche, M. B., 1970. Modern Pacific coccolithophorida: a paleontological thermometer. *Trans. N. Y. Acad. Sci.*, 32:720–731.

McIntyre, A. A., Bé, A.W.H., and Preikstas, R., 1967. Coccoliths and the Plio-Pleistocene boundary. *Prog. Oceanogr.*, 4:3–24.

Monechi, S., Bleil, U., and Backman, J., 1985. Magnetobiochronology of late Cretaceous-Paleogene and late Cenozoic pelagic sedimentary sequences from the northwest Pacific, DSDP Leg 86, Site 577. *In* Heath, G. R., Burckle, L. H., et al., *Init. Repts. DSDP*, 86: Washington (U.S. Govt. Printing Office), 787–797.

Perch-Nielsen, K., 1985. Cenozoic calcareous nannofossils. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy*: Cambridge (Cambridge Univ. Press), 427–554.

Poore, R. Z., Tauxe, L., Percival, S. F., Jr., LaBrecque, J. L., Wright, R., Peterson, N. P., Smith, C. C., Tucker, P., and Hsü, K. J., 1984. Late Cretaceous-Cenozoic magnetostratigraphic and biostratigraphic correlations for the South Atlantic Ocean, Deep Sea Drilling Project Leg 73. *In* Hsü, K. J., La Brecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office), 645–655.

Powers, R. W., Ramirez, L. F., Redmond, C. D., and Elberg, E. L., 1966. Geology of the Arabian Peninsula: sedimentary geology of Saudi Arabia. *U.S. Geol. Surv. Prof. Pap.*, 560-D.

Prell, W. L., Niitsuma, N., et al., 1989, Proc., Init. Repts. 117: College Station, TX (Ocean Drilling Program).

Prell, W. L., and Streeter, H. F., 1982. Temporal and spatial patterns of monsoonal upwelling along Arabia: a modern analogue for the interpretation of Quaternary SST anomalies. *J. Mar. Res.*, 40:143–155.

Pujos, A., 1985. Quaternary nannofossils from Goban Spur, eastern North Atlantic Ocean, DSDP Holes 548 and 549A. *In* de Graciansky, P. C., Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office), 767–792.

Qasim, S. Z., 1982. Oceanography of the northern Arabian Sea. *Deep-Sea Res. Part A*, 29:1041–1068.

Raffi, I., and Rio, D., 1981. *Coccolithus pelagicus* (Wallich): a paleotemperature indicator in the late Pliocene Mediterranean deep sea record. *In* Wezel, F. C. (Ed.), *Sedimentary Basins of Mediterranean Margins*: Bologna (Tecnoprint), 187–190.

Rahman, A., and Roth, P. H., 1989. Late Neogene calcareous nannofossil biostratigraphy of the Gulf of Aden region based on calcareous nannofossils. *Mar. Micropaleontol.*, 15:1–27.

Roth, P. H., 1974. Calcareous nannofossils from the northwestern Indian Ocean, Leg 24, DSDP. *In* Fisher, R. L., Bunce, E. T., et al., *Init. Repts. DSDP*, 24: Washington (U.S. Govt. Printing Office), 969–994.

Roth, P. H., and Coulbourn, W. T., 1982. Floral and solution patterns of coccoliths in surface sediments of the North Pacific. *Mar. Micropaleontol.*, 7:1–52.

Sato, T., and Takayama, T., 1988. Calcareous nannofossil zones of the Quaternary. *Sekiyu Gijutsu Kyokaishi*, 30:205–217.

Shackleton, N. J., and Opdyke, N. D., 1977. Oxygen isotope and paleomagnetic evidence for early Northern Hemisphere glaciation. *Nature*, 270:216–219.

Slater, R. D., and Kroopnick, P., 1984. Controls on dissolved oxygen distribution and organic carbon deposition in the Arabian Sea. *In* Haq, B. U., and Milliman, J. D. (Eds.), *Marine Geology and Oceanography of Arabian Sea and Coastal Pakistan.* New York (Van Nostrand Reinhold), 305–313.

Steinmetz, J. C., 1983a. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 5:4–13.

———, 1983b. Bibliography and taxa of calcareous nannoplankton-II. *INA Newsl.*, 5:29–47.

———, 1984a. Bibliography and taxa of calcareous nannoplankton-III. *INA Newsl.*, 6:6–37.

———, 1984b. Bibliography and taxa of calcareous nannoplankton-IV. *INA Newsl.*, 6:55–81.

———, 1985a. Bibliography and taxa of calcareous nannoplankton-V. *INA Newsl.*, 7:5–28.

———, 1985b. Bibliography and taxa of calcareous nannoplankton-VI. INA Newsl., 7:122–145.

———, 1986a. Bibliography and taxa of calcareous nannoplankton-VII. *INA Newsl.*, 8:12–32.

