41. CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY, LEG 64[1]

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ABSTRACT

To investigate the sedimentology and the spreading history of the Gulf of California, holes were drilled in two different areas of the Gulf (Fig. 1). In most holes, calcareous nannofossils could be used to establish stratigraphy.

To date the oldest sediments on continental and oceanic crusts, three sites were drilled off the tip of southern Baja California on an east-west transect from young oceanic crust (Site 474) to continental crust (Sites 475 and 476). A thick Pleistocene and upper Pliocene nannofossil-rich sedimentary sequence overlying basalt flows and sills was penetrated at Site 474. Pleistocene and Pliocene hemipelagic muds were recovered at Sites 475 and 476. At these sites, calcareous nannofossils indicate an earliest Pliocene age (between 5 and 4.6 Ma) for the oldest fossiliferous sediments found above the continental crust and reveal a major hiatus, corresponding to most of late Pliocene time.

Five sites were drilled in the Guaymas Basin to investigate the sedimentology, paleoceanography, and biostratigraphy of an active spreading basin and the formation of oceanic crust. Sites 477 and 478 were located in the south rift and Site 481 in the north rift. Over 300 meters of upper Pleistocene diatom oozes and turbidites with abundant and well-preserved coccoliths were recovered at Sites 478 and 481. At Site 477, most of the sedimentary sequence had been hydrothermally altered and only 50 meters of upper Pleistocene sediments were fossiliferous.

Sites 479 and 480 were drilled on the Guaymas Basin slope, an oxygen-minimum zone. Calcareous nannofossils were rare and poorly preserved in the hemipelagic, muddy, diatomaceous oozes penetrated at both sites. Because of sampling restrictions, Site 480 could not be studied.

INTRODUCTION

Calcareous nannofossils were studied mainly to make biostratigraphic age determinations. Primarily classical light microscope techniques were used, but selected samples were studied with the scanning electron microscope for complementary data, in particular the distribution of the marker species *Emiliania huxleyi*.

Zonation used is given in Table 1. The upper Cenozoic zones represented and their estimated time relations are given in Table 2. Estimated ages of the calcareous nannofossil datum levels are those proposed by Berggren et al. (1980), Haq and Berggren (1978), Gartner (1977), Thierstein et al. (1977) and Bukry (1975). Tables 3-12 contain the species distribution for each site studied.

CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY

The zonation used here (Table 1) combines zonations proposed by Martini (1971, 1976), Bukry (1973a, b; 1975), and Gartner (1977). The datum levels which have been recognized are those defined by Gartner (1977) and Thierstein et al. (1977) for the Pleistocene and by Bukry (1973) and Haq (in Haq and Berggren, 1978) for the late Neogene. Recognition of the zones and datum levels has been restricted in instances where dissolution has affected Pleistocene sediments, as in the Guaymas Basin, or where reworking has been intensive, as in the Pleistocene turbidites recovered at the mouth of the Gulf.

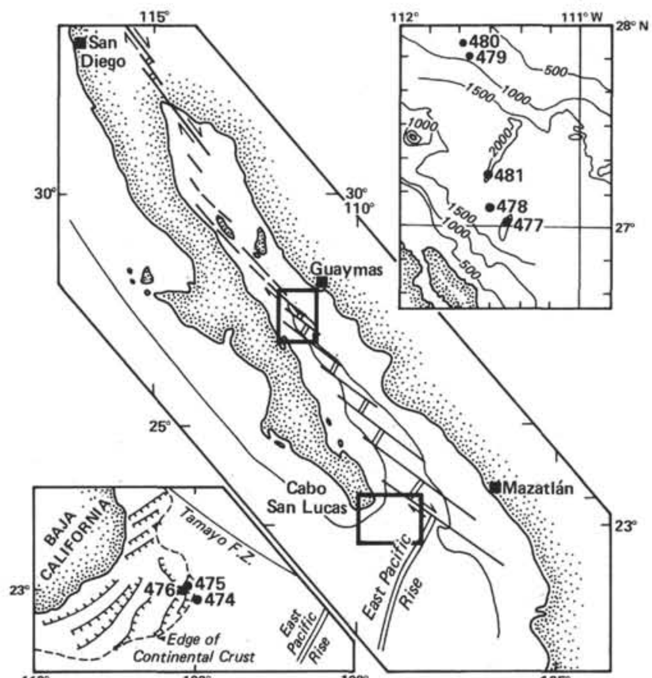

Figure 1. Location of Leg 64 sites.

Thus Zones NN20 and NN21 have been combined in situations where the downhole disappearance of *E. huxleyi* may have resulted from dissolution. In an attempt to recognize datum levels despite strong reworking in turbiditic sequences, numerous samples were taken at close intervals. Discontinuous distribution of the species, sharp

[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

Table 1. Correlation chart and biostratigraphic events used for age assignment at Leg 64 sites.

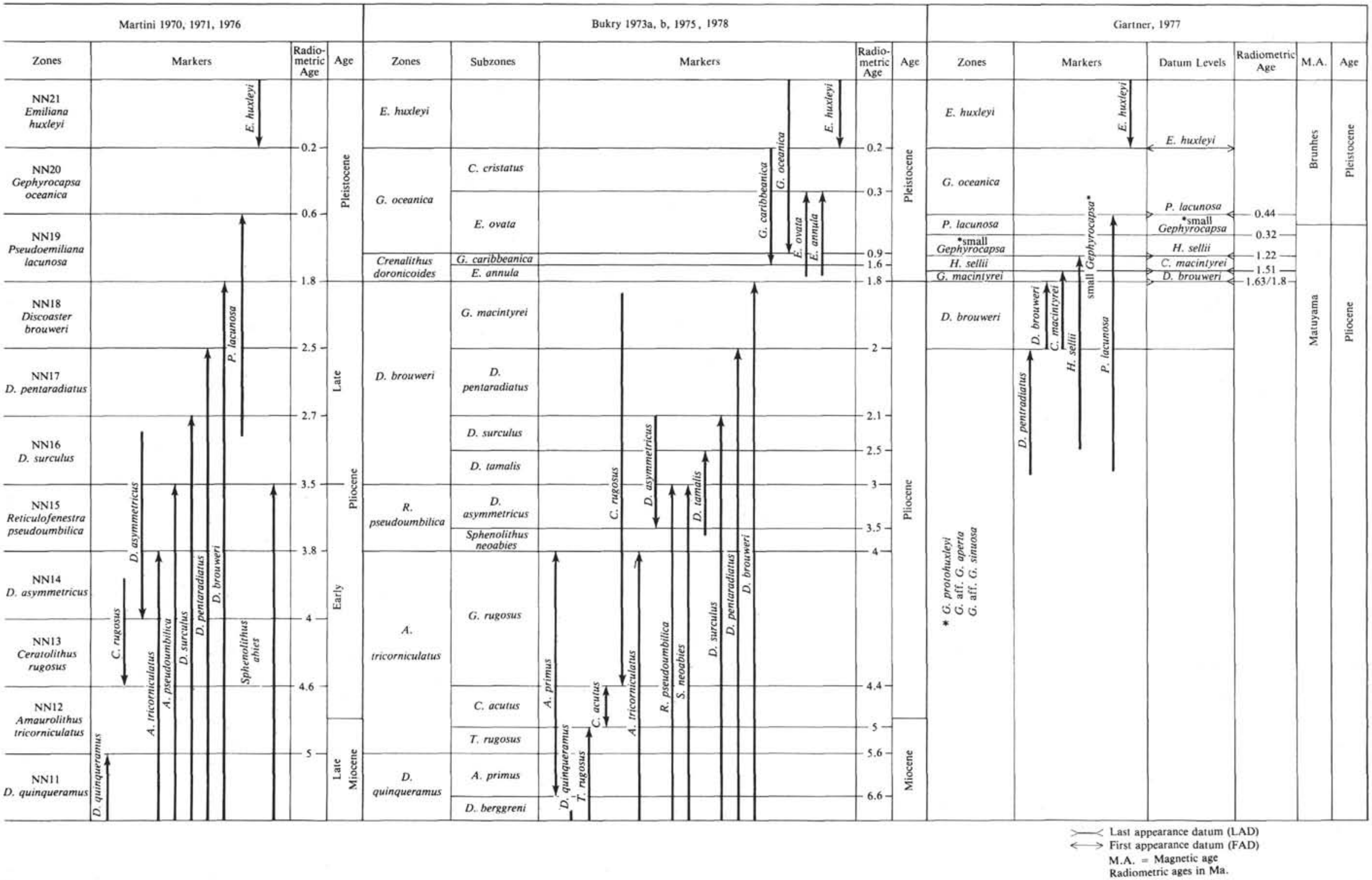

Table 1. (Continued).

Haq and Berggren, 1978: Zones	Markers	Datum Levels	Radiometric Age	M.A.	Age	Thierstein et al., 1977: Datum Levels	O_2 Age	Age	This Paper: Zones	Subzones	Datum Levels	Radiometric Age	Age
								Late Pleistocene	E. huxleyi (NN21)				Pleistocene
						E. huxleyi	0.268				E. huxleyi	0.27	
									G. oceanica (NN20)				
						P. lacunosa	0.458				P. lacunosa	0.458	
									P. lacunosa (NN19)	H. sellii	H. sellii	1.22	
										C. macintyrei	C. macintyrei	1.51	
		D. brouweri	1.65								D. brouweri	1.7	
D. brouweri				Matuyama	Late				D. brouweri (NN18)				Late
		D. pentaradiatus	2.2								D. pentaradiatus	2.2	
D. pentaradiatus									D. pentaradiatus (NN17)				
		D. surculus	2.3								D. surculus	2.3	
D. surculus				Gauss					D. surculus (NN16)	D. tamalis	D. tamalis	2.5	
		R. umbilica	3.2		Pliocene						R. pseudoumbilica	3.2	Pliocene
D. asymmetricus	D. asymmetricus; R. pseudoumbilica; S. abies			Gilbert	Early				R. pseudoumbilica (NN15)				Early
		Amaurolithus spp.	3.6								Amaurolithus spp.	3.6	
									D. asymmetricus (NN14)				
		D. asymmetricus	3.7								D. asymmetricus	3.7	
C. rugosus	C. rugosus								C. rugosus (NN13)				
		C. rugosus	4.6								C. rugosus	4.6	
C. acutus	A. primus; C. acutus								C. acutus				
		C. acutus	5								C. acutus	5	
A. delicatus	A. delicatus			Epoch 5	Late Miocene				A. tricorniculatus (NN12)				Miocene
		A. delicatus / A. primus	5.4										
D. quinqueramus													

Table 2. Zonal assignment and age of cores and sections based on calcareous nannofossils.

