14. OLIGOCENE TO RECENT CALCAREOUS NANNOPLANKTON FROM THE PHILIPPINE SEA, DEEP SEA DRILLING PROJECT LEG 59

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INTRODUCTION

During Leg 59 of the Deep Sea Drilling Project, five sites (447 to 451) were occupied and seven holes drilled between Okinawa and Guam in the Philippine Sea (Fig. 1). All holes except Hole 447 yielded common calcareous nannoplankton at certain intervals cored. Nannoplankton assemblages and their age assignments will be discussed for each site, and fossil lists for selected samples from Holes 447A, 448, 450, and 451 are presented in Tables 1 to 4, covering the middle Oligocene to the Quaternary.

CALCAREOUS NANNOPLANKTON ZONATION

For the Tertiary and Quaternary, I have used the standard calcareous nannonplankton zonation (Martini, 1971) (Fig. 2). Because of the tropical position of the sites occupied, however, the following deviations are necessary.

NN 13/14 (Combined *Ceratolithus rugosus/Discoaster asymmetricus* Zone)

Definition: Interval from the first occurrence of *Ceratolithus rugosus* Bukry and Bramlette to the last occurrence of *C. tricorniculatus* Gartner.

Remarks: Because *Discoaster asymmetricus* Gartner was not found in the sampled material of Hole 451, and there is otherwise no reason for the presence of a hiatus within Cores 4 and 5 of Hole 451, a combined NN 13/14 Zone seems more realistic.

NN 4 (*Helicosphaera ampliaperta* Zone)

Substitute definition: Interval from the last occurrence of *Sphenolithus belemnos* Bramlette and Wilcoxon to the first occurrence of *D. exilis* Martini and Bramlette.

Remarks: As the guide fossil *H. ampliaperta* (Bramlette and Wilcoxon) seems to be absent in the tropical Pacific, *D. exilis* Martini and Bramlette is taken to define the top of Zone NN 4 (Martini and Worsley, 1971).

NP 25 (*Sphenolithus ciperoensis* Zone)

Substitute definition: Interval from the last occurrence of *S. distentus* (Martini) to the last occurrence of *S. ciperoensis* Bramlette and Wilcoxon.

Remarks: The guide fossil *H. recta* (Haq) (= *H. truncata* Bramlette and Wilcoxon) is not present or is too rare in the tropical Pacific, as already noted by Martini and Worsley (1971); thus *S. ciperoensis* is used as a substitute species. Its last occurrence marks the top of Zone NP 25 in Leg 59.

A different zonation, mainly based on Bukry (1971a, 1973), was used during Leg 31 in the Western Philippine Sea and during Leg 60 at the eastern transect of the Philippine Sea. For better comparison of results both zonations and their correlation are shown in Figure 2. The zonations differ in some parts of the tabulated time interval but are otherwise very similar because 20 boundaries are identical in both zonations. There is also general agreement on the age of some major boundaries, indicated by an asterisk in Figure 2. A few remarks, however, seem necessary to avoid misinterpretation, especially in the Oligocene, where some confusion may arise because the same zonal names are used for different time intervals. The base of the *S. predistentus* Zone in both zonations is taken at the last occurrence of *Reticulofenestra umbilica.* In the standard zonation, however, the top of the *S. predistentus* Zone (NP 23) is marked by the first occurrence of *S. ciperoensis*, whereas in Bukry's zonation the top is indicated by the first appearance of *S. distentus*. In the standard zonation, the top of the following zone (*S. distentus* Zone) is marked by the first occurrence of *S. ciperoensis.* That means that the *S. predistentus* Zone and the *S. distentus* Zone of Bukry are equivalent to Zone NP 23 (*S. predistentus* Zone) of the standard zonation. The *S. ciperoensis* Zone of Bukry, on the other hand, is equivalent to Zones NP 24 (*S. distentus* Zone) and NP 25 (*S. ciperoensis* Zone), because the base is indicated by the first occurrence of *S. ciperoensis* and the top is taken at the last occurrence of the same species in this area, although the top of Zone NP 25 was originally defined by the last occurrence of *H. recta* (see also Martini, 1976). In Figure 2, correlations between both zonations are based on index species. Indication of estimated time relations are taken from Martini (1976) for the standard calcareous nannoplankton zonation. Figure 3 shows a summary of the calcareous nannoplankton stratigraphy of holes drilled during Leg 59.

SITE SUMMARIES

Site 447
(18°00.88′N, 133°17.37′E, depth 6022 m)

At Hole 447, on the eastern side of the West Philippine Basin, only manganese nodules and unfossiliferous brown clay were recovered in the core catcher of Core 1. Recovery in Hole 447A was more successful: although Cores 1 to 4 (0–37.5 m) are barren of calcareous nan-

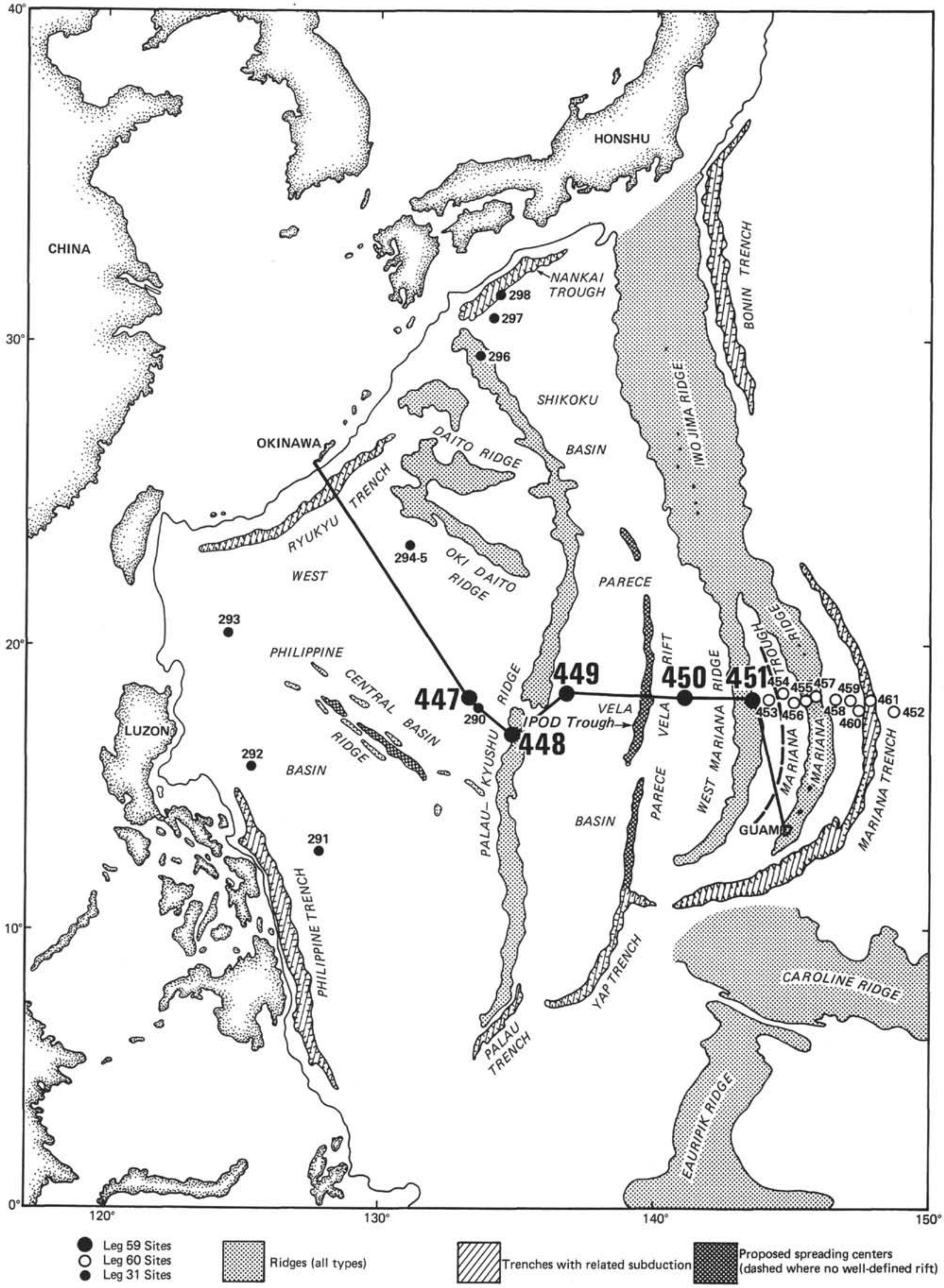

Figure 1. Location of sites drilled during Legs 59, 60, and 31.

			Leg 59	m.y.	Leg 60
Quaternary		NN 21	*Emiliania huxleyi* Zone	0.2	*E. huxleyi* Zone
Quaternary		NN 20	*Gephyrocapsa oceanica* Zone	0.6	*Gephyrocapsa oceanica* Zone
Quaternary		NN 19	*Pseudoemiliania lacunosa* Zone	1.8*	*G.caribbeanica* Zone; *E. annula* Zone
Pliocene	Upper	NN 18	*Discoaster brouweri* Zone	2.5	*Cyclococcolithus macintyrei* Zone
Pliocene	Upper	NN 17	*D.pentaradiatus* Zone	2.7	*D. pentaradiatus* Zone
Pliocene	Upper	NN 16	*D. surculus* Zone	3.5	*D. tamalis* Zone
Pliocene	Lower	NN 15	*Reticulofenestra pseudoumbilica* Zone		*D. asymmetricus* Zone
Pliocene	Lower	NN 14	*D. asymmetricus* Zone	4.0	
Pliocene	Lower	NN 13	*Ceralolithus rugosus* Zone	4.6	*S. neoabies* Zone; *C. rugosus* Zone
Pliocene	Lower	NN 12	*C. tricorniculatus* Zone	5.0*	*C. acutus* Zone; *T. rugosus* Zone
Miocene	Upper	NN 11	*D. quinqueramus* Zone	9.5	*C. primus* Zone; *D. berggrenii* Zone
Miocene	Upper	NN 10	*D. calcaris* Zone	11.0*	*D. neorectus* Zone; *D. bellus* Zone
Miocene	Middle	NN 9	*D. hamatus* Zone		*D. hamatus* Zone
Miocene	Middle	NN 8	*Catinaster coalitus* Zone	12.0	*Catinaster coalitus* Zone
Miocene	Middle	NN 7	*D. kugleri* Zone	13.0	*D. kugleri* Zone
Miocene	Middle	NN 6	*D. exilis* Zone	14.0	*Coccolithus miopelagicus* Zone
Miocene	Middle	NN 5	*Sphenolithus heteromorphus* Zone	17.0	*S. heteromorphus* Zone
Miocene	Lower	NN 4	*Helicosphaera ampliaperia* Zone	18.5	*Helicosphaera ampliaperta* Zone
Miocene	Lower	NN 3	*S. belemnos* Zone	19.0	*S. belemnos* Zone
Miocene	Lower	NN 2	*D. druggi* Zone	20.5	*D. druggii* Zone
Miocene	Lower	NN 1	*Triquetrorhabdulus carinatus* Zone	24.0*	*D. deflandrei* Zone; *Cyclicargolithus abisectus* Zone
Oligocene	Upper	NP 25	*S. ciperoensis* Zone	26.0	*S. ciperoensis* Zone
Oligocene	Upper/Middle	NP 24	*S. distentus* Zone	32.0	
Oligocene	Middle	NP 23	*S. predistentus* Zone	34.0	*S. distentus* Zone; *S. predistentus* Zone
Oligocene	Lower	NP 22	*H. reticulata* Zone	36.5	*Reticulofenestra hillae* Zone
Oligocene	Lower	NP 21	*Ericsonia? subdisticha* Zone	37.5*	*C. formosus* Zone; *C. subdistichus* Zone

Figure 2. Oligocene to Quaternary standard nannoplankton zonation used during Leg 59, correlation to nannoplankton zonation used during Leg 60, and indication of the estimated time relations (in m.y.) for the standard zonation. (Asterisks indicate generally agreed-upon ages of major boundaries.)