———, 1986b. Bibliography and taxa of calcareous nannoplankton-VIII. *INA Newsl.*, 8:66–87.

———, 1987a. Bibliography and taxa of calcareous nannoplankton-IX. *INA Newsl.*, 9:6–29.

———, 1987b. Bibliography and taxa of calcareous nannoplankton-X. *INA Newsl.*, 9:81–109.

———, 1988a. Bibliography and taxa of calcareous nannoplankton-XI. *INA Newsl.*, 10:7–28.

———, 1988b. Bibliography and taxa of calcareous nannoplankton-XII. *INA Newsl.*, 10:60–88.

———, 1989. Bibliography and taxa of calcareous nannoplankton-XIII. *INA Newsl.*, 11:6–23.

Steinmetz, J. C., and Anderson, T. F., 1984. The significance of isotopic and paleontologic results on Quaternary calcareous nannofossil assemblages from Caribbean Core P6304-4. *Mar. Micropaleontol.*, 8:403–424.

Takayama, T., and Sato, T., 1987. Coccolith biostratigraphy of the North Atlantic Ocean, Deep Sea Drilling Project Leg 94. *In* Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94 (Pt. 2): Washington (U.S. Govt. Printing Office), 651–702.

Thierstein, H. R., Geitzenauer, K. R., Molfino, B., and Shackleton, N. J., 1977. Global synchroneity of late Quaternary coccolith datum levels: validation by oxygen isotopes. *Geology*, 5:400–404.

Thunnell, R. C., 1981. Late Miocene-Early Pliocene planktonic foraminiferal biostratigraphy and paleoceanography of low-latitude marine sequences. *Mar. Micropaleontol.*, 6:71–901.

van Heck, S. E., 1979a. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 1:AB1–B27.

———, 1979b. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 1:ABVI–B42.

———, 1980a. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.* 2:5–34.

———, 1980b. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 2:43–81.

———, 1981a. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 3:4–41.

———, 1981b. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 3:51–86.

———, 1982a. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 4:7–50.

———, 1982b. Bibliography and taxa of calcareous nannoplankton. *INA Newsl.*, 4:65–96.

Watkins, D. K., and Bowdler, J. L., 1984. Cretaceous calcareous nannofossils from DSDP Leg 77, southeast Gulf of Mexico. *In* Buffler, R. T., Schlager, W., et al., *Init. Repts. DSDP*, 77: Washington (U.S. Govt. Printing Office), 649–674.

Wise, S. W., Jr., 1973. Calcareous nannoplankton from cores recovered during Leg 18, DSDP: biostratigraphy and observations of diagenesis. *In* Kulm, L. D., von Huene, R., et al., *Init. Repts. DSDP* 18: Washington (U.S. Govt. Printing Office), 569–615.

Woellner, R. A., Blackwelder, P. L., Peterson, L. C., Lynn, M. J., and Prell, W. L., 1988. Monsoonal upwelling in the NW Indian Ocean: modern and Late Quaternary coccolithophorid assemblages. *Geol. Soc. Am. Abstr. Programs*, 20:252. (Abstract)

Wyrtki, K., 1971. *Oceanographic Atlas of the International Ocean Expedition*: Washington (Nat. Sci. Found.).

Date of initial receipt: 1 June 1989
Date of acceptance: 15 March 1990
Ms 117B-127

APPENDIX

During this investigation, 80 species and 25 genera were recognized. Bibliographic references for previously described taxa may be found in Loeblich and Tappan (1966, 1968, 1969, 1970a, 1970b, 1971, 1973), in Steinmetz (1983a, 1983b, 1984a, 1984b, 1985a, 1985b, 1986a, 1986b, 1987a, 1987b, 1988a, 1988b, 1989), and in van Heck (1979a, 1979b, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b).

Calcareous nannofossil species considered in this report
(Listed alphabetically by species epithets)