Zones	Subzones	Datum Levels	Age in Ma	Age		Core/Section (interval in cm) Hole 474	Hole 474A	Hole 475	Hole 476	Hole 477	Hole 478	Hole 479	Hole 481
E. huxleyi (NN21)				Pleistocene	late	1-1 to 16-1, 15-16		1-1 to 3-2	1-1 to 3-6	1-1 to 7-2	1-1 to 33-3	1-1 to 28-4	P2 to P30
		E. huxleyi	0.27										
G. oceanica (NN20)											33-5 to 40,CC		
		P. lacunosa	0.46										
P. lacunosa (NN19)					early	16-1, 37-38 to 13-2	1 to 23-2	3-3 to 7-6	4-1 to 7-2			? 40-2 to 47-6 ?	
		H. sellii	1.22										
	H. sellii						23-3 to 25-1		7-3 to 8-3				
		C. macintyrei	1.51										
	C. macintyrei						25-2 to 28		9-3 to 10-4				
		D. brouweri	1.7										
D. brouweri (NN18)				Pliocene	late		29 to 34	8-1 to 8-5	10-5 to 11-2				
		D. pentaradiatus	2.2										
D. pentaradiatus (NN17)							35-1 to 35-3	8-6 to 9-3	11-3 to 11-7				
		D. surculus	2.3										
D. surculus (NN16)							35-4 to 45	9-4 to 11-3	12-1 to 12-6				
		D. tamalis	2.5										
	D. tamalis							11-4 to 14-7	13-1 to 16-2				
		R. pseudoumbilica	3.2										
R. pseudoumbilica (NN15)					early			15-1 to 15-2	16-3 to 17-1				
		Amaurolithus spp.	3.6										
D. asymmetricus (NN14)													
		D. asymmetricus	3.7										
C. rugosus (NN13)													
		C. rugosus	4.6										
A. tricorniculatus (NN12)	*C. acutus*							15-3 to 17-2	17-3 to 21-2				
		C. acutus	5										
				Miocene									

>——< Last Appearance Datum

<——> First Appearance Datum

variations in their abundances, and differential degrees of preservation have been considered as evidence of reworking.

Site 474 (Holes 474 and 474A)

Holes 474 and 474A were drilled off the tip of southern Baja California in a water depth of 3023 meters. A thin section of late Pleistocene age was recovered, followed by a 360-meter-thick section of early Pleistocene age and a 40-meter-thick section of late Pliocene age. Although the frequency and the preservation of the nannofossils in the assemblages of these sediments are variable, a good biostratigraphic assignment was possible (Table 3; Table 4, back pocket, this volume, Pt. 2).

Pleistocene

Core 474-1 through Section 474-14-1 is assigned to the late Pleistocene Zones NN20–NN21. The presence of *Pseudoemiliania lacunosa* in Cores 474-6 to 474-8 indicates, however, an early Pleistocene age for these three cores, perhaps corresponding to a slump. The presence of the same species, *P. lacunosa*, in Cores 474-16 through 474A-28 indicates an early Pleistocene age. The *Helicosphaera sellii* Subzone was recovered from Sample 474A-23-3, 122–123 cm to Sample 474A-25-1, 16–17 cm, and the *Cyclococcolithus macintyrei* Subzone from this last sample to Sample 474A-28-4, 48–49. The intense reworking in these lower Pleistocene sediments is indicated by the presence of allochthonous species such as *Discoaster brouweri*, but even more conspicuously by the frequent mixing of well- and very poorly preserved coccoliths. The common species are *P. lacunosa, H. carteri, H. neogranulata, Pontosphaera* spp., *Gephyrocapsa caribbeanica, G. oceanica* (abundant in the upper part of the sequence), *Coccolithus pelagicus* and *Cyclococcolithus leptoporus*. The frequency of the helicosphaerids and pontosphaerids indicates a nearshore environment.

Pliocene

The Pliocene/Pleistocene boundary is placed between Cores 474A-28 and 474A-29, at a level below which *Discoaster brouweri* becomes abundant and occurs continuously. The late Pliocene assemblages are moderately rich and abundant. *Discoaster* spp., *Coccolithus pelagicus, Reticulofenestra haqii, Syracosphaera histrica, Cyclococcolithus leptoporus, Helicosphaera carteri, H. sellii*, and *C. macintyrei* are the most common—and also the most dissolution-resistant—forms. However, at some levels, least solution-resistant species such as *Braarudosphaera bigelowii* have been preserved (Samples 474A-31-6, 30–31; 474A-29-3, 15–16). Cores 474A-29–34 are assigned to the *D. brouweri* Zone NN18; Sections 474A-35-1 to 474A-35-3 to the *D. pentaradiatus* Zone, NN17; Sections 474A-35-4 to Core 474A-41 to the *D. surculus* Zone, NN16. Small *R.* cf. *R. pseudoumbilica* occur in Samples 474A-35-2, 99–100 cm, 474A-37-4, 50–51 cm, 474A-41-1, 28–29 cm, 474A-41-5, 28–29 cm, and 474A-45 (Pieces 1A, 1B). Typical *R. pseudoumbilica* was found in a single sample—474A-40-3, 110–111 cm—where it is common but very etched, and is therefore considered to be reworked. *Sphenolithus abies* is present in Samples 474A-41-1, 28–29 cm, 474A-40-3, 110–111 cm, and 474A-35-4, 28–29 cm, and *S. neoabies* in Section 474A-45-1, and Sample 474A-40-3, 110–111 cm. It is uncertain if they are reworked.

Site 475 (Holes 475, 475A, and 475B)

All sediments recovered at Site 475, where three holes were drilled off the tip of southern Baja California in a water depth of approximately 2600 meters, yielded common calcareous nannofossils in various states of preservation and of moderate to high diversity. A complete sequence was identified, from the late Pleistocene Zone NN21 to the early Pliocene Zone NN15. Most of the early Pleistocene is missing. The oldest sediments recovered are earliest Pliocene in age. Because of reworking, the zonal boundaries were, however, difficult to establish. Mixing of well- and poorly preserved nannofossils, discontinuous occurrences of the marker species, and finds of extinct species all constitute evidence of reworking.

Pleistocene (Table 5)

Cores 475-1 and 475-2 and Section 475-3-1 are assigned to Zones NN20–NN21. Gephyrocapsids are dominant. *Coccolithus pelagicus, Helicosphaera carteri, Syracosphaera histrica, Rhabdosphaera clavigera, Ceratolithus cristatus,* and *Pontosphaera* spp. are frequent. The least dissolution-resistant species were not found. *Pseudoemiliania lacunosa* was found in Sample 475-2-1, 70–71 cm, where it is considered to be reworked. *Discoaster brouweri* is present in Samples 475-3-1, 28–29 cm, 475-3-2, 91–92 cm, and 475-2-5, 78–79 cm, where it is obviously reworked. The sediments from Section 475-3-2 to Core 475-7 are assigned to the *P. lacunosa* Zone NN19. *P. lacunosa* occurs abundantly with *Gephyrocapsa* spp. Discoasters are rare. *H. sellii* was found as high as Sample 475-3-7, 39–40 cm, and *Cyclococcolithus macintyrei* as high as Sample 475-5-2, 100–101. Because these two species occur discontinuously and are scarce, and also because of the generally poor preservation of the assemblages in this sequence, the last appearance datums (LAD) of these two markers were not used for zonation. In these lower Pleistocene sediments, *C. macintyrei* is unusually smaller than in the Pliocene sediments and it shows many affinities with *C. leptoporus*. *Coccolithus pelagicus* is frequent but never abundant. *H. carteri, R. clavigera, Pontosphaera* spp., and *Cyclococcolithus leptoporus* are common. The frequency of species belonging to the genera *Pontosphaera, Helicosphaera*, and *Scyphosphaera* indicates shallow waters. The diversity of the assemblages tends to decrease toward the base of the zone, and only solution-resistant species are left (Core 475-7).

Pliocene (Table 6)

Cores 475-8 to 475-14 are late Pliocene in age, Cores 475-15 to 475-17 early Pliocene. The Pliocene/Pleistocene boundary occurs at the top of Core 8. Sample 475-8-1, 19–20 cm contrasts sharply with Sample 475-7-6, 25–26 cm by both criteria: the sudden occurrence in the