	Zones	447A	448	448A	449	450	451
Quaternary	NN 21						1
	NN 20						2
	NN 19						1–2
Upper Pliocene (Piacenzian)	NN 18						2
	NN 17						2–3
	NN 16						3
Lower Pliocene (Zanclian)	NN 15						4
	NN 14						4–5
	NN 13						
Upper Miocene (Tortonian-Messinian)	NN 12						5
	NN 11						5–20*
	NN 10						22–85*
Middle Miocene (Langhian-Serravallian)	NN 9		1			4–6	
	NN 8		1	1		7–8	
	NN 7		1	1		8–12	
	NN 6		1	1	6	13–18	
	NN 5		2–4	1	7	18–35	
Lower Miocene (Aquitanian-Burdigalian)	NN 4		4			?	
	NN 3		4		10–11		
	NN 2		5	2	11–12		
	NN 1		6–8	2–3	12–13		
Upper Oligocene (Chattian)	NP 25		10–12	4	13		
	NP 24	5–6	13–32*	5–6			
Middle Oligocene (Rupelian)	NP 23	7–9 11–12	33–51*	7–51*			
Lower Oligocene (Latdorfian)	NP 22						
	NP 21						

* = Calcareous nannoplankton not found in all cores of the listed interval. 7777777 = Contact with basement.

Figure 3. Calcareous nannoplankton stratigraphy of holes drilled during Leg 59. (Numbers refer to cores. * = calcareous nannoplankton not found in all cores of the listed interval. 777777 = contact with basement.)

noplankton, below a lithologic change between Cores 4 and 5, calcareous nannofossils are present from the top of Core 5 down to Core 12 (37.5–104.0 m), with the exception of Core 10 (85.0–94.5 m). The assemblages in most cases are poorly preserved and the specimens heavily etched. In Cores 5 and 6 *Sphenolithus ciperoensis* is present together with *S. distentus, S. predistentus, Coccolithus abisectus*, and *Dictyococcites dictyodus*, indicating the Oligocene calcareous nannoplankton Zone NP 24 (*S. distentus* Zone). The same assemblage is present in Cores 7 to 12, with the exception of *S. ciperoensis*; consequently these samples are placed in calcareous nannoplankton Zone NP 23 (*S. predistentus* Zone). *C. abisectus*, first occurring at about the same level as *S. ciperoensis* elsewhere and taken as a substitute species for defining the base of Zone NP 24 in high-latitude areas (Müller, 1976), is found in all samples down to Core 12, CC. A similar occurrence of these two species was noted by Ellis (1975) at the nearby Site 290 as well as at Site 296 and may be caused by the high accumulation rate in the area during that particular time interval. Table 1 presents the distribution of calcareous nannoplankton species in selected samples of Hole 447A.

In several samples older species, probably displaced from lower Oligocene deposits, such as *Reticulofenestra umbilica, Cyclococcolithus formosus*, and *Braarudosphaera bigelowi*, are found. This indicates continuous erosion in an adjacent area during this time. In Core 13, at a depth of 113.0 meters, we found basalt below middle Oligocene sediments; volcanogenic rocks were recovered in the remaining cores down to the terminal depth of 296.5 meters.

For the uppermost part of the sedimentary column, a Lamont piston core taken very close to Site 447 was available for inspection. Section 1 of Core V34-10 (18°18′N, 133°12′E, water depth 5899 m) contains brown clay, and samples taken at 13 cm, 50 cm, and 140 cm are barren of calcareous nannoplankton. In a sample from 98 cm, rare displaced Oligocene nannofossils are present.

The upper part of the sedimentary column in Hole 447A is closely similar to that at Hole 290, cored during DSDP Leg 31. At both sites unfossiliferous brown zeolitic clays, which are twice as thick at Hole 290 as in Hole 447A, are underlain by calcareous sediments with the calcareous nannoplankton Zone NP 24 (*S. distentus*

Table 1. Distribution of calcareous nannoplankton in selected samples from Hole 447A and indication of standard nannoplankton zones.

Samples (intervals in cm)	*Coccolithus abisectus*	*C. eopelagicus*	*C. pelagicus*	*Cyclococcolithus floridanus*	*Dictyococcites dictyodus*	*Discoaster deflandrei*-group	*D. tani*	*Helicosphaera euphratis*	*Reticulofenestra* sp.	*Sphenolithus ciperoensis*	*S. distentus*	*S. moriformis*	*S. predistentus*	*Braarudosphaera bigelowi*[a]	*Cyclococcolithus formosus*[a]	*Reticulofenestra umbilica*[a]	*S. pseudoradians*[a]	Preservation	Nannoplankton Zones
5-1, 35–36	×	×	○	●	×	○	×			×	×	×	×			×	×	P, M	
5,CC	×	×	○	●	×	○	×				×	○	×		×	○		P	
6-1, 20–21	×	×	×	○	×	×	×					×	×			×		P	NP 24
6,CC	●	○	×	●	○	○	○			cf.	●	○	●			×	×	P, M	
7-1, 5–6	○	○	×	●	○	○	×				×	×	○			×		P	
7,CC	×	×	×	○	○	×	×				×	×	○					P	
8,CC	×	×	×	●	○	○	×					×	○			×		P	NP 23
9-2, 0–2	○		×	○	○	×	×	×	○		×	×	×					P	
9,CC	×	×	×	○	○	×	×					×	×	×	×	×		P	
10-2, 8 10,CC	Barren																		?
11-1, 3–4	○	×	×	○	○	×			×		×	×						P	
11,CC	○	○	○	●	×	○	×		○		×	○	○			×	×	P, M	NP 23
12,CC	×	×		○	×				×			×				×		P	

Note: × = rare to few, ○ = common, ● = abundant. Preservation: P = poor, M = moderate, G = good. (See also Tables 2–4.)
[a] Reworked species.

Zone) at the top, grading downward into Zone NP 23 (*S. predistentus* Zone) in both holes. Core 12 of Hole 447A may actually be equivalent to part of Core 6 in Hole 290. At Hole 290 the oldest fossil found seems to date from the late Eocene or early Oligocene, but there is a discrepancy between the nannoplankton and radiolarian age determination (Karig, Ingle, Jr., et al., 1975). In Hole 447A displaced lower Oligocene nannofossils are noted throughout the middle Oligocene section, suggesting a continuous input of eroded material from lower Oligocene sediments. This might well apply to Site 290 also, where continuous mixing with upper Eocene radiolarian clays displaced from a nearby source seems to have occurred.

Site 448
(16°20.46′N, 134°52.45′E, depth 3483 m)

Hole 448, at the Palau-Kyushu Ridge, provided a continuous sequence from the middle Miocene (Zone NN 9—*Discoaster hamatus* Zone) to the middle Oligocene (Zone NP 23—*Sphenolithus predistentus* Zone). (For details and distribution of nannoplankton species in Hole 448, see Table 2.) The youngest basalt flow was encountered in Core 37 (337.5–347.0 m), which, according to the nannofossils, is middle Oligocene (calcareous nannoplankton Zone NP 23). Sediment lenses trapped within or between basalt flows in Cores 40, 48, 49, and 51 still contain nannofossils of Zone NP 23. Parts of Cores 20 to 27 (176.0–252.0 m) and Cores 36 to 65 (328.0 to the terminal depth of 583.5 m), with the exception of the trapped sediments mentioned earlier, are barren of calcareous nannoplankton.

Zones NN 6 (*D. exilis* Zone) through NN 9 (*D. hamatus* Zone) are present within Core 1 (0–5.0 m). The boundary between Zone NN 7 (*D. kugleri* Zone) and Zone NN 8 (*Catinaster coalitus* Zone) was cored twice, probably because of resampling or disturbance of material within the liner. Zone NN 5 (*S. heteromorphus* Zone) occurs in Cores 2 to the upper part of 4 (5.0 to approximately 30.0 m). Because the marker species that designates the top of Zone NN 4—*Helicosphaera ampliaperta*—is absent in this area, the first occurrence of *D. exilis* is used to identify tentatively the boundary between Zones NN 4 and NN 5 (Martini and Worsley, 1971). The preservation of discoasters at this level, however, is rather poor, and identifications are somewhat questionable. Displaced calcareous nannoplankton also seems to be present at certain levels between Samples 1,CC and 3,CC, given that *Orthorhabdus serratus, Triquetrorhabdulus carinatus*, and *S. belemnos* are found well above their last occurrences elsewhere (see Table 2). In Sample 5,CC *S. ciperoensis* and *S. distentus* occur in several specimens in calcareous nannoplankton Zone NN 2 (*D. druggi* Zone), also indicating the presence of reworked material from older strata at this particular level.

Sample 4,CC is tentatively placed in Zone NN 3 (*S. belemnos* Zone), although a few specimens of *T.* cf. *carinatus* were found, but because Core 5 (33.5–43.0 m) had a very low recovery rate, this zone might also be present in part of the unrecovered interval of Core 5. Zone NN 2 (*D. druggi* Zone) is present in Core 5; and Zone NN 1 (*T. carinatus* Zone) occurs in Cores 6 to 8 (43.0–71.5 m). The base of this zone, indicated by the

Table 2. Distribution of calcareous nannoplankton in selected samples from Hole 448 and an indication of standard nannoplankton zones.

Samples (intervals in cm)	*Catinaster calyculus*	*C. coalitus*	*Coccolithus abisectus*	*C. eopelagicus*	*C. miopelagicus*	*C. pelagicus*	*C. radiatus*	*C.* sp.	*Coronocyclus. nitescens*	*Cyclococcolithus floridanus*	*C. leptoporus*	*C. macintyrei*	*C. rotula*	*Dictyococcites dictyodus*	*Discoaster brouweri*	*D. calcaris*	*D. challengeri*	*D. deflandrei*	*D. druggi*	*D. exilis*	*D. formosus*	*D. hamatus*	*D. kugleri*	*D. neohamatus*	*D. pseudovariabilis*	*D. tani nodifer*	*D. tani ornatus*	*D. variabilis*	*Discolithina* sp.
1-1, 60–61[a]	○	●				●					×				○	×	×					×		×	×			●	
1-1, 115	×	○			×	●					×					cf.	cf.			×			×		cf.			●	
1-1, 125					×	○					×		×		×		cf.	×		×			○					●	
1-1, 145					×	○					×	×					cf.	cf.		○								●	
1,CC			×		×	○			○	×	×	×			cf.		cf.	○		●								○	
2-1, 5–6			○		×	×			×	●		×						○		○								○	
2,CC			●		×	×			×	●								●		×									
3,CC			●		×	×			×	●		cf.						●		×									
4-2, 0–1			●			×			×	●								●		×									
4-3, 0–1			●		×				×	●			×					●	×	×									
4-4, 0–1			●		×		cf.		×	●								●	×	○	cf.								
4-6, 0–1			○						×	●								●	×										
4,CC			×		×		cf.	×	×	●								●	×										
5-1, 0–1			●					×	×	●								●	○										
5,CC			○		×	×		×	×	●								●	×										
6-1, 2			○		○	×		×	×	●								●											
6,CC			●		×			×	×	●								●											
7,CC			●	○	×	×			×	●								●											
8,CC			○	×	×	×			×	●								●											
10-2, 6–7			●	○	×	×			×	●								○											
10-3, 1–2			●	×		×			×	●								●											
11,CC			○	×		×				●				×				●											
12,CC			●	×		×			×	●				cf.				●											
13-1, 37–38			●	○		×			×	●								●											
13-4, 6–7			●	○		×			×	●				×				●											
14,CC			●	×		×			×	●				×				●											
15,CC			●	○		×			×	●				×				○								cf.			
16,CC			●	○		×			×	●				×				○											×
17,CC			×	×		×			×	●				×				○											
18,CC			○	○		×				●								×											
19,CC			×	○		×			×	●				×				○								×	×		
20-2, 27–29[a]			×	×		×			×	●				×				×											×
23,CC			×	×		×			×	○				×				×									×		
25,CC																													
27,CC																													
28,CC			×	×		×			×	○				×				×								×	×		
30,CC			×	×		×			×	●				×				×											
31,CC			○	×		×			×	●				×				×								×			
32,CC			○	×		×			×	●				×				×								×			
33,CC			○	×		×			×	●				×				×								×			
34,CC			○	×		×				●				×				×								×	×		
35,CC			○	×		×				○								×											
40,CC			×	×		×				×																			
48-3, 97			×	×		×				×																			
49-1, 60–66			×	×		×				○								×											
51-3, 110			×	×		×				×																			

Note: D = displaced from older strata.
[a] Scanning electron microscope (SEM)-studied samples.

last occurrence of *S. ciperoensis*, is taken as the Oligocene/Miocene boundary. Core 9 (71.5–81.0 m) had no recovery.