Sphenolithus abies Deflandre *in* Deflandre and Fert, 1954
Discoaster adamanteus Bramlette and Wilcoxon, 1967
Thoracosphaera albatrosiana Kamptner, 1963
Discoaster asymmetricus Gartner, 1969c
Discoaster bellus Bukry and Percival, 1971
Discoaster berggrenii Bukry, 1971b
Braarudosphaera bigelowii (Gran and Braarud) Deflandre, 1947
Discoaster bollii Martini and Bramlette, 1963
Discoaster brouweri (Tan) emend. Bramlette and Riedel, 1963
Discoaster calcaris Gartner, 1967
Catinaster calyculus Martini and Bramlette, 1963
Gephyrocapsa caribbeanica Boudreaux and Hay, 1969
Helicosphaera carteri (Wallich) Kamptner, 1954
Discoaster challengeri Bramlette and Riedel, 1954
Rhabdosphaera clavigera Murray and Blackman, 1898
Catinaster coalitus Martini and Bramlette, 1963
Neosphaera coccolithomorpha Lecal-Schlauder, 1950
Coccolithus crassipons Bouche, 1962
Ceratolithus cristatus Kamptner, 1950
Discoaster decorus (Bukry) Bukry, 1973c
Discoaster deflandrei Bramlette and Riedel, 1954
Pontosphaera discopora Schiller, 1925
Discoaster exilis Martini and Bramlette, 1963
Cyclicargolithus floridanus (Roth and Hay) Bukry, 1971c
Scapholithus fossilis Deflandre *in* Deflandre and Fert, 1954
Oolithotus fragilis (Lohmann) Martini and Muller, 1972
Reticulofenestra gelida (Geitznauer) Backman, 1978
Discoaster hamatus Martini and Bramlette, 1963
Thoracosphaera heimi (Lohmann) Kamptner, 1941
Sphenolithus heteromorphus Deflandre, 1953
Emiliania huxleyi (Lohmann) Hay and Mohler *in* Hay et al., 1967
Discoaster indica Singh and Vimal, 1976
Pontosphaera indooceanica Cepek, 1973
Discoaster intercalaris Bukry, 1971a
Helicosphaera intermedia Martini, 1965
Helicosphaera inversa Gartner, 1980
Pontosphaera japonica (Takayama) Nishida, 1971
Discoaster kugleri Martini and Bramlette, 1963
Pseudoemiliania lacunosa (Kamptner) Gartner, 1969c
Calcidiscus leptoporus (Murray and Blackman) Loeblich and Tappan, 1978
Calcidiscus macintyrei (Bukry and Bramlette) Loeblich and Tappan, 1978
Helicosphaera mediterranea Muller, 1981
Catinaster mexicanus Bukry, 1971b
Coccolithus miopelagicus Bukry, 1971a
Discoaster mohleri Bukry and Percival, 1971
Sphenolithus moriformis (Bronnimann and Stradner) Bramlette and Wilcoxon, 1967
Sphenolithus neoabies Bukry and Bramlette, 1969a
Discoaster neohamatus Bukry and Bramlette, 1969b
Discoaster neorectus Bukry, 1971a
Gephyrocapsa oceanica Kamptner, 1943
Thoracosphaera operculata Bramlette and Martini, 1964
Discoaster pansus (Bukry and Percival) Bukry, 1973c
Gephyrocapsa parallela Hay and Beaudry, 1973
Coccolithus pelagicus (Wallich) Schiller, 1930
Discoaster pentaradiatus (Tan) emend. Bramlette and Riedel, 1954
Hayaster perplexus (Bramlette and Riedel) Bukry, 1973d
Discoaster prepentaradiatus Bukry and Percival, 1971
Gephyrocapsa protohuxleyi McIntyre, 1970
Reticulofenestra pseudoumbilica (Gartner) Gartner, 1969c
Discoaster pseudovariabilis Martini and Worsley, 1971
Syracosphaera pulchra Lohmann, 1902
Discoaster quinqueramus Gartner, 1969c
Ceratolithus rugosus Bukry and Bramlette, 1968
Triquetrorhabdulus rugosus Bramlette and Wilcoxon, 1967
Helicosphaera sellii Bukry and Bramlette, 1969b
Umbilicosphaera sibogae foliosa (Kamptner) Okada and McIntyre, 1977
Rhabdosphaera stylifera Lohmann, 1902
Discoaster surculus Martini and Bramlette, 1963
Discoaster tamalis Kamptner, 1967
Ceratolithus telesmus Norris, 1965
Amaurolithus tricorniculatus (Gartner) Gartner and Bukry, 1975
Discoaster triradiatus Tan, 1927
Discoaster variabilis Martini and Bramlette, 1963
Helicosphaera wallichii (Lohmann, 1902) Boudreaux and Hay, 1969