Table 3. Hole 474 calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Cyclolithella annula*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp.	*Helicosphaera neogranulata*	*Pseudoemiliania lacunosa*	*Cyclococcolithus leptoporus*	*H. carteri*	*Pontosphaera discopora*	*Scyphosphaera apsteini*	*Syracosphaera histrica*	*Umbilicosphaera mirabilis*	*H. wallichii*	*Rhabdosphaera clavigera*	*Coccolithus pelagicus*	*Sphenolithus* sp.	*Angulolithina arca*	*Pontosphaera scutellum*	*Syracosphaera pulchra*	*Ceratolithus cristatus*	*Cricolithus jonesi*	*H. sellii*	*Ceratolithus simplex*	*Braarudosphaera bigelowi*	*Discoaster brouweri*	*C. rugosus*	*H. inversa*	*D. asymmetricus*	*Emiliania huxleyi*	Zone	Age	Datum Levels	Time (m.y.)
1-1, 10	A	M/P			VA	A			R	R						R		R		R	R	R									R	NN21			
1-1, 100	A	M/P			VA	A			R	R						R	R														R				
1-2, 52	A	M/P			VA	A			R								R					R									R				
2-1, 50-51	A	M			VA	VA			R	R	R											R									R				
2-2, 4-5	R	M			R	R			R							R						R									R				
2-2, 44-45	A	M/P			VA	A			R	R																						NN20			
2-2, 48-49	A	M/G			VA	A			R	R	R				R	R																			
2-3, 5-6	A	G			VA	A			R	R																									
2-3, 101-102	A	G/M			VA	A																													
2-4, 4-5	A	M/G			VA	A			R	R	R	R	R			R	R					R													
3-1, 39-40	A	G/M			VA	A			R	R					R	R	R																		
3-2, 3-4	A	M/P			VA	A			R	R	R						R					R													
3-2, 95-96	C	M			VA	A				R							R					R													
3-3, 21-22	A	M			VA	A			R	R								R				R													
3-3, 121-122	A	P/M			VA	A			R	R												R								R					
4-2, 75-76	A	M/G	H		VA	A			R	R	R						R					R													
4-3, 76-75	C	G		R	A	A		R	R	R							R																		
4-3, 125-126	C	P/M			A	A		R	R	R	R																R					(slump) NN19			
5-1, 34-35	A	M			A	A		R	R	R			R	R	R	R	R			R		R													
5-3, 71-72	A	M/P			VA	VA			R	R																									
5-4, 72-73	C	G			A	A			R	R	R		R	R																					
5-4, 108-109	C	M			A	A			R	R	R		R	R																					
6-1, 66-67	C	M			A	A		R						R			R		R																
6-2, 66-67	A	M			VA	VA		R	R	R	R						R					R							R						
6-3, 14-15	A	M			VA	VA		R	R	C	R			R			VA				R	R													
6-4, 8-9	A	M			VA	A		R	R	B	R						R																		
6-5, 50-51	C	G		R	A	A		R		R				R		C																			
6-5, 106-107	R	G				R																													
6-6, 72-73	C	G/M			A	A			R	R									R																<0.458
6-6, 81-82	R	M		R	A	R	R	R																											
6-6, 103-106	A	M			VA	VA		R	R																										
7-1, 83-86	C	G/M		R	A	A		R	R		R		R																						
7-2, 89-90	R	M/P				R			R																				R						
7-3, 9-10	A	G			A	A		C	R	A	R		R	R		C		R					R			R									
7-3, 97-98	A	M			A	A		C	R	A	R		R	R		C		R					R			R									
7-4, 89-90	C	G/M			A	A		C	R	A	R		R	R		C		R					R			R							late Pleistocene		
7-5, 6-7	C	G			VA	VA		C		R						R	R																		
7-5, 59-60	R	P	L		C	C			R					R																					
7-5, 119-120	A	P/G			VA	VA		R	R	R							R																		
7-6, 16-17	A	P/G			VA	VA		R	R	R	R		R			R	R					R		R			R								
7-6, 55-56	C	G/M			A	A	R	R		R																									
7-6, 120-121	A	G		R	VA	VA	R	R	R	C				R				R		R		R	R			R		R							
7-6, 143-144	A	G		R	VA	VA	R	R	R	C				R		R		R		R		R	R			R									
8-1, 32-33	C	G/P					R	R	R	R	R		R			R	R					R		R	R										
8-5, 86-87	A	M			VA	VA	R	R		R							R		R																
8-6, 78-79	C	M			VA	VA		R	R	R	R				R		R	R				R										NN20			
11-3, 11-12	C	M/P		R	VA	VA			R	R				R				R				R					R								
11-6, 68-69	A	G/M			VA	VA			R	R					R		R																		
12-1, 22-23	C	G/M			A	A			R	R																	R								
13-1, 17-18	C	G			A	VA			R				R		R		R								R										
13-1, 66-67	A	G/M			A	VA		R	R	R	R		R		R		R					R			R	R									
13-1, 97-98	A	G/M			VA	VA	R		R	R			R			R						R		R	R	R									
13-1, 141-142	A	G/M			VA	VA			R	R			R		R	R	R	R						R											
14-1, 3-4	A	G/M			VA	VA			R	R																									
14-3, 2-3	R	M				C			R																										
14-4, 1-2	C	G	M		A	A				R			R				R	C																	
16-1, 15-16	A	G/M		R	VA	VA	R		R	R				R			R	C						R	R									*P. lacunosa*	
16-1, 37-38	C	G		R	A	A		C	R					R			R						R	R								NN19			
16-2, 23-24	C	G			A	A		R																											
16-2, 122-123	C	G			A	A	R	R	R	C		R					R																		
16-3, 73-74	A	G			VA	A		R	R	R			R	R			R	R																	
17-1, 82-83	C	P			C	A	R	R																											
17-2, 80-81	A	G			C	VA	R	R	R	R												R	R												
17-5, 73-74	A	G/M		R	A	VA		R	R	C	R					R		R		R	R														
17-6, 35-36	R	G/M				R	R	R	R					R				R																	>0.458–<1.22
17-7, 14-15	C	G			R	A	R	R																											
18-1, 49-50	C	G			R	VA		R	R									R	R																
18-1, 138-139	C	M				VA		R	R								R																		
18-2, 119-120	C	G				VA	R	R	R					R	R																				
18-3, 29-30	A	G		R	R	VA	R	R	R	R	R		R	R	R	R																			
19-1, 136-130	A	C/M				A	R		R	A	R	R	R	R																					
19-2, 80-81	A	M/P		R	C	A	R	R																											

Note: Symbols used in Tables 3-12 are, for *abundance*, VA = very abundant (numerous specimens in a single field of view), A = abundant (at least one specimen in a single field of view), C = common (at least one specimen in 10-20 fields of view), R = rare (one specimen in >20 fields of view); for *diversity*, LL = very low, L = low, M = moderate, H = high; for *preservation*, G = good, M = moderate, P = poor. G/M, etc. = good to moderate, etc.

former of abundant and well-preserved *Discoaster brouweri*, and the abundance and preservation of calcareous nannofossil assemblages in both samples. *Helicosphaera sellii* and *Cyclococcolithus macintyrei* also become abundant. *D. pentaradiatus* was first found in Sample 475-8-6, 4-5 cm, *D. surculus* in Sample 475-9-4, 34-35 cm. A single individual of this species in Sample 475-8-5, 101-102 cm is considered to be reworked. Thus Sections 475-8-1 to 475-8-5 are assigned to the *D. brouweri* Zone, NN18, Sections 475-8-6 and 475-9-1 to 475-9-8 to the *D. pentaradiatus* Zone, NN17. As at Site 474, small *Reticulofenestra* showing strong affinities with *R. pseudoumbilica* were found in Samples 475-11-3, 36-37 cm, 475-13-1, 34-35 cm, 475-13-2, 34-35 cm, and 475-13-4, 34-35 cm. Typical *R. pseudoumbilica*, however, first occurs at the top of Core 475-15 (Sample 475-15-1, 65-66 cm). Thus Cores 475-11 through 475-14 are assigned to the *D. surculus* Zone (NN16). *Sphenolithus abies* and *S. neoabies* occur in Core 475-14, above the extinction level of *R. pseudoumbilica*. A few individuals of *S. neoabies* were also found in Sample 475-13-2, 34-35 cm, where they are probably reworked. The LAD of *S. abies*

Table 5. Hole 475 Pleistocene calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Ceratolithus simplex*	*Cyclococcolithus macintyrei*	*Coccolithus pelagicus*	*Cricolithus jonesi*	*Cyclococcolithus leptoporus*	*Gephyrocapsa* spp.	*Helicosphaera carteri*	*H. neogranulata*	*H. wallichii*	*Pontosphaera discopora*	*Pseudoemiliania lacunosa*	*G. oceanica*	*Rhabdosphaera clavigera*	*Cyclolithella annula*	*Pontosphaera scutellum*	*Sphenolithus* spp.
1-2, 100-101	C	G	H			R		R	C	R		R			R	VA			
2-1, 70-71	C	G	H			R			C	R		R		R	R	VA			
2-2, 75-76	C	G	H			R		R	C	R						VA			
2-3, 70-71	R	M/P	M					R	R	R		R			R	R			
2-4, 23-26	A	G	H					R	C			R	R		R	VA			
2-5, 78-79	A	G	H					R	C	R		R				VA		R	R
2-6, 80-81	A	M/P	H					R	VA	C			R		R	VA	R		
2-7, 18-19	A	G/M	H			R		R	A	R			R		R	A	R		
3-1, 28-29	A	M	H					R	A	R			R		R	A	R		
3-2, 92-93	A	G	H			R		R	VA	C		R		R	A	C	R	R	R
3-3, 70-71	A	G	M			C			A	R				C		R		R	
3-4, 58-59	R	P	vP					R	R							R			
3-5, 50-51	A	G	H	R		R	R	R	A	R		R	C	R		C			
3-5, 53-54	A	M/P	M					R	VA	R				C		R	R		
3-7, 39-40	A	G	R	R		R		R	VA	R		R			R	VA	R	R	
4-1, 69-70	A	G	H			R		R	A	R			R	R	R	A			
4-3, 70-71	A	G	H	R				R	C					R	R	A	R		R
4-3, 84-85	A	G	H					R	VA	C		R	R	R	R	R	R		
4-4, 30-31	A	G	H	R					VA	A	R		R	R	R	R	R		R
4-5, 81-82	R	P/M	M	R				R	VA		R		R	R		R		R	
5-1, 100-101	A	G	H		R	R		R	VA	C	R		R	R	R	R	R		R
5-2, 100-101	A	G	H			R		R	VA	A		R	R	R		R	R	R	R
5-3, 100-101	A	M	M		R			R	VA	R	R		R	R	R	R	R		
5-4, 100-101	C	M/P	M			R		R	A				R	R		R		R	
5-5, 96-97	C	M	L					R	VA			R		R			R		
6-1, 63-66	R	P	vL	R				R	R	R			R	R					
6-2, 42-43	R	P	L	R				R	R	R			R	R			R		
6-3, 42-43	R	M/P	M			R		R	A	R	R		R	C	R		R		
6-4, 43-44	A	M	M			R		R	VA	C	R	R	R	R	R				R
6-5, 19-20	A	G/M	M		R			R	R	R			R		R			R	R
6-6, 100-101	R	M	L		R	R		A	R		R			R					
7-1, 52-53	R	G	vL			R			R	R									
7-2, 55-56	C	P	M	R		R		R	R	R		R	R	R	R				
7-3, 101-102	R	G/P	M			R		R	R	R			R	R			R	R	
7-4, 88-89	A	G/P	M			R		R	R					R		R			
7-5, 26-27	C	G/M	M	R	R	R		R	R	R	R		R	R					
7-6, 25-26	R	G/P	M	R	R	R	R	R	R	R	R	R	R	R	R				

Core/Section (interval in cm)	*Syracosphaera histrica*	*H. sellii*	*Braarudosphaera bigelowii*	*Scyphosphaera* sp. cf. *S. amphora*	*H.* cf. *H. hyalina*	*S.* sp. cf. *S. coheni*	*S. apsteini*	*Umbilicosphaera mirabilis*	*Ceratolithus cristatus*	*Helicosphaera columbiana*	*Micrascidites* sp.	*Ceratolithus telesmus*	*H. inversa*	*Scapholithus fossilis*	*Discoaster brouweri* (reworked)	*Syracosphaera pulchra*	*Emiliana huxleyi*	Zone	Subzone	Age	Datum Levels	Time (m.y.)
1-2, 100-101		R							R								R					
2-1, 70-71									R				R				R					
2-2, 75-76		R							R				R			R						
2-3, 70-71									R													
2-4, 23-26		R							R							R	R	NN20/ NN21		late Pleistocene		
2-5, 78-79		R						R					R		R							
2-6, 80-81		R						R	R				R									
2-7, 18-19		R							R							R						
3-1, 28-29	R	R							R				R		R						*P. lacunosa*	
3-2, 92-93	R	R											R	R	R	R						0.45
3-3, 70-71	R						R															
3-4, 58-59								R														
3-5, 50-51		R						R		R				R								
3-5, 53-54								R	R													
3-7, 39-40	R		R					R											?			1.22?
4-1, 69-70	R	R										R	R									
4-3, 70-71		R						R	R										*H. sellii*			
4-3, 84-85			R						R				R									
4-4, 30-31		R					R		R													
4-5, 81-82																						
5-1, 100-101		R	R				R		R			R							?			1.51?
5-2, 100-101	R	R					R		R	R	R											
5-3, 100-101	R	R	R																			
5-4, 100-101								R										NN19		early Pleistocene		
5-5, 96-97	R	R																				
6-1, 63-66																						
6-2, 42-43	R						R															
6-3, 42-43					R	R																
6-4, 43-44		R	R	R															*C. macintyrei*			
6-5, 19-20	R																					
6-6, 100-101																						
7-1, 52-53																						
7-2, 55-56																						
7-3, 101-102																						
7-4, 88-89																						
7-5, 26-27																						
7-6, 25-26		R																				

Note: See Table 3 for explanation of symbols.