Zone NP 25 (*S. ciperoensis* Zone) is identified from the top of Core 10 down to Core 12 (approximately 81.0–109.5 m), where the last occurrence of *S. distentus* is noted. As in Site 447 the first specimens of *S. ciperoensis* and *Coccolithus abisectus* do not occur at the same level. This may be partly due to the high sedimentation rate, which would tend to separate these first occurrences, generally reported at approximately the same chronological level (Müller, 1970). The part that contains *S. ciperoensis* is identified as Zone NP 24 (approximately 109.5–299.5 m) and that without *S. ciperoensis*, but still containing *C. abisectus*, is labelled NP 23 (below 299.5 m). In Section 2 of Core 20 a sudden occurrence of *Scyphosphaera* species is noted.

Zygrhablithus bijugatus, which has its last occurrence in Sample 10-2, 6–7 cm, is most common in Cores 16 to 18 (138.0–166.5 m). This form is also present with changing frequency in cores below that level. *Z. bijugatus* is a neritic species and is commonly found in abundance in "near-shore" environments. Similar occurrences of *Z. bijugatus* were previously reported from the upper Oligocene of the Rockall Plateau (Leg 12, Perch-Nielsen, 1972), Iceland-Faeroe Ridge (Leg 38, Muller, 1976), and Reykjanes Ridge (Leg 49, Martini, 1979); such findings indicate the relatively shallow position of these areas, which can also be postulated for the area around Site 448 during part of the Oligocene.

Table 2. (Continued).

Ericsonia fenestrata	*Hayaster perplexus*	*Helicosphaera carteri*	*H. compacta*	*H. euphratis*	*H. intermedia*	*H. recta*	*Orthorhabdus serratus*	*Orthozygus aureus*	*Pontosphaera* sp.	*Reticulofenestra pseudoumbilica*	*R.* sp. (small)	*Scyphosphaera apsteini*	*S. recurvata*	*Sphenolithus abies*	*S. belemnos*	*S. capricornutus*	*S. ciperoensis*	*S. delphix*	*S. dissimilis*	*S. distentus*	*S. heteromorphus*	*S. moriformis*	*S. predistentus*	*S. pseudoradians*	*Triquetrorhabdulus carinatus*	*T. milowii*	*T. rugosus*	*Zygrhablithus bijugatus*	Preservation	Nannoplankton Zones
										×																	○		G	NN 9
										○	×																×		G	NN 8
										○	×																○		G	NN 7
										○												×					×		G	NN 6
	×	×					D		×	○				×								×			D				G	
	×								×												●	×							M	
							D								D						●	×							M	
	×														D						●	×							M	NN 5
																					●	×							M	
							×														○	×							M	
				cf.			×		×												●	○							M	
	×			×			×														×	×							M	NN 4
							×								×			×			○	×			cf.				M	NN 3
							×								cf.			○				×			×				M	NN 2
							×								cf.		D	×	×	D		○			○				M	
											×				cf.				●			○			○	×			M, P	
											×					×			○			●			×	×			M, P	NN 1
				×												cf.			○			○			×	×			M, P	
									cf.										○			○			○				M, P	
×				×					cf.								×		cf.			●			●	×		cf.	M, P	
				×												cf.	×		cf.			●			○	×			M, P	NP 25
											×						●		cf.			●			×			cf.	M, P	
cf.											×						○		cf.			●			×	×		×	M, P	
×				×							×						○			×		●							M, P	
×											×						○			●		●	○		cf.				M, P	
×									cf.								○			○		●	×						M, P	
×																	○			○		●	○					×	M, P	
×																	○			●		●	●	×				○	M, P	NP 24
×				×	×						×						○			●		○	●	×				○	M, P	
×											×						○			○		○	○	×				×	M, P	
×			×	×													○			●		×	○	×					M, P	
○			×	○	×						●	×	○				×			●		○	●	×				×	M, P	
×			×														×			○		×	○					×	M, P	
				Barren																										?
×			×								×						×			×		○	○	×					M, P	
×			×	×							×						×			×		○	○					×	M, P	NP 24
×			×														cf.			×		×	●	×				×	M, P	
×			×														×			×		○	○	×				×	M, P	
×			×																	×		○	●	×				○	M, P	
×			×	×		cf.					×		×							×		×	○	×				×	M, P	
×			×		×						×									×		×	×					×	P	
								×														×	×					cf.	P	NP 23
			×	×							×									×		×	×					×	P	
×			×		×						×									cf.		×	○						P	
											×											×						cf.	P	

Below the highest basalt flow in Core 37, trapped sediment lenses are found within or between basalt flows in Cores 40, 48, 49, and 51 containing calcareous nannoplankton assemblages of Zone NP 23 (*S. predistentus* Zone).

Preservation of calcareous nannoplankton is fairly good in Core 1; below this, specimens are slightly etched and discoasters are more or less heavily overgrown by calcite, which is also true for *Z. bijugatus* in the Oligocene. Poor preservation is generally noted in the lowest sediment layers as well as in sediments trapped within or between basalt flows.

Again, from a nearby site a Lamont piston core was available for comparison. Core V34-13 (16°12′N, 134° 44.5′E, water depth 3325 m) has a total length of 384 cm and contains abundant calcareous nannoplankton. The assemblages are dominated by discoasters; also *Ceratolithus* species are fairly common, whereas other genera are almost missing, probably because of dissolution. The lower part of the core (Samples 284 cm, 325 cm, 384 cm) belongs to Zone NN 11 (*Discoaster quinqueramus* Zone), with the nominate species especially common in the two lower samples. Samples from 70 cm 136 cm, 145 cm, and 200 cm may represent the lower Pliocene, as *D. surculus, D. variabilis,* and *D. brouweri* are abundant in all samples, but because other genera are missing a precise age determination is not possible. *Ceratolithus cristatus* and *C. telesmus* present in the higher samples may represent contamination from the uppermost part. The highest sample taken (at 5 cm) contains a mixture of fairly well-preserved calcareous nannoplankton of Zone NN 21 (*Emiliania huxleyi* Zone), including the nominate species and a solution-affected, discoaster-enriched nannoplankton assemblage probably of the early Pliocene.

Another Lamont piston core from about the same longitude, but 7° to the north, was investigated for discoasters by Takayama (1969). In Core V21-98 (23° 06′N; 134°26′E, water depth 2134 m) abundant *D. brouweri, D. pentaradiatus,* and *D. surculus* were found between 210 and 517 cm, indicating the Pliocene (Zone NN 16 or older) for this particular interval. Because coccoliths were not studied at this time, additional data are not available for this core.

Hole 448A

At Hole 448A, an attempt was made to recover material from the poorly represented intervals of Hole 448. Core 1 (0–5.0 m) contains well-preserved calcareous nannoplankton dominated by discoasters of Zone NN 8 (*Catinaster coalitus* Zone) at the top through NN 5 (*Sphenolithus heteromorphus* Zone) at its base. In Hole 448A the level equivalent to Sample 448-5 was successfully sampled in Core 2 (33.5–43.0 m), but nannoplankton found belong to the lower Miocene Zone NN 1 (*Triquetrorhabdulus carinatus* Zone), with the exception of the uppermost part, which can be placed in Zone NN 2 (*Discoaster druggi* Zone). The Oligocene/Miocene boundary, as indicated by the calcareous nannoplankton, is between Cores 3 and 4 at a depth of approximately 71.5 meters. Nannoplankton assemblages in samples from the Oligocene Zones NP 25 (Core 4, 71.5–81.0 m), NP 24 (Cores 5 and 6, 223.5–237.0 and 252.0–261.5 m, respectively), and NP 23 (Cores 7 to 9, 261.5–290.0 m) and in the sediment layers between basalt (Cores 13, 26, 49, and 51) or out of casts in breccias (Core 42) do not differ from those found in Hole 448. The core-catcher material of Core 6 seems to be heavily contaminated by material caved in from uphole. The Zone NP 25 assemblage in the core catcher must be displaced, because a Zone NP 24 assemblage overlies it in Section 3 of Core 6. Sphenoliths with long projections are abundant in the *S. predistentus-S. distentus-S. ciperoensis* group, and this aspect seems to follow a distributional trend. The hole was terminated in basalt at 914.0 meters (Core 66).

Site 449
(18°01.84′N, 136°32.19′E, depth 4712 m)

In Hole 449, in the Parece Vela Basin, the cores down to the upper part of Core 6 (approximately 42.5 m), as well as the interval between Core 8 and the upper part of Core 10 (57.0–83.5 m), are barren of calcareous nannoplankton, with the exception of reworked late Oligocene nannoplankton including *Sphenolithus ciperoensis* in Core 4. Basalt was encountered in Core 14 at 111.0 meters down to the terminal depth of 151.5 meters.

Discoasters dominate the calcareous nannoplankton assemblage in the lower part of Core 6, which can be placed in the middle Miocene Zone NN 6 (*Discoaster exilis* Zone). Samples from Core 7 contain rare *S. heteromorphus*, indicating Zone NN 5 (*S. heteromorphus* Zone). Calcareous nannoplankton in the lower part of Core 10 and in the upper part of Core 11 are strongly etched, resulting in a selective preservation of shields of only sturdy species and of heavily overgrown discoasters. The poor preservation of this reduced assemblage does not allow a precise age determination, but the lower Miocene Zone NN 3 (*S. belemnos* Zone) may be represented by part of this interval. Below Core 11 (85.5–95.0 m), assemblages are less affected by dissolution and are well-diversified, especially in the lower Miocene Zones NN 2 (*D. druggi* Zone)—between Samples 11-6, 10–11 cm and 12-1, 14–15 cm—and NN 1 (*Triquetrorhabdulus carinatus* Zone)—between Samples 12-2, 12–13 cm and 13-5, 14–15 cm. The same applies for the upper Oligocene Zone NP 25 (*S. ciperoensis* Zone), which is encountered at the base of Core 13 above the basalt. Sphenolith-dominated tropical assemblages are present in Zone NN 1, including *S. delphix* and *S. capricornutus.* A similar assemblage, but also including *D. druggi*, appears in the core catcher of Core 14 below basalt, representing lower Miocene material caved in from above.

Preservation of the calcareous nannoplankton assemblages indicates a deposition above the CCD in the late Oligocene and earliest Miocene, with a subsequent subsidence of the area below the CCD in the late early Miocene. During a relatively short period in the middle Miocene, deposition took place around the CCD, but was well below it again from the late middle Miocene onward.

Site 450
(18°00.02′N, 140°47.34′E, depth 4707 m)

The sediments from Hole 450, in the Parece Vela Basin, consist of brown pelagic clay overlying the ash-rich sediments. Basalt occurs in Core 36, at 330 meters sub-bottom. (For details and fossil content of the site, see Table 3.)

Cores 1 to 5 (0–45.5 m) are barren of calcareous nannoplankton, with the exception of the lowest part of Core 4 and the upper part of Core 5. Here a poorly to moderately preserved nannoplankton assemblage is present, including *Discoaster hamatus, Catinaster calyculus, D. bollii*, and common *D. calcaris* and *D. neohamatus*. This assemblage seems to belong to Zone NN 9 (*D. hamatus* Zone). However, the rather common occurrence of *D. calcaris* and *D. neohamatus* may indicate displaced material from Zones NN 9 and NN 10 (*D. calcaris* Zone) within the unfossiliferous pelagic clay.

From Core 6 downward, calcareous nannoplankton is continuously present. The following middle Miocene zones were identified: NN 9 (*D. hamatus* Zone) in Core 6 (45.5–55.0 m), NN 8 (*C. coalitus* Zone) in Core 7 and the upper part of Core 8 (55.0 to approximately 66.5 m), NN 7 (*D. kugleri* Zone) in the lower part of Core 8 down to Core 12 (approximately 66.5–112.0 m), NN 6 (*Discoaster exilis* Zone) in Core 13 to the upper part of Core 18 (112.0 to approximately 163.0 m), and NN 5 (*Sphenolithus heteromorphus* Zone) in the lower part of Core 18 to the upper part of Core 35 (approximately 163.0 to approximately 324.0 m).

Table 3. Distribution of calcareous nannoplankton in selected samples from Hole 450 and indication of standard nannoplankton zones.