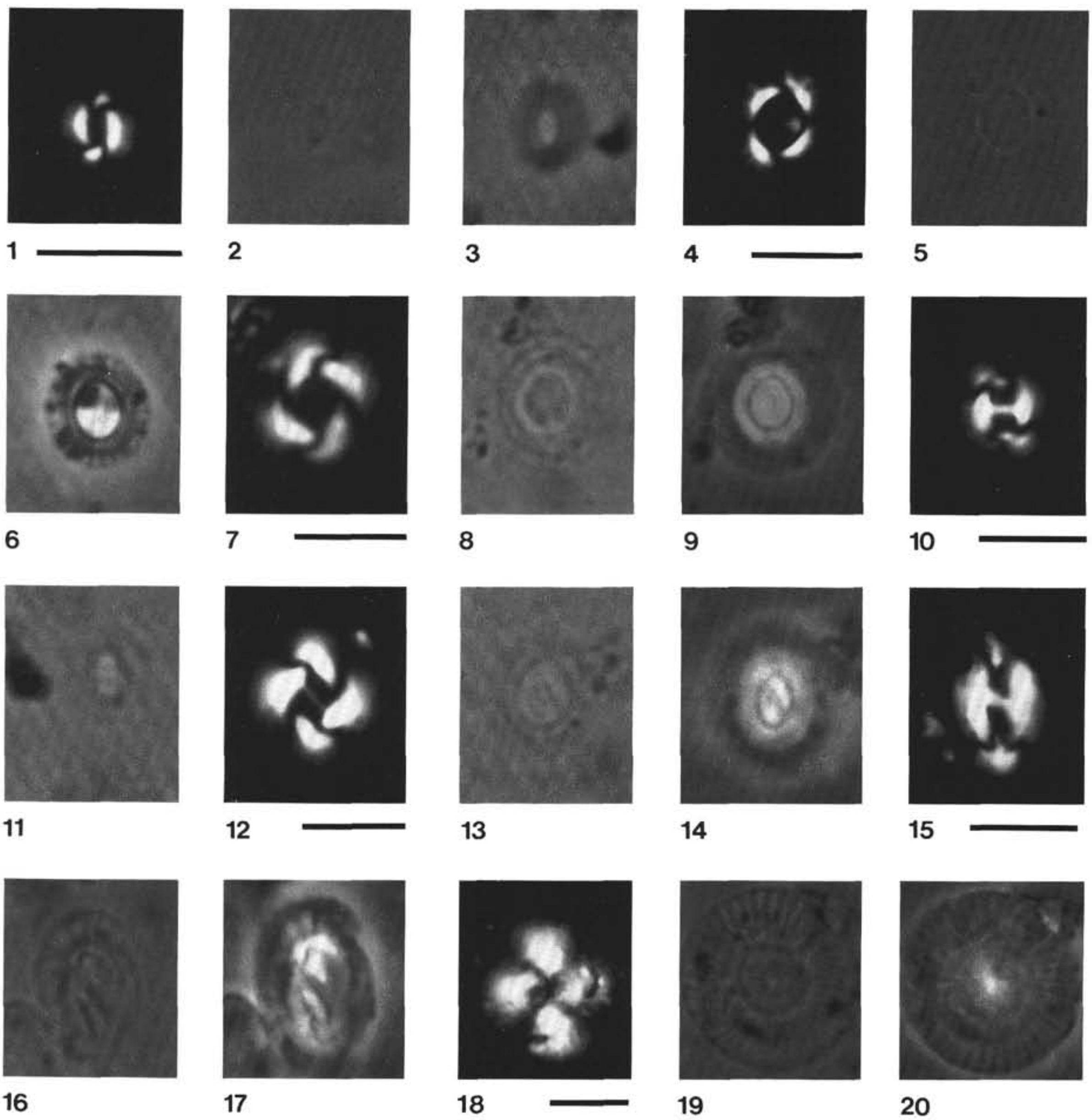

Plate 1. **1–3,** *Emiliania huxleyi*, Sample 117-723A-1H-1, 120 cm; 1 = crossed nicols, 2 = transmitted light, 3 = phase contrast. **4–6,** *Pseudoemiliania lacunosa*, Sample 117-723A-9H-2, 140 cm; 4 = crossed nicols, 5 = transmitted light, 6 = phase contrast. **7–9,** *Reticulofenestra* sp. A (Takayama and Sato, 1987), Sample 117-727A-10H-3, 118 cm; 7 = crossed nicols, 8 = transmitted light, 9 = phase contrast. **10–11,** *Gephyrocapsa parallela*, Sample 117-727A-1H-1, 118 cm; 10 = crossed nicols, 11 = transmitted light. **12–14,** *Gephyrocapsa caribbeanica* (large), Sample 117-725C-14X-3, 118 cm; 12 = crossed nicols, 13 = transmitted light, 14 = phase contrast. **15–17,** *Helicosphaera sellii*, Sample 117-725C-14X-3, 118 cm; 15 = crossed nicols, 16 = transmitted light, 17 = phase contrast. **18–20,** *Calcidiscus macintyrei*, Sample 117-726A-10X-1, 118 cm; 18 = crossed nicols, 19 = transmitted light, 20 = phase contrast. All scale bars are equal to 5 μm.