Table 6. Hole 475 Pliocene calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Amaurolithus delicatus*	*A. primus*	*Ceratolithus acutus*	*Cyclococcolithus leptoporus*	*C. macintyrei*	*Discoaster brouweri*	*D. brouweri recurvus*	*D. variabilis*	*D. pentaradiatus*	*Reticulofenestra pseudoumbilica*	*Sphenolithus neoabies*	*Coccolithus pelagicus*	*D. surculus*	*Ceratolithus armatus*	*Helicosphaera sellii*	*R. haqii*	*A. amplificus*	*H. carteri*	*Pontosphaera scutellum*	*A. bizzarus*	*S. abies*	*D. asymmetricus*	*Ceratolithus separatus*	*D. minutus*	*D. tamalis*	*Pseudoemiliania lacunosa*	*Syracosphaera histrica*	*Umbilicosphaera mirabilis*	*Pontosphaera discopora*	*Rhabdosphaera clavigera*	*Scyphosphaera campanula*	*S. apsteini*	Zones	Datum Levels	Age	Time (m.y.)
1-6																																				NN19	*D. brouweri*	Pleist.	1.7
8-1, 19-21	A	M/P					R	R	R	R					R			R			R	R					R												
8-2, 35-36	A	G					R	R	R	R					R			R	R		R						R		R										
8-3, 142-143	A	G					R	R	R						R				R		R										R					NN18			
8-4, 87-88	C	M/P						R	R						C			R			R						R												
8-5, 101-102	C	G					R	R	R	R					C	R		R	R		R						R										*D. pentaradiatus*		2.1
8-6, 4-5	C	M					R	R	R	R		R						R	R		R						R		R										
8-6, 18-19	C	M/G						R	R	R		R			R			R	R		R						R												
9-1, 38-39	R	G/M						R	R	R					R						R	R					R									NN17			
9-3, 66-67	R	P/M						R	R	R		R			R			R			R																*D. surculus*		2.3
9-4, 34-35	C	M					R	R	R	R		R			R	R		R	R		R																		
9-4, 56-57	C	M						R	R	R		R			R	R		R	R		R						R												
9-4, 133-134	R	M/G						R	R	R					R	R		R				R				R													
10-1, 6-7	C	M/P					R	R	R	R		R			R	R		R	R								R			R									
11-1, 50-51	A	G					R	R	R	R		R				R		R	A			R			R				R	R	R								
11-2, 61-62	A	G/M						R	R	R		R				R			R								R			R								late Pliocene	
11-3, 36-37	C	M					R	R	R	R		R	(R)		R	R		R	R		R	R			R	R				R				R			*D. tamalis*		2.5
11-4, 40-41	C	G						R	R			R			R	R		R	R		R	R			R		R	R		R									
11-5, 50-51	A	G/M						R	R	R		R			R	R		R	R		R						R			R									
11-6, 34-35	C	M						R	R	R	R	R			R	R		R	R		R	R			R		R	R		R									
12-1, 61-62	C	M					R	A	R	R	R	R			R	R			R		R	R					R	R								NN16			
12-2, 32-33	A	G							R			R			R	R		R	R		R	R				R	R	R		R									
12-3, 43-44	A	G					R	C	R	R	R	R				R		R	R		R	R			R		R	R		R									
12-4, 29-30	A	G	High				R	R	R	R		R			R	R		R	R		R	R							R	R	R								
12-5, 18-19	A	P/G					R	R	R	R		A			R	R			R		R	R			R		R	R				R	R						
13-1, 34-35	A	G						R	R			R	(R)			R		R			R	R			R	R	R	R											
13-2, 34-35	C	P/M					R	R	R			R	(R)	(R)	R	R		R	R		R	R				R	R	R	R	R	R								
13-3, 75-76	A	M/P						R	R	R		A			R	R		R	R		R	R				R	R		R	R	R								
13-4, 44-45	A	G/M						R	R	R	R	R	(R)					R	R		R	R			R	R	R	R											
14-1, 11-12	R	P						R	R	R		R		R	R	R									R		R												
14-2, 49-50	C	P/M						C	R	R		R		C		R					R				R	R			R	R	R								
14-6, 146-150	P	M						R	R	R		R		R	R	R		R			R			R	R		R												
14-7, 2-3	C	M/G						R	R	R		R		R	R	R		R	R			R		R	R				R	R	R						*R. pseudoumbilica*		3.2
15-1, 65-66	R	P/M						R	R	R		R	R	R	R		R		R		R			R	R	R	R												
15-1, 81-82	R	G						R	R	R	R	R	R	R		R			R						R	R	R												
15-2, 30-31	C	M						R	R			R	R	R	R	R		R			R	R			R											NN15			
15-2, 72-73	R	P				(R)		R	R				R				R								R														
15-3, 77-78	C	G/P		R		R		R	R	R		R	C		R	R	R		R		R																		4.6
15-4, 103-104	C	G/P				R	R		R	R		R	R		R		R	R	R							R	R												
15-5, 26-27	R	G/P		R	R	R		R	R	R		R	R	R	R		R				R					R													
15-6, 43-44	C	G/M			R	R	R	R	R	R		R	R	R	R	R	R	R	R					R		R												early Pliocene	
16-1, 48-49	A	G/M			R	R		R	R	R	R	R	R	R	R	R	R				R		R			R									R				
16-2, 47-48	C	G/M	Moderate		R	R	R	R	R	R		R	R	R		R				R	R	R				(R)										*C. acutus*			
16-3, 47-48	C	G/M				R		R	R			R	R	R	R	R		R																					
16-4, 46-47	C	M/P			R	R	R	R	R			R	R	R	R	R	R	R	R																				
16-5, 47-48	R	G/M		R				R	R	R		R	R			R																							
16-6, 45-46	R	P							R																														
17-1, 66-67[a]	R	G/M		R		R	R		R	R	R	R	R	R	R	R																							
17-2, 76-77	R	G		R	R	R	R	R	R	R	R	R	R	R																						?			<5

Note: See Table 3 for explanation of symbols.
[a] Samples 475-17-3, 76-77 cm, 475-17-4, 26-27 cm, 475-17-4, 70-71 cm, 475-17-4, 108-109 cm were barren.

and S. neoabies are usually found below or near the LAD of *R. pseudoumbilica*. The distribution of this latter species may have been ecologically controlled. The late/early Pliocene boundary corresponds to the NN16–NN15 boundary and is placed at the top of Core 475-15. Sections 475-15-1 and 475-15-2 are assigned to the *R. pseudoumbilica* Zone (NN15). In the interval between Section 475-15-3 and 475-17-2, nannofossils are diluted by abundant diatoms. The discoasters become scarce and poorly preserved, showing broken and overgrown arms. The assemblages are impoverished, strongly affected by dissolution, and characterized by the presence of *Ceratolithus acutus*, which indicates an earliest Pliocene age. This also reveals a significant hiatus between Sections 475-15-3 and 475-15-4. Sections 475-17-3 and 475-17-4 were barren.

Site 476

Site 476 was drilled off the tip of southern Baja California in a water depth of 2403 meters. The sedimentary sequence penetrated at this site is very similar to that recovered at Site 475—the zonal assignment is similar and the same datum levels are recognized. The calcareous nannofossil assemblages show similar abundance, preservation, and species composition at both sites.

Pleistocene (Table 7)

Core 476-1 and Sections 476-3-1 to 4 are assigned to the *Emiliania huxleyi* Zone, Section 476-2-5 and Core 476-3 to the *Gephyrocapsa oceanica* Zone. These late Pleistocene sediments contain abundant, rich, and generally well preserved calcareous nannofossil assemblages with dominant *Gephyrocapsa* spp. and common *Cyclococcolithus leptoporus, Helicosphaera carteri, Coccolithus pelagicus, Ceratolithus cristatus*, and *Syracosphaera hystrica. Pseudoemiliania lacunosa* was found in Samples 476-2-3, 120–121 cm and 476-4-1, 71–72 cm, where it is reworked. This species, a common element of the assemblages from Section 476-4-5 through Core 476-10, indicates the lower Pliocene Zone NN19. *H. sellii* occurs constantly below Sample 476-7-2, 94–95 cm, and *C. macintyrei* below Sample 476-8-3, 33–35 cm. The two subzones proposed by Gartner (1977) are thus tentatively assigned to Sections 476-7-2 through 476-8-2, and from Section 476-8-3 through Core 476-10.

Pliocene (Table 8)

The Pliocene/Pleistocene boundary is not so sharply marked as it was at Site 475; it is placed between Samples 476-10-5, 82–83 cm and 476-11-1, 70–75 cm. In Sections 476-10-6 to 7, the assemblages progressively change, with an increasing abundance of *Discoaster brouweri, Helicosphaera sellii*, and typical *Cyclococcolithus macintyrei*. The distinction between Zones NN18 and NN17 is uncertain, since *D. pentaradiatus* is present in Sample 476-11-3, 74–75 cm, where it may be reworked, and occurs again in Core 476-12 with *D. surculus*. Core 476-12 through Section 476-16-2 is assigned to the *D. surculus* Zone, NN16. Typical *Reticulofenestra pseudoumbilica* was found in Sample 476-16-3, 58–59 cm, but smaller specimens were already present in Samples 476-12-2, 78–79 cm and 476-14-1, 45–46 cm. As at the previous site, *Sphenolithus abies* and *S. neoabies* were found above the LAD of *R. pseudoumbilica*. The late Pliocene/early Pliocene boundary is placed between Sections 476-16-2 and 476-16-3. Sections 476-16-3 and 476-17-1 are assigned to the *R. pseudoumbilica* Zone, NN15. Typical *Ceratolithus acutus* occurs from Section 476-17-3 through Section 476-21-2 and indicates an earliest Pliocene age for this interval. As at Site 475, a significant interval of time separates the sediments of Sections 476-17-3 and 476-17-1. Sections 476-21-3 and 476-21-4 were barren.

Site 477 (Holes 477, 477A, 477B; Table 9)

Site 477 was drilled in the south rift of the Guaymas Basin, in a water depth of 2003 meters. The sediments recovered from Holes 477 and 477A can be separated into two sequences: an upper sequence of diatom oozes, 58 meters thick in Hole 477 and 42 meters thick in Hole 477A, highly fossiliferous, overlying a dolerite sill at both sites, and a lower sequence of thermally altered muds underlying the sill and entirely barren of nannofossils. The diatom oozes are of late Pleistocene age and are assigned to the *Emiliania huxleyi* Zone (NN21). They yield common, well-preserved coccoliths. The rapid burial of these sediments rich in organic matter explains the good nannofossil preservation. *E. huxleyi* is abundant, with *Gephyrocapsa oceanica, Helicosphaera carteri, Coccolithus pelagicus, Umbilicosphaera mirabilis, Ceratolithus cristatus*, and *Cyclococcolithus leptoporus*.