Samples (intervals in cm)	*Catinaster calyculus*	*C. coalitus*	*Coccolithus abisectus*	*C. pelagicus*	*C. radiatus*	*Cyclococcolithus floridanus*	*C. jafari*	*C. leptoporus*	*C. rotula*	*Discoaster bollii*	*D. brouweri*	*D. calcaris*	*D. challengeri*	*D. deflandrei*	*D. exilis*	*D. hamatus*	*D. kugleri*	*D. neohamatus*	*D. pentaradiatus*	*D. variabilis*	*Discolithina callosa*	*D. multipora*	*Helicosphaera carteri*	*H. euphratis*	*Reticulofenestra pseudoumbilica*	*R.* sp. (small)	*Rhabdosphaera* sp.	*Scyphosphaera apsteini*	*Sphenolithus abies*	*S. heteromorphus*	*S. moriformis*	Reworking	Preservation	Nannoplankton Zones
1-1 to 4-5																Barren																		?
4,CC[a]	×			×				×		×	●	○				×		○	×	●													M	NN 9
5-2, 60–61[a]	○			×				×		×	●	○				×		○	×	●													M	
5-3, 60–61																Barren																		?
5,CC																																		
6-1, 14–15[a]	○	×		×				×			×					×		×		●					×			×					M	NN 9
6,CC[a]	○	×		×			×	×			○		×			×				●			×		×	×			×				M	
7,CC	○	○		×	×			×	×		○		×		×					●			×	×	×	×		×	×				M	NN 8
8-2, 38–39		×		×									×		○					○					×	×			×				M	
8,CC				×	×		×	×	×		×		×		×		×			○			×		×	×	×		×		×		M	NN 7
10,CC				○	×			×	×		×				○		×			●			×		×	×			×		×	×	M	
11,CC				×				×			×				○		×			○			×		×	×			×		×		M	
12,CC				×	×			×			×				○		×			×			×		×	×			×			×	M	
13-3, 19–20				×			×	×			×			×	○					×			×		×	×			×				M	NN 6
14,CC				×	×		×							×	○					×		cf.	×		×	×			×			×	M	
16,CC			×	×	×	×	×				×		×	×	○					×	×	×	×	×	×	×		cf.	×		×		M	
18-3, 39–42			×	×	×		×		×		cf.		×	×	×					×			×		×	×		cf.	×		×		M	
18-5, 41–44			×		×	×								×	○					●					×	×				×	×		M	NN 5
19,CC				×			×		×					×	×					×	×		×		cf.	×			×	×	×		M	
20,CC			×	×	×	×	×	×						×	○					○		×	×	×	○	×			×	×	×		M	
23,CC			○	×	×	○		×						×	○					○	×		×	×	×	○				×	×		M	
26,CC			○	×	×	○	×							×	○					○		cf.	×	×	×	×				×	×		M	
30,CC			×	×		○	×							×	×					×			×		×	×				○	×		M	
33,CC			○	×		●	×							×	×					×			×	×	×	○				●	×		M	
35-1, 74–75			×	×		○								×	○					×										×			P	
35,CC																Barren																		?
36-2, 86–87																																		

[a] SEM-studied samples.

Preservation in this sequence is fairly good, with discoasters only slightly overgrown by calcite, probably owing to the high ash content of the sediment. In the lowest part (Cores 34 and 35), however, the calcareous nannofossils are strongly etched and only the more solution-resistant parts are preserved. The lower parts of Cores 35 and 36 are again barren of calcareous nannoplankton.

Site 451
(18°00.88′N, 143°16.57′E, depth 2060 m)

At Site 451 on the West Mariana Ridge, foraminiferal–nannoplankton ooze is present down to Core 5 (33.5–43.0 m). Foraminiferal-bearing nannoplankton ooze and marly nannoplankton chalk are found below. These oozes and chalks are interbedded with volcanic ash and vitric tuff, which occur with increasing frequency downhole. Volcanogenic sediments dominate in the lower part of the hole (where biogenic sediments form a minor constituent); a volcaniclastic breccia is present at the terminal depth of 930.5 meters.

In this hole there is a complete succession from the upper Quaternary calcareous nannoplankton Zone NN 21 (*Emiliania huxleyi* Zone) down to the lower upper Miocene Zone NN 10 (*Discoaster calcaris* Zone). (For details and distribution of calcareous nannoplankton species in this hole, see Table 4.) At approximately the middle of lithologic Unit 2 (at about 50 m), a remarkable change in the accumulation rate from rapid to slow seems to have taken place—if one compares the first occurrence of *Ceratolithus primus* with the first and last occurrence of *D. quinqueramus* in this section.

In the part with slow deposition, calcareous nannoplankton Zone NN 21 (*E. huxleyi* Zone) is present in Sample 1-2, 1–2 cm, with common *E. huxleyi* identified with the scanning electron microscope. Sample 1-3, 1–2 cm is placed in Zone NN 20 (*Gephyrocapsa oceanica* Zone), and Sample 1, CC belongs to Zone NN 19 (*Pseudoemiliania lacunosa* Zone), as indicated by the presence of *P. lacunosa* in this sample and below. *D. brouweri* was first encountered in Sample 2-4, 8–9 cm and *D. pentaradiatus* in Sample 2-6, 8–9 cm, indicating the presence of Zone NN 18 (*D. brouweri* Zone) and Zone NN 17 (*D. pentaradiatus* Zone). The core-catcher sample of Core 2 contains a well-preserved and diversified nannoplankton assemblage, including *Umbellosphaera tenuis*, besides species listed for Sample 1-2, 1–2 cm in Table 4. In Sample 3-2, 9–10 cm and below, *D. surculus* was noted and consequently placed together with Sample 3, CC, which is still above the last occurrence of *Reticulofenestra pseudoumbilica* in Zone NN 16 (*D. surculus* Zone). Standard nannoplankton Zone NN 15 (*R. pseudoumbilica* Zone) is present in most of Core 4, which contains common *R. pseudoumbilica* and *Sphenolithus abies*. The lower part of Core 4 and the uppermost part of Core 5 is placed in the combined Zone NN 13/14, because *D. asymmetricus* was not found (as discussed previously in the nannoplankton zonation section). Sample 5-2, 9–10 cm contains neither *D. quinqueramus* nor *C. rugosus*; it represents Zone

Table 4. Distribution of calcareous nannoplankton in selected samples from Hole 451 and indication of standard nannoplankton zones.

Samples (intervals in cm)	*Acanthoica* sp.	*Aspidorhabdus stylifer*	*Catinaster calyculus*	*Ceratolithus cristatus*	*C. delicatus*	*C. primus*	*C. rugosus*	*C. telemus*	*C. tricorniculatus*	*Coccolithus miopelagicus*	*C. pelagicus*	*C. radiatus*	*C.* sp.	*Coronosphaera mediterranea*	*Cyclococcolithus jafari*	*C. leptoporus*	*C. macintyrei*	*C. rotula*	*C.* sp.	*Discoaster brouweri*	*D. calcaris*	*D. challengeri*	*D. neohamatus*	*D. pentaradiatus*	*D. pseudovariabilis*	*D. quinqueramus*	*D. surculus*	*D. variabilis*	*Discolithina callosa*	*D. multipora*	*Emiliania huxleyi*	*Gephyrocapsa* sp.	*G. aperta*	*G. oceanica*
1-2, 1-2[a]		×		×				×											×												○		●	○
1-3, 1-2[a]				×				×				×				cf.			×														●	●
1,CC								×				×				×			×											cf.			○	●
2-3, 29-30[a]							○					×		cf.		○			×													○		
2-4, 8-9[a]							○					×		cf.		×	×			○												○		
2-6, 8-9[a]							×				×	○				×	×		×	○				○								○		
3-1, 9-10							×					×				×	×			○				○								○		
3-2, 9-10							×				×	×				○	×			●				○			○					●		
3,CC							×					×				○	×			○				○			●					○		
4-1, 9-10							×									○				●				●			●	×						
4-5, 9-10							×					×				○			×	○				●			●	×		×				
4-6, 9-10					×		×		×			×				×			×	○		×		●			○	×						
5-1, 9-10							×				×	×				×				○				●			○							
5-2, 9-10					×	×					×		×			×	×			○		×		○			○	●						
5-3, 9-10											×		×			×	×	×		●		×		○		○	●	●						
5,CC						×					×	×				×	×	×		●		×		○	×	○	●	○	×					
6,CC										×	×	×					○	×		○		×		×	×	●		×						
7,CC											×	×					×			○						○		×		×				
10,CC	×										×	×					×	×		●						●		○						
14,CC											×						×	×		○	×	×				●		×						
20,CC	×										×	×					×	×		×	×					cf.		○		×				
22,CC										×	×	×					×	×		×								×		×				
25,CC											×	×					×	×		○	×							○						
38-2, 74-76											×	×					×			×								×						
63-2 109-110										×	×	×			cf.		×			○	×		×					○						
78-3, 49			×							×	○	×					×	×		○	×	×	×	cf.				○						
85-4, 91-92			×								×	×					×			×	×							○		×				
94-2, 60-67																																Barren		

[a] SEM-studied samples.

NN 12 (*C. tricorniculatus* Zone), although the nominate species was not found. *D. quinqueramus* is present in Sample 5-3, 9-10 cm and below, indicating the presence of the *D. quinqueramus* Zone (NN 11). The first occurrences of ceratoliths are noted in Sample 5,CC, probably just above the change in the accumulation rate from rapid in the lower part to slow in the upper part of the cored section. The NN 11 assemblage is found from the lower part of Core 5 probably to Core 20 (36.5–185.5 meters), although the lower part of this succession is obscured by nonrecovery and barren intervals. In Core 22 and downward to Core 64, several layers contain poorly preserved nannoplankton assemblages, which may belong to Zone NN 10 (*D. calcaris* Zone), because neither *D. quinqueramus* (first occurrence = base of Zone NN 11) nor *D. hamatus* (last occurrence = top of Zone NN 9) are found in the volcanogenic sediment. The basal part of Zone NN 10 is reached in Cores 78, 80, and 85 where *Catinaster calyculus* is present. Some levels contain only solution-resistant forms inadequate for precise age determination.

The preservation of calcareous nannoplankton in Cores 3 to 14 is fair, and it is good in the two uppermost cores, which were also investigated by scanning electron microscope techniques (see samples specified in Table 4). From Core 20 downward, preservation in the nannoplankton-bearing layers is poor, especially in the last fossiliferous Sample 85-4, 91-92 cm.

PERFORATIONS AND ETCHING MARKS

In a specimen of *Hayaster perplexus* found in Sample 451-2-1, 43-44 cm (Quaternary, nannoplankton Zone NN 19), a circular perforation was noted in one of the segments (Plate 4, Fig. 2). Similar perforations have already been referred to in an earlier paper. (Martini, 1976, Plate 10, Figs. 7, 8). In that case the distal shield of a *Cyclococcolithus leptoporus* specimen, observed in Sample 317-1-1, 5-6 cm (Quaternary, nannoplankton Zone NN 21), was penetrated by two holes. The position and appearance of these holes cannot be correlated to any solution or etching pattern. They were probably caused by bacteria, which seem to be able to penetrate coccoliths as well as other calcareous objects after deposition, as indicated by recent investigations in the Eocene Monte Bolca layered chalks (H. Keupp, personal communication, Erlangen).

Triangular depressions on the surface of specimens of *H. perplexus, Oolithotus fragilis*, and *Triquetrorhabdulus rugosus* found in Holes 448 (Cores 1 and 2) and 451 (Core 1) seem to represent etching marks. In Hole 451 the interval in which the triangular marks were found on *H. perplexus* and *O. fragilis* belongs to nannoplankton Zones NN 17 to NN 21 (late Pliocene to Recent). The depressions are found only on these species, and although other species are still well preserved, these show secondary growth of calcite with well-developed crystal faces in each segment of shields (Plate 4, Fig. 2). In Hole 448, specimens of *T. rugosus* with these marks (Plate 3, Fig. 12) are found in the uppermost part of Core 1 (Miocene, nannoplankton Zone NN 9), where a solution-affected and discoaster-enriched calcareous nannoplankton assemblage is present. These negative marks as well as those found in *H. perplexus* and *O. fragilis* seem to follow the trigonal symmetry of calcite

Table 4. (Continued).