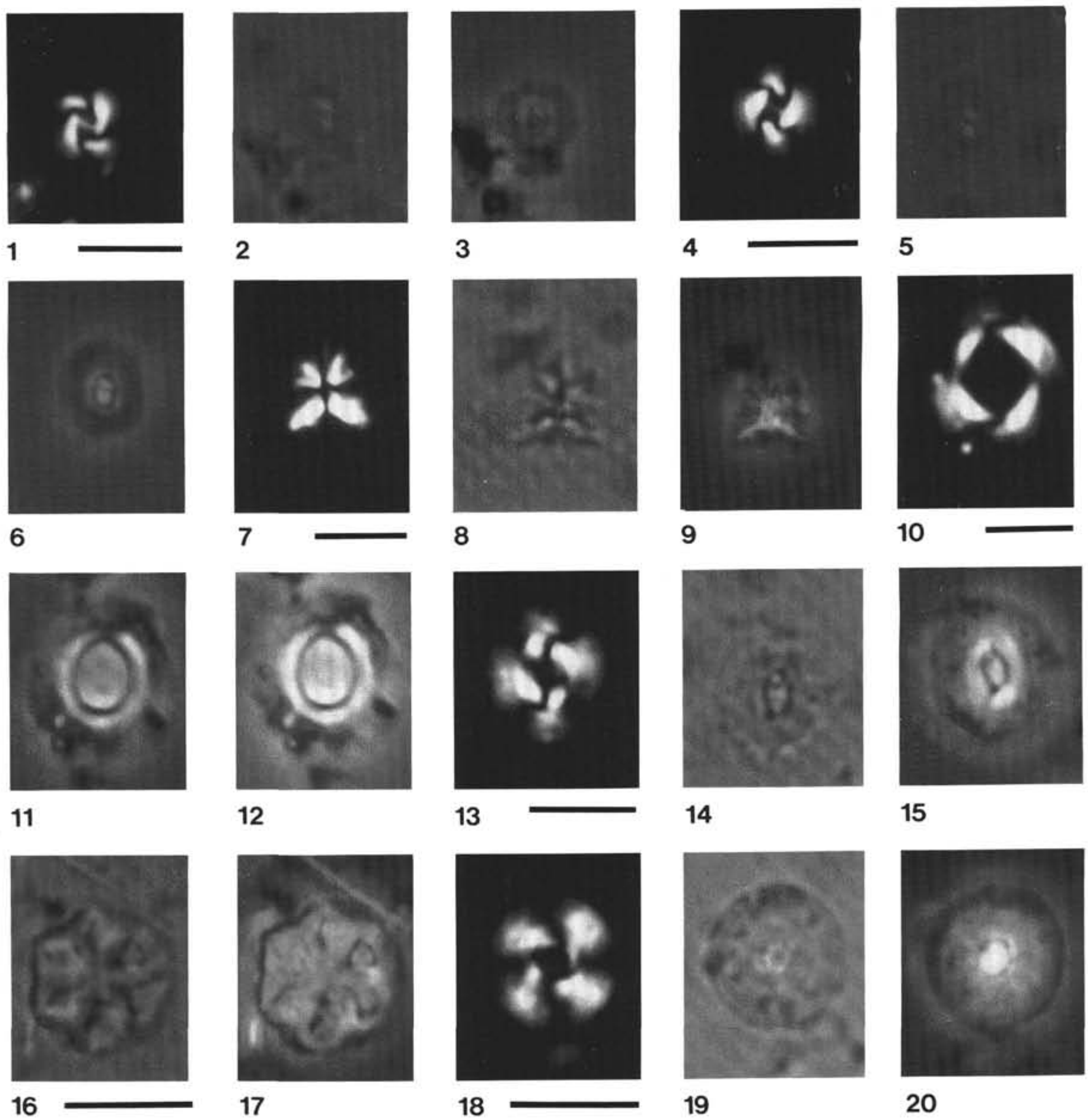

Plate 2. **1–3,** *Gephyrocapsa oceanica*, Sample 117-727A-10H-3, 118 cm; 1 = crossed nicols, 2 = transmitted light, 3 = phase contrast. **4–6,** *Gephyrocapsa caribbeanica*, Sample 117-727A-10H-3, 118 cm; 4 = crossed nicols, 5 = transmitted light, 6 = phase contrast. **7–9,** *Sphenolithus abies*, Sample 117-726A-10X-1, 118 cm; 7 = crossed nicols, 8 = transmitted light, 9 = phase contrast. **10–12,** *Reticulofenestra pseudoumbilica*, Sample 117-726A-10X-1, 118 cm; 10 = crossed nicols, 11 = transmitted light. 12 = phase contrast. **13–15,** *Reticulofenestra gelida*, Sample 117-726A-10X-1, 118 cm; 13 = crossed nicols, 14 = transmitted light, 15 = phase contrast. **16–17,** *Catinaster coalitus*, Sample 117-730A-8X-3, 105 cm; 16 = transmitted light, 17 = phase contrast. **18–20,** *Cyclicargolithus floridanus*, Sample 117-730A-38X-1, 80 cm; 18 = crossed nicols, 19 = transmitted light, 20 = phase contrast. All scale bars are equal to 5 μm.