Site 478 (Table 10)

Site 478 was located 12 km from Site 477 on the basin floor northwest of the south rift, in a water depth of 1889 meters over crust predicted by the plate tectonic model to be not more than 400,000 years old; 310 meters of upper Pleistocene sediments were recovered. Most of the section is assigned to the *Emiliania huxleyi* Zone, the basal part corresponding to the *Gephyrocapsa oceanica* Zone. The shallowness of the site and the high rate at which these thick, young sediments were deposited explain the abundance and the good preservation of their calcareous nannofossils. Except for Cores 478-29 and 478-40, which contain only solution-resistant species such as *Helicosphaera carteri* and *Cyclococcolithus leptoporus*, the composition of the assemblages is very constant throughout the section, with mainly abundant and well-preserved coccoliths. The diversity of the assemblages is, however, low. A few cosmopolitan species are present, each of them being represented by a large number of individuals. Such assemblages are characteristic of restricted oceanic environments. The predominant species are *G. oceanica, E. huxleyi, Coccolithus pelagicus, Cyclococcolithus leptoporus, H. carteri, Ceratolithus cristatus*, and *Pontosphaera* spp. The presence of non-solution-resistant species such as *Braarudosphaera bigelowii* and *Scapholithus fossilis* is proof of the limited effect of early diagenesis on these sediments. Reworked coccoliths of Late Cretaceous age are common at most

Table 7. Site 476 Pleistocene calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Ceratolithus separatus*	*Coccolithus pelagicus*	*Cyclococcolithus leptoporus*	*Helicosphaera carteri*	*H. sellii*	*Syracosphaera hystrica*	*Gephyrocapsa* spp.	*H. wallichii*	*Pontosphaera scutellum*	*Pseudoemiliania lacunosa*	*C. macintyrei*	Reworked discoasters	*Ceratolithus cristatus*	*Sphenolithus* spp.	*C. simplex*	*Pontosphaera discopora*	*Rhabdosphaera clavigera*	*Syracosphaera pulchra*	*Braarudosphaera bigelowii*	*Cyclolithella annula*	*H. neogranulata*	*Scyphosphaera pulcherrima*	*Cricolithus jonesi*	*H. columbiana*	*G. oceanica*	*H. inversa*	*Emiliania huxleyi*	Zone	Subzone	Age	Datum Levels	Time (m.y.)
1-2, 8-9	A	G	H		R	R	R		R	VA	R					R					R							VA		R					
1-2, 80-81	A	M	M		R	R	R			A						R							R					A		R					
1-3, 3-4	A	M/G	M		R	R	R			R					R	R							R					A							
1-4, 50-51	A	M/G	M		A	R	R		R	A		R				R			R	R			R					VA		R					
1-5, 1-2	A	M/G	M		R	R	R		R												R		R					A		R					
1-6, 3-4	C	M/G	M		R	R	R		R	R	R				R	R												R		R					
2-1, 60-61			L		R	R	R		R							R					R		R												
2-3, 120-121			M		R	R	R			R			R			R												R	R	R	NN20/ NN21				
2-4, 40-41	A	M	M		R	R	R		R	R		R				R			R				R					VA	R	R			late Pleistocene		
2-5, 22-23	C	G/M	L		R	R	R			R	R																	R							
3-1, 105-106	A	G/M	H		R	R	C		R	A	R					R		R		R			R					A	R						
3-2, 59-60	A	M	M			R	R			A						R		R										C	R						
3-3, 99-108	A	M	M			R	R			A								R										A							
3-4, 57-58	A	G	L			R				VA																		R							
3-5, 51-52	A	G/M	L			C				VA																		VA							
3-6, 54-55	A	G/M	L			R	C		R	A													C					A						*P. lacunosa*	0.45
4-1, 71-72	A	M	L			R	R			VA			R								R		R					VA							
4-2, 64-65	A	G	H			R	R		R	A					R		R	R					R				R	A							
4-3, 100-101	C	M	L			R			R	A													R	R				A							
4-4, 70-71						R	R		R	A									R				R			R	R	A							
4-5, 37-38	A	G/M	H		R	R	R		R	VA			R			R	R	R	R				R				R	A							
5-1, 51-52	A	M	M		C	R	R			R			R			R	R	R	R								R	A							
5-2, 49-50	C	M	M		R	R	R			A	R		R						R								R	A				small gephyrocapsa + *P. lacunosa*			
5-3, 30-31	A	G	H		R	R	R			VA	R		R				R		R	R							C	A							
5-4, 68-69	A	G	H		R	R	A		R	A	R		R					R								R	R	A							
5-5, 91-92	C	M	M			R	R			VA	R					R			R		R		R					VA							
5-6, 30-31	A	G	H			C	C		R	VA		R	C			R		R	R	R				C			R	VA					early Pleistocene		
6-1, 99-100	R	M/P	L			R			R	R									R								R	R							
6-2, 89-90	A	G	H			R	R		R	VA		R	R				R	R	R					R			R	VA							
6-3, 61-62	A	G	H			R			R	A		R	R						R				R	C		R	R	A							
7-1, 80-81	C	G/M	H		R	C	C			VA		R	C				R		R				R	R			R				NN19				
7-2, 79-80	C	G	M		R	R	R		R	A		R	R				R		R					R			R							*H. sellii*	1.22
7-2, 94-95			H			R	R	R	R	A	R		R			R	R	R		R			R	R											
7-3, 104-105	C	G	H			R	C	R	R	VA		R	C						R	R				R		R									
7-4, 80-81	R	M	M		R	A	C		R	R		R	VA			R				R			R	R		R									
7-6, 75-76	A	P	M		R	R				C	R	R	A			R								R								*H. sellii*			
7-7, 15-16	R	P	L		R	VA	R			C			A											R											
8-1, 34-35	A	M	H			R	R	R		C		C	A			R			C				R		R										
8-2, 59-60	A	M	H		R	R	C	R	R	VA			R				R					R	R	R											
8-3, 34-35	A	M	H			R	C	R		A	R		R	R		R	R		R	R	R													*C. macintyrei*	1.58
9-3, 18-19	B				R																														
10-1, 70-71	C	M	M	R	R	R		R	R	C			R	R		R	R																		
10-2, 69-70	R	M	LL							R					C																	*C. macintyrei*			
10-3, 70-71	R	M	M		R	R	R	R	R	C	R	R	R																						
10-4, 69-70	R	M	L	R	R	R	C	R	R																										

Note: See Table 3 for explanation of symbols.

Table 8. Site 476 Pliocene calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	*Ceratolithus acutus*	*Cyclococcolithus leptoporus*	*Discoaster brouweri*	*D. pentaradiatus*	*D. surculus*	*Helicosphaera carteri*	*Sphenolithus abies*	*S. neoabies*	*C. macintyrei*	*Reticulofenestra minuta*	*D. variabilis*	*D. challengeri*	*R. pseudoumbilica*	*Amaurolithus amplificus*	*A. delicatus*	*A. primus*	*Coccolithus pelagicus*	*Pontosphaera scutellum*	*R. haqii*	*Cricolithus jonesi*	*H. sellii*	*Ceratolithus separatus*	*C. armatus*	*D. asymmetricus*	*Oolithotus antillarum*	*R. minutula*	*Pseudoemiliania lacunosa*	*Umbilicosphaera mirabilis*	*Syracosphaera histrica*	*Rhabdosphaera clavigera*	*Braarudosphaera bigelowii*	*Scyphosphaera campanula*	*Pontosphaera discopora*	*S. pulcherrima*	*Syracosphaera pulchra*	Zone	Datum Levels	Age	Time (m.y.)
																																							D. brouweri		1.7
10-5, 82-83	A	G/M		R	R			R			R	R							R				R						R								R	NN19			
10-6, 71-72	C	M		R	R			R			R	R							R	R			R							R	R			R	R						
10-7, 26-27	R	M/P		R	R			R			R	R							R				R	R		R			R									NN18			
11-1, 70-71	C	M/P		R	R			R			R	R							R				R	R					R	R				R	R						
11-2, 69-70	A	M		R	R			R			R	R							R				R					R	R						R	R			*D. pentaradiatus*		2.1
11-3, 74-75	A	M			R	R		R			R	R							R				R					R	R						R						
11-4, 70-71	C	M/P			R			R			R	R							R				R					R	R												
11-5, 72-73	C	G			R			R			R	R							R	R			R	R				R	R						R						
11-6, 74-75	C	G		R	R			R			R	R							R	R			R					R	R			R	R					NN17			
11-7, 20-21	C	G		R	R			R			R	R							R	R		R	R					R	R		R			R					*D. surculus*		2.3
12-1, 80-81	C	G		R	R	R	R	R			R	R							R	R			R					R	R	R	R	R	R	R							
12-2, 78-79	C	G			R		R	R			R	R			R				R	R			R	R				R	R												
12-3, 51-52	A	G			R		R	R			R	R							R	R			R					R	R												
12-4, 77-78	R	M			R	R	R	R												R									R												
12-5, 76-77	A	M		R	R	R	R	R			R	R								R		R	R	R		R		R	R		R	R	R							late Pliocene	
12-6, 49-50	A	M		R	R	R	R	R			R	R							R	R			R			R		R	R		R	R							*D. tamalis*		2.5
13-1, 85-86	A	M		R	R	R	R	R			R	R											R	R		R		R	R	R	R										
13-3, 84-85	A	M/P		R	R	R	R	R			R	R							R	R	R		R						R	R	R										
13-4, 83-84	A	M		R	R	R	R	R			R	R									R		R			R		R	R	R	R										
13-5, 70-71	C	M/P		R	R	R	R	R			R	R									R		R			R		R	R												
13-6, 83-84	A	G		R	R	R	R	R			R	R								R	R		R						R	R	R							NN16			
13-7, 10-11	C	G			R	R	R	R			R	R							R	R	R		R	R		R		R	R	R	R										
14-1, 46-47	C	M		R	R	R	R	R			R	R			R						R					R			R	R	R										
14-3, 117-118	A	G		R	R	R	R	R			R								R	R	R		R	R		R		R	R	R	R										
14-4, 52-53	A	M/P		R	R	R	R	R			R	R							R	R	R		R	R					R	R	R										
14-5, 51-52	A	M			R	R	R	R			R	R							R		R			R		R		R	R		R										
15-1, 72-73	R	M			R	R		R					R								R							R													
15-2, 77-78	R	M			R	R	R	R				R	R								R							R													
15-3, 73-74	R	M			R	R	R	R	R		R	R								R	R					R		R													
16-1, 66-67	A	M		R	R	R	R	R		R	R	R							R		R		R	R		R		R													
16-2, 67-68	C	M			R			R													R					R		R											*R. pseudoumbilica*		3.2
16-3, 58-59	R	G/P			R	R	R	R	R	R	R				R				R		R					R		R													
16-4, 65-66	C	G		R	R	R	R	R	R	R		R			R				R		R				R	R	R	R													
17-1, 121-122	C	G		R	R	R	R	R		R	R	R			R				R		R																	NN15			
17-3, 51-52	C	G	R	R	R	R	R	R	R	R	R	R			R			R	R		R					R															>4.6
18-1, 49-50	C	G/M	R	R	R	R		R	R	R	R	R	R		R				R		R		R	R	cf.	R															
18-2, 49-50	C	M	R	R	R	R	R		R	R	R	R			R			R	R		R		R	R	cf.	R															
18-3, 49-50	C	P	R	R	R	R	R	R		R		R	R	R	R			R	R		R					R															
18-4, 48-49	R	P	R	R	R	R	R						R		R			R			R			R	cf.	R															
18-5, 50-51	C	M	R	R	R	R	R	R	R	R	R	R			R			R	R		R			R	cf.	R															
18-6, 50-51	C	M	R							R	R	R		R	R			R	R		R		R			R															
19-3, 70-71	C	M	R	R	R		R	R		R		R		R	R		R	R			R																				
19-4, 70-71	A	G	R	R	R	R	R		R	R	R		R		R			R	R		R																			early Pliocene	
19-5, 70-71	C	M	R	R	R		R	R		R		R	R		R			R			R																	*C. acutus* Subzone			
20-1, 79-80	A	G	R		R	R	R	R		R		R			R		R				R			R	cf.																
20-2, 79-80	A	M	R		R	R	R	R		R	R	R			R			R	R	R																					
20-3, 79-80	C	M	R		R	R			R	R	R		R		R			R	R						cf.																
20-4, 80-81	R	P	R			R	R						R		R		R	R																							
20-5, 79-80	A	M/P	R		R		R	R	R	R		R	R		R	R	R	R																							
20-6, 80-81	C	M	R	R	R		R		R	R	R	R	R	R	R																										
20-7, 27-28	B														R										cf.																
21-1, 41-42[a]	C	M	R		R	R	R								R																										
21-2, 40-41	C	A	R	R	R	R	R	R	R	R					R																							?		?	<5