Hayaster perplexus	*Helicosphaera carteri*	*H. euphratis*	*H. hyalina*	*H. sellii*	*Oolithotus fragilis*	*Pontosphaera* sp.	*P. alboranensis*	*P. discopora*	*Pseudoemiliania lacunosa*	*Reticulofenestra pseudoumbilica*	*R.* sp. (small)	*Rhabdosphaera clavigera*	*Scapholithus fossilis*	*Scyphosphaera* sp. (base)	*S. amphora*	*S. ampla*	*S. apsteini*	*S. campanula*	*S. conica*	*S. globulata*	*S. pulcherrima*	*S. recta*	*S. turris*	*S.* sp.	*Sphenolithus abies*	*S. moriformis*	*Syracosphaera* sp.	*S. pulchra*	*S. ribosa*	*Triquetrorhabdulus rugosus*	*Umbellosphaera irregularis*	*Umbilicosphaera mirabilis*	*U. sibogae*	Preservation	Nannoplankton Zones
	○		×	×	×	×						○	×														×	×			×		×	G	NN 21
×	○		×	○		×						○	×	×													○	×			×			G	NN 20
	○				×	×	×	×	○			×	×	×			×							×			○	cf.	×					G	NN 19
	○		×			×		×	●			×		×		cf.	×				×						○					×		M	
	●		cf.			×	×	×	●			×				×	×					×					○					×		M	NN 18
×	○					×			●			×		×							×	×					×							G	NN 17
×	○					×			●					×							cf.						×							M	
	×					×			●			×		×						×	×	×					○							M	NN 16
	×								○		○			×						×	×	×					×							M	
	×					×				○	○				×		×			○	○	×	×		○									M	NN 15
	×					×				○	×						×			×					○		×							M	
	×									○	×									×					○		×							M	NN 13/14
	×									×	×										×				×									M	
	×									×	○						×					×			○									M	NN 12
	×									×	○			×											●									M	
	×									×	●														●									M	
	○										×	×									×				●									M	NN 11
	○	×				×					×			×			×				×	×			●					×				M	
	○	×				×				×	×			×			×				×	×			●	×								M	
	●	×				×					○			×							×				●									M	
×	○	×				×					×			×			×				×	×		×	●	○								P	
											×			×				×	×		×				○	○								P	
	×									×				×											×									M	
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and are aligned in a pattern that agrees with the general orientation of calcite-crystal development in these specimens.

SCYPHOSPHAERA SPECIES IN THE OLIGOCENE

Scyphosphaera species were reported to occur sporadically in the Eocene by Bramlette and Sullivan (1961), Stradner (1969), and Bukry and Percival (1971). In the Oligocene the genus seems to be fairly rare but was described from Trinidad by Bramlette and Wilcoxon (1967). With the middle Miocene, the genus *Scyphosphaera* shows a rapid development of different species and was described by various authors (e.g., Jafar, 1975; Rade, 1975) as common and diversified, especially in the upper Miocene and lower Pliocene of many regions. A few species including the long-ranging *S. apsteini* are living in the present oceans.

In the Oligocene part of the Cipero Formation of Trinidad, *S. apsteini* is rare to few in samples from the *Sphenolithus predistentus* Zone (NP 23), *S. distentus* Zone (NP 24), and *S. ciperoensis* Zone (NP 25), according to Bramlette and Wilcoxon (1967) and our own observations. During Leg 59 a sudden occurrence was noted in Core 20 of Hole 448 on the Palau-Kyushu Ridge. In Section 2, in samples between 27 and 29 cm *Scyphosphaera recurvata* is common and is associated with a few specimens of *S. apsteini*. The level in which these *Scyphosphaera* species occur also contains *Sphenolithus ciperoensis* and *S. distentus* and accordingly can be placed in Zone NP 24 (*S. distentus* Zone). Rare *Scyphosphaera recurvata* are also noted in Sample 448-34,CC, which, on the basis of the nannoplankton assemblage found, belongs in Zone NP 23 (*Sphenolithus predistentus* Zone) of the standard nannoplankton zonation. All other occurrences of members of the genus *Scyphosphaera* found during Leg 59 are from the middle Miocene to late Pliocene interval. As discussed in the foregoing summary of Hole 448, the area around this site may have been in a relatively shallow position during part of the Oligocene, which includes the interval in which the *Scyphosphaera* species are found. Sphenoliths with long projections are also abundant in several samples of this interval, possibly indicating relatively warm surface waters at that time.

The stratigraphic extension of *S. recurvata* from the Miocene into the middle Oligocene should result in a correction of the phylogenetic lineages within the genus *Scyphosphaera* published by Rade (1975), because *S. recurvata* occurs much earlier than was formerly known and seems to be closely related to *S. apsteini* rather than originating from *S. expansa* line.

EVOLUTIONARY TRENDS IN THE GENUS *CATINASTER*

The genus *Catinaster* and two species were first described in 1963 by Martini and Bramlette as occurring in the middle Miocene of Trinidad, in the experimental Mohole cores, and in a Lamont piston core. They noted two main features: the relatively short distribution time and partial overlap of the two species; and a certain trend in *C. calyculus* to increase the length of rays in the upper range of its stratigraphic occurrence. With the initiation of the Deep Sea Drilling Project, more continuous sections became available, and *C. coalitus* was among the species used in the nannoplankton zonation of Bramlette and Wilcoxon (1967), which was later incorporated into the standard nannoplankton zonation (Martini, 1971).

The stratigraphic range of the genus *Catinaster* seems to be restricted to the middle upper Miocene. The first species to occur is *C. coalitus*, which is designated as the index species to define the base of standard Zone NN 8 (*C. coalitus* Zone). The genus *Catinaster* seems closely related to the genus *Discoaster*, but the link between both is not yet known, although the *D. musicus* group seems to be the best group to look at for such a link. The estimated duration of time for Zone NN 8 is very short and may be only 0.2 m.y. Within these limits the second important species—*C. calyculus*—develops from *C. coalitus*, and both are present together in the upper part of Zone NN 8 as well as in most of the following Zone NN 9 (*D. hamatus* Zone), which probably has a duration of 1 m.y. The last occurrence of *C. coalitus*, as evidenced by many deep-sea cores, is between the first occurrence of *D. bollii* and the last occurrence of *D. hamatus*, whereas *C. calyculus* reaches into Zone NN 10 (*D. calcaris* Zone) and has its last occurrence at the same level or shortly above the last occurrence of *D. bollii*.

Bukry (1971b) described another species of the genus *Catinaster*—from the upper Miocene of DSDP Site 3 in the Gulf of Mexico—as *C. mexicanus*. More details on the occurrence of this new species were later published by Ellis, Lohman, and Wray (1972); according to their Table 1 it occurs only together with *C. coalitus*. This leaves some doubt about the correct position of Core 9 of DSDP Hole 3 in the stratigraphic column, because it was placed on the basis of a single specimen. This specimen was believed to represent *D. quinqueramus* in the upper part of Zone NN 11 (*D. quinqueramus* Zone) and in Zone NN 12 (*Ceratolithus tricorniculatus* Zone) and was found during scanning electron microscope (SEM) studies in Sample 3-9-6, 145 cm. If one could exclude the possibility of displaced older material, this core seems to include Zone NN 8 (*Catinaster coalitus* Zone) and represents part of the middle Miocene.

Another strange occurrence of *C. mexicanus* was reported by Müller (1974) from Leg 25 in the western Indian Ocean. In Sample 241-7,CC, this species is quite abundant, but it was not found in any sample uphole or downhole. The sample was placed in the Pliocene Zone NN 15 (*Reticulofenestra pseudoumbilica* Zone). However, it was stated by Muller that the bifurcation of rays from the outer perimeter seems to be less distinct than Bukry described for the species from DSDP Hole 3. Obviously this species needs some additional and detailed study.

Ellis, Lohman, and Wray in 1972 published an SEM picture (Plate 10, Fig. 1) that seems to indicate that *C. mexicanus* originated from *C. coalitus*. As stated earlier, *C. calyculus* developed from *C. coalitus* by extending the six rays of the distal side beyond their former bifurcation point at the rim of *C. coalitus* (compare Plate 3, Figs. 1, 4, 5). These rays are straight and short in specimens from the lower part of the range of *C. calyculus*. There is a continuous development to long and somewhat curved rays toward the end of the range of this species as shown in Plate 3, Figs. 5, 6, 8, 9 and Plate 5, Figs. 3 to 6. This trend was consistently observed in several deep-sea cores with a high accumulation rate. Mixture of short- and long-rayed forms may be an indication of a very low accumulation rate or reworking and displacement, as in the lower part of Core 4 and the upper part of Core 5 of Hole 450 (compare site summaries).

The three species included in the genus *Catinaster* seem to occur in abundance in tropical and subtropical waters, whereas they are missing in high latitudes as well as in the Paratethys. *Catinaster*? *umbrellus* Bukry, 1971, is not thought to belong to the genus *Catinaster*.

REMARKS ON SELECTED CALCAREOUS NANNOPLANKTON TAXA AND SPECIES

Most of the calcareous nannoplankton taxa found on Leg 59 are well documented elsewhere and need no discussion. However, a few taxa that commonly are neglected or have to be grouped together because of their small size and that cannot be differentiated by light-microscope techniques will be discussed for better understanding, especially of the fossil lists (Tables 1 to 4). Also, two new species that appear in the plates need some explanation.

Genus *CERATOLITHUS* Kamptner, 1954. Several species of ceratoliths are found in Hole 451 (Table 4). The differentiation into *Amaurolithus* and *Ceratolithus* (Gartner and Bukry, 1975) is not followed here, because there are many transitional forms whose appearance ranges from "dark" to "bright" in polarized light, although there is a general tendency from more "dark" or "semidark" to "bright" appearence in polarized light during the evolution of late Tertiary to Quaternary ceratoliths. On this basis *A. delicatus* Gartner and Bukry, 1975, is placed into the genus *Ceratolithus* s.l. and is called *C. delicatus* (Gartner and Bukry).

Coccolithus radiatus Kamptner, 1955. This species with small to medium-sized placoliths is subcircular to elliptical in shape and seems to range from about the middle Miocene to the Quaternary. Specimens found are identical with those figured by Jafar (1975, Plate 9, Figs. 10, 11, 18).

Coccolithus sp. In Cores 4 to 6 of Hole 448, medium-sized oval forms with a relatively large central area are found, which show an extinction pattern similar to *Ericsonia fenestrata* (Deflandre and Fert) under crossed nicols (Plate 5, Figs. 7 and 8). The central area is penetrated by a number of pores. This form ranges from the upper part of Zone NN 1 to Zone NN 3.

In Hole 451, Core 5 another medium-sized oval form with probably two shields is found. It shows weak birefringence and is composed of about 36 segments. The central area is perforated by a few pores. These forms were termed *Coccolithus* sp. in Table 4 and were found in the uppermost part of Zone NN 11 and in Zone NN 12.

Cyclococcolithus sp. In Hole 451 small circular forms with the general appearance of the genus *Cyclococcolithus* as seen with the light microscope are listed in Table 4 as *Cyclococcolithus* sp., although specimens found during SEM studies included also *Umbilicosphaera mirabilis* and *U. sibogae* (Plate 4, Fig. 12).

Discolithina sp. A few specimens showing the extinction pattern of the genus *Discolithina* were found in Zone NP 24 of Hole 448, but poor preservation prevented identification of species level.

Discolithina japonica Takayama, 1967. A single specimen not listed in Table 4 was found during SEM studies in Sample 451-2-4, 8-9 cm (upper Pliocene, Zone NN 18) and is shown on Plate 1, Figure 4.

Gephyrocapsa sp. The most common form of the genus *Gephyrocapsa* has a fused bar that spans the central area close to the long axis. It is identical with those figured by Kamptner (1963) as *G. aperta*. This small species is difficult to identify under the light microscope in some samples because of poor preservation but can be identified under the scanning electron microscope. Forms slightly larger and having a fused bar across the central opening closer to the small axis belong to *Gephyrocapsa oceanica* (Plate 1, Fig. 6).

Occurrences of *Gephyrocapsa* species in the upper Pliocene and lowest Quaternary are listed in Table 4 as *Gephyrocapsa* sp. because of the above-mentioned difficulties and may also include *Coccolithus doronicoides* Black and Barnes.

Pontosphaera sp. All forms with single plate and high rim showing the extinction pattern of the genus *Pontosphaera* found in Holes 448 and 451, which could not be properly identified through light-microscope techniques, are grouped together under *Pontosphaera* sp. (see Tables 2 and 4). In Hole 451 *P. alboranensis* and *P. discopora* were identified (Plate 4, Figs. 4 and 5) during SEM investigations of samples from Cores 1 and 2.

Reticulofenestra sp. Under this name all small *Reticulofenestra* species that cannot be differentiated with the light microscope are grouped together. Even SEM investigations failed to provide unequivocal criteria for defining species in the present material, because overall preservation is only moderate and central areas poorly preserved.

Scyphosphaera sp. In Samples 451-1,CC, and 20,CC, rare *Scyphosphaera* specimens are noted that are not complete but seem to have straight walls with an opening larger than the diameter of the base of the lopodolith. In the same hole, occurrences of top or bottom views of various lopodoliths as well as forms with a relatively short rim are found in many samples in the upper Miocene to Quaternary interval and are listed as *Scyphosphaera* sp. (base) in Table 4.