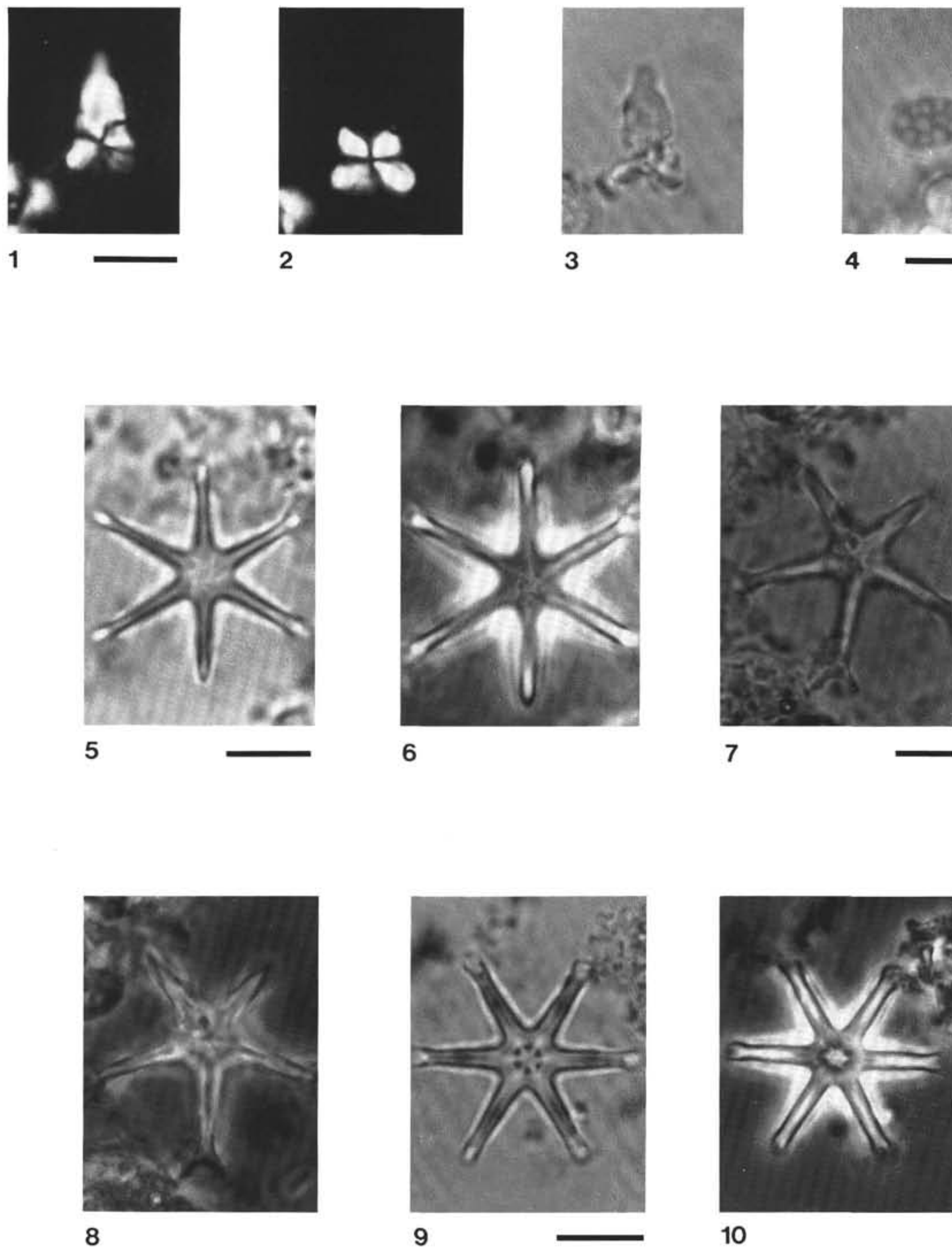

Plate 3. **1–3,** *Sphenolithus heteromorphus*, Sample 117-730A-38X-1, 80 cm; 1 = crossed nicols, 2 = crossed nicols with apical spine 45° to polarizer, 3 = phase contrast. **4,** *Holodiscolithus* sp., Sample 117-728A-9H-3, 118 cm; 4 = phase contrast. **5–6,** *Discoaster brouweri*, Sample 117-728A-9H-3, 118 cm; 5 = transmitted light, 6 = phase contrast. **7–8,** *Discoaster pentaradiatus*, Sample 117-730A-9H-3, 118 cm; 7 = transmitted light, 8 = phase contrast. **9–10,** *Discoaster surculus*, Sample 117-726A-10X-1, 118 cm; 9 = transmitted light, 10 = phase contrast. All scale bars are equal to 5 μm.