Note: See Table 3 for explanation of symbols.
[a] Samples 476-21-3, 40-41 and Samples 476-21-4, 27-28 were barren.

Table 9. Hole 477 calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Coccolithus pelagicus*	*Cyclococcolithus leptoporus*	*Emiliania huxleyi*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp.	*Helicosphaera inversa*	*H. carteri*	*H. wallichii*	*Sphenolithus* sp.	*Syracosphaera pulchra*	*S. histrica*	*Ceratolithus cristatus*	*Pontosphaera discopora*	*Cyclolithella annula*	Zone	Age	Time (m.y.)
2-2, 67–68	C	G	H	R	R	R	VA	A		R	R				R	R	R			
3-1, 19–20	C	G	H		R	R	VA	A		A	R				R	R				
3-1, 96–97	C	G	M		R	R	VA	R	R	C										
4-1, 128–129	C	G	H	R	R	R	VA	A	R	C	R	R		R				NN21	Late Pleistocene	
5-2, 45–46	C	G	M		R	R	VA	A			R	R								
7-1, 4–5	C	G	M	R	R	R	R	R	R	R	R	R								
7-2, 17–18	C	G	M	R	R		R	R		R		R	R							<0.268
7-2, 56–57	B																		?	
15–23	B																			

Note: See Table 3 for explanation of symbols.

levels. Upper Cretaceous rocks which are exposed in the Guaymas region on the north side of the Matopa River may be the source of these nannofossils.

Site 479 (Table 11)

Site 479, drilled on the Guaymas Basin slope at a water depth of 747 meters, penetrated 440 meters into a sequence of diatomaceous oozes to laminated mudstones. Since this site is located in the oxygen-minimum zone of the continental slope, where thick siliceous oozes are being deposited and bottom waters are acid, it was not surprising that we commonly found only scarce and poorly preserved nannofossils. Because of this poor preservation, scarcity, and low species diversity, the coccoliths do not make possible a reliable stratigraphic subdivision at this site, and the sediments are assigned to the undifferentiated Zones NN20–NN21. On the basis of the calcareous nannofossil assemblages, the section is divided into two sequences, separated by an almost barren interval. With the exception of Sample 479-32-1, 103–104 cm, which yielded scarce and poorly preserved Gephyrocapsids and *Cyclococcolithus leptoporus*, the interval between Sample 479-29-1, 59–60 cm and Sample 479-40-2, 31–32 cm is barren of calcareous nannofossils. In the upper part of the sequence, from Core 479-1 to Core 479-18, coccoliths are found in very irregular amounts: they may be rare (most cases), common, abundant, or even absent (Sections 479-21-4, 479-21-6, 479-17-4, and 479-17-5, for instance). Their preservation is usually poor and their diversity varies from low to very low. *Gephyrocapsa* spp. are the most common forms. *Helicosphaera carteri* and other species of the genus, which seem to prefer warm, shallow waters, are frequent, even abundant, in Samples 479-7-3, 56–57 cm and 479-19-6, 88–89 cm. *Coccolithus pelagicus* is at times very abundant (Samples 479-7-3, 56–57 cm and 479-19-6, 88–89 cm). Coccoliths reworked from the Upper Cretaceous are common at this site, as at Site 478. In Samples 479-13-2, 66–67 cm, 479-13,CC and 479-15,CC, *Pseudoemiliania lacunosa* was found and considered to be reworked.

The lower part of the sequence, from Core 479-40 to Core 479-47, differs sharply from the upper part in the composition of the nannofossil assemblages. The diversity of these assemblages is always extremely reduced and the preservation poor, but *C. pelagicus* becomes the dominant species, so abundant that it entirely constitutes thin layers of nannofossil oozes (Samples 479-44-4, 111 cm, 479-44-4, 135 cm, 479-43-2, 48 cm, 479-44-3, 88 cm, 479-44-3, 99 cm, 479-44-3, 113 cm, 479-44-3, 117 cm, 479-44-3, 125 cm, 479-45-3, 115 cm, 479-45-6, 43 cm; Plate 1). As blooms of *C. pelagicus* seem to have been related to cooling trends during the Pleistocene, these layers may indicate the influx of cooler waters into the Guaymas Basin. The low diversity of the assemblages results partly from the effects of early diagenesis, recrystallization, silicification, and dolomitization, but their paucity is the result mainly of severe paleoecologic conditions. The long-ranging species of these assemblages do not permit us to make a more precise age assignment than Neogene to this lower sequence.

Site 481 (Holes 481, 481A; Table 12)

Site 481 was drilled at a water depth of 1998 meters in the north rift of the Guaymas Basin, penetrating 170 meters of upper Pleistocene sediments. Calcareous nannofossils were diluted among abundant diatoms and were never found in abundance, except in Sample 481-P2-2, 9–10 cm, where a single very dissolved species—probably *Cyclococcolithus leptoporus*—is abundant. The preservation decreases downhole, being moderate to good until Core 481A-22 and rather poor below. The coccolith assemblages are of low diversity and are identical from Cores 481A-1 to 481A-22. Species of the genus *Gephyrocapsa* represent the bulk of the assemblages, with *Helicosphaera carteri* sometimes very abun-

Table 10. Site 478 calcareous nannofossil distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	*Gephyrocapsa* spp.	*Cyclococcolithus leptoporus*	*Sphenolithus* sp.	*G. oceanica*	*Cyclolithella annula*	*Emiliania huxleyi*	*Helicosphaera carteri*	Reworked Cretaceous sp.	*Coccolithus pelagicus*	*Syracosphaera histrica*	*H. inversa*	*Ceratolithus cristatus*	*Braarudosphaera bigelowii*	*C. simplex*	*Pontosphaera scutellum*	*H. wallichii*	*Umbilicosphaera mirabilis*	*P. discopora*	*Scapholithus fossilis*	*Syracosphaera pulchra*	Zone	Age	Time (m.y.)
1-1, 96-97	A	M		VA	R		VA		R	R					R											
2-1, 13-14	A	G		VA	R	R	VA		R	R		R							R							
2-1, 69-70	A	G		VA	R		VA		R	R		R		R					R							
2-2, 66-68	A	G		VA	R		VA	R	R	R		R				R			R				R			
2-3, 74-76	A	G		VA	R		VA		R		A			R				R								
2-3, 92-94	C	M/P		A	R		A		R	A		R				R										
3-1, 84-85	A	G		R	R		R		R	R		R		R												
3-2, 100-101	C	G		A	R		A			R		C														
3-3, 76-77	R	M		R	R		R			R										R						
3-4, 65-66	R	M		R			R			R		R														
4-1, 60-61	R	G		R	R		R		R	R																
4-2, 79-80	R	G/M		R			R	R		R									R							
4-3, 41-42	A	G		C			C		R	VA			R									R				
4-4, 104-106	R	P		R	R		R																			
4-5, 22-23	A	G/M		A	R		VA			R																
4-6, 63-64	A	G		R	R		VA		R	R			R													
5-2, 91-92	A	G/M		A			VA		VA	R		R						R			R					
5-4, 101,5	C	G		A	R		A		R	R																
5-4, 121	C	G/M		R			R		R	R		R														
5-5, 17-18	R	G/M		R	R		R			R																
5-5, 110-111	C	G		A	R		A	R	R	R																
5-6, 25-26	A	G		VA			VA		R	R		R	R							R						
5-6, 115-117	A	G		A	R		VA		A	R																
6-2, 43-45	C	G		VA	R		VA		R	R		R		R												
6-4, 117-118	C	G		VA	R		VA		R	R		R														
7-4, 60-61	A	G		VA	R	R	VA	R	R	R	R		A							R						
7-5, 58-59	A	G		VA	R		VA		R	R	R		A	R	R				R							
8-2, 68-69	A	G			R			R		R	R	R														
10-1, 103-104	C	G		VA	R		VA		R	R	R		R	R	R				R							
10-2, 77-78	A	G		VA	R		VA				R															
11-2, 30-31	C	G/M		VA	R		VA				R		R	R	R									NN21		
11-3, 30-31	C	G		VA	R		VA			R	R		R		R											
11-6, 25-26	A	G	Low	VA	R		VA			R	R				R											
12-2, 67-68	A	G		VA	R		VA		R		R														late Pleistocene	<0.465
13-4, 51-52	A	G		VA			VA		R		R															
14-3, 72-73	A	G		VA			VA		R	R			R													
15-2, 126-127	C	M		A	R		A				R		R													
15-4, 116-117	A	G		VA	R		VA		R	R			R													
16-3, 73-74				VA	R		VA				R		R													
16-5, 50-51	A	G		A			A		R	R			R													
17-5, 64-65	C	G		VA	R		VA			R	R		R													
18-1, 14-15	A	M	to	A	R	R	A		R		R		R	R												
19-6, 84-85	A	G		VA	R		VA			R	R		C					R	R							
20-3, 69-70	A	G		R	R		VA			R	R		R													
20-5, 107-108	A	G		VA	R		VA		R		R		R		R											
21-4, 62-63	A	G/M		A	R		A			R	R		VA	R												
22-2, 22-23	A	G		VA	R		VA	R		R	R															
22-3, 113-114	A	G		VA	R	R	VA			R	R						R									
28-0, 43-44	C	G/M		R	R		R	R		R	R		R			R										
28-1, 137-138	C	G/M		A	R		A			R	R				R											
28-4, 52-53	C	M		A	R	R	A				R				R											
28-6, 62-63	C	G		R	R		R			R	R	R														
29-2, 20	C	M	Moderate	A	R		A		R	R	R															
29-2, 90	R	P		R	R		R		R		R															
29-2, 98-99	C	M/P		R							R															
29-2, 140	B																									
29-2, 150	R	P		R	R																					
31-4, 140-142	A	G		A			A			R	R	R	R	R												
32-1, 84-85	R	G		R	R		R																			
32-3, 8-10	C	G		R	R		R			R	R		A													
33-3, 113-114	C	G/M		A			A			R	R		R													
33-5, 37-38	C	G		A	R		A			R	R	R												--?--		
34-1, 135-136	C	G		VA	R		VA	R																		
35-4, 42-43				R	R		R																			
36-2, 123-124	C	G		R	R		R																			
39-2, 91-92	A	G/M		R		R																		NN20		
40-1, 4-5	A	P			R																					
40-1, 73-74	R	P		R	R																					

Note: See Table 3 for explanation of symbols.