Syracosphaera sp. Specimens of one or more *Syracosphaera* species are found in the Pliocene and Quaternary of Site 451. They were identified by their typical extinction pattern under crossed nicols but because of their otherwise small size and weak appearance under the light microscope could not be specifically identified. Some of the specimens found during SEM studies are figured on Plates 1 and 4 and are identified as *S. pulchra* Lohmann. Not figured but also found during SEM studies is *S. ribosa* (Table 4). *Coronosphaera* cf. *mediterranea* (Plate 4, Fig. 1) is probably among forms listed as *Syracosphaera* sp. in case samples were only studied by light-microscope techniques.

Family CALCIOSOLENIACEAE Kamptner, 1927
Genus CALCIOSOLENIA Gran in Murray and Hjort, 1912
***Calciosolenia compacta* new species**
(Plate 4, Fig. 8 and Plate 5, Fig. 1)

Holotype. SM.B 13025, Plate 4, Figure 8.

Description. Scapholiths are composed of a rather fragile rhomboid rim with a groove running along the outer sides (Plate 5, Fig. 1). The central area is covered by a small number of laths of different size. The laths of one side overlap the laths of the other side considerably (Plate 4, Fig. 8).

Size. Length 3.5 μm, width 2.0 μm.

Remarks. The Recent *Calciosolenia tenuis* introduced by Lecal (1960) may be related but is too poorly documented to give any decent data for comparison.

Type locality. Sample 451-2-4, 8–9 cm, upper Pliocene, *Discoaster brouweri* Zone (NN 18).

Distribution. Few in Sample 451-2-4, 8–9 cm, West Mariana Ridge, upper Pliocene (NN 18).

Family RHABDOSPHAERACEAE Lemmermann, 1908
Genus BRAMLETTEIUS Gartner, 1969
***Bramletteius ? duoalatus* new species**
(Plate 4, Fig. 9)

Holotype. SM.B 13026, Plate 4, Figure 9.

Description. Elliptical placolith-like base probably constructed of two cycles of calcite elements closely appressed, with the proximal slightly smaller than the distal cycle. Two paddle-shaped structures extend on the distal side, the shaft being shorter and thinner than the blade of each structure. The upper 3/5 of the structures are in contact with each other, divided by only a small fissure. At the distal end the complex is about twice as wide as at its base.

Size. Diameter of basal plate 2 μm, total height 4.5 μm.

Remarks. This species is quite unique in the Neogene nannoplankton assemblages and is tentatively assigned to the genus *Bramletteius*, which includes the only comparable species (*B. serraculoides* Gartner, 1969) with a similar structure on the distal side of the basal plate. More material is needed to decide on the systematic position of the new species.

Type locality. Sample 451-2-6, 8–9 cm, upper Pliocene, *Discoaster pentaradiatus* Zone (NN 17).

Distribution. Rare in Sample 451-2-6, 8–9 cm, West Mariana Ridge, upper Pliocene (NN 17).

Table 5 lists the species from the Oligocene to Recent interval that are discussed in this chapter and included in the fossil lists (Tables 1–4) or presented in the plates.

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Table 5. Oligocene to Recent calcareous nannoplankton from the Philippine Sea, DSDP, Leg 59.

Acanthoica sp.
Aspidorhabdus stylifer (Lohmann) Boudreaux and Hay, 1969
Braarudosphaera bigelowi (Gran and Braarud) *Deflandre,* 1947
Catinaster calyculus Martini and Bramlette, 1963
Catinaster coalitus Martini and Bramlette, 1963
Ceratolithus cristatus Kamptner, 1954
Ceratolithus delicatus (Gartner and Bukry) nov. comb.
Ceratolithus primus Bukry and Percival, 1971
Ceratolithus rugosus Bukry and Bramlette, 1968
Ceratolithus telemus Norris, 1965
Ceratolithus tricorniculatus Gartner, 1967
Coccolithus abisectus Müller, 1970
Coccolithus eopelagicus (Bramlette and Riedel) Bramlette and Sullivan, 1961
Coccolithus miopelagicus Bukry, 1971
Coccolithus pelagicus (Wallich) Schiller, 1930
Coccolithus radiatus Kamptner, 1955
Coccolithus sp.
Coronocyclus nitescens (Kamptner) Bramlette and Wilcoxon, 1967
Coronosphaera mediterranea (Lohmann) Gaarder, 1977
Cyclococcolithus floridanus (Roth and Hay) Müller, 1970
Cyclococcolithus formosus Kamptner, 1963
Cyclococcolithus jafari, see *Umbilicosphaera jafari* Müller, 1974
Cyclococcolithus leptoporus (Murray and Blackman) Kamptner, 1954, ex 1956
Cyclococcolithus macintyrei Bukry and Bramlette, 1969
Cyclococcolithus rotula (Kamptner) Kamptner, 1956
Cyclococcolithus sp.
Dictyococcites dictyodus (Deflandre and Fert) Martini, 1969
Discoaster bollii Martini and Bramlette, 1963
Discoaster brouweri Tan Sin Hok, 1927
Discoaster calcaris Gartner, 1967
Discoaster challengeri Bramlette and Riedel, 1954
Discoaster deflandrei Bramlette and Riedel, 1954
Discoaster druggi Bramlette and Wilcoxon, 1967
Discoaster exilis Martini and Bramlette, 1963
Discoaster formosus Martini and Worsley, 1971
Discoaster hamatus Martini and Bramlette, 1963
Discoaster kugleri Martini and Bramlette, 1963
Discoaster neohamatus Bukry and Bramlette, 1969
Discoaster pentaradiatus Tan Sin Hok, 1927
Discoaster pseudovariabilis Martini and Worsley, 1971
Discoaster quinqueramus Gartner, 1969
Discoaster surculus Martini and Bramlette, 1963
Discoaster tani Bramlette and Riedel, 1954
Discoaster tani nodifer Bramlette and Riedel, 1954
Discoaster tani ornatus Bramlette and Wilcoxon, 1967
Discoaster variabilis Martini and Bramlette, 1963
Discolithina callosa Martini, 1969
Discolithina japonica Takayama, 1967
Discolithina multipora (Kamptner ex Deflandre) Martini, 1965
Discolithina sp.
Emiliania huxleyi (Lohmann) Hay and Mohler, 1967
Ericsonia fenestrata (Deflandre and Fert) Stradner, 1968
Gephyrocapsa sp.
Gephyrocapsa aperta Kamptner, 1963
Gephyrocapsa oceanica Kamptner, 1943
Hayaster perplexus (Bramlette and Riedel) Bukry, 1973
Helicosphaera carteri (Wallich) Kamptner, 1954
Helicosphaera compacta Bramlette and Wilcoxon, 1967
Helicosphaera euphratis Haq, 1966
Helicosphaera hyalina Gaarder, 1970
Helicosphaera intermedia Martini, 1965
Helicosphaera recta (Haq) Jafar and Martini, 1975
Helicosphaera sellii (Bukry and Bramlette) Jafar and Martini, 1975
Oolithotus fragilis (Lohman) Martini and Müller, 1972
Orthorhabdus serratus Bramlette and Wilcoxon, 1967
Orthozygus aureus (Stradner) Bramlette and Wilcoxon, 1967
Pontosphaera sp.
Pontosphaera alboranensis Bartolini, 1970
Pontosphaera discopora Schiller, 1925
Pseudoemiliania lacunosa (Kamptner) Gartner, 1969
Reticulofenestra pseudoumbilica (Gartner) Gartner, 1969
Reticulofenestra sp. (small)
Reticulofenestra umbilica (Levin) Martini and Ritzkowski, 1968
Rhabdosphaera clavigera Murray and Blackman, 1898
Rhabdosphaera sp.
Scapholithus fossilis Deflandre, 1954
Scyphosphaera sp. (base)
Scyphosphaera ampla Kamptner, 1955
Scyphosphaera amphora Deflandre, 1942
Scyphosphaera apsteini Lohmann, 1902
Scyphosphaera campanula Deflandre, 1942
Scyphosphaera conica Kamptner, 1955
Scyphosphaera globulata Bukry and Percival, 1971
Scyphosphaera pulcherrima Deflandre, 1942
Scyphosphaera recta (Deflandre) Kamptner, 1955
Scyphosphaera recurvata Deflandre, 1942
Scyphosphaera turris Kamptner, 1955
Scyphosphaera sp.
Sphenolithus abies Deflandre, 1954
Sphenolithus belemnos Bramlette and Wilcoxon, 1967
Sphenolithus capricornutus Bukry and Percival, 1971
Sphenolithus ciperoensis Bramlette and Wilcoxon, 1967
Sphenolithus delphix Bukry, 1973
Sphenolithus dissimilis Bukry and Percival, 1971
Sphenolithus distentus (Martini) Bramlette and Wilcoxon, 1967
Sphenolithus heteromorphus Deflandre, 1953
Sphenolithus moriformis (Brönnimann and Stradner) Bramlette and Wilcoxon, 1967
Sphenolithus predistentus Bramlette and Wilcoxon, 1967
Sphenolithus pseudoradians Bramlette and Wilcoxon, 1967
Syracosphaera sp.
Syracosphaera pulchra Lohmann, 1902
Syracosphaera ribosa (Kamptner) Borsetti and Cati, 1972
Triquetrorhabdulus carinatus Martini, 1965
Triquetrorhabdulus milowii Bukry, 1971
Triquetrorhabdulus rugosus Bramlette and Wilcoxon, 1967
Umbellosphaera irregularis Paasche, 1955
Umbellosphaera tenuis (Kamptner) Paasche, 1955
Umbilicosphaera jafari Müller, 1974
Umbilicosphaera mirabilis Lohmann, 1902
Umbilicosphaera sibogae (Weber van Bosse) Gaarder, 1970
Zygrhablithus bijugatus (Deflandre) Deflandre, 1959

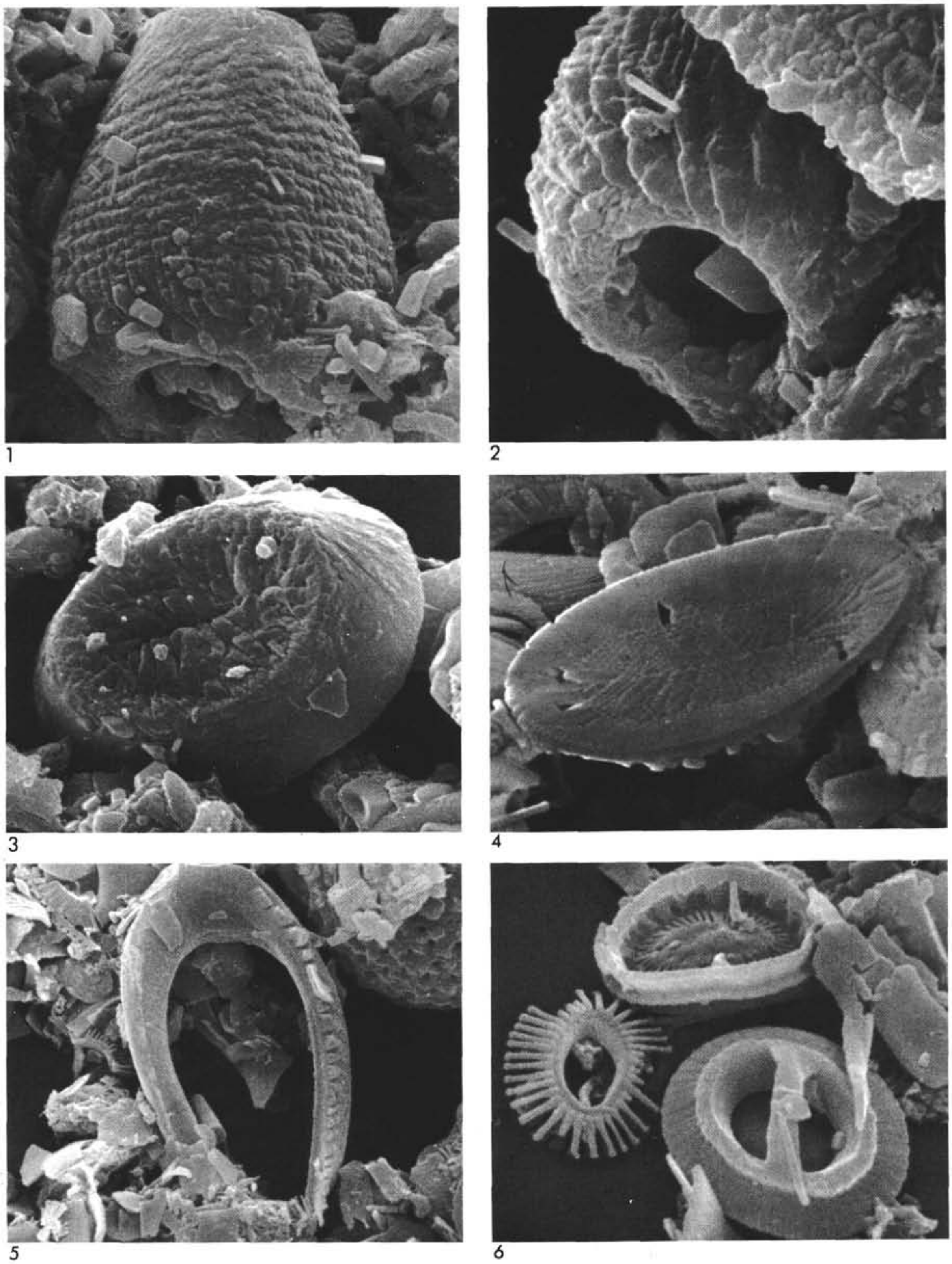

Plate 1. Oligocene, Pliocene, and Quaternary calcareous nannoplankton.