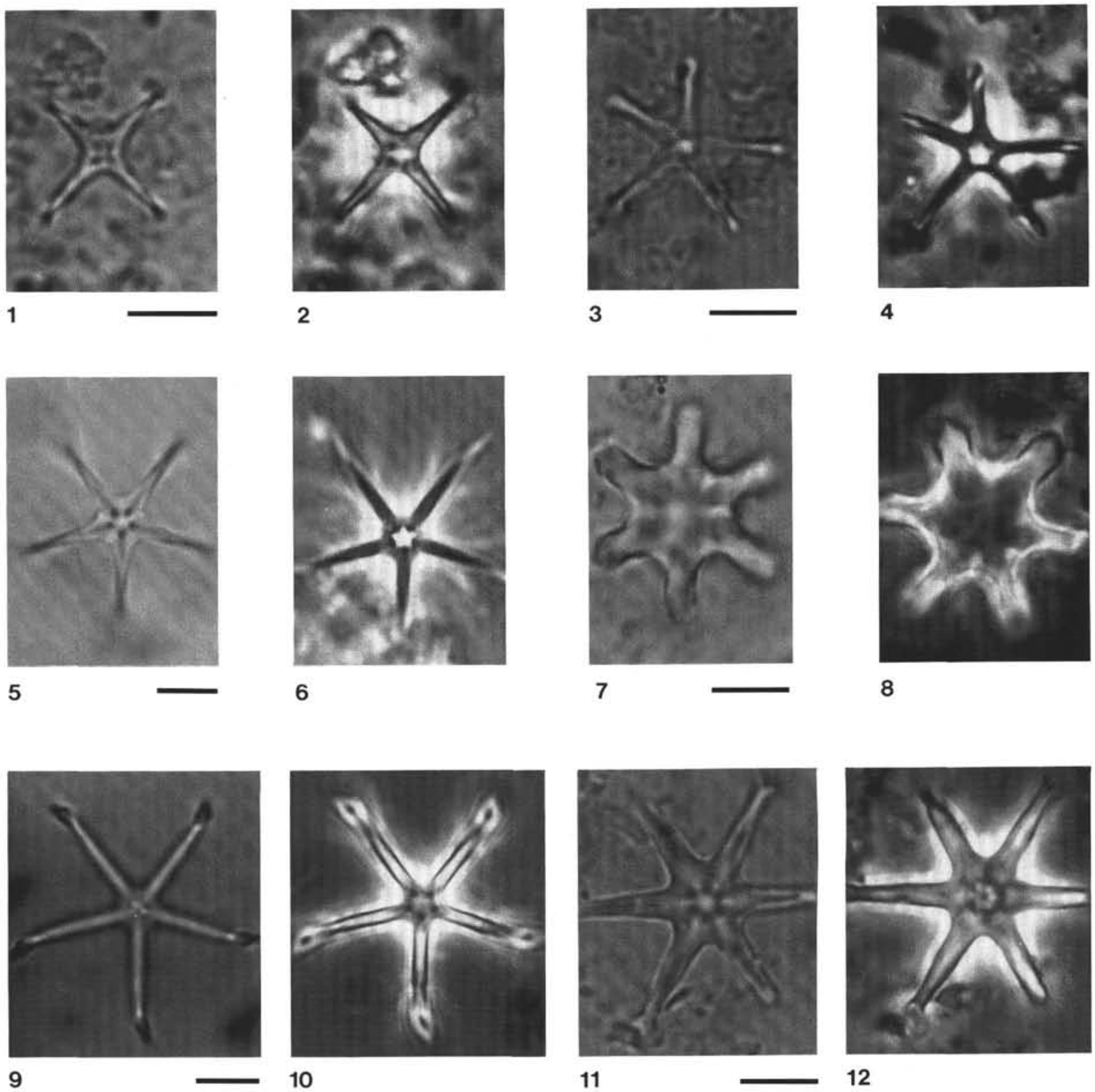

Plate 4. **1–2,** *Discoaster tamalis*, Sample 117-728A-9H-3, 118 cm; 1 = transmitted light, 2 = phase contrast. **3–4,** *Discoaster asymmetricus*, Sample 117-728A-9H-3, 118 cm; 3 = transmitted light, 4 = phase contrast. **5–6,** *Discoaster quinqueramus*, Sample 117-728A-27X-3, 118 cm; 5 = transmitted light, 6 = phase contrast. **7–8,** *Discoaster kugleri*, Sample 117-730A-19X-5, 105 cm; 7 = transmitted light, 8 = phase contrast. **9–10,** *Discoaster hamatus*, Sample 117-730A-6X-1, 105 cm; 9 = transmitted light, 10 = phase contrast. **11–12,** *Discoaster exilis*, Sample 117-730A-20X-3, 105 cm; 11 = transmitted light; 12 = phase contrast. All scale bars are equal to 5 μm.