Table 11. Site 479 calcareous nannoplankton distribution.

Core/Section (interval in cm)	Abundance	Preservation	Diversity	Reworked Cretaceous spp.	*Coccolithus pelagicus*	*Helicosphaera carteri*	*Pontosphaera scutellum*	*Cyclococcolithus leptoporus*	*Gephyrocapsa* spp.	*Syracosphaera hystrica*	*Cyclolithella annula*	*G. oceanica*	*Ceratolithus cristatus*	*H. wallichii*	*Sphenolithus* sp.	*Syracosphaera pulchra*	*Pseudoemiliania lacunosa*	*Umbilicosphaera mirabilis*	*Emiliania huxleyi*	*H. inversa*	*Cricolithus jonesi*	Zone	Age	Time (m.y.)
1-2, 26–27	R	P	LL						R			R												
3-2, 90–91	C	M	M		C	R		R	VA		R	VA							R					
5-5, 37–38	B																							
6-3, 64–65	A	M	M	R	R	R		R	VA			VA		R		R								
6-5, 91–92	R	M	L						R			R												
7-3, 56–57	A	G/M	M		A	C		R	VA	R		VA						R		R	R			
8-2, 78–79	B																							
8-5, 64–65	A	M	M		R			R	R			R					R	R						
9-3, 57–58	R	P	LL						R															
10-6, 62–64	R	P	LL						R															
11-2, 67–68	R	P	LL					R	R															
12-3, 65–66	R	P	LL			R		R	R															
12-6, 103–104	C	P	LL						R															
13-2, 66–67	A	G/M	L			R			VA			R					R							
14-3, 89–90	B																							
14-6, 56–57	B																							
15-1, 24–25	R	P	LL						R															
15-5, 67–68	R	P	LL						R															
16-1, 106–107	R	P	LL					R	R			R												
16-3, 82–83	R	P	LL					R	R															
17-1, 85–87	R	P	LL	R	R			R	R															
17-4, 65–68	B																							
17-5, 38–39	B																							
17-7, 14–15	C	P	LL			R		R	R			R										NN21/ NN22	late Pleistocene	<0.465
18, 44–46	R	P	LL			R		R	R															
19-1, 61–62	B																							
19-5, 51–52	C	M	L		A			R	VA	R						R								
19-6, 88–89	C	M	L			C		R	R			R												
20-2, 40–41	C	G	L			R		R	R			R												
20-3, 139–140	R	P	LL						R															
20-6, 17–18	R	P	LL	R				R	R															
21-2, 67–68	C	M	L	R	R	R	R	R	VA			R												
21-4, 70–71	B																							
21-6, 69–70	B																							
22-2, 120–121	R	P	L	R		R		R	A															
22-6, 51–52	C	M	L		R	R			A															
23-3, 53–55	A	G/M	M		C	R		R	R			R		R	R									
23-6, 67–68	A/C	G/M	M	R	R			R	R			R	R											
24-2, 116–145	R	M/P	L	R	A	R			R															
24-3, 105–106	R	P	L	R	C	R		R	R															
24-6, 29–30	R	P	LL		R			R	R															
25-1, 54–55	A	M	L	R		R		R	VA			VA												
26-1, 24–25	A/C	M	L	R	R	R		R	R			R												
26-6, 60–61	R	M/G	LL		R	R		R				R												
27-2, 89–90	C	M	L	R		R		R				VA												
27-4, 48–49	R	M/G	LL						R			R												
28-1, 8–10	C	G/P	M		R	R		R	VA		R	C												
28-4, 62–63	R	P/G	LL					R	R		R													
										Barren[a]												?	?	
40-2, 75–77	C	P	L		VA			R	R	R														
41-1, 70–71	C	P/G	L	R	R	R		R	R															
43-2, 30–31	R	P	L	R	R	R		R	R															
43-7, 48	A	M	LL		VA				R															
44-1, 74–75	B																							
44-3, 88	A	M/P	LL		VA																			
44-3, 93	A	M/P	LL		VA																			
44-3, 113	A	M/P	LL		VA																			
44-3, 117	A	M/P	LL		VA			R		R														
44-3, 125	A	M/P	LL	R	VA			R																
44-4, 111	A	M/P	LL		VA																			
44-4, 135	A	M/P	LL		VA																			
45-2, 89–91	R	P	L	C	R	R		R														?	late Pleistocene	?
47-1, 20–21	R	P	LL		R			R																
47-1, 105–106	R	P	L	R	R	R		R	R															
47-2, 87–88	B																							
47-3, 105	A	P	LL		VA																			
47-3, 115	R	P	LL		R																			
47-3, 115–116	R	P	LL	R	R	R		R																
47-6, 21–22	R	P	LL	A	R	C																		
47-6, 17–18	R	P	LL	R	VA	R																		
47-6, 42–43	R	P	LL	R	VA		R																	
47-6, 43	A	P	LL		VA																			
47-6, 87–88	R	P	LL	R	VA	R																		
47-6, 103	A	P	LL		VA																			
47-4, 113–114	B		LL	R																				

Note: See Table 3 for explanation of symbols.

[a] The following samples were barren, except for the rare occurrence of poorly preserved *Cyclococcolithus leptoporus* and *Gephyrocapsa* spp. in Sample 479-32-1, 103–104: 479-29-1, 53–60 cm; 479-29-6, 65–66 cm; 479-31-2, 92–93 cm; 479-31-4, 100–101 cm; 479-32-1 103–104 cm; 479-32-2, 61–62 cm; 479-74-1, 69–70 cm; 479-34-4, 36–37 cm; 479-34-5, 104–105 cm; 479-35-3, 53–54 cm; 479-36-1, 79–80 cm; 479-36-4, 69–70 cm; 479-37-4, 122–123 cm; 479-38-1, 78–79 cm; 479-38-5, 21–23 cm; 479-39-2, 84–85 cm.

Table 12. Site 481 calcareous nannoplankton distribution.

Sample (interval in cm)	Abundance	Preservation	Diversity	*Coccolithus pelagicus*	*Cyclococcolithus leptoporus*	*Gephyrocapsa oceanica*	*Gephyrocapsa* spp.	*Helicosphaera carteri*	*Braarudosphaera bigelowii*	*Pontosphaera discopora*	Reworked pre-Pleistocene spp.	*Pontosphaera scutellum*	*Emiliania huxleyi*	*Ceratolithus cristatus*	*Syracosphaera histrica*	*Cyclolithella annula*	*Syracosphaera pulchra*	*Discosphaera tubifera*	Zone	Age	Time (m.y.)
Hole 481																					
P2-1, 110–111	C	M	M	R	R	VA	VA	C			R	R		R	R						
P2-2, 3–4	C	M	L		R	VA	VA	R							R						
P2-2, 9–10	A	P	LL		VA	R	R														
P2-2, 19–20	A	M	M	C	R	VA	VA	A			R				R						
P2-2, 71–72	A	M	M	C	R	VA	VA	VA	R					R	R		R				
P2-2, 95–96	A	M	M																		
P3-1, 74–75	C	M	L		R	VA	VA	R		R											
P3-3, 47–48	A	M	L		R	VA	VA	R			R										
P3-3, 94–95	A	M	L		R	VA	VA	A			R				R						
P4-1, 45–46	A	G/M	L		R	VA	VA	A			R					R					
P7-1, 107–108	C	M	L		R	VA	VA	R		R											
P7-3, 59–60	C	M	L	R	R	VA	VA	R													
P8-1, 30–31	C	M/G	L																		
P8-1, 67–68	A	M/G	L																		
P8-3, 56–57	C	M/G	L	R	R	VA	VA	R			R						R				
P9-1, 110–111			L		R	R	R	R													
P10-1, 87–88	A	M	L	R	R	VA	VA	A		R	R						R				
P10-2, 77–78	A	M	L		R	VA	VA	R			R			R							
P11-1, 18–19	A	M	LL		R	VA	VA	R						R							
P11-1, 81–82	A	M/G	L		R	VA	VA	R									R	R			
Hole 481A																					
1-2, 77–78	C	M		R	R	A	A	R				R			R						
2-1, 53–54			M	R	R	VA	VA	R						R	R						
3-1, 83–84	A	M	L	R	R	VA	VA	R				R			?	R					
4-2, 27–28	C	M	L		R	VA	VA	R								R					
5-1, 70–71	A	M/P	L	R		VA	VA	R	R			A									
5-2, 48–49	A	M	L	R	R	C	C	VA		R											
5-5, 65–66	C	M	L	A	VA	VA	R														
5-6, 68–69	C	M/G	L	C		VA	VA	R						R							
6-2, 46–47	R/C	P	L	R	R	R	R	R													
6-4, 38–39	R/C	P	LL	R		R	R	R													
7-1, 83–84	C	P	L	R	R	VA	VA	R						R							
7-6, 45–46	C	M/P	L	R	R	VA	VA	R					R	R					NN21/ NN20	late Pleistocene	<0.465
8-2, 88–89	C	P/M	LL	R	R	VA	VA	R													
8-6, 85–86	C	M/P	L	R	VA	VA	R		R		R										
9-3, 81–83	C	M/P	L		R	VA	VA			R											
9-6, 10–11	A	P	LL		C	VA	VA	R													
10-1, 35–36	A	M	LL		R	VA	VA	A													
10-3, 39–40	C	M	LL		R	VA	VA	R													
10-5, 13–14	C	M	LL		R	VA	VA	R													
11-2, 36–37	R	M/P	LL		R	R	R	R		R											
11-4, 13–15	R	P	LL			R	R	R													
12-1, 50–51	R	P	LL	R		R	R	R													
12-4, 24–25	R	P	LL	R			R	R													
18-1, 23–24	R	M	L	R	R	R	R	R		R											
20-1, 101–103	R	M	L	R	R	VA	VA	R													
20-1, 128–129	C	M	L		R	A	A	R			R										
20-2, 24–25	R	M	LL			R	R	R													
22-3, 65–66	C		L	R	R	A	A	R				C									
22-6, 43–44	C	M/G	L		R	VA	VA	R													
23-1, 17–18	R	P	LL	R		R	R	R													
24-1, 69–70	C	M/P	LL	R	R	A	A	R													
24-3, 52–53	R	P	LL		R	R	R	R													
25-1, 17–18	C	M/P	LL	C	R	VA	VA	R													
25-2, 28–29	C	M	L	C		A	A	VA		R											
25-4, 11–12	C	M	L	C	R	VA	VA	R													
25-5, 37–38	R	M	L	VA	R	R	R	R													
26-1, 102–103	C	M	L	R	R	VA	VA	R													
26-3, 78–79	A	P	L	A	R	A	A	C													
26-6, 65–66			L	A	R	VA	VA	R													
27-2, 66–67	C	P	LL	A	R	A	A	R													
27-6, 96–97				C		VA	VA	C													
28-1, 26–27	A	M	LL	C	R	VA	VA														
28-6, 88–87	A	M	L	C	R	VA	VA	R	R												
29-1, 58–59	C	M	L	C	R	VA	VA	R													
30-1, 66–67	C	M/G	LL	C	R	A	A	C													
30-6, 43–44	C	P/M	L	A	R	R	R	R													
31,CC, 100–101	B																				
31,CC	C	P/M	L																		