Figures 1, 2. *Scyphosphaera recurvata* Deflandre, 1942. Fig. 1. ×4500, side view. Fig. 2. ×9000, distal opening. Sample 448-20-2, 27–28 cm. Middle upper Oligocene, Zone NP 24.

Figure 3. *Scyphosphaera* sp. cf. *S. recurvata* Deflandre, 1942. ×4500, proximal side. Sample 448-20-2, 27–28 cm. Middle upper Oligocene, Zone NP 24.

Figure 4. *Discolithina japonica* Takayama, 1967. ×9000, proximal side. Sample 451-2-4, 8–9 cm. Upper Pliocene, Zone NN 18

Figure 5. *Ceratolithus cristatus* Kamptner, 1954. ×9000. Sample 51-2,CC. Quaternary, Zone NN 21.

Figure 6. *Syracosphaera pulchra* Lohmann, 1902. *Emiliania huxleyi* (Lohmann) Hay and Mohler, 1967. *Gephyrocapsa oceanica* Kamptner, 1943. ×9000, distal sides. Sample 451-2,CC. Quaternary, Zone NN 21.

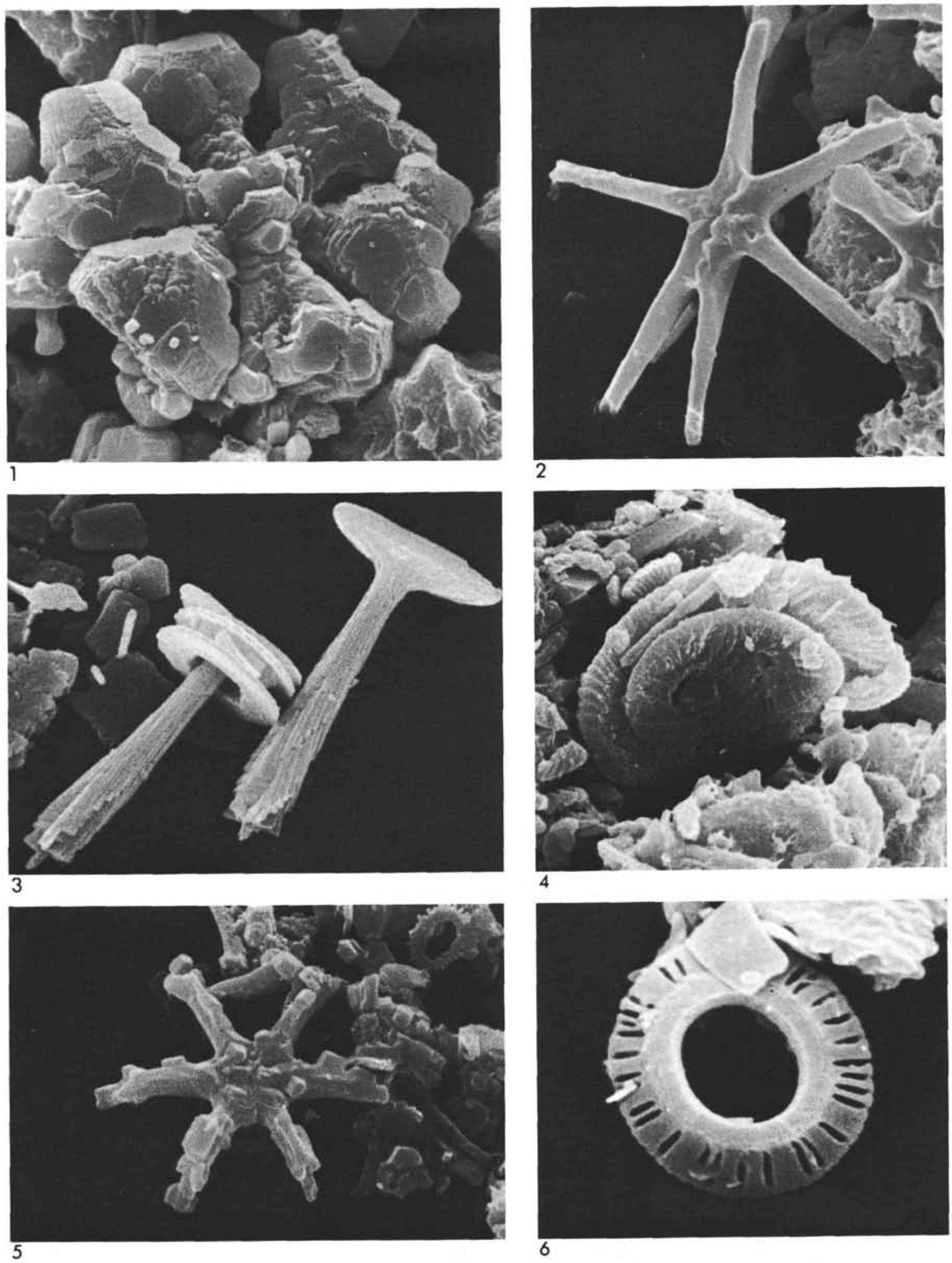

Plate 2. Oligocene to Quaternary calcareous nannoplankton.

Figure 1. *Discoaster variabilis* Martini and Bramlette, 1963. Heavily overcalcified specimen with well-developed crystal faces on rays. ×5000. Sample 450-8-1, 38–39 cm. Middle Miocene, Zone NN 8.

Figure 2. *Discoaster calcaris* Gartner, 1967. Aberrant six-rayed specimen. ×5000, convex side. Sample 448-1-1, 8–9 cm. Miocene, Zone NN 9.

Figure 3. *Rhabdosphaera clavigera* Murray and Blackman, 1898. ×7500, side views. Sample 451-2,CC. Quaternary, Zone NN 21.

Figure 4. *Helicosphaera euphratis* Haq, 1966. ×5000, proximal side. Sample 448-20-2, 27–28 cm. Oligocene, Zone NP 24.

Figure 5. *Discoaster surculus* Martini and Bramlette, 1963. Six-rayed specimen with some secondary growth of calcite. ×5000, convex side. Sample V34-13, 5 cm. Pliocene (Zone NN 16?) with Quaternary admixture (Zone NN 21).

Figure 6. *Pseudoemiliania lacunosa* (Kamptner) Gartner, 1969. ×10,000, distal side. Sample 451-2-2, 68–69 cm. Quaternary, Zone NN 19.

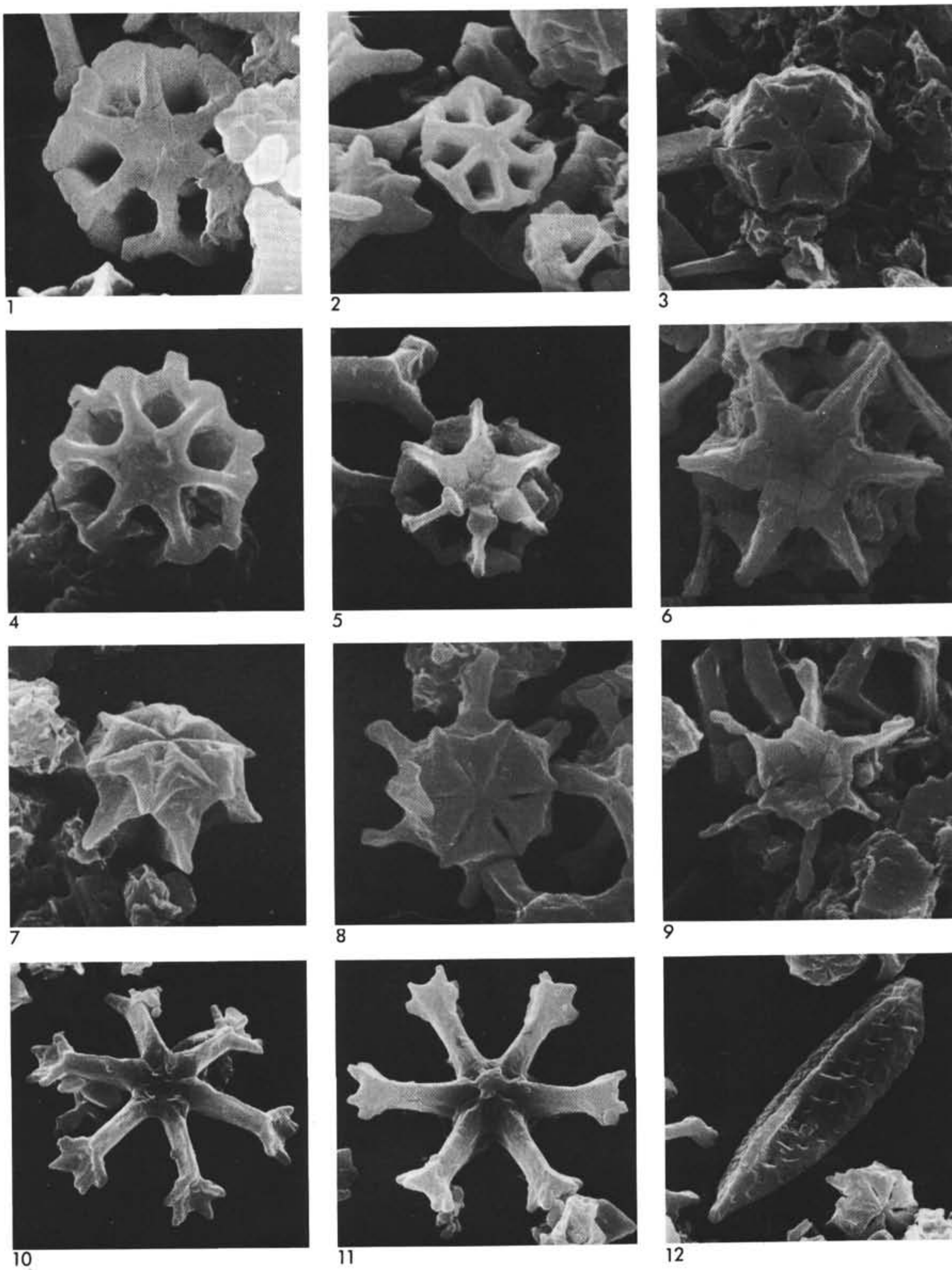

Plate 3. Miocene calcareous nannoplankton.

Figures 1–4. *Catinaster coalitus* Martini and Bramlette, 1963. Figs. 1, 2. ×6000, distal side. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9. Fig. 3. ×6000, proximal side. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9. Fig. 4. ×6000, distal side. Sample 448-1-1, 8–9 cm. Miocene, Zone NN 9.

Figures 5–9. *Catinaster calyculus* Martini and Bramlette, 1963. Figs. 5, 6. ×6000, distal side. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9. Fig. 7. ×6000, proximal side. Sample 448-1-1, 8–9 cm. Miocene, Zone NN 9. Fig. 8. ×6000, distal side. Sample 448-1-1, 8–9 cm. Miocene, Zone NN 9. Fig. 9. ×6000, distal side. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9.

Figures 10, 11. *Discoaster pseudovariabilis* Martini and Worsley, 1971. Fig. 10. ×3000, convex side. Sample 448-1-1, 60–61 cm, Miocene, Zone NN 9. Fig. 11. ×3000, concave side. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9.