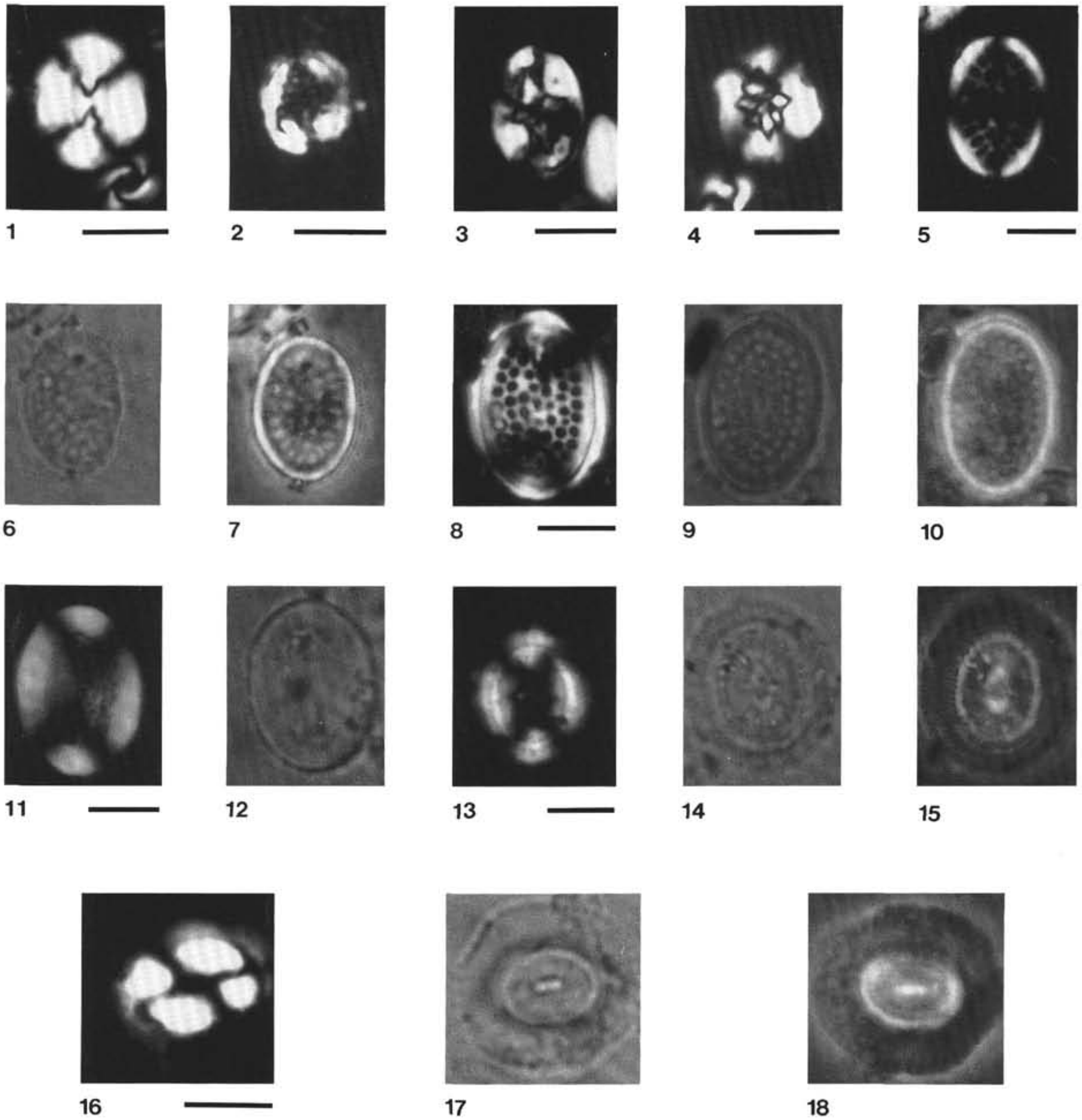

Plate 5. **1–4,** Reworked Late Cretaceous nannofossils; 1 = *Watznaueria barnesae*, Sample 117-727A-1H-1, 118 cm, 2 = *Cribrosphaerella ehrenbergii*, Sample 117-725C-14X-3, 118 cm, 3 = *Eiffelithus eximius*, Sample 117-723A-1H-5, 60 cm, 4 = *Cretarhabdus angustiforata*, Sample 117-726A-10X-1, 118 cm. **5–7,** *Pontosphaera indooceanica*, Sample 117-727A-1H-1, 118 cm; 5 = crossed nicols, 6 = transmitted light, 7 = phase contrast. **8–10,** *Pontosphaera* sp. A, Sample 117-727A-1H-1, 118 cm; 8 = crossed nicols, 9 = transmitted light, 10 = phase contrast. **11–12,** *Pontosphaera* sp C., Sample 117-727A-19X-1, 118 cm; 11 = crossed nicols, 12 = transmitted light; **13–15,** *Coccolithus crassipons*, Sample 117-727A-19X-1, 118 cm; 13 = crossed nicols, 14 = transmitted light, 15 = phase contrast. **16–18,** *Coccolithus pelagicus*, Sample 117-727A-19X-3, 118 cm; 16 = crossed nicols, 17 = transmitted light, 18 = phase contrast. All scale bars are equal to 5 μm.