dant (Samples 481-P2-2, 71–72 cm, 481-P3-3, 94–95 cm, 481-P5-2, 28–29 cm, 481-P10-1, 87–88 cm) as well as *Pontosphaera* spp. (Samples 481-P3-1, 74–75 cm, 481-P10-1, 87–88 cm). Reworked Upper Cretaceous species can occur in abundance, as in Samples 481A-22-4, 65–67 cm, 481-P8-3, 56–57 cm, and Sections 481-P10-1 and 2. A few *Discoaster brouweri* and *D. pentaradiatus*, reworked from the Neogene, were also found (Samples 481-P2-2, 19–20 cm, 481-P3-3, 94–95 cm). Below Core 481A-22, the characteristics of the nannofossil assemblages change; there is both a sudden increase in the abundance of *Coccolithus pelagicus* and a sharp reduction in species diversity. *C. pelagicus* occurs sporadically from Core 481-P1 to Core 481A-4. Its frequency increases progressively from Core 481A-5 to Core 481A-8, then more sharply from Core 481A-24 to Core 481A-30. *C. pelagicus* is well known as an indicator of cooling trends and its fluctuations may be related to paleoceanographic changes.

Because of the generally poor preservation of the assemblages, the absence of *Emiliania huxleyi* may result from dissolution. The generally low diversity of the assemblages is probably related to strong dissolution but is also the consequence of particular ecologic conditions—those that exist in a restricted, shallow, marine environment, rich in silica.

ESTIMATED AGES OF THE OLDEST SEDIMENTS RECOVERED FROM THE GULF OF CALIFORNIA DURING LEG 64

Calcareous nannofossils provided a good biostratigraphic control at most sites drilled during Leg 64. In particular, they enabled us successfully to date the sediments overlying both the oceanic and the continental crust during the transect off the tip of southern Baja California.

Age of the Oceanic Crust at Site 474

The oldest sediments recovered above the dolerite sill, at the bottom of the sedimentary sequence (Sample 474A-37-4, 50–51 cm), between sill 1 and basalt flow 2A (Samples 474A-40-3, 110–111 cm, 474A-41-1, 28–29 cm, 474A-41-5, 28–29 cm), and also included in basalt flow 4 (Samples 474A-45 [Piece 1A] and 474A-45 [Piece 1B]) have been assigned to the lowest part of the *Discoaster surculus* Zone. The LAD of *Reticulofenestra pseudoumbilica*, which is estimated at 3.2 Ma, was not reached. The oldest sediments recovered above the oceanic crust at Site 474 are thus younger than 3.2 Ma (see Curray, Moore et al.; Saunders and Fornari; both this volume, Pt. 2).

Age of the Oldest Marine Sediments at Sites 475 and 476

The sediments recovered just above the conglomerate of continental origin at Site 475 (Sections 475-17-3 and 475-17-4) and the conglomerate overlying a weathered granite at Site 476 (Sections 475-21-3 and 475-21-4) were barren of calcareous nannofossils. The first specimens were found 3 meters above the continental crust at Site 475 and 2 meters above it at Site 476. At both sites, *Ceratolithus acutus* indicates an earliest Pliocene age for the lowest fossiliferous sediments. *C. acutus* is a very short-ranging species, with a first appearance datum (FAD) estimated at 5 Ma, and an LAD very close to the FAD of *C. rugosus*, around 4.6 Ma. The first marine deposition above the continental crust can therefore be estimated at 5 to 4.6 Ma. Deposition was then interrupted for most of the early Pliocene.

Ages of the Sediments in the Guaymas Basin

Calcareous nannofossils did not provide reliable age assignment in the Guaymas Basin and allow only an estimate of their oldest age. At Site 477, the upper 58 meters of diatom oozes are younger than 0.26 Ma. At Site 478, all the sedimentary sequence is younger than 0.45 Ma and most of it was deposited during the last 0.26 m.y. At Site 479, the upper sequence of fossiliferous sediments is younger than 0.45 Ma. The nannofossils do not provide any information about the age of the lower part of the sequence. All the sediments recovered at Site 481 are also younger than 0.45 Ma, and most of them probably younger than 0.26 Ma.

Paleoecology and Paleoceanography

The poor preservation of coccoliths has restricted the possibilities of paleoecologic studies in the Guaymas Basin. Characteristics of each site have been mentioned in the site discussion. In general, a shallow depth of deposition and weakened oceanic influences are reflected in the low diversity of the assemblages and the higher frequency of shallow-water taxa. *Coccolithus pelagicus* blooms observed at Sites 479 and 481 may have been related to cooling trends. Mixing of Upper Cretaceous forms in the Pleistocene sediments indicates the arrival of detritic sediments in the Guaymas Basin from the eastern coast of the Gulf.

CALCAREOUS NANNOPLANKTON SPECIES CONSIDERED IN THIS REPORT

Species are listed in alphabetic order of the species epithets.
Sphenolithus abies Deflandre
Ceratolithus acutus Gartner and Bukry
Scyphosphaera amphora Deflandre
Amaurolithus amplificus (Bukry and Percival)
Cyclolithella annula (Cohen)
Oolithotus antillarum (Cohen)
Gephyrocapsa aperta Kamptner
Scyphosphaera apsteini Lohmann
Angulolithina arca Bukry
Ceratolithus armatus Muller
Discoaster asymmetricus Gartner
Braarudosphaera bigelowii (Deflandre)
Amaurolithus bizzarus Bukry
Discoaster brouweri Tan sens. emend. Bramlette and Riedel
D. brouweri recurvus Borsetti and Cati
D. brouweri rutellus Gartner
Scyphosphaera campanula Deflandre
G. caribbeanica Boudreaux and Hay
Helicosphaera carteri (Wallich)
D. challengeri Bramlette and Riedel
Rhabdosphaera clavigera Murray and Blackman
S. coheni B Boudreaux and Hay
H. columbiana Gartner
Ceratolithus cristatus Kamptner
A. delicatus Gartner and Bukry
Pontosphaera discopora Schiller
G. doronicoides Black and Barnes

Scapholithus fossilis Deflandre
Reticulofenestra haqii Backman
Emiliania huxleyi (Lohmann)
Syracosphaera hystrica Kamptner
H. inversa Gartner
Cricolithus jonesi (Cohen)
Pseudoemiliania lacunosa Kamptner
Cyclococcolithus leptoporus Murray and Blackman
C. macintyrei Bukry and Bramlette
R. minuta (Haq)
R. minutula (Gartner)
Umbilicosphaera mirabilis Lohmann
Sphenolithus neoabies Bukry and Bramlette
H. neogranulata Gartner
G. oceanica Kamptner
G. omega Bukry
Coccolithus pelagicus (Wallich)
D. pentaradiatus Tan sens. emend. Bramlette and Riedel
A. primus (Bukry and Percival)
R. pseudoumbilica Gartner
Scyphoshaera pulcherrima Deflandre
Syracosphaera pulchra Lohmann
Ceratolithus rugosus Bukry and Bramlette
Pontosphaera scutellum Kamptner
H. sellii (Bukry and Bramlette)
C. separatus Bukry
C. simplex Bukry
D. surculus Martini and Bramlette
D. tamalis Kamptner
C. telesmus Morris
D. tristellifer Bukry
Discosphaera tubifera (Murray and Blackman)
Discoaster variabilis Martini and Bramlette
H. wallichii (Lohmann)

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REFERENCES

Berggren, W. A., Burckle, L. H. et al., 1980. Towards a Quaternary time scale. *Quat. Res.*, 13:277–302.

Bukry, D., 1973a. Coccolith stratigraphy, eastern equatorial Pacific, Leg 16, Deep Sea Drilling Project. *In* van Andel, Tj. H., Heath, G. R., et al., *Init. Repts. DSDP*, 16: Washington (U.S. Govt. Printing Office), 653–711.

________, 1973b. Low-latitude coccolith biostratigraphic zonation. *In* Edgar, N. T., Saunders, J. B., et al., *Init. Repts. DSDP*, 15: Washington (U.S. Govt. Printing Office), 685–703.

________, 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.

________, 1978. Biostratigraphy of Cenozoic marine sediments by calcareous nannofossils. *Micropaleontology*, 24(no. 1):44–60.

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

Haq, B. U., and Berggren, W. A., 1978. Late Neogene calcareous plankton biochronology of the Rio Grande Rise (South Atlantic Ocean). *J. Paleontol.*, 52(no. 6):1167–1194.

Haq, B. U., Berggren, W. A., and Van Couvering, J. A., 1977. Corrected age of the Pliocene/Pleistocene boundary. *Nature*, 269(no. 5628):483–488.

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

________, 1976. Cretaceous to Recent calcareous nannoplankton from the central Pacific Ocean (DSDP Leg 33). *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 383–423.

Martini, E., and Worsley, T., 1970. Standard Neogene calcareous nannoplankton zonation. *Nature*, 225(no. 5229):289–290.

Thierstein, H. R., Geitzenauer, K. R., and Molfino, B., 1977. Global synchroneity of late Quaternary coccolith datum levels: Validation by oxygen isotopes. *Geology*, 5:400–405.

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2

3

Plate 1. At Site 479 (Guaymas Basin), thin layers of calcareous nannoplankton oozes consist entirely of a single taxon, *Coccolithus pelagicus*. (All specimens magnified ×5000.) 1–3. Sample 479-44-3, 114 cm.