Figure 12. *Triquetrorhabdulus rugosus* Bramlette and Wilcoxon, 1967. ×3000. Note etching marks. Sample 448-1-1, 60–61 cm. Miocene, Zone NN 9.

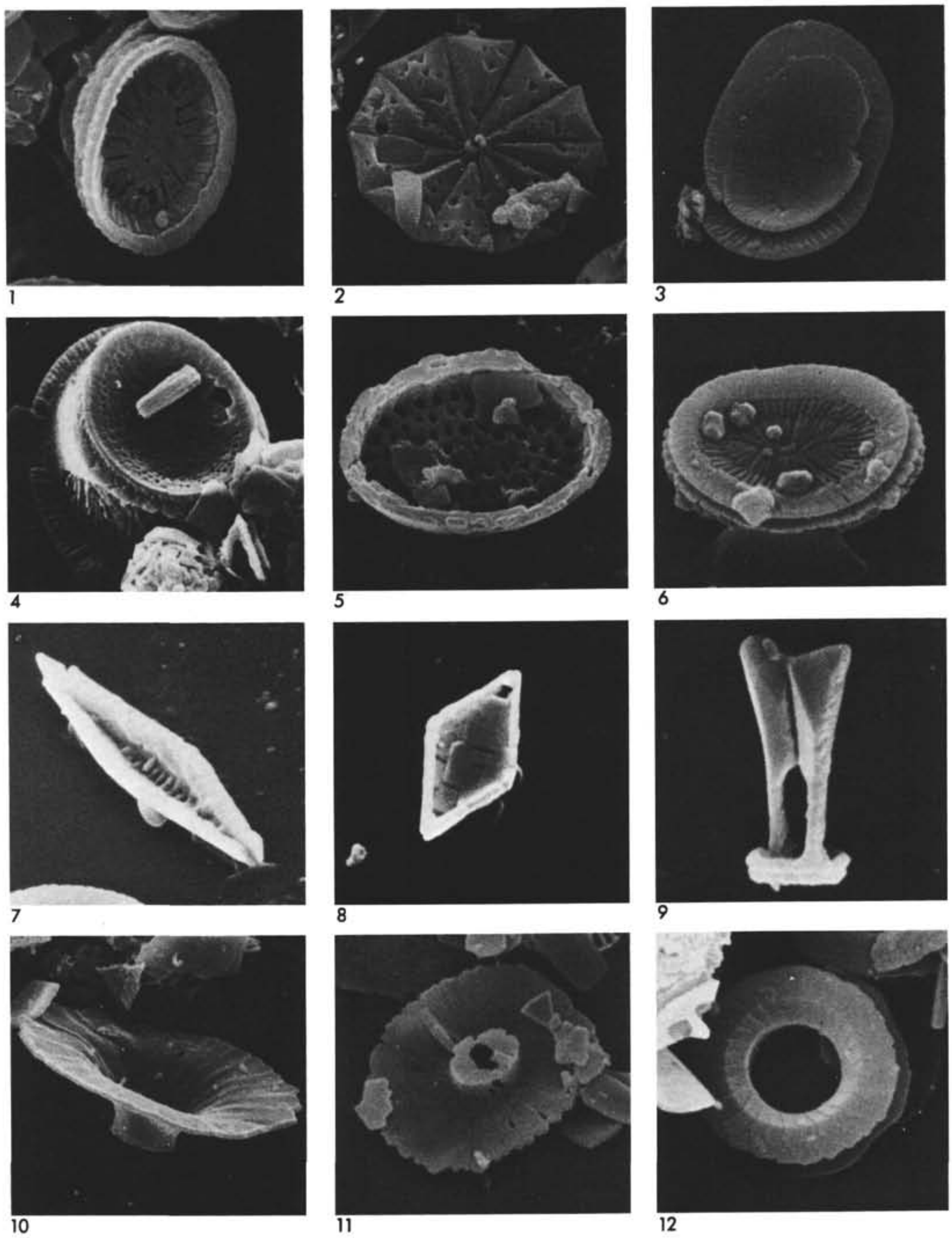

Plate 4. Pliocene and Quaternary calcareous nannoplankton.

Figure 1. *Coronosphaera* cf. *mediterranea* (Lohmann) Gaarder, 1977. ×7000, distal side. Sample 451-2-3, 29–30 cm. Quaternary, Zone NN 19.

Figure 2. *Hayaster perplexus* (Bramlette and Riedel) Bukry, 1973. ×5000. Sample 451-2-1, 43–44 cm. Quaternary, Zone NN 19.

Figure 3. *Helicosphaera hyalina* Gaarder, 1970. ×7600, proximal side. Sample 451-1-2, 1–2 cm. Quaternary, Zone NN 21.

Figure 4. *Pontosphaera alboranensis* Bartolini, 1970. ×5000, proximal side. Sample 451-2-4, 8–9 cm. Upper Pliocene, Zone NN 18.

Figure 5. *Pontosphaera discopora* Schiller, 1925. ×7000, distal side. Sample 451-2-2, 68–69 cm. Quaternary, Zone NN 19.

Figure 6. *Syracosphaera pulchra* Lohmann, 1902. ×7000, proximal side. Sample 451-2-1, 43–44 cm. Quaternary, Zone NN 19.

Figure 7. *Scapholithus fossilis* Deflandre, 1954. ×9500, distal side. Sample 451-1-2, 1–2 cm. Quaternary, Zone NN 21.

Figure 8. *Calciosolenia compacta* new species, ×10,000, distal side. Holotype SM.B 13025. Sample 451-2-4, 8–9 cm. Upper Pliocene, Zone NN 18.

Figure 9. *Bramletteius? duoalatus* new species. ×10,000, side view. Holotype SM.B 13026. Sample 451-2-6, 8–9 cm. Upper Pliocene, Zone NN 17.

Figure 10. *Umbellosphaera irregularis* Paasche, 1955. ×6650, oblique view of distal side. Sample 451-2, 1–2 cm. Quaternary, Zone NN 21.

Figure 11. *Umbellosphaera irregularis* Paasche, 1955. ×8000, proximal side. Sample 451-2,CC. Quaternary, Zone NN 21.

Figure 12. *Umbilicosphaera sibogae* (Weber van Boss) Gaarder, 1970. ×9500, distal side. Sample 451-1-2, 1–2 cm. Quaternary, Zone NN 21.

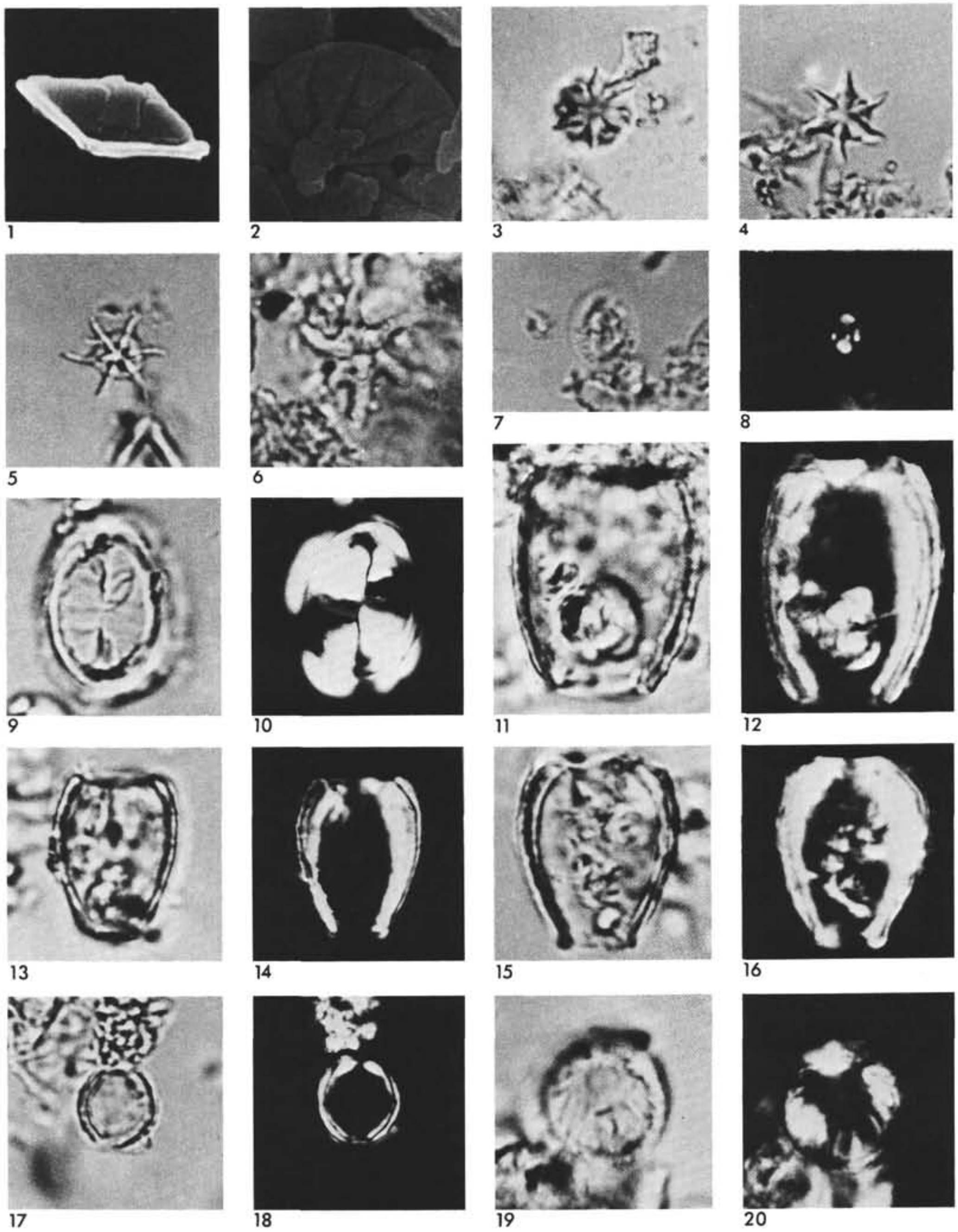

Plate 5. Oligocene to Quaternary calcareous nannoplankton. (All specimens with the exception of Figures 1 and 2 are magnified approximately ×2000.)

Figure 1. *Calcisolenia compacta* new species. ×10,000, distal side. Sample 451-2-4, 8–9 cm. Upper Pliocene, Zone NN 18.

Figure 2. *Hayaster perplexus* (Bramlette and Riedel) Bukry, 1973. ×10,000, proximal side. Note perforation. Sample 451-2-1, 43–44 cm. Quaternary, Zone NN 19.

Figures 3–6. *Catinaster calyculus* Martini and Bramlette, 1963. Fig. 3. Short-rayed form. Sample 450-7,CC. Miocene, Zone NN 8. Fig. 4. Medium-long-rayed form. Sample 450-6-1, 14–15 cm. Miocene, Zone NN 9. Fig. 5. Long-rayed form. Sample 450-4,CC. Miocene, Zone NN 9. Fig. 6. Overcalcified long-rayed form. Sample 451-85-4, 91–92 cm. Miocene, Zone NN 10.

Figures 7, 8. *"Coccolithus"* sp. Sample 448-5,CC. Lower Miocene, Zone NN 2. (Fig. 8. Long axis 0° to crossed nicols.)

Figures 9, 10. *Scyphosphaera* sp. Short-walled lopodolith probably belonging to *S. recurvata* Deflandre, 1942. Proximal side. Sample 448-20-2, 27–28 cm. Oligocene, Zone NP 24. (Fig. 10. Long axis 0° to crossed nicols.)

Figures 11, 12. *Scyphosphaera apsteini* Lohmann, 1902. Sample 448-20-2, 27–28 cm. Oligocene, Zone NP 24. (Fig. 12. Long axis 45° to crossed nicols; side view.)

Figures 13–16. *Scyphosphaera recurvata* Deflandre, 1942. Figs. 13, 14. Sample 448-20-2, 27–28 cm. Oligocene, Zone NP 24. (Fig. 14. Long axis 45° to crossed nicols; side view.) Figs. 15, 16. Sample 448-20-2, 29–30 cm. Oligocene, Zone NP 24. (Fig. 16. Long axis 45° to crossed nicols; side view.)

Figures 17–20. *Scyphosphaera globulata* Bukry and Percival, 1971. Sample 451-4-1, 9–10 cm. Lower Pliocene, Zone NN 15. (Fig. 18. Long axis 45° to crossed nicols; side view. Fig. 20. Crossed nicols; oblique view.)